HGA NAVIGANT

100% Renewable Madison

Achieving 100% Renewable Energy and Zero Net Carbon for City Operations and Leading the Community

Prepared for:

City of Madison, Wisconsin

Submitted by:
Hammel, Green and Abrahamson LLC with Navigant Consulting, Inc.

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OPENING LETTER

This report is about more than energy.

It is about who we are and the community we can be.

The fossil fuels we use every day cause climate change. The consequences are no longer in doubt. 2018 will be the fourth hottest year in recorded history. The only years hotter were 2017, 2016, and 2015. That string of records continues a rapid climb in temperatures since the start of the industrial age. It is a trend we must do all we can to change. If we don't, 136-degree heat waves will be normal in the lives of today's kids. The August 2018 floods in Madison took a huge toll. Imagine the aftermath of supercharged storms in a warmer world.

Other social dynamics have changed along with our climate. Income inequality has skyrocketed. Wealth gaps along race and gender lines are striking. And it is apparent that the impacts of a warming world disproportionately victimize women, people of color, and low-income communities.

This report is the first step toward a new Madison. With it, our city makes clear that we will not accept the threat climate change poses to our community and world. In truth, we cannot afford to do anything but act. Renewable energy technologies have advanced at a staggering pace. Costs continue to plummet. We will save money if we power our future with the sun, the wind, and our own feet. We will also honor our commitment to social and environmental justice.

Enclosed are options to set Madison on course to 100% renewable, zero net carbon energy. We present three timelines and recommended actions to meet each. The first scenario envisions success by 2020 and relies heavily on investing outside the city. The second hits our target by 2023 and requires more local investments. The third reaches our goal by 2030 and requires additional investment with immediate impact.

This is an exciting moment for Madison. It marks the beginning of a movement to transform our lives and economy. But it is only a beginning. To lead our state, our nation, and our world, Madison must have ambitions as big as the dreams of our people.

We have everything we need to create a city that is true to our ideals. Now, let's get to work!

Raj Shukla
Chair, Sustainable Madison Committee

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- Alders and Sustainable Madison Committee
- City Staff
- External Stakeholders

Disclaimer:

This report was prepared by Hammel, Green and Abrahamson, Inc. (HGA) and Navigant Consulting, Inc. (Navigant), separately, for the City of Madison, Wisconsin. The work presented in this report represents HGA's and separately, Navigant's, professional judgment based on the information available at the time this report was prepared. The two entities, HGA, and separately, Navigant, are not responsible for the reader's use of, or reliance upon the report, nor any decisions based on the report. HGA, and separately, Navigant, MAKES NO REPRESENTATIONS OR WARRANTIES, EXPRESSED OR IMPLIED. Readers of the report are advised that they assume all liabilities incurred by them, or third parties, as a result of their reliance on the report, or the data, information, findings and opinions contained in the report.

EXECUTIVE SUMMARY

In March 2017, the City of Madison became the 25th city in North America to set a goal of achieving 100% renewable energy and net-zero carbon emissions.[1] Across the US, over 70 cities, more than five counties, and two states, have also adopted ambitious 100% clean energy goals. Five cities in the US have already hit their targets. These five cities now generate 100% of the energy used communitywide from renewable sources.[2] Despite the lack of climate leadership at the nation's capital as evidenced by the US withdrawal from the Paris Agreement,[3] there is a steady resolve for climate leadership in Madison and the greater Madison region.

In joining other cities around the US and the world, the City of Madison is demonstrating its commitment to using low carbon strategies to meet community-wide economic, environmental, and social challenges. Powering city operations with 100% renewable energy will enable to the city to accomplish multiple city policy objectives including job creation and economic development, cost savings to city taxpayers, promoting racial equity and social justice, contributing to long-term public health and vitality through improved air and water quality, and resilience in the face of more extreme weather events.[4]

This report has three parts. The first part highlights some sustainable projects and initiatives that Madison has implemented to date. The second part presents three time-based scenarios that city officials can use to accomplish renewable and net zero goals, recognizing current powers and limitations of local government to influence the larger community. The third section is a series of appendices that present the details of each time-based scenario and details the programs and initiatives that will enable Madison to reach its goals. The emphasis is on near-term, demonstrable project-based action that will align the City of Madison with the Paris Agreement 1.5°C-2°C path by 2030, while laying the groundwork for further deep decarbonization planning and action needed between 2030 and 2050. These actions provide city officials with options for future planning and implementation while promoting Madison's vibrant culture to retain and attract the people who will continue to make contributions for our community, our planet, and our shared prosperity. With its clean energy and carbon reduction goals firmly in place, the City of Madison is well-positioned to maximize the value of this transition for itself and for the broader community.

[1] City of Madison Resolution, Legislative File 45569 (3/21/07).

[2] The Sierra Club, "Ready for 100," https://www.sierraclub.org/ready-for-100.

[3] United Nations Framework Convention on Climate Change (UNFCC), "The Paris Agreement central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius."

[4] WKOW Chief Meteorologist Robert Lindmeier presented information from Climate Central and the Citizens Climate Lobby at a public meeting on September 27, 2017. He listed risks from climate change such as severe weather events, flooding, drought, health impacts, and risk of fire, among others. His full presentation is available at: www.madison100renewableenergy.com.

1. MADISON'S CURRENT SUSTAINABILITY SUCCESS

Madison has a long history of success in implementing sustainability efforts in local government operations and throughout the community. The Madison Common Council confirmed its greenhouse gas (GHG) emissions reduction goals in its 2016 Energy Work Plan.[5] The City of Madison recently adopted a new comprehensive plan, which includes a priority for the City to implement its 100% renewable energy and net zero carbon emissions goal.[6]

The following sustainability goals were in place as of the writing of this report:

- Reduce carbon emissions by 80% by 2050
- Obtain 25% of electricity heating and transportation energy from clean energy sources by 2025
- Reduce overall energy consumption by 50% by 2030 (kWh and therms per square foot or equivalent unit of measure)
- Achieve 50% electric buses in the Metro Transit's fleet by 2035
- Reduce fuel consumption in the city fleet by 20% by 2020

This report provides three scenarios for policy makers to consider towards achieving the goals listed above. In the current policy environment, local government has limited options available to influence these goals. While the City of Madison has had much success, there is much more work ahead. Taking action to further these goals now is necessary or we risk falling behind to achieve these goals.

1.1 Successes within City of Madison Local Government Operations

Madison has long established itself a leader in sustainability within Wisconsin, the US, and internationally. Madison is a member of ICLEI Local Governments for Sustainability,[7] and participates in national conferences such as the Sierra Club's Ready for 100 Program and actively communicates with other cities around the state, region, and world to share best practices and ideas. To date, the City of Madison has implemented many successful sustainability strategies within local government operations, which are highlighted in this section.

1.1.1 Renewable Energy

The City of Madison has multiple avenues to reach its renewable targets through direct action, innovative programs and investments in renewable energy:

- The City of Madison will have installed approximately 615 kW of solar at city facilities by the end of 2018, with some solar installations implemented through the GreenPower solar installer trainee job training program referenced below.

[5] In this report, the terms "carbon", "carbon emissions" and "greenhouse gases (GHG) emissions" are all synonymous with carbon dioxide equivalent emissions, CO_2e.

[6] Imagine Madison, *The City of Madison Comprehensive Plan*, Green and Resilient section.

[7] ICLEI, "Local Governments for Sustainability," http://iclei.org/.

- The City of Madison incorporates solar in new construction and remodeling projects whenever possible. These solar installations are either part of the bid package for new construction or remodeling or city crews install the system on new building and existing buildings through the City's GreenPower job training program. Over the last 3 years, City Engineering has hired three solar trainees and for 9 months they learn and install solar systems on existing city buildings (see Local Spotlight example below).

Local Spotlight : City of Madison Solar Installer Training Program

The City of Madison has operated a solar installer training program for the last 2 years. This program provides hands –on training to improve participant's job skills for future employment in the solar or electrical trades.
The program has installed over 100 kW or half the total solar on City buildings.

- City officials are actively working with Madison Gas & Electric (MGE) on a large off-site solar array through MGE's Renewable Energy Rider program. City officials have also discussed opportunities to develop renewable energy with Wisconsin Power & Light, Alliant Energy's Wisconsin affiliate (Alliant Energy).
- The City of Madison developed the MadiSUN[8] program an innovative public-private partnership of the City of Madison and supported by the City of Middleton. MadiSUN offers technical information and financial incentives for residential and business customers. Over the past 2 years, 80 Madison-area homes have installed solar panels through the program. The program added a new focus on businesses this year. RENEW Wisconsin, a local non-profit organization working to grow renewable energy statewide, administers the program on behalf of the city.
- The City of Madison is investing in five solar arrays totaling 14 MW under development in western Wisconsin. This investment is procuring 25 years of renewable energy credits (RECs) from these installations, which is equivalent to approximately 37% of the current electricity consumption from local government operations. This investment will support rural Wisconsin, Wisconsin agriculture and dairy industries while helping Madison reach its goal of 100% renewable energy.

1.1.2 Energy Efficiency

The City of Madison has a history of environmental leadership at its facilities and through its operations, reducing carbon emissions by building efficient new construction projects, making existing operations/facilities more efficient and developing programs to engage employees and the community to embrace energy efficiency and renewable energy. These actions have enabled the City of Madison to use

[8] MadiSUN, https://madisunsolar.com/.

less energy and save taxpayer dollars while reducing carbon emissions. Selected energy efficiency initiatives include the following:

- Dedicated funding to improve existing buildings energy performance including insulation upgrades, lighting upgrades, upgrade or add building automation systems, and other strategies
- Energy usage tracking.
- Sharing solar power production with the public through a web portal.
- Mandatory Leadership in Energy and Environmental Design (LEED) building certification for new buildings and major remodels
- Facilities and Energy Management Leadership program for facilities managers to share best practices for energy efficiency and building operations.
- Ongoing retro-commissioning program for major buildings to continually improve building performance on an ongoing basis
- Working with the Wisconsin Focus on Energy program to target energy efficiency improvements at municipal facilities while discussing opportunities to work together with local utilities to promote similar improvements to appropriate residents and businesses in the area.
- The Madison Water Utility is conducting an ongoing analysis of pump optimization using variable speed drives. MWU is working with local architects to design the Water Conservation House.[9]

1.1.3 Transportation

Madison Metro Transit and city agencies, such as Fleet, Parking and Traffic Engineering, are taking proactive steps to reduce carbon impacts from transportation. Select examples include:

- The fleet department has started to implement green fleet practices, such as using biofuels and developing a new fleet procurement menu for city agencies to choose vehicles with less environmental impact while still meeting performance expectations.
- City agencies procured three electric cars through working with MGE.
- A multi-agency task force is working to implement GPS and telematics on mobile assets to save fuel and costs, they are expected to save fuel by identifying and eliminating unnecessary routes, idling, speeding, and other behaviors.
- The Madison Area Transportation Board and Metro Transit are actively working on bus rapid transit and other innovations in public transit and mobility as part of the Madison In Motion Plan.[10]
- Metro Transit will take ownership of its first three electric buses in 2020, with a goal of 50% of the fleet electric by 2035.
- Many of the City's parking garages are being retrofitted with LED lighting projects and Madison will have some of the first Parksmart certified garages in the Midwest.

[9] Madison Water Utility, "Water Conservation House," http://www.cityofmadison.com/water/projects/water-conservation-house

[10] City of Madison, "Department of Planning, Community Development," Madison in Motion, http://www.cityofmadison.com/dpced/planning/madison-in-motion/1569/.

- Madison is among a select cohort of cities participating in Transportation for America's Smart Cities Collaborative to share cutting edge approaches and best practices to implement innovation through the applied use of data.[11]

1.2 Successes within the Greater Madison Area

Throughout the greater Madison metro community, people are excited about clean energy. Residents, businesses, educational organizations, religious communities and others have demonstrated their commitments to renewable energy and reducing their carbon emissions. The City of Madison is actively working with public and private stakeholders to help accelerate the shift to 100% renewable energy. For example, city officials are working with MGE, Alliant Energy and the Wisconsin Focus on Energy program to increase cooperation and promote a model of city-utility cooperation. In 2017, the City of Madison developed a Framework for Collaboration on Shared Energy Goals with MGE,[12] which included several areas where the City and the local utility would collaborate to meet mutual energy and carbon reduction goals. The key features of the Framework for Collaboration on Shared Energy Goals are:

- **Expansion of solar:** The City of Madison is encouraging residential and commercial renewable energy generation by installing solar at city facilities, sponsoring the solar bulk-purchasing MadiSUN program, and working with MGE and Alliant to identify areas for additional solar installations through the Renewable Energy Rider program and encouraging large utility-scale projects.
- **Promotion of energy efficiency:** The City of Madison is implementing energy efficiency projects at city facilities and tracking facility energy usage data. City officials are in discussions with MGE about upgrading to LED street lights and working with utilities to implement smart city initiatives that involve street lights. Smart street lights and other smart city innovation can provide communications, public safety, and traffic monitoring functions for the community. For the larger community, the City of Madison has sponsored the Mpower Champions program for 10 years which works with businesses to reduce energy and carbon emissions through a variety of projects, including energy efficiency, fleet conversion, and renewable energy.
- **Expansion of the use of Electric Vehicles:** The City of Madison is working with MGE and Alliant to promote electric vehicles (EV) and public EV charging stations. The City and MGE work together to locate EV charging stations at City of Madison parking lots and ramps. The City of Madison has worked with MGE to procure its first EVs for city agencies and recently received three Chevy Bolt EVs for the City of Madison Fleet Department. With help from MGE, Metro Transit will receive its first three electric buses by 2020. The City applied for and was notified that it will receive a state grant to purchase 30 additional EVs for the City Fleet.
- **Social equity and economic development:** Clean energy means jobs in Madison and throughout Wisconsin, thereby contributing to social equity and economic development. The City has hosted a job training program for solar installers, the GreenPower program, which hires under-employed or unemployed individuals and trains them through a nine-month solar installation program. According to recent reports, jobs in the solar, wind, and energy efficiency sectors support are some of the fastest growing areas in the state and support over 75,000

[11] Transportation for America, "Our Vision," http://t4america.org/our-vision/.

[12] Framework for Collaboration on Shared Energy Goals, August 21, 2017.

workers in Wisconsin. Nationwide, solar and wind generation support more jobs than coal generation.

MGE and Alliant have goals to reduce their carbon emissions by 80% by 2050. These are consistent with the US Mid-Century Strategy for Deep Decarbonization strategy for meeting the Paris Climate Agreement. Other recent actions from MGE and Alliant include:

- In 2017, the Public Service Commission approved MGE's Renewable Energy Rider. A first-of-its-kind program for Wisconsin, MGE's service allows qualifying commercial customers (e.g., the City of Madison) to power their operations with electricity generated from new, off-site renewable generators.
- The Public Service Commission of Wisconsin approved MGE's plans to build a 66 MW wind power plant in Iowa. When placed in service later in early 2019, its output will account for 7% of MGE's power supply.
- In May 2018, MGE announced its intention to acquire 100 MW of solar generation by December 2021. The utility will acquire a 50 MW share of the Badger Hollow project in Iowa County and a 50 MW share of the Two Creeks project in Manitowoc County. The projects are expected to be operational by 1/1/2021.
- MGE installed more than 140 kW of solar on its corporate headquarters and 15 kW on a neighboring parking canopy covering several EV charging stations.
- Alliant Energy hosts solar panels, energy storage, and EV charging stations at its corporate headquarters in Madison.
- In May 2018, Alliant submitted an application to construct 150 MW of wind power in Kossuth County, Iowa. If approved, the plant would be placed in service in late 2020.

Educational institutions are also actively involved. The largest rooftop solar array in Wisconsin, with a capacity of 1.8 MW, is now under construction at Madison College's Truax Campus. Madison College also hosts a solar training program. Large businesses, such as American Family Insurance, have installed solar at their buildings. Smaller businesses, such as Ale Asylum Brewing, are installing solar systems. Religious institutions, such as Holy Wisdom Monastery, have too.

Local government around south-central Wisconsin is actively involved.

- Dane County is building its largest solar system on a 41-acre parcel at the airport.
- The City of Madison is participating in the Dane County Council on Climate Change effort to pursue common energy goals regionally.
- Property Assessed Clean Energy (PACE), enables commercial property owners to obtain low cost, long-term loans for energy efficiency, renewable energy, and water conservation improvements, is authorized in Dane County, joining over 30 other counties in Wisconsin.

The City of Madison is joined by many cities locally and around the world taking proactive steps to address climate change by implementing cost-effective measures that lead to increased economic, social, and environmental impacts for residents. The City of Madison has signed on to Climate Mayors and the

We Are Still In Declaration.[13] Since April 2017, more than 230 cities and mayors have demonstrated leadership to significantly cut carbon emissions—joining more than 1,060 mayors who have signed on to the US Council of Mayor's Climate Protection Agreement.[14]

[13] Climate Mayors (www.climatemayors.org), We Are Still In.

[14] ICLEI, *Localizing the Paris Agreement*, 2017.

2. SCENARIOS TO ACHIEVE 100% RENEWABLE ENERGY AND ZERO NET CARBON

This section includes three scenarios with strategies and policies for the City of Madison to achieve its goal of 100% renewable energy and zero net carbon emissions for municipal operations while providing leadership for the greater community.

Consultants developed forecasts of Madison's demand and supply of energy between 2018 and 2050. These forecasts show that local government operations can achieve its goals by 2020-2030 through a combination of investing in efficient buildings and facilities, the water distribution system, city street lights and traffic lights, renewable energy, efficient and electric fleet and transit vehicles and REC purchases. Further aggressive decarbonization planning would be required for local government to operate without the use of RECs or carbon offsets.

The three principles of this effort are:[15]

1) Reducing energy demand from local government operations to the minimum required to provide services through energy efficiency and behavioral measures
2) Supplying electricity through renewable energy and to the extent possible, generating renewable energy locally
3) Supplying remaining energy needs from Renewable Energy Credits (REC) and carbon offsets as a bridge strategy, while Madison continues to invest in efficient transportation, energy efficiency, and renewable energy as opportunities arise.

Based on feedback from stakeholders, three scenarios or timelines were developed. Each of the scenarios and measures showcase different opportunities for city officials to achieve multiple policy objectives—economic development, cost savings to taxpayers, quality of life, culture including racial equity and social justice, as well as improved air and water quality in Madison. The three scenarios or timelines for Madison to reach its goals are:

1. **100% Renewable Energy and Zero Net Carbon by 2020**
2. **100% Renewable Energy and Zero Net Carbon by 2023**
3. **100% Renewable Energy and Zero Net Carbon by 2030**

The three scenarios developed meet the City goal of 100% Renewable Energy and Net Zero Carbon in a way that, in the long term, is likely to positively impact the financial situation of the City by having positive net present values. The scenarios present policy options for city officials based on different amounts of investments and the timeframe for required investments. Scenario 1 has the least initial capital investment requirement but also the smallest positive net present value. Scenario 2 and 3 have increasing capital investments over longer terms but also have greater net present values than Scenario 1 due to more operational savings. Measures in each scenario are grouped by demand-side, supply side, and transportation strategies. Key components of the scenarios are summarized in Table 1 and Table 2 below. A brief narrative description of each scenario follows. Details of the technical measures and financial analysis for each scenario are included in Appendix B.

[15] Based on The World Wildlife Fund, Ecofys, OMA, *The Energy Report: 100% Renewable Energy by 2050*, 2011.

Table 1. 100% Renewable Energy and Zero Net Carbon Timeline Menu

SCENARIOS	HIGHLIGHTS	BENEFITS OUTCOMES OVERVIEW	ACTIONS
SCENARIO 1 100% Renewable Energy and Zero Net Carbon by 2020	• 15% carbon reduction • 85% RECS/Offsets	10% self-generated renewable electricity • Quick start to achieve 100% renewable energy goal while planning for next steps • Invest in statewide solar and economic development	**EFFICIENCY (DEMAND)** • HVAC RCx **RENEWABLE GENERATION (SUPPLY)** • Behind-the-Meter Solar: Phase 1 • Utility Scale Solar (MGE RER or Alliant) • Utility Fuel Mix (MGE and Alliant) **TRANSPORTATION (DEMAND)** • Green Fleet Measures • Passenger Car EV Procurement • Light Duty EV Procurement **INVESTMENTS** • Renewable Energy Credits (RECs) • Carbon Offsets
SCENARIO 2 100% Renewable Energy and Zero Net Carbon by 2023	• 40% carbon reduction • 60% RECS/Offsets	15% self-generated renewable electricity • Jumpstart implementation to inspire the greater community • Measures can be quickly implemented by local government	**ALL SCENARIO 1 MEASURES** **EFFICIENCY (DEMAND)** • Lighting Retrofits • HVAC Controls Retrofits • Street Lighting Upgrades • Water Distribution Optimization Strategies **TRANSPORTATION (DEMAND)** • 50% Electric Buses • Landfill CNG Fueling
SCENARIO 3 100% Renewable Energy and Zero Net Carbon by 2030	• 55% carbon reduction • 45% RECS/Offsets	25% self-generated renewable electricity • Investments in efficient buildings, street lights, and water distribution • Green and electric fleet and transit vehicles	**ALL SCENARIO 1 & 2 MEASURES** **EFFICIENCY (DEMAND)** • HVAC Retrofits • Plug Load Management Strategies • Building Envelope Improvements **RENEWABLE GENERATION (SUPPLY)** • Behind-the-Meter Solar: Phase 2 **TRANSPORTATION (DEMAND)** • 100% Electric Buses • Mid Duty EV Procurement • Heavy Duty CNG Procurement

Source: HGA

Table 2. Scenario Key Financial Estimates

	Scenario 1 (2020)	Scenario 2 (2023)	Scenario 3 (2030)
Total Investment	$7 million	$57 million	$95 million
Net Present Value (NPV) (2050)	$10 million	$71 million	$116 million
Internal Rate of Return (2050)	15%	17%	17%
Simple Payback	2024	2027	2029

Source: HGA

Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020
The Scenario 1 objective is to quickly reach the goal of 100% Renewable Energy and Net Zero Carbon for city operations. By 2020, city government will cut its carbon emissions by 15% with at least 10% of municipal operations' electricity use sourced by self-generated renewable energy. Investments in RECs and carbon offsets will cover the remaining 85% of carbon emissions in this scenario.

In Scenario 1, the city will expand its current efficiency investments in facilities and implement green fleet and pilot programs to gain early momentum. Investments in solar include installing at least 1 MW of Behind-the-Meter Phase 1 solar projects. City officials will continue to work with local utilities to encourage development of larger solar arrays. Investing in RECs and/or carbon offsets that meet the City's standards for additionality make up the remainder of the carbon balance.

Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023
The Scenario 2 objective is to implement a broad range of efficiency measures and accelerate current plans for electrifying vehicle and transit fleets while investing in renewable energy. By 2023, city government will cut its carbon emissions by 40% with at least 15% of municipal operations' electricity sourced by self-generated renewable energy. Investments in RECs and carbon offsets make up the remaining 60% of carbon emissions in this scenario.

In Scenario 2, the city will invest in a combination of energy efficiency measures in buildings, streetlights and water distribution, renewable energy installations, transportation measures and accelerating the electrification of fleet and transit vehicles to achieve 50% electric buses by 2023. These measures were selected based on cost-effectiveness and their ability to be implemented quickly by local government. Fleet investments for green fleet measures provide favorable carbon abatement potential. Investments in electric vehicles were selected based on vehicles with the highest miles traveled and the lowest cost options for electric vehicles - currently passenger vehicles and light trucks or SUVs. Phase 1 solar will be completed leading to at least 3 MW of solar at municipal locations.

Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030
The Scenario 3 objective is to implement known measures to reduce the carbon footprint from city operations and minimize the reliance of external RECs or carbon offsets. By 2030, city government will cut its carbon emissions by 55% with at least 25% of municipal operations' electricity sourced by self-generated renewable energy. Investments in RECs and carbon offsets make up the remaining 45% of carbon emissions balance. This path is most consistent with the longer-term mid-century deep decarbonization strategies, involving more extensive investment over a longer period.

Scenario 3 achieves the 100% renewable energy and zero net carbon goal with RECs or carbon offsets as bridge strategies while the city continues to work toward implementing more renewables generation and other carbon emissions reduction measures. Energy efficiency measures with short and longer paybacks are included, such as HVAC retrofits in buildings, in addition to water distribution and street and traffic lights. The City will invest in greening its fleet with all vehicles being converted to operate on electricity or compressed natural gas from non-fossil sources by 2030. Electrification of the fleet enables the City to economically further expand its internal renewable energy generation, adding additional renewable generation opportunities to Phase 1 and Phase 2 behind-the-meter solar on buildings.

Accelerating the Goals
Additional suggestions to accelerate progress towards reaching 100% renewable energy and zero net carbon goals are included in Appendix D. For example, as Metro Transit buses and city fleet vehicles are

electrified, the city should add additional solar, energy storage and electric vehicle charging capacity to accommodate these vehicles and to further plan for electric vehicle charging infrastructure for the community.

The energy ecosystem is changing rapidly. Renewable energy, energy storage and electric vehicle markets are undergoing rapid technological innovation and price declines. A balanced approach of investments in energy efficiency, transportation strategies, and renewable energy installations, along with RECs and carbon offsets, is one key to reaching the 100% renewable energy and zero net carbon goal quickly and cost-effectively.

City officials should review their plans every two years to confirm progress and update milestones due to the rapidly changing economic, technology, and policy landscape. As the landscape continues to evolve, the most effective strategies to reach the City of Madison's goals will also evolve.

APPENDIX A. CITY OF MADISON EMISSIONS REPORT

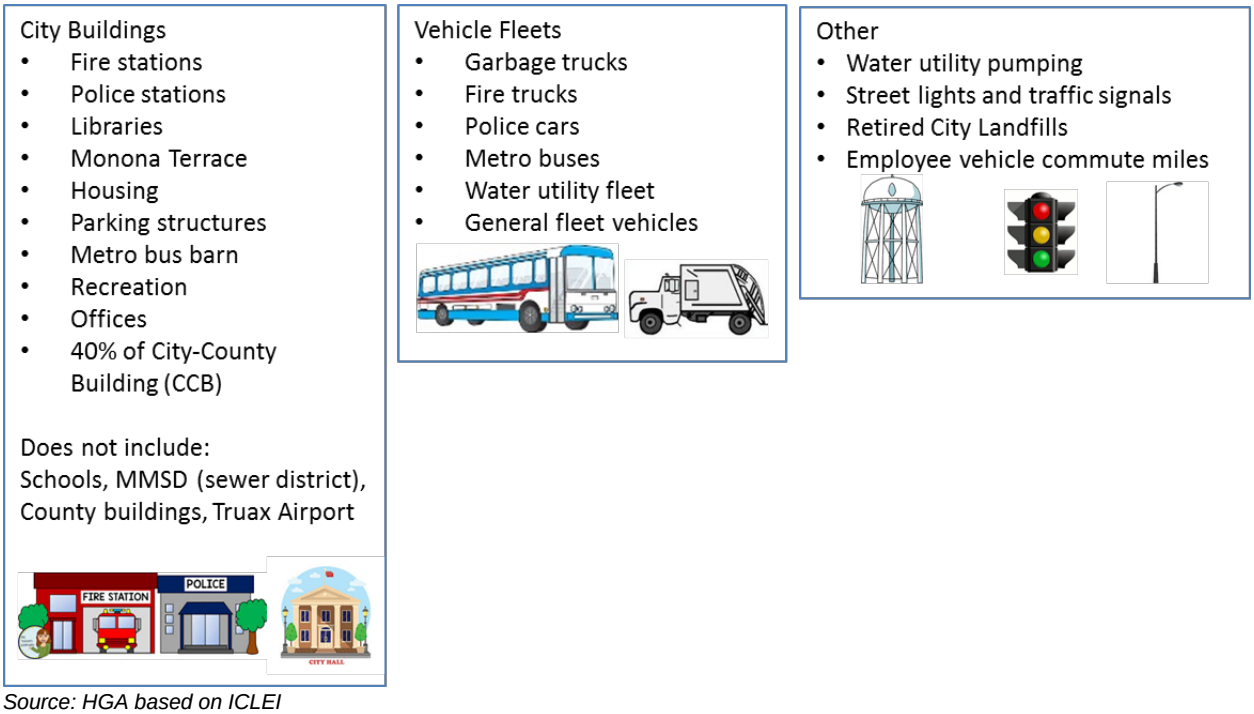
The City of Madison is responsible for providing municipal services for over 250,000 city residents. These include a wide range of services from public safety/health, transportation, parks/recreation, water delivery, streets, housing, planning, permitting, and many other community services. The City has extensive infrastructure, assets, and resources to support these services, including the following:

- **Buildings and Facilities:** 63 major buildings and over 300 structures with over 3.2 million square feet
- **Fleet:** 1,017 vehicles and equipment
- **Transit:** 218 buses
- **Water:** 21 pumping stations that pump 10 billion gallons a year
- **Employees:** 3,500 employees (2,800 FTE employees)

A.1 Baseline Emissions

There are a number of sources of emissions that are attributable to the City of Madison. Figure A-1 presents the major sources of emissions.

Figure A-1. Sources of CO_2 Emissions from City Operations



Source: HGA based on ICLEI

The City of Madison is a member of ICLEI, an international non-profit organization of local governments working toward sustainability.[16] The City of Madison tracks emissions for local government operations and the entire community through the ICLEI Clearpath tracking tool. The ICLEI Clearpath web-based tool uses accepted protocols to quantify GHG emissions, and break down CO_2 (carbon dioxide) emissions into three categories, or scopes. Table A-1 identifies the three scopes: direct emissions, indirect emissions, and other.

Table A-1. ICLEI Emission Scopes (Categories) for Local Government Operations

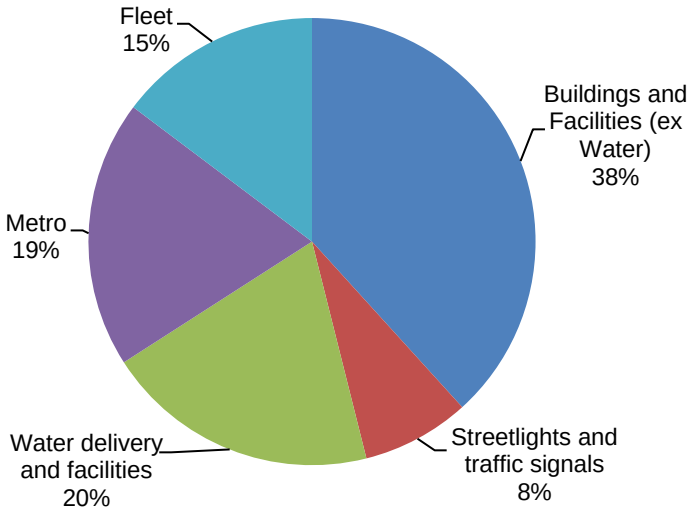
Scope 1: Direct Emissions	Scope 2: Indirect Emissions	Scope 3: Other
Vehicle exhaust	Purchased electricity	Employee commutes
Retired city landfills	Purchased steam	City-owned housing
Onsite natural gas combustion		Supply chain and waste emissions (not included)

Source: HGA based on ICLEI

The City used Clearpath to inventory emissions from city operations in 2010, 2012, and 2014, which showed baseline city operations emissions was 95,210 tons CO_2e (carbon dioxide equivalent). This study excluded emissions from landfills and Scope 3 supply chain emissions sources were not included in the City's carbon inventory. Supply chain emissions historically have not been included in the local government emissions inventory due to the difficult nature of collecting this data. Additionally, the city has limited to no control of supply chain emissions from third parties. Figure A-2 shows baseline city operations emissions was 81,141 tons CO_2e broken out by category. The business as usual (BAU) case includes an average increase of 2% each year due to expected new facilities and operations. Local government operations baseline emissions (not including landfill, employee commute, or City-owned housing emissions) grows from 81,141 tons of CO_2 in 2018 to 88,188 tons of CO_2 in 2030.

[16] ICLEI, "Local Governments for Sustainability," http://iclei.org/.

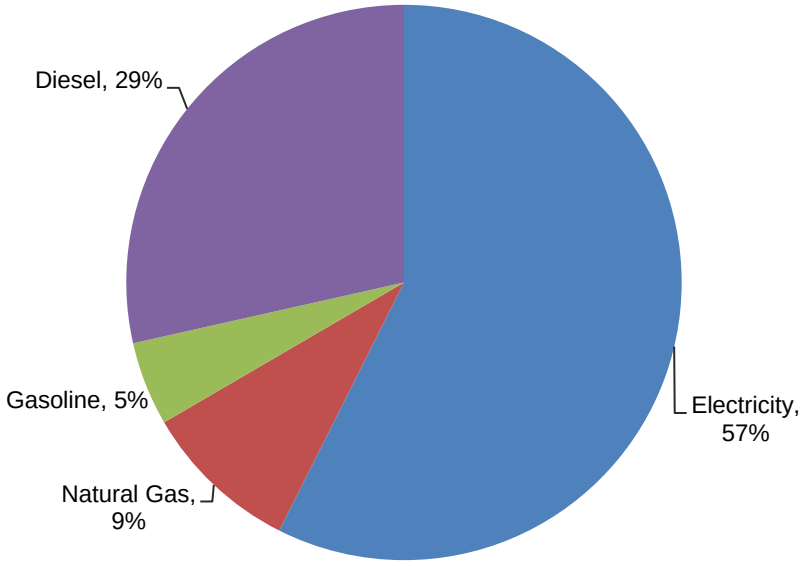
Figure A-2. Baseline Carbon Emissions for City Operations by Category*



**Excludes landfill, city employee commute, and City-owned housing emissions*
Source: HGA based on ICLEI

Figure A-3 illustrates baseline carbon emissions for municipal operations by fuel type in 2018, the baseline year for the report, including electricity (57%), diesel (29%), natural gas (9%) and gasoline (5%).

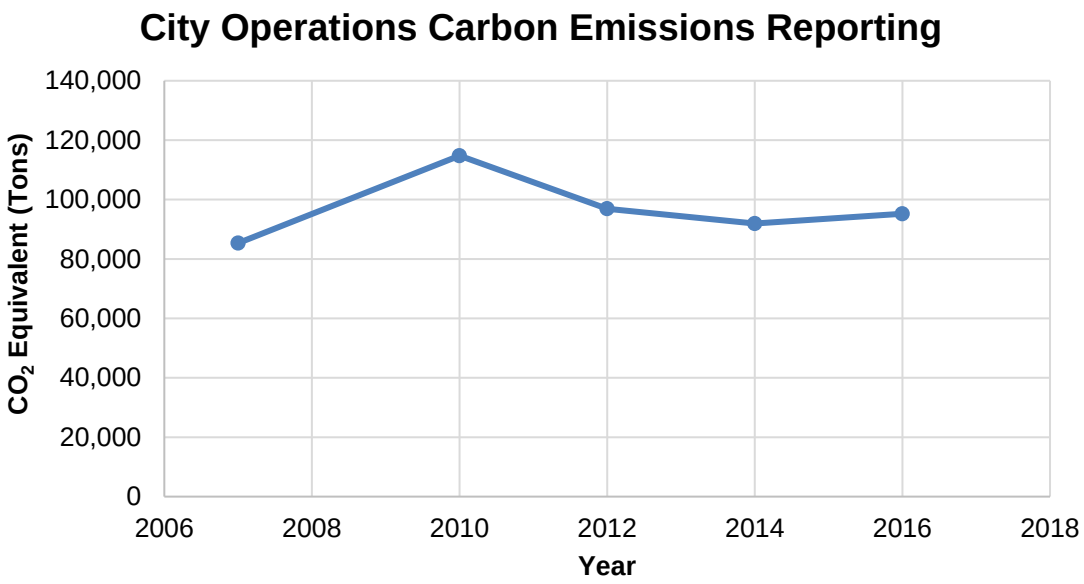
Figure A-3. Baseline Carbon Emissions City Operations by Fuel Type*



**Excludes landfill, city employee commute, and City-owned housing emissions*
Source: HGA based on ICLEI

Figure A-4 illustrates municipal emissions tracking over the past 10 years, which have fluctuated as a result of changes in the city's building inventory, such as the removal of the Overture Center from the city's building inventory, and some variations in reporting methodologies.

Figure A-4. City Operations Carbon Emissions Reporting



Source: HGA based on ICLEI

For purposes of this analysis, the consulting team took an average use of recent City of Madison energy consumption for electricity, natural gas, gasoline, and diesel, and assigned costs per unit based on recent cost estimates. This method resulted in a baseline estimate of $14.1 million, or approximately 4.5% of its 2018 annual operating budget of $315 million.

Table A-2. Baseline Fuel Consumption and Expenditures

Fuel (unit)	Electricity (kW-hr)	Diesel (gallons)	Natural Gas (therms)	Gasoline (gallons)	Total
Amount	53,000,000	2,088,088	1,182,000	534,473	N/A
Cost/unit	$0.10/kWh	$3.24/gal	$0.50/therm	$2.70/gal	N/A
Annual cost	$5,300,000	$6,765,405	$591,000	$1,443,077	$14,099,482

Source: Navigant analysis of City of Madison data

The estimated carbon impact from the use of electricity includes an 80% reduction in carbon emissions by 2050 based on stated goals of MGE and Alliant to reduce the carbon intensity of their electricity fuel mix. Other fuels remain constant throughout the study period.

Table A-3. Carbon Emissions by Fuel (2018-2050)

Energy Carrier	Unit	2018	2030	2050
Electricity	ton CO_2/MWh	0.873	0.544	0.175
Natural gas	ton CO_2/Therm	0.006	0.006	0.006
Gasoline	ton CO_2/Gallon	0.0098	0.0098	0.0098
Diesel	ton CO_2/Gallon	0.0112	0.0112	0.0112

Source: Navigant analysis of EIA, DOE data

A.2 Constraints to Further Sustainability Success

There are opportunities for the City of Madison to achieve its goal of 100% renewable energy and zero net carbon emissions for municipal operations while providing leadership to the greater Madison region. However, some constraints are worth noting:

A.2.1 Regulatory

There are several regulatory constraints that directly affect the City of Madison's options for powering city operations with 100% renewable energy. For example, the City of Madison must purchase its power from its current electricity providers; it cannot choose to purchase power from other providers. In other states, such as Texas, consumers and businesses may purchase power from a variety of electricity providers who compete for customers based on customer service and increasingly, green attributes of their power. Net metering requirements further restrict solar PV development. Wisconsin requires regulated utilities to offer net energy billing (also known as net metering) to customers who supply themselves with renewable electricity generated on their premises. Solar electric systems up to 100 kW are eligible for MGE's net metering tariff, while Alliant Wisconsin Power & Light (WP&L) has a limit of 20 kW. To be eligible for the net metering rate, customers must generate less electricity than they consume over the "true-up" period. Currently the true-up period is determined on an annual basis. For customers that do not qualify for the "net-metering" rate, excess electric production to the grid is credited at a wholesale price, currently around $0.03/kWh. Many of the City's large electrical loads would require solar systems greater than 100 kW to meet their annual electrical loads. Without net metering, the economics of rooftop solar are not as favorable with the current tariff structures and electricity rates.

The City of Boulder, Colorado is exploring the creation of a municipal electric utility to achieve its goals of 100% renewable energy and 80% reduction in carbon emissions by 2050.[17] The City of Minneapolis, Minnesota negotiated franchise agreements[18] with its utility providers to incorporate higher standards for renewable energy generation and a public-private partnership to further mutual goals for the parties.[19] These options are not feasible for the City of Madison because current state policy does not allow for renewals of franchise agreements. An effort to municipalize MGE would require expensive legal action that, even if successful, would not enable the city to pursue its renewable and clean energy goals any

[17] City of Boulder, Colorado, "Energy Future," https://bouldercolorado.gov/energy-future.

[18] Minneapolis, Minnesota, "Energy Utility Franchise Agreements," http://www.ci.minneapolis.mn.us/energyfranchise/index.htm.

[19] Minneapolis Clean Energy Partnership, https://mplscleanenergypartnership.org/.

differently than MGE can under its regulatory requirements.[20] City officials therefore chose to negotiate an agreement with MGE[21] identifying key areas for collaboration, including working together to expand solar and the use of EVs, promote energy efficiency, promote projects that contribute to social equity and economic development, and other ongoing collaborative projects. Additional information is included in sections below.

A.2.2 Jurisdictional

The City of Madison's local government operations are an important piece of climate change in the greater Madison region, but the City needs public and private partners to work together to broaden the collective impact. This document emphasizes actions that the City can take under its own jurisdiction, while referring to areas where the City has jurisdiction or influence, such as through permitting and inspection for solar installations or tax incremental financing (TIF) for new construction, land use planning and transit.

A.2.3 Economic

City of Madison policymakers must make difficult choices when allocating valuable taxpayer resources to address multiple policy goals, all of which are compelling and important. The scenarios in this plan have important multiple co-benefits—promoting public health, racial equity and social justice, and contributing to economic development.

[20] City of Madison Attorney's Office, "Franchise Agreements and Municipalization; Issues Relating to the Collaboration MOU," (August 16, 2017).

[21] "Memorandum of Understanding Between the City of Madison and MGE Regarding A Framework for Collaboration on Shared Energy Goals" (August 16, 2017).

APPENDIX B. TECHNICAL DETAIL OF SCENARIOS

Table B-1 includes the sources of information, along with interviews with city officials, that were used to estimate energy consumption and costs.

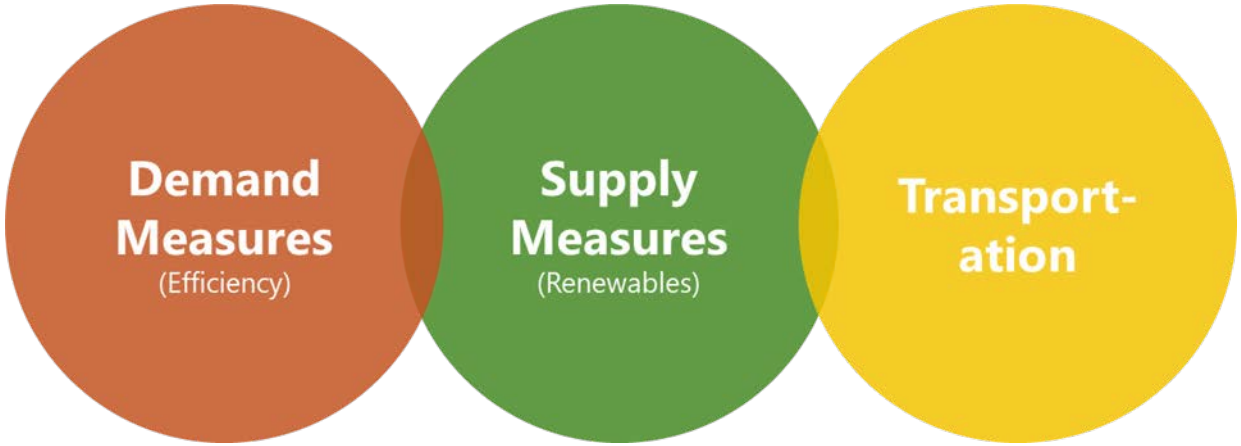
Table B-1. Sources of Information

Measure	Sources
Facilities and Buildings	City of Madison Energy CAP data; site reports, HGA field experience; Brendle Report (2015); ICLEI reports (2012, 2014)
Water Distribution	Water Utility Optimization Memo (2016)
Streetlights and Traffic Signals	Brendle Report (2015)
Fleet Vehicles	City of Madison data; ICLEI reports (2012, 2014)
Metro Transit	ICLEI reports (2012, 2014), Metro reports (various)
Fuel Mix and Emissions Data	EPA eGrid, Utility Annual Reports
Renewable Energy	Madison solar planning document, RENEW Wisconsin; UW Extension; Madison Solar Consulting; HGA field experience; Navigant reports

Source: Navigant

This section includes additional detail for the technical measures used in the three modeled scenarios. They are grouped by demand-side, supply side, and transportation strategies. Demand-side measures are strategies that reduce the consumption of fuels, such as energy efficiency measures. Supply side measures are strategies that generate renewable energy from sources, such as wind and solar power. Transportation measures include actions to reduce carbon emissions from fuel efficiency, fuel switching, and electrification of fleet and transit vehicles.

Figure B-1. Key Strategies for Achieving 100% Renewable Energy Goal



Source: HGA

B.1 Demand-Side Strategies

Energy efficiency improvements are one aspect of carbon emissions reductions. While energy efficiency does not have the glamor of renewable energy, it does provide opportunities in terms of economics and payback of the city's investments. The city has invested in energy efficiency for 10 years. Many efficiency opportunities remaining at city facilities require substantial investments in building systems or may cause substantial interruptions for important city services. Aggressively targeting energy efficiency measures with a simple payback of less than ten years is part of all the scenarios.

B.1.1 Facilities Energy Efficiency

To better manage facility energy consumption, the City of Madison has been tracking and reporting all building energy performance since 2010. This system enables the City to monitor building performance over time and validate impacts of efficiency upgrades. In the last ten years, the city has invested roughly $250,000/year in energy efficiency improvements.

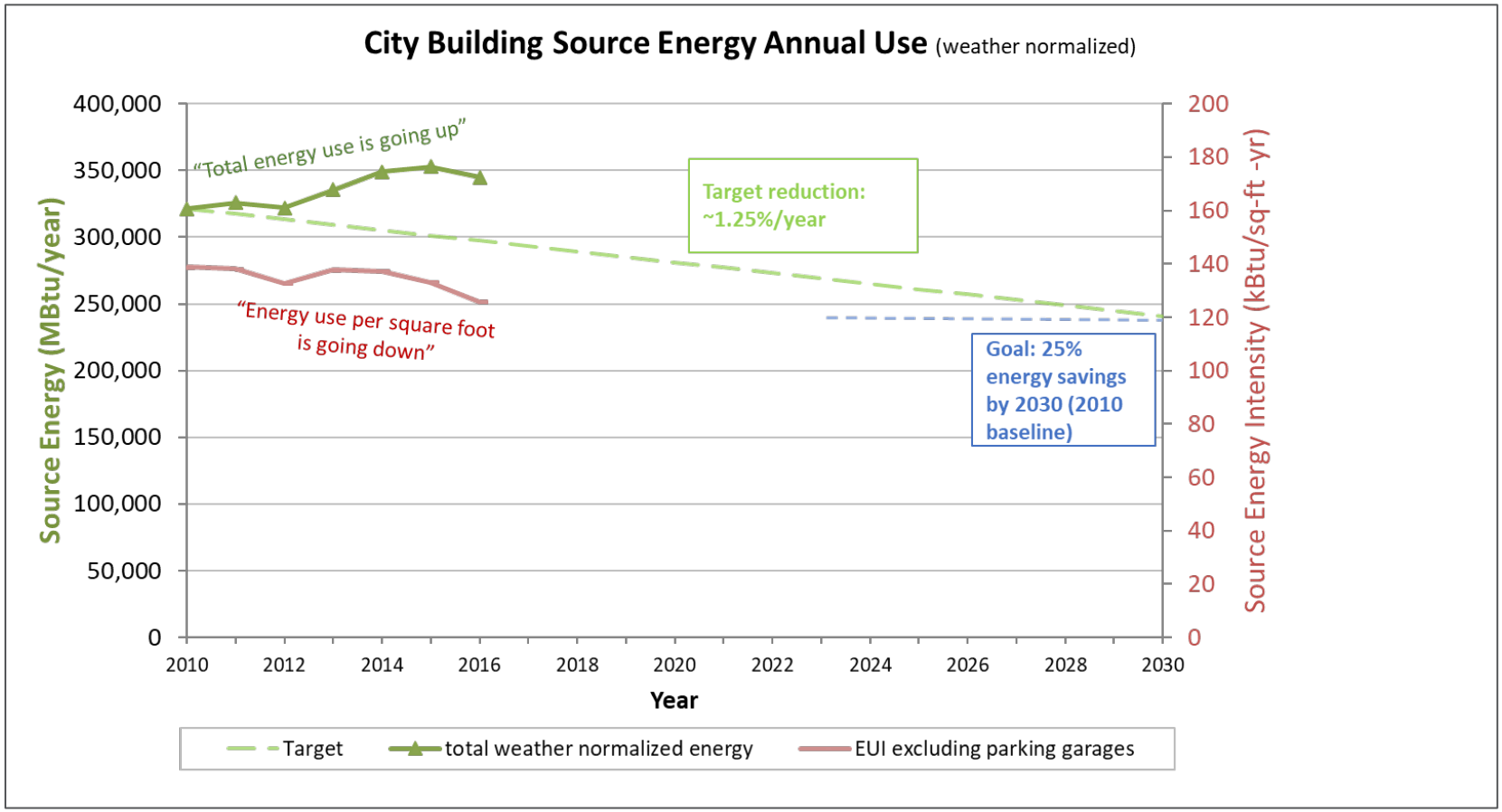
Building energy performance is most effectively tracked using total source energy consumption and source energy consumption per square foot of building area, normalized for variations in weather. Figure B-2 illustrates both these metrics over the last six years. As indicated below, there is a general decline of energy use intensity (red line, excludes parking) over the last six years, indicating that energy consumption has been reduced

when normalized for total square footage and weather. However, the overall energy consumption has increased because energy consumption of new city buildings has outpaced efficiency improvements in existing buildings. By implementing the recommended building efficiency measures, the City of Madison may achieve up to 25% energy savings by 2030 with a simple payback of less than six years (assuming no new city buildings, only replacement buildings).

Lighting and HVAC equipment have advanced rapidly in the last 10 years. There is ample opportunity for the City to upgrade existing facilities with more efficient lighting and HVAC equipment. In June of 2015, city engineering received an energy analysis on the existing City of Madison building stock and developed a list of retrofit measures along with associated costs and savings. The retrofit measures included the following categories: lighting, HVAC, controls, plug loads and water distribution measures.

This section details energy efficiency strategies that can be implemented to reduce the City's total energy consumption.

Figure B-2. Historic and Projected Building Energy Consumption



Source: HGA analysis of City of Madison data

B.1.2 Facilities Retro-Commissioning (RCx)

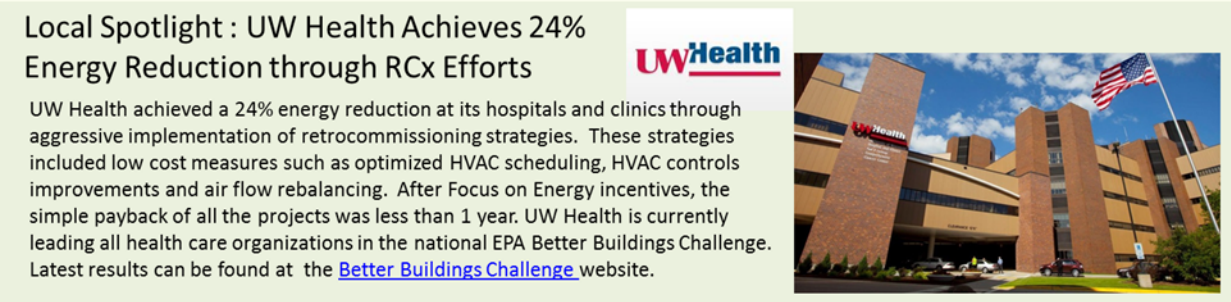
Retro-Commissioning (RCx) is a process that identifies operational and maintenance improvements in existing buildings and brings the buildings up to the design intentions of its current usage. RCx optimizes existing system performance, rather than relying on major equipment replacement, resulting in improved indoor air quality, comfort, and energy efficiency.

Focus on Energy currently incentivizes RCx making it even more attractive from a financial perspective. Typical paybacks for RCx are 1-2 years without incentive, and 6-12 months with Focus on Energy incentives.

The City of Madison has started retro-commissioning some buildings. Completing RCx on at least 5 buildings per year would achieve a minimum of 2% additional annual savings over the entire COM building stock. RCx costs including implementation are typically around $0.50/sq-ft. Implemented savings continue to save year after year, with the average measure having at least a 5-year life.

The RCx program could be administered by the sustainability coordinator and funded through the sustainability fund. The RCx program could be used as a model for the community and share information with companies that are implementing similar programs. For example, UW Health has implemented an RCx program at its facilities.

Figure B-3. Retro-Commissioning in the Community



Source: HGA

B.1.3 Lighting Retrofits

The City has aggressively replaced incandescent and T12 fluorescent fixture with higher efficiency T8 fluorescent or LED fixtures. However, as LED lighting technology has continued to improve in performance and decrease in price, there are still additional opportunities for lighting retrofits. The Brendle Group identified lighting retrofits targeting T12 linear fluorescent replacement, T8 linear fluorescent replacement, and parking garage high intensity discharge lighting.

Lighting retrofits are most economically performed when spaces are being remodeled. Spaces with no future plans for remodeling would be great candidates for immediate lighting retrofits. Table 16 in the Brendle group report identifies existing lighting retrofit opportunities.

B.1.4 Smart Streetlights

The City of Madison owns many of its streetlights, but not all. City officials are working with local utilities to upgrade existing streetlighting to smart streetlights. Smart streetlights are energy efficient LED lights with added sensors or other technologies that collect and process data to offer a variety of city services, including air quality monitoring, communications, security, EV charging, traffic management, and smart parking, among others.[22] As of 2016, LED prices have dropped by more than 90% since 2008. LEDs are now the standard replacement for street lighting in most cities around the world. Utility officials are developing a rate structure for street lights that would recognize energy savings through replacing current street lights with LED street lights.

B.1.5 HVAC Retrofits

Heating, ventilating and air conditioning (HVAC) uses up to 50% of a building's total energy use. Replacing existing equipment with more efficient equipment can significantly reduce building energy consumption. The Brendle Group Report Table 18 identifies HVAC retrofits for over 20 city buildings. While some of the paybacks are quite high, there are numerous projects outlined that can be completed with a net savings to the city.

Energy recovery can reduce the need for heating and cooling substantially. These systems can often relatively easily be retro-fitted to the existing building systems provided there is space. Waste heat from air conditioners and chillers can be utilized to heat hot water in the summer or directly for heating in the cold seasons from sources such as computer rooms or other high energy intensive spaces.

Chillers and air conditioners have become significantly more energy efficient over the last few years and technologies such as magnetic bearing chillers are often good investments when larger equipment needs replacement. Even smaller roof top units come with more efficient options such as electronically commutated motors (ECM) for fans that can significantly improve the performance of these units when replacement becomes necessary.

Dedicated outdoor air units (DOAS) can be excellent options when updating facilities. These units typically include energy recovery and can reduce the ceiling space requirements significantly compared to a traditional VAV system when coupled with a water or refrigerant type of heating-cooling distribution system such as fan coils, radiant heating and cooling, distributed geothermal system, or variable refrigeration flow (VRF) systems.

As HVAC equipment is replaced in existing buildings, opportunities for electrification of the HVAC systems could be explored. Electrification of HVAC systems could accelerate the City's path to 100% renewable energy and reduce future reliance on natural gas consumption with renewable energy generation. As the utility grid becomes cleaner, energy efficient electrified HVAC equipment will generate less carbon than a natural gas heating system. From the City perspective, low carbon electricity may be achieved in the next five years through on-site and off-site renewable systems. The ability to change the carbon intensity of electricity in the short term, may enable the city to begin electrification efforts earlier and not have to wait for more renewables in the utility grid mix.

[22] Navigant Research, *Smart Streetlights for Smart Cities*, 2017.

The city has embraced geothermal heating and cooling technology in many of its buildings. Geothermal heating and cooling should continue to be used for new construction, where feasible. Air source heat pumps are also becoming more suitable for cold climates. Where geothermal systems may not be feasible, air source heat pumps should be evaluated.

Monona Terrace and the City County Building both use steam from the natural gas-fired Capital Heat and Power Plant. One option is to reconfigure this plant to use renewable fuels such as wood chips or agricultural waste products. Another option is to reconfigure these buildings to an electric system, such as geothermal utilizing lake water, but this will need to be implemented over decades. Geothermal systems typically produce cooler hot water in the 120°F range. Therefore, all the heating coils in the facility are typically required to be replaced with larger coils. This option therefore requires extensive equipment replacement and high costs.

The Madison Metro Maintenance garage is scheduled for a large renovation in the next few years. Alternatives to gas heating should be explored during the early stages of the design process. Once a building is built to use natural gas heating, future retrofits to efficient electrified heating are unlikely due to the high retrofit costs.

B.1.6 HVAC Controls

HVAC controls can be a powerful tool in reducing building energy consumption. The City of Madison has digital controls systems in many of its buildings. However, there are some buildings that lack digital controls and a building automation system that can be remotely monitored and controlled. Remote monitoring allows operators to more quickly identify issues and also adjust schedules to match building occupancy. Table 19 of the Brendle Group report identifies controls related projects in over 34 city buildings averaging a simple payback of 13 years.

B.1.7 Plug Load Management

Building plug loads include electricity consumption from computers, office equipment, space heaters, fans and chargers. These loads typically account for 10%-20% of building energy consumption. Strategies to reduce plug loads include improving the comfort of the spaces (less fans/heaters), sleep settings on computers, use of virtual desktop computers and power strips that turn off based on a time of day schedule. Table 20 of the Brendle Group identifies plug load management strategies for 32 city buildings with a payback around 10 years.

B.1.8 Water Utility Distribution Optimization Measures

Madison Water Utility (MWU) pumping accounts for approximately 20% of the city's electrical consumption. As part of a previous report, a list of water distribution strategies was developed. The list of water distribution optimization strategies included system optimization and controls, infrastructure upgrades, and an end user reduction program.

Water distribution system optimization includes measures that reduce electrical consumption by coordinating zones, optimizing system pressures and improving cross over operations. These efficiencies would be achieved through enhancing the supervisory control and data acquisition (SCADA) platform, programming updates and related control system hardware and sensors.

Infrastructure upgrades include larger capital improvements including variable speed motor drive installations, premium efficiency motor replacements, and distribution valving modifications.

Reducing the city's total water consumption through conservation will also reduce the associated pumping energy. In 2017, MWU pumped the lowest amount of water in 50 years at 9.5 billion gallons. This reduction was achieved largely through conservation activities and the closure of a large industrial facility with high water consumption. MWU has offered rebates for water efficient fixtures and is developing the Water Conservation House, a modest single-family home that will feature innovative water-saving technology inside and out. It includes plans for a 500 gallon rainwater harvesting system, energy efficient water heating and wastewater heat recovery, native plant and turf, rain gardens and permeable pavement, and high efficiency appliances and plumbing fixtures. Together, these features are expected to cut the home's municipal water use by half.[23]

B.2 Supply Side Strategies

The emergence of very economical wind and solar have created an opportunity for the City to rapidly increase the amount electricity generated from renewable sources, while decreasing overall utility costs. For the first time ever, renewables are enabling consumers to reduce energy costs while and reducing fossil fuel consumption.

This section includes three primary strategies for the City to increase its renewables generation:

- Solar photovoltaics (PV) on or close to buildings (behind-the-meter solar)
- Off-site solar
- Off-site wind turbines

Other renewable energy technologies that are currently less economical include combustion of biomass, biodigesters, garbage combustion, and in some locations geothermal heat. The more traditional hydropower which is often very economical, has in most cases already been developed to its optimal capacity in this area, considering the limited hydro resources available in the region.

The City of Madison currently supplies 1% of its 2018 electricity consumption from behind-the-meter solar PV (on or near city buildings). In addition, utility supplied electricity includes 10% (in 2016)[24] from renewable sources, excluding voluntary green tariff programs which provide an additional 3%.

This section of the report outlines strategies for achieving rapid adoption of renewable energy generation for city operations.

B.2.1 Behind-the-Meter Solar PV

Behind-the-meter solar is one of the most cost-effective renewable technologies available to the City because the economic value of the generated electricity is equal to the retail value of the electricity. By

[23] Madison Water Utility, "Water Conservation House," http://www.cityofmadison.com/water/projects/water-conservation-house.

[24] MG&E https://www.mge.com/about-mge/electricity/elec-from.htm

the end of 2018, the City will have installed over 618 kW of behind-the-meter solar to date, generating approximately 1% of the City's 2018 electricity consumption.

Different organizational and finance methods are available to install solar panels, all of which have pros and cons. To date, all City solar installed has been self-financed. The City can also self-install solar as it has done with the GreenPower job training program or by incorporating solar into major remodels or new construction projects. Self-financing is a straightforward and economically viable process for cities to purchase solar PV systems. However, self-financing does not enable cities to take advantage of the 30% federal Investment Tax Credit. This tax credit will begin to taper down in 2020 and 2021. For cities that are looking to reduce first costs and monetize the federal tax credit, alternative financing mechanisms have been used. The most common finance mechanism is the Energy Services Agreement. This model involves co-ownership of a solar system with the solar developer. The developer largely covers the initial cost of the system in this arrangement. The City would pay for the system over time and have an option to buy the system out after the developer has fully monetized the remaining investment after the tax credit and the accelerated depreciation. In the Energy Services Agreement the terms of the deal can be arranged to achieve positive cash flow from day one.

Sauk County, City of Monona, and City of Milwaukee are Wisconsin municipalities that have used this type of financing scheme to develop additional roof top solar systems. The City of Monona worked with a local organization to install panels (Legacy Solar Co-op).[25] Some cities have issued RFPs, such as the City of Milwaukee. The RFP calls on the solar industry to install solar at a number of facilities all at once, the ownerships of the systems are held for a set number of years so that the tax credits can be utilized. During that time, the city pays the installer for the power. Then the ownership of the systems transfers to the City.

Local Spotlight: Sauk County Solar Cash Flow Positive from Day 1

In January of 2018, the Sauk County Board approved an Energy Services Agreement with a solar installer to install over 650kW of solar on two of the county's buildings.

The contractual model used allows the county to pay for the system over time, while reducing its overall electric costs. It is estimated that the county will save over $500,000 over the life of the system.

This model is economically attractive because the 30% tax credit can be monetized by the installer and the County avoids issuing a bond to finance the system. The tax credit is scheduled to be phased out starting in 2020.

Potential behind-the-meter sites have been identified for over 3,000 kW (3 MW) of solar PV for City operations. When compared to offsite solar or wind, behind-the-meter solar installations are relatively straightforward and do not require lengthy approval process from the public service commission (PSC), system operator (MISO) or the local utility. These lowest cost PV sites (referred to as phase 1 solar) could

[25] Solar Energy Finance Guide, https://erc.cals.wisc.edu/wp-content/blogs.dir/14/files/2017/08/SolarEnergyFinancingGuide.pdf

produce enough energy to offset 7% of the city's 2018 electrical consumption. Table B-2 includes a list of existing solar and phase 1 solar sites.[26]

Table B-2. Existing and Proposed Rooftop Solar PV Installations (sites with install date from 2017 and early have already been installed)

Site	Install Year	DC Size (kW)	Total (kW)
Alicia Ashman Library	2007	7.1	7
Engineering Operations Facility Office Buildings	2008	4.2	11
Greentree Landfill	2008	6.3	18
Demetral Landfill	2008	6.3	24
Madison Police Department East District Station	2009	9.6	34
Water Utility Office Building	2009	9.84	43
Water Utility Vehicle Storage Building	2009	9.84	53
Streets Waste Transfer Station	2009	9.84	63
Streets East Garage	2012	9.36	72
Madison Public Library Central Library	2013	18.72	91
Engineering Operations Facility Garage	2013	18.72	110
Madison Fire Department Station 13	2014	25	135
Madison Police Department Training Center	2016	19.14	154
Warner Park Community Recreation Center	2016	16.3	170
Traffic Engineering Building C	2016	8.7	179
Yahara Hills Golf Course	2016	18.56	198
Water Utility Well 9	2016	5.7	203
Streets West Vehicle Storage	2017	99.9	303
Madison Fire Department Station 12	2017	18.9	322
Water Utility Well 26	2017	21.6	344
Library Maintenance & Support Center	2018	50	394
Engineering Operations Addition	2018	75	469
Goodman and Park Maintenance Facility	2018	50	519
Fire Station 11	2018	25	544
Fire Station 05	2018	5	549
Fire Station 06	2018	5	554
Fire Station 07 + Police West	2018	50	604

[26] City of Madison, "Photovoltaic System Locations," Sustainability, http://www.cityofmadison.com/engineering/photovoltaic-system-locations.cfm.

Site	Install Year	DC Size (kW)	Total (kW)
Sycamore - Streets East	2018	100	704
Midtown Police Station	2018	21.6	725
Fire Station 14	2018	120	845
Madison Municipal Building	2019	57	902
Pinney Library	2019	100	1,002
Warner Park Community Recreation Center	2019	15	1,017
Olbrich Gardens	2019	20	1,037
Metro East Washington – New Roof	2019	1,000	2,037
New Fleet at Nakoosa Trail	2020	100	2,137
Water Utility – Patterson	TBD	100	2,237
CDA – Olin – Housing	TBD	100	2,337
Sayle Street – Traffic Engineering	TBD	100	2,437
Nakoosa Trail Bus Barn	TBD	100	2,537
Brittingham Apartments	TBD	202	2,739
Romnes	TBD	200	2,939
East Madison Community Center	TBD	155	3,094
TPA	TBD	57	3,151
Parkside Senior	TBD	30	3,181
Tenney Park	TBD	16	3,197

Source: HGA analysis of City of Madison data

There are additional sites beyond the 3 MW identified above that would be suitable for solar as the price of solar PV further decreases. This includes locations such as parking garages, surface lots, and retired landfills. HGA estimates that there is potential for an additional 5,000 kW (5 MW) of City-owned PV that could be installed economically as the price of PV continues to decline and as the vehicle fleet is converted to electric vehicles.

The total behind-the-meter solar PV generation for Scenario 3 would total 8 MW, or approximately 19% of the city's 2018 electric consumption. Unfortunately, the potential sites for behind-the-meter solar are limited. The majority of City energy is consumed at pumping stations and urban multi-story buildings with limited space for solar. Due to these constraints, off-site renewable energy is required to further increase the amount of electricity generated from renewable sources.

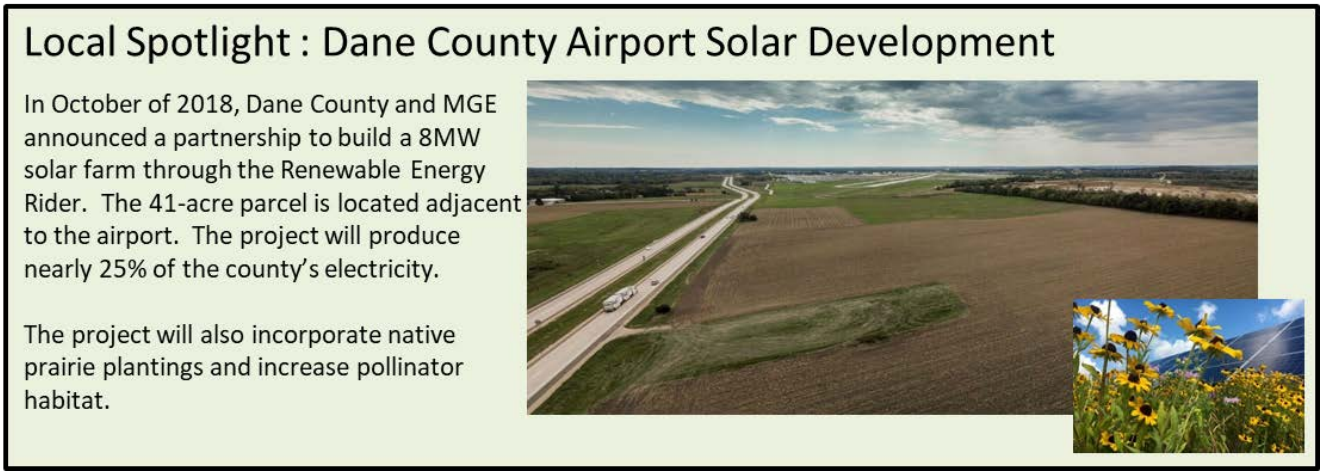
B.2.2 Off Site Solar Farm

Madison Gas and Electric (MGE) was the first Wisconsin utility to offer a sleeved tariff that enables large customers to purchase renewable energy from an offsite system owned by MGE or from a third party through MGE's Renewable Energy Rider (RER) tariff.

The energy produced by the offsite renewable system displaces energy that would have been purchased from the grid. This allows participants to reduce their fossil-based generation consumption. However, current RER requirements mandate renewable production to be less than an RER participant's instantaneous consumption to avoid perceived cross-subsidization between participating and non-participating utility customers. Based on Madison's current load profile for RER qualified meters, only 5MW of solar PV could be installed before overproducing without the use of energy storage systems.

Offsite solar PV is a viable option for significant renewable energy production for the City. A 5 MW solar PV system would generate approximately 15% of the City's 2018 electrical consumption. In an RER project, the unit cost of electricity produced by a solar PV system is expected to be comparable to existing rates that the city currently pays. City officials developed a map that illustrates City-owned land sites that could host a 5 MW PV system. The system could be owned by the City, third party, or the local utility. In addition to City-owned properties, the city officials are exploring solar projects with other entities and at other locations throughout the area.

As the City electrifies its fleet, it can continue to add additional off-site solar capacity, while avoiding over production and reduced buy back rates. HGA estimates that 50% of the electricity for fleet charging can be produced from renewable sources. A 100% fully electrified bus fleet would require 16-20 MW of solar to provide the fleet's charging needs with 100% renewable energy.



B.2.3 Off Site Wind Farm

Utility scale wind is currently the most economic renewable resource in the Midwest. However, there are obstacles to the city generating its own wind energy. Specifically, siting a new wind resource of the size required by the City of Madison is challenging due to zoning requirements. There is little incentive for wind developers to provide power purchase contracts for a small system, such as two to three wind turbines.

Due to the limitations of the offsite system generation not exceeding the City's consumption, wind power creates some additional challenges. Wind generation is not predictable and peak generation may not coincide with the City's peak consumption in the same way that solar power does. This limits the potential system size to avoid selling power back to the utility at wholesale rates when contracted through a net-metering arrangement.

The city should continue to explore options for wind developments with MGE and wind developers, but at this time a solar RER project is more feasible. Improved battery technology will also allow for additional flexibility of intermittent power. As policies and technology continue to evolve, the City should continue to explore how to incorporate additional wind generation into its renewable mix.

B.2.4 Greening of the Electric Grid

The City of Madison purchases power from two electric utilities, MGE and Alliant Energy's Wisconsin Power & Light (Alliant). The majority (98%) of the electricity for local government operations is supplied by MGE with the remaining (2%) coming from Alliant Energy. Both utilities have stated goals to reduce their carbon emissions by 80% by 2050. MGE has adopted a framework[27] with goals to grow renewable generation and reduce carbon emissions:

- CO_2 reduction consistent with the US targets established through the Paris Agreement
- 40% reduction in CO_2 emissions by 2030 from 2005 levels
- 30% renewable energy by 2030 with 25% by 2025
- 80% reduction in CO_2 emissions by 2050 from 2005 levels

MGE CEO Jeff Keebler noted that "If we can go further, faster, we will." In the past 8 months, MGE has announced three large renewable energy projects. The Saratoga Wind Farm is a 66 MW development located in Howard County, Iowa, with an opening planned for 2019. In May 2018, MGE also announced a 100 MW solar development at two sites in Wisconsin, referred to as Badger Hollow and Two Creeks. The solar development is currently in the review process by the PSC of Wisconsin, while Saratoga is approved and under construction. Alliant Energy has announced plans for the 210 MW Richland Wind Farm in Sac County, Iowa and has additional strategies to reduce greenhouse gas (GHG) emissions 26%-28% by 2025 and CO_2 32% by 2030, while increasing renewables to 30% by 2030.[28] The table below includes ongoing MGE and Alliant/WPL initiatives to expand renewable generation serving Madison electricity customers.

Renewable Generation in the Pipeline for Madison Gas & Electric and Wisconsin Power & Light

Project Name + Docket No.	Utility	Project type	Utility's capacity share (in MW)	Anticipated capacity factor	Anticipated in-service date
Saratoga (IA) 3270-CE-127	MGE	Wind	66	49%	12/2018
Badger Hollow (WI) 9697-CE-100	MGE	Solar	50	25%	12/2020
Two Creeks (WI) 9696-CE-100	MGE	Solar	50	23%	12/2020
Kossuth (IA) 6680-CE-181	WPL	Wind	150	47%	12/2020

Source: RENEW Wisconsin

[27] Madison Gas and Electric, "Energy 2030," https://www.energy2030together.com/en/.

[28] Alliant Energy, "Sustainability Report 2018," https://sustainability.alliantenergy.com/energy-climate/#energy-vision.

Continued electrification of vehicles, strategic electrification, declining renewable energy costs and electrification of heating are all activities that enable utilities to invest in renewable energy technologies. The City of Madison continues to work with MGE and Alliant on their mutual goals.

B.2.5 Renewable Energy Credits

Renewable energy credits (RECs) are a means of accounting for the renewable attributes associated with the production of electricity from a renewable source.

The intent of RECs is that they will lower the cost of renewable energy installation for utilities and other renewable developers while enabling entities to invest in renewable energy. This is accomplished by allowing some of the excess cost related to the renewable system to be offset by the sale of RECs generated from the renewable installation. With the rapid decrease in the cost of renewable energy systems, such as wind and solar, many utilities are installing renewable systems as the least cost generation systems. However, RECs are still playing an important role in the small to midsize market in enabling the building of new solar generation. Without the REC revenue these systems may not be built or may be delayed until favorable economics could be achieved.

Currently, RECs associated with the MISO territory sell for as little as $0.30/MW-hr. The City of Madison could offset all of its electrical consumption for $15,000/year with generic RECs. Many cities that have pursued 100% renewable goals have purchased generic RECs. However, not all RECs are created equal. It is recommended that any RECs purchased by the City meet the standards of the Corporate Renewable Energy Buyer's Principles[29] including the following criteria:

- Additional renewable resources are built as a direct result of the REC investment. This is referred to "additionality."
- Renewable resources are located in Wisconsin.

RECs meeting these criteria are estimated to be in the $5.00-$10.00/MW-hour range. Typically, these RECs are unbundled, meaning the City would claim the benefits of the renewable generation, but would not actually use the electricity associated with the RECs.

RECs are useful as a transitional tool while the direct purchase of renewable energy is procured and as the cost of energy storage continues to decline. RECs are also useful for offsetting fuels that will be more difficult to replace with renewable energy in the short term, such as natural gas for heating. Unlike direct purchase of renewable energy, which may enable savings compared to conventional produced electricity, purchasing RECs is an additional cost above and beyond the purchase of electricity.

As of the writing of this draft, the City has approved a contract to purchase RECs in southwest Wisconsin. Under the recently approved project, the City will purchase, beginning in 2019, 25 years of RECs from five arrays developed by OneEnergy. The arrays will be constructed in 2019 and will be located in the following municipalities: Argyle, Cumberland, Elroy, Fennimore, and New Lisbon. These REC's will offset emissions equivalent to approximately 37% of the City's current electric consumption.

[29] Corporate Renewable Energy Buyers' Principles https://buyersprinciples.org/

Local Spotlight : Organic Valley Renewable Investment

Organic Valley announced last year that it would source all its electricity from renewable sources by 2019. In addition to its on-site wind and solar installations, OV entered into a long term REC contract with a solar developer. As part of this deal, OV purchases RECs from a local utility scale wind farm. The local municipal utility feeds this solar power into the grid for its customers, which include OV.

The REC investment by OV enabled the electricity prices from this system to be competitive with fossil fuel produced electricity. Without this REC boost, the solar project would not have been feasible.

B.3 Transportation

Vehicle emissions from the City of Madison and Metro Transit account for a third (34%) of the carbon footprint from City of Madison local government operations. In the greater Madison metro area and nationwide, transportation is one of the top contributors of GHG emissions. The need to provide clean, decarbonized, and efficient transportation plays an important role in solving many of the most serious challenges facing the greater Madison area including public health, air quality, noise pollution, and the City of Madison's Racial Equity and Social Justice (RESJI) goals. In addition to negative health effects from vehicle emissions, traffic congestion can also have additional negative economic consequences including reduced productivity, investment, and workforce development. Investments in green fleet and EVs can lead to economic, health, and environmental benefits in addition to helping the City of Madison achieve its goals for 100% renewable energy and net zero carbon emissions.

The City of Madison can lead by example for the greater community by implementing efficient and electric fleet strategies while planning for the expected increase of EVs to the Madison area. Many of the green fleet strategies described for the City of Madison in this report are transferrable to private sector businesses or other organizations in the community. While outside the scope of the financial analysis, it is reasonable to expect those communities would see similar cost savings, as well as health, environmental, and carbon benefits for the community.

There are a variety of diverse ways for the City of Madison, and other area local governments or businesses, to reduce fleet emissions. Most of these involve decreasing the amount of transportation fuel in use by fleet vehicles, but a second approach entails switching to fuels that emit fewer GHG emissions (i.e., replacing a vehicle that uses gasoline with one that runs on lower emissions, such as compressed natural gas (CNG) or propane). Table B-3 includes a list of strategies reviewed for this analysis.

Table B-3. Strategies for Reducing City Fleet Emissions

Reducing Fuel Use	Switching Fuels
Right-Sizing Vehicles	Biodiesel
Operator Training	Propane
Idle Reduction	Landfill Compressed Natural Gas
Sharing Best Practices	Electricity

Source: Navigant

B.3.1 Madison Fleet and Madison Metro Transit Characteristics

This section characterizes City of Madison and Metro Transit fleet groups included in this analysis. In 2017, the City of Madison Fleet vehicles consumed 709,837 gallons of diesel and 450,928 gallons of gasoline. The City spends approximately $2 million annually on transportation fuels.

Table B-4. City of Madison Fleet Characteristics

Segment	Example	Number	Fuel
Heavy duty truck	Freightliner M2	168	Diesel
Mid duty truck	Ford F450 Truck	47	Diesel or Gasoline
Light truck	Ford F250 Truck	85	Diesel or Gasoline
Light duty vehicle	Ford Escape	121	Gasoline
Passenger car	Chevy Malibu	162	Gasoline
Other equipment	Forklift, Lawnmower; Leaf Blower	491	Diesel or Gasoline
Total		1,074	

Source: Madison Fleet Data

Metro's fleet is primarily fixed route and paratransit buses with some light duty vehicles and passenger cars. The 28 vehicles use 80,000 gallons of gasoline while the 232 buses use 1,300,000 gallons of diesel annually. Metro spends $4.5 million annually on transportation fuels. Metro operates 21 hybrid electric buses.

Table B-5. Metro Transit Fleet Characteristics

Segment	Example	Number of Vehicles	Fuel
Bus	40-foot fixed route	194	Diesel
Bus	Hybrid 40-foot fixed route	21	Diesel
Bus	28-foot paratransit	17	Diesel
Light duty vehicle	Ford Escape	14	Gasoline
Passenger car	Chevy Malibu	14	Gasoline
Total		260	

Source: Metro Transit data

B.3.2 Reducing Fuel Use through Green Fleet Strategies

Green fleet strategies provide opportunities for the City of Madison to achieve emissions savings, cost savings and contribute to operator safety. The City of Madison Fleet department has started to develop an alternate fuels fleet menu, listing qualified fuel-efficient vehicles for city agencies to consider right-sizing vehicles when making procurement requests. Operator training opportunities include safety and fuel conservation training and frequently are paired with installing GPS vehicle tracking. This can contribute to operator safety and accountability. Idle-reduction strategies include battery auxiliary power systems, air heaters, automatic power management systems and waste heat recovery systems.[30] For utility trucks, using auxiliary power to avoid power take off and reducing idling from these vehicles is a potential strategy for community stakeholders with these types of fleet vehicles.[31]

Under the leadership of the City of Madison Fleet Superintendent Mahanth Joishy, a group of fleet managers representing public fleets from around the Madison area met to share information at the first Madison Area Fleet Managers meeting in June 2018. The fleet managers discussed best practices in procurement, operations, safety, and sustainability. Agreeing to meet again periodically, the fleet managers identified several opportunities to consider collaborating in the future, which may help contribute to efficient implementation of green fleet strategies for the City of Madison and other public fleets, leading to further emissions reductions from fleet operations.

Green fleet initiatives have the potential to achieve fuel cost savings between 15%-20% of annual fleet expenditures ($295,000-$414,000) and estimated GHG emissions reductions between 10%-20% of current fleet annual emissions (956–1,673 tons CO_2e). Initial investment for green fleet strategies ranges from $150,000 to $400,000 and includes initial cost estimates to fully develop a right-size fleet menu, operator education materials, and training and supporting fleet managers best practices discussions for a period of 3 years. Idle-reduction costs vary and require additional research to identify specific vehicles for implementation.

B.3.3 Adding Biodiesel and Propane to Fuel Vehicles

The City of Madison Fleet department added B5 biodiesel to its diesel fuel mix in 2018 to reduce GHG emissions from vehicle operations at a comparable cost to traditional diesel fuel. A biodiesel mix between B5 and B20 is allowed by most vehicle manufacturers without voiding engine warranties. A lower mix of biodiesel (B5) is necessary to cope with cold weather during Madison's winters, with a higher mix (up to B20) potentially available for use during summer months. Cost estimates for biodiesel are comparable with traditional diesel and in some cases may even save money on fuel costs. Biodiesel is associated with emissions reductions from vehicle operations of between 5% and 20%, depending on the mix.[32] Another option for some equipment is fueling with propane, which emits fewer GHG per gallon equivalent and is less expensive than gasoline or diesel.[33]

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[30] US Department of Energy, "Light Duty Vehicle Idle Reduction Strategies," Alternative Fuels Data Center, https://www.afdc.energy.gov/conserve/idle_reduction_light.html.

[31] US Department of Energy, "Clean Cities: Idling Reduction," Alternative Fuels Data Center, https://www.afdc.energy.gov/uploads/publication/work_truck_idling_reduction.pdf.

[32] US Department of Energy, "Biodiesel," Alternative Fuels Data Center, https://www.afdc.energy.gov/fuels/biodiesel.html.

[33] US Department of Energy, "Propane Vehicle Emissions," Alternative Fuels Data Center, https://www.afdc.energy.gov/vehicles/propane_emissions.html.

B.3.4 Fueling Vehicles with Landfill CNG from Dane County Landfill

Dane County fuels vehicles using compressed natural gas (CNG) from its landfill. The City of Madison has held initial discussions with Dane County about fueling vehicles from landfill gas. A recent case study of refuse fleets indicated potential fuel cost savings from 30%-50% while reducing GHG emissions from vehicle operations.[34] Drivers in the case study, which included the City of Milwaukee, Wisconsin, reported being more satisfied with their vehicles' operations due to the lack of diesel fumes and quieter operation.[35] Additional technical and financial review is necessary before any large-scale conversion can occur, as fuel costs are not yet available.

B.3.5 Strategic Electrification of Fleet Vehicles and City Equipment

Some Madison fleet vehicles, such as small cars and light duty vehicles, are good candidates to replace with battery EVs. Others, such as larger vehicles, may need a few more years to have suitable electric replacements. City agencies host a variety of vehicles and equipment that may be converted to electric at an appropriate time, such as lawnmowers, street sweepers, and leaf blowers. In September 2018, the City of Madison was awarded a grant to purchase 30 electric vehicles.

B.3.6 Strategic Electrification of Metro Transit Bus Fleet

Metro Transit has a goal of converting 50% of the transit fleet to electric buses by 2035. Electric buses powered by renewable energy will significantly reduce carbon emissions and provide multiple benefits, including potential cost savings in operations and maintenance, increased air quality, reduced noise pollution, and the potential to encourage greater bus ridership.[36] A recent national analysis indicates that the total cost of ownership for an electric bus is favorable to that of a bus fueled by diesel or CNG.[37] According to a recent study, an electric bus charged from the City's regional grid will produce fewer emissions than a hybrid diesel powered bus.[38] Custom tariffs can be developed for electric buses that would enable the city to move forward with electrifying the fleet. Recommendations are included in Appendix D Suggested Actions section.

According to the Union of Concerned Scientists, the city's current electricity grid fuel mix results in EVs being only marginally more beneficial for GHG emissions than an efficient internal combustion engine.[39] However, as Madison's local electric utilities add renewable energy to their electricity fuel mix, the GHG emissions benefits of driving an electric car or electric bus will increase. Adding renewable energy to charge EVs and buses could enable the transportation sector to transform its GHG emissions from

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[34] US Department of Energy, "Case Study – Compressed Natural Gas Refuse Fleets," Alternative Fuels Data Center, https://www.afdc.energy.gov/uploads/publication/casestudy_cng_refuse_feb2014.pdf.

[35] US Department of Energy, "Case Study – Compressed Natural Gas Refuse Fleets," Alternative Fuels Data Center, https://www.afdc.energy.gov/uploads/publication/casestudy_cng_refuse_feb2014.pdf.

[36] Navigant Research, *Market Data: Electric Drive Buses*, 2017.

[37] C40 Electric Buses in Cities, March 29, 2018.

[38] Union of Concerned Scientists, "Electric vs. Diesel vs. Natural Gas: Which Bus is Best for the Climate?" https://blog.ucsusa.org/jimmy-odea/electric-vs-diesel-vs-natural-gas-which-bus-is-best-for-the-climate?_ga=2.226102682.1843563386.1532023761-1843342382.1531829971.

[39] Union of Concerned Scientists, "How Clean is Your Electric Vehicle? Using Zip Code 53711," https://www.ucsusa.org/clean-vehicles/electric-vehicles/ev-emissions-tool#z/53711/_/_/_.

vehicle operations from one of the largest sources of pollution to zero emissions, while adding additional solar capacity to the city. If all city vehicles would use electricity from renewable sources (e.g., solar or wind), then the only large source of emissions associated with the fleet would be those arising from vehicle manufacture. Deploying renewable energy to power electric fleet and transit vehicles is one of the greatest opportunities for the City of Madison to work with local utilities to reduce GHG emissions.

B.3.7 Status of EV Charging Infrastructure in Madison

EV charging infrastructure is a critical enabler for encouraging people to adopt EVs as their primary mode of transportation. Cities and utilities around the country are working together to map current EV charging infrastructure and plan for additional installations. EV charging infrastructure can provide an important role not only in charging EVs, but also in supporting the effective use of electric grid resources, providing opportunities to implement energy storage, and supporting investments into modernization of the electric grid and smart grid applications. The City of Madison can play a vital role in organizing and orchestrating the planning, marketing, and deployment of EV charging stations.

There are already efforts underway to promote and deploy EV charging infrastructure in Madison. These include:

- There are 62 EV charging stations within 10 miles of the center of Madison.[40] Locally, Madison Gas & Electric has installed eight EV charging stations in City of Madison parking facilities as part of a pilot program to study their use and reliability.[41]
- MGE has an EV charging station map on its website and offers programs to customers to charge at home and at the workplace.[42] MGE hosts EV charging stations at its corporate headquarters on the near-east side of Madison.
- Alliant offers EV charging programs for residential and business customers.[43] Alliant hosts EV charging stations for employee and public use at its corporate headquarters on the far-east side of Madison.

EV charging stations have a hidden cost: the need to provide significant power to charge the EV in an increasingly short timeframe. Whenever an EV is connected to a charging station, the building's electrical infrastructure experiences a high current surge, and consequently, an electrical demand spike. Actively managing and spreading the load across infrastructure assets and time via energy storage systems and vehicle-grid integration technologies can mitigate some infrastructure upgrade costs and may also decrease grid balancing costs. Some cities and utilities are planning their electricity load estimates by actively managing EVs and charging infrastructure energy storage systems and vehicle-grid integration technologies. These technologies present opportunities to manage demand charges, provide backup power and push toward investments in smart grid and smart city integration.[44] Utility tariffs and rate structures must also be created to address the needs of EV and EV charging infrastructure.

[40] EV Stations Local, "Map of Electric Vehicle Charging Stations in Madison," https://evstationslocal.com/states/wisconsin/madison/.

[41] City of Madison, "Parking Utility," Electric Vehicle Charging Stations, https://www.cityofmadison.com/parking-utility/garages-lots/electric-vehicle-charging-stations.

[42] Madison Gas & Electric, "Plug-in Electric Vehicle Basics," EV Basics, https://www.mge.com/environment/electric-vehicles/ev-basics.htm.

[43] Alliant Energy, "Electric Vehicles," https://www.alliantenergy.com/InnovativeEnergySolutions/SmartEnergyProducts/ElectricVehicles.

[44] Navigant Research, *Vehicle Grid Integration*, 2017.

APPENDIX C. SCENARIOS TO REACH 100% RENEWABLE ENERGY

This section includes three scenarios for the City of Madison to reach the goal for 100% renewable energy and zero net carbon emissions for local government operations while providing leadership for the greater community. Detailed descriptions of demand, supply, and transportation measures are included in a subsequent section. Additional description of the tools used to create the scenarios follows.

C.1 Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020

By 2020, local government operations will cut its carbon emissions by 15% with at least 10% of the city's electricity sourced by self-generated renewable energy. Investments in RECs and carbon offsets make up the remaining 85% of carbon emissions in this scenario. This scenario provides a strong start to build momentum and plan for additional capital-intensive measures necessary for mid-century deep decarbonization strategies.

The City of Madison will reduce carbon emissions by 15%. The City will initiate a building retro-commissioning program to reduce energy demand. Transportation emissions will be reduced through a package of green fleet measures including operator training to reduce fuel consumption and developing green fleet vehicle menu for city agencies to select fuel efficient vehicles. The city would replace its highest usage (in operating time or vehicle miles traveled) passenger and light duty SUV vehicles with electric vehicles to start to save money from transportation fuels and reduce carbon emissions from fuel usage.

The city will increase the supply of self-generated renewable electricity to 10% of its electricity use by initiating Phase 1 behind-the-meter solar installations on or near city buildings and installing at least 1 MW of solar by 2020. City officials will work with local utilities to develop a utility scale solar project. City officials will continue to identify renewable energy or carbon reduction projects that meet the city's investment criteria for the remaining 85% carbon balance. Technical details of each measure are included in Appendix B.

There are opportunities to implement additional actions that would further reduce carbon emissions for local government or for the larger community. For example, city officials could review and implement policy and finance updates to promote clean energy, develop a municipal building energy data program, develop such as reviewing its solar permitting and inspection process, develop an Electric Vehicle and EV Charging Infrastructure Plan, and initiate a City Energy Challenge and Green Revolving Fund. Appendix D includes suggested actions to accelerate progress for the city and the larger community.

Table C-1 includes a list of measures included in this scenario.

Table C-1. 100% Renewable Energy and Zero Net Carbon by 2020 – Key Measures

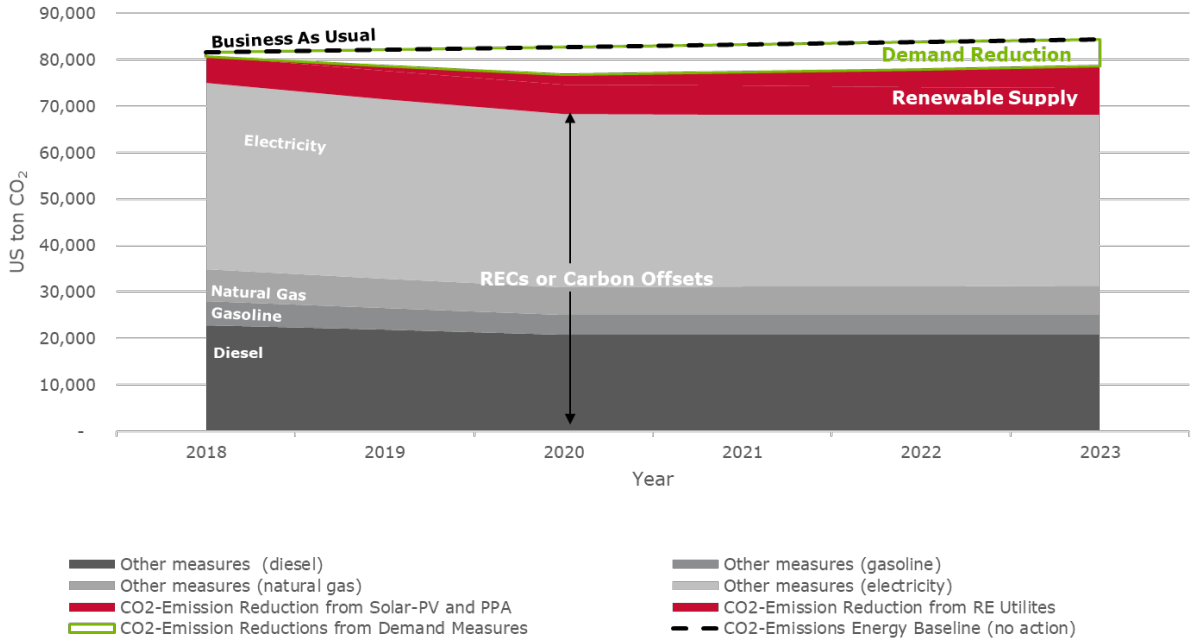
Measure Type	2020	Measures
Efficiency	X	Develop RCx Program
Renewable Generation	X	Initiate Behind-the-Meter Solar: Phase 1
	X	Utility Fuel Mix (MGE and Alliant)
	X	Utility Solar Project (MGE RER or Alliant)
Transportation	X	Green Fleet Measures
Transportation	X	Fleet Passenger Car EV Procurement
Transportation	X	Fleet Light Duty EV Procurement
Transportation	X	Landfill CNG Vehicle Pilot
Transportation	X	First Three Electric Buses Arrive in Madison
Policy	X	RECs and Carbon Offsets

Source: HGA

C.1.1 Impacts

The graph below provides a visual representation of the fuel mix for city operations in the 2020 scenario. The first dotted line includes the business as usual trajectory, which assumes emissions from local government operations grows from 81,141 tons in 2018 to 83,981 tons in 2023 (not including landfill or employee commute emissions). The demand reduction measure, the RCx program, reduces carbon by 6,062 tons (7%) in 2020 and holds steady until 2023. Implementing Phase 1 behind-the-meter solar accounts for 8,374 tons (10%) carbon reduction by 2020. The remaining fossil fuel supply is the amount of electricity, natural gas, and transportation fuels used by local government operations, which is offset by investments in RECs and carbon offsets to make up the remaining carbon balance. In 2018, the amount to be offset is 74,999 tons of CO_2 (92%) decreasing to 68,332 tons (83%) in 2020. Under this scenario, the relative percentage would hold steady from 2020 through 2023 and beyond, with and slight decreases in the need for RECs and carbon offsets due to the slight increases in renewables added to the utility fuel mix. Figure C-1 includes corresponding calculations for the 2020 scenario.

Figure C-1. Results 2020 Scenario



Source: Navigant

Figure C-2. Fuel Mix in Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020

	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO_2 emissions (baseline)	ton	81,141	81,699	82,261	82,829	83,402	83,981	84,565	85,155	85,750	86,351	86,957	87,570	88,188
CO_2 reduction (demand)	ton	878	3,490	6,062	6,016	5,971	5,925	5,880	5,834	5,788	5,743	5,697	5,652	5,606
	%	1%	4%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	6%
CO_2 reduction (supply)	ton	5,762	7,136	8,374	9,091	9,762	10,385	10,957	11,476	11,940	12,347	12,694	12,979	13,200
	%	7%	9%	10%	11%	12%	12%	13%	13%	14%	14%	15%	15%	15%
CO_2 remaining	ton	74,999	71,575	68,332	68,233	68,185	68,191	68,253	68,373	68,554	68,798	69,108	69,486	69,934
	%	92%	87%	83%	82%	81%	81%	80%	80%	79%	79%	79%	79%	79%
RECs Electricity	ton	40,170	38,641	37,293	37,092	36,942	36,844	36,802	36,818	36,893	37,031	37,234	37,504	37,843
	%	49%	47%	45%	45%	44%	44%	43%	43%	43%	43%	43%	43%	43%
RECs Natural gas	ton	6,813	6,424	6,035	6,106	6,177	6,249	6,322	6,395	6,469	6,544	6,620	6,696	6,773
	%	8%	8%	7%	7%	7%	7%	7%	7%	7%	8%	8%	8%	8%
RECs Gasoline	ton	5,145	4,667	4,189	4,221	4,252	4,284	4,315	4,346	4,378	4,409	4,440	4,472	4,503
	%	6%	6%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
RECs Diesel	ton	22,872	21,843	20,814	20,814	20,814	20,814	20,814	20,814	20,814	20,814	20,814	20,814	20,814
	%	28%	27%	25%	25%	25%	25%	24%	24%	24%	24%	24%	24%	23%

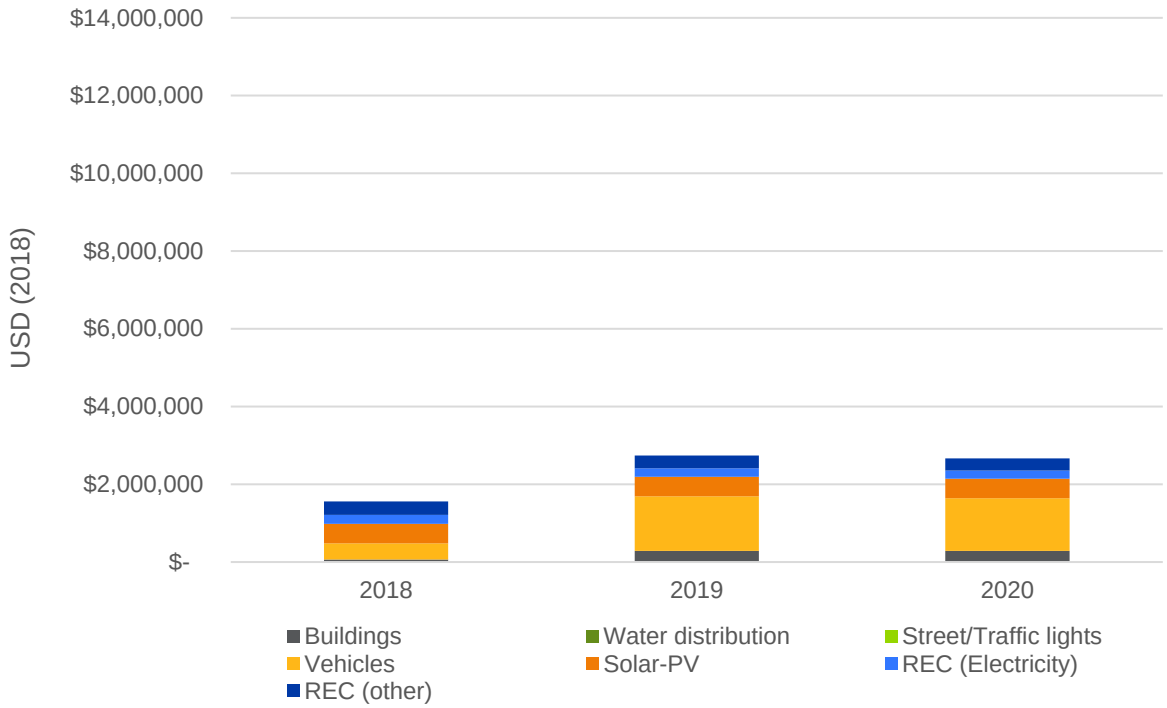
Source: Navigant

C.1.2 Costs

This analysis assumes that all expenditures are city funded. In Scenario 1, cumulative incremental investments between 2018 and 2020 amount to $7 million. Investments include implementing efficiency measures in buildings totaling $500,000. The city will begin solar Phase 1, installing at least 1 MW of behind-the-meter solar, which is estimated at $1.5 million. Vehicle investments, including passenger electric vehicle (EV) cars, light duty EV, landfill CNG pilot and green fleet investments are $3 million. The City will add staff or other resources to develop and implement this initiative estimated at $500,000.

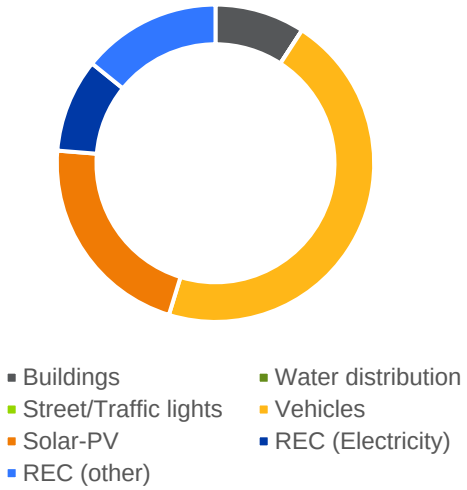
Investments in RECs or carbon offsets are estimated at $1.5 million, with costs estimated at $10 per ton of carbon for carbon offsets and $5/MWh for renewable energy credits.

Figure C-3. Annual Investments in Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020



Source: Navigant

Figure C-4. Cumulative Investments in Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020

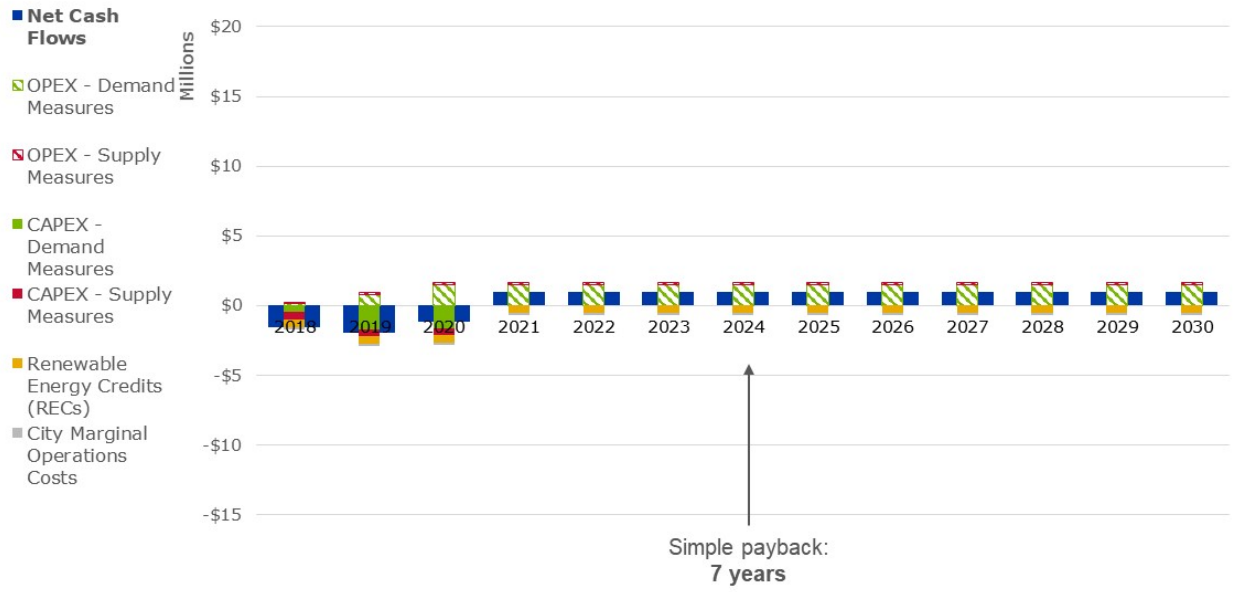


Source: Navigant

Economic Analysis for Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020

The financial analysis below shows how the 2020 scenario influences cash flow to 2030, assuming the city allocates all capital expenditures (CAPEX) investments and receives cost savings from operating expenses (OPEX) due to the investments. Net cash flows are negative for 3 years and become positive in 2021. The 2050 NPV of the $7 million investment is $10 million with an internal rate of return of 7%. The simple payback occurs at 2024 (7 years).

Figure C-5. Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020 – Cash Flow Summary



Source: Navigant

Figure C-6. Scenario 1: 100% Renewable Energy and Zero Net Carbon by 2020 – Cash Flow Summary

(figures in million $)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAPEX Demand Measures	-0.5	-1.7	-1.6	0	0	0	0	0	0	0	0	0	0
CAPEX Supply Measures	-0.5	-0.5	-0.5	0	0	0	0	0	0	0	0	0	0
Renewable Energy Credits (RECs)	-0.6	-0.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
City Marginal Operations Costs	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
OPEX Demand Measures	0.1	0.8	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
OPEX Supply Measures	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Net Cash Flows	**-1.5**	**-2.0**	**-1.2**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**

Source: Navigant

C.2 Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023

By 2023, local government operations will cut its carbon emissions by 40% with at least 15% of the city's electricity sourced by self-generated renewable energy. Investments in RECs and carbon offsets make up the remainder 60% of carbon emissions in this scenario. From a first cost perspective, this option provides a combination of investment in favorable opportunities for the city building, facilities, water distribution, fleet and Metro, investments in behind-the-meter solar and offsite renewable energy development.

To cut carbon emissions by 40%, the City will implement efficiency measures at city buildings, such as retrofitting and replacing lighting, heating, and cooling systems, improving building envelopes and managing plug loads. The city will implement water distribution system optimization and replace current street lights with efficient street lights. Together, these measures will reduce the city government's use of electricity and natural gas.

Use of transportation fuels, such as gasoline and diesel, will be reduced through green fleet strategies, fueling medium and heavy-duty vehicles with landfill CNG and replacing light and medium duty fleet vehicles with EVs. Madison Metro accomplishes its goal of 50% electric buses by 2028 instead of by 2035 as currently planned.

To increase generation of renewable energy at city facilities to 15% of its electricity use, the city will complete phase 1 of its solar self-generation plan, resulting in 3 MW of solar at municipal locations. City officials will continue to work with local utilities to implement at least one utility scale solar project and will attempt to implement more than one project if possible. Local utilities MGE and Alliant are incorporating solar and wind and are on track to meet their goals of having 30% of their fuel mix powered by renewable energy by 2030, thereby lowering carbon emissions from electricity for the entire community. Investments in RECs and carbon offsets will make up the remaining 60% of the carbon balance. Technical details of each measure are included in Appendix B. Cost details are included in Appendix D.

There are opportunities to implement additional actions that would further reduce carbon emissions for local government or for the larger community. For example, as the city adds more electric vehicles and buses, it can add solar and energy storage to electric vehicle charging stations to power these vehicles with renewable electricity. Appendix D includes suggested actions to accelerate this scenario.

Table C-2 includes a summary of the technical measures included in Scenario 2 – 100% Renewable Energy and Zero Net Carbon by 2023.

Table C-2. 100% Renewable Energy and Zero Net Carbon by 2023

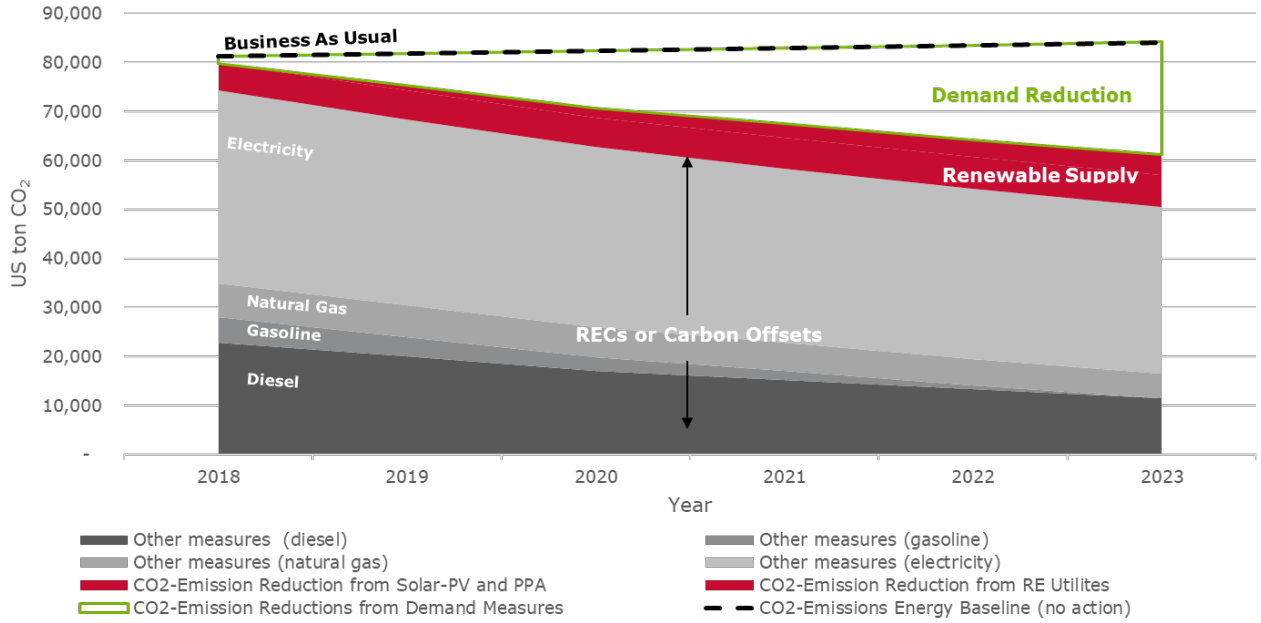
Measure Type	2023	Action
Efficiency (Demand)	X	Lighting Retrofits
	X	HVAC Controls Retrofits
	X	HVAC RCx
	X	Street Lighting Upgrades
	X	Water Distribution Optimization Strategies
Renewable Generation (Supply)	X	Behind-the-Meter Solar: Phase 1
	X	Utility Scale Solar (MGE RER or Alliant)
	X	Utility Fuel Mix (MGE and Alliant)
Transportation (Demand)	X	Green Fleet Measures
	X	50% Electric Buses
	X	Passenger Car EV Procurement
	X	Light Duty EV Procurement
	X	Landfill CNG Fueling
Investments	X	RECs and Carbon Offsets

Source: HGA

C.2.1 Impacts

Figure C-7 provides a visual representation of the fuel mix for city operations in the 2023 scenario. The first dotted line includes the business as usual trajectory, which assumes emissions from local government operations grows from 81,141 tons in 2018 to 83,981 tons in 2023 (not including landfill or employee commute emissions). Demand reduction measures, such as energy efficiency and transportation (noted in green), reduce the amount of carbon emissions each year. In 2023, the combination of demand measures reduce carbon by 22,997 tons (27%) and supply measures reduce carbon by 10,764 tons (13%). The remaining fossil fuel supply is the amount of electricity, natural gas, and transportation fuels used by local government operations, which is offset by investments in RECs and carbon offsets to make up the remaining carbon balance. In 2018, the amount to be offset is 74,212 tons of CO_2 (91%) decreasing to 50,249 tons (60%) in 2023. Table D-3 includes corresponding calculations for the 2023 scenario.

Figure C-7. Fuel Mix in Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023



Source: Navigant

Table C-3. Fuel Mix in Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023

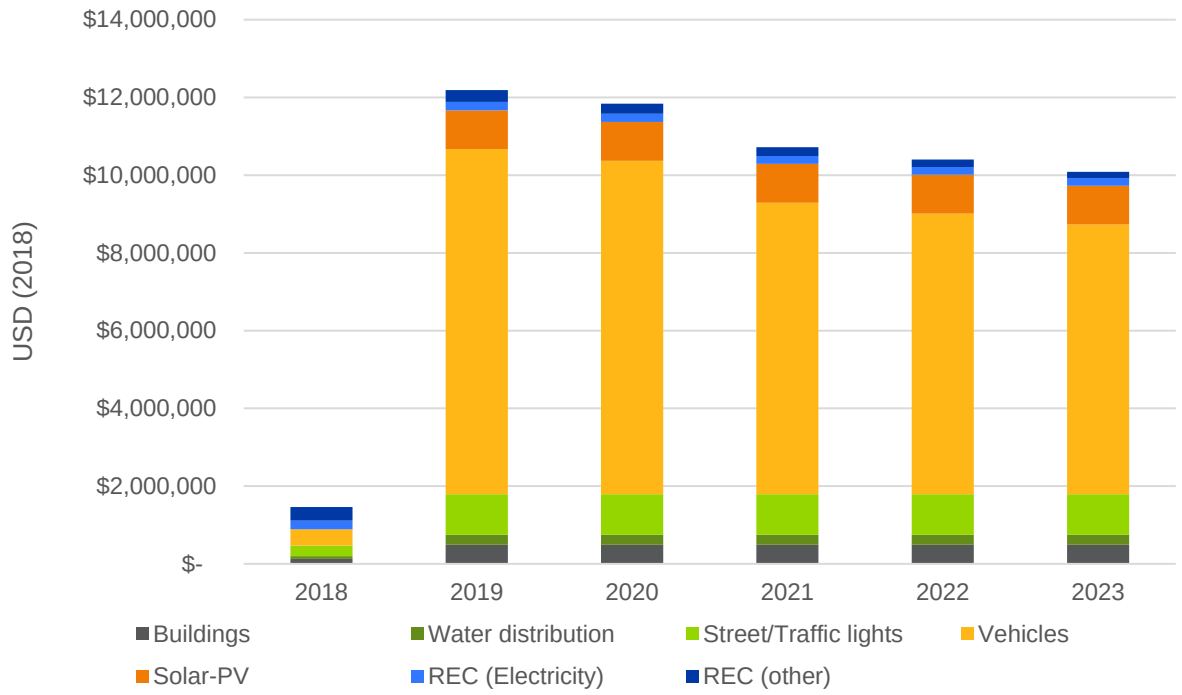
	Unit	2018	2019	2020	2021	2022	2023
CO_2 emissions (baseline)	ton	81,141	81,699	82,261	82,829	83,402	83,981
CO_2 reduction (demand)	ton	1,359	6,494	11,589	15,432	19,234	22,997
	%	2%	8%	14%	19%	23%	27%
CO_2 reduction (supply)	ton	5,597	6,876	8,028	9,058	9,969	10,764
	%	7%	8%	10%	11%	12%	13%
CO_2 remaining	ton	74,212	68,357	62,672	58,368	54,228	50,249
	%	91%	84%	76%	70%	65%	60%
RECs Electricity	ton	39,392	37,970	36,719	35,635	34,715	33,956
	%	49%	46%	45%	43%	42%	40%
RECs Natural gas	ton	6,803	6,448	6,093	5,740	5,386	5,034
	%	8%	8%	7%	7%	6%	6%
RECs Gasoline	ton	5,145	3,964	2,782	1,783	784	0
	%	6%	5%	3%	2%	1%	0%
RECs Diesel	ton	22,872	19,975	17,078	15,210	13,342	11,474
	%	28%	24%	21%	18%	16%	14%

Source: Navigant

C.2.2 Costs

Figure C-8 includes annual investments from 2018-2023, which are $57 million. Investments in buildings are $2.5 million. Water distribution optimization is $1.5 million. Streetlights are $5.5 million. Solar phase 1 is completed by 2023 and costs $5 million. The city invests $900,000 in additional staff or other resources to implement these initiatives. Vehicle investments are $40 million to purchase 116 electric buses to achieve the goal of 50% electric buses for Metro Transit, green fleet and electric vehicles. Costs for bus batteries are assumed as leased and therefore are included in operating expenses only. Additional vehicle investments include green fleet measures and electric vehicles. RECs and carbon offsets require $2.6 million through 2023, with costs ranging from $10 per ton of carbon for carbon offsets and $5/MWh for renewable energy credits.

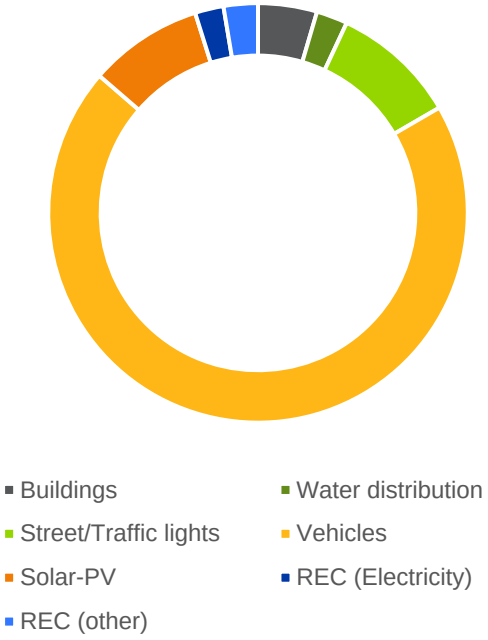
Figure C-8. Annual Investments in Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023



Source: Navigant

This analysis assumes that all expenditures are city funded. In Scenario 2, cumulative incremental investments between 2018 and 2023 amount to $57 million.

Figure C-9. Cumulative Investments in Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023

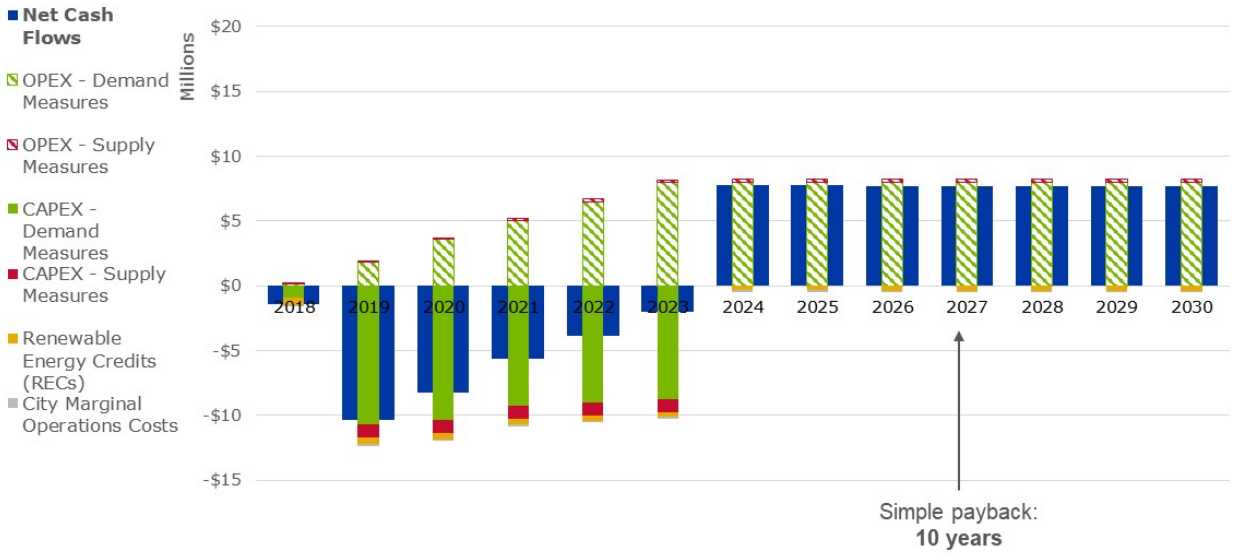


Source: Navigant

Economic Analysis for Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023

The financial analysis below shows how the 2023 scenario influences cash flow to 2030, assuming the city allocates all capital expenditures (CAPEX) investments and receives cost savings from operating expenses (OPEX) due to the investments. Net cash flows are negative for 6 years and become positive in year 2024. The 2050 NPV of the $57 million investment is $71 million with an internal rate of return of 17%. The simple payback occurs at 2027 (10 years).

Figure C-10. Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023 – Cash Flow Summary



Source: Navigant

Table C-11. Scenario 2: 100% Renewable Energy and Zero Net Carbon by 2023 – Cash Flow Summary

(figures in million $)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAPEX Demand Measures	-0.9	-10.6	-10.4	-9.3	-9.0	-8.7	0	0	0	0	0	0	0
CAPEX Supply Measures	0	-1.0	-1.0	-1.0	-1.0	-1.0	0	0	0	0	0	0	0
Renewable Energy Credits (RECs)	-0.6	-0.5	-0.5	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
City Marginal Operations Costs	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
OPEX Demand Measures	0.1	1.9	3.6	5.0	6.5	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
OPEX Supply Measures	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Net Cash Flows	**-1.4**	**-10.4**	**-8.3**	**-5.7**	**-3.9**	**-2.0**	**7.7**	**7.7**	**7.7**	**7.7**	**7.7**	**7.7**	**7.7**

Source: Navigant

C.3 Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030

By 2030, local government operations will cut its carbon emissions by 55%, with at least 25% of the city's electricity sourced by self-generated renewable energy. Use of transportation fuels, such as gasoline and diesel, will be reduced to zero. Investments in RECs and/or carbon offsets will make up the remaining 45% of the carbon balance.

To cut carbon emissions by 55%, the city will implement demand reduction measures including building efficiency, street light efficiency, and water distribution system optimization. The city will reduce carbon emissions from transportation measures by implementing green fleet strategies, fueling with landfill CNG and electrifying fleet vehicles. All Metro Transit buses are electric buses in this scenario.

To increase generation of renewable energy at city facilities to 25% of its electricity use, the city will complete phase 1 and phase 2 of its solar self-generation plan and will continue to work with local utilities to implement at least one utility scale solar project. Investments in RECs and carbon offsets will make up the remaining 45% of the carbon balance. Technical details of each measure are included in Appendix B. Cost details are included in Appendix D.

There are opportunities to implement additional actions that would further reduce carbon emissions for local government or for the larger community. For example, as the city adds more electric vehicles and buses, it can add solar and energy storage to electric vehicle charging stations to power these vehicles with renewable electricity. Appendix D includes suggested actions to accelerate this scenario.

As with the other scenarios, our model estimates assume that local utilities MGE and Alliant have incorporated solar and wind to achieve 30% of their fuel mix powered by renewable energy by 2030, thereby lowering carbon emissions from electricity for the entire community. Table C-4 includes the mix of technical measures used in Scenario 3.

Table C-4. Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030

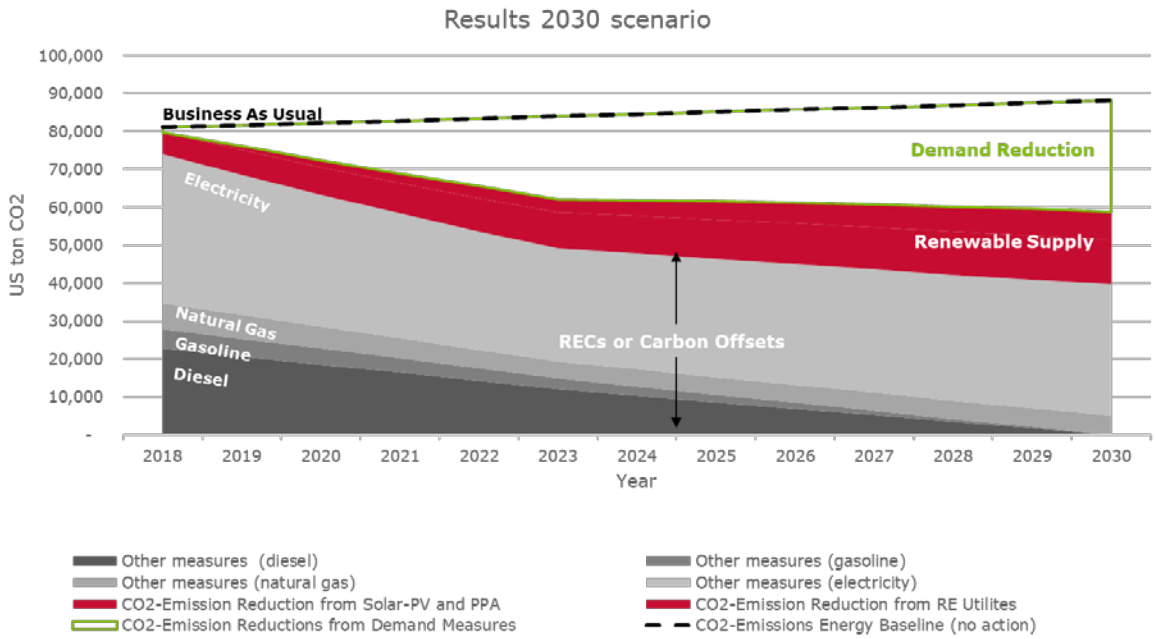
Measure Type	2030	Action
Efficiency Demand	X	Lighting Retrofits
	X	HVAC Retrofits
	X	HVAC Controls Retrofits
	X	HVAC RCx
	X	Plug Load Management Strategies
	X	Building Envelope Improvements
	X	Street Lighting Upgrades
	X	Water Distribution Optimization Strategies
Renewable Generation Supply	X	Behind-the-Meter Solar: Phase 1
	X	Behind-the-Meter Solar: Phase 2
	X	Utility Scale Solar (MGE RER or Alliant)
	X	Utility Fuel Mix (MGE and Alliant)
Transportation (Demand)	X	Green Fleet Measures
	X	100% Electric Buses
	X	Passenger Car EV Procurement
	X	Light Duty EV Procurement
	X	Landfill CNG Fueling
	X	Mid Duty EV Procurement

Measure Type	2030	Action
	X	Heavy Duty CNG Procurement
Investments	X	RECs
	X	Carbon Offsets

C.3.1 Impacts

Figure C-12 provides a visual representation of the fuel mix for city operations in the 2030 scenario. The top dotted line includes the business as usual trajectory which grows from 81,141 tons of CO_2 in 2018 to 88,188 tons of CO_2 in 2030. Demand reduction measures, such as energy efficiency and transportation (noted in green), reduce the amount of carbon emissions each year, starting with 1,416 tons of CO_2 in 2018 (2%) to 29,328 tons of CO_2 in 2030 (33%). Supply measures, such as behind-the-meter solar, utility scale solar projects, and the addition of renewable energy to the electricity fuel mix by utilities, (noted in red) further reduce the amount of carbon emissions each year, starting with 5,597 tons of CO_2 in 2018 (7%) to 19,171 tons of CO_2 in 2030 (22%). The remaining fossil fuel supply is the amount of electricity, natural gas and transportation fuels used by local government operations which is offset by investments in renewable energy and carbon offsets to make up the remaining carbon balance. In 2018, the amount to be offset is 74,128 tons of CO_2 (91%) decreasing to 39,689 tons of CO_2 (45%) in 2030. Table C-5 includes supporting information.

Figure C-12. Fuel Mix Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030



Source: Navigant

Table C-5. Fuel Mix Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030

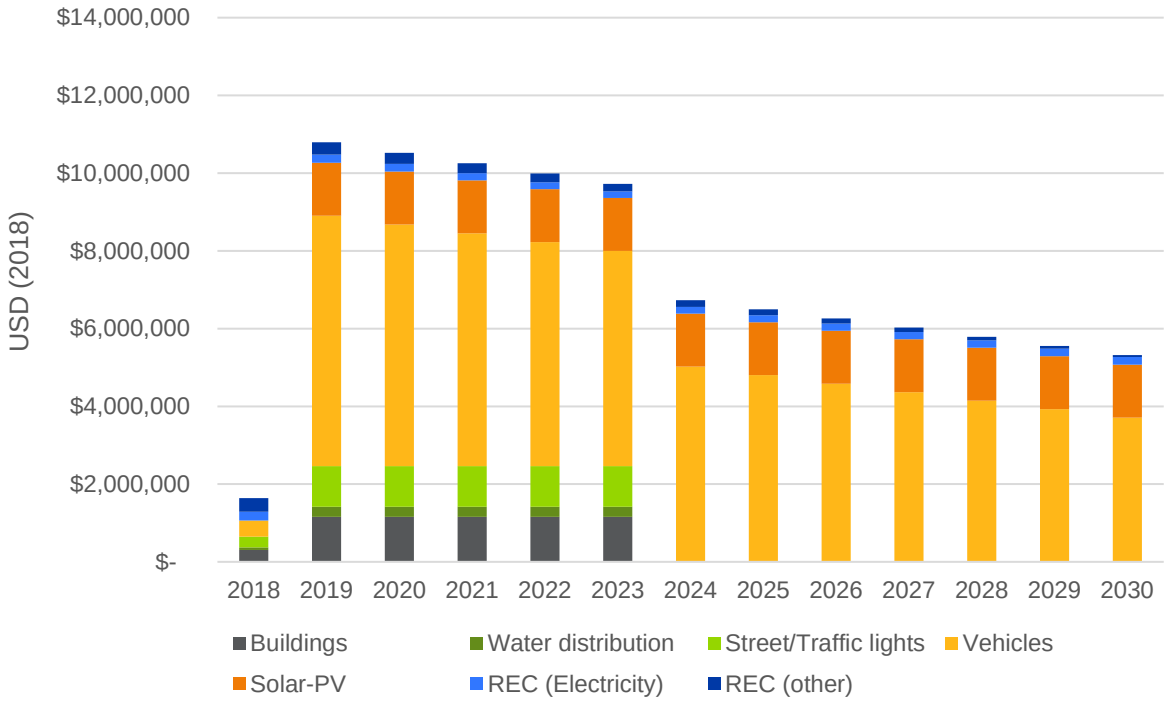
	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO_2 emissions (baseline)	ton	81,141	81,699	82,261	82,829	83,402	83,981	84,565	85,155	85,750	86,351	86,957	87,570	88,188
CO_2 reduction (demand)	ton	1,416	5,640	9,796	13,882	17,900	21,849	22,644	23,531	24,508	25,577	26,736	27,986	29,328
	%	2%	7%	12%	17%	21%	26%	27%	28%	29%	30%	31%	32%	33%
CO_2 reduction (supply)	ton	5,597	7,478	9,136	10,582	11,824	12,871	14,073	15,181	16,191	17,099	17,902	18,594	19,171
	%	7%	9%	11%	13%	14%	15%	17%	18%	19%	20%	21%	21%	22%
CO_2 remaining	ton	74,128	68,581	63,329	58,365	53,679	49,261	47,848	46,443	45,051	43,675	42,319	40,989	39,689
	%	91%	84%	77%	70%	64%	59%	57%	55%	53%	51%	49%	47%	45%
RECs Electricity	ton	39,337	36,869	34,698	32,813	31,206	29,866	30,513	31,166	31,831	32,513	33,214	33,939	34,694
	%	48%	45%	42%	40%	37%	36%	36%	37%	37%	38%	38%	39%	39%
RECs Natural gas	ton	6,774	6,310	5,847	5,384	4,922	4,461	4,533	4,607	4,681	4,756	4,832	4,908	4,985
	%	8%	8%	7%	7%	6%	5%	5%	5%	5%	6%	6%	6%	6%
RECs Gasoline	ton	5,145	4,675	4,204	3,734	3,263	2,792	2,395	1,997	1,600	1,202	804	407	0
	%	6%	6%	5%	5%	4%	3%	3%	2%	2%	1%	1%	0%	0%
RECs Diesel	ton	22,872	20,726	18,580	16,434	14,288	12,142	10,407	8,673	6,939	5,204	3,470	1,735	0
	%	28%	25%	23%	20%	17%	14%	12%	10%	8%	6%	4%	2%	0%

Source: Navigant

C.3.2 Costs

Investments from 2018-2030 are estimated at $95 million. The city will implement demand reduction measures including building efficiency ($6 million), street light efficiency ($5 million), and water distribution system optimization ($1.5 million). The City invests in staff and other resources at $1.5 million. All Metro Transit buses are electric buses in this scenario. Vehicle cost estimates are $60 million, representing the incremental costs for 232 electric buses, procurement of electric vehicles, implementing landfill CNG fueling and green fleet strategies. Investments in solar Phase 1 and solar Phase 2 are $16 million. Investments in RECs or carbon offsets are estimated at $5 million, with costs ranging from $10 per ton of carbon for carbon offsets and $5/MWh for renewable energy credits.

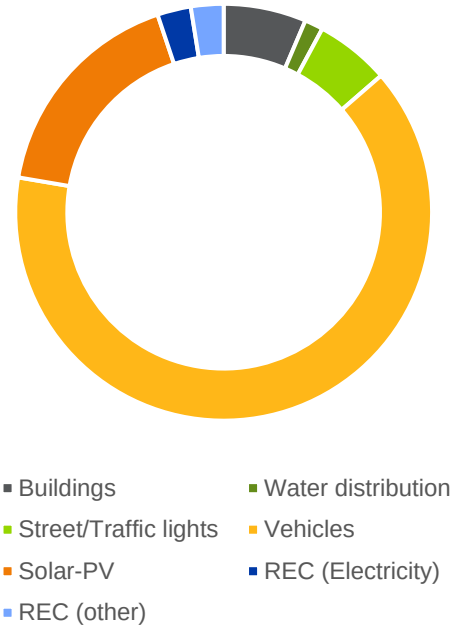
Figure C-13. Annual Investments in Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030



Source: Navigant

This analysis assumes that all expenditures are city funded. In the 2030 Scenario, cumulative additional investments between 2018 and 2030 amount to $95 million.

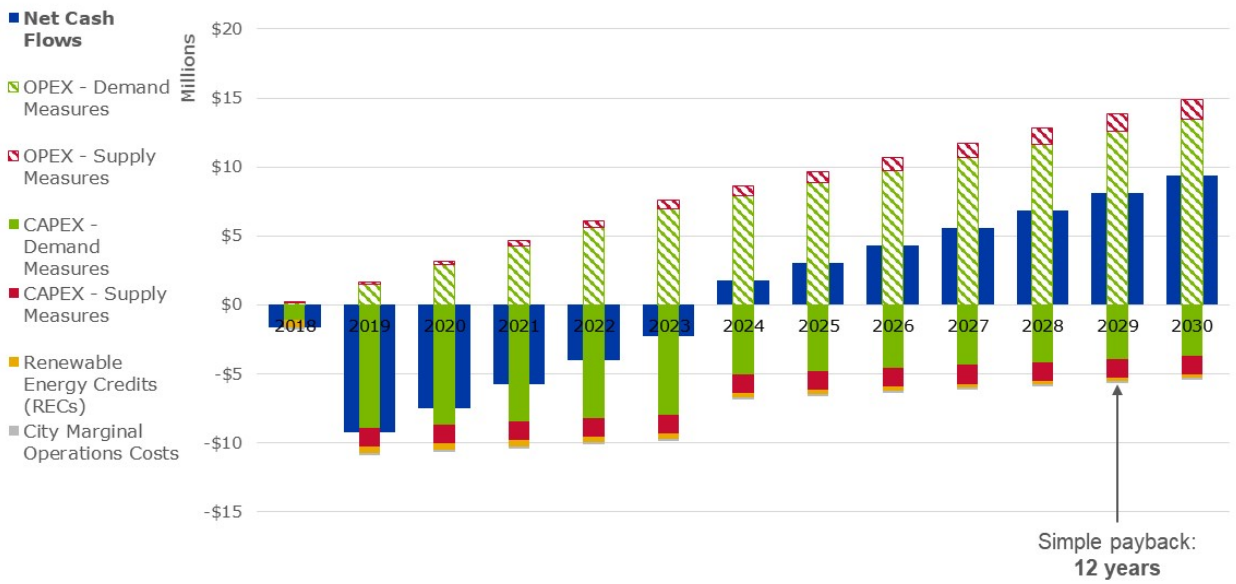
Figure C-14. Cumulative Investments in Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030



Source: Navigant

This cash flow analysis illustrates the 2030 scenario, assuming the city allocates all capital expenditures (CAPEX) investments and receives cost savings from operating expenses (OPEX) due to the investments. The 2050 NPV of the $95 million investment is $116 million with an internal rate of return of 17%. The net cash flow turns positive in year 6 (2024). The simple payback occurs at 2029 (12 years).

Figure C-15. Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030 – Cash Flow Summary



Source: Navigant

Table C-6. Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030 – Cash Flow Summary

(Figures in $ Millions)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAPEX Demand Measures	-1.1	-8.9	-8.7	-8.5	-8.2	-8.0	-5.0	-4.8	-4.6	-4.4	-4.1	-3.9	-3.7
CAPEX Supply Measures	0	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Renewable Energy Credits (RECs)	-0.6	-0.5	~-0.5	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2
City Marginal Operations Costs	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
OPEX Demand Measures	0.1	1.5	2.9	4.3	5.6	7.0	7.9	8.8	9.8	10.7	11.6	12.6	13.5
OPEX Supply Measures	0.0	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4
Net Cash Flows	**-1.6**	**-9.3**	**-7.5**	**-5.8**	**-4.0**	**-2.3**	**1.7**	**3.0**	**4.3**	**5.6**	**6.9**	**8.1**	**9.4**

Source: Navigant

C.4 Model Outputs and Assumptions

Carbon reduction strategies include a wide variety of actions and measures with different costs, ways of measuring payback, and other non-economic returns. This section includes a brief description of the tools used to create the City of Madison's timelines to achieve 100% renewable energy and zero net carbon

emissions. The three tools are the low carbon calculator, the marginal abatement cost curve, and a marginal cash flow analysis. Together, these tools enable policymakers to assess CO_2 emissions reduction potential and the financial impacts of the proposed measures.

The **Low Carbon Calculator** uses energy consumption estimates from city facilities, street lights and traffic signals, water distribution, fleet vehicles, Metro Transit and solar installations to estimate carbon impacts from each and establish or verify baseline consumption from local government operations. After energy impacts are determined, the calculator estimates carbon impacts of demand-side measures (such as energy efficiency) and supply side measures (such as solar PV).

The **Marginal Abatement Cost Curve** is used for comparing and prioritizing specific abatement options, both in terms of cost-effectiveness and total emissions abatement potential.

The **Marginal Cash Flows Analysis** demonstrates the expected financial effects of the abatement measures for financial planning and forecasting.

C.4.1 Low Carbon Calculator

The three modeled scenarios used technical measures including demand-side, supply side, and transportation measures. Demand-side measures are strategies that reduce the consumption of fuels, such as energy efficiency measures. Supply side measures are strategies that generate renewable energy from sources such as solar. Transportation measures include actions to reduce carbon emissions from fuel efficiency, such as using more efficient vehicles and fuel switching, such as the electrification of fleet and transit vehicles. Additional measures, such as battery storage or city policies, are not part of the low carbon calculator outputs but are included in the report. Additional technical information about the demand and supply measures follows in Appendix B.

C.4.2 Marginal Abatement Cost Analysis

A marginal abatement cost curve (MAC curve or MACC) visualizes the cost and carbon reduction potential of various decarbonization scenarios (or measures). A MACC presents the extra (or marginal) costs and carbon reduction (or abatement) potential of these options relative to the business as usual case. These curves allow policymakers to understand the cost-effectiveness and total abatement potential of each abatement measure; factors which they can consider when prioritizing action and allocating resources. This analysis compared the costs of reducing carbon emissions from 20 measures (18 demand-side measures and 2 supply side measures) from solar, energy efficiency in buildings, optimizing water distribution, efficient street lights, and vehicle efficiency or electrification for comparison purposes. Costs are represented as a US ton (2,000 lbs.) per 2018 US dollar.

The graph shows 13 measures with negative costs to reduce carbon (eight vehicle options, transit buses, behind-the-meter solar phase 1, building efficiency retro-commissioning program, water distribution optimization measures, and efficient lighting in buildings). These measures are forecast to earn back their investment within their technical lifetime.

Other measures may not earn back their financial investment within their technical lifetime but will still reduce CO_2 emissions at different costs. These measures may also have additional impacts—contributions to public safety, improved indoor environmental quality, and health benefits to city employees. For example, efficient or smart street lights have a low cost ($17/ton CO_2) while reducing CO_2

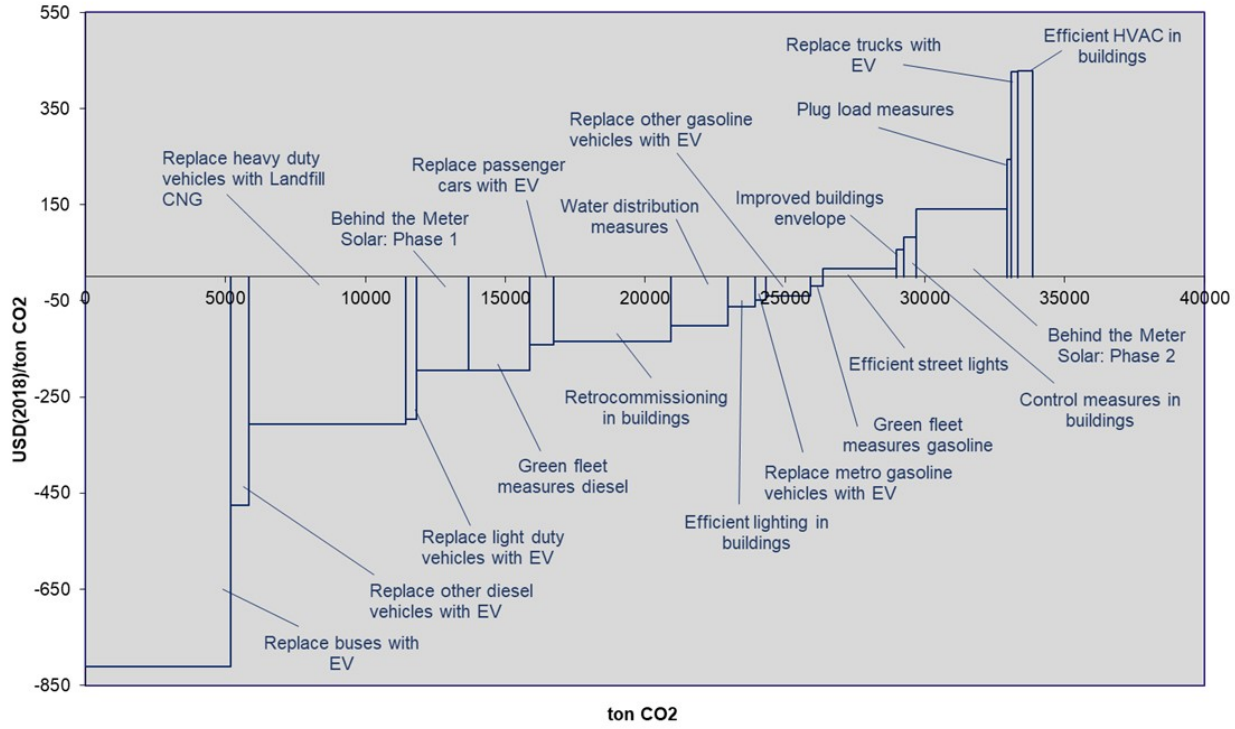
emissions significantly. If combined with sensors, smart street lights can contribute to public safety by hosting wireless networks or monitoring traffic and further Madison's smart city initiatives. Other measures may require greater investment, such as improving plug loads in buildings ($245/ton CO_2) or efficient HVAC in buildings ($428/ton CO_2). However, investments in efficient buildings yield additional non-energy impacts such as improved indoor environmental quality, which leads to increased productivity and health benefits for city employees and people visiting city facilities.

Figure C-16 shows the CO_2 reduction potential per measure on the horizontal axis and the additional costs expressed in USD/ton CO_2 reduced on the vertical axis. The measures with the lowest incremental cost of carbon are at the left.

The figure is read in the following way.

- Each bar represents a single low carbon option.
- The width of the bar represents the abatement potential per year, *relative to business as usual*.
- The height of the bar represents the abatement cost per year, *relative to business as usual*.
- The costs are expressed in dollars per ton emissions avoided.
    - For options with negative abatement costs (i.e., with bars below the horizontal axis), the cost savings (e.g., through reduced energy or fuel costs) are expected to exceed the cost of implementing the measure.
    - Measures with positive abatement costs (i.e., with bars above the horizontal axis) are projected to cost the city more to implement than will be saved over their operational life.

Figure C-16. Marginal Abatement Cost Curve Measures – City of Madison Local Government Operations



Source: Navigant

The 20 measures (18 demand-side measures and two supply side measures) are ranked in Table C-7 according to the cost/ton for carbon reduction. For example, replacing Metro buses with electric buses (rank 1) is the measure with the lowest cost of carbon/ton; it is located on the left side of the graph in Figure D-15 and is first in the table in Table D-8 below.

Table C-7. Measures Carbon Reduction Potential and Costs of Carbon Reduction

Rank	Measure	Costs (USD/ton CO_2 reduced)	CO_2 reduction potential (ton CO_2)	Measure investment $USD
1	Replace Metro buses with electric buses	$-812	5,186	-$4,208,921
2	Replace diesel vehicles with electric vehicles	$-475	639	-$303,696
3	Replace heavy duty trucks with CNG vehicles	$-307	5,632	-$1,729,583
4	Replace light duty vehicles with electric vehicles	$-296	368	-$109,058
5	Behind-the-Meter Solar: Phase 1	$-195	1,863	-$363,567
6	Green fleet measures for diesel vehicles	$-195	2,175	-$517,308
7	Replace passenger cars with electric vehicles	$-141	882	-$124,587

Rank	Measure	Costs (USD/ton CO_2 reduced)	CO_2 reduction potential (ton CO_2)	Measure investment $USD
8	HVAC Retro-commissioning in buildings	$-135	4,169	-$564,129
9	Water distribution measures	$-102	2,056	-$209,771
10	Efficient lighting in buildings	$-62	955	-$59,525
11	Replace Metro gasoline vehicles with electric vehicles	$-48	402	-$19,488
12	Replace other gasoline equipment with electric equipment	$-40	1,593	-$64,462
13	Green fleet measures gasoline	$-19	449	-$5,749
14	Efficient street lights	$17	2,625	$45,799
15	Improved envelope in buildings	$57	266	$15,229
16	Controls measures in buildings	$83	432	$35,823
17	Behind-the-Meter Solar: Phase 2	$142	3,264	$462,185
18	Plug load measures in buildings	$245	141	$34,651
19	Replace light duty trucks used by Madison Fleet with electric vehicles	$427	239	$101,807
20	Retrofit HVAC in buildings	$428	511	$218,867

Source: Navigant

C.4.3 Marginal Cash Flows Analysis

The purpose of a marginal cash flows analysis is to assess the extra (or marginal) cash inflows and cash outflows that would result from a particular investment. To conduct the marginal cash flows analysis, the consultants calculated a price per reduced US ton of CO_2 equivalent for each of the selected measures based on marginal CAPEX, marginal OPEX, measure useful life, interest rate, and expected carbon abatement or reduction potential. Information used was based on data or reports from the City of Madison and industry literature where Madison-specific data was not available. The key cashflow sources to consider when assessing investment in carbon emissions reduction measures are:

- **Marginal capital expenditures (CAPEX):** The additional funds required to acquire or upgrade physical assets such as buildings or equipment. For example, for the measure to replace the gas buses with electric buses, the marginal CAPEX is the difference between the cost of buying a new gas bus and buying an electric bus. If the new measure costs less to acquire or upgrade than the baseline building or equipment, the marginal CAPEX is a cash inflow (positive cashflow) and may be referred to as an avoided cost; if vice versa, the marginal CAPEX is a cash outflow (negative cashflow).
- **Marginal operating expenses (OPEX):** The additional funds required to maintain, power, or operate physical assets such as buildings or equipment. For example, for the measure replacing gas buses with electric buses, the marginal OPEX is the difference between the operating cost

(i.e., cost of fuel/energy, maintenance) of the gas and electric buses. If operating costs of the new measure are lower than the baseline, the marginal OPEX is a cash inflow (positive cashflow) and may be referred to as an avoided cost; if vice versa, the marginal OPEX is a cash outflow (negative cashflow).

- **Measure Useful Life:** The technical lifetime of the measure, such as the amount of years the city can expect to use a vehicle or piece of equipment.
- **Interest Rate:** The interest rate in effect to borrow money using general obligation bonds.
- **Carbon Reduction or Abatement Potential:** The amount of carbon emissions saved by the measure.
- **City Marginal Operations Costs:** Include any other costs required to implement the measure under consideration, such as the cost of hiring new personnel to administer and monitor the implantation of a set of measures.
- **RECs:** Can be purchased to offset the remaining carbon emissions not abated by other measures. The City would pay for these certificates on an annual basis and therefore they result in a negative annual cash flow.

In the marginal cash flow analysis for the City of Madison, the cash flows from each of these sources are estimated for each measure from 2018 to 2050. All of these positive and negative cash flows are then summed for each year, yielding in the **Marginal Net Cash Flow**, which shows how much more or less the city is predicted to pay each year as a result of investment in the proposed package of emissions reduction measures, assuming that the city pays for the full cost of the measures using a financial mechanism such as general obligation bonds.

The **Net Present Value (NPV)** is the difference between the present value of cash inflows and outflows over a period of time. This value is often used in capital budgeting to analyze the profitability of a projected investment or project and is calculated from the marginal net cash flows. The NPV calculation also includes an assumed discount rate, which determines how much the value of future cash flows are reduced.

APPENDIX D. SUGGESTED ACTIONS TO ACCELERATE MADISON'S GOALS

There are some specific actions that the City of Madison can implement immediately at low cost that help jump-start the City's efforts toward 100% renewable energy and zero net carbon emissions in municipal operations. These opportunities are ways for the City of Madison to continue its role in leading the development of a clean energy future for the greater Madison area. The following suggested actions can be implemented as policy or initiatives, by specific departments, or city wide. What follows are actions focused on City operations, and programs focused on the greater Madison community.

D.1 Suggested Actions for City of Madison Operations

The following suggested actions by the City of Madison will accelerate reaching the 100% renewable energy and zero net carbon emissions goals.

D.1.1 Publicize Municipal Building Energy Data

The City of Madison currently tracks all electric and natural gas usage for city operations. The City uses this data to help prioritize investments in energy efficiency or a renewable energy system.

Action: The City of Madison should make municipal building energy data information publicly accessible through an online data portal or website for the public, so the community can see how city buildings perform. By using municipal operations as an example, the City can work with the private sector to develop similar programs for tracking commercial building energy data. The City of Madison should work with the business community and local utilities to develop appropriate standards and platforms for accessing commercial building energy data, taking appropriate precautions about data privacy concerns into account.

D.1.2 Fast-Track Solar Permitting and Inspections

The City of Madison can save time and money for solar contractors in the area by reviewing solar permitting and fee requirements and updating them to make them clearer, streamlined, and less expensive. The City of Milwaukee recently adopted lower permit fees that were over-burdening large solar systems.

Action: The City of Madison should host a series of roundtable discussions/trainings with local solar contractors to identify areas of concern in the permitting and inspection process and to identify opportunities to fast-track solar permitting and inspections. These should be implemented immediately.

D.1.3 Review Madison City Policies and Practices to Align with 100% Renewable Energy Goal

Reviewing Madison city policies and practices will identify areas where policies, or the absence of policies, may be conflicting with 100% renewable energy and zero net carbon goals. Examples may include TIF, commercial and residential new construction permitting, city planning, procurement and enforcement of parking regulations, among others.

Action: Review existing city policies and practices to determine conflicting goals and standards to the 100% renewable energy and zero net carbon goal. An initial list is included below:

- **New Construction:** Provide incentives for developers and contractors to build solar-ready and EV-ready for 5-10 years, as appropriate; after which, these programs are phased into mandates for residential and commercial new construction and major retrofit projects, incorporating solar-ready and EV-ready attributes into all projects.
- A requirement on builders of flat-roofed buildings that meet certain criteria (e.g., more than 100,000 sq. ft. of unshaded roof space) to incorporate solar PV in the roof design to the extent practicable based on expected building usage and current net metering service.
- Requirement on the part of developers of commercial and office buildings to disclose to City Planning their plans, if any, for solar self-generation.
- A requirement on City Planning to refer new commercial building proposals to the MadiSUN program for a solar consultation.
- Require home-builders to design new houses with solar-ready south-facing roof space
- Require solar generation and master-metering on new multifamily dwellings above a certain size, to enable the electricity to flow through to building tenants.
- **TIF**: Explicitly allow TIF funds to reimburse developers who construct 100% RE/net zero carbon buildings.
- **Planning**: Encourage the creation of 100% RE/net zero carbon zoning overlay districts surrounding city facilities that showcase sustainable building practices and carbon reduction.
- **Electric vehicle zoning and permitting:** The City of Madison should implement an EV and EV charging station zoning and permitting policy. Identifying areas of the city with appropriate grid requirements or needs where EVs and vehicle-grid initiatives could support strategic zoning and appropriate investments. City permitting requirements should be transparent and clear. Some cities include incentives and/or requirements for EV charging stations in new developments or major retrofit projects and in projects that receive city subsidies or financing, such as TIF.
- **Agency Vehicle Procurement:** For procurement, city agencies in Madison make vehicle acquisition requests to the Fleet department. The Fleet department is responsible for procuring, maintaining, and fueling agency vehicles with costs billed back to individual city agencies. While not uncommon among cities, this approach creates a split incentive for city agencies to implement green fleet policies. An opportunity to improve this procurement arrangement is to enable the city agencies to budget for and keep a portion of operational cost savings for efficient vehicles and EVs. Additional policies could include required right-size and green fleet training for

city agency staff in charge of vehicle procurement requests and reviewing internal city policies or practices for vehicle requisition to ensure compliance with green fleet goals and strategies.

- **Enforcement of Parking Regulations:** It is critical that city parking enforcement ensures that publicly available EV charging stations are properly used by carefully enforcing time limits and vehicle requirements at EV charging stations. For example, enforcing parking violations for a non-EV parked at an EV charging station or an EV that has exceeded the allotted time requirements at an EV charging station.

- **Future Mobility:** Develop appropriate policies, permitting, and taxation for automated vehicles, mobility, and ridesharing as part of Madison in Motion. For example, many cities assess fees to ridesharing to raise funds for transit.[45]

D.1.4 Establish Green Revolving Fund

Many cities around the country have dedicated funding sources for sustainability, known as Green Revolving Funds.

Action: Establish a Green Revolving Fund to maintain investments in clean energy.

D.1.5 Energy Storage Pilots

Energy storage provides opportunities to manage energy and the costs for energy storage are coming down.

Action: Develop energy storage pilots at municipal facilities. Monitor how energy storage affects use. Develop education and outreach materials to share with public and private stakeholders.

D.1.6 Piloting Additional Solar with Energy Storage and EV Charging Stations

Due to current regulatory net metering restrictions that limit the amount of generation to the building's consumption, a total of 8 MW (as outlined in solar phase 1 and solar phase 2, above) could be installed at municipal rooftop locations with additional solar capacity planned for in the future.

Action: The City should identify and pilot additional solar installations, such as solar canopies, building integrated PV, energy storage, and EV charging stations. Energy storage and EV charging stations help manage the electricity generation and consumption to stay within net metering requirements. Use these examples for education and outreach. Work with utilities to pilot energy storage and EV charging applications in the community.

D.1.7 Investing in Safe, Efficient, and Affordable Housing

The Community Development Authority (CDA) Housing Operations Division administers 742 public housing units and 115 multifamily housing units at 40 locations in the City of Madison for low income

[45] Liz Farmer, "Governments Increasingly Tax Uber and Lyft for Transit Revenue," *Governing The States and Localities*, April 4, 2018.

families, people over the age of 50, and individuals with disabilities. In addition, the CDA administers the Section 8 Housing Choice Voucher Program which provides assistance to approximately 1,600 low income households in the City of Madison. The CDA is working with Focus on Energy and other groups to implement safe, efficient, and affordable housing in several locations, including Mosaic Ridge in Allied Drive. The City of Madison promotes efficiency and renewables in private sector developments through various means, such as the TIF and the Affordable Housing Trust Fund.

Action: Install policies and/or funding preferences for CDA and the Affordable Housing Trust Fund that all new single-family homes built with CDA funds should be certified as Net Zero Ready, and all affordable housing using city funds should be built as renewable-ready and EV-ready. Use successful examples, such as Rethke Terrace (LEED Platinum and Passive House certified), educational and outreach tools to promote successful strategies for the larger community to incorporate Net Zero Ready, and similar goals.

Local Spotlight: Rethke Terrace Madison, Wisconsin

Rethke Terrace is a new multifamily housing facility off of East Washington and Aberg Ave that was funded in part by the City of Madison. This project reached PassiveHouse and LEED Platinum certification earlier this year. It became the first multifamily project in Madison (and the Midwest) to reach this rigorous sustainable design goal.

D.1.8 Develop a Program for Municipal Building RCx and Water Distribution Optimization

The City of Madison provides dedicated funding to improve existing buildings energy performance. The City of Madison has performed retro-commissioning (RCx) services on all libraries, some parks, and water utility buildings, and where possible, is moving forward on police stations.

Action: The City of Madison should develop an RCx program for all the city's major buildings on a rotating basis (every 2-4 years) including budgeting for the RCx and implementing measures. In addition, the City should have a dedicated person to oversee the energy performance of its buildings and that the RCx efforts are completed. A similar energy optimization program should be implemented for the Madison Water Utility for water pumping. Consider opportunities to generate energy from gravity fed water pipes.[46] By using municipal operations as an example, the city can work with the private sector and help develop and promote a similar initiative for RCx private sector commercial buildings. Other cities or water utilities in charge of water distribution may learn from Madison's water pumping optimization program.

[46] The City of Portland, Oregon has installed electricity generating turbines in some of its gravity fed water pipes. Source: Alastair Boone, "How Portland Is Sourcing HydroPower from Its Drinking Water," *CityLab*, January 17, 2018.

D.1.9 Smart Streetlight Pilot

The City of Madison is in discussions with MGE and Alliant about options to replace street lights with more energy efficient LED street lights and smart street lights.

Action: The City of Madison should continue discussions with MGE and Alliant about implementing LED street lights and should pilot smart street lights in appropriate areas. Madison's smart street lights can be an example for other local governments around Wisconsin.

D.1.10 Smart City Public-Private Partnership

Many smart city applications have already started in Madison. The City of Madison participates in the Smart Cities Collaborative.[47] The City of Madison is experimenting with intelligent data collection, analysis and sharing. This smart infrastructure is laying the groundwork for connected networks in the Park Street Corridor where traffic signals will communicate with smart cars and buses. [48] The University of Wisconsin-Madison participates in this project and hosts a robust automated vehicle testing program.[49] Some public-private partnerships incorporate EVs and charging infrastructure into larger initiatives related to urban mobility, smart cities, and the use of data. For example, in Columbus Ohio, the Smart Columbus Initiative has a goal to increase adoption of EVs by increasing consumer awareness and consideration, improving the consumer purchasing experience, and conducting market research and evaluation to direct public and private action.[50]

Action: The City of Madison should continue to work with groups like the Smart Cities Collaborative. The City of Madison should immediately fund an initiative to work with other stakeholders to create a smart city public-private partnership to build on its early smart city success.

D.1.11 Smart Grid and Grid Modernization

Grid modernization is the centerpiece of a transition to the advanced energy economy and a distributed, smart, clean energy generation market. A smart grid can enable the City of Madison to maintain a resilient, flexible, technologically advanced growth strategy and continue to pursue implementation of solar and other distributed energy resources.[51]

Action: Immediately fund a plan to work with MGE and Alliant to pilot smart grid initiatives. Support regulatory initiatives that fund grid modernization upgrades.

D.1.12 Landfill CNG Pilot

Dane County fuels vehicles using CNG from the Dane County landfill.

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[47] Transportation for America, "Smart Cities Collaborative," http://t4america.org/.

[48] Yang Tao, PhD, "Collaborating Towards a Smart Future," Wisconsin AV Stakeholder Summit, https://wiscav.org/wp-content/uploads/2017/03/Madison-Smart-City-AV-Summit.pdf.

[49] University of Wisconsin Automated Vehicle Proving Grounds, "Automated Vehicles," https://wiscav.org/.

[50] Smart Columbus, https://smart.columbus.gov/.

[51] Thanks to Gary Radloff of The Radloff Group for this recommendation.

Action: The City of Madison Fleet should launch a landfill CNG pilot using heavy duty vehicles to determine whether using landfill CNG is feasible for fleet vehicles. Additional questions to answer include costs for CNG fueling infrastructure or accounting to fuel at Dane County facilities (if allowed), training staff in CNG vehicle operations and maintenance, and costs to retrofit existing garage space for landfill CNG vehicles.

D.1.13 Set and Maintain High Performance Green Building Standards for Municipal New Construction and Major Renovations

The City has been maintaining a high standard of building performance for municipal new construction and should continue to be aggressive with future projects. On most projects, the City has used the LEED Building standard to ensure that its buildings maintain an elevated level of performance and sustainability. Electrification of the domestic water heating and building heating is also critical for achieving citywide net zero carbon goals. Once a building is constructed with natural gas infrastructure it is extremely expensive to retrofit these systems. As grid electricity becomes cleaner over the coming decade, electrified buildings will be positioned to take advantage of these changes. Geothermal heating/cooling or air source heat pumps are some technologies that use electric compressors to provide building conditioning.

Action: With a 100% renewable energy goal, it is critical that the city aim to achieve net zero energy for new municipal buildings. Net zero energy may not be possible on all new construction, but it should be the goal. Creative financing tools, such as co-ownership, may be required to enable solar PV to be incorporated into these buildings while meeting available budgets. Use municipal buildings as educational and outreach case studies to inspire the greater community to build net zero new construction. Madison could consider novel approaches to facilitating low carbon solutions. For example, work with local organizations to initiate net zero energy design competitions to envision future development, such as the far west-side Research Park as a net zero energy campus.

D.1.14 City of Madison Employee Commuting

A survey of City of Madison employee commuting patterns indicated that almost half of City employees use some form of transportation to commute to work other than a personal vehicle.[52] The City of Madison has worked with a local non-profit organization to implement behavioral based games to encourage employees to reduce consumption of energy and materials.[53] The City of Madison and Madison Metro offer several benefits to city employees, including a free Metro bus pass, paratransit benefit, and guaranteed ride home.[54]

Action: Continue strategies to reduce carbon emissions from employee commuting by offering education and outreach, competitions, and incentives to employees. Conduct education and outreach to public and private stakeholders to share information and gain momentum.

D.1.15 Work with Other Local Governments to Pool Resources

[52] University of Wisconsin, Madison LaFollete School of Public Affairs, *Madison City Operations Tracking Framework: A Roadmap to Sustainability*, Spring 2015.

[53] Cool Choices, https://coolchoices.com/.

[54] City of Madison, “City of Madison Pass,” https://www.cityofmadison.com/metro/fares/PassPrograms/CityofMadison.cfm.

The City of Madison participates in ICLEI Local Governments for Sustainability, the Sierra Club Ready for 100 program, and the Dane County Council on Climate Change, among other national and international sustainability efforts. The City of Madison Fleet department convened a meeting with area fleet managers to discuss best practices in fleet management, safety, and sustainability.

Action: Immediately fund continued participation in these initiatives. Identify opportunities to work with other local governments to promote sustainability, racial equity, and social justice—regionally, statewide, nationally, and internationally.

D.2 Suggested Actions for the Madison Community

The following recommendations include ways for the City of Madison to provide leadership for the greater community as people and businesses add renewable energy and lower their carbon footprint. These actions focus on lowering the carbon footprint of city citizens and will reinforce Madison's role as a sustainability leader for its citizens.

D.2.1 Plan for EV Charging Infrastructure

Electric vehicle (EV) growth in Madison and the surrounding area is estimated at 50%-60% per year. The City of Madison and MGE have installed eight EV charging stations in public parking garages to date and the number is growing with the addition of two new public parking garages. There are 62 EV charging stations within 10 miles of the center of Madison.[55]

Lack of publicly available charging stations is one of the primary barriers to increased adoption of electric vehicles, along with battery life and customer choices. As batteries continue to improve and more EV options become available leading to increased customer uptake, Madison will need more public EV charging stations to accommodate this growth. Nationwide, recent research estimates that cities must install somewhere between one and five public charging stations for every 1,000 EVs expected within its geographic area.[56] By 2030, this research indicates that the expected number of EVs in Madison would require the City of Madison to add 320 additional EV charging stations.

Similar cities, such as Ann Arbor, Michigan, Columbus, Ohio, and Austin, Texas, have comprehensive EV programs.

Action: To accommodate the rapidly increasing demand for EVs in Madison and the surrounding area, the City should immediately develop a comprehensive plan for the implementation of EVs and EV charging infrastructure. The City should use its Madison in Motion plan (2017) and work with the Madison Area Transportation Board, MGE, Alliant, and other organizations to develop appropriate plans for future distribution and procurement of public EV charging stations through 2030. Whenever possible, public EV charging stations should be accompanied by solar PV installations (and energy storage if beneficial) to ensure that EVs are charged with renewable energy and to provide educational and outreach

[55] Madison Gas and Electric, "Working Together to Grow the Electric Vehicle Market," https://www.mge.com/environment/electric-vehicles/growing-ev-market.htm.

[56] Capital Times cites WisPIRG as estimating that Madison will need 328 public EV charging stations by 2030 to support an anticipated 9,000 EVs in Madison. Readying America's Cities for the Arrival of Electric Vehicles, citing research from EPRI, NREL. https://uspirg.org/reports/usp/plugging.

opportunities for the public. Utility tariffs and rate structures must also be created to address the needs of EVs and EV charging infrastructure. An initial target for public EV charging stations could include 100 new public EV charging stations by 2023 and 250 new public EV charging stations by 2030. The target should be revised as needed based on market research and customer surveys. The City of Madison EV implementation plan should include the marketing of current EV charging stations to include an interactive map of current EV charging stations via a public website.

D.2.2 Develop and Promote Community Solar Options

Under the current regulatory framework, the City of Madison cannot build its own large-scale solar array without local electric utilities. The City has developed a map of City-owned land that could house a large solar array and has been in communication with local electric utilities about developing a community solar project. Dane County is developing a large solar array by the Dane County Regional airport. Other municipalities in the area have committed to 100% renewable energy and have installed, or are planning to install, solar at municipal locations.

Alliant developed the 5 MW Dubuque Solar Project in an innovative partnership with the City of Dubuque and the Greater Dubuque Development Corporation.[57] Alliant also offers its customers a green-e certified renewable energy called Second Nature.[58]

MGE's community solar program, Shared Solar, gives customers the option to add solar-generated electricity without having to install solar panels on their homes. MGE developed a community solar program on the roof of the City of Middleton Municipal Operations Center in 2016, which sold out quickly. MGE is planning to expand its shared Solar program and invites MGE customers to join its waiting list.[59]

Action: Continue to work with other local governments and electric utilities to develop and promote community solar options. Set appropriate targets, aim to develop 5 MW of community solar by 2020, 20 MW by 2023 and 30 MW by 2030.

D.2.3 Promoting Solar in Land-Use Planning

The City made a priority for renewable energy in its Imagine Madison comprehensive land-use plan, which was approved in 2018.

Action: Designate solar development as a conditional or permitted use in appropriate locations. Educate the private sector and neighborhoods about expectations to incorporate solar development, EV charging infrastructure, energy storage, and other projects in development plans.[60]

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[57] Alliant Energy, "Our Energy Vision," Solar Generation, https://www.alliantenergy.com/OurEnergyVision/AdvancingCleanEnergy/SolarGeneration.

[58] Alliant Energy, "Innovative Energy Solutions," Easy and Affordable Renewable Energy, https://www.alliantenergy.com/InnovativeEnergySolutions/SustainableEnergyChoices/SecondNature.

[59] Madison Gas and Electric, "Shared Solar Program," https://www.mge.com/environment/green-power/solar/shared-solar-program.htm?redirect=index.htm.

[60] University of Wisconsin, *Extension Solar Energy Financing Guide*, 2017.

D.2.4 Promote Clean Energy Policies for Wisconsin

The City of Madison has negligible control fossil generation, which is implemented by state or federal policies or regulations. There are policy and regulatory changes that could be implemented to accelerate the retirement older generation resources, including coal generation. State energy policies, such as the current renewable portfolio standard or net metering restrictions, could be revisited to determine opportunities to help support energy efficiency or renewable energy.

Action: The City should work with other public and private stakeholders to intervene in regulatory proceedings and support the development of rate structures and financial and accounting tools that incentivize energy efficiency and renewable energy in the marketplace, while taking care to ensure that apportioned costs are fair for the early retirement of assets. City officials should encourage public bodies with a presence in the City of Madison to adopt carbon reduction and renewable energy acquisition goals similar to those of the City. Likely targets include Madison Metropolitan Sewerage District, Madison Metropolitan School District, Madison College, UW-Madison, State of Wisconsin, and Dane County. Continue to work with MGE and Alliant to identify opportunities for strategic electrification in the transportation and buildings sectors in conjunction with increased adoption of renewable energy to power increased electricity demand. As the city and the community adopt these lower emission and lower lifecycle cost electric technologies, electric demand is increased, allowing further investment in renewable generation. This virtuous cycle will accelerate the City and community's path to 100% renewable energy.

D.2.5 Incentivize Affordable Clean Energy in the Community

More efficient, affordable, green, and net zero energy projects are developed in Madison and across Wisconsin each year. However, Madison needs more of these projects implemented more quickly.

Action: Consistent with the recommended policy and practice review above, the City can incentivize the private sector to invest in efficient, affordable, and green new construction that may be able to achieve net zero energy by providing technical resources and financial incentives such as TIF for energy efficient and renewable energy technologies. The City could take that one step further by creating an area where all new construction meets a zero net standard. For example, New Berlin, Wisconsin has a development where all the single-family homes come with solar on the roof and are certified as Zero Energy Ready.[61]

D.2.6 Develop Investment Options for Community Clean Energy

People in Madison are excited about supporting clean energy. The City can help encourage support of clean energy by supporting initiatives to develop a clean energy fund in the private sector or by developing its own approach. For example, the City of Madison recently announced Madison community bonds for the expansion of Olbrich Botanical Gardens.[62] This model could be used to encourage private sector investment into renewable energy and energy efficiency. The City of Cleveland, Ohio has

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[61] Tim O'Brien Homes, a single-family home builder with offices in Milwaukee and Madison, recently opened its first model at the Red Fox Crossing in New Berlin. For details, please see https://www.bizjournals.com/milwaukee/prnewswire/press_releases/Wisconsin/2018/07/16/UN52291.

[62] City of Madison, "City of Madison Community Bonds," http://www.cityofmadison.com/community-bonds.

successfully implemented this approach.[63] Another innovative example of clean energy investment opportunities for the commercial sector is the PACE Wisconsin Fund, that was authorized in Dane County in 2018.[64] Other options include working with non-profit organizations and private sector businesses to develop appropriate investment tools to encourage community clean energy.

Action: The City should assess various options for community clean energy investment mechanisms for individuals and businesses that would like to invest in clean energy through the City Finance department and by working with local organizations. For example, the City of Madison could develop a program for encouraging City employees, alders and committee members, vendors and suppliers, and other constituencies that it may influence to subscribe to utility shared solar programs, purchase RECs from local electricity providers, or invest in City bonds that explicitly finance renewable energy investments. This program should have a recurring recognition component that highlights exemplary community actions to reduce carbon emissions.

D.2.7 Promote the Home Energy Scores Program for Residential Energy Data

Focus on Energy offers a voluntary program, Home Energy Scores, which enables residential customers to receive a summary of energy-related use, costs of energy and cost-effective improvement options at their homes and can be added to the multiple list service (MLS) for real estate transactions.[65] Some cities, including Austin, Texas, Berkeley, California, Santa Fe, New Mexico, Boulder, Colorado, and Portland, Oregon offer this program and/or require that a seller of a single-family home include a home energy score as part of a residential property transaction.[66]

Action: The City should work with Focus on Energy to convene interested property owners, realtors, and other interested stakeholders to develop appropriate standards for promoting the Home Energy Scores program and adding information to the MLS. Work with other local governments to develop a timeline to make Home Energy Scores a mandatory provision in Madison-area real estate transactions.

D.2.8 Continue to Expand Education, Outreach and Programs, such as MadiSUN

MadiSUN is a program of the City of Madison and supported by the City of Middleton.[67] MadiSUN provides group buys for homes, solar for business, and a solar loan program. RENEW Wisconsin, a local non-profit organization working to grow renewable energy statewide, administers the program on behalf of the City. Over the past 2 years, 80 Madison-area homes have installed solar panels through the program. The program added a new focus on businesses this year. West High School students petitioned the Madison Metropolitan School District to pursue a solar energy project at Madison West High School. Other area schools have also installed solar panels.

Action: Continue and expand funding for MadiSUN and consider funding additional community engagement initiatives, such as crowd-sourcing ideas or competitions.[68] Increase collaboration with the

[63] Cleveland Climate Action Fund, http://www.clevelandclimateaction.org/.

[64] PACE Wisconsin, http://www.pacewi.org/.

[65] Focus on Energy, "Home Energy Score," https://focusonenergy.com/score.

[66] City of Portland Home Energy Score, https://www.pdxhes.com/.

[67] MadiSUN, https://madisunsolar.com/.

[68] Examples include Cool Choices https://coolchoices.com/ or MIT Climate Co-Lab, www.climatecolab.org

Focus on Energy program. Begin a dialogue with the Madison Metropolitan School District about energy efficiency and renewable energy at area schools. Expand work with neighborhood associations and the faith community to provide education and outreach about the benefits of clean energy for Madison.

APPENDIX E. STAKEHOLDER ENGAGEMENT

The approach for this assignment was based on national and international best practices and confirmed through consult with City of Madison staff and members of the Sustainable Madison Committee (SMC). Emphasis over the last year has been working with the City of Madison to take action while prioritizing the possible opportunities.

While the focus of technical assessments and recommendations is on local government operations for the City of Madison, many findings and recommendations in this report may be adopted by stakeholders in the greater Madison-area community.

E.1 Kick-Off Meetings

The consulting team refined goals and objectives for this study by interviewing city staff and members of the SMC through kickoff meetings in August 2017. These meetings included discussion items such as defining and establishing objectives, defining stakeholder roles and resources, developing interim milestones and timelines, and establishing communication protocols.

E.2 Information Gathering

Over the course of this engagement, the consulting team gathered information from stakeholders, previous reports, and data from the City of Madison. The consulting team reviewed previous reports from the City of Madison, including the 2016 Energy Work Plan, the 2011 Sustainability Plan, and additional documents.[69] The consulting team gathered and reviewed applicable data for energy efficiency and renewable energy opportunities, reviewing baseline estimates from previous assessments and operational performance data provided by City of Madison staff.

E.3 Stakeholder Engagement

The consulting team engaged internal stakeholders, such as City of Madison departmental staff and the SMC; and external stakeholders, such as utilities, non-profit organizations, businesses, and higher education, such as University of Wisconsin, Madison and Edgewood College. The consulting team engaged stakeholders through in-person interviews and meetings, public input meetings, and developing a website that included a public internet survey.

The team's approach to stakeholder engagement supported a process that was credible, understandable, and transparent. Throughout the process, the consulting team provided information designed to achieve the following goals:

- Offer perspectives and/or help defining and structuring these perspectives
- Share values and/or help finding the shared values among the stakeholders
- Explain analyses

[69] Appendix includes a list of reference documents.

- Communicate results and options

E.3.1 Stakeholder Engagement – In-Person Interviews with Government Officials

The consulting team attended meetings with City of Madison Facilities, City of Madison Fleet, Madison Metro Sewerage District, the Madison Water Utility, Dane County, Madison Metro, Madison Department of Planning & Community & Economic Development, City Attorney's office, City Finance, and Traffic Engineering.

E.3.2 Stakeholder Engagement – External Stakeholders

The consulting team met with representatives from local environmental organizations, businesses, local utilities and the Focus on Energy program administrator. Additional meetings included the UW-Madison Energy Institute, Edgewood College and other local stakeholders.

E.3.3 Stakeholder Engagement – Website

The City developed a website to host information about the Madison 100% renewable energy study.

Figure E-1. Screen Shot of 100% Renewable Energy Website

Source: Madison 100% Renewable Energy Study

E.3.4 Stakeholder Engagement – Public Meetings

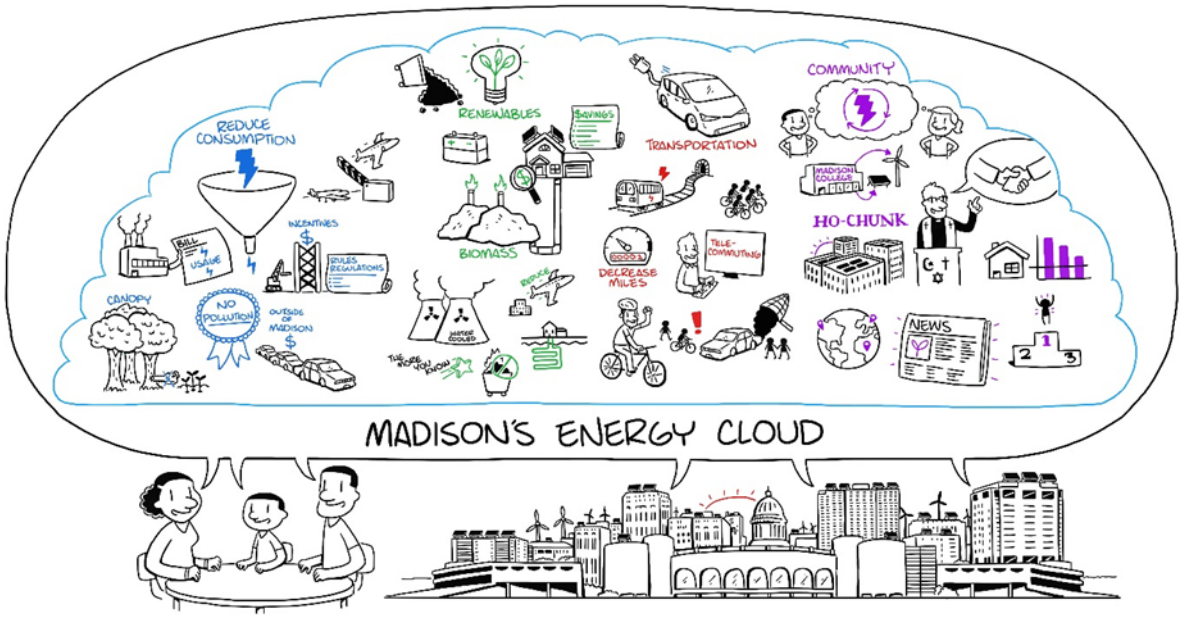
The consulting team organized one large-scale public meeting held at the City of Madison Central Library on September 27, 2017. Almost 100 people attended the meeting to provide input on what they would like to see out of the process and submitted feedback through written notes, discussion, and an internet survey. Participants comments were used to create the Madison Energy Cloud graphic. The meeting featured guest speaker Bob Lindmeier, Chief Meteorologist at WKOW-27, who shared forecasts about how climate change may effect Madison and the region and how people can get involved though the Citizens Climate Lobby. Media for the meeting included WKOW-27, the Madison City Channel, the Wisconsin State Journal, and the Badger Herald newspaper.

Figure E-2. City of Madison 100 Percent Renewable Energy and Zero Net Carbon Public Meeting September 27, 2017

Source: Molly Liebergall, The Badger Herald

At the public meeting, participants provided comments about what they would like to see out of the city's goals. This information was captured in illustrations and combined to create a summary picture of participant comments, referred to as the Madison Energy Cloud.

Figure E-3. Madison Energy Cloud



Source: Navigant, artist credit TruScribe

E.3.5 Stakeholder Engagement – Public Internet Survey

The consulting team developed a public internet survey in conjunction with the large-scale public meeting. Over 200 responses were received to the internet survey.

Part 1 of the survey asked people for qualitative responses to Madison's 100% renewable energy goal. Part 2 of the survey asked respondents to select different ideas for ways for the city to reduce energy consumption. The team received 37 responses. The top choices selected were energy efficiency in existing buildings and operations (34 responses), behavioral practices (31 responses), and upgrades in codes and standards for new construction (30 responses).

Part 3 of the survey asked respondents to provide feedback about renewable energy technologies and business models. The first question about renewable energy technologies received 49 responses. The highest scoring responses were solar PV (42 responses), wind (39 responses), geothermal (34 responses), solar thermal (31 responses), biomass (26 responses), and hydroelectric (14 responses).

The second question in part 3 asked about business models or methods that the city should use to bring on more renewables. The team received 37 responses. The highest scoring responses were city self-installation (28 responses), closely followed by community solar (27 responses) and grid-scale solar cooperation with utilities (27 responses). Respondents were also highly supportive of public-private partnerships (25 responses) and city investment in renewable energy projects (24 responses). Contracting with third parties to install solar at specific locations was less popular than the other high scoring responses (22 responses).

When asked about transportation, 49 responses were received. Responses were most favorable to electric and electric hybrid vehicles (40 responses, note that they are broken out by vehicles 26 responses, electric 14 responses), public transit (39 responses) and traffic infrastructure, design, and demand management (36 responses). Next most popular was carpooling (24 responses). Hydrogen and alternative fuels for conventional fuel scored 16 and 12 responses, respectively.

The team received 48 responses about what other community partners or organizations are important to help accomplish the city's goal. Government entities, such as Dane County or the State of Wisconsin, was the highest scoring response (42 responses), followed closely by community organizations (41 responses) and small businesses (40 responses). Utilities such as MGE and Alliant/WPL and non-profit organizations each received 38 responses. Large corporations (35 responses) and business associations (30 responses) were less frequently selected. Religious organizations received 16 responses.

E.3.6 Stakeholder Engagement – SMC Meetings

The consulting team attended SMC meetings each month starting in July 2017 to provide project updates and discussing project topics throughout the year.

Stakeholder engagement materials, presentations and media from the project are available on the City of Madison 100% renewable energy website at www.madison100renewableenergy.com.

APPENDIX F. ADDITIONAL INFORMATION

F.1 Project Support Documents

Materials, presentations and media from the project are available on the City of Madison 100% renewable energy website at www.madison100renewableenergy.com.

F.2 City Climate Action Resources

100% Renewable Energy for the World
The World Wildlife Fund, Ecofys, OMA, “The Energy Report, 100% Renewable Energy by 2050.” January 1, 2011. https://www.worldwildlife.org/publications/the-energy-report

United Nations Environment Program
UN Environment. "The Emissions Gap Report." November 2017.
https://www.unenvironment.org/resources/emissions-gap-report

Mission 2020
Mission 2020. "Global Climate Action Summit: Taking Ambition to the Next Level."
http://www.mission2020.global/

Mission 2020 Climate Turning Point
Harris, Victoria and Revill, Chloe. "2020: The Climate Turning Point." April 2017.
http://www.mission2020.global/wp-content/uploads/2020-The-Climate-Turning-Point.pdf

Covenant of Mayors for Climate & Energy
Mayors Adapt. "Join now 9,000+ European cities taking action for climate and energy!"
https://www.eumayors.eu/

ICLEI: Local Governments for Sustainability
"Our pathways, our approach." 2018. http://www.iclei.org/en/our_approach.html

C40 Chicago Climate Charter
North American Climate Summit. "Chicago Climate Charter." 2017.
https://www.cityofchicago.org/content/dam/city/depts/mayor/Press%20Room/Press%20Releases/2017/December/2017ChicagoClimateCharter.pdf

America’s Pledge
America's Pledge on Climate. "America's Pledge." 2018. https://www.americaspledgeonclimate.com/

Climate Mayors
Climate Mayors. "US Mayors Demonstrate Ambitious, Collective Climate Leadership." 2017.
http://climatemayors.org/

EEI Strategic Electrification

Edison Electric Institute. "Global Electrification Forum." 2018. http://www.eei.org/about/meetings/meeting.aspx?EEIEventId=63A692F2-5BAA-4049-87A3-0B107AD68F7D

Global Covenant of Mayors
Global Covenant of Mayors for Climate & Energy. "About the Global Covenant of Mayors for Climate & Energy." https://www.globalcovenantofmayors.org/about/

World Resources Institute
http://www.wri.org/
World Wildlife Fund WWF Climate Initiative
World Wildlife Fund. "Climate." 2018. https://www.worldwildlife.org/initiatives/climate

Rocky Mountain Institute Carbon-Free City Handbook
Rocky Mountain Institute. "The Carbon-Free City Handbook." November 2017. https://www.rmi.org/wp-content/uploads/2017/11/the-Carbon-Free-City-Handbook-1.0.pdf

Climate CoLab
Climate CoLab. "Work with people from all over the world to create proposals for how to reach global climate change goals." https://www.climatecolab.org/

International Living Future Institute
International Living Future Institute. "Let's Make Our Communities Socially Just, Culturally Rich, and Ecologically Restorative." 2018. https://living-future.org/

Architecture 2030, Zero Cities project
Architecture 2030, Achieving Zero. "Framework." http://achieving-zero.org/framework/framework-accelerate/

CNCA – Carbon Neutral Cities Alliance
Carbon Neutral Cities Alliance (CNCA). "A Global Collaboration of Cities Cutting Emissions by 80% or More, by 2050 or Sooner." https://carbonneutralcities.org/

USDN – Urban Sustainability Directors Network
Urban Sustainability Directors Network (USDN). "Connecting People. Fostering Innovation." 2018. https://www.usdn.org/home.html?returnUrl=%2findex.html

US Environmental Protection Agency
Avoided Emissions and Generation Tool (AVERT)
https://www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avertEPA Avert/COBRA Tool

F.3 Municipal Green Fleet and EV References

Austin Energy (Austin, Texas)
https://austinenergy.com/ae/about/environment/electric-vehicles

Smart Columbus (Columbus, Ohio)
https://smart.columbus.gov/

Drive Electric Ann Arbor Partnership (Ann Arbor, Michigan)
https://www.a2gov.org/a2energy/homeowner/Pages/plug-in-electric-vehicles.aspx

Electric Vehicles (Saint Paul, Minnesota)
https://www.stpaul.gov/departments/public-works/transportation/electric-vehicles

Pacific Gas & Electric, Electric Vehicle & Smart Grid Pilot (San Francisco, California)
http://www.pgecurrents.com/wp-content/uploads/2017/06/PGE-BMW-iChargeForward-Final-Report.pdf

F.4 Local Area Industry Resources (Transportation)

Madison Area Transportation Planning Board
http://madisonareampo.org/

Madison Gas & Electric
https://www.mge.com/environment/electric-vehicles/ev-basics.htm

Alliant Energy
https://www.alliantenergy.com/InnovativeEnergySolutions/SmartEnergyProducts/ElectricVehicles

Navigant Research Transportation Efficiencies
https://www.navigantresearch.com/research/transportation-efficiencies

Wisconsin Clean Cities
https://wicleancities.org/

Electric Power Research Institute
https://www.epri.com/

US Department of Energy, Alternative Fuels Data Center
https://www.afdc.energy.gov/

Argonne National Lab – GREET Fleet Carbon and Petroleum Footprint Calculator
https://greet.es.anl.gov/carbon_footprint_calculator

F.5 Additional Examples and Case Studies

This section includes examples of community efforts to promote renewable energy and actions that individuals could consider taking to support renewable energy in our community.

Case Study: Madison College Renewable Energy Program
Madison College offers a program for students interested in the design, engineering, economic analysis, installation, maintenance, and repair of various types of renewable energy systems. Interested in joining the clean energy economy? For more information, check out: https://madisoncollege.edu/program/renewable-energy

Source: Madison College

Case Study: Madison West High School Green Club Promotes Solar
Students at Madison West High School collected signatures to pursue a solar energy project at their school to increase awareness of renewable energy and create a learning opportunity for students and faculty. Interested in contributing? By donating to West Green Club through the Foundation for Madison's Public Schools, a registered 501(c)(3) nonprofit committed to supporting children's education, individuals will receive recognition for their tax-deductible contribution. Donations are accepted at https://www.westgreenclub.org/donate

Source: West Green Club

Case Study: Holy Wisdom Monastery
In 2014, Holy Wisdom Monastery became a solar customer by adding additional PV panels that generate 60% of the monastery building's energy needs. Their goal is to eventually generate 100% of their energy needs.

Source: Holy Wisdom Monastery

Community: How can I contribute to Madison's 100% renewable energy goals?

- Call or email your alder to let them know you support the City's 100% renewable energy goal for city operations and leadership for the greater community
- Reduce your energy consumption
    - Replace incandescent lights with LEDs
    - Install a smart thermostat and schedule your residence's HVAC system
    - Enroll in the Focus on Energy Assessment Program
    - Work with your employer to join Sustain Dane's MPower program
- Explore solar PV for your residence or workplace through the MadiSUN Solar Group Buy Program
- Sign up for MGE's Shared Solar program
- Decide if you can save money through MGE's Time of Use rate
- Vote for elected officials that support clean energy policies
- Support organizations that lobby for state and federal policies that accelerate the transition to 100% renewable energy
- Purchase voluntary RECs or carbon offsets