

100% RENEWABLE *Madison*

ACHIEVING 100% RENEWABLE ENERGY &
ZERO NET CARBON FOR CITY OPERATIONS
& LEADING THE COMMUNITY



..... NOVEMBER 2018

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Opening Letter

We have set an ambitious goal for our city—**100% RENEWABLE ZERO NET CARBON ENERGY**. Madison is the first city in Wisconsin to set our sights so high. We aim to be the first to meet the challenge. But understand, this work is about more than “the environment.”

Clean energy is about people, the community we can be, and the city we deserve.

The fossil fuels we use every day cause climate change. 2018 will be the fourth hottest year in recorded history. The only years hotter were 2017, 2016, and 2015. That string of records is part of a rapid climb in temperatures since the start of the industrial age. And the warning signs for what could come are all around us. Fires rage. Floods rise. Wildlife disappears. Food and water grows scarce for too many each day.

At the same time, income inequality has skyrocketed. Disparities along race and gender lines persist. And women, people of color, low-income communities and other historically marginalized populations stand to lose the most as the planet warms.

Scientists are very clear that our health and safety depend on rapid changes to the way we live and work. Our community is just as clear that Madison must show the way toward a green future.

We can’t afford to wait to confront the threat of climate change. Renewable energy technology has advanced at breakneck speed and costs continue to plummet. Our city will save money if we power our lives with the sun and wind. We will also honor our commitment to social and environmental justice. This report is the first step.

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.

It is an exciting moment for Madison. But it is only a beginning. Our people have big dreams. It is up to all of us to create a city that is true to our ideals.

We have everything we need. Now, let’s get to work!

Raj Shukla
Chair, Sustainable Madison Committee

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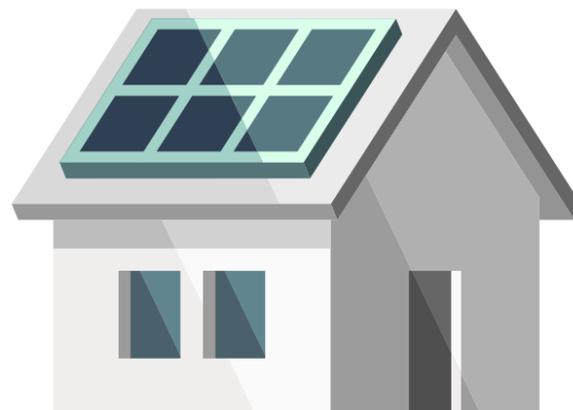
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Disclaimer:

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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 ZERO NET CARBON EMISSIONS**.¹ Across the US, over 97 cities, more than five counties, and two states, have also adopted ambitious 100% clean energy goals. Six cities in the US have already hit their targets. These six cities now generate 100% of their community-wide energy uses from renewable sources.² The City of Madison must achieve similar success, with local government operations leading the way. We don't have much time. According to a recent report from the Intergovernmental Panel on Climate Change (IPCC), global net human-caused emissions of carbon dioxide (CO₂) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050.³ Despite the lack of climate leadership at the nation's capital as evidenced by the US withdrawal from the Paris Agreement,⁴ 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 city officials 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.⁵ Recent extreme weather events underscore the need for city officials to take bold climate action now.

This report has four parts.

- 1. Recent sustainability successes from City of Madison local government operations and the greater Madison area community.**
- 2. An overview of three time-based scenarios that city officials can use to accomplish renewable and net zero goals**
- 3. Details about the three scenarios for Madison's low-carbon future**
- 4. Additional suggestions to accelerate progress toward reaching 100% renewable energy and zero net carbon goals for local government operations and for the larger Madison area 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/commitments>.

³ Intergovernmental Panel on Climate Change (IPCC) The report finds that limiting global warming to 1.5°C would require "rapid and far-reaching" transitions in land, energy, industry, buildings, transport, and cities. https://www.ipcc.ch/news_and_events/pr_181008_P48_spm.shtml

⁴ United Nations Framework Convention on Climate Change (UNFCCC), "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."

⁵ 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.

Three scenarios were developed to demonstrate how local government can achieve the **100% RENEWABLE ENERGY AND ZERO NET CARBON** goal between 2020 to 2030 by:

1. **Reducing energy demand from local government operations through energy efficiency and behavioral measures (i.e., demand-side measures)**
2. **Supplying electricity through renewable energy and to the extent possible, generating renewable energy locally (i.e., supply-side measures)**
3. **Supplying remaining energy needs from Renewable Energy Credits (RECs) and carbon offsets as a bridge strategy, while local government continues to invest in efficient transportation, energy efficiency, and renewable energy as opportunities arise.**

The three scenarios developed meet the City goal of **100% RENEWABLE ENERGY AND ZERO NET 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 (NPV), contributing to green jobs and economic development and promoting public health, racial equity and social justice. These scenarios feature demonstrable project-based action by local government operations — investing in efficient buildings and facilities for local government, the water distribution system, city street lights and traffic lights, renewable energy, efficient and electric fleet and transit vehicles, and REC purchases. 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. Greater investments in efficient government facilities and vehicles in Scenario 2 and 3 include larger estimated co-benefits for the community — resulting in the potential for more significant impacts in the forms of local green jobs, economic development, public health, racial equity and social justice. Measures in each scenario are grouped by demand-side, supply side, and transportation strategies. Scenarios in this report assume that current policy, technology and economic conditions and barriers identified in Section 1.3 remain in place.

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 ZERO NET CARBON** for city operations. By 2020, city government will cut its carbon emissions by 15% with at least 10% of municipal operations' electricity sourced by self-generated renewable energy. The city will expand its current efficiency investments in city facilities and implement green city fleet and pilot programs to gain early momentum. Investments in self-generated renewables include installing at least 1 MW of Behind-the-Meter Phase 1 solar projects at city buildings. City officials will continue to work with local utilities to encourage development of larger solar arrays. Investments in RECs and/or carbon offsets that meet the city's standards for additionality make up the remaining 85% 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 for city operations. 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/or 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 city buildings, streetlights and water distribution, renewable

energy installations, transportation measures and accelerating the electrification of city fleet and Metro 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. Investments for green city 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/or carbon offsets make up the remaining 45% of carbon emissions balance. This path is most consistent with the Paris Agreement requirements, involving more extensive investment over a longer period. 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 city buildings.

In the last section of the report, additional suggestions are presented to accelerate progress toward reaching **100% RENEWABLE ENERGY AND ZERO NET CARBON** goals for local government operations and for the larger Madison area community. 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. Appendices located at the end of this report include details about this study and information about national and international resources for climate action.

In summary, the energy ecosystem is changing. 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 key to reaching the **100% RENEWABLE ENERGY AND ZERO NET CARBON** goal quickly and cost-effectively.

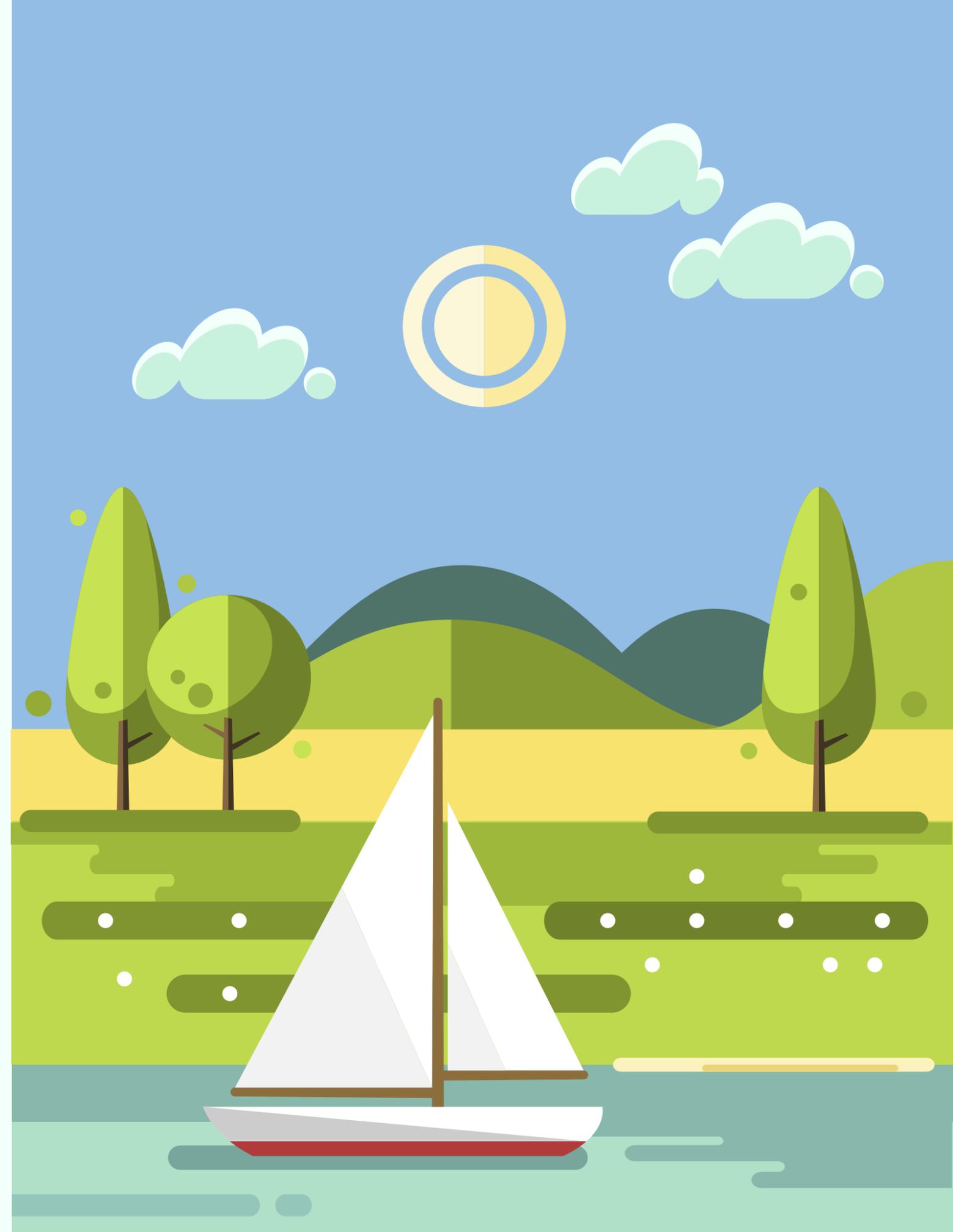
In order to ensure that Madison stays focused on its ambitious sustainable journey, City officials should review their plans every two years to confirm progress and update milestones due to the rapidly changing economic, technology, and policy landscape. As the energy landscape continues to evolve, the most effective strategies to reach the City of Madison's goals will also evolve.

City officials have an urgent need for future climate 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 its energy and climate transition for local government operations and for the broader community.

TABLE ES-1: 100% RENEWABLE ENERGY AND ZERO NET CARBON TIMELINE MENU

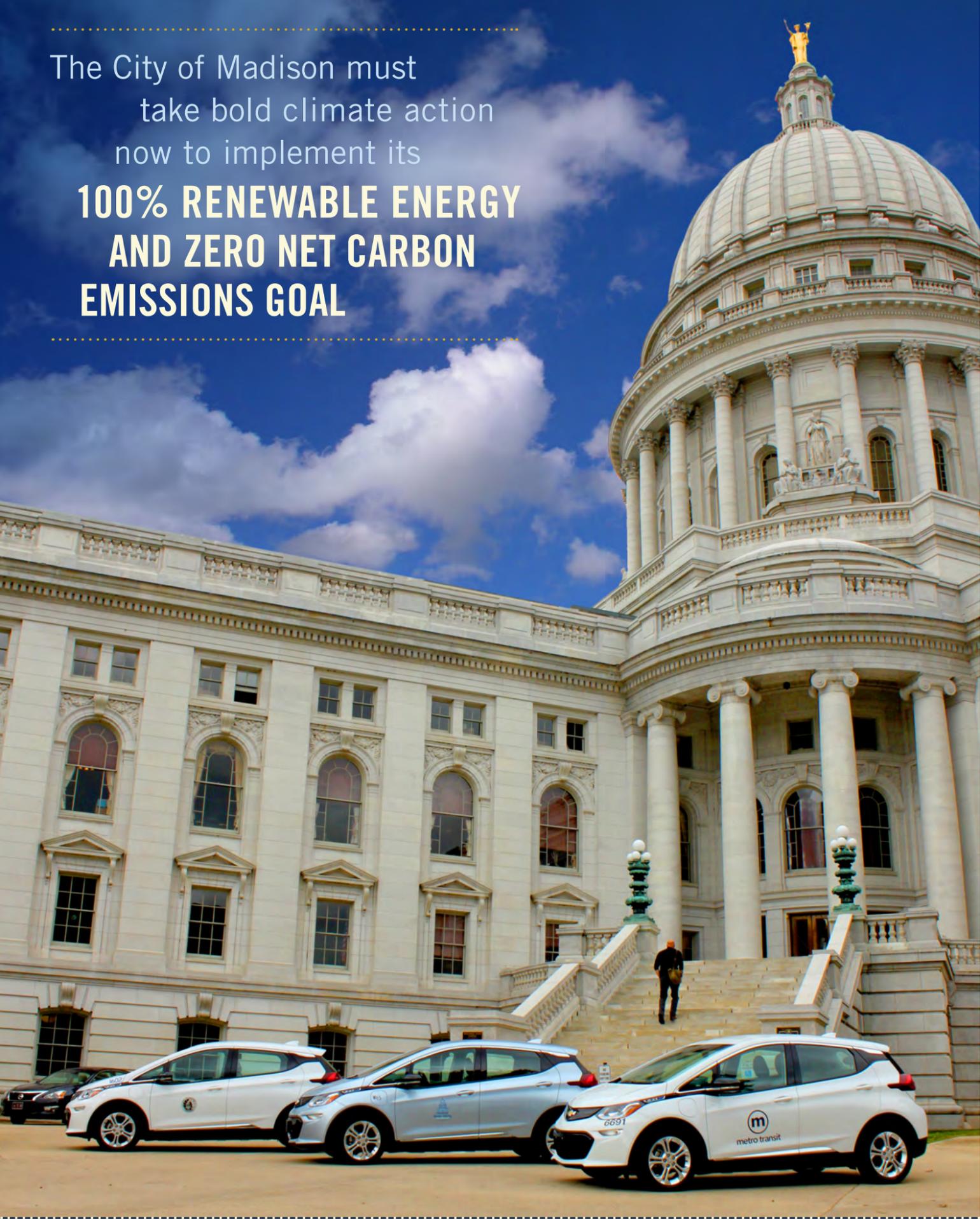
SCENARIO	ACTIONS	BENEFITS/OUTCOMES
<p>SCENARIO 1 100% Renewable Energy and Zero Net Carbon by 2020</p>	<p>Efficiency (Demand) Develop RCx program</p> <p>Renewable Generation (Supply) Efficiency (Demand) Develop RCx program Renewable Generation (Supply) Behind-the-Meter Solar (1 MW) Utility Fuel Mix (MGE and Alliant) Utility Solar Project (MGE RER or Alliant)</p> <p>Transportation Green Fleet Measures Fleet Passenger Car EV Procurement Fleet Light Duty EV Procurement Landfill CNG Pilot First Three Electric Buses Arrive in Madison</p> <p>Policy RECs and Carbon Offsets</p>	<ul style="list-style-type: none"> •15% carbon reduction with 10% self-generated renewable energy •85% RECs and carbon offsets •\$7M investment over 3 years; IRR 15% •Cost savings to city of \$18M by 2030 •Reduce total carbon emissions by 200,000 tons by 2030 •Societal co-benefits range from \$10M - \$76M by 2030
<p>SCENARIO 2 100% Renewable Energy and Zero Net Carbon by 2023</p>	<p>All Scenario 1 Measures</p> <p>Efficiency (Demand) Lighting Retrofits HVAC Control Retrofits Street Lights Water Distribution</p> <p>Renewable Generation (Supply) Behind-the-Meter Solar (Phase 1)</p> <p>Transportation 50% Electric Buses Landfill CNG Fueling</p> <p>Policy RECs and Carbon Offsets</p>	<ul style="list-style-type: none"> •40% carbon reduction with 15% self-generated renewable energy •60% RECs and carbon offsets •\$57M investment over 6 years; IRR 17% •Cost savings to city of \$66M by 2030 •Reduce total carbon emissions by 372,000 tons by 2030 •Societal co-benefits range from \$18M - \$141M by 2030
<p>SCENARIO 3 100% Renewable Energy and Zero Net Carbon by 2030</p>	<p>All Scenario 1 & 2 Measures</p> <p>Efficiency (Demand) HVAC Retrofits Plug Load Management Strategies Building Envelope Improvements</p> <p>Renewable Generation (Supply) Behind-the-Meter Solar (Phase 2)</p> <p>Transportation 100% Electric Buses Mid-Duty EV Procurement Heavy Duty CNG Procurement</p> <p>Policy RECs and Carbon Offsets</p>	<ul style="list-style-type: none"> •55% carbon reduction with 25% self-generated renewable energy •45% RECs and carbon offsets •\$95M investment over 13 years; IRR 17% •Cost savings to city of \$78M by 2030 •Reduce total carbon emissions by 426,000 tons by 2030 •Societal co-benefits range from \$21M - \$162M by 2030

Source: HGA



The City of Madison must take bold climate action now to implement its

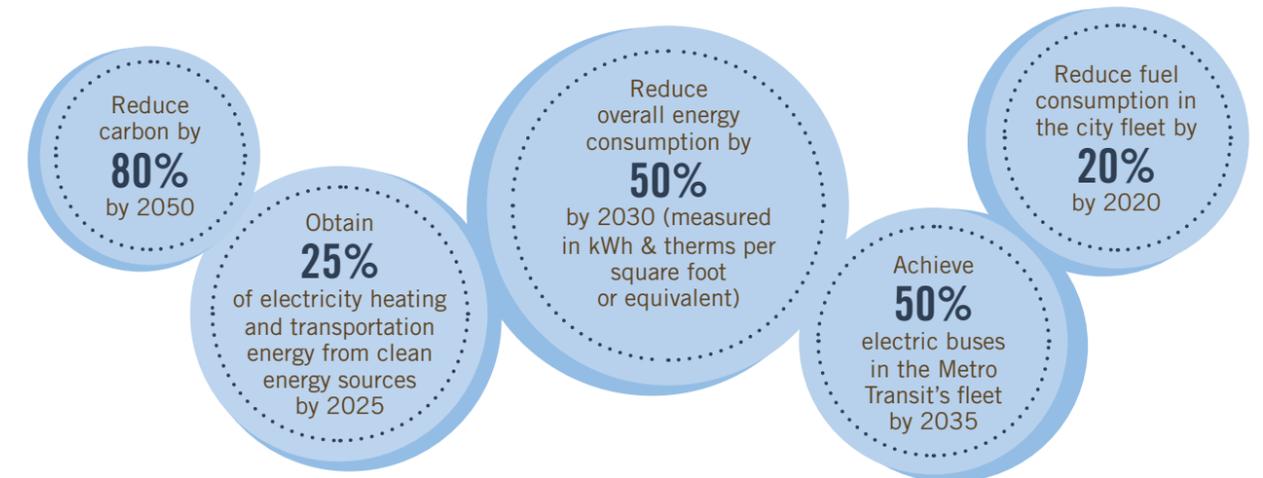
100% RENEWABLE ENERGY AND ZERO NET CARBON EMISSIONS GOAL



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.⁶ The City of Madison recently adopted a new comprehensive plan, which includes a priority for the City to implement its **100% RENEWABLE ENERGY AND ZERO NET CARBON EMISSIONS** goal.⁷

THE FOLLOWING SUSTAINABILITY GOALS WERE IN PLACE AS OF THE WRITING OF THIS REPORT:



This report provides three scenarios for policy makers to consider towards achieving the goals listed above. 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 International Council for Local Environmental Initiatives (ICLEI) Local Governments for Sustainability,⁸ 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.
- The City of Madison incorporates solar or solar-ready 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 on next page).

⁶ In this report, the terms "carbon", "carbon emissions" and "greenhouse gases (GHG) emissions" are all synonymous with carbon dioxide equivalent emissions, CO₂e.

⁷ Imagine Madison, The City of Madison Comprehensive Plan, Green and Resilient section.

⁸ ICLEI, "Local Governments for Sustainability," <http://iclei.org/>.

- 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 MadiSUN⁹ program an innovative public-private partnership to grow solar PV installations. MadiSUN offers technical information and financial incentives for residential and business customers to install solar panels. Over the past 3 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.

Local Spotlight

CITY OF MADISON SOLAR INSTALLER TRAINING PROGRAM

The City of Madison has operated a solar installer training program for the last 3 years. This program provides hands-on training to improve participant's job skills for future employment in the solar electrical trades. The program has installed over 300 kW of solar on City buildings.



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 and solar-ready 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 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 and benchmarking of all buildings updated with monthly consumption data.
- Sharing solar power production with the public through a web portal.

⁹ MadiSUN, <https://madisunsolar.com/>.

Local Spotlight

MADISON FIRE DEPARTMENT STATION 12 - A GREENER FIREHOUSE

Station 12 is certified under the LEED Platinum green building rating system indicating it has incorporated energy and water conservation measures, improved indoor environmental quality and stewardship of resources. The site includes a geo-exchange system, green roof, solar hot water and stormwater collection. A community room, in honor of Dr. Darren Bean, is available for community use.



- 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.¹⁰

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.

¹⁰ Madison Water Utility, "Water Conservation House," <http://www.cityofmadison.com/water/projects/water-conservation-house>.

Local Spotlight

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 westgreenclub.org/donate

Source: Madison West Green Club



- 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.¹¹
- 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.
- 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.¹²
- Fleet department was awarded a grant by the Office of Energy Innovation to cover the incremental cost of purchasing 20 full electric vehicles in 2019.

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,¹³ 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 20 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

Local Spotlight

CLIMATE CHANGE & PUBLIC HEALTH

Climate change is a public health crisis. Societal costs include: premature mortality among adults and infants, hospital admissions from asthma, cardio-vascular and other diseases, obesity, lost work and productivity from increased mental and physical stress from severe weather events, among others. Investments in energy efficiency, renewable energy and active, efficient and electric transportation create opportunities to improve the health of individuals and the greater community by reducing climate pollution and increasing physical activity among children and adults. Globally, the average marginal co-benefits of avoided mortality ranges from \$50 to \$380 ton/CO₂.¹⁴



¹¹ City of Madison, "Department of Planning, Community Development," Madison in Motion, <http://www.cityofmadison.com/dpced/planning/madison-in-motion/1569/>.

¹² Transportation for America, "Our Vision," <http://t4america.org/our-vision/>.

¹³ Framework for Collaboration on Shared Energy Goals, August 21, 2017.

¹⁴ Co-benefits of Global Greenhouse Gas Mitigation for Future Air Quality and Human Health (Nat Clim Chang. 2013 October 1; 3(10): 885-889. doi:10.1038/NCLIMATE2009.) with thanks to Jonathan Patz, MD, MPH, Director Global Health Institute, UW-Madison.

sectors support are some of the fastest growing areas in the state and support over 75,000 workers in Wisconsin. Less reliance on imported fossil fuels results in more dollars staying in Wisconsin's economy. Less reliance on imported fossil fuels results in more dollars staying in Wisconsin's economy. Nationwide, solar and wind generation support more jobs than coal generation.

UTILITIES: 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 in 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.

Local Spotlight

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



Local Spotlight

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: madisoncollege.edu/program/renewable-energy

Source: Madison College



Educational institutions are 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 governments around south-central Wisconsin are 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 Middleton is collaborating with MGE on a 5 MW solar PV system at the Middleton Airport. This system will produce renewable energy for the City of Middleton's electric consumption and the MGE Shared Solar program.

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.¹⁵ 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.¹⁶

¹⁵ Climate Mayors (www.climatemayors.org), We Are Still In.

¹⁶ ICLEI, Localizing the Paris Agreement, 2017.

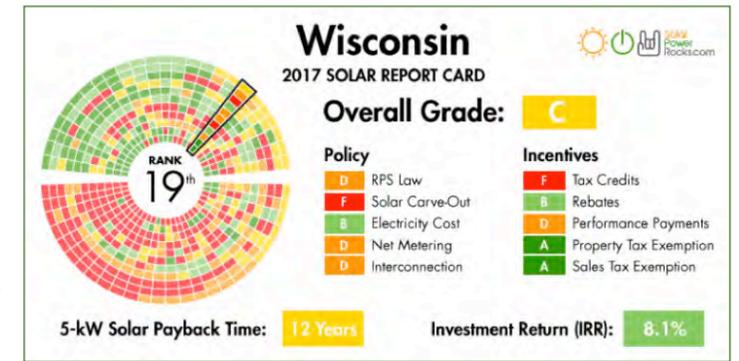


1.3 Constraints to Further Sustainability Success

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. Constraints to further sustainability success are outlined below.

1.3.1 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.

Examples from other cities illustrate additional regulatory constraints. For example, 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 agreements¹⁸ 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 law does not allow for renewals of franchise agreements. An effort to municipalize MGE, which is not currently under consideration, would require expensive legal action that, even if successful, would not enable the city to pursue its renewable and clean energy goals any differently than MGE can under its regulatory requirements.²⁰ City officials in Madison therefore chose to negotiate an agreement with MGE²¹ identifying key areas for collaboration between local government and MGE, 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. This decision was recognized as a strong example of city-utility collaboration to promote renewable energy.²²

The City of Madison is actively working with public and private stakeholders to help accelerate the shift to

100% RENEWABLE ENERGY

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/>.
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).
²² "Cities Like Madison Lead the Way to Local Clean Energy," *Forbes.com* (December 5, 2017) <https://www.forbes.com/sites/pikerresearch/2017/12/05/madison-clean-energy/>.

1.3.2 Jurisdictional

The City of Madison's local government operations are an important piece of combating climate change in the greater Madison region, but local government needs public and private partners to work together to broaden the collective impact. This document emphasizes actions that local government can take under its own jurisdiction, while referring to areas where the city officials have 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. Working with other local governments to share resources and best practices will accelerate achieving the goals.

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 or Alliant's Second Nature program



Decide if you can save money through MGE's Time of Use rate or Alliant Energy's Time of Day Pricing program



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

Source: HGA



Charging an electric vehicle.

1.3.3 Economic

In Wisconsin, 65 percent of electricity is produced from imported fossil fuels — so each year, \$13-\$15 billion leaves the state to purchase these fuels. Producing more local and clean energy will keep dollars in the local economy. 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. Through prudent financial management, the City of Madison has earned a high-quality bond rating and has a low cost of borrowing as a unit of local government. However, the state constitution imposes a debt limit and debt financing is costly, which limits the dollars available for climate action. While investment analyses in this report were made assuming capital expenditures, other economic models, such as ESCO and Green Revolving Fund, are increasingly available to implement energy efficiency and renewable energy while staying within limits for capital budgets. While climate action requires investment, it is important to acknowledge that many financial institutions, including the credit rating agency Moody's, are increasingly recognizing local government exposure to climate risks and whether a local government has taken steps to address climate mitigation and adaptation strategies.²³ Capital investment requirements, despite favorable returns, remain a hurdle for many investors, including local government. For city operations, the energy savings performance contracting model is a mature financing option for demand-side energy conservation measures. Supply options like onsite solar and storage are increasingly being added to performance contracting projects. City officials can further explore these options to avoid city capital expenditures and stay within prescribed budget constraints. Section 4 includes further discussion.

²³ Moody's Investor Services, https://www.moody.com/research/Moodys-Climate-change-is-forecast-to-heighten-US-exposure-to-PR_376056.

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.

2.1 Overview of Scenarios

Consultants developed forecasts of demand and supply of energy for local government operations 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 renewable energy credit (REC) purchases. 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 Madison area community. Madison's commitment to 100% renewable energy will evolve over time to include greater percentages of self-generated renewable energy within city operations and the greater Madison community. Barriers such as those listed in Section 1.3 effectively prevent city officials from developing large-scale solar or wind projects without the cooperation of one or more local utilities and surrounding local governments in the area. Initial estimates to generate enough renewable energy from solar to power city operations would require installing one or more solar arrays covering approximately 10 acres of solar panels (equivalent to 106 MW) and was estimated to cost \$137 million. While this is a large array, similarly sized solar projects are now being proposed in Wisconsin. Supplying city operations with wind power would require 29 MW of wind and cost \$46 million. Wind projects in Wisconsin and Iowa are larger. City officials are currently working with local utilities to identify opportunities to develop more renewable energy for Madison. In a parallel path, the scenarios included in this report are based on practical ideas that can be implemented by local government in the short-term, while continuing to work towards meeting its 100% renewable energy and zero net carbon emissions goals without the use of RECs or carbon offsets.

The three principles of this effort are:²⁴

1. Reducing energy demand from local government operations 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 showcase different opportunities for city officials to achieve multiple policy objectives — economic development, cost savings to taxpayers, promoting racial equity and social justice and contributing to public health in Madison.

Key components of the scenarios are summarized in Table 2-1. A narrative description of each scenario follows. Details of the technical measures and financial analysis for each scenario are included in Section 3.

TABLE 2-1. 100% RENEWABLE ENERGY AND ZERO NET CARBON TIMELINE MENU

SCENARIO	ACTIONS	BENEFITS/OUTCOMES
SCENARIO 1 100% Renewable Energy and Zero Net Carbon by 2020	Efficiency (Demand) Develop RCx program Renewable Generation (Supply) Efficiency (Demand) Develop RCx program Renewable Generation (Supply) Behind-the-Meter Solar (1 MW) Utility Fuel Mix (MGE and Alliant) Utility Solar Project (MGE RER or Alliant) Transportation Green Fleet Measures Fleet Passenger Car EV Procurement Fleet Light Duty EV Procurement Landfill CNG Pilot First Three Electric Buses Arrive in Madison Policy RECs and Carbon Offsets	<ul style="list-style-type: none"> • 15% carbon reduction with 10% self-generated renewable energy • 85% RECs and carbon offsets • \$7M investment over 3 years; IRR 15% • Cost savings to city of \$18M by 2030 • Reduce total carbon emissions by 200,000 tons by 2030 • Societal co-benefits range from \$10M - \$76M by 2030
SCENARIO 2 100% Renewable Energy and Zero Net Carbon by 2023	All Scenario 1 Measures Efficiency (Demand) Lighting Retrofits HVAC Control Retrofits Street Lights Water Distribution Renewable Generation (Supply) Behind-the-Meter Solar (Phase 1) Transportation 50% Electric Buses Landfill CNG Fueling Policy RECs and Carbon Offsets	<ul style="list-style-type: none"> • 40% carbon reduction with 15% self-generated renewable energy • 60% RECs and carbon offsets • \$57M investment over 6 years; IRR 17% • Cost savings to city of \$66M by 2030 • Reduce total carbon emissions by 372,000 tons by 2030 • Societal co-benefits range from \$18M - \$141M by 2030
SCENARIO 3 100% Renewable Energy and Zero Net Carbon by 2030	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 100% Electric Buses Mid-Duty EV Procurement Heavy Duty CNG Procurement Policy RECs and Carbon Offsets	<ul style="list-style-type: none"> • 55% carbon reduction with 25% self-generated renewable energy • 45% RECs and carbon offsets • \$95M investment over 13 years; IRR 17% • Cost savings to city of \$78M by 2030 • Reduce total carbon emissions by 426,000 tons by 2030 • Societal co-benefits range from \$21M - \$162M by 2030

Source: HGA

²⁴ Based on The World Wildlife Fund, Ecofys, OMA, The Energy Report: 100% Renewable Energy by 2050, 2011.

2.2 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 will initiate a building retro-commissioning program to reduce energy use and carbon emissions. 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 Section 3.

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 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. Section 4 includes suggested actions to accelerate progress for city operations and the larger community.

Table 2-2 includes a list of measures included in this scenario.

TABLE 2-2. 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2020 – KEY MEASURES

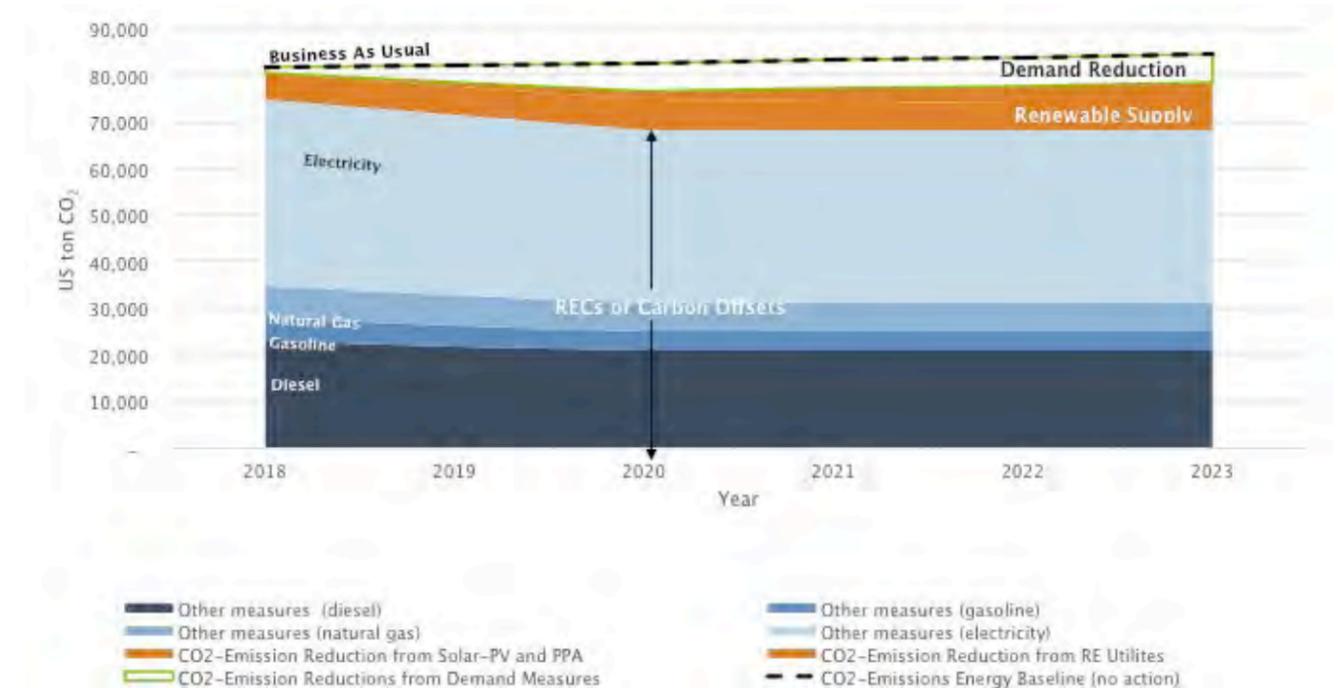
MEASURE TYPE	MEASURES
Efficiency	Develop RCx Program
Renewable Generation	Initiate Behind-the-Meter Solar: Phase 1
	Utility Fuel Mix (MGE and Alliant)
	Utility Solar Project (MGE RER or Alliant)
Transportation	Green Fleet Measures
	Fleet Passenger Car EV Procurement
	Fleet Light Duty EV Procurement
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

Source: HGA

2.2.1 Impacts

Figure 2-1 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 (noted in green), reduces carbon by 6,062 tons (7%) in 2020 and holds steady until 2023. Implementing Phase 1 behind-the-meter solar (noted in orange) 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 (noted in shades of blue) offsets to make up the remaining carbon balance. In 2018, the amount to be offset is 74,999 tons of CO₂ (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 slight decreases in the need for RECs and carbon offsets due to the slight increases in renewables added to the utility fuel mix.

FIGURE 2-1. RESULTS 2020 SCENARIO



Source: Navigant

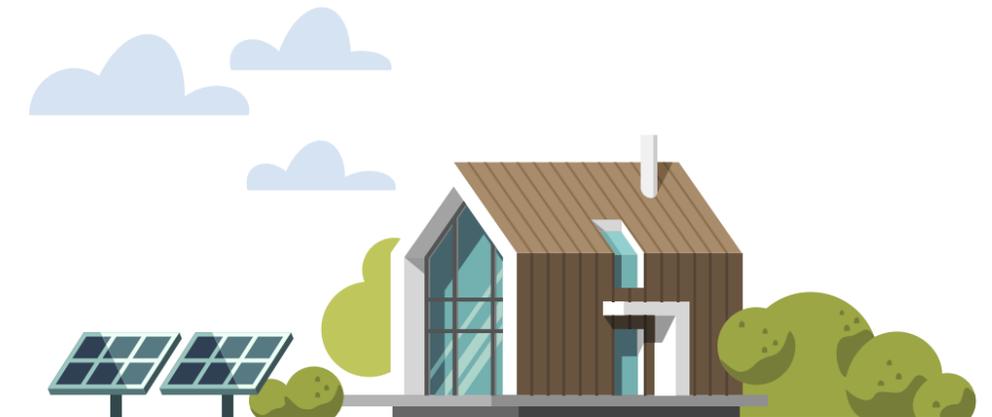


Figure 2-2 includes corresponding calculations for the 2020 scenario.

**FIGURE 2-2. FUEL MIX IN SCENARIO 1:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2020**

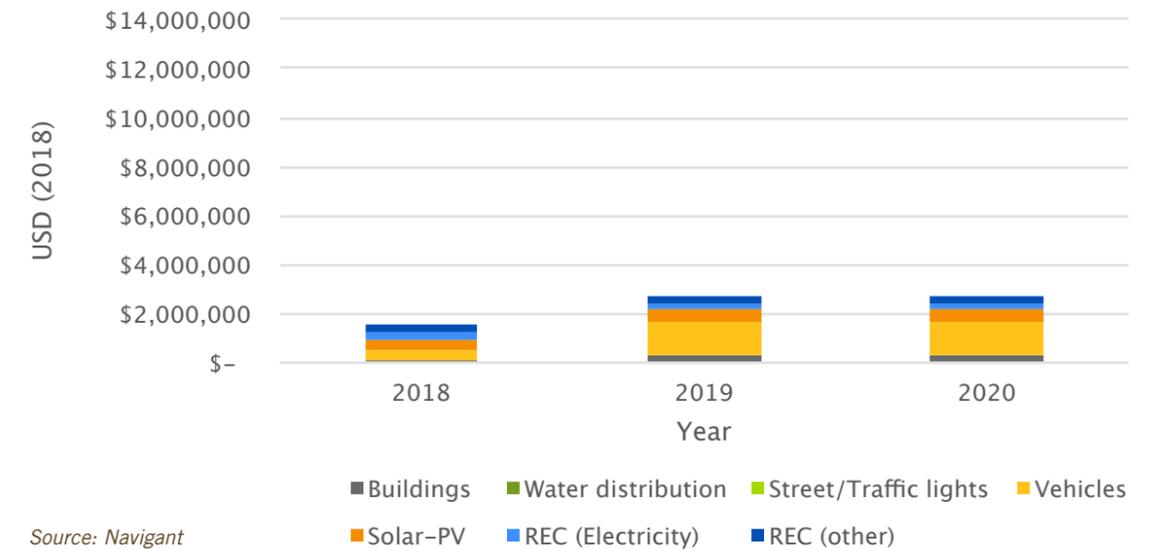
	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO ₂ Emissions (Baseline)	ton	81,141	81,699	82,261	82,829	83,402	83,981	84,565	85,155	85,750	86,351	86,957	87,570	88,188
CO ₂ Reduction (Demand)	ton	878	3,490	6,062	6,016	5,971	5,925	5,880	5,834	5,788	5,743	5,697	5,652	5,606
	%	1%	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

2.2.2 Costs

Figure 2-3 below includes annual investments from 2018-2020, which are \$7 million. Investments include implementing efficiency measures in buildings totaling \$500,000. City officials will begin solar Phase 1, installing at least 1 MW of behind-the-meter solar on city buildings, which is estimated at \$1.5 million. Vehicle investments in the city fleet, including passenger electric vehicle (EV) cars, light duty EV, landfill CNG pilot and green fleet investments are \$3 million. City officials 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.

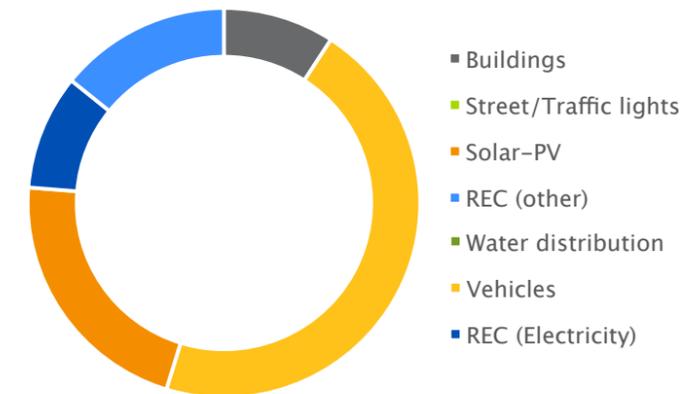
**FIGURE 2-3. ANNUAL INVESTMENTS IN SCENARIO 1:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2020**



Source: Navigant

This analysis assumes that all expenditures are city funded. For Scenario 1, cumulative incremental investments between 2018 and 2020 amount to \$7 million.

**FIGURE 2-4. CUMULATIVE INVESTMENTS IN SCENARIO 1:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2020**



Source: Navigant

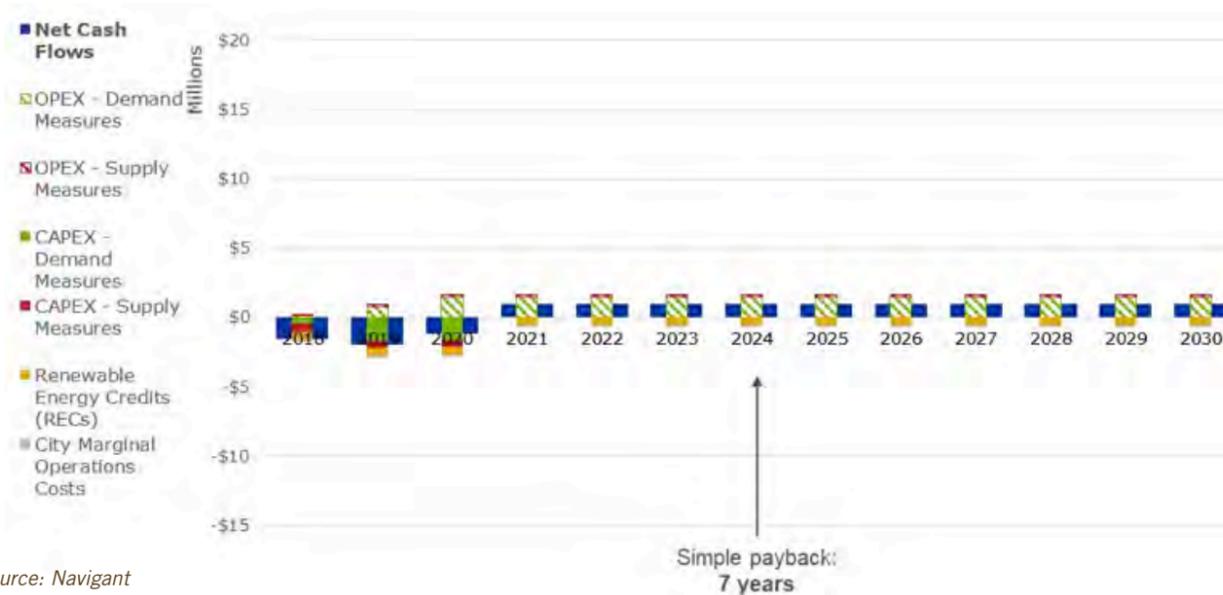


Madison Metro has a goal of acquiring more electric buses, such as the Proterra Catalyst (pictured), in the future.

2.2.3 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. Figures 2-5 and 2-6 illustrate net cash flows as 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 15%. The simple payback occurs at 2024 (7 years).

FIGURE 2-5. SCENARIO 1: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2020 – CASH FLOW SUMMARY



Source: Navigant

FIGURE 2-6. 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	2035	2040	2045	2050
CAPEX Demand Measures	-0.5	-1.7	-1.6	0	0	0	0	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	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	-0.6	-0.6	-0.6	-0.7
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	-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	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	0.2	0.1	0.1	0.1
Net Cash Flows	-1.5	-2.0	-1.2	1.0	0.8	0.8	0.7	0.7									

Source: Navigant



Ground mounted solar panels near Madison's Fire Department Station 12.

2.3 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%, city operations 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 use of electricity and natural gas in city operations.

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 Section 3.

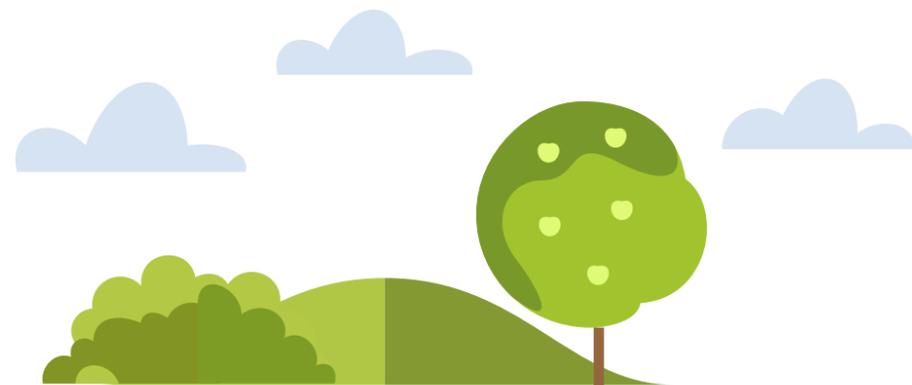
There are opportunities to implement additional actions that would further reduce carbon emissions for local government or for the larger community. For example, as the city adds more electric vehicles and buses, it can add solar and energy storage to electric vehicle charging stations to power these vehicles with renewable electricity. Section 4 includes suggested actions to accelerate goals through city operations and for the larger Madison area community.

Table 2-3 includes a summary of the technical measures included in Scenario 2 – **100% RENEWABLE ENERGY AND ZERO NET CARBON** by 2023.

TABLE 2-3. 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2023

MEASURE TYPE	ACTION
Efficiency (Demand)	Lighting Retrofits
	HVAC Controls Retrofits
	HVAC RCx
	Street Lighting Upgrades
	Water Distribution Optimization Strategies
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
	50% Electric Buses
	Passenger Car EV Procurement
	Light Duty EV Procurement
	Landfill CNG Fueling
Investments	RECs and Carbon Offsets

Source: HGA



2.3.1 Impacts

Figure 2-7 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 (noted in orange), 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 (noted in shades of blue) to make up the remaining carbon balance. In 2018, the amount to be offset is 74,212 tons of CO₂ (91%) decreasing to 50,249 tons (60%) in 2023.

FIGURE 2-7. FUEL MIX IN SCENARIO 2: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2023

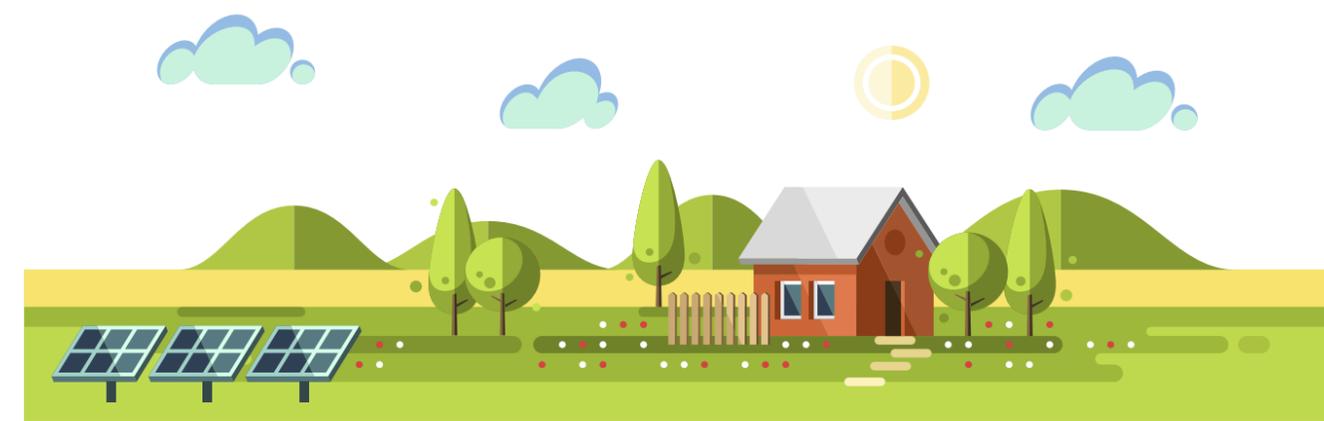
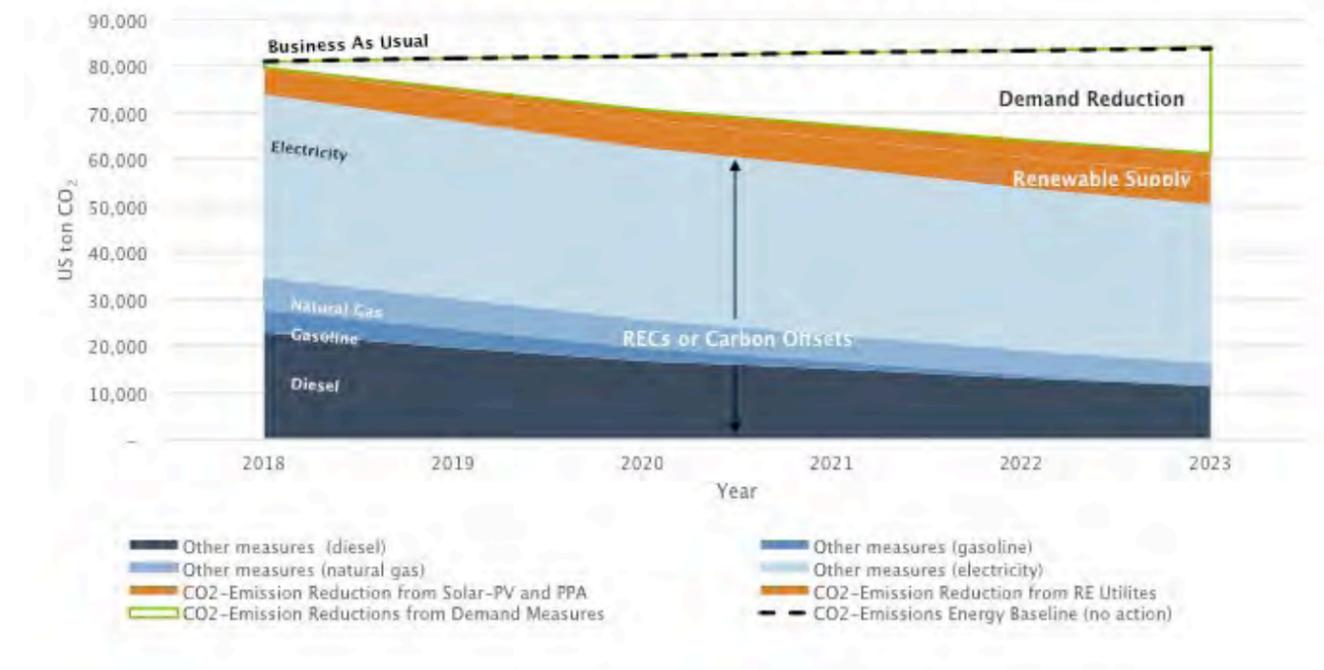
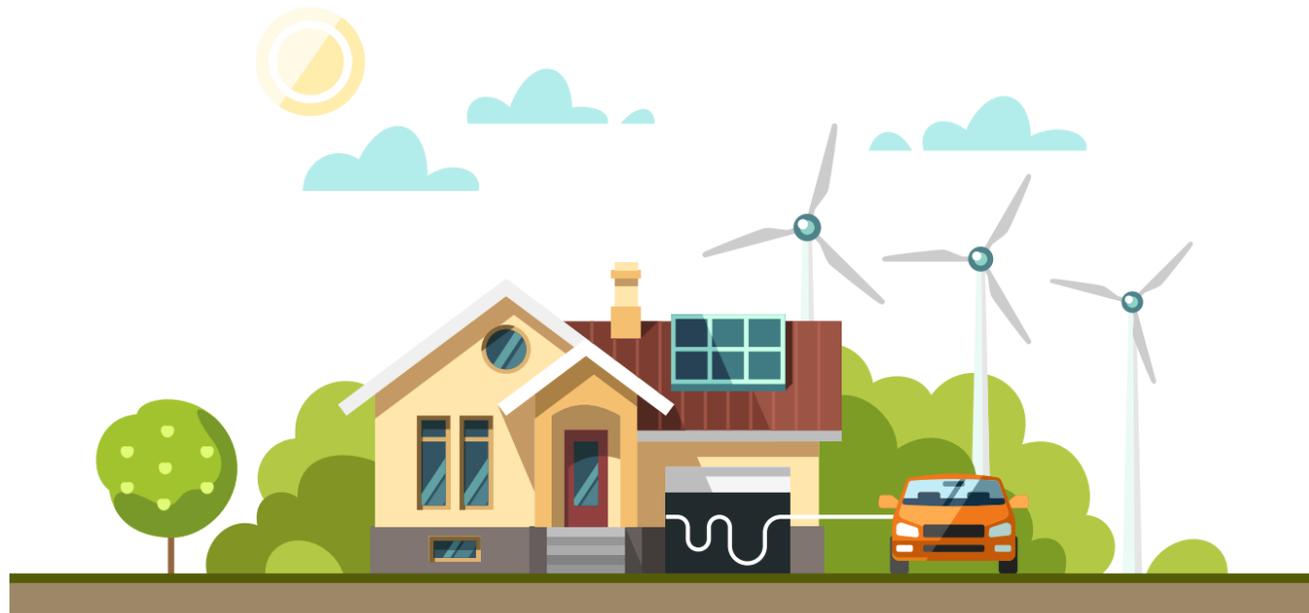


Figure 2-8 includes corresponding calculations for the 2023 scenario.

**FIGURE 2-8. FUEL MIX IN SCENARIO 2:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2023**

	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	1,359	6,494	11,589	15,432	19,234	22,997	22,876	22,756	22,635	22,514	22,394	22,273	22,153
	%	2%	8%	14%	19%	23%	27%	27%	27%	26%	26%	26%	25%	25%
CO ₂ Reduction (Supply)	ton	5,597	6,876	8,028	9,058	9,969	10,764	11,533	11,937	12,293	12,600	12,854	13,052	13,194
	%	7%	8%	10%	11%	12%	13%	14%	14%	14%	15%	15%	15%	15%
CO ₂ Remaining	ton	74,212	68,357	62,672	58,368	54,228	50,249	50,185	50,491	50,851	51,266	51,740	52,274	52,871
	%	91%	84%	76%	70%	65%	60%	59%	59%	59%	59%	59%	60%	60%
RECs Electricity	ton	39,392	37,970	36,719	35,635	34,715	33,956	33,788	33,988	34,242	34,550	34,916	35,342	35,830
	%	49%	46%	45%	43%	42%	40%	40%	40%	40%	40%	40%	40%	41%
RECs Natural Gas	ton	6,803	6,448	6,093	5,740	5,386	5,034	5,107	5,180	5,254	5,329	5,405	5,481	5,558
	%	8%	8%	7%	7%	6%	6%	6%	6%	6%	6%	6%	6%	6%
RECs Gasoline	ton	5,145	3,964	2,782	1,783	784	0	0	0	0	0	0	0	0
	%	6%	5%	3%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%
RECs Diesel	ton	22,872	19,975	17,078	15,210	13,342	11,474	11,474	11,474	11,474	11,474	11,474	11,474	11,474
	%	28%	24%	21%	18%	16%	14%	14%	13%	13%	13%	13%	13%	13%

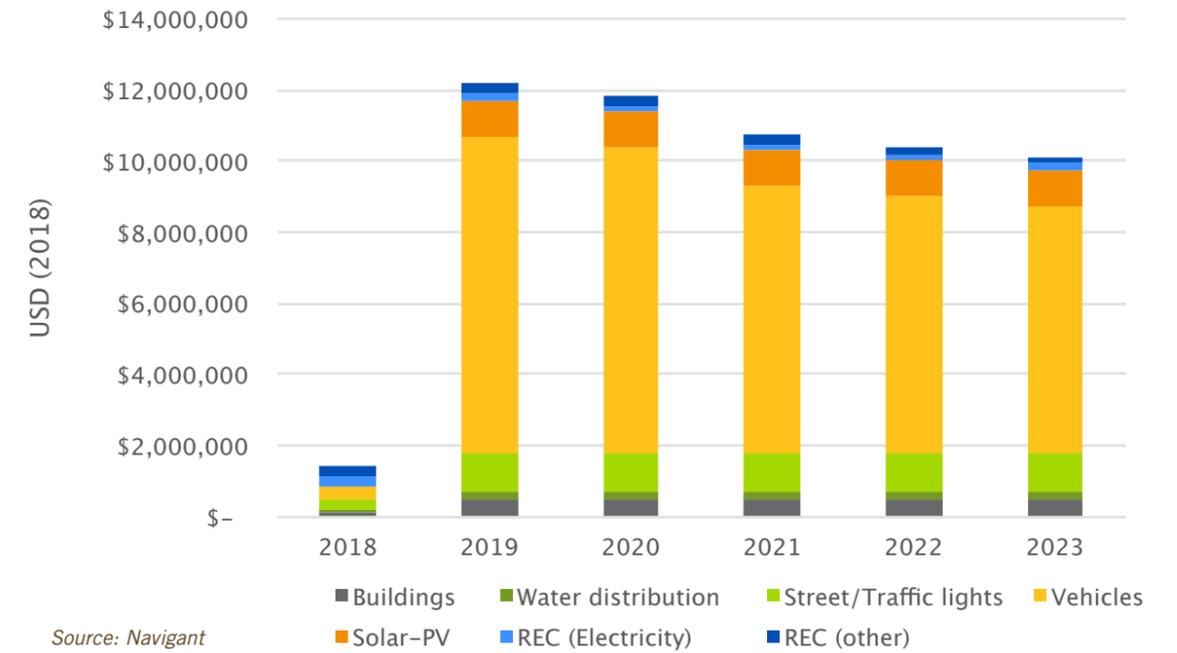
Source: Navigant



2.3.2 Costs

Figure 2-9 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.

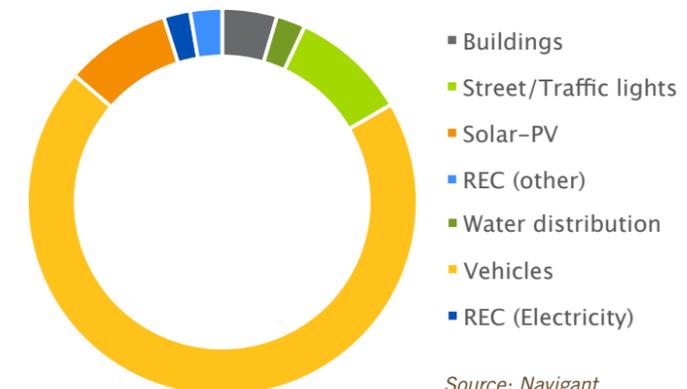
**FIGURE 2-9. ANNUAL INVESTMENTS IN SCENARIO 2:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2023**



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, illustrated in Figure 2-10 below.

**FIGURE 2-10. CUMULATIVE INVESTMENTS IN SCENARIO 2:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2023**

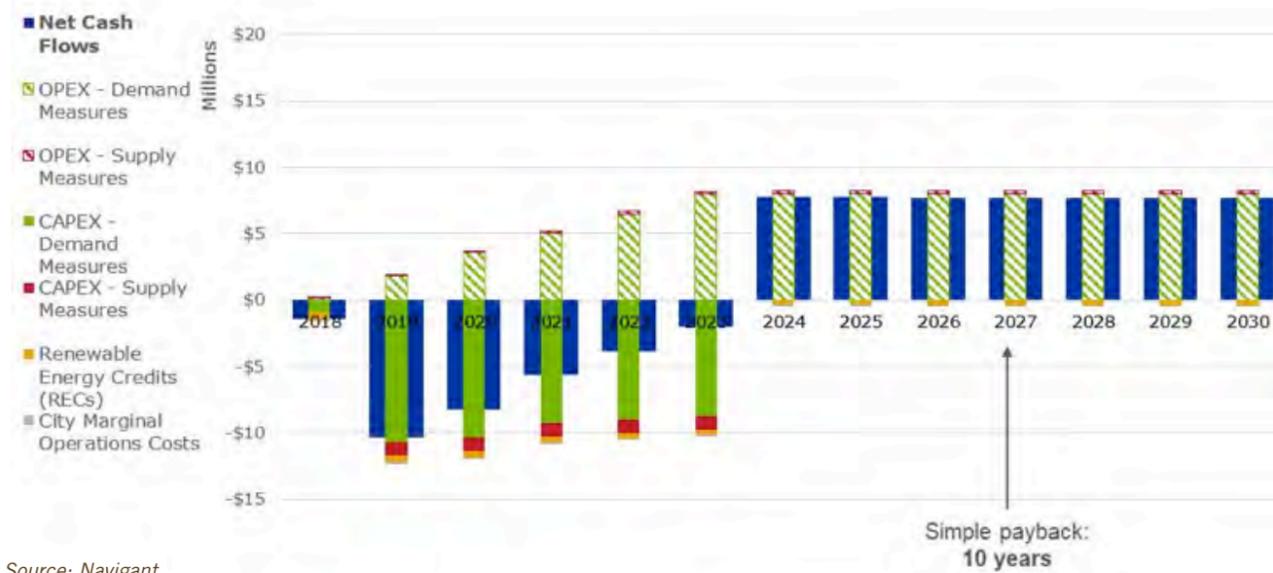


Source: Navigant

2.3.3 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. Figures 2-11 and 2-12 illustrate net cash flows as 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 2-11. SCENARIO 2: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2023 – CASH FLOW SUMMARY



Source: Navigant

FIGURE 2-12. 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	2035	2040	2045	2050
CAPEX Demand Measures	-0.9	-10.6	-10.4	-9.3	-9.0	-8.7	0	0	0	0	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	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	-0.3	-0.3	-0.3	-0.4
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	-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	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	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	7.2	7.2	7.6	7.6						

Source: Navigant



A residential participant has solar panels installed through the MadiSUN program with trade ally Full Spectrum Solar, a local small business in Madison.

2.4 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 Section 3.

There are opportunities to implement additional actions that would further reduce carbon emissions for local government or for the larger community. For example, the city can continue to work with Focus on Energy and other organizations to develop programs to promote energy efficiency and renewable energy. Section 4 includes additional actions to accelerate goals for city operations and the larger Madison area community.

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 2-4 includes the mix of technical measures used in Scenario 3.

TABLE 2-4. SCENARIO 3: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030

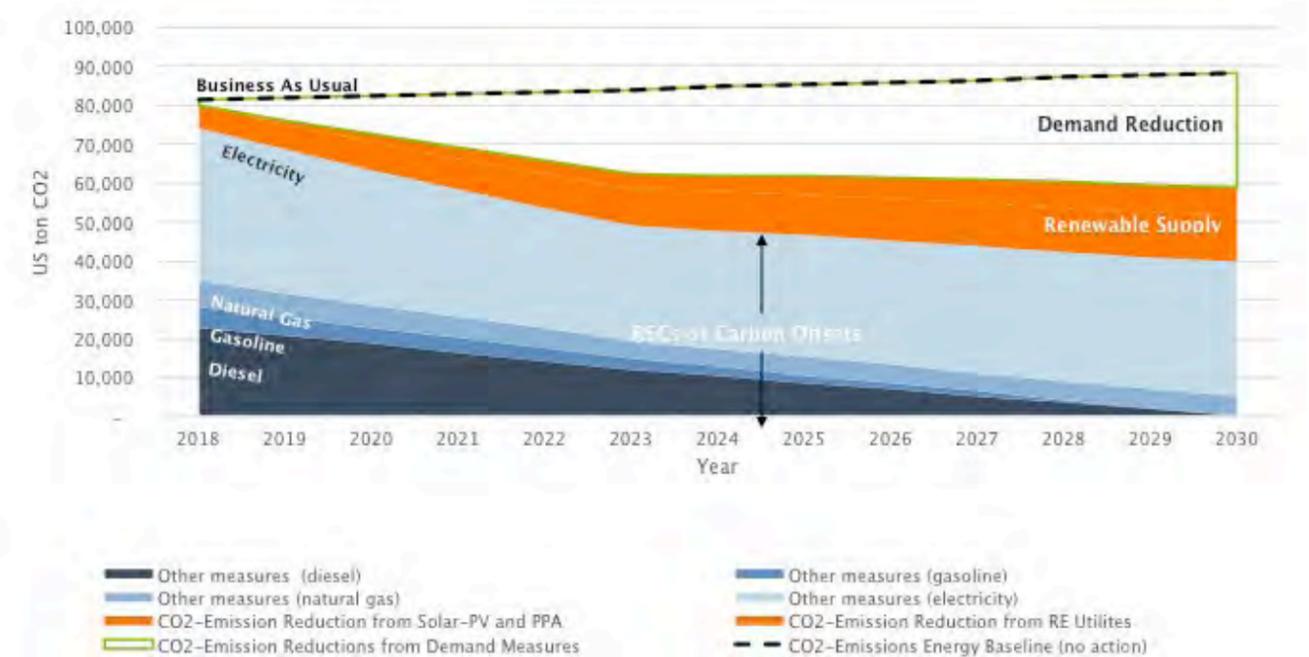
MEASURE TYPE	ACTION
Efficiency (Demand)	Lighting Retrofits
	HVAC Retrofits
	HVAC Controls Retrofits
	HVAC RCx
	Plug Load Management Strategies
	Building Envelope Improvements
	Street Lighting Upgrades
	Water Distribution Optimization Strategies
Renewable Generation (Supply)	Behind-the-Meter Solar: Phase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

Source: HGA

2.4.1 Impacts

Figure 2-13 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 CO2 in 2018 to 88,188 tons of CO2 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 CO2 in 2018 (2%) to 29,328 tons of CO2 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 orange) further reduce the amount of carbon emissions each year, starting with 5,597 tons of CO2 in 2018 (7%) to 19,171 tons of CO2 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 (noted in shades of blue) to make up the remaining carbon balance. In 2018, the amount to be offset is 74,128 tons of CO2 (91%) decreasing to 39,689 tons of CO2 (45%) in 2030.

FIGURE 2-13. FUEL MIX SCENARIO 3: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030



Source: Navigant



Figure 2-14 includes supporting information.

**FIGURE 2-14. FUEL MIX SCENARIO 3:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030**

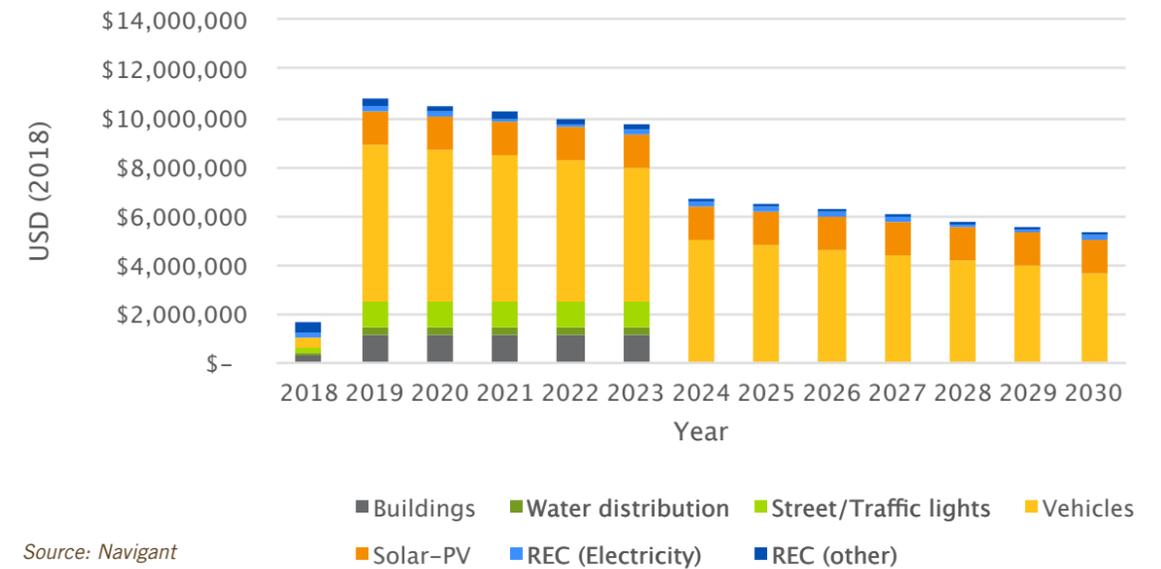
	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO ₂ Emissions (Baseline)	ton	81,141	81,699	82,261	82,829	83,402	83,981	84,565	85,155	85,750	86,351	86,957	87,570	88,188
CO ₂ Reduction (Demand)	ton	1,416	5,640	9,796	13,882	17,900	21,849	22,644	23,531	24,508	25,577	26,736	27,986	29,328
	%	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

2.4.2 Costs

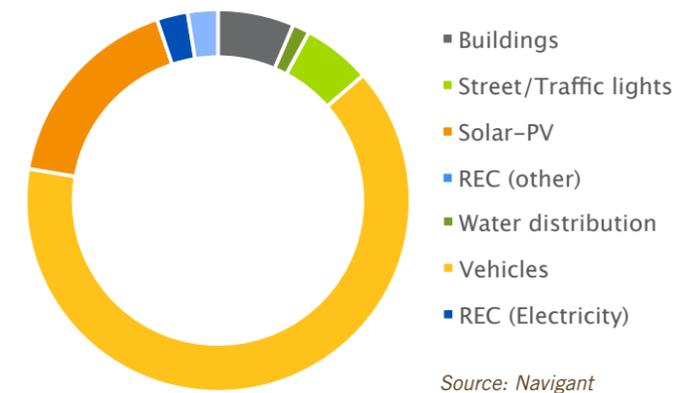
Figure 2-15 below includes annual investments from 2018-2030, estimated at \$95 million. The city will implement demand reduction measures including building efficiency (\$6 million), street light efficiency (\$5 million), and water distribution system optimization (\$1.5 million). The City invests in 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 2 15. ANNUAL INVESTMENTS IN SCENARIO 3:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030**



This analysis assumes that all expenditures are city funded. In the 2030 Scenario, cumulative additional investments between 2018 and 2030 amount to \$95 million, illustrated in Figure 2-16 below.

**FIGURE 2-16. CUMULATIVE INVESTMENTS IN SCENARIO 3:
100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030**

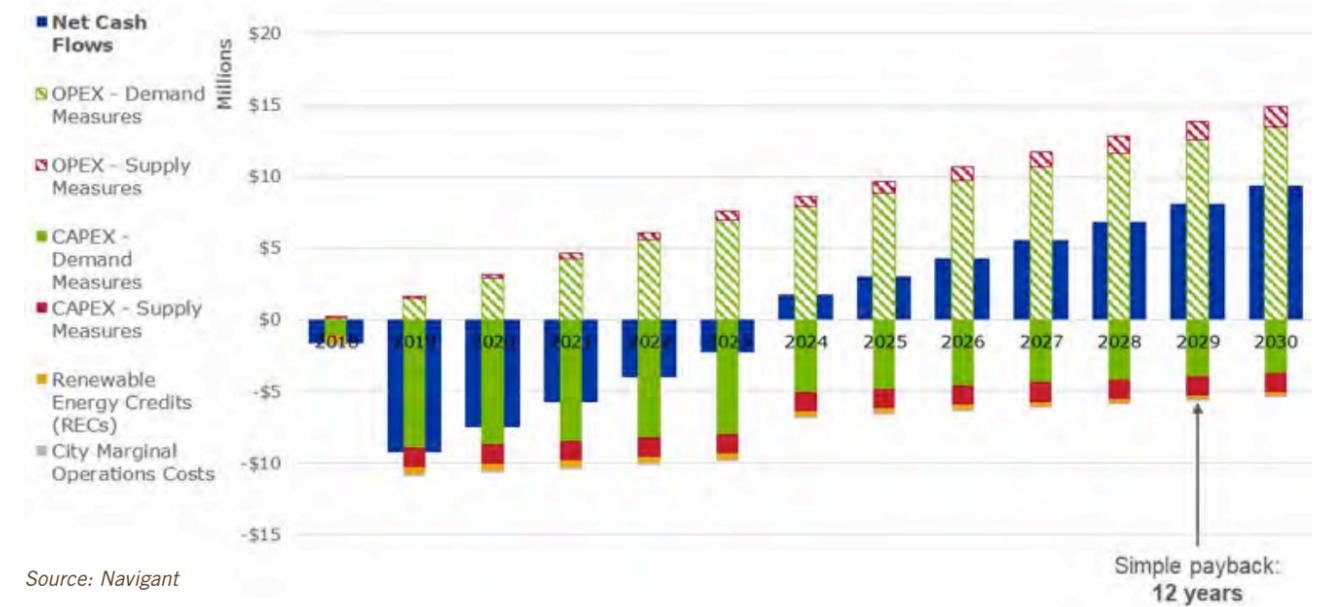


Solar photovoltaic and solar hot water panels on a rooftop in Madison.



The cash flow analysis below in Figure 2-17 and 2-18 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 2-17. SCENARIO 3: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030 – CASH FLOW SUMMARY



Source: Navigant

FIGURE 2-18. SCENARIO 3: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030 – CASH FLOW SUMMARY

(figures in million \$)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
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	-0.1	-0.1	-0.1	-0.1
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	0	0	0	0
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	-0.3	-0.3	-0.3	0.4
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	-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	13.5	13.5	13.5	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	1.4	1.4	1.4	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	14.4	14.4	14.4	14.3

Source: Navigant



GO BY BIKE!
Active transport, such as biking, contributes individual and public health benefits while reducing our carbon footprint.

3. TECHNICAL DETAIL OF SCENARIOS

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 3-1. KEY STRATEGIES FOR ACHIEVING 100% RENEWABLE ENERGY GOAL



Source: HGA

Table 3-1 includes the sources of information, along with interviews with city officials, that were used to estimate energy consumption and costs.

TABLE 3-1. SOURCES OF INFORMATION

MEASURE	SOURCES
Facilities & 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 & 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 & Emissions Data	EPA eGrid, Utility Annual Reports; U.S. EIA Energy Outlook 2017-2050
Renewable Energy	Madison solar planning document, RENEW Wisconsin; UW Extension; Madison Solar Consulting; HGA field experience; Navigant reports

Source: Navigant

3.1 Demand-Side Strategies

Energy efficiency improvements are one aspect of carbon emissions reductions. The city has invested in energy efficiency throughout all its facilities over the 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.

3.1.1 Facilities Energy Efficiency

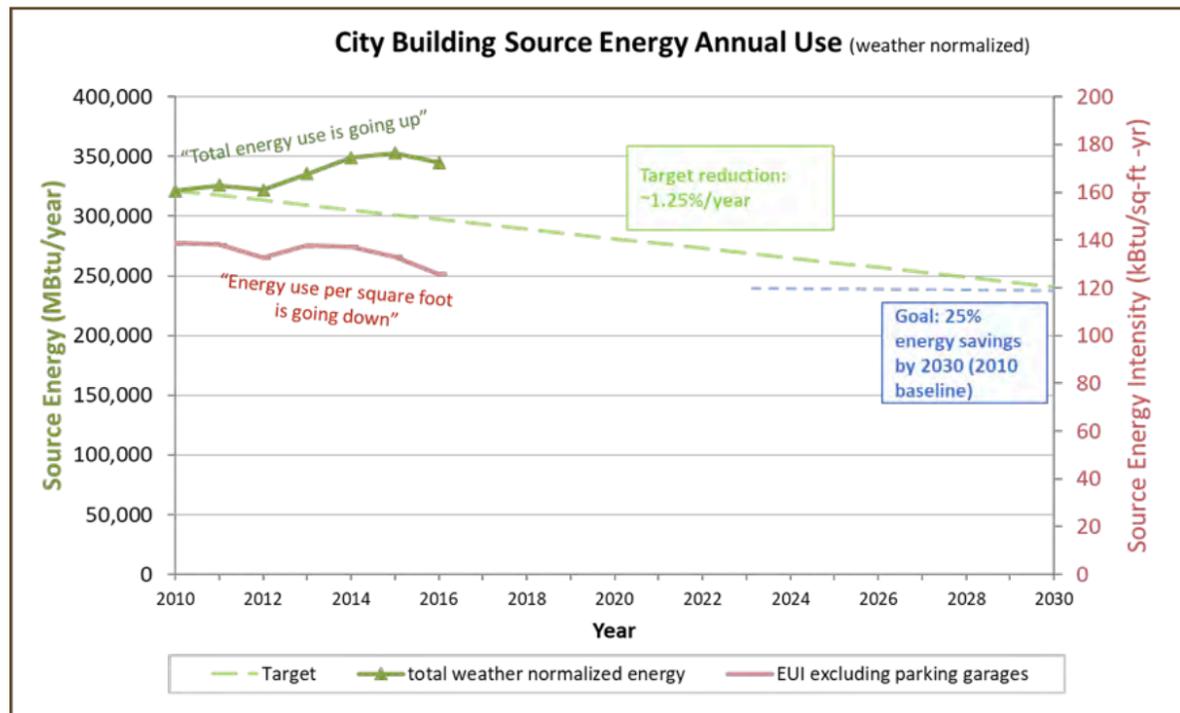
To better manage facility energy consumption, the City of Madison has been tracking and reporting all building energy performance since 2010. This system enables the City to monitor building performance over time and validate impacts of efficiency upgrades. In the last ten years, the city has invested 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 3 2 illustrates both these metrics over the last six years. As indicated below, there is a general decline of energy use intensity 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 and 40% by 2050 (using 2010 as a baseline) 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 to target energy reduction of 1.25% per year.

FIGURE 3-2. HISTORIC AND PROJECTED BUILDING ENERGY CONSUMPTION



Source: HGA analysis of City of Madison data

3.1.2 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.

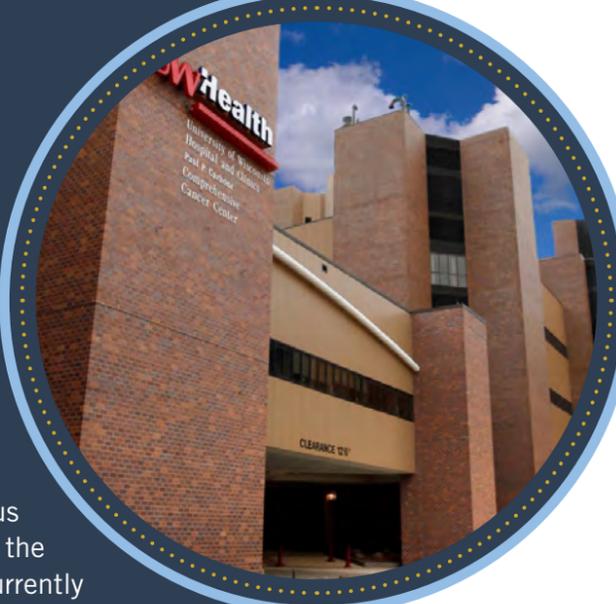
The City of Madison has started retro-commissioning some buildings. Completing RCx on at least 5 buildings per year would achieve a minimum of 2% additional annual savings over the entire COM building stock. RCx costs including implementation are typically around \$0.50/sq-ft. Implemented savings continue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

The RCx program could be 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.

Local Spotlight

UW HEALTH ACHIEVES 24% ENERGY REDUCTION THROUGH RCx EFFORTS

UW Health achieved a 24% energy reduction at its hospitals and clinics through aggressive implementation of retrocommissioning strategies. These strategies included low cost measures such as optimized HVAC scheduling, HVAC controls improvements and air flow rebalancing. After Focus on Energy incentives, the simple payback of all the projects was less than 1 year. UW Health is currently leading all health care organizations in the national EPA Better Buildings Challenge. Latest results can be found at the Better Buildings Challenge website.



3.1.3 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.

3.1.4 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.²⁵ 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.

3.1.5 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 onsite and offsite 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.

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.

3.1.6 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.

3.1.7 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.

3.1.8 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.²⁶

3.2 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 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)
- Offsite solar
- Offsite 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)²⁷ 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.

3.2.1 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 the end of 2018, the local government will have installed over 611 kW of behind-the-meter solar to date, generating approximately 1% of the 2018 electricity consumption by city operations.

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-

Local Spotlight

SAUK COUNTY SOLAR

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.



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).²⁸ 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.

City officials have identified potential solar installations on city buildings totaling 2,746 kW (2.7 MW) of solar PV. When compared to offsite solar or wind, behind-the-meter solar installations at city operations can be potentially by installed more quickly since these buildings are part of city government operations.

²⁶ Madison Water Utility, "Water Conservation House," <http://www.cityofmadison.com/water/projects/water-conservation-house>.

²⁷ MG&E <https://www.mge.com/about-mge/electricity/elec-from.htm>.

²⁸ Solar Energy Finance Guide, <https://erc.cals.wisc.edu/wp-content/blogs.dir/14/files/2017/08/SolarEnergyFinancingGuide.pdf>.

These lowest cost PV sites (referred to as phase 1 solar) could produce enough energy to offset 7% of local government operations' 2018 electrical consumption. Table 3-2 includes a list of existing solar and phase 1 solar sites, sites with an install date of 2018 or earlier have already been installed.²⁹

TABLE 3-2. EXISTING AND PROPOSED ROOFTOP SOLAR PV INSTALLATIONS

SITE	INSTALL YEAR	DC SIZE (kW)	TOTAL (kW)
Alicia Ashman Library	2007	7	7
Engineering Operations Facility Office Buildings	2008	4	11
Greentree Landfill	2008	6	18
Demetral Landfill	2008	6	24
Madison Police Department East District Station	2009	10	34
Water Utility Office Building	2009	10	44
Water Utility Vehicle Storage Building	2009	10	54
Streets Waste Transfer Station	2009	10	64
Streets East Garage	2012	8	72
Madison Public Library Central Library	2013	19	91
Engineering Operations Facility Garage	2013	19	110
Madison Fire Department Station 13	2014	25	135
Madison Police Department Training Center	2016	19	154
Warner Park Community Recreation Center	2016	16	170
Traffic Engineering Building C	2016	9	179
Yahara Hills Golf Course	2016	19	198
Water Utility Well 9	2016	6	203
Streets West Vehicle Storage	2017	100	303
Madison Fire Department Station 12	2017	19	322
Water Utility Well 26	2017	22	344
Library Maintenance & Support Center	2018	52	396
Engineering Operations Addition	2018	86	482
Goodman and Park Maintenance Facility	2018	57	539
Midtown Police Station	2018	22	561
Fire Station 14	2018	50	611

SITE	INSTALL YEAR	DC SIZE (kW)	TOTAL (kW)
Fire Station 11	TBD	25	636
Fire Station 05	TBD	5	641
Fire Station 06	TBD	5	646
Fire Station 07 + Police West	TBD	50	696
Sycamore - Streets East	TBD	100	796
Madison Municipal Building	TBD	57	853
Pinney Library	TBD	100	953
Warner Park Community Recreation Center	TBD	15	968
Olbrich Gardens	TBD	20	988
Metro East Washington – New Roof	TBD	600	1,588
New Fleet at Nakoosa Trail	TBD	100	1,688
Water Utility – Patterson	TBD	100	1,788
CDA – Olin Housing	TBD	100	1,888
Sayle Street – Traffic Engineering	TBD	100	1,988
Nakoosa Trail Bus Barn	TBD	100	2,088
Brittingham Apartments	TBD	200	2,288
Romnes	TBD	200	2,488
East Madison Community Center	TBD	155	2,643
Truax Public Apartments	TBD	57	2,700
Parkside Senior	TBD	30	2,730
Tenney Park	TBD	16	2,746

Source: HGA analysis of City of Madison data

There are additional sites beyond the 2.7 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 2018 electric consumption from local government operations. Unfortunately, the potential sites for behind-the-meter solar are limited. The majority of electricity for local government operations is consumed at pumping stations and urban multi-story buildings with limited space for solar. Due to these constraints, offsite renewable energy is required to further increase the amount of electricity generated from renewable sources.

3.2.2 Off Site Solar Farm through Utility Partnership

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 local government operations. 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 offsite solar capacity, while avoiding over production and reduced buy back rates. A 100% fully electrified bus fleet would increase the City's electric consumption by nearly 50% and would require the equivalent of 16-20 MW of solar to provide the bus fleet's charging needs with 100% renewable energy.

Local Spotlight

DANE COUNTY AIRPORT SOLAR DEVELOPMENT

In October of 2018, Dane County and MGE announced a partnership to build a 8MW solar farm through the Renewable Energy Rider. The 41-acre parcel is located adjacent to the airport. The project will produce nearly 25% of the county's electricity.

The project will also incorporate native prairie plantings and increase pollinator habitat.



3.2.3 Off Site Wind Farm through Utility Partnership

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. Such requirements are not insurmountable, for example, a medical software company successfully developed a wind project to provide power to its corporate campus in Verona.

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.

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. There are innovative renewable procurement options that are being used by corporate renewable buyers utilizing virtual power purchase agreements (VPPA). This VPPA format would be an additional option for the City to pursue in addition to utility partnerships, behind the meter solar, and renewable energy certificates.

3.2.4 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 framework³⁰ with goals to grow renewable generation and reduce carbon emissions:

- CO₂ reduction consistent with the US targets established through the Paris Agreement
- 40% reduction in CO₂ emissions by 2030 from 2005 levels
- 30% renewable energy by 2030 with 25% by 2025
- 80% reduction in CO₂ emissions by 2050 from 2005 levels



³⁰Madison Gas and Electric, "Energy 2030," <https://www.energy2030together.com/en/>.

As the grid electricity is increasingly generated from renewable sources, the City's and community's carbon footprint will be further reduced.

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 150 MW Kossuth Wind Farm in north-central Iowa and has additional strategies to reduce greenhouse gas (GHG) emissions 26%-28% by 2025 and CO2 32% by 2030, while increasing renewables to 30% by 2030.³¹ Table 3-3 includes ongoing MGE and Alliant/WPL initiatives to expand renewable generation serving Madison electricity customers.

TABLE 3-3. 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-12	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

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.

3.2.5 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.

One intent for some investors 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.

The Sustainable Madison Committee has recommended that any RECs purchased to offset local government operations meet the standards of the Corporate Renewable Energy Buyer's Principles,³² including the following criteria:

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

RECs meeting these criteria for additionality and geographic proximity have recently cleared between \$5.00-\$10.00/MW-hour. Typically, these RECs are unbundled, meaning that city operations would claim the attributes of the REC without using the direct electricity produced by the actual solar panels at a given location.

RECs can be 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 officials have 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 to be developed in 2019 and located in the following Wisconsin municipalities: Argyle, Cumberland, Elroy, Fennimore, and New Lisbon, WI. These REC's will offset emissions equivalent to approximately 37% of the current electricity consumption from local government operations.

Local Spotlight

ORGANIC VALLEY RENEWABLE INVESTMENT

Organic Valley (OV) 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.



³¹ Alliant Energy, "Sustainability Report 2018," <https://sustainability.alliantenergy.com/energy-climate/#energy-vision>.

³² Corporate Renewable Energy Buyers' Principles <https://buyersprinciples.org/>.

To further support the growth of local residential and commercial solar PV systems, the city officials could purchase REC's from local residential and commercial PV installations in the greater Madison area community. These REC purchases would likely lower the cost of PV installations in the community and could potentially increase the number of Madison residents and business owners installing solar. However, a city program to invest in local RECs would require additional study to design appropriate incentive levels while coordinating with other market actors and addressing additionality and social equity.³³

3.3 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 active transport, green fleet, and electric vehicles (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 recently adopted Madison in Motion, a comprehensive sustainable transportation master plan, that features recommendations for pedestrian and bike infrastructure, improving transit service and improving roadway efficiency and safety.³⁴ This section includes suggestions for how local government 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 3-4 includes a list of strategies reviewed for this analysis.

TABLE 3-4. 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

3.3.1 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 3-5. CITY OF MADISON FLEET CHARACTERISTICS

SEGMENT	EXAMPLE	NUMBER	FUEL
Heavy Duty Truck	Freightliner	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 3-6. 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

³³ Focus on Energy offers technical resources and financial incentives to develop solar in Madison and elsewhere in Wisconsin. An additional example is NV Energy (Nevada) Solar Generation program <https://www.nvenergy.com/cleanenergy/renewable-energy-incentives/solargenerations-incentive>. Thanks to David Bender of Earthjustice for providing this example.

³⁴ City of Madison, Department of Planning Community Development, Madison in Motion, <https://www.cityofmadison.com/dpced/planning/madison-in-motion/1569/>

3.3.2 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.³⁵ 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.³⁶

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 CO₂e). 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.

3.3.3 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.³⁷ Another option for some equipment is fueling with propane, which emits fewer GHG per gallon equivalent and is less expensive than gasoline or diesel.³⁸

3.3.4 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.³⁹ 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.⁴⁰ Additional technical and financial review is necessary before any large-scale conversion can occur, as fuel costs are not yet available.

3.3.5 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.



Solar photovoltaic panels.

3.3.6 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.⁴¹ 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.⁴² 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.⁴³ Custom tariffs can be developed for electric buses that would enable the city to move forward with electrifying the fleet.

According to the Union of Concerned Scientists, Madison's current electricity grid fuel mix, with a high percentage of coal-fired power plants, results in EVs being only marginally more beneficial for GHG emissions than an efficient internal combustion engine.⁴⁴ However, as Madison's local electric utilities add more 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 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.

3.3.7 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. City officials can play a vital role in organizing and orchestrating the planning, marketing, and deployment of EV charging stations.

³⁵ US Department of Energy, "Light Duty Vehicle Idle Reduction Strategies," Alternative Fuels Data Center, https://www.afdc.energy.gov/conservation/idle_reduction_light.html.

³⁶ US Department of Energy, "Clean Cities: Idling Reduction," Alternative Fuels Data Center, https://www.afdc.energy.gov/uploads/publication/work_truck_idling_reduction.pdf.

³⁷ US Department of Energy, "Biodiesel," Alternative Fuels Data Center, <https://www.afdc.energy.gov/fuels/biodiesel.html>.

³⁸ US Department of Energy, "Propane Vehicle Emissions," Alternative Fuels Data Center, https://www.afdc.energy.gov/vehicles/propane_emissions.html.

³⁹ 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.

⁴⁰ 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.

⁴¹ Navigant Research, Market Data: Electric Drive Buses, 2017.

⁴² C40 Electric Buses in Cities, March 29, 2018.

⁴³ 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.

⁴⁴ 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/#/53711/_/_.

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.⁴⁵
- MGE owns 30 public charging stations in the Madison area, including 27 Level 2 chargers and three DC fast chargers — eight of these stations are located in City of Madison parking facilities.⁴⁶ MGE plans to install another DC fast charger at Home Depot in November 2018, and three additional Level 2 chargers by the end of the year. MGE also offers a Charge@Home program that currently has 50 participants with approval to enroll up to 100 customers. The Charge@Home and public charging programs allows MGE to study charging behavior and how to best manage the impact of EV charging on its distribution system. MGE also partners with businesses and developers to install charging stations for employees and apartment residents.⁴⁷
- Alliant offers EV charging programs for residential and business customers.⁴⁸ 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.⁴⁹ Utility tariffs and rate structures must also be created to address the needs of EV and EV charging infrastructure.

4. 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.

4.1 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.

4.1.1 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.

⁴⁵ EV Stations Local, "Map of Electric Vehicle Charging Stations in Madison," <https://evstationslocal.com/states/wisconsin/madison/>.

⁴⁶ City of Madison, "Parking Utility," Electric Vehicle Charging Stations, <https://www.cityofmadison.com/parking-utility/garages-lots/electric-vehicle-charging-stations>.

⁴⁷ Madison Gas & Electric, "Plug-in Electric Vehicle Basics," EV Basics, <https://www.mge.com/environment/electric-vehicles/ev-basics.htm>.

⁴⁸ Alliant Energy, "Electric Vehicles," <https://www.alliantenergy.com/InnovativeEnergySolutions/SmartEnergyProducts/ElectricVehicles>.

⁴⁹ Navigant Research, Vehicle Grid Integration, 2017.



4.1.2 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.

4.1.3 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, Zoning and Inspections: Promote stretch building codes and provide incentives to reach them.
- 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.
- Establish 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.



- Include a requirement on the part of developers of commercial and office buildings to disclose to City Planning their plans, if any, for solar self-generation.
- City finance could consider feasibility of implementing an internal carbon fee or accounting standard to factor into relevant policies and decisions.
- Implement 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.
- Tax Incremental Financing (TIF): Explicitly allow TIF funds to reimburse developers who construct 100% RE/net zero carbon buildings.
- City procurement - the city should consider incentives to decarbonize its supply chain by identifying and providing preferences for suppliers with low or no carbon profiles, while balancing other procurement priorities.
- Promote power resiliency by working with local utilities to review opportunities to underground transmission/distribution and to harden power transformers and substations.
- 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, appropriate investments and racial equity and social justice initiative goals. 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.
- Consider opportunities to incorporate low-albedo specifications for road and roof replacements or to apply low-albedo treatments where appropriate.
- 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, active transportation, and ridesharing as part of Madison in Motion. Many cities offer fare free transit at times or in certain locations and some cities assess fees on ridesharing to generate revenue for such activities.⁵⁰

⁵⁰ Liz Farmer, "Governments Increasingly Tax Uber and Lyft for Transit Revenue," *Governing The States and Localities*, April 4, 2018.

4.1.4 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. Green Revolving Funds and other financing tools, such as energy performance contracting, can offer city officials alternatives to implementing energy efficiency and renewable energy projects while minimizing capital expenditures.

4.1.5 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.

4.1.6 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.

4.1.7 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 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, or existing properties that are renovated, 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 continue to offer funding to rehabilitate existing homes for energy efficiency and renewable energy.

4.1.8 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.⁵¹ 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.

4.1.9 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.

4.1.10 Smart City Public-Private Partnership

Many smart city applications have already started in Madison. The City of Madison participates in the Smart Cities Collaborative.⁵² 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.⁵³ The University of Wisconsin-Madison participates in this project and hosts a robust automated vehicle testing program.⁵⁴ 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.⁵⁵

Local Spotlight

RETHKE TERRACE MADISON, WI

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.



⁵¹ 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.

⁵² Transportation for America, "Smart Cities Collaborative," <http://t4america.org/>.

⁵³ 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>.

⁵⁴ University of Wisconsin Automated Vehicle Proving Grounds, "Automated Vehicles," <https://wiscav.org/>.

⁵⁵ Smart Columbus, <https://smart.columbus.gov/>.

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.

4.1.11 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.⁵⁶

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

4.1.12 Landfill CNG Pilot

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

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.

4.1.13 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.

4.1.14 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.⁵⁷ 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.⁵⁸ 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.⁵⁹

Every **GREEN SPACE**
in Madison provides **MULTIPLE**
BENEFITS to **INDIVIDUALS**
and the **COMMUNITY**

23
TREES PLANTED =
1 TON OF AVOIDED CO₂
(source: US EPA)

Access to nature increases individual well-being and benefits public health

Reduces heat island impacts

Performs critical ecosystem services

57
⁵⁶ Thanks to Gary Radloff of The Radloff Group for this recommendation.
⁵⁷ University of Wisconsin, Madison LaFollete School of Public Affairs, Madison City Operations Tracking Framework: A Roadmap to Sustainability, Spring 2015.
⁵⁸ Cool Choices, <https://coolchoices.com/>.
⁵⁹ City of Madison, "City of Madison Pass," <https://www.cityofmadison.com/metro/fares/PassPrograms/CityofMadison.cfm>.



Spring at the state capitol building in Madison.

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.

4.1.15 Work with Other Local Governments to Pool Resources

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.

4.1.16 Future Opportunities for Local Biogas Production

As noted in the transportation section, utilizing existing landfill gas for heavy duty vehicle fuels was included in the scenario analysis and was a key strategy for reducing large vehicle emissions. Digesting manure and/or food waste to generate biogas for energy alone is currently a less financially viable process compared to solar PV or wind turbine renewable energy generation. If there are other goals of these digesters, such as keeping manure off fields to prevent phosphorous from entering our lakes or preventing methane emission to the atmosphere from landfills, then digesters and other biogas processes can provide energy at reasonable rates when additional benefits are accounted for. As technologies, fuel costs and values evolve, biogas should be revisited as a financially viable 100% renewable energy strategy complementing wind and solar generation. The City of Madison and Dane County are currently evaluating food waste digester programs.

4.2 Suggested Leadership Actions for the Madison Community

The following recommendations include ways for the City of Madison local government operations 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 local government's role as a sustainability leader for the greater Madison community.

4.2.1 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.⁶⁰

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.⁶¹ 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 opportunities for the public. Utility tariffs and rate structures must also be created to address the needs of EVs and EV charging infrastructure, while also meeting racial equity and social justice initiative goals. 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.

4.2.2 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.⁶² Alliant also offers its customers a green-e certified renewable energy called Second Nature.⁶³

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

⁶⁰ Madison Gas and Electric, "Working Together to Grow the Electric Vehicle Market," <https://www.mge.com/environment/electric-vehicles/growing-ev-market.htm>.

⁶¹ 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. Readyng America's Cities for the Arrival of Electric Vehicles, citing research from EPRI, NREL. <https://uspig.org/reports/usp/plugging>.

⁶² Alliant Energy, "Our Energy Vision," Solar Generation, <https://www.alliantenergy.com/OurEnergyVision/AdvancingCleanEnergy/SolarGeneration>.

⁶³ Alliant Energy, "Innovative Energy Solutions," Easy and Affordable Renewable Energy, <https://www.alliantenergy.com/InnovativeEnergySolutions/SustainableEnergyChoices/SecondNature>.

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.⁶⁴

We Energies in Milwaukee is proposing a pilot program where customers would receive a monthly lease payment in exchange for allowing We Energies to put solar panels on their property.⁶⁵

Action: Continue to work with other local governments and electric utilities to develop and promote community solar options, while also meeting the goals of the racial equity and social justice initiative. Set appropriate targets, aim to develop 5 MW of community solar by 2020, 20 MW by 2023 and 30 MW by 2030.

4.2.3 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.⁶⁶

4.2.4 Promote Clean Energy Policies for Wisconsin

The City of Madison has negligible control over policy and regulation impacting electricity generation facilities, which is implemented by state or federal agencies. There are policy and regulatory changes that could be implemented to accelerate the retirement of 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



Agricultural land surrounding the Madison area.

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.

4.2.5 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, including strategies that meet the goals of the City's racial equity and social justice initiative.

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 or low-interest financing⁶⁷ 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.⁶⁸

4.2.6 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.⁶⁹ This model could be used to encourage private sector investment into renewable energy and energy efficiency. The City of Cleveland, Ohio has successfully implemented this approach.⁷⁰ Another innovative example of clean energy investment opportunities for the commercial sector is the PACE Wisconsin Fund, that was authorized in Dane County in 2018.⁷¹ 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

⁶⁴ Madison Gas and Electric, "Shared Solar Program," <https://www.mge.com/environment/green-power/solar/shared-solar-program.htm?redirect=index.htm>.

⁶⁵ <https://www.jsonline.com/story/money/business/energy/2018/11/20/we-energies-proposes-pilot-solar-projects/2031616002/>.

⁶⁶ University of Wisconsin, Extension Solar Energy Financing Guide, 2017.

⁶⁷ The Madison Office of Community Development currently offers home rehabilitation loans to provide financial incentives to upgrade housing units in need of rehabilitation, resulting in an improved housing stock. Office of Community Development www.cityofmadison.com/dpced/economicdevelopment/home-rehabilitation-loans/314/.

⁶⁸ 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.

⁶⁹ City of Madison, "City of Madison Community Bonds," <http://www.cityofmadison.com/community-bonds>.

⁷⁰ Cleveland Climate Action Fund, <http://www.clevelandclimateaction.org/>.

⁷¹ PACE Wisconsin, <http://www.pacewi.org/>.

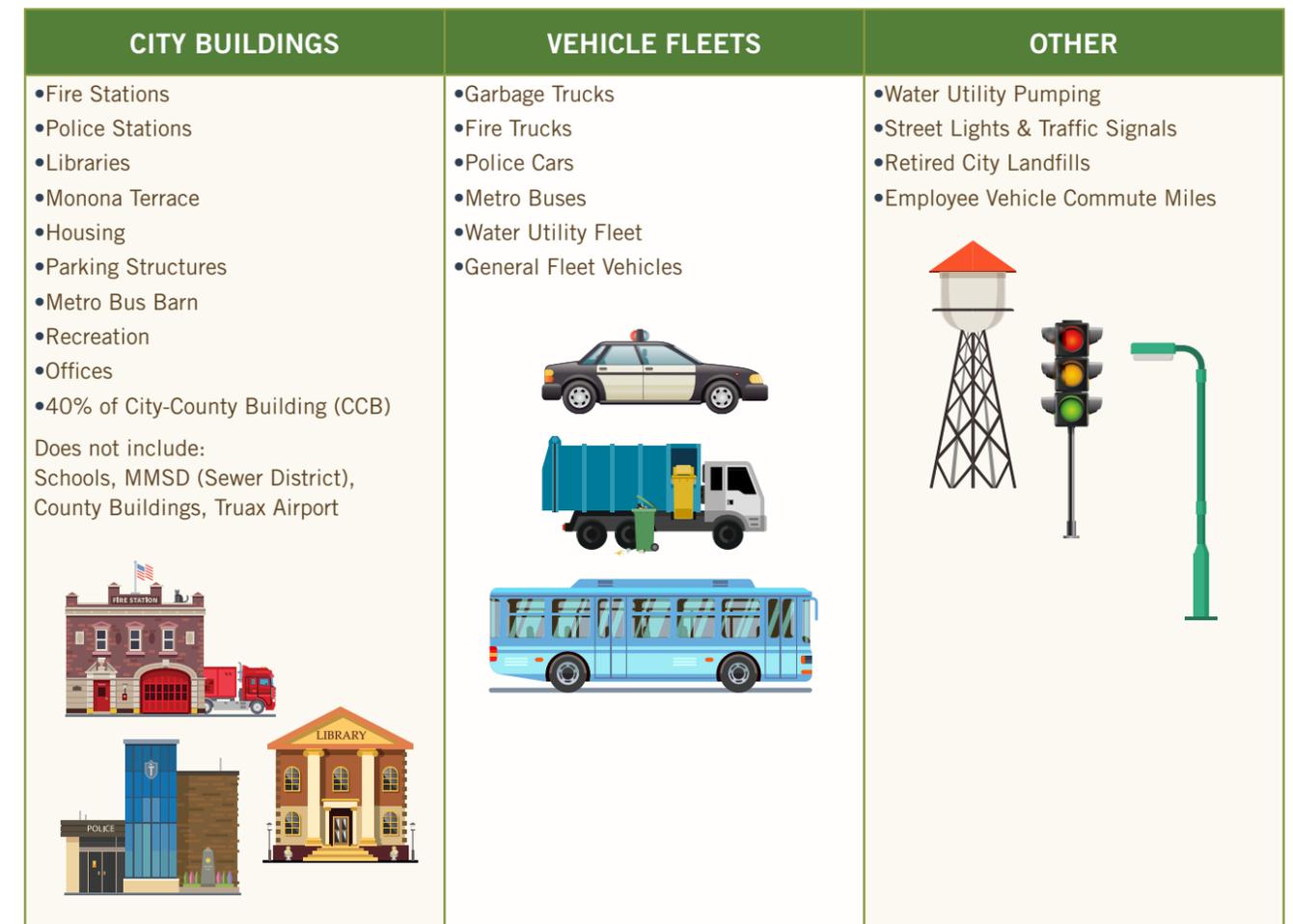


APPENDIX A. CITY OF MADISON EMISSIONS REPORT

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)

FIGURE A-1. SOURCES OF CO2 EMISSIONS FROM CITY OPERATIONS



Source: HGA based on ICLEI



A view of Madison's downtown.

The City of Madison is a member of ICLEI, an international non-profit organization of local governments working toward sustainability.⁷⁸ 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 to break down CO₂ (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

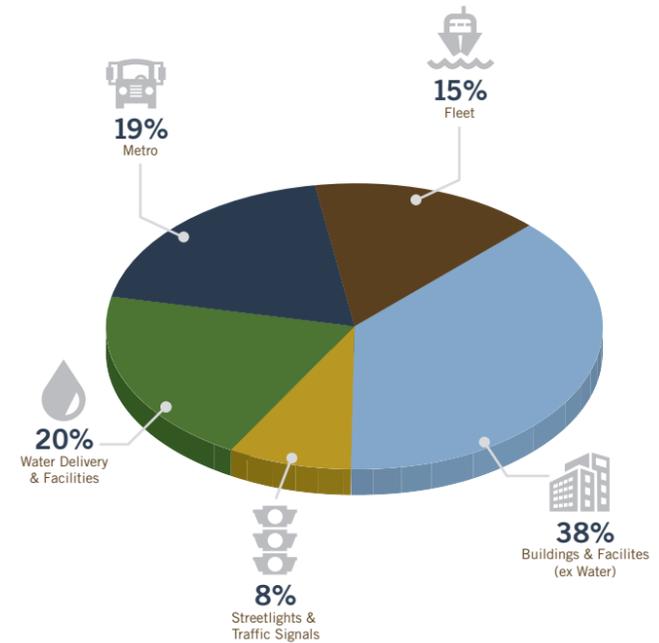
SCOPE 1: DIRECT EMISSIONS	SCOPE 2: INDIRECT EMISSIONS	SCOPE 3: OTHER
Vehicle exhaust	Purchased electricity	Employee commutes
Retired city landfills	Purchased steam	City-owned housing
Onsite natural gas combustion		Supply chain and waste emissions (not included)

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 CO₂e (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 CO₂e 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 CO₂ in 2018 to 88,188 tons of CO₂ in 2030.

⁷⁸ ICLEI, "Local Governments for Sustainability," <http://iclei.org/>.

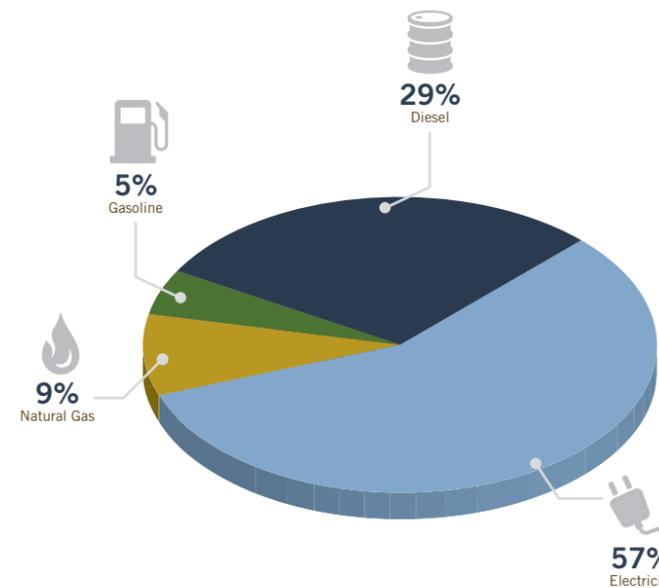
FIGURE A-2. BASELINE CARBON EMISSIONS FOR CITY OPERATIONS BY CATEGORY*



**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%).

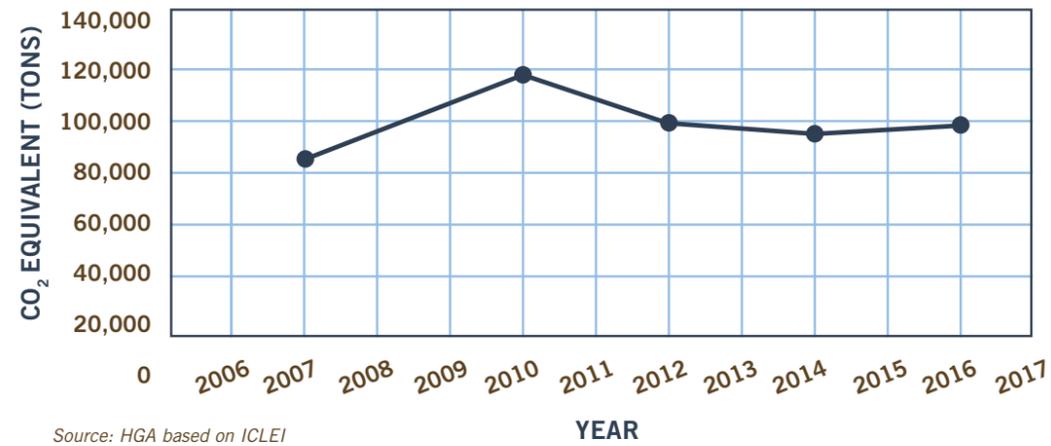
FIGURE A-3. BASELINE CARBON EMISSIONS CITY OPERATIONS BY FUEL TYPE*



**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
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 costs⁷⁹ 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, EIA data

The use of electricity includes an 80% reduction in carbon emissions from electricity 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

⁷⁹ Costs of fuel between 2017 and 2050 were estimated from the U.S. Energy Information Administration Annual Energy Outlook. <https://www.eia.gov/outlooks/aeo/>.



A yard sign indicates that this household is participant in the MadiSUN solar program.

APPENDIX B. 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 CO2 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.

B.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.

B.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 two 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.

Figure B 1 shows all 20 measures included in the analysis. There are 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.

The other 7 measures may not earn back their financial investment within their technical lifetime but will still reduce CO2 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

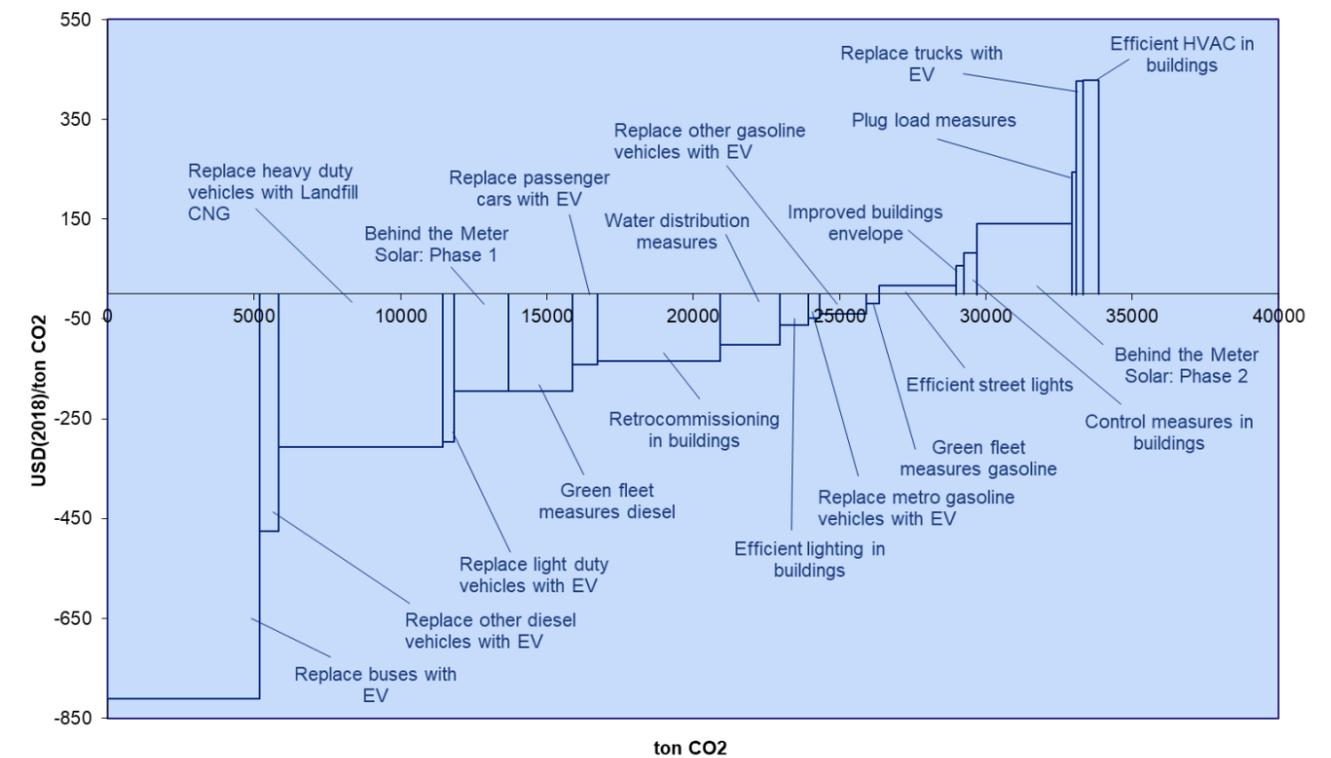
lights have a low cost (\$17/ton CO2) while reducing CO2 emissions significantly. If combined with sensors, smart street lights can contribute to public safety by hosting wireless networks or monitoring traffic and further Madison's smart city initiatives. Other measures may require greater investment, such as improving plug loads in buildings (\$245/ton CO2) or efficient HVAC in buildings (\$428/ton CO2). 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.

For the 20 measures included in this analysis, Figure B-1 shows the CO2 reduction potential per measure on the horizontal axis and the additional costs expressed in USD/ton CO2 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 more to implement than will be saved over their operational life.

FIGURE B-1. 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 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 Figure B-1 and is first in Table B-1.

TABLE B-1. 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
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	2,265	\$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

B.2.1 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 CO₂ 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 inflow⁸⁰ (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.

⁸⁰ Costs of fuel were estimated from EIA Outlook 2017.

APPENDIX C. 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.

C.1 Kick-Off Meetings

The consulting team refined goals and objectives for this study by interviewing city staff and members of the SMC through kick-off 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.

C.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.⁷⁹ 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.

C.3 Community 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
- Communicate results and options

C.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.

C.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.

C.3.3 Stakeholder Engagement – Website

The City developed a website to host information about the Madison 100% renewable energy study. Materials, presentations, and media from the project are available on the City of Madison 100% renewable energy website at www.madison100renewableenergy.com.

FIGURE C-1. SCREEN SHOT OF 100% RENEWABLE ENERGY WEBSITE



Source: Madison 100% Renewable Energy Study

C.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 affect Madison and the region and how people can get involved through the Citizens Climate Lobby. Media for the meeting included WKOW-27, the Madison City Channel, the Wisconsin State Journal, and the Badger Herald newspaper.

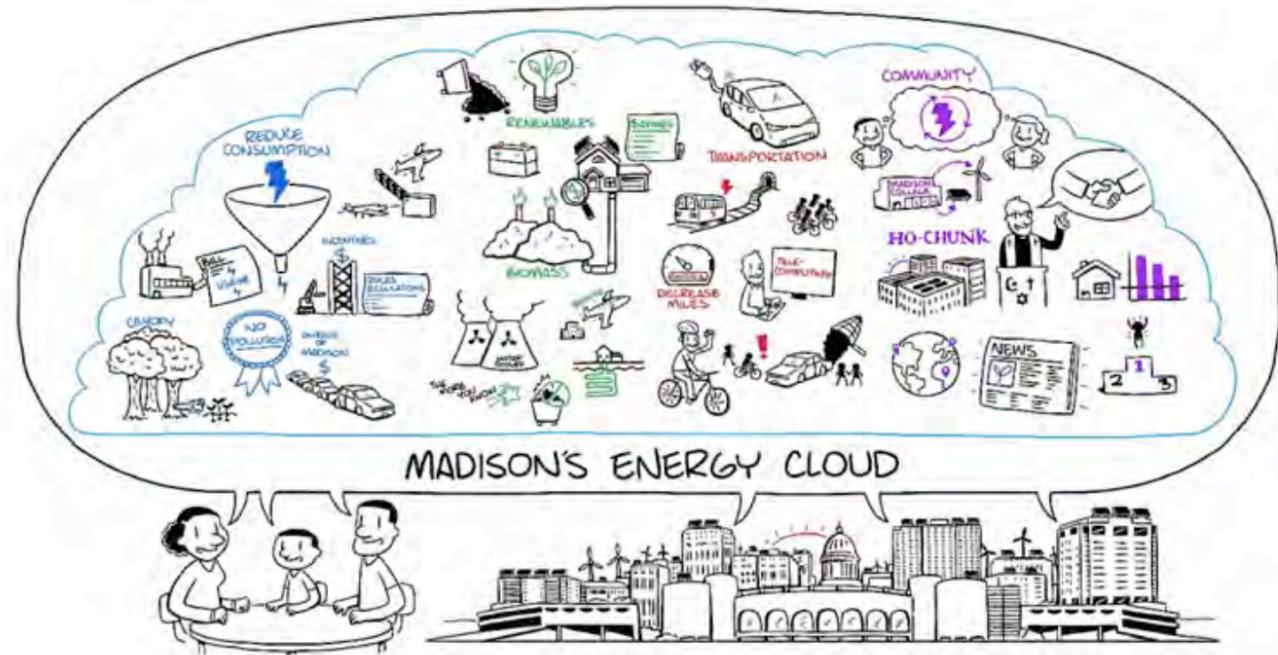
FIGURE C-2. CITY OF MADISON 100% RENEWABLE ENERGY AND ZERO NET CARBON PUBLIC MEETING SEPTEMBER 27, 2017



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 C-3. MADISON ENERGY CLOUD

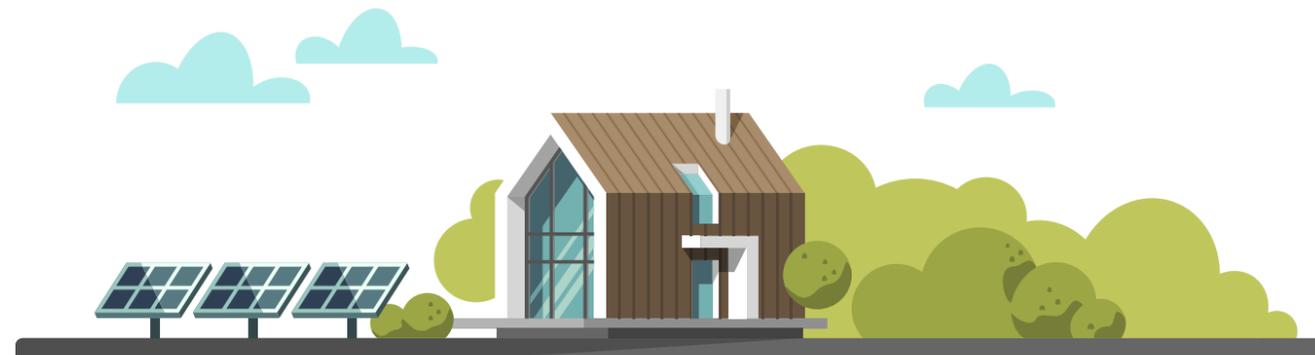


Source: Navigant, artist credit TruScribe

C.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).



Wind turbines in the Midwest.

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 (In second sentence, update to "(40 responses, note that they were broken out by electric vehicles 26 responses and electric hybrid vehicles 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.

C.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 D. ADDITIONAL INFORMATION

D.1 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/>

EI 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>

D.2 City Transportation & Mobility Resources

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

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>



Glossary

100% Renewable – This report utilizes the Sierra Club “Ready for 100” definition for the meaning of 100% renewable. Specifically, city operations are 100% renewable when the amount of energy generated from renewable energy sources equals or exceeds 100% of the annual energy consumed.

Biogas – A gaseous mixture consisting mainly of methane and carbon dioxide produced by the anaerobic digestion of organic matter (broken down by microorganisms in the absence of oxygen).

Carbon emissions – Carbon dioxide and other greenhouse gas equivalents emitted from the combustion of fossil fuels. In this report, the terms “carbon”, “carbon emissions” and “greenhouse gases (GHG) emissions” are all synonymous with carbon dioxide equivalent emissions, CO₂e.

Carbon footprint – The amount of carbon emissions emitted by a specific person or group over a defined period.

Carbon offsets – A reduction in carbon emissions made in one place, in order to compensate or offset carbon emissions elsewhere.

Clean energy – Energy produced from renewable, zero emission sources such as solar, wind, hydropower, geothermal or biomass which can be regenerated over short periods of time and cannot be depleted.

CNG – Methane / natural gas in a compressed state is compressed natural gas (CNG).

Community solar – A solar power installation that accepts capital from and provides power to community participants.

Demand side – Demand side measures are strategies that reduce the consumption of energy, such as energy efficiency measures.

Focus on Energy – Wisconsin’s state administered energy efficiency and renewable energy incentive program.

IRR – Internal rate of return (IRR) is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero.

kW – A unit of power defined as a kilowatt.

kWh – A unit of energy defined as a kilowatt-hour.

LEED – A green building certification program which stands for Leadership in Energy and Environmental design.

MadiSUN Program – A solar PV group buy program funded by the City of Madison.

Glossary

MGE – Madison Gas and Electric.

MW – A unit of power defined as a megawatt which equals 1,000 kW.

MWh – A unit of energy defined as a megawatt-hour which equals 1,000 kW-hr.

Net present value – Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time.

PACE – Property Assessed Clean Energy is a type of loan utilized for efficiency or renewable energy installations.

Plug load – Energy consumed by products plugged into building electrical outlets.

Public Service Commission of Wisconsin – The state regulatory agency that oversees and regulates Wisconsin’s public utilities.

Renewable Energy – Energy produced from renewable, zero emission sources such as solar, wind, hydropower, geothermal or biomass which can be regenerated over short periods of time and cannot be depleted.

Renewable Energy Credits (RECs) – Tradable, non-tangible energy commodities that represent proof that 1 megawatt-hour (MWh) of electricity was generated from an eligible renewable energy resource (renewable electricity) and was fed into the shared system of power lines which transport energy.

Self-generated renewables – Energy produced from on-site generation, such as behind the meter solar PV systems or local dedicated renewable resources built to serve the city.

Site energy – Energy consumed directly at a building or facility such as metered electrical consumption or metered gas consumption.

Solar – In this report, “solar” refers to electrical generation utilizing solar PV systems.

Solar ready – A building which is designed for future installation of solar PV systems, including structural and electrical design considerations.

Source energy – Amount of energy consumed by a facility after accounting for the energy required to generate and deliver this site energy.

Therms – A measure of energy content of a fuel equal to 100,000 British thermal units (Btu).

Zero Net Carbon – A system that produces or procures enough carbon-free energy equal or greater to its consumption on an annual basis.

List of Acronyms for the City of Madison 100% Renewable Energy Report

ACRONYM	DEFINITION
4-5G LTE	4th-5th Generation Long Term Evolution
Apts	Apartments
BAU	Business As Usual
BEV	Battery Electric Vehicle
BUI	building
CAP	capital
CAPEX	Capital Expenditure
CC	Community Center
CCB	City County Building
CDA	Community Development Authority
CNCA	Carbon Neutral Cities Alliance
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CO2 eq	Carbon Dioxide Equivalent
CO2e	Carbon Dioxide Equivalent
COM	City of Madison
EE	Energy Efficiency
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EUI	Energy Use Intensity
EV	Electric Vehicle
ft	Foot
FTA	Federal Transportation Authority
FTE	Full Time Equivalent
Gal	Gallon
GHG	Greenhouse Gas
GPS	Global Positioning System
REET	The Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model
HEV	Hybrid Electric Vehicle
HID	High Intensity Discharge
HVAC	Heating Ventilation and Air Conditioning
ICEV	Internal Combustion Engine Vehicle
ICLEI	International Council for Local Environmental Initiatives
kW	Kilo Watt
kWh	Kilo Watt Hour
kW-hr	Kilo Watt Hour
LB	Pound
lbs	Pounds
LDV	Light Duty Vehicle
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
M\$	Million Dollars
MAC	Marginal Abatement Cost
MGE	Madison Gas & Electric
MHDV	Medium and Heavy Duty Vehicle

MISO	Midcontinent Independent System Operator
MMB	Madison Municipal Building
MMSD	Madison Metropolitan School District
MMSD	Madison Metropolitan Sewage District
MOU	Memorandum Of Understanding
MPG	Miles Per Gallon
MROEast	East Region of Micontinent Independent System Operator
MW	Mega Watt
MW-hr	Mega Watt Hour
NA	Not Applicable
NREL	National Renewable Energy Laboratory
OMA	Office for Metropolitan Architecture
OPEX	Operational Expenditure
OV	Organic Valley
PACE	Property Assessed Clean Energy
PHEV	Plug-in Hybrid Electric Vehicle
PPA	Power Purchase Agreement
PSC	Public Service Commission
PSCW	Public Service Commission of Wisconsin
PV	Photovoltaic
RCx	Retro-commissioning
RE	Renewable Energy
REC	Renewable Energy Credit
RER	Renewable Energy Rider
RESJI	Racial Equity and Social Justice Initiative
RFI	Request for Information
RFP	Request for Proposal
SCADA	Supervisory Control and Data Acquisition
SEG	Sustainable Engineering Group
SMC	Sustainable Madison Committee
sq-ft	Square Foot
SUV	Sport Utility Vehicle
TBD	To Be Determined
TCO	Total Cost of Ownership
TIF	Tax Incremental Financing
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States Dollar
USDN	Urban Sustainability Directors Network
UW	University of Wisconsin
VGI	Vehicle Grid Integration
VMT	Vehicle Miles Traveled
WisPIRG	Wisconsin Public Interest Research Group
WKOW	ABC Affiliated Television Station Licensed to Madison, Wisconsin
WPL	Wisconsin Power & Light
WWF	World Wildlife Fund
yr	Year
ZNE	Zero Net Energy

