Madison Community Operations
2014 Carbon Emissions Inventory

Prepared for the City of Madison by

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Energy Analysis and Policy Capstone
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Forward

This report is the third in the series of biennial community-level greenhouse gas emission inventories for the City of Madison, and is the result of collaboration between the Nelson Institute of Environmental Studies' Energy Analysis and Policy graduate certificate program (EAP) at the University of Wisconsin-Madison, the City of Madison, and the Sustainable Madison Committee. The objective of this report is to aid in the City's goal of an 80 percent reduction in community greenhouse gas emissions from 2010 baseline levels by 2050. It builds off of the two previous community inventories recording 2010 and 2012 greenhouse gas emissions. The report includes policy recommendations developed by comparing emission levels between each report since 2010, forecasting where the community is in meeting its reduction goals, and identifying areas in electricity and heat use, transportation, or waste disposal and treatment where specific policies could further reductions.

As described on the Nelson Institute's website:

> EAP's interdisciplinary curriculum gives students the knowledge and skills needed to become leaders in industry, government, consulting, non-profits, and other roles in the energy field. EAP's interdisciplinary curriculum considers scientific, technical, economic, political, and social factors that shape energy policy formulation and decision-making. It examines topics in energy resources, market structures, public utilities, technology, linkages to the environment, demand for energy services, and public policy. Every EAP student also gains experience in designing, conducting, and communicating analysis for real-world clients in the energy sector.

EAP students completed this report as part of their Capstone course for the certificate program. The capstone is designed to allow students to "demonstrate a variety of skills related to energy system and energy policy analysis as part of a…project for a real client," using quantitative analysis and addressing policy implications (citation course syllabus 2015). The following inventory highlights the encouraging progress already made in community emissions reductions in just the two years since the previous inventory. The goal of this report is continuing that trend, having the next inventory reflect even greater progress toward reaching the community greenhouse gas emissions reductions target.

Acknowledgements

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List of Abbreviations

CH_4 – Methane
CO_2 – Carbon Dioxide
CO_2e – Carbon Dioxide Equivalent (all greenhouse gas emissions converted to corresponding CO_2 levels)
GHG – Greenhouse Gas
ICLEI – International Council for Local Environmental Initiatives
kWh – Kilowatt Hour
MG&E – Madison Gas and Electric
MMBTU – Million British Thermal Units
MROE – Midwest Reliability Organization East
MW – Megawatt
N2O – Nitrous Oxide
O_3 - Ozone
$PM_{2.5}$ - Particulate Matter

Executive Summary

By the year 2050, the City of Madison hopes to have cut greenhouse gas emissions by 80% of 2010 levels, or to emit less than one million metric tons (MT) of CO_2e annually. In order to monitor greenhouse gas (GHG) emissions, community and city emissions inventories are compiled biennially. This report covers GHG emissions for the Madison community in 2014 and finds that in 2014 Madison emitted 4.66 million MT of carbon dioxide equivalents (CO_2e), where CO_2e is the combined climate impact of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

This is the third community-wide inventory completed for the City of Madison, with the first completed for 2010 emissions and the second for 2012 emissions. Between the three inventories, new inventory management tools and techniques have been adopted, yielding discrepancies amongst the inventory calculation methods. Further, errors found in the 2012 inventory overestimate GHG emissions of the Madison community and have been corrected and addressed within this report.

The three sectors that continue to contribute the most to Madison's GHG emissions are transportation, commercial, and residential. Transportation accounted for 1.902 million MT (41%) of the 2014 annual emissions, commercial accounted for 1.397 million (30%) and residential accounted for 0.811 million (17%). The remaining emissions are from industrial, water, wastewater, and solid waste sectors and yield small contributions to Madison's overall emissions.

Within the context of this report, we recommend three reduction strategies targeting the three major contributing sectors. First is introducing stronger renewable energy targets, including generating 25% of electricity from renewables by 2025 and 100% by 2050. Second, we encourage the city to develop and institute transit-oriented design in city planning to reduce personal vehicle miles traveled (VMT) in the community. Finally, we used data from the city's Georgetown University Energy Prize competition entry to assess the impact residential benchmarking may have on the community's GHG emissions.

The reduction strategies applied to the future of Madison's GHG emissions alone, however, do not achieve the City's 2050 reduction targets. Although applying large renewable portfolio standards, encouraging neighborhood development along a bus rapid transit shed, and promoting energy efficiency in the residential sector allows future annual GHG emissions to decline by over 1.2 million MT of CO_2e, total annual CO_2e emissions are still 5 million MT greater than the intended reduction target of fewer than one million MT CO_2e.

Increasing the city's renewable portfolio standards to offset fossil fuel electricity and natural gas consumption has the greatest impact, and is a reduction strategy we highly recommend. Future inventories should assess major transportation overhauls to generate declines in VMT and personal vehicle emissions. A combination of reduction strategies across all sectors is recommended for Madison to meet and exceed its GHG reduction targets.

Introduction

Climate Change

The Earth's atmosphere is naturally composed of a certain amount of GHGs, including trace amounts of CO_2, CH_4, N_2O, water vapor, and ozone (O_3), which retain heat to keep the temperature of the earth suitable for living. Recently, however, excessive GHG emission from anthropogenic activities has led to a warming effect on the global climate. According to the IPCC 5th assessment report, human influence on the climate system is 'extremely likely' as the cause of the global warming, and the concentration of GHG has reached the highest levels in history (Intergovernmental Panel on Climate Change, 2014).

Changes in climate may have caused impacts on natural and human system across the globe. Globally, snow cover has decreased by more than 10% in last forty years, and the average sea level has risen between 1/3 and 2/3 of a foot over the course of last century. The increasing temperature is projected to accelerate the water cycle, which may increase the frequency of extreme weather such as extreme high temperatures, excessive precipitation, and drought. Risks associated with extreme weather are increasing with continued global warming (IPCC, 2014). More frequent and heavier precipitation causes flooding and storms, which may incur considerable economic cost to property, infrastructure, and human life. Extreme events may reduce the availability of fresh food and water, interrupt communication and utilities, and contribute to mental health impacts such as stress disorder (CCSP, 2008). The increased fire activities as a result of drought are expected to cost more than over $2 million in California alone (citation California drought costs).

Weather and climate play important roles in human health. Global warming may lead to more frequent heat waves. Heat waves can cause heat stroke and dehydration, which is the most common cause of weather-related deaths. Children, elderly people, and people with medical conditions are more vulnerable to heat waves. Urban areas are typically warmer than rural areas due to urban heat island effect, which will consequently increase the electricity consumption, leading to further increasing emission of GHG and air pollutants (EPA, 2009). In addition, heat waves are usually associated with a stagnation event, a condition favorable for air pollution. The warmer temperature and stagnant air are likely to worsen the ozone pollution, which is one of the most health-damaging air pollutants. Climate change may adversely impact allergies and respiratory health. For example, warming climate could facilitate the spread of ragweed, which is an invasive plant with very allergenic pollen. Changes in climate may also enhance the transmission of pathogens (USGCRP, 2009). These changes and more that develop due to climate change have an impact on populations worldwide, including in Madison.

Greenhouse Gas Emission Inventory

The City of Madison is committed to sustainability through the creation of the Sustainable Design and Energy Committee (SDEC). The SDEC changed to the Sustainable Madison Committee (SMC) in 2012, took on the task of updating the city's sustainability report, and assists various groups of stakeholders and experts. In the Sustainability Plan of 2011, Madison's sustainable effort focuses on six key areas, including energy, buildings, neighborhoods, transportation, parks, and food systems. Almost all of these key areas include a focus related to reducing GHG emissions.

The establishment of a GHG emission inventory is a crucial step to reach Madison's sustainability targets. The first emission inventory documented the city's GHG emissions from 2010. The GHG emission inventory for 2012 was later conducted in 2014. Both reports are collaborations between the City of Madison and graduate students from University of Wisconsin-Madison. The purpose of this report is to develop the emission inventory for 2014. In addition to presenting the current emission inventory, this report assesses trends in sectoral GHG contributions over time by comparisons with previous inventories. From our comparisons, we noticed errors in previous inventory calculations and made corrections as necessary to provide accurate inventory information. We use ClearPath, a program developed by the International Council for Local Environmental Initiatives (ICLEI), to record the inventory and to estimate future GHG emissions in the coming decades (present to 2050). From these results, we propose and investigate three potential GHG emission reduction strategies: increased renewable energy consumption, transportation-oriented development (TOD) in the bus rapid transit shed, and residential benchmarking. Our results indicate that in order to meet future reduction goals by 2050, Madison will need to make extreme decisions in regulating fossil fuel consumption.

Role of ICLEI - *Local Governments for Sustainability*

ICLEI is an organization that provides assistance for local governments to achieve sustainable development. It applies a performance-oriented framework and methodology to assist governments in developing and implementing localized approaches to reducing GHG emissions. ICLEI set five milestones for climate mitigation:

a) Conduct a baseline emissions inventory and forecast.
b) Adopt an emission reduction target.
c) Develop GHG emission reduction strategies.
d) Implement policies and measures.
e) Monitor and verify the results.

ICLEI released the Community-Scale GHG Emission Accounting and Reporting Protocol in 2011 in response to continued commitment of local governments to creating policies to mitigate GHG emissions. The protocol establishes standards for community-scale inventories, which can provide local governments with standard guidance to review the processes contributing to GHG emissions. ICLEI's ClearPath software calculates and tracks GHG emissions associated with electricity, fuel use, and waste disposal. The tool uses the methodologies and accounts for all the emissions sources established in the Local Government Operations Protocol.

ClearPath Emissions Processing Tool

In 2014, ICLEI replaced its original emissions processing tool, the Climate Air and Climate Protection software, with ClearPath. ClearPath is an online tool that collects GHG emission inventory, forecasts future emission and tests the reduction strategies. It allows users to develop baseline inventories, track emissions overtime, forecast emissions under multiple scenarios, analyze the benefits of emission reduction, and visualize the planning scenarios for reducing emissions. Sectors in this report include residential energy, industrial energy, commercial energy, transportation, water and wastewater, and solid waste.

Methodology

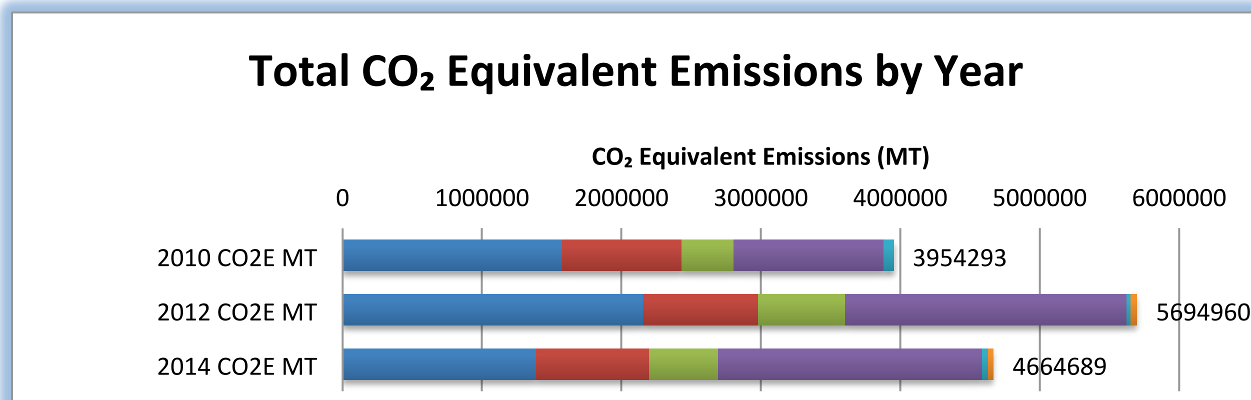
Developing the Madision GHG emissions inventory requires several steps in order to assess the in current status of GHG contributions in Madison and evaluate trends and changes from recent years. These are described below.

- Identify the base year: The base year for forecasting in this report is 2014. We noticed some substantial errors with the 2012 GHG emission inventory, including undercounting transportation emissions by 1 million MT CO_2e. The errors may skew the forecast results and lead to inappropriate programming. Thus, we chose 2014 as the baseline year. Further, we chose to use 2014 over 2010 as our base year for forecasting because the 2010 emissions inventory was conducted using older ICLEI software that may lead to inconsistent results.
- Data collection: We collected data for the GHG emissions inventory from multiple groups, including local governmental departments and private organizations. Data contacts are listed in Appendix E. The data were manually entered into ICLEI. In our report, we try to avoid double-counting data. The known double-counted data were marked as "information only" and subtracted from the total emission inventory.
- Current inventory-year emissions: After entering all the inventory data we summed the emissions to calculate current year emissions. To calculate GHG emissions, ICLEI requires entry of information about emissions sources as well as activity data during the reporting year. Users can provide specific emission factors, information about fuel and vehicle types, or municipally-operated utility electricity mix not included in the default factors.
- Emission forecast: With the inventoried emissions, we then forecasted future emissions in ClearPath based on assumptions of growth rates in residential population and job increase as well as changes in energy consumption and carbon intensity over time. The starting values are directly taken from the baseline emission inventory, which in the case of this report is 2014 emissions. Assumptions regarding the growth rates were obtained from U.S. Energy Information Administration and Department of Administration of Wisconsin.
- Planning strategies: Using the forecast, we then estimated the impacts of potential reduction strategies. Assumptions regarding energy savings are provided from specific reduction strategies, along with assumptions regarding changes in the community over the target period. The specific assumptions are described in the Planning Modules section of this report.

Community Operations Inventory 2014 Results

The total Madison community GHG emissions from 2014 were 4,664,689 MT CO_2e, an 18% decrease from the 2012 levels and an 18% increase from 2010 baseline levels (Figure 1).

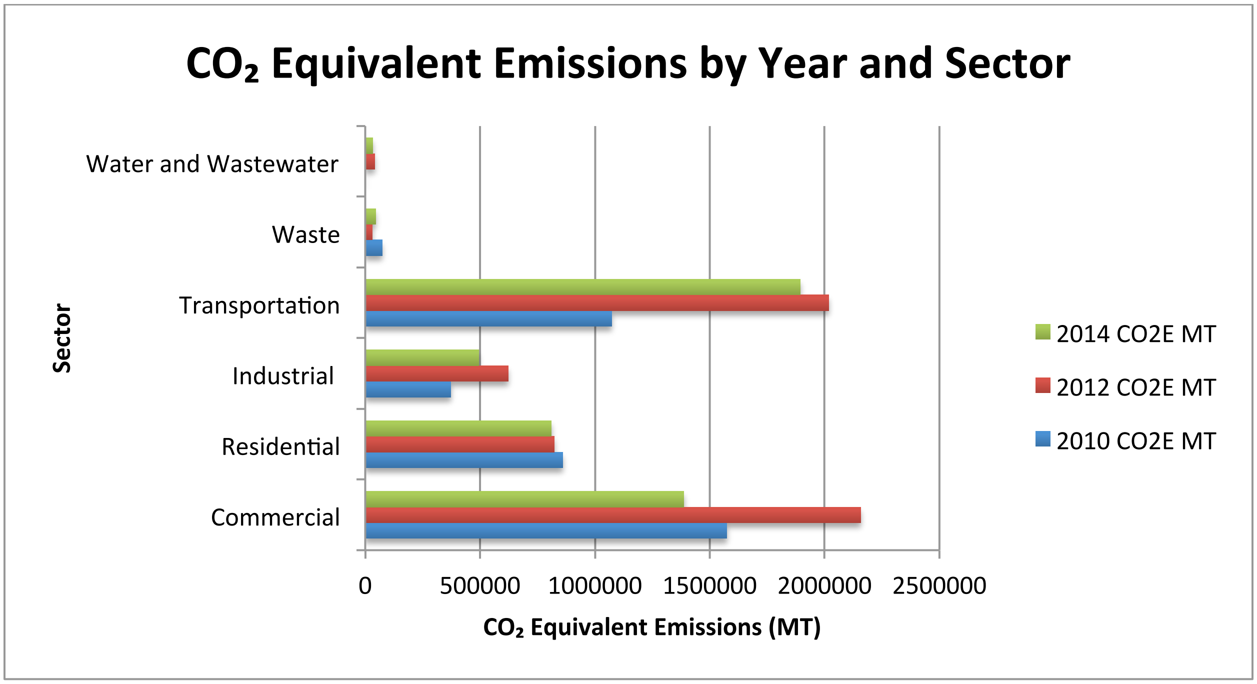
Figure 1 Total CO_2e emissions for each inventory year



	2014 CO2E MT	2012 CO2E MT	2010 CO2E MT
Commercial	1387486	2157848	1574096
Residential	810907	823390	859582
Industrial	494290	622563	373254
Transportation	1893958	2018727	1073720
Waste	45372	30951	73641
Water and Wastewater	32676	41481	0
Total Emissions	4664689	5694960	3954293

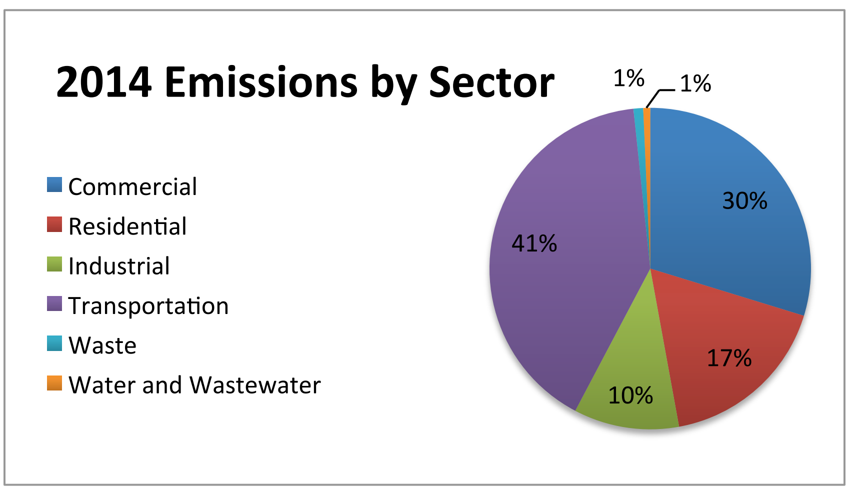
The increase from 2010 levels is likely due to the use of ICLEI's newer ClearPath software and emissions calculation methods for the 2012 and 2014 inventories, which include several new emissions sources—water, wastewater, and updated stationary fuel combustion source emissions—that were not included in the 2010 inventory (Anderson et al., 2014). Because the 2012 and 2014 inventories include the same source data and software, the decrease in CO_2e emission from 2012 to 2014 is a more helpful measure for gauging the community's progress toward 80% GHG emission reductions. Comparisons between 2010 and 2014 are still included in this report, however, along with comparisons between 2012 and 2014 and suggested reasons for increases or decreases in GHG emissions over time. Note that because the 2012 and 2014 reports are more inclusive in what sources are incorporated, the reductions from 2010 levels in the Commercial, Residential, and Waste sectors likely reflect actual emissions reductions rather than a change in what sources were included (see Figure 2).

Figure 2 CO_2 emissions compared across each year by inventoried sector



Consistent with the 2010 and 2012 inventories, the sectors with the largest amount of emissions are Transportation, Commercial, and Residential energy use, in that order. As shown in Figure 3, in 2014, Transportation accounted for 41% of total GHG emissions, Commercial electricity and natural gas use accounted for 30%, and Residential electricity and natural gas use accounted for 17% of the total GHG emissions in the Madison community.

Figure 3 Total emission make-up by sector for 2014 inventory



The overall decrease in emissions from 2014 to 2012 is likely due to increased energy efficiency in the residential and commercial sectors and slightly improved fuel efficiency in transportation. The largest reduction was in the commercial sector, with a decrease of 770,362 MT CO_2e (35.7%) from 2012 levels, and a decrease of 186,610 MT CO_2e, or 11.9% decrease, from 2010 levels. Industrial emissions have the next largest reduction, with an 128,273 MT decrease from 2012 levels, or 20.6% decrease. Industrial emissions in 2014 are

32.4% greater than 2010 levels, likely due to measurement and data inclusion differences between the 2010 and 2014 inventories.

Residential and transportation sectors decreased slightly from the 2012 inventory. The residential sector emitted 12,483 fewer MT CO_2e in 2014, a 1.5% decrease from 2012 (48,675 fewer MT CO_2e or a 5.7% decrease from 2010 levels). Transportation contributed 124,769 fewer MT CO_2e, or a 6.2% decrease for transportation emissions (46.6% increase over 2010 numbers due to increased sources included, such as boats and airplane fuel). Solid Waste was the only sector that showed an increase in emissions from 2012 to 2014, with an extra 14,421 MT CO_2e emitted, or a 46.6% increase over 2012 solid waste emissions. Reasons for this discrepancy are likely due to inclusion of additional sources, which is further explained in the Solid Waste sector analysis and in Appendix A.

Tables 1 and 2 show the total difference in MT CO_2e from 2010 to 2014 and 2012 to 2014 for each sector, as well as the corresponding percent change. A more detailed examination of changes in emissions over time per sector in Appendix A.

Table 1 Total Emissions by Year and Sector

Sector	2014 MT CO_2e	2012 MT CO_2e	2010 MT CO_2e
Commercial	1,387,486	2,157,848	1,574,096
Residential	810,907	823,390	859,582
Industrial	494,290	622,563	373,254
Transportation	1,893,958	2,018,727	1,073,720
Waste	45,372	30,951	73,641
Water & Wastewater	32,676	41,481	N/A
Total Emissions	**4,664,689**	**5,694,960**	**3,954,293**

Table 2 Differences between Emissions by Year and Sector

Sector	Difference 2014-2012 (MT CO_2e)	Percent Change 2014-2012 (%)	Difference 2014-2010 (MT CO_2e)	Percent Change 2014-2010 (%)
Commercial	-770,362	-35.70	-186,610	-11.86
Residential	-12,483	-1.52	-48,675	-5.66
Industrial	-128,273	-20.60	+121,036	+32.43
Transportation	-124,769	-6.18	+820,238	+76.39
Waste	+14,421	+46.59	-28,269	-38.39
Water & Wastewater[1]	-8,805	-21.23	N/A	N/A
Total Emissions	**-1,030,271 MT CO_2e**	**-18.09%**	**+710,396 MT CO_2e**	**+17.97%**

[1] Note that Water and Wastewater emissions were not included in the 2010 inventory so they are not included in the difference analysis.

Summary by Source

Residential, Commercial, and Industrial Electricity Consumption

Total electricity consumption, as provided by Alliant Energy and MG&E, across Residential, Commercial, and Industrial sectors decreased by 1,098,112 MWh total over 2012 consumption levels. This reduction is equivalent to 726,712 MT CO_2e fewer emissions in 2014. Each electricity-consuming sector saw a decrease in electricity consumption from 2012 levels (Table 3).

Table 3: Electricity consumption and related CO2e emissions by sector, 2012 to 2014

	Electricity Consumption (MWh)			CO_2e Emissions (MT CO_2e)		
Sector	2014	2012	Difference, 2014-2012	2012	2014	Difference 2014-2012
Residential	669,470	759,326	-89,857	405,173	557,863	-152,690
Commercial	1,351,082	2,224,158	-873,077	992,562	1,633,962	-641,400
Industrial	326,480	352,710	-26,230	239,846	259,116	-19,270
Total	**2,347,031**	**3,336,194**	**-989,163**	**1,637,581**	**2,450,941**	**-813,360**

The overall reduction in electricity-generated emissions from 2012 to 2014 could be partly due to increased energy efficiency efforts, especially in the Commercial and Residential sectors. Additionally, the reductions may reflect a decrease in energy-intensive activities such as running air conditioners. 2012 was a hotter year on average than 2014, with a highest summer monthly average of 91° F compared to 81° F in 2014 (weatherspark.com, 2013). Air conditioning can account for an average of 6% of a household's total energy use (Energy.gov, 2014). This would only be the difference of 45,560 MWh of residential electricity use in 2014 versus 133,449 MWh of commercial electricity use in 2012, which is not enough to explain the total difference between 2012 and 2014 electricity-related emissions levels, but could have contributed to part of the decrease between 2012 and 2014 electricity consumption.

	Natural Gas Consumption (Therms)			CO_2e emissions (MT CO_2e)		
Sector	2014	2012	Difference 2014-2012	2014	2012	Difference 2014-2012
Residential	60,006,908	49,934,727	10,072,181	319,086	265,527	+53,559
Commercial	74,269,102	97,983,525	-23,714,423	394,924	521,025	-126,101
Industrial	54,087,926	68215010	-14,127,084	287,071	362,050	-74,979
Total	**188,363,936**	**216,133,262**	**-27,769,326**	**1,001,081**	**1,148,602**	**-147,521**

Table 4: Energy use and emissions change for Residential, Commercial, and Industrial Heating from 2012 to 2014

Residential, Commercial, and Industrial Heating

Consumption of natural gas for heating in the Residential, Commercial, and Industrial sectors also decreased in 2014 from 2012 levels. In 2014, MG&E provided 188,363,936 therms of natural gas to residential, commercial, and industrial customers, or 27,769,326 fewer therms than the amount used in 2012. This reduction is resulted in 147,521 MT fewer CO_2e emissions. All sectors saw a decrease in natural gas consumption except for Residential, which had a 20% increase from 2012 levels. Results are as shown in Table 4.

Overall reductions in natural gas-related GHG emissions are most likely due to increased energy efficiency and conservation efforts, especially in the Commercial and Industrial sectors. 2014 had a colder winter than 2012, with a lowest average monthly temperature of 3° F in January 2014 compared to a lowest averagely monthly temperature of 17° F in January 2012. Considering the temperature was an average of 14° F colder in 2014 and natural gas consumption still decreased from 2012 levels, energy intensity per household and building for heating might have decreased substantially.

Transportation Energy Use

Table 5 Emissions from Transportation from 2012 to 2014

CO_2e Emissions (MT CO_2e)			
Sector	**2012**	**2014**	**Difference 2014-2012**
Transportation and Mobile Sources	2,018,727	1,891,938	-126,789

Total vehicle miles traveled (VMT) reported in 2012 from on road transportation and public transit was 3,304,477,825 miles and in 2014 was 3,253,727,966 miles, a difference of approximately 51 million miles. The off road emission, especially from air travel, is higher in 2014. Due to reduction of overall VMT, however, GHG emission reduced by 126,789 MT CO_2e (6.28% decrease) in 2014 compared to 2012 (Table 5). Appendix A provides the details of emissions from each category from this sector.

Solid Waste

Table 6 Emissions from Solid Waste from 2012 to 2014

CO_2e Emissions (MT CO_2e)			
Sector	**2012**	**2014**	**Difference 2014-2012**
Solid Waste	30,951	42,639	11,688

The quantity of community-generated waste entering landfills is reported as approximately 3.73 times less in 2014 (51,000 tons) compared to 2012 (190,245 tons). This resulted in the reduced waste generation emission in 2014 (i.e. the future emission from waste disposed in the inventory year) as shown in Appendix A. The 2012 inventory, however, does not include in-jurisdiction landfill emissions from Dane County Rodefeld Landfill. Therefore, GHG emissions from solid waste is higher in 2014 by 11,688 MT CO2e from the 2012 inventory (37.76% increase, Table 6).

Water and Wastewater

Table 7 Emissions from Water and Wastewater treatment from 2012 to 2014

CO_2e Emissions (MT CO_2e)			
Sector	**2012**	**2014**	**Difference 2014-2012**
Water and Wastewater	41,481	32,676	-8,805

Volume of water treated was 13,411million gallons in 2012 and 14,600 million gallons in 2014. Natural gas use also increased in 2014, from 16,078,929 standard cubic feet (scf) in 2012 to 34,310,000 scf in 2014. Electricity use decreased in 2014 (22,692,000 kwh compared to 34,184,654 kwh in 2012). Volume of water delivered by Madison Water utility was 10,659 million gallons in 2012 and 8,885 millions gallons in 2014. Accordingly, electricity use was lower in 2014 than in 2012 (21,022,877 kWh and 19,172,238 kWh respectively). Overall, water and wastewater GHG emission in 2014 decreased by 8,805 MT CO_2e (21.22% decrease, Table 7).

Madison Community Forecasted Emissions, 2014 to 2030 and 2050

Business as Usual

Inventories are used to predict future GHG emissions based on a variety of conditions. We used both the 2012 and 2014 inventories to evaluate business as usual (BAU) emissions scenarios out to 2030. Different forecasts were conducted using projected growth of the Madison Service Sector (projected Madison population growth plus projected Madison job growth) or a combination of future changes in carbon intensity, natural gas consumption, electricity consumption, light duty vehicle VMT, and bus activity—all from the EIA—in conjunction with Madison service sector growth. Data from the forecasts are presented in Table 8.

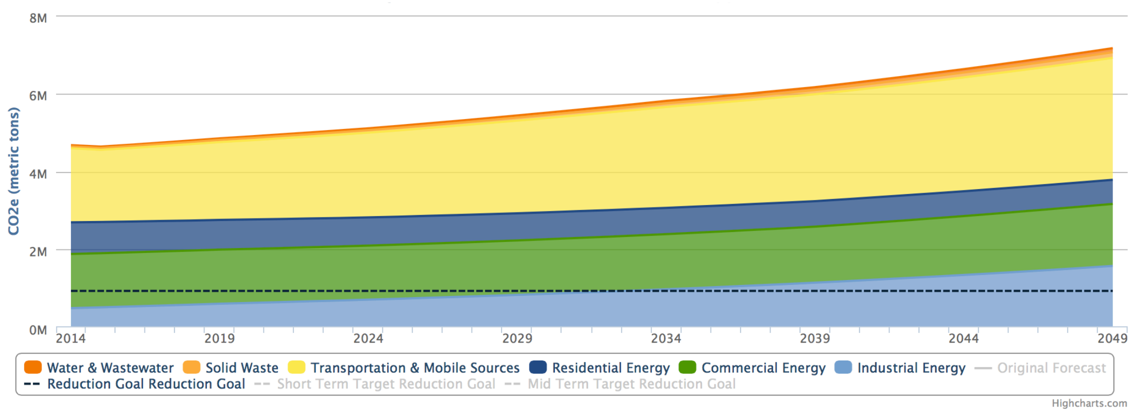
Table 8 Forecasts of future emissions showing differences in emissions between base year and factor set chosen

Base Year & Factor Set Type	2014 (MT CO_2e)	2025 (MT CO_2e)	2030 (MT CO_2e)	2050 (MT CO_2e)
2012, EIA	5,658,166	6,345,675	6,744,865	8,794,688
2012, MSN	5,658,166	8,420,477	9,869,684	18,045,796
2014, EIA	4,672,689	5,168,394	5,505,960	7,161,340
2014, MSN	4,672,689	6,828,072	8,003,217	14,633,136

For both 2012 and 2014 base-year forecasts, using EIA-derived future growth rates improved future emissions. For instance, using the EIA values and a base year of 2014 predicts approximately a one million MT CO_2e increase in annual total CO_2e emissions by 2030, while using the Madison Service Sector growth rate causes future CO_2 emissions to nearly double by 2030, increasing from 4,672,689 MT CO_2e to 8,003,217 MT CO_2e by 2030, and more than tripling to 14,633,136 MT CO_2e by 2050. Although EIA-derived growth rates are not necessarily specific for projected growth in Madison, WI, the projected growth rates determined by the EIA are disaggregated into detailed items and thus provide a best estimate of anticipated changes in electricity consumption, energy intensity, VMT growth, and more.

Using the 2012 emission inventory resulted in significantly greater present-day (2014) emissions that are projected to nearly double using Madison Service Sector growth rates, from approximately 5.6 million MT emitted in 2014 to approximately 9.9 million MT of CO_2e emitted by 2030 and 18 million MT CO_2e emitted in 2050. Our 2014 inventory presented in this report states total annual emissions were 4,672,869 MT CO_2e and, with future growth emissions, are expected to reach over 7 million MT by 2050 (Figure 4). Analysis from previous sections indicate that projections using the 2012 data will likely be inaccurate. Therefore, the forecasts presented below and included in the planning modules use the 2014 inventory as the base year with EIA forecasted growth rates through 2040. Forecast growth rates for 2040-2050 are assumed to be the same as the forecasted growth rates from 2035-2040 due to lack of data.

Figure 4 Business as usual forecasted GHG emissions (MT CO_2e) for Madison community using the present inventory and forecast growth rates from EIA and projected growth in Madison population and jobs.

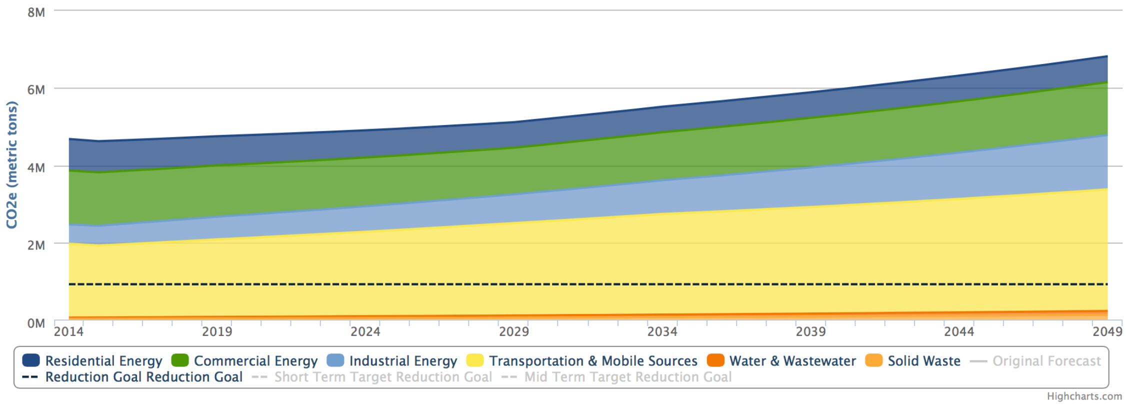


Clean Power Plan Impact on Madison Community Emissions

In anticipation of the EPA's proposed Clean Power Plan, our study chose to use the 2014 inventory forecast using EIA growth rate data along with estimated changes in electricity fuel mix due to the Clean Power Plan (U.S. EPA, 2014). If the Clean Power Plan, which restricts emissions from new and existing coal power plants, were to take effect, emissions from coal-fired power plants in Wisconsin would likely decline by 34% by 2030 (Milwaukee Public Radio, 2015). By modifying the state's current electricity-generating fuel mix and contribution to emissions to include less coal-fired electricity generation and more natural gas- and wind-generated electricity (assuming other fuels like oil and hydropower remained constant), we were able to assess the effect the Clean Power Plan may have on CO_2 emissions in the future. Note that we only assumed changes to electricity generation and not to the separate category of natural gas consumption. Details about these calculations are in Appendix B.

We chose to use the most accurate forecast, which used the 2014 inventory and the EIA-based forecast growth rates. Including carbon intensity changes due to the Clean Power Plan slows emissions growth rate from a BAU projection of 5,505,960 MT of CO_2e in 2030 to 5,182,063 MT of CO_2 by 2030 (Figure 5), a difference of over 300,000 MT introduced from replacing 34% coal with 28% natural gas and 6% wind power. The greatest emissions decreases occur in sectors that consume electricity, most notably residential and commercial. These sectors, with the help of the Clean Power Plan, could see reductions in total emissions between 7.9% and 19%, respectively, by 2030.

Figure 5 Forecasted emissions with Clean Power Plan, based on 2014 inventory base



Planning Modules – *Policy Applications to Madison's Future GHG Emissions*

To help Madison prepare for or prevent changes due to climate change, the Sustainable Madison Committee's plan for "Fostering Environmental, Economic and Social Resilience" outlines ten Sustainability Categories with strategies for addressing emissions reduction and efficient resource use in each category over short-, medium-, and long-term timeframes. The following policy recommendations address not only the sectors that emit the largest amount of GHG in the community, but try to further goals within this sustainability plan. Relevant to this report, the Committee aims to:

- Decrease O_3 precursor pollutants to meet increasingly strict EPA National Ambient Air Quality Standard likely to reach 60 parts per billion by 2016 and eliminate incidences of Clean Air Action days by 2020;
- Reduce CO_2 and CH_4 emissions by 80% based on 2010 baseline emissions by 2050 (as described in the introduction to this report);
- Obtain 25% of electricity, heating, and transportation energy from clean energy sources by 2025;
- Maximize use of alternative transportation through improved marketing strategies, and more generally influence reductions in transportation-related carbon impacts;
- Upgrade existing buildings, equipment, and infrastructure, as well as improve new buildings and development;
- Upgrade energy efficiency and sustainable materials use in low-income housing; and
- Report the carbon footprint to the public, engage the public in energy efficiency and climate change programs, and continue community education and outreach (Sustainable Madison Committee, 2011).

To address each of these concerns, this report focuses on 1) working with the electricity and heat utilities to develop and achieve renewable energy goals; 2) establishing alternative transportation incentives and infrastructure through creating transportation-oriented development (TOD) combined with a bus rapid transit system; and 3) implementing commercial benchmarking to encourage greater efficiency in existing and future buildings. These proposals are also in line with the City of Madison's Program Plan for the Georgetown University Energy Prize. The Energy Prize is part of a nationwide competition between cities to achieve energy reductions, and Madison is one of the semi-finalists. For the competition, the City aims to achieve a 3% annual reduction in energy consumption (resulting in a saving of $10 million) for 2014 until the final award decision is made in 2016 (City of Madison, 2014). More information on the Georgetown University Energy Prize can be found at guep.org.

Strategy 1: Achieving 25% Renewable Electricity Use by 2025

The state of Wisconsin has a renewable portfolio standard of achieving 10% renewable electricity by 2015, which was reached in 2013 (Public Service Commission of Wisconsin 2013; Atkin 2014). Given that a 2013 bill to raise the standard to 30% by 2030 failed to pass in the state legislature (*2013 Wisconsin Assembly Bill 876*, 2013), however, and with the current PSC's acceptance of new utility rates that many argue disincentivize energy saving and renewable use,

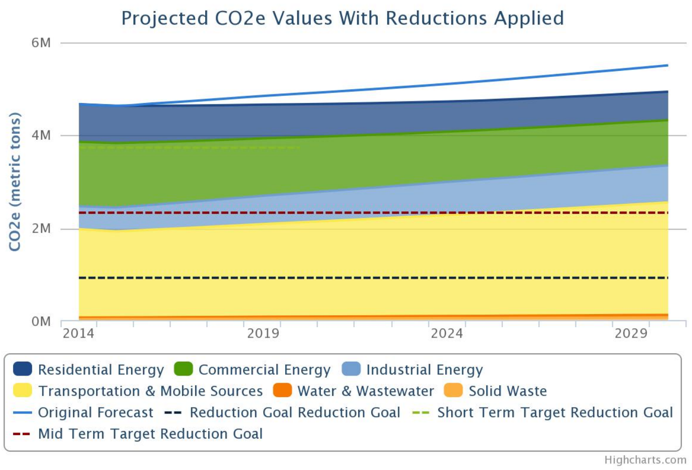


Figure 6 Emissions reduction from 25% renewable electricity sources by 2025

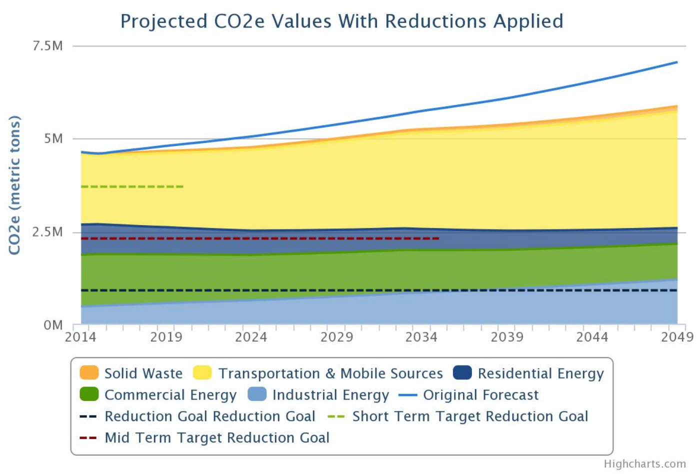


Figure 7 Emissions reduction from 100% renewable electricity by 2050

Madison will likely to need to develop its own approach for meeting the Sustainable Madison Committee's goals of 25% renewable energy by 2025.

The following are three possible approaches available to the City to accomplish this, ranging from informal and less time- and resource-intensive "Community Conversations" to develop shared values and cooperation with MG&E, to a more formal memorandum of understanding, to the most intensive and serious, municipalization of the utility. Options are explained in greater detail in Appendix C.

Implications for Madison

We modeled the impact a memorandum of understanding with MG&E and Alliant Energy or municipalization could have on emissions reductions if Madison was able to use either to achieve the Sustainable Madison Committee's goal of 25% of electricity from renewables by 2025, as well as what the total impact could be if Madison was able to increase that percentage each year after 2025 to achieve 100% renewable electricity by 2050. By 2025, using 25 % renewable energy for electricity would save a total of 276,006 MT CO_2e over nine years (Figure 6). By 2050, using 100% renewable energy for electricity would save a total of 1,284,945 MT CO_2e over 34 years (Figure 7; Table 9). Methods and further analysis are in Appendix C.

Total Emission Reduction by 2025	MT CO_2e
Residential	-75919
Commercial	-165843
Industrial	-43823
Total	**-285585**

Total Emission Reduction by 2050	MT CO_2e
Residential	-290662
Commercial	-722991
Industrial	-280871
Total	**-1294524**

Table 9 Total emission reduction from achieving 25% renewable electricity by 2025 and 100% by 2050

Strategy 2: Transit Oriented Development in Bus Rapid Transit Shed

Transportation has the largest emissions in the 2014 Madison GHG emission inventory, contributing 41% of the total emissions. The 2012 Madison GHG emission inventory calculated the impact of a potential Bus Rapid Transit (BRT) system in Madison to reduce emissions from this sector (Anderson et al., 2014). If the BRT system is built, and if transit oriented development (TOD) is encouraged for higher density commercial and residential centers near proposed transit corridors, particularly around key BRT stations as shown in Appendix D, then this could encourage transit ridership and reduce the use of personal automobiles. We analyze the impact of compact, walkable neighborhood development around the transit corridor as a way to reduce transportation emissions.

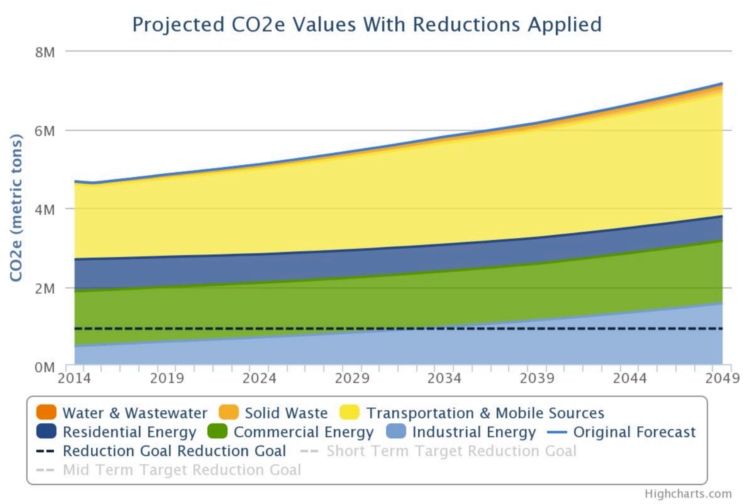


Figure 8 Reductions of GHG emissions due to transit-oriented development are minimal from implementation through 2050.

In Dane County, 62,000 new households are expected between 2010 and 2035. There is a demand for 44,640 new households in walkable, mixed-use (residential and commercial) places in Dane County. If TOD is implemented in the BRT shed (defined as the half-mile radius of 54 key BRT stations identified), 7,200 homes could be added in this shed due to TOD and served by the BRT system by 2035. This is expected to provide a total VMT savings of 14,277,600 miles according to a report on the future of Madison's walkable, transit-supported neighborhood development (Lagro et al., 2013).

We used this estimate to calculate the GHG reduction due to the full implementation of TOD in the BRT shed by 2035. Unfortunately, the impact of this strategy is very small. Assuming that BRT is built and TOD is implemented starting in 2016, CO_2e emissions slowly decline by a few thousand MT CO_2e annually, reaching a decline of 7,689 MT CO_2e in 2035 and 7,765 MT CO_2e by 2050 when compared to the base case. Changes in emissions beyond 2035 are not evaluated because it is difficult to know the continued impact TOD will have on Madison's GHG emissions when coupled with further population and job growth. BAU emissions from transportation are 3,123,722 MT of CO_2e in 2050. By 2050, a TOD strategy will only contribute to a reduction of less than half of a percent of 2050 BAU emissions from Transportation and marginally overall.

Strategy 3: Residential Benchmarking

The City of Madison submitted their plan for the Georgetown University Energy Prize (GUEP) competition in November of 2014. The plan serves as a trajectory for reducing energy consumption in residential, municipal, and K-12 buildings across the community. Through the implementation of this plan, the City of Madison will achieve 3% annual reduction in energy use, or approximately 445.5 M kBTU.

Within the City of Madison's GUEP submission, they proposed to build a full-service retrofit program to reduce residential energy consumption. Specific strategies of the program include: 1) provide a single point of contact; 2) offer energy assessment; 3) access to contractor and quality control; 4) assistance with rebates and incentives; 5) include financing partners and options; 6) focus on deep savings measures and non-energy benefits.

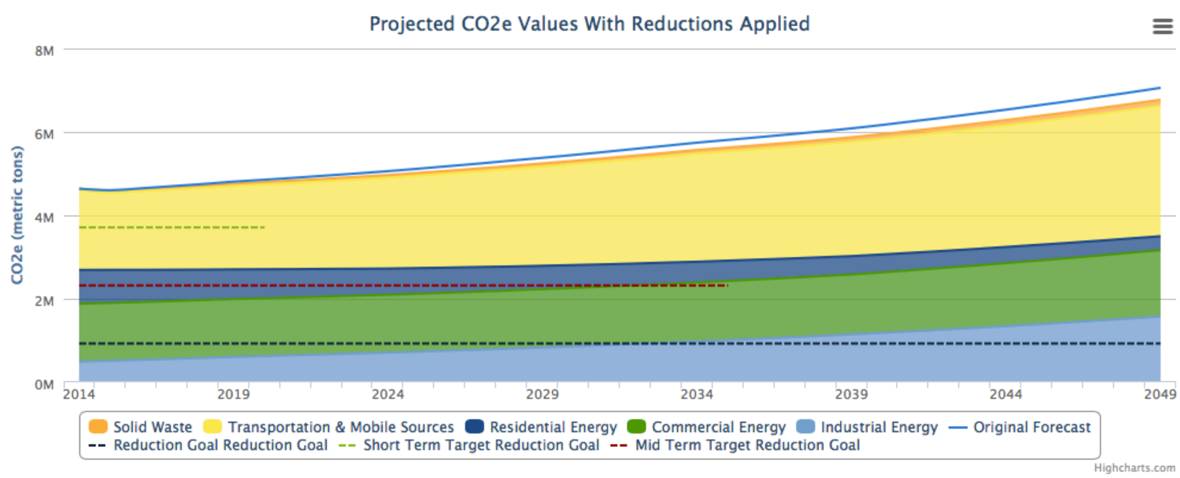
Madison City Council had considered implementing a benchmarking ordinance requiring owners of large commercial and apartment buildings to publicly report energy use. However, the Council postponed the decision in 2014 after the Madison Chamber of Commerce and development-focused organizations opposed the proposal. The Council put together a committee of real estate representatives and energy conservation experts to study additional options for achieving the energy-reduction and cost-saving goals of benchmarking. The GHG emission inventory report of 2012 implemented commercial benchmarking strategies and assessed the potential benefits of commercial benchmarking. Here we present an analysis of residential benchmarking and its impact on Madison community GHG emissions.

The proposed retrofit program is consistent with the benchmarking ordinance of commercial buildings, but with a focus on residential sectors. The City of Madison anticipates a 1.5% penetration rate across single-family homes and a 5% penetration rate across multifamily units. The total energy savings for retrofit and other capital improvements to the building stock is about 38,592,979 kBTU. The annual energy savings generated by the City's strategy will achieve 114,840,602 kBTU. Under existing residential program and efforts, electricity occupies 22% of the total residential energy consumption and natural gas occupies 78%. We assume the achieved energy savings will be distributed between electricity and natural gas following the existing proportion. Thus, annual energy savings for natural gas are 89,575,669 kBTU (89, 575.669 MBTU) and the energy savings for electricity are 25,264, 941 kBTU (25,264.941 MBTU).

The energy savings will continue to rise after the competition with the long-lasting physical building improvements continuing to save energy for building owners and occupants. The strategy is designed to develop a longer-term approach to engage residential building owners over time and energy savings will be cumulative. In this report, we assume the effective useful life will continue after 2050 to correspond with Madison's target GHG reduction goals.

Based on the expected energy savings by implementing residential benchmarking, the total resulting GHG emission reduction annually will be 152,912 MT CO_2e by 2050. By 2030, the annual GHG emission reduction from electricity alone will be 76,704 MT CO_2e, which is 1.05% of the total residential GHG emission from electricity (7,618,819 MT CO_2e). The annual GHG emission reduction from natural gas is 76,208 MT CO_2e, which is 1.52% of the total residential GHG emission reduction (5,001,165 MT CO_2e). By 2050, the annual GHG emission reduction from residential benchmarking is expected to reach 317,760 CO_2e MT, which is about 1.3% of the total residential GHG emission (24,374,521 MT CO_2e). As shown in Figure 9, the emission reductions from the proposed program only is small. Since the proposed plan has a cumulative impact, however, it is expected that the proposed plan will have long-term impact on emission reduction.

Figure 9: Estimated reduction in GHG emissions from 2014 to 2050 from residential benchmarking



Reduction Strategy 4: Combined Impact of Renewables, Transit-Oriented Development, and Residential Benchmarking

Since individual reduction strategies evaluated potential reductions from individual emission sectors, we present a fourth strategy incorporating all of the sector reductions combined. With all of the reduction strategies combined, annual GHG emissions in 2050 are reduced by 1.2 million MT of CO_2e (Figure 10). Although this is a 17.3% reduction from the BAU emissions scenario, Madison will still be emitting more than 5 million more MT CO_2e in 2050 than their 80% GHG reduction target. Transportation emissions are identified as the problem sector, and significant advances in reducing emissions from personal and transit vehicles is necessary if Madison wants to dramatically cut their future emissions.

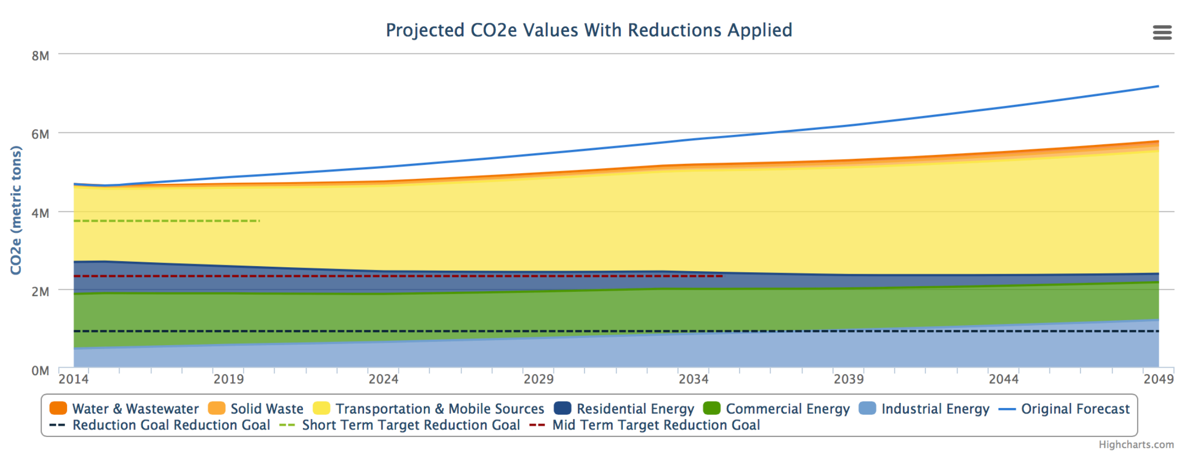


Figure 10 GHG Emissions forecast to 2050 applying all of the reduction strategies.

Impacts of Emissions on Madison Community

Climate change and GHG emissions are changing the planet, and implications of climate change on our weather, ecosystems, and air quality are not to be ignored (U.S. Global Change Research Program, 2014). In the future, the city of Madison can expect to experience dramatically different temperature, precipitation, and living conditions overall from those of today.

During the period of 1950-2006, summer nighttime minimum temperatures across Wisconsin warmed more dramatically than daytime temperatures. Future projections indicate past trends will continue and that by mid-century average annual temperatures in Wisconsin will increase by 6 to 7 °F (Figure 11), with the greatest change in temperature occurring in the winter (Wisconsin Initiative on Climate Change Impacts, 2011). Winter temperatures are projected to warm the most, while summer temperature will warm the least, however the number of days with maximum daytime temperatures above 90 °F are projected to increase. Precipitation is expected to be in the form of frequent, large rainfall events, with more rain and freezing rain in the winter due to warming temperatures. Warmer temperatures and increased precipitation will lead to continued changes in ice cover, wetlands, and agricultural runoff (Wisconsin Initiative on Climate Change Impacts, 2011).

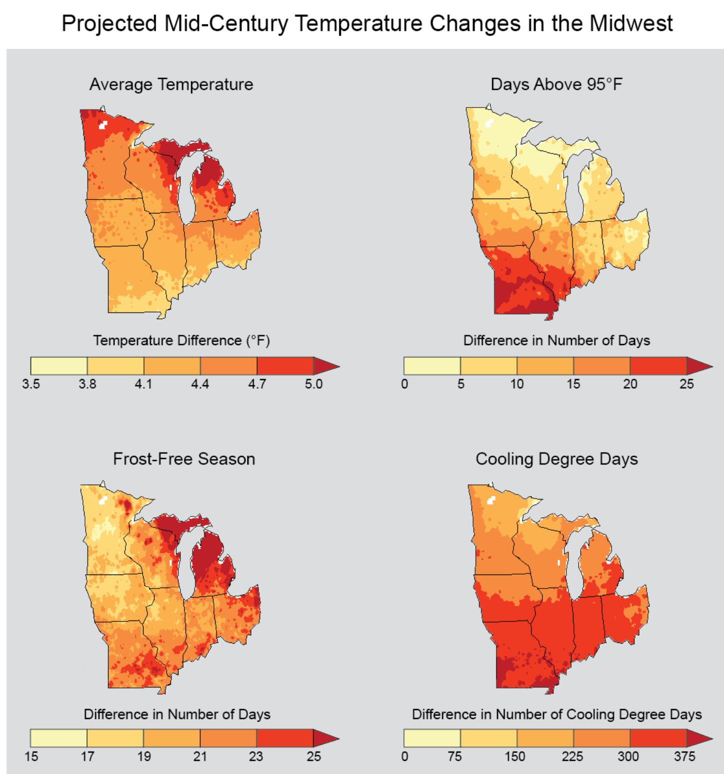


Figure 11: Projected future average annual temperatures. Source: National Climate Assessment Report 2014.

Air Quality in Madison

The U.S. Environmental Protection Agency (EPA) regulates six criteria pollutants deemed harmful to human health and well-being. The EPA sets concentration standards and enforces them under the National Ambient Air Quality Standards (NAAQS). Counties that experience concentrations above the standard are subject to additional pollution reduction procedures including vehicle emissions testing and further installation of technologies to remove pollution from smokestacks. In Madison, four of the six pollutants—sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), and carbon monoxide (CO)—remain below the NAAQS threshold; this trend is expected to continue with advanced technology applications. However, two pollutants remain problematic for Madison and exceed the NAAQS up to several days out of the year: Ozone and fine particulate matter Ozone (O_3)—a gas formed from the reactions of nitrogen oxides (NO_X, a combination of NO_2 and other oxides of nitrogen) and volatile organic compounds (VOCs)—and fine particulate matter ($PM_{2.5}$)—composed of suspended liquid and solids that are both directly emitted and formed from oxidation reactions of emitted gases—both continue to be recorded by ground-level monitors in the Madison area. To meet the NAAQS, concentrations of O_3 must remain below 75 parts per billion (ppb) [2] and $PM_{2.5}$ must remain below an annual average of 12 micrograms per cubic meter ($\mu g/m^3$) and a daily average of 35 $\mu g/m^3$ [3].

Two ground-level monitors track $PM_{2.5}$ concentrations in Madison: 2302 Hoard Street on the east side and 2557 University Avenue near the University of Wisconsin—Madison Hospital. Concentrations at these monitors show a continuous downward trend in annual averaged $PM_{2.5}$ concentrations (Figure 12), most likely due to technological improvements, as consumption and population growth remain positive. $PM_{2.5}$ concentrations in Madison are currently well below the EPA standard. Should the particulate standard be reduced, Madison will still be able to meet the EPA requirements.

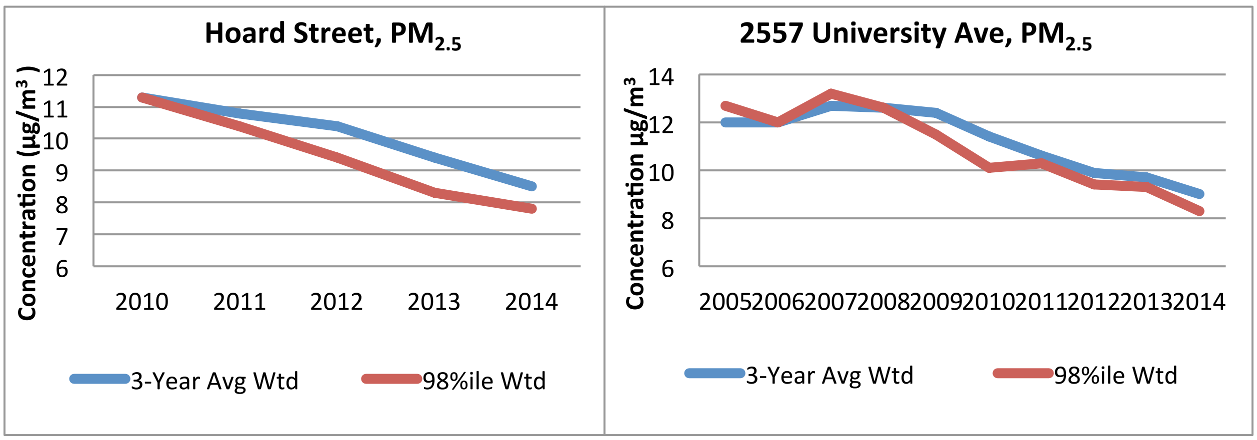


Figure 12 Ground observations of $PM_{2.5}$ at Hoard Street and at University Avenue.

Historical monitoring of these pollutants in Madison show that in addition to $PM_{2.5}$, O_3 concentrations remain well below the current NAAQS as well. Several O_3 monitors in Madison have been taken offline in the past few years, though one still exists at 2302 Hoard Street on the east side of Madison (Figure 13). This location has been recording ground-level O_3 concentrations since 2005. Since then, the 4^{th} highest maximum daily 8-hour average concentrations have fluctuated between 60 ppb and 80 ppb, but 3-year averages consistently remain below the NAAQS of 75 ppb.

However, updates to the NAAQS based on health implications of short- and long-term exposure to O_3 may result in stricter air quality regulations enforced by the EPA. The Obama Administration has mentioned lowering the O_3 standard to 70 ppb or even 65 ppb—standards Madison may have problems meeting. The reduction strategies presented later in this report have

[2] The O_3 NAAQS states that the 4^{th} highest maximum daily 8-hour average averaged over 3 years needs to remain below 75 ppb. This allows room for exceedancdes due to upwind pollution or exceptional pollution events.
[3] The $PM_{2.5}$ NAAQS states that the annual mean *or* the 98^{th} percentile averaged over the previous three years cannot exceed either the annual (12 ug/m^3) or daily (35 mg/m^3) standard. For more information, see http://www.epa.gov/air/criteria.html#3.

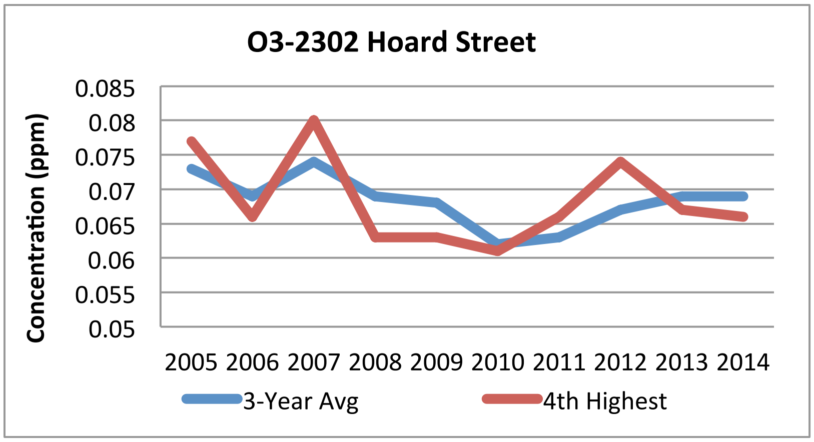


Figure 13 Ground observations of O_3 at the Hoard Street monitoring location.

implications not only for climate change, but for reducing O_3 precursor emissions of NO_X and VOCs from electricity, natural gas, and transportation as well.

Climate Change Implications and the Madison Community

Climate change will likely bring direct and indirect negative health implications to the people of the Madison community. Direct impacts like heat waves, droughts, excessive precipitation, and flooding, can cause discomfort or death. Indirect impacts include things such as changes to air quality, water borne and vector borne diseases, migration to Madison from coastal areas, and food supply disruptions in the Madison community that may disrupt or damage livelihood.

Anthropogenic climate change has introduced significant quantities of GHG into the atmosphere, which act to modify weather conditions from typical to extreme. The most recent and close to home example of extreme weather and the repercussions that resulted was from 2007-2008 when Wisconsin experienced an intense drought through most of the summer. August brought torrential downpours, which the dried and hardened ground could not absorb and thus flooded sewer drainage systems. This was followed by extreme snowfall that winter, 101 inches in total, oversaturating the ground and leading to further flooding. With climate change, increasing instances of abnormal weather patterns such as these are expected to occur.

Climate change indirectly influences a variety of things including food production, atmospheric chemistry of air pollution, and changes in the spread of water- and vector-borne diseases. For instance:

- Changes to the growing season in an altered climate will alter the current agricultural and food production seasons. Further, higher concentrations of CO_2 and other pollutants negatively impact crop yield (United States Department of Agriculture, 2013).
- Atmospheric chemistry is affected by meteorology, including temperature, water vapor content, and wind speed. Increased concentrations of different chemicals can also impact air pollution formation and destruction. Nonlinearities in atmospheric chemistry can lead to more pollution in rural areas and less in urban areas.
- Biogenic emissions from plants and trees are temperature-dependent, and emissions of volatile organic compounds (VOCs) contribute to both O_3 and $PM_{2.5}$ formation. With increased temperatures, biogenic emissions are expected to cause in increase in regional O_3 and $PM_{2.5}$ (e.g. Steiner, Tonse, Cohen, Goldstein, & Harley, 2006; Wu et al., 2008).
- Increased quantities of anthropogenic emissions from fossil fuel combustion due to population growth and expanded need for air conditioning for cooling purposes are also expected to occur with rising temperatures. Not only would this lead to greater GHG emissions, but emissions of health-damaging pollutants would increase as well.

- Higher temperatures and increased amounts of rainfall influence the development of pathogens in vectors like insects and plants (Gage, Burkot, Eisen, & Hayes, 2008). As such, climate change can increase the footprint of vector-borne diseases, making diseases like malaria easier to spread into Wisconsin.

Logistically, the above-mentioned implications may prove to be challenging to manage. People require food to survive, and changes to the food supply can influence prices as well as availability. Changes in air quality may result in new, local regulations to meet federal standards, such as vehicle emissions testing or increasing taxes or electricity costs to pay for new pollution removal technologies. Finally, increased diseases mean increased amounts of lost work and school days, increased hospital visits, and more.

Year	ER Visits	Hospitalizations
2002	1042	298
2003	1075	314
2004	973	284
2005	903	352
2006	802	278
2007	918	326
2008	911	377
2009	918	362
2010	991	343

Table 10 Annual ER visits and hospitalization rates for asthma in Madison, WI.

The most susceptible people to changes due to climate change are children and the elderly. Extreme temperatures are most harmful to these age groups, and if the elderly are not provided aid in times of extreme heat or large snowfall, they are more likely to be harmed. Indirectly, children and the elderly are also more likely to be harmed than the average person by air pollution. Higher instances of air pollution are associated with more hospital visits and greater rates of asthma and heart conditions (e.g. Delfino, Sioutas, & Malik, 2005; Nowak et al., 1996). Data for Dane County asthma-related emergency room visits and hospitalizations are presented in Table 10. From 2002 through 2010, instances of asthma-related visits and hospitalizations declined corresponding with declines in $PM_{2.5}$ concentrations (Figure 12). Beyond mitigating climate change in Madison, reducing VMT and encouraging active commuting by bike or walking reducing air pollution *and* improves human health (Grabow et al., 2012). Improvements in air quality are linked with improvements to human health, even in Dane County.

When evaluating Madison's contribution to GHG emissions, it is important to include the impact on the people living in the community as well. Although human activities contribute to GHG emissions in Madison, regulations and reduction strategies can help reduce emissions and improve livelihood.

Discussion and Conclusions

Limitations, Recommendations for Future GHG Emission Inventories

As mentioned in previous reports, the fact that each inventory has been done by UW-Madison graduate students means information and methodology can vary substantially year to year, and detailed methods are sometimes lost due to student turnover. The switch to using the ClearPath software for the 2012 and subsequent inventories created the opportunity for greater consistency but also means information from the 2010 inventory is less accessible because it uses different source information and methods than the more recent reports. To address these inconsistencies and limitations in comparability between inventories, this section offers information on some of the challenges faced in putting together this assessment and some recommendations that were helpful from previous reports or would have been beneficial for this inventory and could help students or city employees conducting future inventories.

<u>Consider using 2012 or 2014 as the baseline inventory</u>: Given the difference in methods and data inclusion between the 2010 and 2012, and even the 2012 and 2014, inventories, it is likely more accurate to use at least 2012 or 2014 as the baseline year for assessing GHG emission reduction targets. 2010 emission amounts are misleadingly low due to the amount of emission sources left out; 2012 is more encompassing, but has some unusual data including surprisingly low fuel efficiency levels for motor vehicles and limited recorded source information on factors such as airport emissions and landfill data when compared to the present inventory. It is also not clear if the 2012 inventory double-counts electricity and natural gas use from the water utility by including it under both the Water and Wastewater sector and the Commercial Energy sector, which could account for approximately 40,000 extra MT CO_2e included in the 2012 report. 2012 is more complete than 2010, however, and close enough to 2014 methods and results that it could make an effective baseline year if the city wants an earlier starting point than 2014 for comparing emissions reductions. For the aforementioned reasons, we used 2014 and not 2012 as the baseline in our forecasts and planning scenarios.

<u>Continue conducting inventories biennially</u>: Reducing GHG emissions will be less abstract and more rewarding with regular progress measurement. The differences found between 2014 and 2012 emission levels indicate that substantial physical emission reductions can take place in just two years. Keeping track of this progress every other year can help city policy-makers and Sustainability Committee members develop new reduction goals and programs in specific sectors while increasing community support with numbers that show progress and impact. Continuing the inventories every two years will also help institutionalize the measurement and hopefully streamline data collection and evaluation for future reports, reducing the institutional knowledge loss that could worsen if more time passes between each inventory.

<u>Initiative data collection even earlier than assumed (and be persistent):</u> Fortunately, the 2012 inventory recommended this and while we thought we started early we still did not receive a large chunk of data until two weeks before the report deadline. So, to ensure enough time to develop policy recommendations and create forecast and planning modules, we recommend reaching out to agencies and utilities for data as soon as group members know they will be conducting the inventory. For a head start, we recommend going through the 2014 inventory

records in ClearPath and making a list of the contacts as noted in the comment box at the end of each record. Although specific sources might change within each organization, the following agencies and utilities consistently provide the bulk of the data:

Residential, Commercial, and Industrial: MG&E and Alliant Energy
Transportation: Madison Metro Transit and Department of Natural Resources
Water and Wastewater: Madison Water Utility
Solid Waste: City of Madison Engineering Division and Dane County Public Works Solid Waste Division.

<u>Send spreadsheets to agencies and utilities to encourage consistent and more streamline data input:</u> To limit the amount of time spent converting data into the format necessary to input into ClearPath, we recommend creating spreadsheets for each data request and sending that along to the agency or utility contact, asking that they use the spreadsheet for data input if they find it helpful. The spreadsheets from the 2014 inventory are attached at the bottom of the records for each of the sectors and can be easily updated for use in future inventory data collection.

<u>Provide detailed inventory notes and follow consistent labeling between years:</u> While we aimed to keep the same scope as that of the 2012 inventory, source information, calculations, and links would have helped ensure that our methods and data sources were more consistent with those the 2012 report. For this inventory we left detailed information in the "Notes" boxes at the end of each ClearPath inventory record and used consistent labeling for each record. This can help ensure future inventories are more comparable to previous ones and was helpful within our group for keeping track of where each piece of information came from and what each inventory record represented as we each worked on different aspects of the report.

<u>Continue working with UW students:</u> Previous reports recommended creating a staff position responsible for data collection, which could be helpful if Jeanne Hoffman at the city is burnt out from keeping tabs on data collection and ensuring we had all the data we needed as quickly as possible (Thank you, Jeanne!). These inventories provide a fun and beneficial learning experience, however, for graduate students and especially students in capstone courses. We recommend establishing regular connection with the Nelson Institute, Lafollette, or other graduate capstone courses to conduct these inventories every other year. Since one of the more difficult parts of creating this report was keeping the scope from becoming too broad or unwieldy, in off-years groups of students could also work to expand on some of the findings, quality control the data, or provide more detailed policy recommendations made in each inventory. For example, while we were able to include a small section on the co-benefits of decreased O_3 and $PM_{2.5}$ production through increased energy efficiency, health co-benefits could be an entire report on their own.

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Appendix A: Detailed Sector Analysis

Residential, Commercial, and Industrial Heating

While the 2012 inventory included additional non-utility emission sources under the Commercial sector that were not included under 2014 Commercial energy use, such as diesel generators and solid waste combustion, these additions do not fully explain the decrease in 2014 Commercial emissions from 2012 Commercial emissions. With all of these additional sectors except for diesel generation, the 2014 inventory includes these emissions under other major sectors. Aviation gas, for example, is included under the Commercial sector in 2012, yet for 2014 aviation gas is counted as a Transportation emission. Additionally, for solid waste combustion, the 2014 emissions are under "Solid Waste" and "Wastewater" depending on whether they came from combustion of landfill waste or capture of methane from wastewater, respectively. These changes in categorizing sources were made after conferring with ICLEI's ClearPath expert J.R. Killigrew. The only Commercial sector emission category in the 2012 inventory that is not in the 2014 inventory is the 2,141 MT of CO_2e emissions from diesel generators, because this data was not reported by any of the agencies and utilities which provided data. However, this 2,141 MT CO_2e is small compared to the overall GHG reductions of more than one million MT CO_2e measured from 2012 to 2014.

Residential Energy

Residential energy includes electricity, provided by the utilities MG&E and Alliant Energy, and stationary combustion fuels, which, in the case of Madison, is natural gas provided by MG&E. Table A1 shows the amount of energy provided by each utility.

Table A1: Madison Residential Energy Consumption by provider

Residential Energy	
Electricity (MWh)	
MG&E	Alliant
538,419.90	131,049,67
Natural Gas (Therms)	
MG&E	Alliant
60,006,908	N/A

Data was provided by Jesse Shields at MG&E and Bridget Creighton at Alliant Energy when asked for Residential energy use within city limits.

Commercial Energy

Commercial energy includes the same sources and providers as residential energy, with both MG&E and Alliant Energy providing electricity and only MG&E providing natural gas. The Commercial sector continually has the highest or second highest energy consumption. Table A2 shows the total energy provided by each utility.

Commercial Energy	
Electricity (MWh)	
MG&E	Alliant
1,220,261.54	130,819.98
Natural Gas (Therms)	
MG&E	Alliant
74,269,102	N/A

Table A2: Madison Commercial Energy Consumption by provider

Data was provided by Jesse Shields at MG&E and Bridget Creighton at Alliant Energy when asked for Commercial energy use within city limits.

Industrial Energy

Industrial energy use is generally less than that of the Residential and Commercial sectors, likely due to less Industrial space than Residential and Commercial space in Madison. As with Residential and Commercial energy, MG&E and Alliant Energy provide electricity and MG&E provides natural gas. Table A3 shows the total energy provided by each.

Table A3: Madison Industrial Energy Consumption by provider

Industrial Energy	
Electricity (MWh)	
MG&E	Alliant
217,530.64	108,948.95
Natural Gas (Therms)	
MG&E	Alliant
54,087,926	N/A

Data was provided by Jesse Shields at MG&E and Bridget Creighton at Alliant Energy when asked for Industrial energy use within city limits.

Transportation and Mobile Sources

We included emissions from On-Road Transportation, Public Transit, and Off-Road Mobile Sources. Table A4 provides specific emission sources under each of the three categories and the comparison between 2012 and 2014 Transportation and Mobile sources inventory.

Table A4 Comparison between 2012 and 2014 Transportation inventory

	Source/Activity	2012 (MT CO_2e)	2014 (MT CO_2e)
Emissions from Public transit	Madison Metro Public Transit buses	12493	12904
	Madison Metro Paratransit buses	368	363
	Madison Metro Contracted Service – Total	1262	1451
	Total	**14123**	**14718**
Emissions from On Road Transportation	Urban On-Road Transportation - VMT Gasoline	1301965	1241243
	Urban On-Road Transportation - VMT Diesel	461231	416124
	Urban On-Road Transportation - VMT Diesel - Light Commercial Truck	30392	10020
	Urban On-Road Transportation - VMT Gasoline - Light Commercial Truck	174222	135092
	On-Road E85 Passenger Cars and Light trucks	No Data	216
	Total	**1967810**	**1794126**
Emissions from Off Road mobile sources	Airport Off road mobile source	5908	53659
	Boats in Dane County	30886	30886
	Total	**36794**	**84545**
	All Total	**2018727**	**1891938**

For Public Transit and On-Road transportation emission calculation we used the "VMT & MPG" method in ClearPath to calculate emissions from each source. This method required VMT as well as vehicle characterization, such as the average on-road fuel economy and the CH_4 and N_2O

emission rates of the vehicles operating in the community for the inventory year. This information was saved as a Factor Set and applied for calculating CO_2e emissions.

For air travel emission calculations, ClearPath protocol suggests to only include emissions from aircraft/Auxiliary Power Units (APU), aircraft ground support equipment (GSE), and airport

Ownership	Sources	MT CO_2e
Airport owned	Dane county regional airport Fleet Vehicles	280
Airport/Tenant Owned	Aircraft – Above Ground Level (up to 3,000 feet)	15,961
	Aircraft – APU	1,830
	Aircraft – Cruise (above 3,000 feet)	76,293
	Aircraft - Engine Startup	309
	Aircraft – Taxi	10,300
	GSE – Deicing Operations	129
	GSE – Other Tenants/Activities	1,454
	GSE – Wisconsin Aviation	762
	Total	**107,318**

Table A5: Emissions from different sources at the Dane County Regional Airport. Source: 2012 Dane County Regional Airport Sustainability Plan

fleet vehicles and to exclude emissions from stationary sources, purchased electrical consumption, and ground access vehicles as these are captured elsewhere in the community inventory. Emissions as shown in Table A5, as provided by 2012 Dane County Regional Airport Sustainability Plan (the most recent data available), are taken into account to calculate transportation emission from air travel

The calculation below was used to attribute air travel emissions to the Madison community, following ICLEI protocol (TR.6.D. ICLEI Method). According to Brent S. McHenry, Director of Marketing & Communications of Dane County Regional Airport, 50% of passengers travelling through the airport are from the Madison community:

Annual CO_2e emission= [No. of passengers travelling to or from the Madison community that use the airport / Total no. of passengers that use the airport]*CO_2e inventory reflecting only aircraft and APU, GSE and airport fleet vehicles
=[50% of 1615841/1615841]*107318=53659 MT of CO_2e

Water and Wastewater

For this sector, we calculated emissions from three categories:

- Wastewater Treatment Energy Use to account for emissions from grid electricity and natural gas used in Madison Metropolitan Sewerage District (MMSD) wastewater treatment process.
- Combustion of Digester Gas, which involves further treatment of organic solids from the wastewater treatment process in an anaerobic tank (digester) that produces a gas that is captured and burned to generate energy.

- Potable Water Supply to account for emissions from grid electricity and natural gas use in the supply and distribution of potable water by Madison Water Utility. Electricity use was already included as Commercial energy use in the data supplied by MG&E and thus was not counted under the Water sector. Madison Water Utility does not use natural gas in their operations to supply water.

Source	2012(MT CO_2e)	2014 (MT CO_2e)
Emissions from Wastewater Treatment Energy Use	25,992	18,546
Emissions from the Combustion of Digester Gas	45	45
Emissions from the Supply of Potable Water	15,444	14,085
Total	**41,481**	**32,676**

Table A6 Comparison of 2012 and 2014 Water and Wastewater inventory

Emissions from following seven categories are not included in the 2014 Water and Wastewater inventory:

- Fugitive Emissions from Septic Systems to account for methane emissions from portions of your community utilizing individual septic systems for wastewater treatment. MMSD does not measure this.
- Emissions from Combustion of Biosolids and Sludge to account for emissions from the combustion of biosolids. MMSD does not burn biosolids or sludge.
- Process Emissions from Wastewater Treatment Lagoons to account for methane emissions from wastewater treatment lagoons—centralized system that may have solid processing like anaerobic digestion. MMSD does not measure this.
- Nitrification/Denitrification Process N_2O Emissions from Wastewater Treatment to account for N_2O emissions from centralized wastewater treatment facilities and covers both cases of whether the facility does or does not employ Nitrification/Denitrification. This is irrelevant to MMSD.
- Process N_2O from Effluent Discharge to Rivers and Estuaries to account for N_2O emissions from effluent discharge to rivers and estuaries. This is irrelevant to MMSD.
- Emissions from the Incomplete Combustion of Digester Gas to account for emissions that result from the incomplete combustion of Digester Gas from an open flare. MMSD produces 800,000 cubic feet of digester gas each day, which it uses as fuel in three engines: two of them turn generators and one of them turns a blower. MMSD uses digester gas as a fuel in both hot water and steam boilers. MMSD only burn gas in the flare if it cannot use it in the engines and boilers when engines are out of service for maintenance. In 2014, 21% of the gas was used as fuel in the boilers, 78% was used as fuel in the engines, and 2% was flared. In the 2014 inventory, we have not considered emission due to incomplete combustion of this 2% digester gas flaring.
- CO_2 Emissions from the Use of Fossil Fuel Derived Methanol to account for anthropogenic CO_2 emissions from the use of fossil-fuel-derived methanol used in biological nitrogen removal in a wastewater treatment plant. MMSD does not use methanol.

Solid Waste

The Solid Waste sector includes landfill emissions, which have two parts: emission from In-Jurisdiction Landfills and emission from Waste Generation and Disposition for in-boundary or outside-boundary landfills. Emission from In-Jurisdiction Landfills accounts for emissions from all waste disposed of in in-boundary landfills (i.e. emissions from landfills inside the Madison boundaries) regardless of where the waste was generated (i.e. whether it was inside Madison community or outside) and who generated the waste (i.e. whether within the Madison community or not). This category estimates inventory year emissions associated with waste generated and disposed in previous years following the inventory protocol method SW.1.

Madison currently operates one open landfill inside its boundaries: the Dane County Rodefeld Landfill that is in operation since 1984. Madison also supervises the monitoring, operation, and maintenance of five closed landfills inside its boundaries: Mineral Point Landfill, Greentree Landfill, Olin Landfill, Demetral Landfill and Sycamore Landfill. We accounted for emissions from both the open and retired landfills. Currently, waste generated by the Madison community is disposed of in Dane county Rodefeld Landfill, which is in located inside the Madison community boundary.

Emission from Waste Generation accounts for emissions resulting from waste generated and disposed of by the community regardless of where the waste is disposed—whether it is in landfill inside the community boundary or outside. This category estimates future emissions resulting from solid waste generated and deposited in an in boundary or out of boundary landfill in the inventory year following the inventory protocol method SW.4.

Inventory protocol outlines emission calculations from various categories within the solid waste sector. In this inventory, however, we only consider landfill emissions. We do not include combustion emission from burning municipal solid waste because Madison does not have an in-jurisdiction municipal solid waste combustion facility and it does not combust community-generated waste outside the city boundary (communication with Jeanne Hoffmann, 2015). Since the waste generated in Madison community is not delivered to facilities outside the community's boundaries, transport emissions and process emissions associated with landfilling of the community generated waste in not included in the inventory. The protocol advises not to add collection emissions because of possibility of double counting. Further, ClearPath protocol does not yet have a method for estimating fugitive emission from composting, hence the collection emission and emission from composting are also excluded in this inventory.

Rodefeld Landfill reported a fugitive CO_2 emission of 2733 MT CO_2. However, CO_2 produced by landfills is considered biogenic in ClearPath and thus should not be counted in the inventory. The landfill also combusts the CH_4 captured through methane collection system to generate electricity, which MG&E buys and supplies to Madison. The process releases 15,331 MT CO_2. CO_2 from combusted landfill gas is also classified as biogenic and hence is not counted. 85% of the total CH_4 generated in the landfill is captured and sent to generators with approximately 1% escaping (1,411 MT CO_2e). This escaped 1% should be included in the emissions inventory, but because ClearPath does not have an activity calculator to measure this, it is not included in the 2014 inventory.

Table A7: Comparison between 2012 and 2014 Solid Waste emissions

Source/Activity	2012 (MT CO_2e)	2014 (MT CO_2e)
Emission from In jurisdiction landfills- 5 Retired Landfills	14,300	13,275
Emission from In Jurisdiction landfill- Open New Dane County Rodefeld Landfill	No data	24,900
Emission from Waste generation	16,651	4,464
Total	**30,951**	**42,639**

Appendix B: Forecast Data Collection and Clean Power Plan Estimates

Several forecasts were conducted in ClearPath for comparison in this report. Inputs into the forecasts included forecasted growth rates and the chosen GHG emissions inventory. Specific Madison community growth rate information for households, population, and jobs were provided by Bill Schaefer and Jeffrey Greger of the Madison Area Transportation Planning Board. Additional forecast growth rates were calculated from U.S. Energy Information Administration Annual Energy Outlook 2014. Data for future growth rates were projected out to the year 2040. For our forecasts out to 2050, we applied the same growth rate from 2035-2039 through 2050, assuming no changes in growth rate from 2035 through 2050.

A sensitivity forecast using information from a report by the Wisconsin Public Radio analyze potential changes in electricity generation fuel supply due to the EPA's proposed Clean Power Plan. This report stated estimates that impacts of the Clean Power Plan will reduce coal-fired electricity generation by 34% by the year 2030. For this sensitivity forecast, we assume that the Clean Power Plan will take effect starting in 2016 and coal-fired electricity generation will decline linearly through 2030. Assumed changes to fuel mix include the following:

- Coal fired electricity generation declines;
- Natural gas electricity generation increases;
- Wind-generated electricity increases; and
- Oil, hydro, and solar generated electricity remain constant.

We make these assumptions based off of the national state of electricity generation fuels, where oil is sparingly used for electricity, renewables are anticipating to increase, and natural gas prices are cheaper relative to coal. Wisconsin does not have the capacity to generate significant amounts of hydro power, and solar generated electricity is currently 0% of the fuel mix, therefore we assume these remain constant.

Table 14 shows the changes made from the current fuel mix to assess the influence of the Clean Power Plan. Coal generation reduces by 34% according to the Wisconsin Public Radio report, and assuming electricity generation does not decline, the loss of coal must be applied elsewhere. We distribute the 34% by weighting the contribution to electricity generation from natural gas and wind, and we find that natural gas electricity generation increased from 8.5% to 36.9% and wind generated electricity increases from 1.7% to 7.3%.

Resources	Present	2030 with Clean Power Plan
Coal	62.5%	**28.5%**
Oil	1.1%	1.1%
Natural Gas	8.5%	**36.9%**
Biomass	2.2%	2.2%
Hydropower	3.3%	3.3%
Nuclear	20.7%	20.7%
Wind	1.7%	**7.3%**
Solar	0%	0%

Table B1 Breakdown of electricity sources and fuel mix for present conditions and in 2030 under the Clean Power Plan

To determine the change in emissions based on this change in electricity generation fuel mix, we calculate a negative annual carbon intensity growth rate of 0.0206 by taking the percent change of greenhouse gas emissions (CO_2, CH_4, N_2O)

between the current and future estimated fuel mixes, where coal, oil, and natural gas contribute to GHG emissions.

Appendix C: Increased Renewable Electricity Planning Scenario

Three options for achieving increased renewable electricity are: 1) Informal utility cooperation through "Community Conversations", 2) A Memorandum of Understanding, and 3) Municipalization.

Community Conversations

MG&E plans to begin "Community Conversations" to facilitate better input and relations between the city and the utility. This could offer an avenue for the community to discuss setting an informal renewable energy goal with MG&E. Because MG&E just unveiled the program, it is unclear how effective it will be at creating a dialogue between community stakeholders, the city, and MG&E. Ideally, it could allow each participant to help shape an energy savings and renewable energy plan that addresses both City goals of more sustainable energy use as well as MG&E's obligations to its shareholders. Because the program is ultimately run by MG&E, however, its effectiveness will depend on what level of participation and understanding the utility expects and facilitates. What each participant expects from the conversations should be laid out in the early stages to ensure those goals are structured into the meetings. Since this program is still in its initial stages, however, and its structure has not been completely revealed by MG&E, this report does not include an in-depth evaluation of the potential effectiveness of "Community Conversations" for setting and reaching renewable energy goals.

Memorandum of Understanding

The second option is creating a formal memorandum of understanding with the utilities to establish energy goals. Minneapolis, MN just established such a memorandum in 2014 outlining the "Clean Energy Partnership" between the City and its two largest utilities, Xcel Energy and CenterPoint Energy (American Council for an Energy-Efficient Economy 2014; City of Minneapolis and Xcel Energy 2014). The goal of the partnership is to use cooperation between the parties to achieve the City's energy goals and reduce GHG emissions by 80% of 2006 baseline by 2050, similar to Madison's GHG reduction targets. The City negotiated the memorandum partly by using its franchise agreement that allows the utility right-of-way on public property in order to do the necessary infrastructure building and maintenance to supply electricity and heat to customers. It essentially builds off of the franchise agreement to include an "active role" of the utilities in reaching Minneapolis' energy goals (American Council for an Energy-Efficient Economy, 2014; City of Minneapolis, 2014).

Together, the City, Xcel, and CenterPoint "intend jointly and cooperatively to study, prioritize, plan, coordinate, implement as reasonably as possible and permitted, market, track, and report progress on clean energy activities in the City," to support the City's sustainable energy plans. Goals outlined in the memorandum include increasing electricity from local and renewable energy sources combined with "significant energy efficiency improvements" in all sectors. To accomplish this, the memorandum also creates a board made up of officials appointed by each participating party (elected city officials and designated senior company officials), with an equal number of appointees for each party. The board will develop a biennial work plan, meet at least quarterly, and provide the necessary staff and resources to complete the work plan. They will also have advisors and advocates to provide information to the board members and will include an appointed member representing "critical communities" to a standing advisory committee. The advisory committee will review and provide feedback on each work plan and performance reports, research additional special initiatives, and provide outreach as the Board requests. No authorization is needed from any other governmental body besides the City Council to carry out the agreement, and it does not create a "partnership" in the legal sense, as each party is responsible for its own obligations.

Because of this structure, the actual work plan outlining how to best meet this overall goal of more sustainable energy consumption is left open to the participating members and can be flexible to change as needed. The memorandum did outline options to consider for inclusion on the work plans, however, including numerous plans that match Sustainable Madison's own goals:

- Reduce energy costs to businesses and the public through energy efficiency programs;
- Address equity through energy efficiency programs for multi-family buildings;
- Meet renewable energy usage goals through different transportation and electricity options, especially by "piloting innovative options";
- Increase job and economic development; and
- Understand the strengths and weaknesses of the grid, including expected investments and other changes needed for more distributed or different energy sources.

Minneapolis is the first city in the nation to develop such an agreement, so its effectiveness is unknown. Combining the expertise, values, and resources of the utilities and the city appears to provide a way to fully address many of the goals listed above, while ensuring each party benefits socially and economically. While Minneapolis is slightly larger than Madison, at 400,000 people, and has more political support for renewable energy at the state level in Minnesota than Wisconsin currently does, negotiating through a franchise agreement could help Madison accomplish a similar memorandum of understanding with MG&E and Alliant, especially if MG&E has already begun the process to engage more with the community. Such an agreement also does not need to exclude the possibility of continued Community Conversations, if those have proven useful to both the utility and the community.

Municipalization

The pressure for Minneapolis' utilities to agree to the memorandum was also due to stakeholder groups pushing for including municipalization of the utilities on the upcoming election ballot. As a foil to Minneapolis' memorandum of understanding, Boulder, CO (which is also serviced by Xcel Energy) decided to pursue municipalization after years of limited cooperation from Xcel. One city council member stated that they had "reached out to Xcel Energy at least 50 times in public meetings," with the public record showing the city's efforts to create an agreement with Xcel since at least 2010, with earlier discussions on the issue dating back to 2005. While still leaving the door open to a possible agreement with Xcel if the company responds, Boulder finally decided to pursue municipalization in 2014.

Ballot measures were approved in 2011 and 2013, in which voters expressed support for exploring more options within the city to "deliver clean, reliable, low-cost, local energy" (City of Boulder, 2015a). With that mandate, the city council developed the "Energy Future Transition Work Plan" outlining the possibilities for accomplishing municipalization (Brautigam, Carr, & Bailey, 2014). In 2014, the city adopted an ordinance to create a municipal electric utility and filed a "condemnation petition" with the Boulder District Court seeking allowance to purchase portions of the electricity infrastructure Xcel owns.

Beyond pushing a utility business out of the city, the downsides to municipalization are the high costs and increased staffing requirements for acquiring and running the utility infrastructure. Boulder created a spreadsheet to model the cash flow expected at different stages of the process based on data from national laboratories, publicly available numbers from Xcel, and other utilities' benchmarking data. The modeling took more than six months and involved more than 70 members of the community to establish assumptions and identify different power supply scenarios. The city had not released the model at the time of this report, due to its use of software that is not subject to the Colorado Open Records Act and to concern from the City that releasing the models would give Xcel an "unfair advantage in negotiations and litigation" (City of Boulder, 2015b). Minneapolis did research on what municipalization cost other communities, however, when the city was evaluating it as an option and found that the "estimated initial costs could range from several hundred million dollars to more than a billion dollars" (City of Minneapolis, 2014).

Even if municipalization means that Madison is able to pursue cost-saving efficiency and alternative energy programs by taking control of its own utility, it will take a large upfront investment between acquiring the infrastructure and paying any resulting legal costs through the process. Reaching a memorandum of agreement would be ideal, but the City will have to compare the costs and benefits (in dollars, energy saved, and increased access gained for the community to determine its own energy future) if it chooses to evaluate municipalization as an option. If the city did municipalize its electricity utility, it could set a renewable energy goal as aggressive as that in Austin, TX, where Austin owns its utility and aims to be carbon-neutral in all community energy use by 2050 (City of Austin, 2015).

Reductions Estimate

The estimate for reductions from renewable energy use by 2025 come from modeling a 2% increase in renewable electricity use each year from starting in 2016 and ending in 2024 in order to achieve 25% renewable electricity by 2025. The model assumes a 2% increase in renewable energy use for electricity is comparable to a 2% reduction in carbon intensity per year from 2016 to 2025. In order to estimate the reductions from 100% renewable electricity use by 2050, the model assumes a 3% increase in renewable electricity use each year starting in 2025 and ending in 2049 in order to achieve the additional 75% renewable electricity use by 2050.

The impact of increasing renewable electricity use would decrease the combined Residential, Commercial, and Industrial sector energy use emissions, even with increased population and job growth in the community up until 2025 (See figures C1 and C2 for emissions without and with increased renewable electricity, respectively). After 2025, the combined emissions from

Residential, Commercial, and Industrial energy use stay relatively flat, resulting in 92,600 fewer MT CO_2e emitted in 2050 than in 2014 (Figure C2). Within each sector, both Residential and Commercial energy emissions decrease each year. Industrial energy use, originally the sector with the lowest emissions of the three, increases despite greater renewable electricity use to become comparable to Commercial energy use in amount of emissions, but it emits 356,500 fewer MT CO_2e in 2049 than it would have without increased renewable electricity. The increase

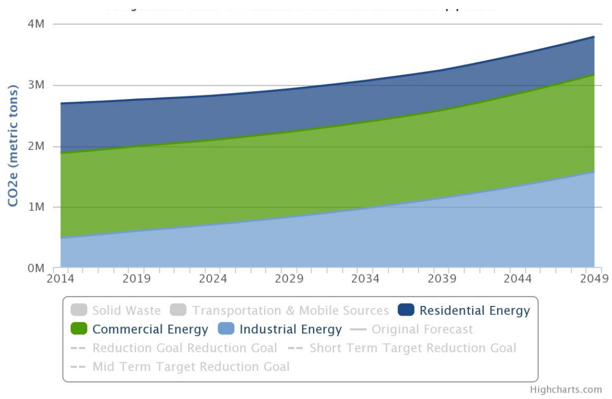


Figure C 1 Emissions from Residential, Commercial, and Industrial energy use with no increase in renewable electricity after the statewide RPS expires in 2015

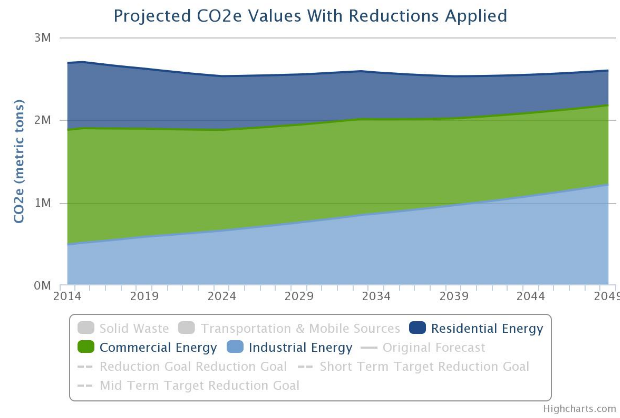


Figure C 2 Emissions from Residential, Commercial, and Industrial energy use with 25% renewable electricity by 2025 and 100% by 2050

in emissions from Industrial energy is due to more than half of 2014 Industrial emissions coming from natural gas consumption rather than electricity use. Ideally, however, a community-wide renewable energy goal could include increased renewable energy for heating, as well, which would further lower overall reductions from Residential, Commercial, and Industrial energy use.

Sector	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Residential	-9579	-9264	-8959	-8664	-8396	-8135	-7883	-7638	-7401	-75919
Commercial	-19890	-19512	-19140	-18776	-18410	-18050	-17698	-17353	-17014	-165843
Industrial	-4542	-4640	-4739	-4841	-4897	-4954	-5011	-5070	-5129	-43823
Total	-34011	-33416	-32838	-32281	-31703	-31139	-30592	-30061	-29544	-285585

Table C1: Emission reduction in Residential, Commercial, and Industrial energy use from 25% renewable electricity by 2025

Table C2: Emission reduction in Residential, Commercial, and Industrial energy use from 100% renewable electricity by 2050

Sector	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Residential	-12945	-12456	-11985	-11532	-11096	-10691	-10301	-9926	-9564	-9215
Commercial	-30052	-29202	-28376	-27573	-26793	-26054	-25334	-24635	-23955	-23294
Industrial	-9335	-9347	-9359	-9371	-9383	-9395	-9408	-9420	-9432	-9445
Total	-52332	-51005	-49720	-48476	-47272	-46140	-45043	-43981	-42951	-41954

Sector	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Residential	-8891	-8578	-8276	-7985	-7704	-7433	-7171	-6919	-6676	-6441
Commercial	-22665	-22054	-21459	-20880	-20316	-19959	-19608	-19263	-18924	-18591
Industrial	-9457	-9469	-9481	-9494	-9506	-9519	-9531	-9543	-9556	-9568
Total	-41013	-40101	-39216	-38359	-37526	-36911	-36310	-35725	-35156	-34600

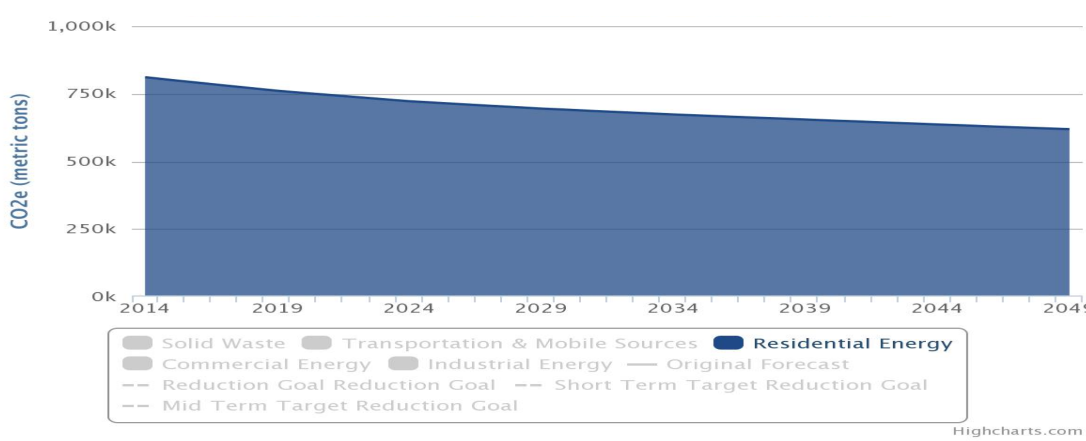
Sector	2045	2046	2047	2048	2049	Total from 2025-2049	Total from 2016-2049
Residential	-6214	-5995	-5784	-5581	-5384	-214743	-290662
Commercial	-18264	-17942	-17627	-17316	-17012	-557148	-722991
Industrial	-9581	-9593	-9606	-9618	-9631	-237048	-280871
Total	-34059	-33530	-33017	-32515	-32027	-1008939	-1294524

Included are figures for the change in emissions rates from Residential, Commercial, and Industrial energy use without an increase in renewable electricity compared to the rates if the goal of 25% renewable electricity by 2025 and 100% renewable electricity by 2050 are reached through evenly spread increases in renewable electricity each year, from 2016 through 2024 and from 2025 through 2049.

Residential

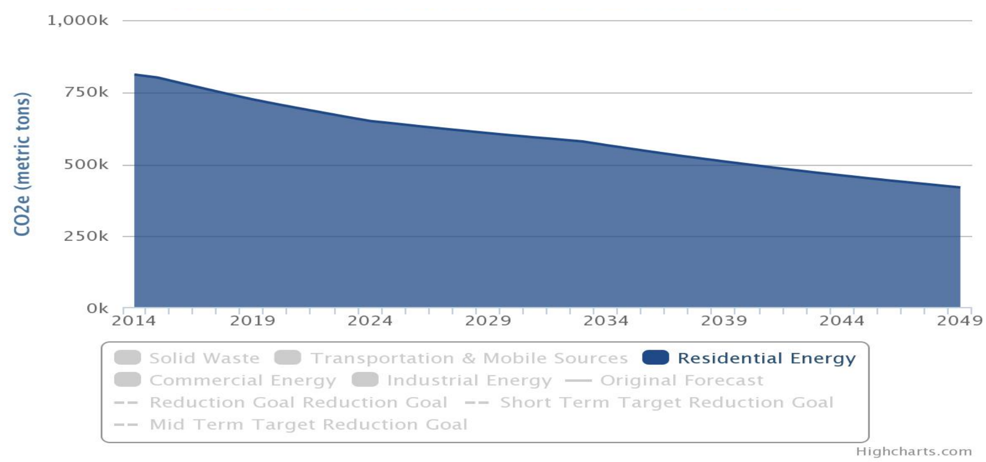
Residential energy use emits 199,362 fewer MT CO_2e in 2049 with increased renewable electricity (down to 419, 257 MT from 618,619 MT). That is a reduction of 381,650 MT from 2014 levels.

Figure C3: Residential energy emissions to 2050 without increased renewable electricity



With increased renewable electricity:

Figure C4: Residential energy emissions to 2050 with increased renewable electricity

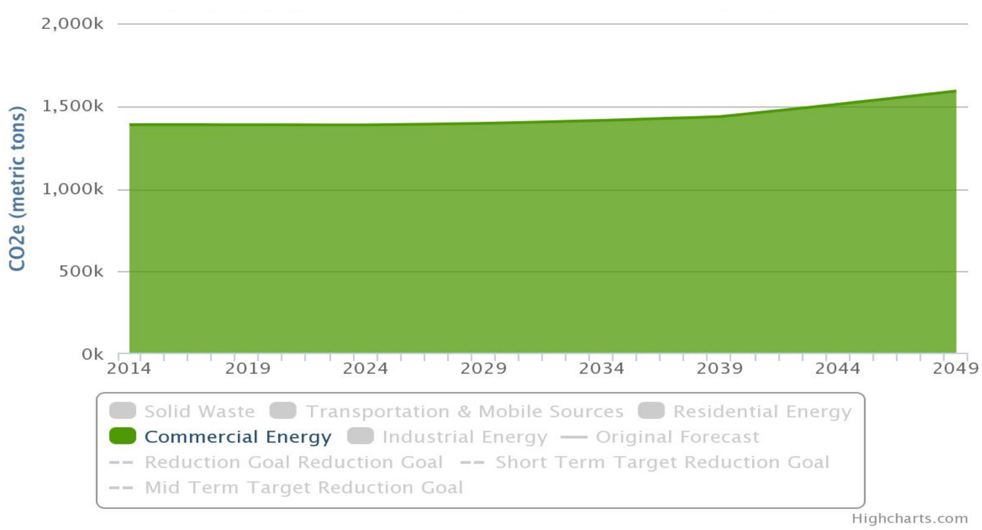


<u>Commercial</u>

Commercial energy use emits 629,841 MT fewer CO_2e in 2049 with increased renewable electricity (down to 960,918 MT from 1,590,759 MT). That is a reduction of 426,568 MT from 2014 levels.

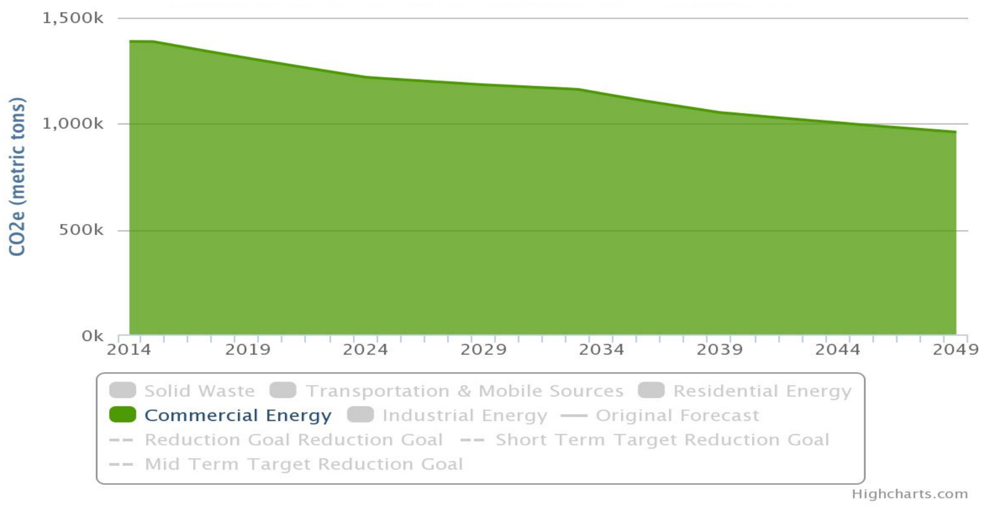
Without increased renewable electricity:

Figure C5: Commercial energy emissions to 2050 without increased renewable electricity



With increased renewable electricity:

Figure C6: Commercial energy emissions to 2050 with increased renewable electricity

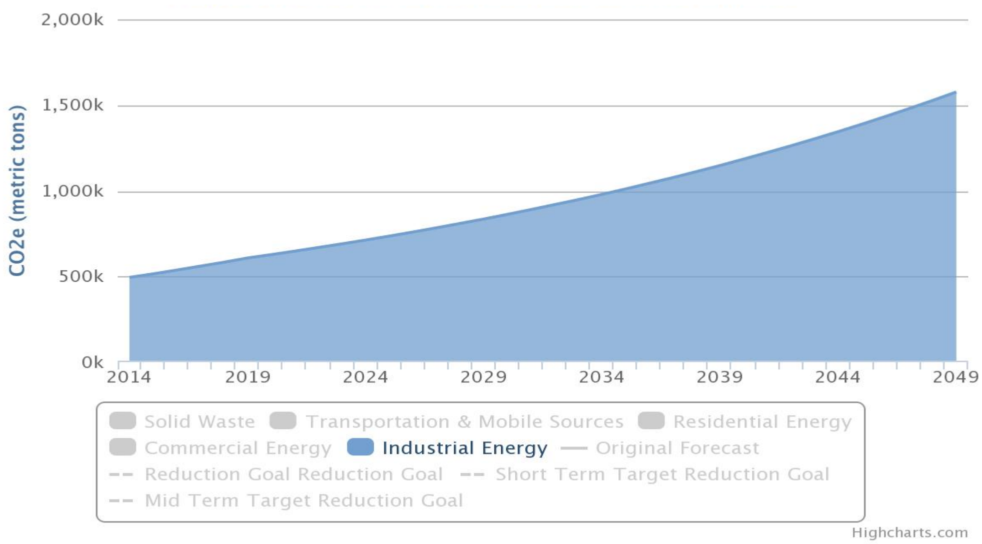


Industrial

Industrial energy use emits 356,573 MT fewer CO_2e with increased renewable electricity use (down to 1,219,884 MT from 1,576,457 MT). That is still a 725,594 MT increase from 2014 levels, however, emphasizing that additional measure will be necessary to reduce emissions from industrial energy use, which are predominantly from natural gas heating.

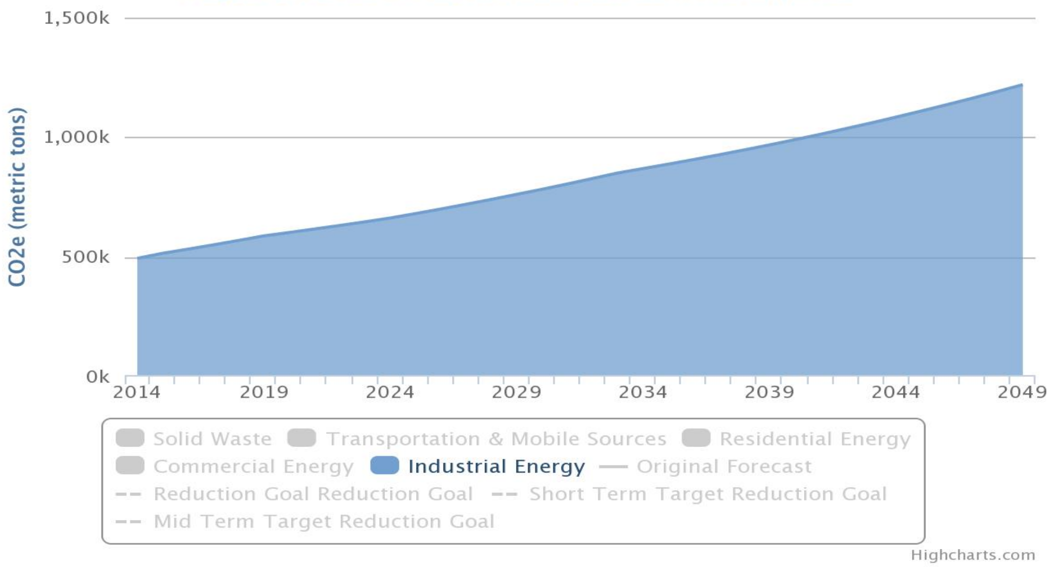
Without increased renewable electricity:

Figure 7: Industrial energy emissions to 2050 without increased renewable electricity



With increased renewable electricity:

Figure C8: Industrial energy emissions to 2050 with increased renewable electricity



Appendix D: Proposed BRT and TOD in BRT shed

In the figures below, A is the highest density area and F is the lowest density area. The figures show the projected density changes around the proposed BRT stations due to TOD by 2035.

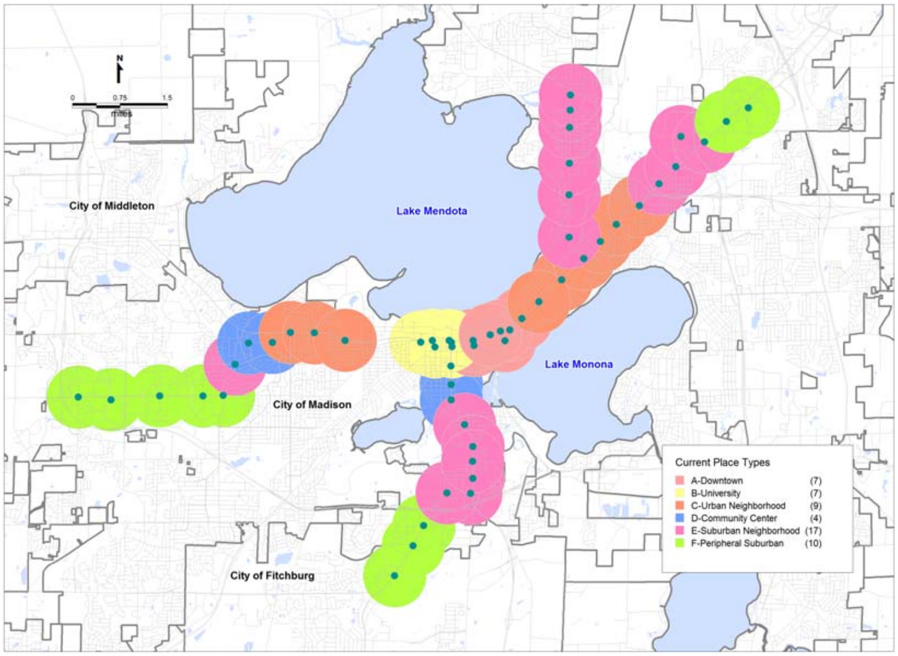


Figure D 1 Current development/density-type map in BRT shed (dots indicate BRT station/stop)

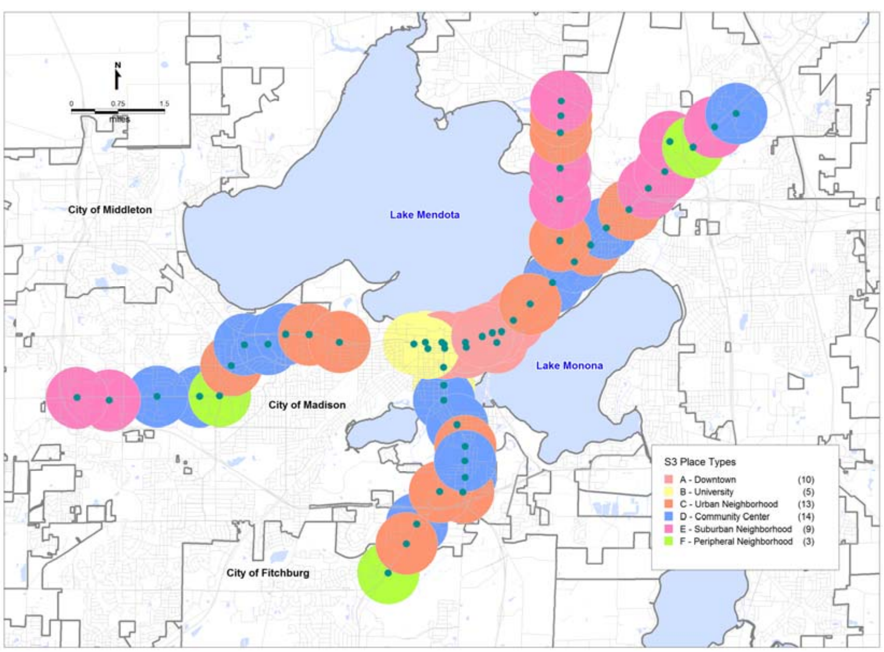


Figure D 2 2035 development/density-type mape in BRT shed due to TOD

Source: Crscc et.al., 2013

Appendix E: Data Contacts

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