Madison Community Operations Carbon Inventory 2012

Prepared for the City of Madison

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Foreword

This report is the result of a collaboration between the La Follette School of Public Affairs at the University of Wisconsin–Madison and the Wisconsin Department of Public Instruction. Our objective is to provide graduate students at La Follette the opportunity to improve their policy analysis skills while contributing to the capacity of the Department of Public Instruction to evaluate educator effectiveness.

The La Follette School offers a two-year graduate program leading to a master's degree in public affairs. Students study policy analysis and public management, and they can choose to pursue a concentration in a policy focus area. They spend the first year and a half of the program taking courses in which they develop the expertise needed to analyze public policies.

The authors of this report are all in their final semester of their degree program and are enrolled in Public Affairs 869 Workshop in Public Affairs. Although acquiring a set of policy analysis skills is important, there is no substitute for doing policy analysis as a means of learning policy analysis. Public Affairs 869 gives graduate students that opportunity.

This year the workshop students were divided into six teams. Other teams completed projects for the U.S. Government Accountability Office, the Wisconsin Department of Public Instruction, the Wisconsin Children's Trust Fund, the Wisconsin Department of Children and Families, and the Financial Clinic of New York City.

In the absence of an effective national strategy on climate change, local governments are trying to understand how to make a difference. Before they can answer that question, they need to first understand the relative greenhouse emissions they are responsible for, and the source of those emissions. To make effective policy change, they will also benefit from understanding the effects of specific competing policy options to reduce emissions. This report helps the City of Madison face these knowledge challenges. It first uses new software to undertake the most comprehensive inventory of greenhouse emissions yet completed for Madison. It next takes three politically salient policy proposals to reduce emissions and estimates their effect. The results leave little doubt that much remains to be done if Madison is to achieve targeted reductions in greenhouse emissions.

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Special thanks to others instrumental in this report: Jeanne Hoffman, Lisa MacKinnon, and J.R. Kilgrew.

List of Abbreviations

CH_4 – Methane
CO_2 – Carbon Dioxide
CO_2e – Carbon Dioxide Equivalent
GHG – Greenhouse Gas
ICLEI – International Council for Local Environmental Initiatives
kWh – Kilowatt Hour
MGE – Madison Gas and Electric
MMBTU – Million British Thermal Units
MROE – Midwest Reliability Organization East
MW – Megawatt
N_2O – Nitrous Oxide

Executive Summary

The City of Madison has the goal of reducing greenhouse gases (GHG) by 80 percent of the 2010 baseline by 2050. As part of the effort to reach that goal, Madison conducts periodic inventories of GHG emissions. This report includes a GHG inventory for the City of Madison for 2012 and estimates that in that year Madison emitted 4.5 million metric tons of carbon dioxide equivalents (CO_2e).

This is the second community-wide inventory that Madison has completed. Significant differences between this inventory and the first community inventory completed for 2010 prevent effective comparisons between them. However, this inventory provides a more complete estimate of Madison's GHG emissions, and new software allows for projections of the impacts of various GHG reduction strategies. This report, for the first time, offers insights into the changes in GHG emissions by implementing policies at the city level.

Three sectors accounted for most of the emissions: commercial energy, transportation, and residential energy. Numerous proposals have been made to reduce Madison's GHG emissions. We consider three such proposals, one for each of these three sectors.

For commercial energy, we recommend implementing commercial building energy efficiency benchmarking. For transportation, we recommend implementing Bus Rapid Transit. For residential energy, we recommend implementing a full-scale solar photovoltaic bulk purchase program. Each of these policies reduces GHG emissions in the short term and contains opportunities for future expansion for continued reduction of GHG emissions.

While each of these proposals results in decreases in GHG emissions, these proposals combined do not counteract the growth in GHG emissions projected from population growth. In addition to these recommendations, the City of Madison will need to enact more reduction tactics to meet the goal of 80 percent reduction by 2050.

The ability to monitor Madison's GHG emissions is an integral part of a long-term effort to reduce such emissions. Madison has inherent advantages in these monitoring efforts because it has already invested in software to analyze data and can easily draw upon resources from the University of Wisconsin-Madison. However, the current approach is still somewhat ad-hoc. We recommend additional steps to streamline the process for future inventories, reducing the transaction costs involved, while moving to a more routinized approach.

Introduction

There is an ever-increasing scientific consensus that the global climate is changing and that human actions are the main cause of those changes. The Intergovernmental Panel on Climate Change (IPCC) is the scientific body charged with bringing together the work of thousands of climate scientists. The IPCC's Fourth Assessment Report states, "Warming of the climate system is unequivocal." Furthermore, the report finds that "most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations."

The year 2012 was the hottest on record for the continental United States, with two dozen cities breaking or tying their all-time high temperature records. Globally, the 12 years from 2001-2012 are among the 14 hottest on record, and 1998 was the only year in the 20^{th} century hotter than 2012. The last year with a below average global temperature was 1976. The steady uptick in average temperatures is significant and expected to continue if action is not taken to greatly reduce greenhouse gas emissions.

In the absence of unified, coordinated guidance and leadership at the federal level, many communities in the United States are taking responsibility for addressing emissions at the local level. Local governments have a strong role to play in reducing greenhouse gas emissions within their boundaries. Since many of the major sources of greenhouse gas emissions are directly or indirectly controlled through local policies, these small-scale efforts can combine to have profound impacts. Through proactive measures around land use patterns, transportation demand management, energy efficiency, green building, waste diversion and more, local governments can lead the way to emissions reductions throughout the United States.

In 2010, the Sustainable Madison Committee, formerly the Sustainable Design and Energy Committee, increased the city's efforts toward reducing GHG emissions by beginning the process of inventorying emissions within the city's borders. In partnership with graduate students at University of Wisconsin, the city cataloged all energy use and resultant GHG emissions attributable to government operations for the year 2007 (Dart, et al. 2010). To complete this inventory, students used software available through the City's membership to the International Council for Local Environmental Initiatives (ICLEI). In 2011, again in partnership with University of Wisconsin graduate students, the city completed an inventory for the year 2010; however, in this iteration the scope was expanded to include emissions attributable to the entire Madison community (Bray-Hoagland, et al. 2011). Two more inventories tallying only GHG emissions attributed to Government Operations were conducted for years 2010 and 2012 (Brauneller 2011, Chung, et al. 2013). This report, targeting 2012 community-wide GHG energy use, is the fifth inventory conducted for the City of Madison.

The publishing of this current report coincides with the City's recent allocation of one million dollars to aid implementation of GHG reduction strategies outlined in The Madison Sustainability Plan (Budget 2014). In this plan the city has articulated its vision and goals for promoting sustainability across Madison's ten different sectors and enumerated actions and first steps for these sectors (Sustainable Madison Committee 2011).[1] The quantity and variety of these goals and actions have led to debate over the best way to allocate the City's resources. This report informs this debate by providing estimates of the GHG mitigating impact of a few policy alternatives identified in The Sustainability Plan, namely, increased electricity production from solar, electricity use reduction through building efficiency benchmarking, and increased bus ridership through the implementation of bus rapid transit. These alternatives were chosen based on the availability of evidence regarding their potential impact, the scale of that potential impact, and the political feasibility of their implementation in the Madison context. As our analysis uses new software capable of forecasting GHG emissions under various scenarios, this is the first inventory that includes emissions reduction estimates for policy options.

Given the intention of the City of Madison to conduct subsequent GHG emissions inventories, this report presents a number of recommendations to facilitate future efforts. In particular, numerous difficulties in the data collection process may be lessened or avoided in future inventories. These difficulties and possible solutions are presented in the final section of this report.

Ultimately, the intent of this report is to help the residents and policymakers of the City of Madison make better informed decisions regarding energy use and policy as efforts are made to mitigate the effects of climate change. It is clear, however, that none of the policy options considered in this report will, on their own, result in GHG emissions reductions on a scale large enough to achieve the city's stated goal of an 80 percent reduction in GHG emissions by the year 2050 (Sustainable Madison Committee 2011). Furthermore, one million dollars represent only a small fraction of the resources that will likely be necessary to achieve these goals. Therefore, in addition to considering the efficacy of a few of the many GHG reduction alternatives available, readers of this report are encouraged to consider the ways in which efforts may be institutionalized into the budgets and processes of all the city's agencies and departments.

ICLEI

ICLEI is an organization that assists local governments in achieving sustainable development. ICLEI offers its members tools for climate action and sustainability planning, skills training, toolkits, technical support, and resources like case studies and sample policies. ICLEI members include more than one thousand cities and local governments across 84 countries. In the United States ICLEI has 450 participants across 46 states. ICLEI works toward achieving "strong climate protection goals and create cleaner, healthier, more economically viable communities" (ICLEI Local Governments for Sustainability USA 2014). ICLEI also offers the opportunity for local governments to learn best practices from one another and share success stories (ICLEI Local Governments for Sustainability USA 2014).

[1] The Sustainability Plan divides Madison sustainability efforts into ten sectors: Natural Systems, Planning and Design, Transportation, Carbon and Energy, Economic Development, Employment and Workforce Development, Education, Affordable Housing, Health, and Arts, Design and Culture.

ClearPath

In 2014, ICLEI introduced the ClearPath software to replace the Clean Air and Climate Protection software used in previous Madison carbon inventories. This report presents Madison's first inventory with the new software. The ClearPath software provides several inventory options for the community emissions analysis. Of these options, this report focuses on residential energy, commercial energy, industrial energy, transportation and mobile sources, water and wastewater, and solid waste. Additional inventories offered by ClearPath that are outside the scope of this report are agriculture, process and fugitive emissions due to leaks, upstream impacts of activities, and emissions due to consuming goods created elsewhere. ClearPath allows users to develop inventories, track changes in emissions over time, forecast scenarios for future emissions, and analyze the benefits of emissions reduction measures (ICLEI, ClearPath FAQ n.d.).

Additional services offered by ClearPath that were not available to previous inventories utilizing the Clean Air and Climate Protection software include cloud data storage, comparison between inventory reports, chart creation, and climate action planning. By allowing governments to store all inventory data from multiple years in the same place ClearPath enables governments to track emissions over time and compare inventories easily. In addition, the forecasting tool in ClearPath allows policymakers to estimate the reduction in emissions for different policy options (ICLEI, ClearPath FAQ n.d.). We use this forecasting tool to estimate emissions reductions for the policy alternatives presented later in the report.

Inventory Methodology

Understanding a Greenhouse Gas Emissions Inventory

The first step to reduce GHG emissions in the Madison community is to identify baseline emissions sources and activities and quantify the scale of emissions from those sources and activities. This inventory adopts the approach and methods provided by ICLEI's Community Greenhouse Gas Emissions Protocol.

As of October 2010, this protocol is regarded as a new national standard in guidance to help US local governments develop effective community GHG emissions inventories (ICLEI, icleiusa.org 2014). It establishes reporting requirements for all community GHG emissions inventories and provides detailed accounting advice for quantifying GHG emissions related to emission sources and community activities. Also, it gives optional reporting frameworks to help local governments customize their community GHG emissions inventory reports based on their local capacities and environment.

Quantifying Greenhouse Gas Emissions

There are two categorizations of emissions in the community inventory used for quantifying GHG emissions. The first is GHG emissions produced by sources that are within the community boundary. Source-based emissions include tangible processes within the jurisdictional boundary that release GHG emissions into the atmosphere. The second is GHG emissions produced as a result of community activities. Activity-based emissions consist of the use of energy, materials, and/or services by members of the jurisdictional boundary that cause the GHG emissions, regardless of the location of emissions. By reporting on both GHG emissions sources and activities, local governments can deepen their understanding of GHG emissions within, and resulting from, their communities and develop better informed reduction strategies.

GHG emissions are quantified in two distinct ways. First, measurement-based methodologies refer to the direct measurement of GHG emissions that are emitted from a power plant, wastewater treatment plant, landfill or industrial facility. Second, calculation-based methodologies calculate emissions using activity data and emission factors (ICLEI, icleiusa.org 2014). The basic equation used for this calculation is:

Activity Data * Emission Factor = Emissions

Activity data are relevant measurements of the total occurrence of particular activities that require the use of GHG generating processes such as fuel composition by fuel type, metered annual electricity consumption, and annual vehicle miles traveled. Emissions factors are research-based calculations of the estimated total GHG emissions associated with each unit of activity. Various emission factors are built into the ClearPath software. This report utilizes a set of factors based on the unique characteristics of the Madison community. A detailed summary of the emission factors used in this report is available in Appendix A.

Community Operations Inventory Results

The results of the 2012 inventory for the City of Madison show that overall GHG emissions were 4,438,398 metric tons of CO_2e, which is a 12 percent increase from the 2010 inventory. To put this in context, Madison emitted 18.5 metric tons of CO_2e per person in 2012 compared to the state average of 16.8 metric tons (EIA, Rankings: Total Carbon Dioxide Emissions 2011).

The increase between the two inventories has several explanations. Much of this increase is due to the fact that the 2012 ClearPath-based inventory contains several new sources of emissions, such as water and wastewater emissions, and several stationary fuel combustion sources, that were not included in the previous inventory. In addition to adding new sources of data, the newly implemented ClearPath software uses updated conversion factors for calculating GHG emissions.[2] It is difficult to ascertain exactly how these factors may have affected the data. The affects, however, are likely relatively small compared to the final potential discrepancy concerning the physical boundary within which energy use data was included for each inventory. Both of Madison's primary energy providers bill according to zip code, and some of these zip codes expand into neighboring jurisdictions. Because of this, it is necessary to include some energy use data that may, in fact, originate from outside the City of Madison. The 2010 inventory does not expressly state the boundaries within which data were collected, so it is impossible to determine whether the geographic boundaries of each of the inventories are

[2] These changes reflect updates to standards enumerated in the International Panel on Climate Change's 4th Assessment. The Clean Air and Climate Protection software relied on standards in the Panel's 3rd assessment.

identical. The lack of clarity regarding the possible discrepancies between the 2010 and 2012 requires caution in making direct comparisons. Discrepancies such as these should not be a problem for future reports since ClearPath software now automatically stores previous year data on its central server. Furthermore, to avoid boundary discrepancies we have included a detailed list of the zip codes used in the 2012 inventory in Appendix A.

Figure 1: Top 3 Sectors Based on CO_2e Emissions

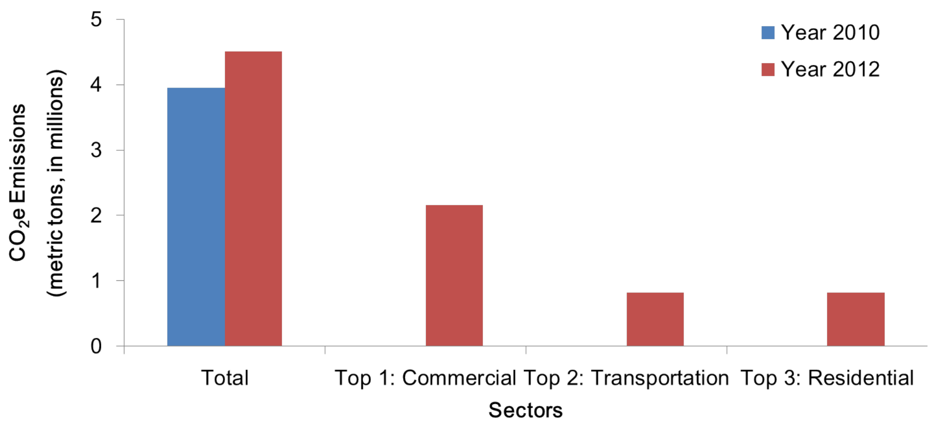
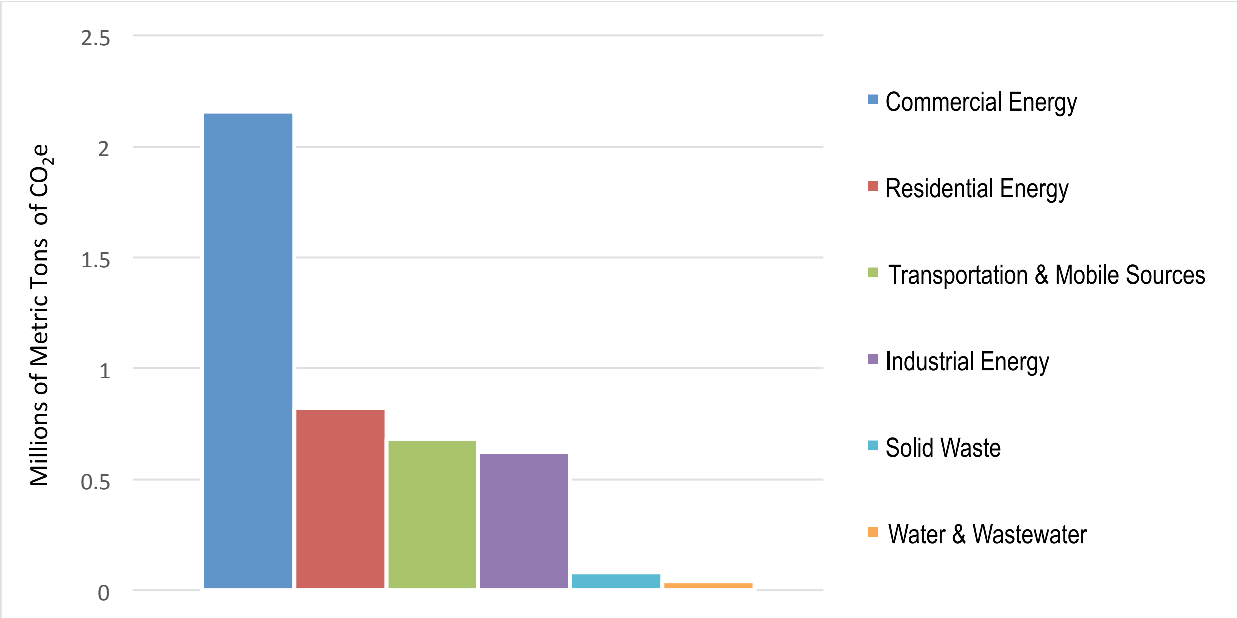


Table 1: CO_2e Totals by Inventory Year and Sector

	2010 CO_2e (Metric Tons)	2012 CO_2e (Metric Tons)	Difference	Percent change
Commercial	1,574,096	2,157,848	+583,752	+37.1
Residential	859,582	823,390	-36,192	-4.4
Industrial	373,254	623,245	+249,991	+67.0
Transportation	1,073,720	822,705	-251,015	+23.4
Waste	73,641	81,290	+7,649	+10.4

The 2012 inventory finds that the sectors contributing the most toward GHG emissions were commercial energy, transportation, and residential energy. These results parallel those found in the 2010 inventory. The percentage of total emissions by sector changed between inventory years, as shown in Figure 2. Commercial energy made up 46 percent of emissions, up from 40 percent in 2010. Industrial energy also saw an increase in the share of emissions, to 14 percent from nine percent. Both the residential and transportation sectors saw decreases in the share of emissions. Residential energy decreased to 18 percent of emissions from 22 percent, while transportation decreased to 19 percent of emissions from 27 percent. Water and wastewater were not featured in the 2010 Community Inventory but only make up one percent of 2012 emissions. Future inventories will benefit from using the same software, eliminating the possibility of differences in output due to differences in how the software programs calculate the totals.

Figure 2: CO_2e Emissions by Sector in 2012



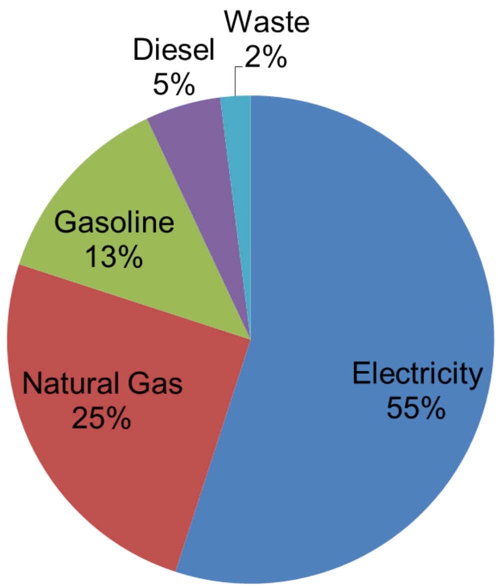
Summary by Source

The top three sources of emissions remained the same from the 2010 inventory: electricity, natural gas and other fuels. In 2012, the majority of GHG emissions came from electricity use, which comprised over half of total CO_2e emissions, a five percent increase from 2010. The next largest source was natural gas followed by gasoline. In 2010 gasoline was the second largest source, making 25 percent of emissions, which decreased to 14 percent in 2012. Natural gas made up 26 percent of emissions, up from 21 percent in 2010. Even though there was an increase of 162 percent inthe CO_2e emissions from diesel, it is still a small sector. Also, it is noteworthy that gasoline remains the main source of N_2O emissions and a significant contributor to CH_4 emissions.

Table 2: Emissions by Source 2012

Source	CO_2 (metric tons)	CH_4 (metric tons)	N_2O (metric tons)	CO_2e (metric tons)
Electricity	2,437,610	36	42	2,450,941
Natural Gas	1,145,939	108	2	1,149,284
Gasoline	575,871	183	86	606,167
Diesel	219,127	22	<1	219,796
Waste	0	3252	0	81,290
Total	4,378,547	349	345	4,507,478

Figure 3: CO_2e Emissions by Source in 2012



Energy Delivered and Carbon Intensity by Source

To better understand the data we also looked at how much energy is delivered by source and the carbon intensity of each source. Electricity accounts for over half of the emissions but only provides 27 percent of energy, showing that electricity is a very carbon intensive source. Natural gas is the opposite, only producing 25 percent of emissions but accounting for over half of energy. Diesel and gasoline stay roughly the same across percent emissions and percent energy.

The carbon intensity of each source varies widely. Natural gas has the lowest carbon intensity while diesel fuel has the highest carbon intensity. Electricity also has high carbon intensity because coal and natural gas are the main fuels burned to produce electricity. Gasoline and stationary combustion (this category includes a variety of fuels) are very similar in terms of carbon intensity.

Figure 4: Percent of Total Energy Created by Source 2012 (MMBTU)

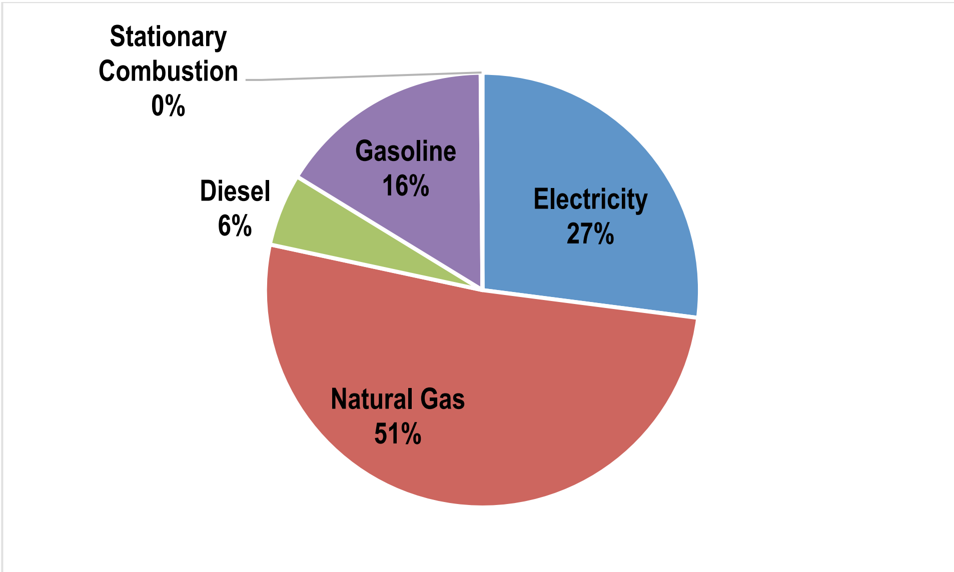


Table 3: Carbon Intensity by Source 2012

Source	Energy (MMBTU)	CO_2e (Metric Tons)	Carbon Intensity (Metric Tons CO_2e /MMBTU)
Electricity	11,386,463	2,450,941	0.2153
Natural Gas	21,613,327	1,149,284	0.05317
Diesel	2,265,856	1,368,052	0.6038
Gasoline	6,787,451	506,298	0.07459
Stationary Combustion	55,514	4,245	0.07647

Summary by Sector and Source

One way to consider Madison's GHG emissions is to consider each sector, such as residential, and examine the sources for that sector, such as electricity and natural gas. This detailed look is provided in Table 3 and is a tool for policymakers to set specific targets for emissions reduction. Policymakers can see not only which sectors produce the most emissions but what source of energy within that sector is causing the emissions. Commercial energy, for example, is the largest sector of emissions. Looking at the sources within commercial energy we see that electricity makes up 75 percent of the emissions for that sector. If policymakers would like to reduce emissions from commercial energy, therefore, electricity use would be a great place to start. All energy is calculated in million British Thermal Units (MMBTU) as a standardized way to look at energy across different sources. The sources for water and wastewater were calculated together, making it impossible to distinguish how much energy and emissions came from electricity and how much came from natural gas and therefore are listed together.

Table 4: Energy Consumption and CO_2e Emissions by Sector and Source 2012

Source	Energy Consumption (MMBTU)	CO_2e (metric tons)
Residential		
Electricity	2,591,693	557,863
Natural Gas	4,993,473	265,527
Commercial		
Electricity	7,590,983	1,633,962
Natural Gas	9,798,353	521,025
Stationary Combustion	36,866	2,848
Industrial		
Electricity	1,203,787	259,116
Natural Gas	6,821,501	362,732
Stationary Combustion	18,648	1,397
Transportation		
Diesel	2,265,856	1,368,052
Gasoline	6,787,451	506,298
Water and Wastewater		
Electricity/Natural Gas	371,868	41,481
Solid Waste		
Waste and Retired Landfills	-	81,290

Policy Recommendations

There are a myriad of approaches Madison's decision makers can take in the effort of to curb GHG emissions generated within the community. The Madison Sustainability Plan lists 77 recommended actions to achieve the six goals listed in its Carbon and Energy section alone. It is easy to imagine, therefore, how difficult it is to prioritize actions and direct limited resources. One criterion that may be helpful in these decision processes is the CO_2e mitigating impact of various policies. Determining these impacts, however, was not possible in the absence of a thorough inventory of baseline emissions in the community. By utilizing ICLEI's powerful and comprehensive ClearPath software, this report now provides decision makers with the detailed information necessary to provide estimates based on Madison's unique emissions environment.

The following portion of this report provides this form of newly possible contextualization for three reduction strategies that have been identified as particularly salient for the City of Madison.

One reduction from each of the three largest sectors contributing to GHG emissions was selected from the possibilities based on the timeliness with which they have been discussed by the Sustainable Madison Committee, their apparent political feasibility, the impact their implementation has been shown to have in other communities, and the degree to which their impacts are estimable. These qualities have been determined with the combination of an extensive review of the relevant literature, a review of minutes of the Sustainable Madison Committee's proceedings, qualitative interviews with members of the Sustainable Madison Committee and city government and community stakeholders, and the availability of reliable impact estimates from other communities. The exclusion of any particular reduction strategy is in no way a statement as to its efficacy. The three strategies considered are merely the initial foray into a new approach for evaluating emissions reduction strategies in Madison's unique context.

Since the largest contributor to GHG emissions in Madison is the commercial sector, the first policy evaluated in this report is mandatory benchmarking of commercial building energy usage. As the transportation sector is the second largest contributor to GHG emissions in Madison, the second policy evaluated is Bus Rapid Transit. The third and final policy evaluated, solar bulk purchasing, targets GHG emissions resulting from residential energy use.

Commercial Energy: Commercial Building Energy Efficiency Benchmarking

It has recently been proposed that Madison join a handful of other cities in adopting an ordinance to require commercial buildings over a certain size to publicly report information regarding their energy usage (Mosiman 2013). The reporting process proposed would be coordinated through the use of Energy Star Portfolio Manager. In the Portfolio Manager system, building characteristics and energy usage are entered into a national database that compares each building's energy usage to buildings with similar characteristics in similar climates. This allows buildings to be categorized into percentiles for overall energy efficiency. It is this percentile rank among building peers that is then made publicly available (Star, Energy Star Portfolio Manager Data Trends 2012).

Policymakers believe that by creating a market and demand for energy efficient commercial rental property, building owners will be incentivized to take steps to increase the energy efficiency of their buildings. It is widely believed that many low-cost, easy-to-implement improvements currently go unmade simply because there is no market force to incentivize them. Market mechanisms depend partly on the availability of data on the value of a product. Benchmarking enables such mechanisms to emerge by making previously inaccessible information on energy efficiency available to potential renters. When energy efficiency information is accessible, renters are able to estimate and compare future energy cost when considering alternative rental options. Each renter, then, will make the purchase that maximizes benefits. Because energy efficiency reduces cost, this utility is expected to positively correlate with increased efficiency; therefore, there will be a market premium for energy efficient buildings. Market efficiency theory suggests that this premium will lead to an increased supply of efficiency among buildings. This, ultimately, will result in reductions in overall energy consumption. This form of market-based policy has been widely implemented in attempts to curb climate change (Stavins 2003, Wustenhagen and Bilharz 2006). Fuel efficiency in vehicles, for example, is now cited as the most important attribute by new car purchasers (Reports 2009). This would likely not be the case if not for the introduction of reporting standards in 1978.

Ordinances passed in at least nine major metropolitan areas reflect a consensus that policymakers find that ordinances must be mandatory in order to be effective (IMT 2013). Several pieces of evidence support this conclusion. Madison buildings, for example, have earned only 48 Energy Star certification labels since 2008, whereas buildings in Austin, Texas, where a mandatory benchmarking ordinance was enacted in 2008, have earned 244 Energy Star labels over the same time period (Star, Energy Star Labeled Buildings and Plants 2013). Over this period, Austin quadrupled the number of labels earned in the previous six years. This compares to the doubling that Madison has seen compared to the six years prior to 2008. This is evidence only of the number of top-performing buildings in each jurisdiction; however, evidence from analyses of non-mandatory policies across the European Union also point to low levels of participation (Perez-Lombard, et al. 2009). The most apparent reason for these low rates is that non-participation by low-performing buildings discourages mid-performing buildings from participating, as they will be compared only to high-performing buildings and, therefore, be perceived as inefficient. Mandatory ordinances ensure that percentile designations of buildings are not directionally biased due to systematic non-participation.

Among the cities that have implemented this form of ordinance, variations exist in the size and type of building required to report. Some jurisdictions require every building with 10,000 or more gross square feet of floor space to report, while others only target buildings over 50,000 square feet. Some only include apartment buildings with a certain number of units or more, regardless of total floor space (IMT 2013). The most widely distributed proposal for the City of Madison would require reporting for commercial buildings over 15,000 square feet and apartment buildings with 35 or more units.

None of the ordinances compared for this report, including the Madison proposals, require building owners or occupants to make any improvements or alterations to their structures; nor do they impose any form of fine or levy for poor performance. The mandatory nature of the ordinances, however, requires some form of penalty for those who fail to report. In one iteration of the Madison proposal, fines can be levied for each day of non-compliance, not to exceed two thousand dollars in total. Energy-saving improvements to buildings are completely voluntary. The city, in partnership with local non-profits such as Sustain Dane, would merely direct owners to resources that are available to guide and assist those who desire to improve the energy efficiency of their buildings.

Evidence of the impacts of benchmarking ordinances on individual building and community-wide energy savings are available to varying degrees. A number of studies have estimated the energy-saving potential of voluntary participation in benchmarking and certification programs such as Energy Star Portfolio Manager and LEED (Howarth, Haddad and Paton 2000, Lee and Burnett 2008). The most frequently cited of these studies estimates a 2.4 percent annual reduction in energy usage per Portfolio Manager participating building over a three-year timeframe (Star, Energy Star Portfolio Manager Data Trends 2012). This estimate includes primarily buildings participating voluntarily. Estimates of the impact of mandatory policies are few. In fact, we were able to find only one study making such estimates (California Energy Commision 2005). This study estimates that a mandatory benchmarking policy in California resulted in annual energy savings of 0.13 kWhs per square foot and 0.002 therms per square foot. ICLEI's ClearPath software has adopted these values for use in its reduction strategy calculator for commercial energy benchmarking. These values, therefore, are used when calculating the estimated impact of a commercial building energy efficiency benchmarking ordinance in Madison. These reductions are expected to be cumulative for the first few years of implementation; however, it is unclear at what point reductions can be expected to taper off, because these impacts have only been studied over a three-year period.

Table 5: Estimated Madison Citywide Energy Reductions per Ordinance Building Size Cut-off

Size Included in Ordinance	Total Square Feet Affected	Estimated kWhs Reduction	Estimated therms Reduction
All	97,307,790	12,650,012	194,615
10,000+ square feet or 35+ units	71,956,234	9,354,310	143,912
15,000+ square feet or 35+ units	64,951,695	8,443,720	129,903
20,000+ square feet or 35+ units	59,634,669	7,752,506	119,269
25,000+ square feet or 35+ units	55,199,615	7,175,949	110,399

Source: Authors' calculations made from data obtained from City of Madison Assessor's Office

According to conversion calculations using ICLEI's ClearPath software, a benchmarking threshold of 25,000 square feet can be expected to result in emissions reductions of 5,859 metric tons of CO_2e per year. Using the Environmental Protection Agency's GHG Equivalencies Calculator, this represents the equivalent annual GHG emissions of 1,233 passenger vehicles, or the creation of electricity to power 535 residential homes (EPA 2014). The cost savings to building operators at this threshold are estimated to be $724,043 per year.[3]

Transportation: Bus Rapid Transit

Our inventory shows that the second largest sector of GHG emissions in Madison in 2012 was due to transportation. Both Madison government and the broader Madison community have invested significant time and energy into considering various public transit options to meet the city's transportation needs, including rail and streetcars (Capital Region Sustainable Communities Initiative 2013). The Madison Sustainability Plan makes frequent references to increasing and improving public transportation due to its role in reducing emissions as well as its role in increasing accessibility. Specifically, Bus Rapid Transit is mentioned under multiple goals within the plan and tied in with others, such as corridor planning, as a way to increase residential and commercial density (Sustainable Madison Committee 2011).

Bus Rapid Transit would identify highly traveled transit corridors and implement routes with frequent bus service. In 2013, the Capital Region Sustainable Communities Initiative identified a potential Bus Rapid Transit system for Madison, reaching into some adjacent municipalities. The plan outlined a Bus Rapid Transit system for Madison with two established routes, a North-South route and an East-West route, which would share the isthmus and the University of Wisconsin – Madison campus. Buses would run every 10 minutes during peak transit times. The plan also incorporated other aspects into Bus Rapid Transit for Madison, including dedicated bus lanes, sixty-foot articulated buses, transit signal priority, bike storage onboard, and WIFI. Overall, Bus Rapid Transit is a faster, more reliable bus service, with many similarities to light rail but less expensive to implement (Capital Region Sustainable Communities Initiative 2013).

[3] This figure assumes a constant total square foot area affected per year and does not account for potential growth or demolition of commercial real-estate. This figure uses 2014 pricing data obtained from MGE.

The Madison Sustainability Plan also views implementing a Bus Rapid Transit program as a way to increase the capacity of Madison Metro, which is experiencing overcrowding issues. While Madison Metro buses seat 34 to 38 passengers, some bus routes often see over 65 passengers per bus (Capital Region Sustainable Communities Initiative 2013). Despite current overcrowding, Mayor Soglin wants to double bus ridership in the next ten to 20 years, increasing from 14.7 million rides in 2013 to over 30 million rides per year by 2035 (Rusch 2014).

The Capital Region Sustainable Communities Initiative did not consider emissions reductions in its report but they are estimated here. Emission reduction estimates are provided for implementing the entire proposed Bus Rapid Transit system, as well as for just the East corridor. This is in acknowledgment that, with initial capital costs estimated at $120 million, Bus Rapid Transit may only have the funding and the political feasibility to implement one route at a time, and at $23.82 million the East corridor has the lowest estimated initial capital costs of the four corridors (Capital Region Sustainable Communities Initiative 2013).

Table 6: Emissions Reductions Estimates and Sources for Bus Rapid Transit

	East corridor	Entire system
Estimated decrease in personal vehicle miles traveled	612,561	4,893,084
Estimated decrease in emissions from increase in transit use (metric tons CO_2e/year)	209	1676
Estimated number of new buses needed	8	34
Estimated decrease in emissions from increased bus efficiency (metric tons CO_2e/year)	157	450
Total estimated emissions reduced (metric tons CO_2e/year)	366	2126

Sources: Capital Region Sustainable Communities Initiative, Authors' calculations using ClearPath

Bus Rapid Transit is estimated to provide emissions reductions in two ways. First, a projected increase in ridership will decrease emissions from personal vehicles as people chose transit options over driving. Second, the hybrid buses proposed to be used for Bus Rapid Transit would be more efficient than Madison Metro's current fleet, and the corridors would replace existing bus routes or portions of bus routes (Capital Region Sustainable Communities Initiative 2013). The proposed Bus Rapid Transit buses are diesel electric hybrids, which provide an average reduction of 30 to 48 percent of CO_2 emissions (Lutsey 2011). Using the lower end of 30 percent, the total emissions reductions are estimated at 366 metric tons CO_2e/year for the East corridor, and 2126 metric tons CO_2e/year for the entire system.

The estimated reductions for the East corridor are equivalent to taking 77 cars off the road, or providing the energy for 33 homes for a year. The estimated reduction for the entire Bus Rapid Transit system are equivalent to taking 448 cars off the road, or providing the energy for 194 homes for a year (EPA 2014). Further emissions reductions could be realized with a growth in ridership and with Transit Oriented Development (Capital Region Sustainable Communities Initiative 2013). Details on Bus Rapid Transit emission reduction estimates are in Appendix B.

Residential Energy: Solar Electricity Generation

The residential sector is the third largest contributor to GHG emissions. In this section, we examine implementation of bulk solar photovoltaic to increase renewable energy production. By helping residents increase renewable energy production, the residential sector would meet some of its own electricity needs while decreasing GHG emission. We will mainly focus on forecasting the impacts of expanding photovoltaic installations, including changes in CO_2e and electricity cost savings. Before the main forecasting, we first consider the successful solar energy usage example in California to identify feasible implications in the Madison community.

Example of Solar Energy Initiative in California

According to Interstate Renewable Energy Council report (IREC 2013), the capacity of photovoltaic is one of the important standards to gauge the use of solar energy. Photovoltaic is commonly referred to as solar panels, which generate electricity when exposed to the sun. In 2012, solar installations were 12 percent of electric power sources. The largest photovoltaic installations were in California, the US leader in photovoltaic use. In 2012, California had approximately 983 MW in total capacity, including residential, non-residential and utilities, compared to 8.2 MW in Wisconsin.

The California Solar Initiative provides customers with different incentive levels based on the performance of their solar panels. This performance framework makes California's solar systems less expensive while encouraging each customer to generate as much solar energy as possible. The total budget of the California Solar Initiative program from 2007 to 2016 is $2.2 billion, and approximately 1,940 MW of new solar generating capacity is expected to be installed under this budget. Thus far, the California Solar Initiative program has installed 1,625 MW of solar generating capacity. Assuming a lifetime for these systems at an average of 20 years, California is estimated to avoid emitting 38 million metric tons of carbon dioxide. It is equivalent to GHG emissions of eight million passenger vehicles, equivalent to the amount of carbon sequestered by 31 million acres of US forests in one year, or the electricity use of 5.4 million homes for one year.

Implications in the Madison Community

The California Solar Initiative program could serve as a model for solar electricity generation within the Madison community, especially since Madison was designated a Solar America City by the US Department of Energy in 2007. Due to environmental differences, of course, the benefits and costs that can be expected in Madison would not be the same as in California. As shown in Table 7, the majority of the states ranked highest in photovoltaic capacity in 2012 are located on the West or East coasts, and not in the Midwest. Within the Midwest, however, Wisconsin lags its neighbors in installed photovoltaic capacity regardless of similar weather conditions. Wisconsin's capacity in 2012, which is only 8.2 MW (cumulatively 21.1 MW), was still less than that of Illinois at 26.7 MW (42.9 MW), Missouri at 16.6 MW (18.5 MW), and Ohio at 48.3 MW (79.9 MW). This demonstrates that, while not having as advantageous weather as sunnier states, Midwestern states can benefit from photovoltaic. See Appendix C for the full rankings of photovoltaic installations by state in 2012.

Table 7: 2012 Annual Top Ten States of Solar Capacity Installed in 2012

2012 Rank by State	2012 (MW)
1. California	983
2. Arizona	709
3. New Jersey	391
4. Nevada	226
5. Massachusetts	123
6. North Carolina	122
7. Hawaii	114
8. Colorado	103
9. Maryland	80
10. New York	56
All Other States	434
Total	**3,341**

Source: IREC (2013)

Madison has many ways to develop solar electricity generation programs. In fact, some of the best options for generating solar electricity can happen at the local community level. For example, warning lights, public signs and communication towers for cell phones can operate using solar energy without the need for transmission grid electricity (The Center for Social Inclusion 2009). Furthermore, increasing solar energy production addresses multiple goals enumerated in Madison's sustainability plan. In particular, the plan states that the city will improve air quality by obtaining 25 percent of electricity, heating and transportation energy from clean energy sources by 2025. Promoting solar electricity generation at the community level will require the city to invest in technological support and incentives for individuals and organizations.

Forecasting the Impacts of Expanding Photovoltaic Installations

According to the Lawrence Berkeley National Laboratory's report, the price of installed panels has declined from 1998 through 2012 (Barbose et al. 2013). Prices also differ due to economies of scale in the size of the installation. In California, the median installed price of residential and commercial systems is $5.70 per Watt for 10 kW systems or smaller, $5.30 per Watt for systems between 10 to 100 kW, and $5.00 per Watt for systems larger than 100 kW. Wisconsin has the same median installed price of residential and commercial systems, which is $5.90 per Watt, without any economies of scale for larger systems (Barbose et al. 2013).

To strengthen our analysis, we used information from two previous pilot projects by the City of Madison, focusing on promoting solar photovoltaic through bulk purchasing. We determined the Madison Community will get one MW of solar energy capacity by 2020 through a bulk purchasing program for Madison residents, with total solar installations costs of $620,000. According to the previous pilot projects, photovoltaic systems with a capacity of 110 kW were installed from 2008 to 2013, and an additional photovoltaic system for 25 kW is under construction in 2014. Although most photovoltaic systems in the pilot projects are city-owned systems, we exclude those capacities and assume new bulk purchasing of solar installations in residential sectors.

Through a full-scale photovoltaic bulk purchasing program, the City of Madison could incentivize sufficient residential photovoltaic installations to meet this goal. If 200 kW capacities are installed each year from January 2015 to January 2020 to meet the target of one MW capacity installation for the residents by 2020, GHG emissions will be reduced by 2355 metric tons CO_2e through 2020. Assuming an average $5 per watt installation cost and 2012 residential electricity cost at $0.118 per kWh, total savings could be $370,700 by 2020. Further explanation is in Table 8.

Table 8: CO_2e Changes and Commercial Electricity Cost Savings (2015-2020)

Year	CO_2e Reductions (metric tons)	Commercial Electricity Cost Savings ($)
2015	-157	25,975
2016	-314	50,982
2017	-471	75,048
2018	-628	98,198
2019	-785	120,458
Total	**-2355**	**370,661**

Policy Recommendations Conclusion

It may be apparent that none of the three policies examined in this report will, on their own, lead to a level of GHG mitigation necessary to reach Madison's stated reduction goal. In fact, they are not expected to even counterbalance emissions increases as Madison continues to grow. The orange line at the top of Figure 5 shows the projected growth in GHG emissions for Madison through 2030 if the city made no attempts to reduce GHGs as it grows. While this inaction is not the expected scenario, it is shown to illustrate the impact of implementing the three policies considered in this report. The gap, indicated by the arrow to the right of the graph, between the orange line and the color-shaded regions below represents the reductions that can be expected if the most conservative versions of these strategies are implemented.[4]

While this difference is small relative to the whole, several assumptions made for forecasting should be considered. First, this model does not include possible growth in square feet tracked through benchmarking due to new buildings, buildings growing past the cutoff and entering the program, or lowering the threshold for buildings to participate. Second, this model does not include any growth in the use of Bus Rapid Transit. While growth is expected, the growth rate is highly dependent upon supportive policies to increase its growth. Third, this model assumes that Madison implements no further programs to incentivize residential solar electric generation after it reaches its goal of one megawatt of solar electricity capacity in 2020. Growth in any of these programs would further decrease GHG emissions. Additionally, while the city's reduction goal is 80 percent by 2050, the projection is made only through 2030 because of the difficulties in maintaining our assumptions over such a long time range. Figure 6 shows the estimated impact

[4] The conservative estimate includes a 25,000 square foot threshold for benchmarking; 1 MW of residential solar installation; and 4,893,084 offset vehicle miles traveled due to Bus Rapid Transit.

of implementing versions of the strategies with more optimistic estimates of their initial efficacy.[5]

Figure 5: GHG Emissions Projection through 2030 with Conservative Effects of Reduction Strategies

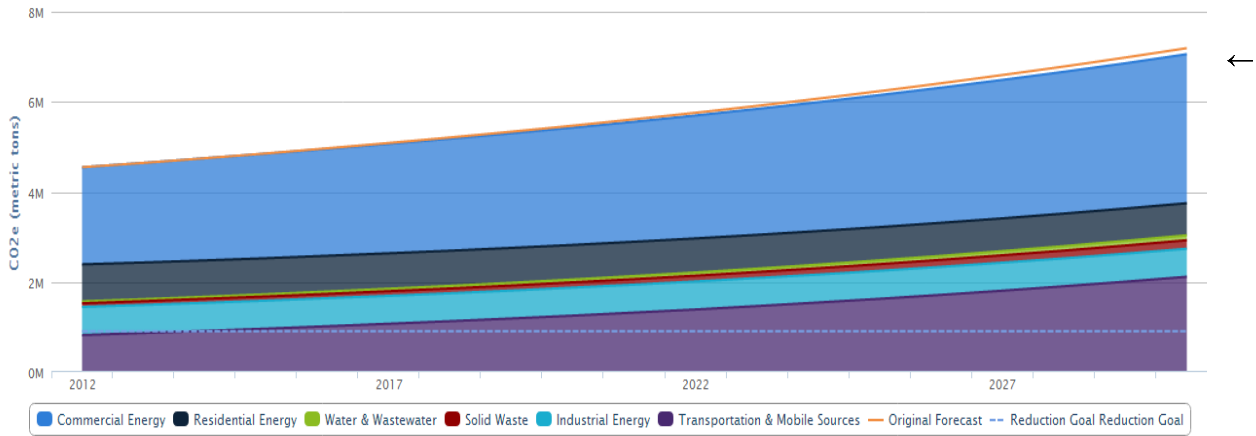
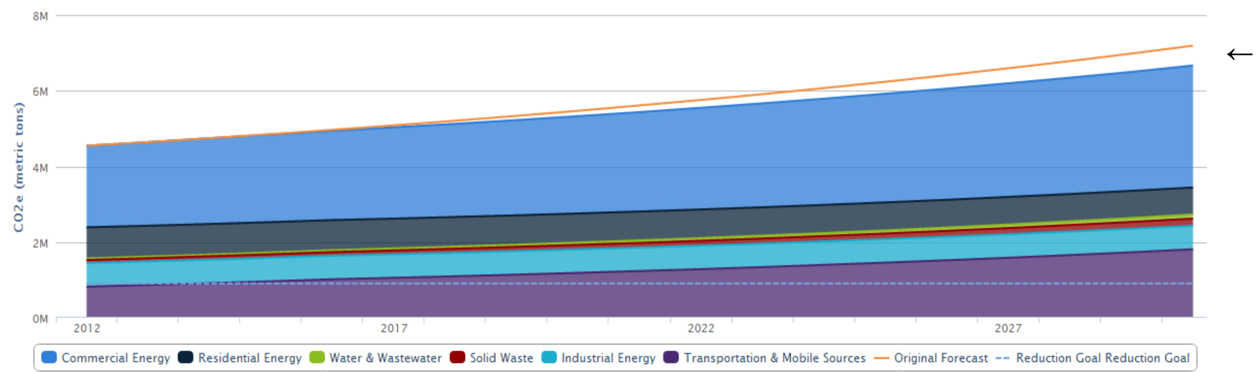


Figure 6: GHG Emissions Projection through 2030 with Optimistic Effects of Reduction Strategies



Limitations in the complexity and thoroughness of the ICLEI software modeling warrant a caution against viewing Figures 5 and 6 as predictions of how emissions in Madison will look in 16 years. The figures are not intended to be a prediction of the future, but simply lay out a baseline based on changes to the status quo. They also allow a means for policymakers to consider the relative impacts of the numerous policy options in the effort to curb emissions. The results of this inventory are emissions baselines from which policymakers, administrators, academics, and community stakeholders alike can begin consideration of the potential impacts of alternative approaches.

[5] The optimistic estimate includes all of Madison's commercial space participating in benchmarking; 10 MW of residential solar installed; and 48,930,840 vehicle miles traveled offset due to Bus Rapid Transit.

In order to reach 80 percent GHG emissions reduction by 2050, it is clear that the City of Madison will need to implement many more strategies than those examined in this. It is possible that it will require all 77 GHG-reducing actions listed in the Madison Sustainability Plan, and more. Nevertheless, these three policies would establish GHG reduction as a priority and allow Madison to build upon these initial steps. Making informed, data-driven decisions regarding policy efficacy and priority will be key to the city's success in its effort to reduce the emission of GHG gasses. If Madison is to become a leader among cities in this effort, it will be necessary to envision a multitude of steps toward sustainability.

Recommendations for future GHG emission inventories

In the process of creating a GHG emission inventory using the baseline year of 2012, team members have gained knowledge of the city's relevant data sources, experience with the ClearPath software and the ICLEI protocols, and understanding of emission trends. By partnering with UW-Madison, the city has been able to complete inventories without using significant staff resources. However, this creates some loss of institutional knowledge across time as the students who completed one inventory graduate. Inevitably each incoming team faces a learning curve. The following is a summary of recommendations that could benefit the future emission data collection and data processing. Appendix D details contacts used for this report.

Identify a Consistent Timeline for Community Baseline Year

By creating regular emission inventory intervals, the City of Madison can have a more comprehensive understanding of emission patterns within Madison's community and make appropriate policy decisions. Based on our comparison with emission inventory using 2010 as the first baseline year, we recommend City of Madison track emission changes at least every two years. This allows leaders to examine the effectiveness of any policy enacted and forecast future trends. It may also help to raise public awareness of patterns of GHG emissions, and draw media attention to how the City of Madison is performing against its goals of reducing emissions.

Systematically Document for Comparisons

To analyze and compare changes in GHG emissions for the City of Madison, a systematic documentation of GHG emission data at different baseline years is necessary. Data should be saved in consistent formats and documented with similar languages in order to ease the burden of cross-year inventory comparisons. For example, guidelines for language uses and data formats should be systematically documented. Additionally, all data should be saved at the same digital cloud drive to allow for accessibility of future use. It is also extremely important that future inventories use data from within the same geographic boundary. The boundaries used for this report are listed in Appendix A.

Initiate Data Collection before Inventory

For the next inventory, it is recommended that communications with the data providers, especially the larger utilities and major industries, be initiated prior to the inventory to ensure that the data can be collected in the necessary timeframe. With each round of data collection city staff and students have to negotiate with utilities and major industries. In some cases, these negotiations go well and data is quickly provided; in some cases not. Since inventories have been completed over the course of the academic calendar, such delays can significantly undermine the potential to complete the report. The process of data collection could be eased if the mayor's office established a Memorandum of Agreement with data providers to share data with inventory teams in the future. This policy should be implemented before the next the next inventory is initiated.

Generate Usable Data

Team members spent a great amount of time transferring data to the format that can be entered in the ClearPath software, on activities such as data cleaning and unit transformation. Future inventories could benefit from a structured data format that is tailored for the ClearPath software, specifically under the consensus built with data sources.

Create Staff Position for Data Collection

Finally, we suggest a staff position be created for data collection. Changing teams of students are unable to build and maintain a long-term relationship with data providers to guarantee the availability of emission data. Also a staff member familiar with the data collection and use of ClearPath software can prevent potential errors. In particular, with students' schedules limited by the semester, a creation of a comprehensive inventory is infeasible. All these factors lead to the similar conclusion that making inventory creation a regular part of government operations can dramatically decrease the time and efforts needed to complete future inventory reports.

Appendix A: Detailed Methodology

Demographics

The inventory relied on population data, called "population served," to calculate GHG emissions for the community in City of Madison. The population served data can help track indicators that allow users to "analyze performance of community over time and account for changes that result from community growth." The inputs are provided by the U.S. Census Bureau.

Madison Energy

General Background

Two electrical utilities supply the City of Madison with electricity they are MGE (MGE) and Alliant Energy. Each utility markets their electricity to a non-profit organization called Midwest Reliability Organization East (MROE). MROE manages what many refer to as "the grid," making sure minimal electricity needs are met with the quality of electricity within federal guidelines. MGE and Alliant Energy power plants only produce electricity when their marginal cost is lower than the price offered on the MROE market. MROE can demand a utility produce electricity even if the marginal cost is greater than the offered price. Should the prices be too low or MROE not need additional electricity to maintain quantity and quality, power plants will not turn on for that specific day unless under other obligations.

The other portion of energy consumption is the stationary combustion on site. This is the emission produced from the use of natural gas for heating, cooking, and other uses. MGE is the sole provider of natural gas in the City of Madison.

Justifications for using MROE emissions data

The electricity supplied to the City of Madison generally comes from MGE and Alliant facilities; however, electricity flows freely along power lines and Madison electricity may be produced at distant locations. As a result, Madison utilities do not fully represent the composition and emission of the electricity being supplied along the grid. Because the electricity may be supplied from several locations, the MROE standard presents the best data on the emissions caused by electricity consumption in Madison. See Table 9 for breakdown of MROE emission data.

Table 9: 2012 MROE Emissions Rates

Green House Gas	Emission Rates (lbs/MWh)
CO_2	1621.42
NO_x	0.10794
CH_4	0.01873

Source: United States EPA eGRID

Residential Energy

Residential energy is composed of electricity and stationary combustion fuels, primarily natural gas. MGE and Alliant both provide electricity to the City of Madison; however MGE is the only supplier of natural gas. Table 10 shows a breakdown of the energy consumption from each utility in the City of Madison.

Table 10: Madison Residential Energy Consumption

	MGE	Alliant
Electricity (kWh)	632,044,642	127,321,437
Natural Gas (Therms)	49,934,727	--

Sources: Laura McFaden (MGE) and Bridget Creighton (Alliant)

MGE data as presented is for the zip codes 53717, 53719, 53705, 53706, 53726, 53715, 53713, 53703, 53716, 53714, and 53718. The boundaries of the city do not align with zip codes and MGE bills are based on a zip code system. The zip codes listed are those that best represent the City of Madison without including too many outside residences.

Commercial Energy

Commercial energy has the same distribution structure as residential energy, with the two supplier of electricity again being MGE and Alliant Energy. MGE is the sole provider of natural gas. Commercial energy does have a significantly higher level of consumption compared to residential and industrial. In addition, Madison's commuter path lights are also included in this total. A breakdown of energy consumption is presented in Table 11.

Table 11: Madison Commercial Energy Consumption

	MGE	Alliant
Electricity (kWh)	2,096,833,714	127,324,436
Natural Gas (Therms)	97,983,525	--

Sources: Laura McFaden (MGE) and Bridget Creighton (Alliant)

As was the case for residential energy, data for MGE is for the zip codes 53717, 53719, 53705, 53706, 53726, 53715, 53713, 53703, 53716, 53714, and 53718 for the same reason as stated in the residential section of the appendix.

Industrial Energy

Industrial energy consumption is relatively small compared to commercial and residential. Data for MGE was collected from zip codes 53717, 53719, 53705, 53706, 53726, 53715, 53713, 53703, 53716, 53714, and 53718. A breakdown of energy consumption is presented in Table 12.

Table 12: Madison Industrial Energy Consumption

	MGE	Alliant
Electricity (kWh)	241,265,682	111,444,150
Natural Gas (Therms)	6,821,501	--

Sources: Laura McFaden (MGE) and Bridget Creighton (Alliant)

Transportation and Mobile Sources

The transportation inventory is broken down into three categories: road transportation, emissions from public transportation and emissions from off-road mobile sources. The first category we looked into was emissions from public transit. All data was provided by Drew Beck, Planning and Scheduling Manager for Madison Metro Transit. Madison Metro Transit offers three: the transit buses, paratransit buses and contracted paratransit services. Madison Metro Transit uses ultra low sulfur diesel fuel in all of its buses. The contracted services use a mix of gasoline and diesel vehicles. Since it is impossible to know which vehicle miles traveled for the contracted services use diesel and which use gasoline, the diesel fuel was converted into gasoline to capture the emissions from all of the vehicle miles traveled (Beck 2014).

The second category studied was on-road transportation. Vehicle miles traveled are broken down between gasoline and diesel. This data was provided by Sheralynn Stach, Chief of Business Support and IT Section at Bureau of Air Management from Wisconsin Department of Natural Resources. While the data provided is from Dane County, we relied on the urban area data for the transportation factor set. The transportation inventory requires the total vehicle miles traveled and the breakdown of vehicles by fuel type. The averages for Dane County were very different from the default values offered in ClearPath. For diesel fuel, ClearPath estimates 0.3 percent passenger vehicles, 1.3 percent light trucks, 5.4 percent heavy trucks. Dane County is comprised of 0.91 percent diesel passenger vehicles, 1.53 percent light trucks, and 3.81 percent diesel heavy trucks. For gasoline vehicles ClearPath estimates 60.6 percent passenger vehicles, 32.4 percent light trucks and no heavy trucks. Dane County is comprised of 80.59 percent gasoline passenger vehicles, 11.16 percent gasoline light trucks and 1.54 percent gasoline heavy trucks (Stach 2014).

The third category we examined for the transportation and mobile source was off-road transportation. We received information on two off-road sources: emissions from boating in Dane County (Stach 2014) and emissions from vehicles used at the Dane County Regional Airport, provided by Benjamin Siwinski, Senior Airport Planner/Project Manager. Our inventory includes Scope One emissions from the airport (Siwinski 2014).

Table 13: GHG Emissions by Source within Transportation and Mobile System 2012

	Vehicle Miles Traveled (Diesel)	Vehicle Miles Traveled (Gasoline)	Boats in Dane County	Airport	Madison Metro Transit	Madison Metro Paratransit	Madison Metro Contracted Services
CO_2 (Metric Tons)	154678	475517	29619	5908	12480	368	1234
CH_4 (Metric Tons)	16	183	10	0	0.2879	0.0099	0.1767
N_2O (Metric Tons)	0.3909	84	3	0	0.0214	0.0010	0.0800
CO_2e (Metric Tons)	155191	505036	30886	5908	12493	368	1262

Solid Waste

The solid waste inventory is broken down into three categories: waste generation, in-jurisdiction landfills, and collection and transportation emissions. Waste generation includes the total waste generated by households and businesses. Information on methane emitted was provided by John Welch, Solid Waste Manager for the Dane County Public Works, Solid Waste Division (Welch 2014). A total waste estimation was provided by George Dreckmann, Strategic Initiatives Coordinator for the City of Madison, Streets Division. The total waste was estimated using the US Environmental Protection Agency estimates of 4.38 pounds per person (Dreckmann 2014). Madison operates one landfill and supervises five closed landfills. Information from the retired landfills that are still emitting methane was provided by Brynn Bemis, Hydrogeologist for the City of Madison Engineering Division (Bemis 2014). The third category is emissions from the collection and transportation of solid waste. This information could not be obtained and is not included in the report.

In order to get a full picture of emissions from solid waste, the ClearPath software uses a waste characterization factor set. The waste characterization factor breaks solid waste into its components and asks for the percentage of each. Items include the percentage of newspaper, food scraps, and grass, among others. The waste characterization allows the ClearPath software to accurately calculate the emissions from solid waste (DNR 2014).

Water and Wastewater

The ClearPath software breaks down emissions from water and wastewater into several categories. Only three of the categories had data: emissions from wastewater treatment energy use, emissions from the supply of potable water, and emissions from the combustion of digester gas. Other categories either unavailable or irrelevant for Madison were: process emission from wastewater treatment lagoons, fugitive emissions from septic systems, and emissions from combustion of biosolids and sludges, among others.

Information on the emissions from wastewater generation was provided by Todd Gebert, a Collection System Engineer for the Madison Metropolitan Sewerage District (MMSD). Gebert provided us with standard reports that MMSD compiles each month including: plant influent flow, power use, energy use, MGE gas use, and digester gas use. The average daily electrical power purchased from the utility and the average daily electrical power produced and used by MMSD had to be converted into kWh and totaled for the year. There were two erroneous data points, June 29 and June 30, which were replaced with the average for the month of June to give a more accurate picture of electricity use. Gebert also provided the average daily natural gas purchased from the utility and the use of digester gas at the facility (Gerbert 2014). To prevent double counting, only the natural gas that was purchased from the utility was used in the wastewater category. The use of digester gas was calculated under the emissions from the combustion of digester gas category. MMSD treated 13.4 million gallons of water in 2012. This required 34,184,654 kWh of electricity and 16,078,929 standard cubic feet of natural gas for the treatment process. The population of Madison was used as the population served. Based on these inputs, the following are emissions outputs provided by Clearpath: Wastewater electric energy equivalent133,200 MMBTU; CO_2 25,853 megatons; CH_4 0.45928 metric tons; N_2O

0.42838 metric tons; gallons per capita 55,803; CO_2e 25,992 metric tons; and per capita CO_2e 0.10816 metric tons per person.

Information on the emissions from the supply of potable water was obtained from the 2012 Water Audit provided by Robin G Piper, Customer Service Manager for the Madison Water Utility. The Madison Water Utility pumped 1,065,838,000 gallons in 2012, serving 248,907 people, slightly larger than the population of the City of Madison. Some 21,022,877 kWh were used in the delivery of potable water. Natural gas is not used to provide potable water (Piper 2014). Given these inputs, ClearPath provides the following emissions outputs: water supply energy equivalent 71,750 MMBTU; CO_2 15,360 metric tons; CH_4 0.23163 metric tons; N_2O 0.26243 metric tons; CO_2e 15,444 metric tons; gallons per capita 42,821; and per capita CO_2e 0.062048 metric tons.

The last water and wastewater category is the combustion of digester gas. MMSD uses an average of 830,903.45 cubic feet of digester gas per day, with a heating content of 550 BTU per cubic feet. The emissions outputs for the combustion of digester gas are: energy equivalent of 166,918 MMBTU, biogenic CO_2 of 8,691 metric tons, CH_4 of 0.53414 metric tons, N_2O of 0.10516 metric tons, and CO_2e at 45 metric tons.

Growth Rates

The forecast growth rates are defined by the user starting in the year 2000 and are broken down into five-year increments ending in the year 2049. Examples of forecast growth rates used included: total energy intensity, total electricity consumption, and natural gas consumption. The primary source of these growth rates is the Energy Information Agency's Annual Energy Outlook 2013, which forecasts through 2040, as well as population forecasts provided by the City of Madison (City of Madison 2006) (Energy Infromation Agency 2013).

Forecasts

The ClearPath software allows users to forecast the impact a policy would have on emissions in the future. The simulation allows users to select different growth rates to account for sector growth and changes in energy intensity. The software then forecasts expected emissions using the different rates and effects (Energy Infromation Agency 2013).

Planning Scenarios

Planning scenarios allow policies to be evaluated based on user-defined forecasts. The software then deducts the GHG changes caused from the policy change over the course of the policy's lifetime. Once the emissions are deducted, the program supplies a graph showing the change in CO_2e emissions and also provides expected net benefit of the savings each policy option produces. While scenarios are user-defined, ClearPath provides the required inputs necessary for computing the emission reduction.

Fuel Prices

The ClearPath software uses fuel prices for a variety of fuels to estimate savings during forecasts. In 2012, the price of electricity was $0.1188 per kWh (EIA, Electric Power Monthly 2014). The price of kerosene was $3.16 per gallon in 2012 (EIA, Petroleum and Other Liquids n.d.). The average gas price in 2012 was $3.62 per gallon and the price of diesel was $3.968 per gallon (EIA, Petroleum and Other Liquids n.d.). Ethanol was $2.23 per gallon (EIA, Today in Energy 2013). In 2012, natural gas cost $1.05 per therm (EIA, Natural Gas 2014). Propane cost $2.47 per gallon and fuel oil cost $4.02 per gallon (EIA, Weekly Heating Oil and Propane Prices 2014).

Net Present Value Parameters

The ClearPath software uses inflation rates and discount rates in the forecast models. The general inflation rate has averaged around two percent for the last decade and we expect this inflation to continue into the future (US Inflation Rate n.d.). The electricity inflation rate is 1.1 percent (EEI 2006). The natural gas inflation rate is 3.6 percent (Consumer Price Index Summary 2014). The petroleum fuels inflation rate is one percent (EIA, Shorterm energy Outlook 2014). The waste disposal inflation rate is 1.75 percent (Residential Curbside Collection Service Rate Study 2013).

Appendix B: Bus Rapid Transit Estimates

Emissions for Bus Rapid Transit were estimated using three steps. First, the increased emissions from the hybrid fleet of buses proposed in the plan were estimated based on route length and trips per year to estimate the total miles traveled each year. The proposed trips per year were calculated by using the bus frequency proposed, which varies during peak time, off peak time, evenings, weekends and holidays. This data is found in the Capital Region Sustainable Communities Initiative (Capital Region Sustainable Communities Initiative 2013).

Table 14: Estimate of Proposed Bus Rapid Transit System Miles Traveled Per Year

	Route length (mi)	Trips per year	Miles traveled per year
East/West route	29.78	22,256	662,734
North/South route	24.02	11,795	283,307
Only East corridor	12.56	22,256	279,535
Entire system		34,051	946,091

Second, the emissions reductions for personal miles travelled were estimated based on projections of people choosing Bus Rapid Transit over personal transportation. These estimates were based upon the number of new riders expected due to Bus Rapid Transit, and an average trip length of 3.6287 miles, and an estimated number of trips per year. The estimates of new riders are found in the Capital Region Sustainable Communities Initiative (Capital Region Sustainable Communities Initiative 2013). The average trip length is the existing average trip length of current Metro riders, which is calculated from 14.6 million miles per year (Metro Transit 2013) and 52.4 million passenger miles (Cechvala 2014). Finally, each new rider is assumed to be a commuter, traveling twice daily for 255 non-holiday weekdays.

Table 15: Estimate of Total Miles Offset from Projected New Riders

	Projected new riders	Total miles offset
East corridor	331	612,561
Entire system	2644	4,893,084

Finally, the proposed Bus Rapid Transit System will duplicate many existing Madison Metro routes. Where duplicative, routes would be eliminated or shorted to the portions that are not served by the proposed Bus Rapid Transit system. Routes affected are provided in the Capital Region Sustainable Communities Initiative (Capital Region Sustainable Communities Initiative

2013). Route lengths were estimated using an online mapping system. The annual number of trips for each route, as well as the portion of the route that would be duplicative of the proposed Bus Rapid Transit system, were estimated using Madison Metro's Ride Guide (Madison Metro 2014).

Table 16: Estimate of Miles Reduced in Current Madison Metro Routes

Route number	Reduced by	Miles reduced
5	75 percent	108,469
6	90 percent	251,684
10	90 percent	169,646
20	50 percent	65,998
22	50 percent	42,211
25	75 percent	6,254
27	75 percent	17,136
29	75 percent	7,956
44	50 percent	9,180
48	50 percent	6,783
67	100 percent	89,740
Total		**775,058**

The process was repeated to consider only the East corridor proposed in Bus Rapid Transit, with routes affected and reduction amounts estimated from the Madison Metro Ride Guide (Madison Metro 2014).

Table 17: Estimate of Miles Reduced in Current Madison Metro Routes for East Corridor

Route number	Reduced by	Miles reduced
5	50 percent	72,313
6	50 percent	139,825
10	10 percent	18,849
20	10 percent	13,200
25	75 percent	6,254
27	75 percent	17,136
29	25 percent	2,652
Total		**270,229**

The totals for estimated emissions reductions used in this report are based on the emissions increase from the proposed Bus Rapid Transit hybrid buses, the emissions decrease from people switching from driving to using Bus Rapid Transit, and the emission decrease from offsetting current Madison Metro routes.

Appendix C: Photovoltaic Installations by State

Table 18: Solar Photovoltaic Installations by State

State	Capacity Installed in 2012 (MW)			
	Residential	*Non-Residential*	*Utility*	*Total*
Arizona	66.2	69.0	573.7	708.8
California	200.1	295.2	487.8	983.2
Colorado	20.1	15.5	67.4	102.9
Connecticut	3.8	3.7	-	7.5
Delaware	2.0	2.7	15.0	19.7
Florida	5.3	10.4	6.2	21.9
Georgia	0.6	6.6	1.0	8.2
Hawaii	70.3	37.0	6.9	114.3
Illinois	1.0	2.7	23.1	26.7
Indiana	0.4	0.6	-	1.1
Iowa	0.4	0.7	-	0.3
Kansas	0.1	0.2	-	0.3
Louisiana	11.0	0.9	-	11.9
Maryland	6.5	42.8	30.4	79.7
Massachusetts	14.6	104.1	4.5	123.2
Michigan	3.4	7.7	-	11.1
Minnesota	1.3	3.2	27.9	6.5
Missouri	6.9	9.7	-	16.6
Nevada	2.1	8.5	215.0	225.6
New Jersey	42.9	262.9	84.9	390.7
New Mexico	5.2	4.8	27.9	37.9
New York	15.8	39.8	-	55.6
North Carolina	0.5	20.0	101.9	122.4
Ohio	2.0	40.4	5.9	48.3
Oregon	5.8	4.9	10.0	20.6
Pennsylvania	10.0	21.3	-	31.3
Tennessee	-	0.2	22.8	23.0
Texas	9.3	9.6	35.7	54.7
Utah	1.3	3.7	0.6	5.6
Virginia	1.0	4.3	-	5.2
Washington	5.2	2.0	-	7.2
Wisconsin	0.9	7.3	-	8.2
Total	528.9	1,053	1,759	3,341

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