Perceptions and Possibilities:

Renewable Energy on the UW-Madison Campus

Ally Burg, Andrea Eibergen, Jordan Hersh, Suzie Kazar

Abstract

This study examined the perceptions and possibilities of future renewable energy utilization on the University of Wisconsin-Madison campus to determine the realistic future of implementation. We accomplished this through GIS site suitability analysis, a survey of UW-Madison students, and interviews with UW-Madison professionals and experts on renewable energy. Renewable energy on campus is not ideal due to lack of space and varying complexities with campus infrastructure, administrative politics, and economic considerations. However, strong support for renewable energy from students demonstrates the interest for UW-Madison to source its energy responsibly. Information gathered from our interviews suggests that an off-campus investment is one of the best paths to clean energy. The University administration should further their own interest in renewable energy, as well as considering energy conservation and efficiency.

Table of Contents

A. Introduction 4

1. Study Area 5

2. Basic Methodology 5

B. Literature Review 7

1. Renewable Energy Overview 7

2. Forms of Renewable Energy Overview 8

3. Other Forms of Renewable Energy Considered 9

4. Storage 10

5. Microgrids 11

6. Energy Efficiency 11

7. Renewable Energy on UW-Madison Campus 12

8. Solar 16

9. Wind 18

10. Biomass 21

11. GIS: Renewable Energy and Optimal Site Analysis 25

12. Public Perceptions of Renewable Energy 27

13. Factors and Influences on Public Perception 29

C. Methods 30

1. GIS 30

Suitable Locations for Photovoltaic Solar 30

Suitable Locations for Wind 32

Suitable Locations for Biomass 33

2. Surveys 34

3. Interviews 34

D. Data Results and Analysis 35

1. GIS 35

2. Surveys 36

3. Interviews 39

E. Discussion 41

1. Observations 41

Solar: 41

Wind: ... 41
Bioenergy: ... 42
Significance: ... 43
2. Limitations and Future Research ... 43
GIS: ... 43
Survey: ... 44
Time: ... 45
F. Conclusion ... 46
G. Acknowledgements ... 46
H. References ... 47
I. Appendices ... 53
Appendix 1: Introduction and Literature Review Figures ... 53
Appendix 2: Methods Figures ... 57
Appendix 3: Bryan Johnson Interview ... 62
Appendix 4: Greg Nemet Interview ... 64
Appendix 5: Doug Reinemann Interview ... 67
Appendix 6: John Greenler Interview ... 70
Appendix 7: Josh Arnold Interview ... 74
Appendix 8: Michael Vickerman Interview ... 77
Appendix 9: Ann Terlaak Interview ... 82
Appendix 10: Renewable Energy Site Suitability Maps ... 84
Appendix 11: Survey Results and Analysis ... 87

A. Introduction

Our research focuses on the current extent, future potential, and possible limitations of renewable energy on the University of Wisconsin-Madison (UW) campus. We aim to explore specific locations on campus where any type of renewable energy technology is currently being utilized, and limitations that restrict full generating capacity. In addition, we will discover where renewable energy could be implemented through GIS analysis. In this study, we will consider renewable energy to include photovoltaic solar power, wind power, and biomass. We are also analyzing the possibility of increasing renewable energy by collecting student and faculty perceptions, opinions, and knowledge pertaining to renewable energy through surveys and interviews. Campus opinions on renewable energy can demonstrate level of support, and therefore hold weight with administrators when making energy decisions. With enough student and faculty pressure, researching and utilizing renewable energy could become a priority for UW and lead to greater implementation in the future.

We are defining renewable energy as "energy sources that are continually replenished by nature and derived directly from the sun . . ., indirectly from the sun. . . , or other natural movements and mechanisms of the environment" (Ellabban et al. 2014, 749). Additionally, we are analyzing the following types of energy for electricity only, not heating or cooling. We have chosen to focus on renewable energy for electric production from wind, photovoltaic solar, and biomass for this project.

We chose these three types of renewable energy due to their feasibility on the University of Wisconsin's campus, as well as their relative abundance. First, as the University of Wisconsin is located on an isthmus, wind patterns are generally strong and prevalent on campus. Second, Madison receives an average of 2,635 hours of sunlight per year, with 60.1 percent of daylight hours being considered sunny ("Sunlight and Daylight Hours" 2014). Considering the relative ease with which photovoltaic solar panels can be installed, solar is a practical source of renewable energy on campus. Biomass is the last form of renewable energy we chose to evaluate due to the large amount of food waste generated not only on campus, but also in the world. Organic matter used for biomass is plentiful, and rather than creating more waste in landfills, we could be using it to generate electricity or fuel. The City of Madison is developing a compost collection system, and the university is seeking to expand their compost program as well. We have chosen to omit other forms of renewable energy, such as hydroelectric, geothermal, concentrated solar, and tidal.

1. Study Area

The study area is the University of Wisconsin - Madison, which is one of thirteen public universities in Wisconsin. The main campus is composed of 936 acres which support the study and academic interests of 43,338 undergraduate and graduate students, as well as 21,752 faculty and staff members (University of Wisconsin-Madison 2017). We are not including UW Athletic buildings in our analysis, namely the Kohl Center and Camp Randall Stadium. This is mostly due to the nature of the different administrative structure the department functions under. The Athletics Department is run as an auxiliary of campus, and receives different orders of funding. An image of the study area can be found in Appendix 1, Figure 1.

2. Basic Methodology

Our basic methodology, starting with research, will be analyzing our three chosen types of renewable energy: wind, photovoltaic solar, and biomass. After compiling our research to create a broad background of information, we will then be evaluating potential locations for renewable on the University of Wisconsin - Madison campus. Our team also wants to focus on the perceptions surrounding renewable energy to predict the feasibility of implementation on campus. This data will be collected via interviews and surveys which will be discussed further in the expanded methods section.

Public and student views of renewable energy can have a large impact on the administrative decision of whether to actually implement renewable energy on campus or not. Therefore, we will be conducting surveys around campus of a sample of students and staff. We will also be interviewing a variety of individuals with renewable energy knowledge and/or experience to gain further insights on renewable energy in general. Some of the information we are hoping to gather from individuals includes the current status and future potential of renewable energy on the UW campus, others' opinions on the matter, and new energy projects or developments. We will collect responses and analyze the information from different people to be used in our literature review, discussion, and results.

Furthermore, to assess the potential of renewable energy on campus, our team will perform a GIS analysis of the UW-Madison campus to determine where renewable energy could be implemented and create a map of the resulting data. This will include specific potential locations for the implementation of our three chosen types of renewable energy. With this, we aim to pinpoint and highlight areas where renewable energy is feasible, in order to offer options for the university, students, and faculty to consider. This GIS analysis will indicate future potential of renewable energy in regard to feasibility, including technological, financial, and administrative considerations.

Through the culmination of our research and from the results of our surveys and interviews, we will have a solid foundational understanding of student and faculty level of support, opinions, perceptions, and knowledge surrounding renewable energy, and its future implementation on the UW-Madison campus. We will also be able to uncover specific siting locations to assess potential for future renewable energy utilization on campus. We can gauge feasibility of the UW-Madison campus transitioning towards increased renewable energy in the future.

B. Literature Review

1. Renewable Energy Overview

Renewable energy has existed for thousands of years. Wind energy, used for sailing in the Mediterranean, has been recorded as far back as 5,500 years ago (Sørenson 1991, 8). In fact, the majority of energy use up until the development and spread of fossil fuels was renewable.

Fossil fuels have also been in use for thousands of years. There is evidence of surface mining and coal utilization in China dating back to 3490 BC, as well as small European mining operations amidst the Middle Ages (Moore 2016). However, fossil fuels did not become as popular as they are today until the Industrial Revolution of the late 18th century. The ideal energy source of the technology developed, such as the steam engine, was fossil fuel ("History of Fossil Fuel Usage" 2017). The first rock oil well, drilled in Pennsylvania in 1859, introduced the petroleum era (Moore 2016). As automobiles, trains, and planes were invented, the need for oil and other fossil fuels dramatically increased. From 1965 until 2007, global oil consumption increased from 3.8 billion tons to 11.1 billion tons per year (Moore 2016). The United States, and much of the world, is dependent on nonrenewable energy for transportation, heating, and numerous aspects of day-to-day life.

Nonrenewable energy cannot last as long as the rate of consumption exceeds rate of natural fossil fuel formation, a fact that the general American public discovered in 1973. Interest in renewable energy skyrocketed after the oil embargo of 1973-1974 (Sørenson 1991, 10; Shah et al. 1999, 692). Previous embargos had made slight waves, but the event in 1973 sparked a movement in the United States. In the midst of the Arab-Israeli War, Arab members of the Organization of Petroleum-Exporting Countries (OPEC) decided to impose an embargo against the United States due to, among other reasons, the latter's choice to provide supplies to the Israeli Army ("Oil Embargo 1973-1974" 2017). As a result, oil costs quadrupled and helped to cause a recession in the United States (Amadeo 2017). These factors, along with OPEC's growing control of oil resources and the U.S.'s declining oil production, prompted a shift towards renewable energy development. The recent rise in fossil fuel costs has also spurred renewable energy development and popularity.

2. Forms of Renewable Energy Overview

Wind energy is a form of solar energy, with winds created by "the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth" ("Wind Energy Basics" 2017). The wind flow then can be gathered in by wind turbines and used to generate power, which can then be converted to energy ("Wind Energy Basics" 2017).

The second form of renewable energy we have chosen to focus on is photovoltaic solar, a form that has skyrocketed in popularity over the last thirty years (Shah et al. 1999). Photovoltaic cells act as converters to turn solar energy directly into electricity (Wysocki and Rappaport 1960, 576). They use semiconductor materials, such as silicon, to form electric fields. As light hits the cell, electrons are scattered and form an electrical circuit, which can be captured as electricity ("How do Photovoltaics Work?" 2008).

Biomass is any organic matter that comes from plants, animals, or humans wherein the sun's energy is stored in organic matter, either directly or indirectly, through photosynthesis. Bioenergy is biomass that is converted into a form of energy that can be used for electricity, heat, or fuel. Biofuels are biomass that is burned as fuel or converted into liquid fuel (Ellabban et al.

2014, 750). Biomass can also be left to decompose and create methane gas, which can be collected and used for electricity or heating. Generally, this is done through composting, digesters, or landfills.

3. Other Forms of Renewable Energy Considered

Hydroelectric energy uses damming to increase the energy potential of water, which can then be turned into electricity (Hamid et al. 2017). Damming is often controversial, as it offers harmful ecological risks and can change the systems of bodies of water were constructed (Sharpe 2014). It is highly unrealistic that additional dams will be constructed on the shores of Lake Mendota or Lake Monona, the two closest bodies of water, given all the factors that must be considered. Another consideration is that majority of the decent hydroelectric sites in Wisconsin have already been developed to the ideal capacity (Vickerman, Interview).

Geothermal energy is energy stored deep in the earth's magma, where heat is continuously produced (Hamid et al, 2017; Fridleifsson 2001; "How Geothermal Energy Works" 2014). It can be gathered in not just at seismic hotspots, but anywhere on earth. There are a few different systems that can be used to capture geothermal energy, and the term is very general. For example, it can be converted to electricity through a technology called Enhanced Geothermal Systems, which taps into the heat below earth's surface, converts it to steam, and then uses that to power electric generators ("How Geothermal Energy Works" 2014). Another possibility for utilizing geothermal energy is a geo-exchange system where a building is heated or cooled using the temperature below the ground. A series of ducts controls the air based on temperature, relying on principles of heat transfer. In summer, the ground is cooler than the air above and outside so a heat pump transfers heat into the cooler ground. The reverse happens in winter, where heat is extracted from the ground to be circulated through the system. However, this system involved heating and cooling, which we have decided to leave out of our analysis to instead focus on electricity. This is also due to the intensive nature of installing geo-exchange systems, especially when retrofitting a building. If looking into a geothermal power plant, many additional factors come into play including: cost, siting, politics with the local electricity company, and more.

Concentrated solar power (CSP) uses “high-concentrating reflective mirrors to generate high-temperature thermal energy that is fed into conventional steam or gas turbines for the production of utility-scale power” (Lemus and Martínez-Duart 2012). CSP indirectly converts solar energy to electricity, has less installation capacity and energy storage than photovoltaic solar, is more complicated, and is geared towards utility-scale applications (Gaspar 2013; Rashad et al. 2013). For these reasons, we have decided not to analyze the potential of CSP on the University of Wisconsin-Madison’s campus.

Tidal energy generates electricity from waves, currents, ocean thermal energy, and salinity gradients. As Madison is not near an ocean or any saltwater, we have omitted the exploration of renewable tidal energy from this article.

4. Storage

Electricity storage is regarded as one of the largest obstacles to wider implementation of renewable energy. Electricity storage is needed when there is “more supply than demand,” and the energy needs somewhere to go for later release (“How Energy Storage Works” 2017). There are multiple types of energy storage, such as thermal storage, Compressed Air Energy Storage (CAES), hydrogen, pumped hydroelectric storage, flywheels, and batteries (“How Energy Storage Works” 2017). None of these solutions are perfect. As it pertains to batteries, one of the main problems is the high cost (Green 2012). When using batteries to store electricity, prices hike up to around 20 times the normal cost, making battery storage an unrealistic large-scale solution (Trainer 2017, 386-393). In regard to all energy storage technology, it is often too expensive, not supported by policy, and in too low of a demand to justify necessary research and development ("How Energy Storage Works" 2017). Renewable energy must be cost competitive in order to be realistic and justifiable. The technology is also not advanced enough to make many types of storage a feasible solution economically.

5. Microgrids

The concept of microgrids is crucial towards successfully implementing renewable energy into the grid. This is because a microgrid accommodates and facilitates renewable energy generation and transmission **(**Ekanayake et al. 2012). A microgrid is essentially a very high-tech and efficient energy grid. Common traits of a microgrid are as follows: communication links to ensure effective operation, integrated operation of generators and transmission circuits, automatic control systems, smart and technological metering, combination of technologies and end user solutions, more reliability through maintaining power quality, and they allow for open access to directly to markets **(**Ekanayake et al. 2012). Madison Gas and Electric (MG&E), has included in its Energy 2030 framework the goal of building a dynamic, integrated electric grid to enable new technology (MGE's Energy 2030 Framework, n. d.). This grid will transition from one-way power flows to two-way power flows to enable distributed energy sources such as solar and battery storage to contribute to Madison's energy needs.

6. Energy Efficiency

While we have researched and analyzed many different types of renewable energy technology, reducing energy consumption and increasing energy efficiency are crucial beginning steps to renewable energy implementation. Reducing energy consumption can often be easily achieved through looking at simple reductions in daily energy usage. It takes recognition of devices that are used infrequently but always on, or switching to appliances and electronics that use less energy. For example, thousands of printers and computers are left on all day at universities across the world, despite only being used for a fraction of that time (Avila et al. 2017, 1269). Even when something is turned off, it still draws energy from the grid, called phantom energy.

The university has already taken a few measures to reduce energy usage, including the campus organization We Conserve. We Conserve, founded in 2006, created the goal to reduce campus-wide energy consumption by 20 percent by 2010 ("Sustainability at UW-Madison" 2017). They not only achieved their original goal, but reached a 25 percent energy reduction from 2006 levels even after the university had just invested $29 million for energy-saving projects across the campus (Sakai 2011). Given the university's previous investments in energy efficiency, renewably sourced energy is a logical next step.

7. Renewable Energy on UW-Madison Campus

As of 2016, close to 15 percent of annual campus electricity usage was from renewable sources or 70 million kilowatt hours (kWh). While some of this energy comes from solar projects on campus, the University also buys Renewable Energy Credits or Certificates (RECs) from various energy entities, like Madison Gas and Electric (MGE) ("UW-Madison EPA Challenge" 2017). Currently, there is no wind power being utilized on campus; there are no wind turbines or windmills present. The nearest large-scale wind project is located in Cross Plains, Wisconsin known as Epic's Galactic Wind Farm. However, MGE does own and produce 137 megawatts (MW) of wind through various wind farms in Wisconsin and Iowa ("Wind Power" 2017.)

Solar energy was first explored on campus in 1954 through the Solar Energy Lab (SEL), created by a chemistry professor named Farrington Daniels and a chemical engineering professor named John Duffie (Schmidt 2014). The first thing they studied was how to power home appliances by harnessing energy from the sun. The biggest early accomplishments of the SEL, as told by Duffie, were that they "built the springboard from which the lab's later successes were launched" (Schmidt 2014). Later, in the 1970s, the SEL built the TRaNsient SYStems (TRNSYS) software that could evaluate any type of energy system. Recently, the SEL has been focused on creating new CSP plants to produce electricity more efficiently while taking up less area, as well as constructing new CSP plant cooling methods (Schmidt 2014). See Appendix 1 for archived photos.

Additionally, there are various solar projects implemented on campus. There are solar panels on Dejope and other buildings in the Lakeshore residence hall neighborhood such as Leopold. Photographs of solar panels in Lakeshore can be seen below in Appendix 1, Figures 5-6. Furthermore, the Wisconsin Energy Institute has completed five photovoltaic solar panels on top of their facility, along with many other eco-friendly designs and features ("WEI Building" 2017). A few other locations you might spot solar panels include the Discovery Building and the visitor center at the UW Arboretum, where solar provides electricity and about 40 percent of the building's heat ("Visitor Center" 2017). Please see Appendix 1, Figures 2-4 for images of renewable energy on the UW-Madison Campus.

Besides having solar and geothermal systems installed, the Wisconsin Energy Institute (WEI) is a leader in energy research, with their focus being "the transition away from fossil fuel dependence toward new clean energy systems and solutions" ("About" 2017). WEI consists of various professors, engineers, and researchers all working towards the most pressing energy challenges, from batteries to biofuels and more. Housed within the Wisconsin Energy Institute, the University of Wisconsin - Madison is also the chief university of the Department of Energy's (DOE) Great Lakes Bioenergy Research Center (GLBRC), in partnership with a few other universities ("DOE GLBRC" 2017). The GLBRC focuses on the conversion of sunlight and plants into biofuels through a variety of disciplines. Sustainable biofuel production is important to help meet the world's growing energy needs. If the research the GLBRC is doing could be incorporated into the university's disposal process for organic waste, a holistic solution could be reached to minimize waste and produce energy.

In regards to biomass, the UW-Madison currently has a small compost collection system, with a large capacity for expansion. Compost is collected from campus residence halls, dining halls, the unions, and select public compost bins. Within University Housing, there are six different dining facilities on campus, along with 19 residence halls. According to the University Housing Sustainability and Communications Coordinator Breana Nehls, about seven tons of compost is collected per week, with close to 40 percent of the organics originating from University Housing (Nehls, pers. comm.). Outside of any dining or residence hall there are bins to compost, along with countless other individual sites on campus (Burg, pers. comm.). The two unions, Memorial Union and Union South, also collect compost on site. There are two public compost collection sites on campus: Parking Ramp 76 and Parking Lot 62 ("Composting" 2017). These collection sites generally include larger bins that anyone can access outside.

The compost from each site is collected by Facilities Planning and Management and sent to the West Madison Agricultural Research Station (WMARS). WMARS is run by the university for use by the College of Agriculture and Life Sciences and other campus departments. WMARS contains 575 tillable acres of land used for agriculture, plants and gardening, and compost

("About Us" 2015). The compost is collected in windrows, which are long rows of compost that gets frequently turned over to maintain heat and capabilities. The finished product is used on site or on campus, and the high quality compost is packaged and sold in bulk to the community.

The Office of Sustainability on campus is currently working with Housing to address issues of contamination in the compost (Burg, pers. comm.). One of our group members, Ally Burg, works as a student intern for the Office of Sustainability, and has knowledge of their projects. The future plans are to move forward with collecting compost from all parts of campus to bring to WMARS. They are working on an outreach program to educate students on correct composting practices, as well as composting opportunities on campus. The goal is to increase use the of the compost bins, while maintaining a clean compost stream free of contamination. Additionally, the dining facilities are in the process of transitioning all their to-go ware to compostable products. After communicating with WMARS, all of these products are cleared to be combined with compost in the windrows. This creates a another possible compost stream, as long as there's enough awareness surrounding these products. Once enough students are made aware of the possibilities of composting all around campus, there's potential for a large increase in the amount of food waste and products that are composted.

Overall, an increase in the amount of compost collected depends on more education and awareness about composting on the UW campus. However, a large amount of compost opens up discussions about investing in the use of a digester to process everything. This would be a costly investment, but would allow for the collection of methane gas, along with a high capacity of compost that can be collected, and a wider range of food waste or products allowed. WMARS is doing an informal experiment to see how their windrows can handle the addition of all of the compostable to-go products. However, there have already been some complications, such as the larger containers blowing away in the wind. If the compostable plastics and to-go containers don't break down in conjunction with the rest of the food waste, then these products will be contaminating the rest of the compost that could be sold or used, slowing down the whole process. These problems would be eliminated with the use of a digester to compost. If the university could partner with a facility to cost-share the use of a digester, both can benefit from the end-products.

8. Solar

Photovoltaic solar is one of the primary renewable energy technologies we will be analyzing. As stated previously, photovoltaic cells capture incoming solar radiation and convert that energy into electricity that can be directly used in the grid (Wysocki and Rappaport 1960, 574). The electricity produced is in the form of direct current. The solar panels are primarily comprised of silicon based systems and their efficiency largely depends on scale. Concentrating solar energy can increase the efficiency of photovoltaic cells by up to 40 percent (Ellabban et al. 2014, 757). The trends in regards to pricing and production also appear very optimistic, as "photovoltaic production costs have dropped by more than 20 percent for every doubling of production quantity and in the past decade PV production has doubled every 2-3 years" (Boyle 2012, 104). Furthermore, it is estimated that capital costs will be halved by 2030 and perhaps even decreased as much as one fourth of their current costs by 2040. This, along with growing global installation, has led to predictions of doubling of the world's photovoltaic implementation for every two to three years moving forward. This would then result in raising the world's solar energy supply up to 21 percent by 2050 (Boyle 2012, 112).

Solar photovoltaic has several advantages, one of which is the implementation of large module manufacturing to allow for economies of scale and much larger efficiency. In addition to utilizing direct sunlight, new and improved technologies can harness the diffuse rays of sunlight meaning that panels can still generate some electricity if the sky is not completely clear. This also means that solar panels have more flexible positioning requirements and can be located in varying locations (Ellabban et al. 2014, 750). Additionally, solar panels have minimal environmental impact. Photovoltaic solar panels, unlike wind turbines, are quiet and relatively unobtrusive (Green 2012). They make no noise, do not move once installed, contain practically no gaseous or liquid pollutants, and potentially do not require any additional land if installed on previously existing buildings. Large solar farms do take up land and solar panels do have some visual impacts, but overall their environmental impact is very small compared to conventional fossil fuel methods of energy generation. However mining for silicon, which is used to produce the panels themselves, has considerable environmental consequences (Boyle 2012, 88).

Photovoltaic solar does have several other limitations and disadvantages. One key issue is that intermittency affects both the storage rate and volume of solar power. The energy would have to be stored at a high rate for many short periods, which would be very inefficient and costly. In regards to solar, the capacity factor is currently too low for ideal storage, especially in the winter, and this technological limitation really puts a check on how widespread solar can truly become right now. Solar energy can be sporadic, as the sun is not always shining due to clouds or nighttime, and when there is no insolation there can be no photovoltaic electricity generation. Solar ray availability varies geographically and therefore can heavily limit where solar photovoltaics can be efficiently utilized (Trainer 2017, 386-393). As already mentioned, there are economic concerns regarding the storage of electricity from photovoltaic solar (see section 4 of Literature Review). Large scale plants are significantly more efficient, which ties into land use concerns as well as geographic limitations of insolation. In addition, sun rays are not very concentrated, ultimately limiting the capacity factor and efficiency to capture solar energy to be harnessed (Boyle 2014, 89).

9. Wind

Renewable wind energy is derived indirectly from the sun. As the sun heats different areas at uneven rates, air either rises or falls to creates wind, and turbines harness that wind energy (Rosenberg 2008, 517; "Wind Energy Basics" 2017). In Wisconsin specifically, there is an abundance of viable wind sources. In a study that generated roadmaps for all 50 states to reach 100 percent renewable energy sources, Wisconsin garnered 45 percent of its energy from onshore wind and 30 percent from offshore wind (Jacobson et al. 2015, 2099). However, on the state level, wind growth in Wisconsin is stagnant. Wind energy is growing by 45 percent in five surrounding states, but only by 3 percent in Wisconsin due to an unfriendly political climate (Content 2016). Locally, the only physical growth in wind energy has been by Epic Systems in Verona, who have constructed six new turbines (Content 2016). Madison Gas and Electric (MGE) also provides its local Madison customers with about 12 percent of renewable energy, a bit higher than the 8 percent standard required by the state ("MGE's Electricity Sources" 2017). As briefly mentioned before, MGE's wind capacity of 137 MW helps to contribute to their total mix of renewable sources of energy. With only two in Wisconsin, MGE has sourced out to Iowa for three additional wind farms, one of which was recently approved in November of 2017 ("Wind Power" 2017). While the actual infrastructure is located a state away, Wisconsin energy consumers do benefit through MGE's investments in green wind technology.

Wind energy, in theory, is a very popular form of renewable energy. Compared to others, it has high and stable levels of public support. Once installed, there is no fuel cost for generation of power, so there is no volatility in fuel pricing (Rosenberg 2008, 522). Additionally, wind follows predictable patterns. While it may not always follow these patterns closely, it can be mapped where wind energy is more reliable and productive and thus where it should be installed. Wind energy, along with other renewable energy sources, has fewer downsides than fossil fuels. Using more renewable energy, including wind, would help to eradicate energy-related air pollution and emissions. This would additionally offset the health and environmental impacts that occur in conjunction with fossil fuel use. The new industry would, additionally, create jobs and help to stabilize energy prices (Jacobson et al. 2015, 2114).

There are several drawbacks to wind power, however. First, since wind itself can not be reserved, the energy needs to be stored for later use and energy grids need to be created for transportation. ("Wind Energy Basics" 2017). Second, wind energy does not respond to energy demand. No matter how much electricity may be needed, wind, although following general patterns, is sporadic ("Wind Energy Basics" 2017). Lastly, wind turbines can often be noisy and unaesthetically pleasing to those who live or work nearby. For all of the support wind energy gathers during polls or surveys, once new farms are proposed there is often controversy and opposition (Devine-Wright 2004, 126; Devine-Wright and Howes 2010, 271). Factors such as visual impacts and noise are frequently cited as negative impacts of wind turbines. Wind farms can also have significant impacts on surrounding wildlife and environment. One manner is through noise pollution. Wind turbines can be very loud, typically in the range of 40-50 decibels, yet newer models are designed to be much quieter. Furthermore, there are instances of electromagnetic interference in which they can reflect waves distorting signals. In addition, the American Bird Conservancy reports that approximately 100,000 to 440,000 birds collide each year with wind turbines (Boyle 2012, 342). However, when put in perspective, the collision rate is not that high compared to the 100 million to 1 billion that collide with glass windows and buildings per year (Boyle 2012, 342). New design mechanisms have proven successful to reduce that number by making them have larger slower blades and due to strategic positioning (Boyle 2012, 343).

If wind energy is implemented directly on the UW-Madison campus, it will have to be harnessed by small-scale turbines that only service the buildings on which they are installed. Due to UW's contract with MGE, the University cannot act as its own utility. Therefore, one way to get around that is to create a closed loop system and only have the building producing the energy use it (Aley, pers. comm.). There are two primary forms of small-scale wind turbines, HAWTs and VAWTs. HAWTs, or horizontal-axis wind turbines, are typically best in open areas with consistent, straight air flow and few impediments (Cace et al. 2007, 8). VAWTs, or vertical-axis wind turbines, are often deployed in urban settings as they are well-suited for turbulent wind flows (Dayan 2006, 34). VAWTs can then be divided into two subcategories, Savonius and Darrieus. The rotation speed of a Savonius VAWT's blades is always lower than the wind speed, while a Darrieus VAWT can spin faster than the wind speed (Cace et al. 2007, 9). Darrieus VAWTs have more advantages than Savonius VAWTs, as they have a lower visual impact, reduced noises, and a better response to turbulent and skewed oncoming winds (Balduzzi et al. 2012, 924-5).

There are multiple siting factors that play into the efficiency of small-scale wind turbines. It is best for large buildings with a flat roof approximately 50 percent taller than surrounding structures with annual mean wind speeds of at least 5.5 m/s. There are preferably multiple turbines located at the roof's center, and the lowest position of the rotor should be above the roof by at least 30 percent of the building height (Cace et al. 2007, 31).

There are various small wind turbines to explore. However, many of them, like the popular Windspire, cannot be utilized on campus as it needs to be tied to an electricity grid ("How Does The Windspire Work" n.d.). Likewise, the Southwest Windpower Skystream 3.7 also needs to be tied into a grid (Hurst 2008). One model that could work is the Southwest Windpower Air X, which is designed to power small appliances in off-grid installations, although it may not provide enough energy for a campus building (Hurst 2008).

While small-scale wind turbines are the most feasible to implement on UW-Madison's campus, they are ultimately less effective and efficient than utility scale wind (Lombardo 2015). Realistically, the best way to increase wind energy on campus is to push utilities, such as Madison Gas and Electric, to continue to build wind farms and to lobby the state legislature to make Wisconsin a friendlier place to build wind farms.

10. Biomass

Biomass energy is a form of energy created using the sun's energy that is stored in organic matter from photosynthesis (Ellabban et al. 2014, 749-750). Using biomass as a type of renewable energy is dependent on one caveat: a renewable source of organics. If the organic material used to create energy cannot be sustainably produced and harvested, biomass energy falls short of the basic definition of renewable energy. Biomass constitutes any organic material including, but not limited to, food, animals, manure or human waste, and any vegetation. This organic material can then be converted into energy through a variety of ways including: direct combustion, gasification, pyrolysis, digestion, and fermentation (Sriram and Shahidehpour 2005, 1-3). Direct combustion involves burning biomass to create steam to push a turbine that is connected to a generator. This generator therefore produces electricity to be stored and used. However, only certain organic materials are best suited for this type of production. Gasification is the process of converting biomass into a liquid fuel or a synthetic gas (syngas). This syngas, composed of carbon monoxide, hydrogen, and other hydrocarbons, can be chemically converted to ethanol and other fuels. It can also be used as fuel in combustion engines, turbines, and more. Pyrolysis comes from the breakdown of organic matter into a smaller, more dense form of energy commonly referred to as biochar. However, the process also produces a mixture of bio-crude, a combustible oil fuel, and syngas (Sriram and Shahidehpour 2005, 2). The product yield of the thermal decomposition (combustion with the absence of oxygen), is mostly dependent on the temperature used. Another form of biomass energy production, called fermentation, implements the use of microorganisms and yeast to produce ethanol, the most widely used biofuel (Sriram and Shahidehpour 2005, 2-3). Lastly, digestion also relies on microorganisms to decompose organic material into a variety of byproducts that can be reused. For the purposes of our analysis, we will be primarily investigating the possibilities of digestion to convert biomass into energy, in the form of an anaerobic digester (AD).

In anaerobic digestion, different bacteria and archaea work together to break down organic biomass in a series of stages. The final products generally consist of methane, carbon dioxide, and a solid and liquid digestate ("The AD cycle" 2017). This is a very efficient use of biomass as it produces three byproducts as waste, all of which can be reused in some form. There are two ways the byproducts of digestion can be collected: through a machine, like an anaerobic digester, or through gas collection from a landfill. In the latter, organics that are thrown away sit in landfills to accumulate and decompose over time. The methane from this decomposition can be collected through putting an impervious layer over the waste and funneling the gas through tubes to surface to be collected and used. This is a better alternative to this methane, which will be produced anyways, contaminating the air. Methane is a very potent greenhouse gas, considered around 25 times worse than carbon dioxide over a 100 year time span (EPA "Overview of Greenhouse Gases" 2017). Therefore, one of the main benefits of digestion is that this important process helps to eliminate methane released into the atmosphere.

Some other benefits of using an AD include waste diversion, soil benefits, and the fact that it's a renewable energy source. Every year, about 1.3 billion tons of food waste is produced in the food supply chain worldwide (Xu et al. 2017, 1). The tons of food waste sent to landfills can be greatly reduced by wider implementation of composting practices and anaerobic digesters. On top of this, manure, excess landscaping, human sewage, and other organic waste can all be reused to create bioenergy and cut down on waste. Another major benefit to producing bioenergy is that one of the bioproducts include a mixture of solid and liquid digestate. Both of these byproducts are incredibly nutrient rich and, when added to soil, increase soil organic matter and improve the general soil health in a variety of ways (EPA "Environmental Benefits of AD" 2017). With any great technology, however, there are several limitations and drawbacks.

One of the largest complaints with the anaerobic digestion process is the smell. This is due to the fact that part of the acidogenesis process (the second stage of breaking down organics) consists of a very small amount of hydrogen sulfide, which gives off a rotten-egg smell (EPA "Frequent Questions" 2016). However, given the nature of anaerobic digestion, the system is contained to prevent oxygen from entering and the smell from leaving. Carbon dioxide is also generated in the digestion process and is a part of the final product. The burning of methane to use as energy also produces carbon dioxide in small amounts. However, both of these emissions are outweighed by replacing fossil fuels with bioenergy, therefore amounting to a net reduction in CO_2 (U.S. EIA 2017). Another downfall of ADs is the up-front costs associated with infrastructure. First, ADs require a sizeable amount of land upon which to place the physical digester. The area required, however, will largely vary with the size of the system. In addition to land, the digester can cost anywhere from $3,700 - $7,000 per kilowatt hour (Navaratnasamy, Edeogu, and Papworth 2008, 4). Lastly, there's conflict in the scientific literature about whether bioenergy can actually be considered a renewable energy source. According to the EPA, bioenergy is renewable because it's inputs are "replenished in short periods of time" ("Frequent Questions" 2016). Some would argue otherwise, stating how biofuels can only be sustainable when using feedstock with lower overall greenhouse gas (GHG) emissions than fossil fuels and little to no competition with food crops or production (Tilman et al. 2009, 270). With a growing population, it's essential to maintain food security while decreasing waste. Implementing anaerobic digester on a university campus can significantly decrease the amount of food waste that ends up in landfills, while minimizing environmental harms.

One example of a digester that would suit the University's needs is the Flexibuster, a compact system made in the UK that processes food waste. This system costs approximately $40,000 and has the capability to handle between 1,000 to 6,000 lbs of feedstock per day. The system is designed to be modular and stackable, so if the waste stream grows the system can be grown as well. The system consists of a pasteurization tank and digester, biogas storage, and a small CHP unit. Food waste and other feedstock materials are loaded into one end, and the system manages the rest. It monitors the flow of waste into the buffer tank to ensure that the bacteria are not "overwhelmed" with organics. The bacteria then consume the feedstock, creating biogas, fertilizer, and water, as well as some heat in the process (SEaB Energy 2017, 15-18).

Some articles recommend pulping the feedstock, which allows the system to run smoothly and cut down on maintenance costs (Mastro et al. 2017, 15-18). According to Breana Nehls, the university currently uses pulpers in its two biggest dining halls, Gordon and Dejope (pers. comm.). New pulpers would integrate seamlessly into the system and could be implemented in additional dining halls to produce more suitable matter for use in the digester. With the composting system in place at the University of Wisconsin-Madison, and anaerobic digester would be a logical next step to increase renewable energy use and cut down on both cost and waste.

11. GIS: Renewable Energy and Optimal Site Analysis

Due to the multitude of variables surrounding the siting factors for each of our chosen types of renewable energy, many data sources are needed as well as a robust way to maintain different data layers and assist in analysis. A GIS-based approach is well supported throughout the literature as a way to organize and aggregate these data layers (Malczewski 1999). GIS approaches have been used in countless studies surrounding solar, even specifically on a university campus. Kucuksaria (et al. 2014, 1604-1610) studied urban rooftop solar photovoltaic availability and potential for the next two decades using a geographic information systems approach. Cloud cover, atmospheric scattering, inclination, orientation, shadowing due to the nearby objects, and surrounding terrain are all considered in order to accurately estimate the irradiance needed for photovoltaic units (Kucuksaria et al. 2014, 1606). The schema proposed in this report has been put into effect on a real campus in Arizona. Their proposed variables included orientation, slope, irradiation, and area. Due to the study area and variables, this analysis is extremely applicable to our analysis.

GIS analysis has also been frequently used in siting of wind energy, most notably by the National Renewable Energy Laboratory (NREL). Another example comes from Janke's (2010, 2228-2234) analysis using geographic information systems to determine which land cover types are associated with high wind energy potential and establish which locations would be most viable for wind energy production. The author adds a disclaimer that while GIS models are very helpful, any site that is determined to be suitable must also be verified to ensure that local wind conditions are as determined in the model. It is especially important to verify sites in cities where microwind patterns can completely change the expected energy output of a system (Kalmikov et al. 2010, 24). To determine where rooftop solar would be suitable on campus, the accepted specifications are large buildings with flat rooftops that are at least 50 percent taller than surrounding infrastructure or natural features (Cace et al., 2007, 9). Furthermore, one must ensure there are no protected or endangered species inhabiting the area, that people who live in the area consent to having wind turbines in their backyard (NIMBYism), and that there is not any other factor that will inhibit the ability to harvest wind energy in the given area (Janke 2010, 2230).

GIS analysis of biomass analysis typically focuses on analysis of proximity to feedstock sources such as municipal wastewater treatment plants or agricultural areas, but in the University of Richmond case study, the authors focus specifically on food waste on campus, just as we are in our analysis. In Mastro's (et al. 2017, 15-18) assessment of the University of Richmond, they propose using an anaerobic digester on to cut down on food wastes produced by their dining halls. The team highlights the ways in which introducing this infrastructure will support the university's goals and ideas. Using geographic information systems analysis, the researchers propose potential locations for a digester on campus based off the slope of the ground, distance from water bodies, and distance from residence halls, in addition to proximity to dining halls, the steam plant, and major roads (Mastro et al. 2017, 15-18). The information in Mastro's (et al. 2017, 15-18) paper will be an integral part of our research and GIS analysis because it is up to date and congruent with the research we will be doing.

Despite studying three different types of renewable energy, the studies mentioned above all have one thing in common: they include multiple data types and forms of analysis. The data types we will be using include vector and raster data. Vector data is defined as data that represents real world spatial conditions using lines and edges in the form of points, lines, and polygons. The vector layers that we will be using will include those that must be excluded from our analysis, such as protected areas or roads. Raster data is a continuous field of pixels that is used to represent spatial conditions and their characteristic gradience (Maffini 1987, n.d.). The raster layer utilized in our analysis will be the digital elevation model from which we will extract slope and aspect data. To extrapolate meaning from all this data, we will be using both a Boolean and fuzzy logic system of analysis. Boolean analyses are often used for vector data, and fuzzy logic for raster (Janke 2010, 2229). A Boolean analysis involves rigid operators - either the object being studied fits the conditions or not. Fuzzy logic is more of a continuum of conditionality - it is based on “degrees of truth” (Janke 2010, 2229). These articles informed our site selection variables in our analysis and assisted in creation of our conceptualization and implementation diagrams.

12. Public Perceptions of Renewable Energy

For our study, it is also important to research renewable energy student opinions in other areas to compare and analyze the literature with our own results. Celikler’s (2015, 649-653) paper examined seventh and eighth grade students perceptions and opinions from Turkey. The study looked at 445 students using three open-ended interview questions followed by a 26-question survey. The data was then analyzed using statistical analysis. In summary, the data suggested that most of the students had learned what renewable energy was back in elementary school and some in their secondary school, but really hinted that the internet and media had no real role in framing their knowledge or awareness. Hydrogen and biomass were often left out when considering what renewable energy to be, but most were accurate in citing two of the larger forms of renewable energy (wind and solar). The study further indicated that the majority of the students believed that there were numerous harms involved in the operation of power stations, including renewable ones, and that they would be unwilling to live close to one (Celikler 2015, 649-653). They also felt that renewable sources were safer and cheaper compared to conventional fuels. Moreover, the survey indicates that a vast majority of students believe in climate change and its dangerous consequences. They demonstrated knowledge of renewables and were in favor of the opinion that renewable energy would reduce those impacts and is environmentally friendly. In addition of what the article demonstrates the significance of education in its responsibility to raise awareness (Celikler 2015, 649-653).

Another research study done in Turkey focused on studying rural versus urban students as well as looking at how gender impacts people's responses. The study was administered using a survey and had many interesting conclusions. Most of the students had a limited ability in identifying renewable versus non renewable sources of energy. However, 87 percent were in favor of renewable energy as being a viable option for the future and most stated they were open to adopting renewable energy even if more expensive. Overall, females were significantly more knowledgeable than males about renewable energy and fossil fuels as a whole, including nuclear energy, and showed more awareness over the subject. Furthermore, urban-living students showed increased knowledge and more positive opinions when compared to rural area students. This is due to better education from superior schooling districts than compared to rural areas with poorer school systems with less resources (Zyadin 2012, 78-85).

13. Factors and Influences on Public Perception

There are several different factors and influences that impact people's opinions and perceptions pertaining to renewable energy. From the above articles, some factors include gender, age of exposure, level of education, and urban versus rural backgrounds. However there are several additional influences. One study carried out by Van der Horst (2017, 2705-2714) explores protests in response to renewable energy facilities being installed in neighborhoods. It looked at six key variables that were essential in forming people's opinions: spatial distance, temporal extent, inclusion of passive versus active protesters, extent of the power of protest leaders and followers, strength and nature of expressed opinions of those in favor of wind power, and the extent to which interviewees avoid being labeled as NIMBY but by citing other legitimate reasons for opposition. The data was collected through interviews to attain people's opinions and their level of knowledge and experience in dealing with this issue. The goal was to explore the relevance of location and politics as influential factors. The first conclusion was that location, specifically proximity, had an incredibly strong influence in people's attitudes to proposed wind projects. Yet many other factors such as value of the land, nature, and time also played into opinions for more tangible projects. Rural communities were very opposed to renewable energy facilities. Furthermore, people had a negative connotation of being categorized as NIMBY, which impacted their responses to the questions when asked (Van der Horst 2017, 2705-2714).

Another study (Bidwell 2016, 743-768) explored the idea of providing information to increase knowledge of renewable energy to see if that had any effects on the public's attitudes. The study was conducted by providing in depth information about wind and other renewable energy to two groups, one control and one not, and evaluating their perceptions and stance on the matter after the session. They received participants from a coastal community in Michigan that was already relatively in favor of wind energy to see if they could further influence their mindsets. Surveys were administered before and after the sessions. This article indicates the group which received the in depth knowledge had much higher excitement and intrigue for renewable energy development than the control group. Their level of enthusiasm was significantly higher as well as their confidence in the wind's ability to provide ample energy to their community. This ultimately led to the experimental group to have much higher support for wind energy overall. This article helped prove that knowledge has a definite effect on influencing people's opinions in regards to renewable energy. It also reinforces the notion that increased knowledge about renewable energy and other environmental topics is important in early education. With this in mind, the authors believe that more widespread knowledge about renewable energy can lead to greater positive opinions and increased implementation in the future (Bidwell 2016, 743-768).

C. Methods

1. GIS

In order to evaluate the possibilities for renewable energy on campus, we have implemented a multifaceted approach. The proposed structure of our GIS renewable energy potential analysis begins with evaluating where each of our selected types of renewable energy could be implemented.

Suitable Locations for Photovoltaic Solar

The design for photovoltaic solar energy potential analysis starts with a geographical assessment of the area to determine areas where photovoltaic systems can be implemented. To begin the analysis of rooftop solar, buildings that have historical significance must be removed from the analysis. Then, due to lack of data (no DEM detailed enough) for rooftops on campus, we will use Google Earth Pro, wherein we select all the buildings that have flat roofs (Harju et al., 2016). Google Earth Pro uses Landsat 8 and Sentinel 2-A data from 2014, so it is relatively recent and most buildings will still have the same roof makeup as when the aerial imagery was captured. By altering the aspect of the Google Earth imagery, we were able to determine which buildings had flat roofs and then select them from our buildings shapefile to be used in our solar analysis. For our analysis of ground-based solar, we begin by using the area solar radiation tool to calculate the insolation across an entire landscape, in this case the UW-Madison Campus. The calculations are repeated for each location in the input topographic surface, producing insolation maps for an entire geographic area (ArcGIS, Spatial Analyst Toolbox, n.d.). Then, the slope tool is used to calculate slope of the geographic area. For each cell in the desired area, the slope tool calculates maximum change in elevation from each cell to its eight neighbors (a 3x3 grid), which identifies the steepest slope from the cell (ArcGIS, Spatial Analyst Toolbox, n.d.). Finally, we must find the aspect of each cell in order to pick out those that are flat or relatively south facing and will therefore be suitable for photovoltaics. To do so, we use the aspect tool, which is very similar to the slope tool, as it determines slope directionality. The Aspect tool identifies the downslope direction of the slope from each cell to its neighbors (again, in a 3x3 grid). The values of each cell in the output raster indicate the compass direction that the surface faces in that particular cell (ArcGIS, Spatial Analyst Toolbox, n.d.). The result of this analysis is the suitable rooftops on campus, as well as suitable areas for ground-based photovoltaics. Please see Appendix 2, Figures 8 for our implementation diagram.

Suitable Locations for Wind

The framework for our wind based GIS analysis starts with an assessment of small-scale wind turbines, as the site selection factors surrounding conventional turbines mean that conventional turbines are not feasible on the UW-Madison campus. Using an alternative style of wind turbine will allow us to place more turbines on the landscape in a way that will interfere less with the lives of humans. To begin, we will use data from the National Renewable Energy Laboratory (NREL) on wind speeds and directionality in this area. Although there are microwind patterns due to the positioning of buildings, we do not have enough time in our research period to measure and map these, so NREL speeds and directionality will have to suffice. The minimum wind speed for small scale wind turbines is 5.5 m/s (Cace et al. 2007, 31). The NREL data for Madison asserts that the average wind speed for the UW-Madison Campus is between 5.5 and 6 meters per second (NREL, 2017). Next, using Google Earth Pro, we selected all the buildings that have flat roofs (Harju et al., 2016). Google Earth Pro uses Landsat 8 and Sentinel 2-A data from 2014, so it is relatively recent and most buildings will still have the same roof makeup as when the aerial imagery was captured. By altering the aspect of the Google Earth imagery, we were able to determine which buildings had flat roofs and then select them from our buildings shapefile to be used in our wind analysis. Since there was no attribute information pertaining to building height, determining the relative height of the potential locations was done by reviewing building reports to confirm that the selected locations were at least 50 percent taller than their surroundings. The buildings found as feasible in this analysis were selected in ArcGIS and made into a new layer. Please see Appendix 2, Figure 9 for our implementation diagram.

Suitable Locations for Biomass

First, we had to determine the amount of biomass available on campus. We spoke with Breana Nehls, UW Housing's Sustainability and Communications Coordinator, to determine the quantity of food waste and compostable materials produced on campus. The university produces about seven tons of compostable material per week, and of that, approximately 40 percent is produced by University Housing, which is comprised of the dining and residence halls on campus. Based on these figures, we identified a small-scale digester called the Flexibuster that suits the university's waste stream. The digester choice is important because we must factor the area required for the digester into our GIS analysis. From this, we used ArcGIS to eliminate areas such as water bodies, floodplains, environmentally protected areas, and anthropogenic areas such as roads and buildings. We also will rule out areas where the slope of the land is not feasible for supporting a digester. Finally, we must consider distance to supply sources such as dining halls and residence halls, and distance to power infrastructure to further minimize transportation cost. Please see Appendix 2, Figure 10 for our implementation diagram.

Our site suitability analysis of biomass potential, rooftop photovoltaic potential, and wind potential will be aggregated to create a final map of the potential areas on campus for renewable energy. This will give us insight into not only where on campus the types of energy could be located, but also where there is potential for overlap in energy types. It will also allow for comparison of the GIS analysis to the surveys being given to see if support for renewables on the UW-Campus is congruent with the feasibility of implementing renewables on campus. Please see Appendix 2, Figure 7 for our conceptualization diagram.

2. Surveys

One of our key methods of gaining data about student and faculty perceptions, opinions, and knowledge surrounding renewable energy is through a survey. We used Qualtrics to administer the survey and analyze the results once the data was collected. We distributed the survey through social media, e-mail, and in-person via mobile device. The first several survey questions are demographic based, to look at the general descriptive information for each respondent. This way, we are able to analyze our data and compare it to other studies. From there, the survey is focused on statements relating to global climate change, renewable energy, and renewable energy on the UW-Madison campus that were answered using a Likert scale of agreement. We are asking statements about global climate change to gain background of the student's environmental awareness before going into renewable energy. The statements begin broadly talking about renewable energy in general, and then in relation to renewable energy's ability to combat climate change, before focusing on its use on Madison's campus. To gauge realistic support, we asked a final question about willingness to pay to implement renewable energy on campus. Please see Appendix 2, Figures 11-15 for a copy of our survey questions. For the survey results, please see the results section below and Appendix 11.

3. Interviews

In addition to a survey, we collected data by conducting interviews of qualified individuals knowledgeable about the field of renewable energy. There are number of experts and professionals in the UW-Madison community that were willing to meet with our group and give insights for our project. Please see the Appendix for a complete collection of who our group interviewed and our interview transcripts. Our first questions will cover a general overview of renewable energy to gain insight on what they think overall of renewable energy. We focused on how the interviewee got involved in the field and ask them to list some advantages and disadvantages. After gaining some background information, we transitioned to asking specific questions pertaining to UW-Madison. We asked several questions to try to affirm where renewable energy currently is being utilized, and where it has potential to be implemented on campus, and what form(s) of renewable energy would be ideal given UW-Madison's geography. Finally, we closed our interviews asking for information about limitations and challenges of implementing renewable energy on the UW-Madison campus. The subjects' answers to these questions provide insights to many aspects of our research question. Please see Appendices 3-9 for a copy of our transcripts.

D. Data Results and Analysis

1. GIS

The photovoltaic solar site suitability map, which can be seen in Appendix 10, Figure 16, is a product of the radiation and topography, specifically insolation, slope, and aspect, of the ground area of the UW-Madison Campus. Our initial aim was to include rooftop solar as well; however, a DEM with a high enough resolution to capture rooftop information was not available. As one can determine from the map, some of the areas that solar is most feasible on campus include the Near and Far West Fields, UW Marching Band Field, Parking Lot 60, and the McClimon Sports Complex. This is due to the large area of these spaces with little to no shade effect, low ground slopes, and south or neutral aspects. While we can discern from this analysis that solar on campus is feasible, due to the available space it would have to be small-scale wind.

Our anaerobic digester site suitability analysis map, which can be found in Appendix 10, Figure 17 involved an intensive extraction of land cover and land use conditions to determine where a digester could be implemented on campus. Bodies of water, roads, buildings, natural areas, and protected areas all had to be excluded from our analysis as these are inadequate land uses for our purposes. The areas that are most suitable for location of an anaerobic digester include the Near and Far West Fields, the UW-Marching Band field, Parking Lot 60, and the McClimon sports complex. This is mostly due to the large land areas relative to the rest of campus and the low slope. Implementing an anaerobic digester on campus is feasible in any of these areas, but there is some regional overlap with the solar suitability.

Potential for wind energy on the UW-Madison campus is limited, as the space is obviously not large enough to house large scale wind in any capacity. Due to this, we looked at siting factors for small scale wind. Our map was created through use of aerial imagery to reference the building heights and slope. As evident from the map we produced, which is available in Appendix 10, Figure 18, the only areas that are suitable for small scale wind energy production are large, tall buildings with flat roofs, of which there are eight in total. This includes such buildings as the Signe Skott Cooper Hall, the Veterinary Medicine Building, the Natatorium, Goodnight and Phillips Residence Halls, and Van Hise Hall. From the low site availability of campus, we determined that it may be more feasible to implement wind energy as offsite wind farms or production credits.

2. Surveys

Our gathered comments about the survey and the student and faculty responses helped to uncover opinions and knowledge of renewable energy in general and for specifically on campus. The questions directly correlate to our research focus and have provided useful data and information to analyze to help provide answers to our research question. We received 206 survey responses in total, but we excluded faculty responses and incomplete responses to bring the total down to 195 responses. We excluded faculty because we had only received two faculty/staff responses. Since this is not representative of the faculty and staff at UW-Madison, so we decided to cut those two responses from our analysis. Additionally, some people that started the survey did not finish or complete all of the questions, and therefore we cannot count their survey. We had a variety of students take the survey with majors ranging from a multitude of disciplines such as engineering, business, and social sciences. For a complete breakdown of the academic majors of responders and other demographic information, please see Appendix 2, Figures 11-15

The survey results were very skewed towards favoring renewable energy. Over 96 percent of respondents indicated that they are in favor of solar, with 82.5 percent in favor of wind, and 66 percent in favor of bioenergy (Appendix 11, Figure 23). Of 192 responses, 94 percent of people agree that UW-Madison should implement more renewable energy on campus. Many people questioned their knowledge of renewable energy, as the responses varied more between strongly agree and strongly disagree. People's confidence (or lack of) in their knowledge about renewable energy likely had an impact on the rest of their answers. The other question in which we saw the highest diversity of answers was about the economic viability of renewable energy. Almost 9 percent of respondents did not agree nor disagree, and 5 percent somewhat disagreed. However, just over 90 percent of people strongly agreed that renewable energy is important to the environment. For the detailed breakdown of our survey responses, please see Appendix 11.

When analyzing the survey question about willingness to pay, we found that a majority of students were willing to increase their segregated fees for further implementation of renewable energy on campus. The average amount that students were willing to add to their segregated fees per semester was $120.49. The most common response was $100 and the median was $70. The amounts ranged from $0 to $800. There was some confusion surrounding the wording of the question, which asked specifically "How much *more* money would you be willing to pay, in segregated fees, so that UW-Madison could become more renewable?" Current segregated fees for the 2017 academic year are $630.12 per semester for a full-time student. Answers over $630.12 were counted as additional to the original segregated fees amount. For example, if a student wrote $730.12, we interpreted that to mean $730.12 in addition to $630.12 as opposed to an additional $100, unless explicitly stated. Additionally, if a respondent gave a range of responses, we counted their response as the average of those numbers. For example, one response gave the range "$50-100," which was counted as $75. Lastly, if a response contained only words with no number specification, the dollar amount we counted was $0. This was true for answers such as "unsure" and "I don't know," and also for answers like "As much as is required to commit to 100 percent clean energy on campus." Although responses were not necessarily representative of the University as a whole, we found that across all the surveyed majors the dollar amount students were willing to pay remained relatively constant (See Appendix 11, Figures 30-31). For example, fourteen economics majors were willing to pay an average of $144.29 additionally, fourteen environmental studies were willing to pay an average of an additional $140.35, and sixteen political science majors were willing to pay an average of $130.94 additionally. There were some outliers, such as the one vocal performance major willing to pay $0 in additional fees and the one tuba performance major willing to pay $500 additionally. Overall, however, students from all majors were willing to increase their segregated fees in order to implement more renewable energy on campus.

3. Interviews

All of the complete interview transcripts can be found below in Appendices 3-9. The interviews were collectively analyzed for recurring and important insights that are summarized in the following paragraphs.

There are several key takeaways from the interviews that should be highlighted. When asked what they consider the most feasible renewable energy source, interviewees agreed that photovoltaic solar is currently the most feasible. Reasoning for this include the declining costs, flexible implementation on existing buildings, and the fact that sun is the most accessible resource available. Many issues were highlighted with wind power, such as resource availability issues and the fact that the urban sprawl of Madison is not the most logical place to put a wind farm. There were several issues brought up with biomass as well. Biomass in the form of an anaerobic digester was attempted before on the UW-Madison campus, but the initiative fizzled out before it could make a significant impact. In theory, the university is an ideal location for an due to the amount of food waste that is produced through the dining halls. However, multiple complications, such as issues pertaining to contamination problems, limit its success and viability.

Another important takeaway from the interviews is that there are many challenges dealing with current infrastructure on the UW-Madison campus that need to be overcome in order for a successful technical implementation to occur. For instance, it was revealed from the interviews that UW-Madison does not own any university buildings; they are owned and run by the state government. Therefore, any renewable energy projects would have to go through state funding and approval processes. This is an obstacle due to the current political climate in Wisconsin, as it is in favor of more conventional and traditional sources of energy such as fossil fuels. Additionally, Madison is currently set up with a microgrid that is technologically outdated. Essentially, the UW campus has system of underground piping and wiring that is linked throughout the campus, which is technically a microgrid. If renewable energy is to be implemented throughout the campus, a smart microgrid with increased efficiency and high tech upgrades would be required to successfully connect all the individual systems. Thus the complexity and cost of upgrading the current microgrid is another hurdle in the process of increased implementation.

There are many other economic considerations that were also brought up in the interviews. For instance, as highlighted in the literature review, storage technologies are outrageously expensive at the current moment. The technology continues to develop in both increasing efficiency potential and lowering costs, but at the current moment, it is economically unrealistic. This is due to the necessity of electricity from renewable energy generation being cost competitive with the two other MGE power plants in Madison.

Perhaps the most significant insight that the interviewees mentioned was that UW-Madison does not have to generate 100 percent renewable on energy in order to be considered clean. Instead, UW-Madison should try and strive for becoming 100 percent clean through a myriad of techniques. An important place to start would be with energy conservation and efficiency to reduce the amount of energy consumed on campus. From there, many interviewees mentioned community based solar projects, as well as several other methods in which the University can gain Renewable Energy Credits. For instance, UW-Madison could sponsor a wind farm in another location in Wisconsin or the Midwest and receive production credits in that way. Furthermore, UW-Madison could ship its biomass to another facility to achieve more efficient sorting and processing methods. These options are far more probable for UW-Madison given the university and surrounding city’s resource availability and the ease of implementation.

E. Discussion

1. Observations

Overall, our three methods of data collection and respective analyses intersect on many fronts to help answer our research question.

Solar:

Production of solar energy on campus is extremely feasible, as evidenced by our GIS site suitability analysis, and has a lot of potential beyond our study in the form of rooftop solar. The one main concern with the results of our GIS analysis is that the implementation of solar in the proposed locations could create land use conflicts, as these areas are already being used as recreation areas. Despite this, solar is still well suited for our campus. This is supported by the interviews we conducted with local experts. Our interviews concluded that photovoltaic solar power is the most realistic renewable energy source to be further implemented and utilized due to flexibility of the technology, availability of solar resources in Madison compared to the other renewable resources, and declining costs. In addition, there is great support amongst students for solar power. 96 percent of students stated they were in favor of solar energy. Therefore, there is evidence of great support amongst students and some of the faculty that we interviewed indicating that UW-Madison should further explore future implementation.

Wind:

While 82.5 percent of survey respondents indicated that they were in favor of renewable wind energy, it would be technically difficult to implement on campus. There were only eight locations surveyed in our GIS analysis that would be appropriate for small-scale wind turbines, and large scale wind is simply not feasible in this urban environment. These eight locations were also identified as appropriate for photovoltaic solar panels, which could prove to be a hindrance in that rooftop solar may be more suitable or efficient than small scale wind technologies. Additionally, while small-scale wind is growing in popularity and becoming more advanced technologically, there is still a lack of turbines suitable for UW-Madison's specific needs. At this time it is more appropriate to look at off-campus wind farms through MGE or other electric utilities in order to increase wind energy usage on campus. The interviews further emphasized this point of sponsoring off-site projects.

Bioenergy:

One reason why bioenergy was much less favorable than solar energy (66 percent versus 96 percent) could be due to the lack of knowledge around this type of energy. Solar and wind have long been established as renewable energy sources, and are among the most researched and known about forms (Ellaban et al. 2014, 752-754). Despite having a Bioenergy research center on campus, many students are unfamiliar with bioenergy and the idea of using an anaerobic digester to produce energy or natural gas (Burg, pers. comm.). Biomass energy shares many characteristics with fossil fuels, which is another reason people may view it less favorably (Ellaban et al. 2014, 750). While we found some large areas to be viable for locating an anaerobic digester in the GIS site suitability analysis, these areas overlap with the suitable areas in the solar analysis and are already being used by the university for recreation. At the time of this analysis, it is in the university's best interest to look into cooperative use of a digester, possibly with the City of Middleton. The interviews brought up issues of prior contamination problems serving as roadblocks to successful biomass operations, despite the amount of resource technically available.

Significance:

Our research is of particular significance at this time as UW-Madison's contract with Madison Gas and Electric is coming up for renewal in the spring of 2018. Madison Gas and Electric supplies a majority of the energy used by UW-Madison. Our study gives some insight into what UW-Madison students envision for the future of this contract. Specifically, students would like to see more renewable energy included in UW-Madison's energy consumption, even if they have to pay more in segregated fees to accomplish it. Also, the Office of Sustainability is working on a Solar PV Development course offered by the Midwest Renewable Energy Association, focused on actual implementation of PV arrays on campus, or at least solar funded by UW. Our research was already used in the application process, and will be invaluable during the completion of the course. Many student organizations on campus are also looking towards the university to divest from fossil fuels or use more renewable energy sources. A few examples of the more prominent organizations include 350.org, the Climate Reality Project, and Campus Leaders for Energy Action Now (CLEAN). Our group has already spoken with numerous members of these organization that have shown interest in using our research to support their activism. Many entities on campus are interested in the results of our study, which shows the importance of our topic to the university and the Madison community as a whole.

2. Limitations and Future Research

GIS:

Perhaps the largest limitation of our solar analysis was the lack of a high resolution DEM that included the minutiae of UW campus rooftops. This hindered our analysis in that the rooftops of campus buildings provide an entirely new dimension of availability for solar, and we were not able to consider this. Another limitation that arose from our analysis is the complication of competing land use types. Most of the sites that were found as highly suitable in our analysis are already highly utilized by the university, whether that be for university sports, band practice, or parking. This would possibly create some friction in the implementation of solar in these locations.

While biomass is perhaps the most feasible form of renewable energy from a spatial extent, one limitation of our analysis was the actual amount of biomass produced on campus that we could utilize in a digester. We were able to find data on the food waste production from UW-Housing, which includes both residence halls and dining halls, and was approximately 7 tons per week. However, we did not have any data on other forms of biomass around campus, such as yard waste from lawn trimming or leaf raking, so that limited our ability to model a scenario and choose a digester for analysis.

One important limitation for our spatial wind siting analysis was the availability and resolution of data. The data that was available to us from the National Renewable Energy Laboratory was only available on a small scale, so we had to work with data that was not ideal for our analysis. Since our study site is an urban area, wind patterns are heavily influenced by the buildings and infrastructure as they move through the city. Micro-wind patterns are needed to adequately represent this; however, despite contacting the Department of Atmospheric and Oceanic Sciences in an attempt to obtain this data, we were unable to find adequate microwind data. This limits our analysis not only in accuracy, but also the extent of our research.

Survey:

There are also several limitations in regards to our survey. We were limited in our access and therefore distribution of our survey to students. We could only reach out to students with whom we had connections, as we did not have access to a master list-serv of all the students, and therefore could not generate a random sample. Furthermore, our demographics do not represent UW-Madison as a whole as we only received 195 responses out of roughly 40,000 total students that attend the university, and of these our responses were skewed to be male and upperclassmen, as seen in our analysis. We were also limited in assessing faculty opinions from our survey due to the lack of responses we received. While we did receive some insight from some faculty through our interviews, only two faculty members responded to our survey. For future research, we envision having greater access to students and faculty to more effectively survey the campus population.

Time:

There were also many limitations for our project due to the amount of time we were given. Our group only had a semester to conceptualize and implement this research project, and therefore we had many time constraints. For instance, we would have liked to interview several additional experts and professionals that we were not able to set up a meetings with ahead of our deadline. Furthermore, our group would have liked to explore more than the three technologies we have selected to determine if any other renewable energy forms and sources could have been viable for the UW-Madison campus. Another important aspect of renewable energy that we would like to delve into deeper is energy storage, which has a massive impact on adoption and efficiency of renewable energy technologies. We also would have liked to do a more detailed financial analysis of the discussed technologies to further assess their level of feasibility and implementation on campus. Finally, we would like to run more comparative statistics to be able to juxtapose our survey with those found in the literature review to identify overarching trends in the data.

F. Conclusion

Our study aims to determine the student perceptions of and spatial possibilities for renewable energy on the University of Wisconsin - Madison campus through the use of surveys, interviews, and a GIS analysis. Despite mediocre spatial suitability for our explored renewable energy technologies on the UW-Madison campus, there are very high levels of support surrounding increased future implementation, as outlined by our survey results. Solar PV ultimately is the most realistic technology for the University to further pursue on campus, but off-site production in order to earn renewable energy credits is more viable due to the various challenges and complexities of adopting renewable energy on campus infrastructure (such as issues with storage, economics, and politics). Off campus wind and wind production credits are another way to still utilize renewable energy without producing it on campus. Collaboration for use of an anaerobic digester off-site is another option to work towards more renewable energy. However, before UW-Madison can implement any renewable energy, it needs to become more energy efficient. Energy conservation and reduction will be a critical step towards accomplishing the larger goal of becoming more environmentally conscious. UW students have proven they are willing to pay, but increased sourcing of renewable energy will come down to the university administration's willingness to invest in the future.

G. Acknowledgements

We would like to extend a huge thank you to our canine collaborator Murphy Burg for all the emotional support he gave us throughout this process.

We would like to thank all of our wonderful interviewees and collaborators for sharing their time and information with us.

Finally, we would like to thank our instructor, William Gustav Gartner, for his support, words of encouragement, and guidance.

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I. Appendices

Appendix 1: Introduction and Literature Review Figures

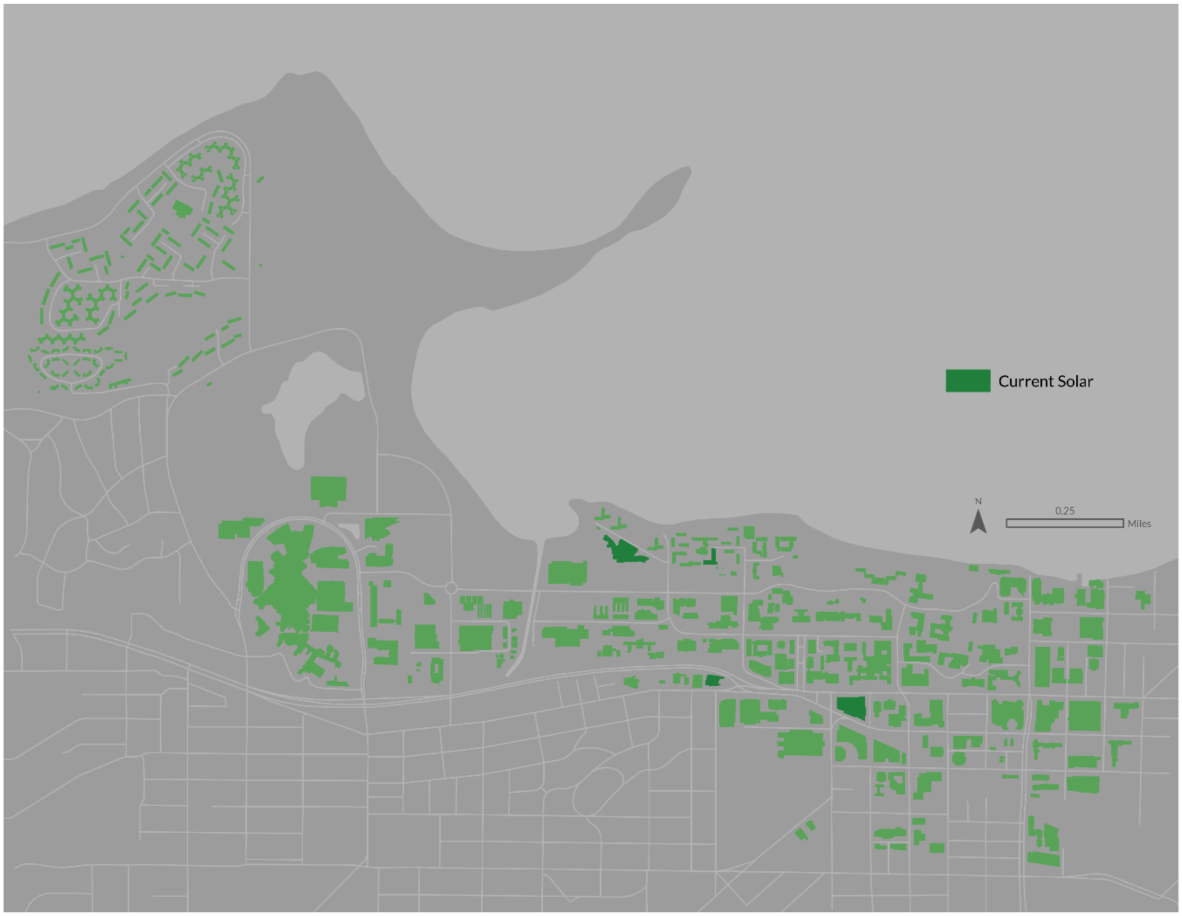

Figure 1: Study Area: University of Wisconsin – Madison campus.

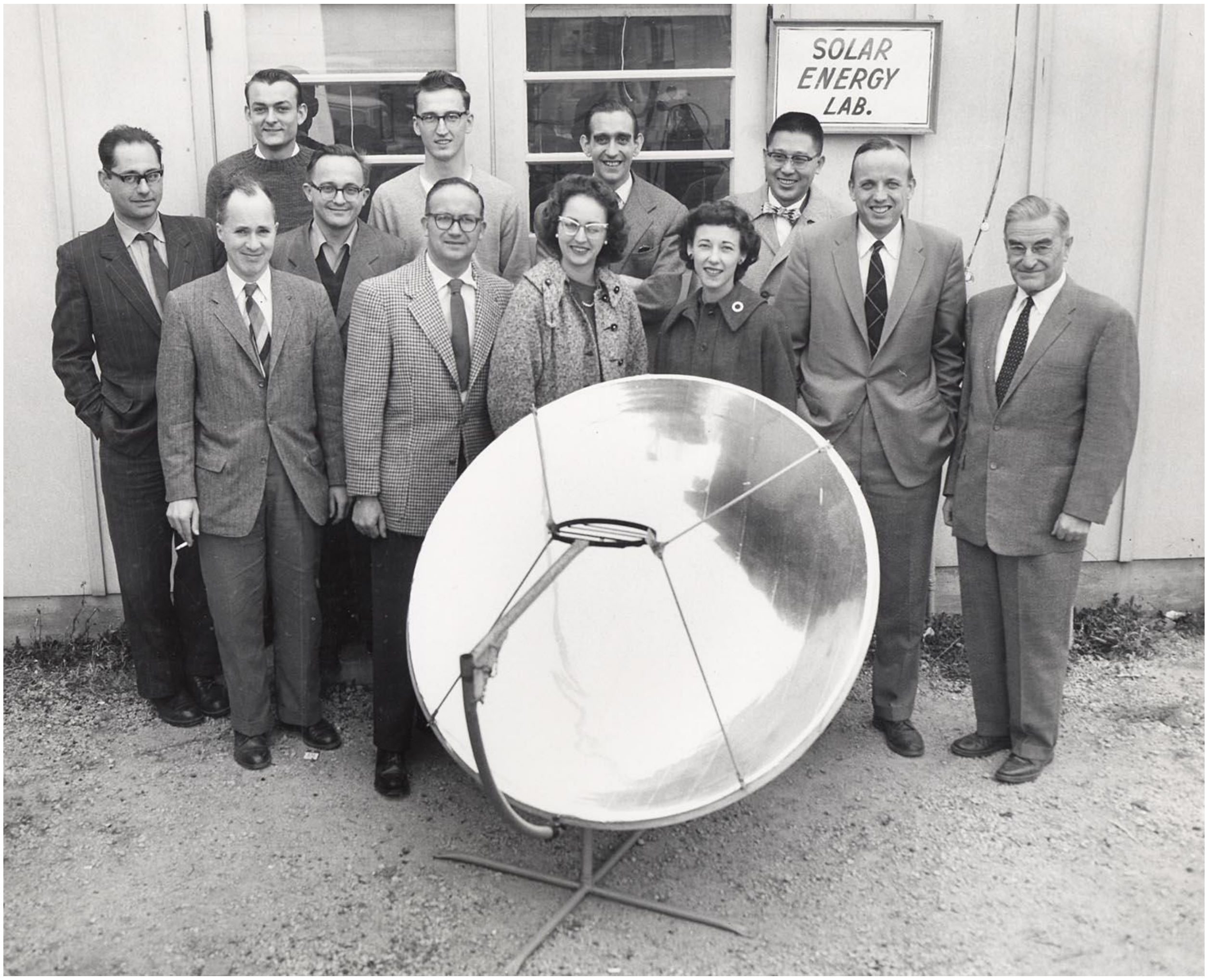

Figure 2: Solar Energy Lab Staff in 1959
Image courtesy of the UW-Madison Archives, #S09144

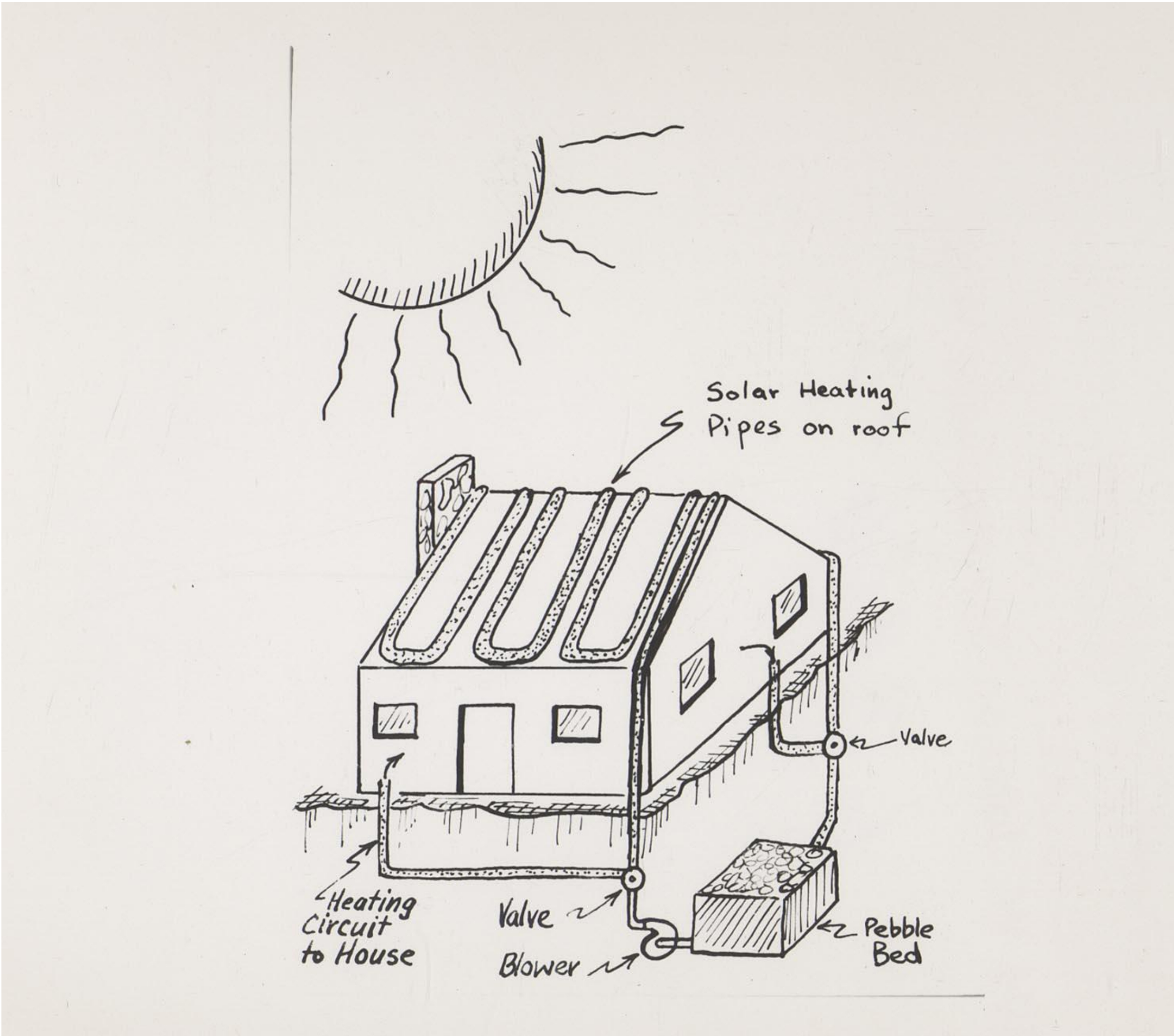

Figure 3: "A sketch for an invention by Farrington Daniels."
Image courtesy of the UW-Madison Archives, #S09156

Figure 4: "Professors Jack Duffie & Farrington Daniels at Solar Furnace with solar energy instrument."
Image courtesy of the UW-Madison Archives, #S15603

Figure 5: Solar panels on Dejope Residence Hall. (Jordan Hersh, September 19, 2017).

Figure 6: Solar panels on Leopold Residence Hall. (Jordan Hersh, September 19, 2017).

Appendix 2: Methods Figures

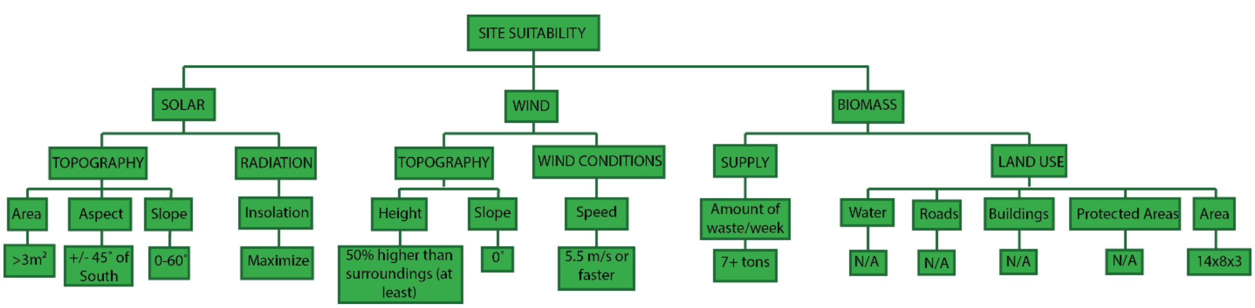

Figure 7: Conceptualization Diagram for GIS Site Suitability Analysis.

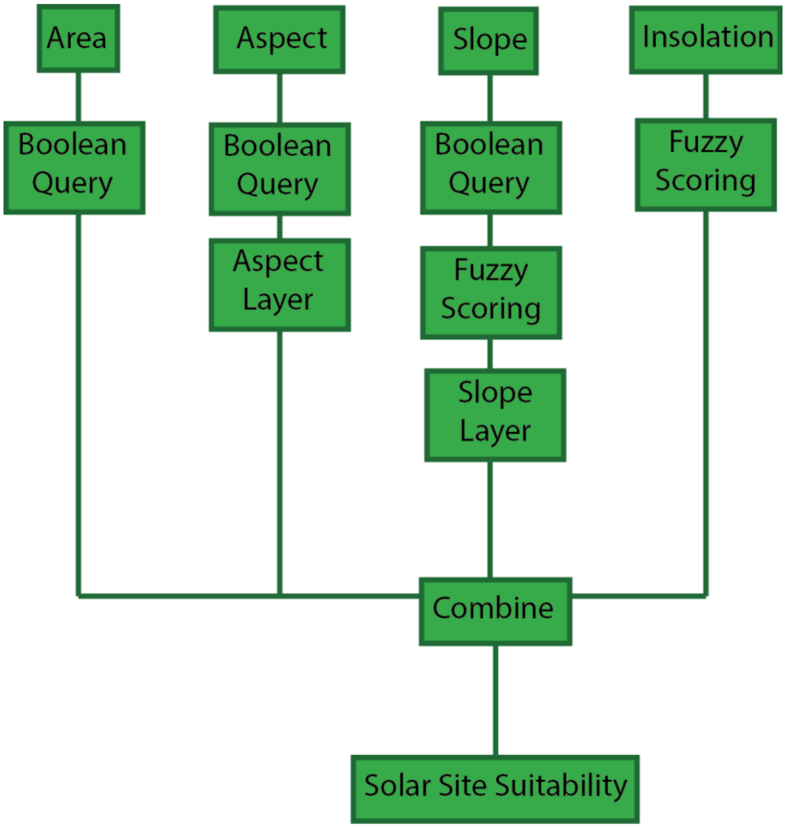

Figure 8: Implementation Diagram for Solar Site Suitability Analysis.

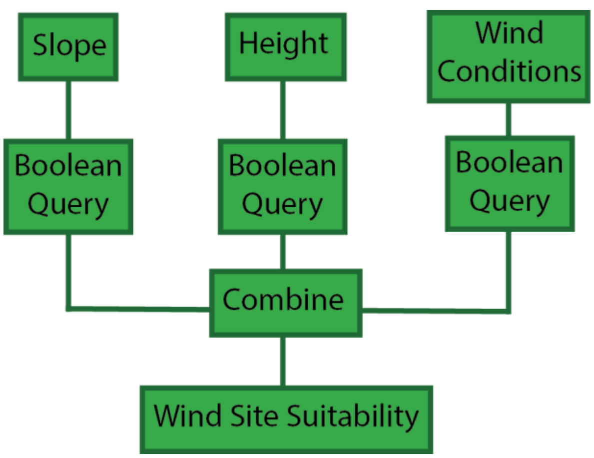

Figure 9: Implementation Diagram for Wind Siting Analysis.

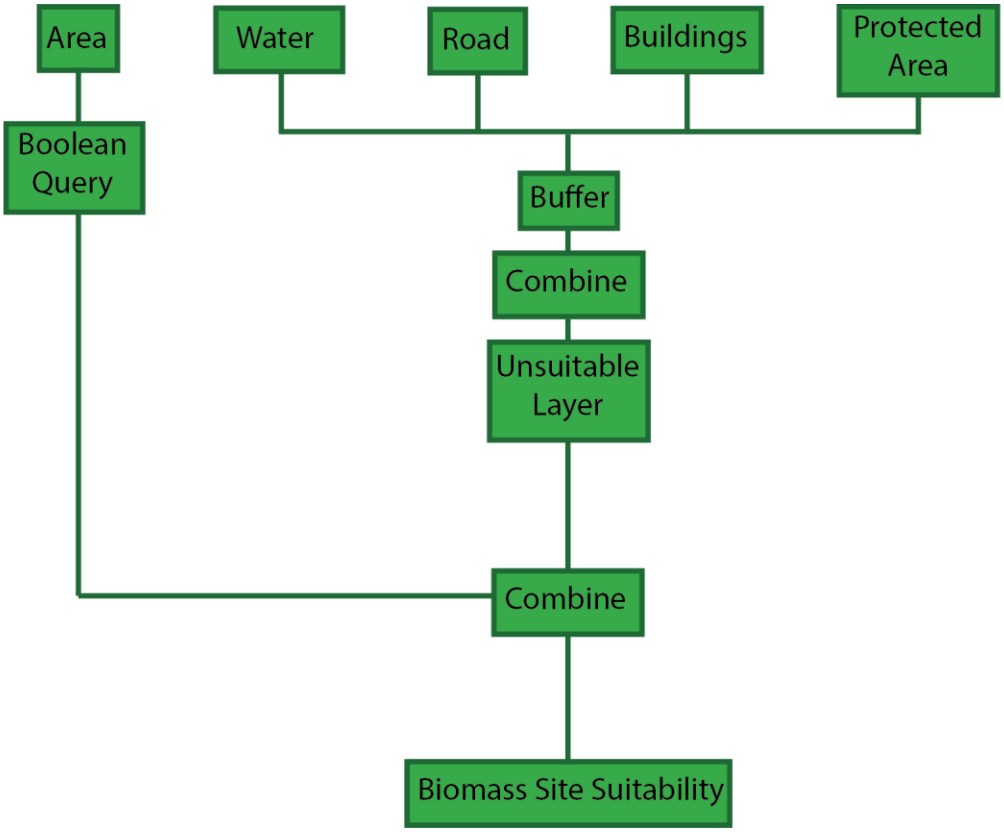

Figure 10: Implementation Diagram for Anaerobic Digester Site Suitability Analysis.

Biological Sex:

- Male
- Female
- Other

In which type of setting have you spent the majority of your life?

- Rural
- Suburban
- Urban

What year in school are you?

- Freshman
- Sophomore
- Junior
- Senior
- Graduate Student
- Faculty/Staff

Figure 11: Demographic Questions from Survey

What is your major or area of interest? (If Undecided, write in Undecided)

Figure 12: Year or Area of Interest Survey Question

Which of the following types of renewable energy are you in favor of?

- ☐ Solar
- ☐ Wind
- ☐ Bioenergy
- ☐ Other
- ☐ None

Figure 13: Favorability of Renewable Energy Survey Question

Please rate your level of agreement with the following statements.

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I feel knowledgeable about renewable energy	○	○	○	○	○
Current global climate change is occurring due to human activity	○	○	○	○	○
Renewable energy is important to the environment	○	○	○	○	○
Replacing fossil fuels with renewable energy is an important issue	○	○	○	○	○
Renewable energy is economically viable	○	○	○	○	○
UW-Madison should implement more renewable energy on campus	○	○	○	○	○

Figure 14: Likert Scale Renewable Energy Survey Questions

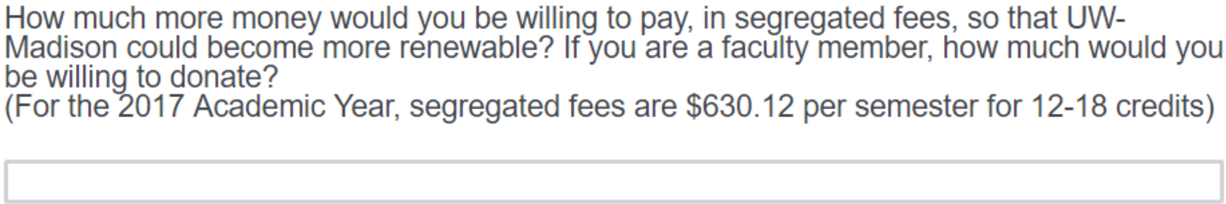
How much more money would you be willing to pay, in segregated fees, so that UW-Madison could become more renewable? If you are a faculty member, how much would you be willing to donate?
(For the 2017 Academic Year, segregated fees are $630.12 per semester for 12-18 credits)

Figure 15: Willingness to Pay Survey Question

Appendix 3: Bryan Johnson Interview

Bryan Johnson - Recycling Coordinator and Public Information Officer for the City of Madison
Interviewed 11/3/17 at 9:30am at 1501 Badger Rd., the City of Madison Streets building

1. What anaerobic digester does the City of Madison use?

We don't. We don't have one.
Whole story of organics program:

- Started in 2011 by Mr. Johnson's predecessor
- Taking food waste to Columbia Co. food waste facility
    - Didn't care what we gave them quality-wise
        - We gave them kitty litter, diapers, a lot of things allowed at that time that they didn't care about - waste was not for compost but for erosion control
    - Went out of business
- Next: going to UW-Oshkosh digester (Bryan Landolph)
    - Initially were somewhat forgiving but it wasn't tenable economically
        - They're trying to sell it economically - can't have diapers, coat hangers, batteries -- "wishcycling"
    - Got kicked out because it was too contaminated
    - All successful programs have a decontamination mechanism but CoM doesn't have that and residents aren't necessarily conscious enough
- Then: going to the digester in the town of Springfield, WI (Middleton)
    - Owned by Gunderson Lutheran people
    - Operated by a different company now -- West Engineering, but still owned by Gunderson Lutheran
    - Use methane to generate electricity to sell it back to the grid
    - Purple Cow gets what's on the back end
    - Eventually got kicked out of there too for a plastics problem
    - AST6400 compostable bags are fine but expensive
        - People go to the cheaper ones, greenwashing happens
- Waunakee Digester
    - Want more liquids

        - Solids: Jefferson Co. farmer uses solids for animal bedding; that's their only market so they don't necessarily need more material
- Blue RIbbon composter in Caledonia, WI
    - Most recent partner
    - Digester options are shut at this point
    - Again, contamination
        - People still putting cat litter, diapers, etc. in it because they used to be able to -- need to find a way to reach these people, like with the newspaper story
    - There is a digester in Potawatomie but CoM doesn't have the tech for this facility

Only other option in-state? Denmark, WI - 3 hour one-way drive, 6 hours round trip

    - Would they even be willing to work with us? Who knows, just too far to drive
- Milwaukee has a program
- Sannamax (grease company?) has a food waste section, takes food waste up to Caledonia
- Right now?
    - Donut hole, no place to go
    - Potential options in the near-term where it doesn't make sense to shut her down
    - Trying to clean up what we have
    - Caledonia -- too many people putting in plastic bags
        - Bag ban still in place
    - Sometimes eject people from the program for too many plastic bags
    - Resident turnover can be hard -- don't like working with rental properties because someone has to be the communication point
    - Need to do a better job of addresses and communication
    - Technically nowhere but Waunakee isn't necessarily shut, he just needs to find a place for the solid waste
        - 1100 homes and 7 businesses - 6/7 tons/week

Purple Cow: organic, OMRI, can't take those compost bags b/c they're not organic enough

- But we don't want OMRI to decide what we can take and where when they're not even local

Dane County sold their composting equipment

Can you explain the depackaging system?

Look at publication called BioCycle -- US promoting composting -- US Composting Council, biocycle.net

On the website, they have an equipment list and they have companies listed that make depackaging macinese

You can watch depackaging videos on YouTube
Fairly water-intensive
    Might partner with sewage, use wastewater
Need a reliable place to send it and a reliable place to pick it up.

2. Where is it located?

Right now, the organics go to 121 East Olin Ave transfer station, dump it on to tipping floor area, put it on a semi, send semi away -- aggregated there for as long as possible to try to find a home for it and if not, send it to a landfill

Appendix 4: Greg Nemet Interview

Greg Nemet - Associate Professor of Public Affairs and Environmental Studies, chair of the Energy Analysis and Policy graduate certificate program
Interviewed 11/16/17 at 3:00 p.m. at Enzyme Institute, Room 144A

- Please say a little about yourself and how you became involved in Renewable Energy (RE) and any research you do pertaining to RE?
    - Teach courses in energy analysis, energy policy
    - Innovation in clean technology, and how policy can be used create innovations
    - What policies would stimulate innovation in the future?
        - Energy efficiency, carbon capture, solar, wind power, negative emissions technology (as a way of reducing climate change) - burning organics and capturing the CO_2 and sending it underground
        - Has focused on solar due to quick innovation and decreasing costs
    - Technology and innovation of clean energy that gives him hope for future with climate change
        - Technologies keep getting better and cheaper makes it optimistic
    - You can't just wait and expect the technology to be there, use it and try it to build it and make it useful for that problem
        - Tech isn't ready unless you prove it works, makes it better by trying and continuing to improve
        - Might need to subsidize things initially, but can't wait and expect it to be there
    - Appealing for UW to start working on these technologies
        - Not realistic to just wait 10-20 years
    - Enzyme Institute: built in the 50's, start improving buildings now, you can't just demolish everything and rebuilt new energy efficient
- What forms of RE power generation are most suitable for the UW campus and why? Also where would it go?

- Forms and why:
  - PV solar because it keeps getting cheaper
    - People don't understand how cheap it is already
  - Wind power - good wind resources in the state
  - Geothermal for heating, not electricity
    - To some extent cooling in the summer
  - Heat pumps
  - Electric vehicles (EV)
    - Makes a lot of sense on a campus with such a massive fleet
    - Short distances, electric is a good choice even right now
    - Look at the economics of battery or hybrid vehicles or using natural gas (NG) as an intermediary
      - Starting to export a lot of NG
      - Bit more of a risk with going to NG than electricity
  - Even though we use a lot of coal, still argument for EV
    - Proving technology works
    - Still better off than burning gasoline or diesel
  - Don't need to do on the physical campus
    - Satellite research stations outside madison
    - Other people's land to use wind power
  - Roof space and parking lot space for PV
  - There's no reason not to do something on a landfill or on rooftops
- Where?
  - Energy storage
    - Getting cheaper all the time, does make economic sense
      - At the same rate that solar is getting cheaper
    - Perceptions are often a few years in the past
      - Didn't make sense 5 years ago, now it's 1/3 of the cost
    - Batteries are getting cheapest most quickly
    - Not much capacity to do underground air storage nor hydro with hills

- Do you believe that achieving 100 percent RE generation on campus is feasible? (The Solutions Project suggests that WI can be 100 percent renewable now). How can we get there?
  - Not all production, then yes. Not that hard to put renewable energy elsewhere
  - How soon? Not sure.
  - Building physical energy supply elsewhere - PV, wind turbines somewhere else
  - Co-gen facility: too soon to shutdown the plant
    - Lots of plants are getting shut down right now
    - Use it as backup in the case of an unsunny or not windy period

- Looking at how bigger entities are trying to do it (NY state)
    - Easier if you don't get to 100 percent but the last 10 percent by offsets (recs or carbon credits somewhere else)
    - Nuclear! Nuclear power plants that are low carbon; two north of here (about 50 years old)
    - 100 percent clean rather than 100 percent renewable for more flexibility
      - Allowing nuclear and offsets (80 percent strictly renewable)
- Besides batteries and storage, what are some other obstacles to implementing more RE on campus?
  - Existing infrastructure that we're kinda stuck with
  - Pipes to cool buildings and equipment - changing all that is hard
    - Requires behavioral changes by those that run but also use the campus
  - The human part, not the technological part
  - Much easier to start over an design everything in a more sustainable way
    - Take advantage of excess heat
    - But we're starting in the same place
  - People are often resistant to change
    - Same things are comforting and familiar
    - Parking somewhere else, not driving, bus is now electric, bus stop moves
    - Those are a little hard on people and would likely wouldn't be happy
  - Even if things make sense, the existing rules and regulations aren't flexible enough
    - Retiring buses to buy electric
    - Saving over many years is harder to grasp
- In terms of implementing more renewable energy on campus, where is the best place to start? (who to talk to, where to go, etc.)
  - It's not going to be a big bang strategy where the leader of campus gets convinced
  - Need top-down (working with administration) and bottom-up (starting getting a few new projects on campus - diverse groups working on different angles and projects)
    - Facilities - hearing from different groups about these different angles (wind, solar, transportation)
    - We want commitment - they listen to students up a lot
  - Long-term goals, some changes can happen pretty quickly but this needs a bigger time horizon
  - Vehicles can be quickly, but buildings take a while longer
  - Look at deals made for West co-gen facility
  - Anything about how the university purchases energy
  - Public services commission (PSC)
    - Might be ones to talk to for contracts with MGE

            - Can we talk to Facilities and Planning Management (FPM)?
                - Get in front of Jeffrey Pollei
                - That's part of human aspect as a big barrier
                - Involves change, and money, and time
    - That's something that will have to change - back down to top-down and bottom-up approach
    - Chancellor and provost starting asking facilities for info… that's when things
- Biodigesters:
    - Big push about 8-10 years ago
    - Methane got super cheap with fracking, digesters got nixed
    - Accidents happened with leaks and what not - not in strong favor right

Appendix 5: Doug Reinemann Interview

Professor Doug Reinemann
Interviewed 11/8/17 at 1:00 PM at 460 Henry Mall, Room 115e

Please say a little about yourself and how you became involved in Renewable Energy (RE) and any research you do pertaining to RE?

- o Masters degree during last energy crisis, oil embargo, got whole world thinking about energy, did an energy project for masters thesis - using wind power on Wisconsin farms
- o Cornell and did a PhD (one chapter that had to do with energy and aquaculture) production systems
- o Worked to establish a department of energy in Pakistan
- o Came to Wisconsin - agricultural energy issues
- o Started RE course, 300 students enrolled every year

What forms of RE power generation are most suitable for the UW campus and why? Also where would it go?

- o Forms and why:
    - § Madison is not great for solar, not great for wind energy resources, biomass system didn't really work out
    - § Not one source that is fantastic, no obvious winner, renewable resources moderate
    - § That's a challenge
    - § Most economical - solar thermal, very overlooked renewable energy sources, could use for water heating, maybe about half of water on campus, economics are good
    - § Have to compete with 2 power plants, a low cost alternative

        - § Republicans cancelled burning natural gas and biomass in the power plant, would have served as a dual fuel, could switch between them
        - § Biomass does make a lot of sense here, we have real transport, good biomass resources in proximity, would fit into distribution system
        - § Campus electrical distribution system that both power plants feed into is underground, tunnel system underground that links electricity, steam for heat, and chilled water for cooling, kind of like a campus microgrid which is connected to the city grid, can be sectionalized
    - o Where?
        - § Most storage would be offsite for biomass for months, would come in on train rail cars, a day or two storage on site, would be a daily trainload for biomass

Do you believe that achieving 100 percent RE generation on campus is feasible? (The Solutions Project suggests that WI can be 100 percent renewable now)

- o Anything is possible
- o Epic is a great example- use solar pv, use 6 wind turbines off their campus - turbines go into grid and they still buy separate electricity from the grid, ground source heat pump, they are carbon neutral- produce as much as they buy in the end, might be importing and still rely on grid to fill in on their demand, sell when they have more than they need,
    - § Not meeting 100 percent every day, but evens out in the end
    - § Wind turbines produce energy sold into the grid, they sometimes buy energy from the grid still
- o Most practical way for us, we can't be removed from the grid due to storage expenses

Some argue that a true smart grid is a microgrid that allows for distributed, decentralized energy generation and storage. Ideally, every place connected to a micro-grid could generate, transmit, store, and use RE. Is it possible to build such a microgrid on the UW campus? What are the obstacles for building a UW campus RE microgrid?

- o A lot of the infrastructure is already there, already have a microgrid, its getting smarter- implementing smart grid, done work with buildings to improve lighting efficiency: motion detectors for lights
- o We kind of have a smartgrid, not using all technology, version 1.0, upgrading to version 3.0 (current version) is possible but would have to update more than the grid: the control systems in the buildings, would need some sort of storage - thermal storage for heating and cooling
- o 3-way microgrid with heating cooling and electricity, combining gives more opportunity for control
- o electricity microgrid is done through wires underground, come together at the generators, infrastructure can lead to a lot of creative things

Japan uses Modular Vanadium Flow Battery Storage Units to store energy generated by small scale solar plants, while Australia and other countries are using Compressed Air to store energy generated by small and medium scale RE plants. There have also been some interesting developments with High Power and Long Duration Flywheels. Are any of these technologies feasible for energy storage on the UW campus? What other technologies might deliver large capacity, on-demand RE storage? If these or other storage technologies are feasible for the UW campus, what barriers exist for their implementation? Any other challenges to storage/batteries?

- Thermal storage system for heating, have a large thermal load for campus
    - Molten salt for concentrated solar, lot of heat stored in small space
- Flywheels
    - Very feasible and great option to store electricity
    - Electric motor/generator, hooked to an enormous flywheel, combination of rotational mass and rotational speed, varying sizes from very small to very large, off the shelf technology, heavy thing spinning around, electrical control- can make it run at varying speeds to control energy in and out, can be used as a generator- one moving part, electrical control is something UW is very good
- Batteries
    - Technically fantastic but costs are insane, up to 5 times more expensive, great to store electricity
- Would want some of each, a combination, need to look at technology and cost
- Cost is largest challenge by far, lot of technologies available, new technology development is very oriented on cost

Small scale RE production, electric cars, and portable electronic devices all seem to be driving research into the development of new battery technologies. Graphene Storage Films and Carbon Nanotube Batteries, for example, have received a lot of press lately. What might the battery of the future look like?

- If I could answer that I'd be a millionaire and retire
- A lot of work going into it all over the world
- Molybdenum, chromium, vanadium, need to look at where the supplies come from and how available that is
- Ideal battery would be made up of widely available materials that aren't too expensive, environmentally friendly materials are important too- turning materials into batteries can be harmful too, needs to be low cost too
- Lithium is battery material of choice today
- Energy density is important too and is a way to measure

Besides batteries and storage, what are some other obstacles to implementing more RE on campus?

- o A lot of enthusiasm on campus, but campus buildings are state buildings not university buildings, state has budgets, state is not favorable on renewables, political climate of the state, and money issues are a hurdle- no building budget

In terms of implementing more renewable energy on campus, where is the best place to start? (who to talk to, where to go, etc.)

- o Don't leave out energy conservation, focus on saving energy, cutting down the energy use of the campus in half is more feasible than generating that much energy using renewables, temperature concerns, lighting has gotten better - new buildings all have LEDs, replace fluorescents would be huge

Economic barriers seem to be a bigger obstacle than technological barriers for the implementation of small scale RE generation. There are high initial capital and balance of system costs that disproportionately affect small scale RE generation around the world. Yet, the cost of installing small scale solar and wind plants in Germany, Denmark, and other European Countries are much less than the US, even though labor costs there are higher. What market barriers and distortions make RE comparatively expensive, and fossil fuel power generation relatively cheap, here in the US?

- o Mainly energy policy
- o Economies of scale
- o Question if costs of small scale is different here in US or in Europe, they just have more of it, larger market and supply system
- o Energy buy back has to do with energy policy system, largest reason for economic difference
    - § Willingness of EU to put a higher value on renewables, external costs are internalized, policy decision made by a society

Is there anything else you would like to add?

- o One area that people on campus can make a big difference is their transportation
    - § Fuel efficient vehicle, smaller vehicle,
    - § This is where individuals can make the biggest difference in the shortest amount of time
    - § Use the most amount of energy in transportation is most for Doug

Appendix 6: John Greenler Interview

John Greenler
Interviewed 11/28/17 at 11:00 AM at Wisconsin Energy Institute, Room 1150

- Where to your knowledge is RE being used on the UW-Madison campus?

- Electrical power today? How do we get to clean energy today?
  - Rely on significant scaling up of energy systems
  - Petroleum that we use for transportation could instead be electrified
  - EVs - the future, govt. Pushing and the industries
    - Revolution with EVs - the gears are in motion
    - We've hit the tipping point from the industry side
  - The future is electricity
- Bioenergy is a good transition source
- What's possible on UW?
- WEI as a building:
  - LEED Gold certified
  - Lot has to do with energy efficiency - big part of it
  - Solar panels on the roof
  - Lots of natural light
  - Massive heat exchangers - grab all the potential waste air and used to heat air that's coming into the building
    - Need to have a lot of air exchange - for chem labs and what not
- Geothermal - you can build vertical wells (much more expensive)
  - James Tinjun - engineering professor on campus
    - Geothermal expert, also knows a good amount about wind energy
  - Wisconsin has great opportunity for geothermal - hot summers and really cold for good balance
    - Due to our seasonality
  - More difficult on a space-constrained campus like this
  - Not impossible - but difficult, probably not profitable
  - Residential
  - Vertical
  - Horizontal
    - Much less expensive

- What forms of RE power generation are most suitable for the UW campus and why? Also where would it go?
  - Energy generation - lots of losses come from actual generation rather than from transmission
  - Moving electricity around is the easy part - you have to put up wires and what not, but it's very efficient
  - Microgrids: can be done incrementally
    - Remote places: electricity over long distances, etc.
      - Microgrids make a lot of sense and can payback quickly
    - co-op s with smaller energy generation capacity on their own microgrid
    - It's out there, being utilized

        - High reliability - penitentiaries, redundancy that they need to NEVER lose power
        - On UW: could probably cluster it down to make a few microgrids - 8-10 buildings "neighborhood"
            - Uw hospital buildings, engineering buildings, CALS buildings
            - Can also do residential neighborhoods
        - If we had a carbon tax or cap and trade - microgrids would take off right away
    - Wind:
        - Small-scale - usually just really windy, limited energy needed
        - Wind scales up very highly - exponentially better than a small one
        - Small-scale not a great idea - rather put wind down the road
    - Solar:
        - Good exposure - pretty much worth it to put
- Do you believe that achieving 100 percent RE generation on campus is feasible within the foreseeable future? And how would that look? (The Solutions Project suggests that WI can be 100 percent renewable now)
    - Yes, we should!
    - But it's tricky
    - Lots of the solutions wouldn't be obvious
    - Very space constrained on campus
        - Wind turbines - lots of siting issues
    - Our energy will be networked - through a microgrid
        - By the UW putting net neutral energy production somewhere else - what's important is the global balance
        - We can claim the renewable energy credits
    - Community Solar - have a building, good siting - it should be done
        - But instead we can buy into a community solar garden of sorts really allows for a better opportunity
        - Taking advantage of the economy of scale
    - Energy efficiency!!! WEI - LEED gold certified
        - Biggest elements - integrative design
            - Can be done at different scales (UW, city - computation extensive)
        - They were able to optimize all the functionality of the building
        - Optimizing heating and cooling, less bends, etc.
    - Charter street - natural gas from coal - one of them was meant to be biomass
        - Got nixed by Scott Walker before he even came into office
        - Would have provided a great research opportunity
    - Biomass:
        - AD: can't generate electricity cheaply enough to sell it

            - But you can clean up the gas and put it in the pipelines for natural gas
        - Troy Runge
        - If concerned about GHG - natural gas has some big positives and negatives
            - From the tailpipe, you're emitting a lot less carbon
            - Releasing less carbon
        - Natural gas is largely made up of methane - leaking methane is a very potent
            - Approximately 30x the global impact
            - Lots of diffuse emissions that hard to track, quantify and deal with
        - Whole life cycle assessment - natural gas may be doing more harm than good - Cornell research
            - Can account for 4 percent of GHG emissions
- In terms of implementing more renewable energy on campus, where is the best place to start? (who to talk to, where to go, etc.)
    - Collaborations: we're a part of Madison, of Dane County - both of them are really moving on this
    - Lots of opportunities for economy of scale
        - Planning and execution
    - The more we can be working in a holistic fashion
    - Gary Radloffe - policy person at WEI involved with city and county projects

Research:

- Corn grain - could be used instead for making food or feed for animals
    - Instead, looking at switchgrass for fuel!
        - Can be used on marginal lands, wetlands,
        - Perennial
    - Can use a lot of residues - sawdust, slash (forests) or corn residues
- Everything comes from petroleum
    - Political views, economy - got a lot of long-run problems
- $1 billion efforts to retool transportation in terms of energy inputs
- Electrical power systems: wind, solar
    - More distributed energy sources - how are we going to manage that system?
    - Microgrids - like cellphones, highly distributed
        - Future of electrical power will look like this
        - University might have its own grid - tailored to meet that specific area
        - Networked to each other, one high and one low they can be averaged out between each other
        - Much more clean, tailored to specific needs, efficient

Appendix 7: Josh Arnold Interview

Josh Arnold
November 20th, 2017
6:00 pm in Henry Mall room 306

- Please say a little about yourself and how you became involved in energy and any research you do pertaining to renewable energy ?
  - Consultant at Navigant, about 10 years
  - Some of their larger clients include
    - Utilities: working with some of biggest in NA, Europe, Middle East, Asia
      - CommED In Chicago
      - Europe: OnGE
  - Associate Director in Energy Practice: help clients transform energy
    - All phases of energy, generation, transmission, efficiency, and renewables
    - Finding ways to generate clean energy in a way that makes sense to everyone (triple bottom line)
  - Work with utilities, govt. Agencies, people in charge of energy and how we use it
- What work are you doing with the City of Madison?
  - Sustainable Madison Committee:
  - Navigant was hired by the City along with Sustainable Engineering groups to chart out a path to 100 percent renewable energy for city operations
    - Specialty with facility and site level thing for GIS analysis
    - Local solar groups they work with
      - AKA RENEW
    - First, baseline and full understanding of where the city uses energy, electricity, natural gas, transportation (gasoline, diesel)
    - Doing this now
    - Talking with city staff, different stakeholders (business community, environmental community,
  - Next, ideas of how to reduce usage of fossil fuels, and incorporate renewable energy
    - Come up with different ideas/suggestions
    - Ex: making buildings more efficient, behavioral aspects (educating vehicle operators), putting solar on buildings, working with utilities to build large scale solar arrays
    - Transportation: looking into policies and procedures in order to purchase EV's and then generating that electricity
- Do you believe that achieving 100 percent RE generation on campus is feasible within the foreseeable future? And how would that look? (The Solutions Project suggests that WI can be 100 percent renewable now)

- Technical feasible: definitely possible
    - Building efficiency
    - Transportation more efficient
- Economic side:
    - It will cost some upfront money to do
    - Solar: costs have continuously been coming down
    - Even with EV's outside of just passenger vehicles too - forklifts, tractors, landscaping motors
        - Costs of EV batteries are coming down and will go way down
    - Savings in the future
    - Problem with the budgets - solvable
- Political side: real big challenge - but not permanent
- Definitely achievable - takes combo of political will and making sure the right economics are there
    - Technology is sort of the easier part
- So many groups making the 100 percent commitment - it's just a matter of time to put all the right pieces together

- What forms of RE power generation are most suitable for the UW campus and why? Also where would it go?
    - Forms and why:
        - Hydro: fully exhausted in WI
        - One thing that makes a lot of sense in wisconsin is geothermal - ground source heat pumps
            - Ground below 6 feet is pretty constant with 55 degrees
            - Free cooling during the summer,
            - Long payback period (will be owned by state for forever compared to businesses that might not be there for more than 10 years
            - Designing and retrofitting buildings to be efficient as possible
                - Orientation, where it's built, window to wall ratio
                - Retrofitting:
                - Adding geothermal or solar onto that
        - Big plans in the future - new construction standards
            - For including renewable energy
            - Residence halls
        - Especially for state-owned buildings it makes a lot of sense - huge advantage for geothermal and renewable because of the payback period
    - Small-scale wind: vertical wind turbines - never heard of them being high-functioning turbines, can be a good educational tool
        - But in terms of actual energy generation - probably not

        - Using evaporation from the lakes to generate energy - not commercially available yet
            - Energy with the lakes?
                - Figure out ways to generate energy from them
        - Where?
- Besides batteries and storage, what are some other obstacles to implementing more RE on campus?
- In terms of implementing more renewable energy on campus, where is the best place to start? (who to talk to, where to go, etc.)
    - Talking with faculty senate with their
    - CONTRACT WITH MGE: making sure whatever group (JEFF POLLEI) knows the student's interests/demands
        - Making that accessible to people and giving it to Jeff
            - Other methods of communications to get to him
        - Petition? Get the Faculty Rep, the CLEAN group
        - Position to work together with them, contract creates negotiations for significant requests with renewables
        - Working with MGE?
        - Alliant Energy: WI power and light
    - Using the collaborative approach
    - Talk with the press, use social media,
- Is there anything else you would like to add?
    - So many great models to look at (Europe)
    - Look at what other universities and cities are doing - great case studies
        - The more you can use these to direct to say this is how it could work on our campus
        - Lots of low hanging fruit to start with
        - For the CoM they're doing these small steps to start off
    - Big initiative with the county - forming working groups in different topics
        - Dane County Office of Climate Change
            - Keith Reopelle
                - reopelle.keith@countyofdane.com
- Microgrids: Navigant does a lot of work with this
    - Campus is sort of its own island, with the way the grid is set up
    - You could put up solar arrays in suitable areas, and could use that electricity
    - Jumping on the MGE contract ending is HUGE opportunity
        - Negotiate some things out of it
        - Agrees with Vickerman with the renewable energy riders
    - Ohio State University: outsourcing their facilities management to a private entity

        - University was paid close $1 BILLION in exchange for leasing their energy facilities to a private company for about 30 year lease or so
        - Included provisions to increase energy efficiency and include renewable energy
        - On their website

Appendix 8: Michael Vickerman Interview

Michael Vickerman - Policy Director of RENEW Wisconsin
Member of the Sustainable Madison Committee (SMC)
Interviewed 11/14/17 at 3:00pm at RENEW Wisconsin Office

Questions:

- Please say a little abosut yourself and how you became involved in Renewable Energy (RE) and then RENEW?
    - Job at RENEW: policy director
    - Renew is a state based renewable energy advocacy and education agency, lead and accelerate clean energy in Wisconsin
        - Shoot for homegrown energy (based in WI)
        - Public Service commission
    - Work with utilities - generally they like to own their own energy
        - Sun prairie, waunakee, mount horeb all have their own municipal utilities
    - Involved with transmission lines
        - Utility systems have to respond to changing usage, changing number of customers, seasonal factors
        - Development in wind power in many areas - Iowa, MN starting to close the gap, Illinois, Indiana,
    - Public Service Commission (PSC) approved proposal for MGE to build wind power in Saratoga, Iowa
        - 33 turbines 66 MW
            - 7 percent of electricity of MGE sells
        - RENEW helped with infrastructure and getting the energy over across the Mississippi River to Middleton
    - Another LaFollete County for Quilt Pod?
    - SW has potential to renewable energy
    - Limitations to renewable energy in WI:
        - Lack of leadership at state level
            - Nothing was happening - for a while, WI was stagnating (not anymore)

        - Utilities lacking any further goals in state, (renewable energy standard is already met)
            - MGE - irresponsible to let renewable energy go
    - Limitations for homeowners: Really just solar
        - Trees block, cause shade
        - What if you don't own property?
        - Homeowners association covenants?
        - Cost barrier - expensive
            - MGE initiated program in 2008 that made solar homeownership worth a look
            - Have to wait 15-20 years for payback
            - Electricity credited at 25 cents, when electricity was selling at 12 cents per kwh
            - Price dropped 70 percent with today's technology
    - Limitations to commercial:
        - Depends on time horizon
            - If you'll be in your building for 20+ years, solar will pay off
                - Less than 10 years with incentive something?
        - Landscape
        - Non-profit, governmental, place of worship, schools?
            - Driven by availability of tax credits - worth 30 percent of system costs
                - 10k system is actually 7k out of pocket
                - Nonprofits can't utilize that
            - Need better incentives
                - Falls to local governments and organizations (like RENEW)
        - Solar for Good - proposals for solar on businesses
            - Fund will help compensate places like non-profits who can't utilize tax credits
    - MI just went to 15 percent minimum at utilities
        - WI sitting at 10 percent
        - Iowa
    - Mid American Energy - Iowa's largest energy owned by Berkshire (Warren Buffett - big believer in utility renewable energy)
    - Each year, increases in size of installations, number of installations,
        - Community solar
            - Middleton project - 500 kw of solar on their public works facility
            - Residential customers can subscribe up to 50 percent of their usage
            - 1 kw produced about 1250 kwh

        - Amount of electricity is credited on your bill
        - Pay small upfront fee (small @ MGE) 1 KW of solar about $180
            - Credit whittles it down, nets out at zero in about 15 years - after that it's profit
- What are the goals for renewable energy in Wisconsin?
    - Solar for Good is direct service to nonprofits
    - Most of renewable energy will have to come from utility scale systems in WI and outside of state
    - Find more opportunities to collab with utilities - easier as costs decline
    - Until state govt is willing to adopt a goal/policy for renewable energy
- What are the best sources for renewable energy in Wisconsin? (ex. Solar, geoenergy)
    - Principal source will be wind power, then solar, certain uses of bioenergy (biogas from agricultural operations, wastewater treatment plants - easier and more economical to clean it up and pump it into a pipeline for renewable natural gas rather than electricity)
    - Geoexchange - building heating and cooling, rather than electricity
    - Some hydro - but best locations have been fully exploited
    - IA: about 40 percent of electricity comes from wind - WI close to 2.2 percent
        - Lagging because utilities don't need to look for new wind sources when current 10 percent status was obtained in 2010/2011
            - Now wind is just starting up again
        - Some of the best wind resources (windiest areas) are too close to population centers
            - Relationships have been rocky between people and projects
            - SW population lower, economy is dominated by agriculture - plan to stay and pass down farms
    - Potential for small scale wind? Solar's declining costs have squeezed out small wind
        - Solar available at around $3000 kwh
        - Easy technology to maintain, no moving parts, quiet
- Can you talk about the successes of the Renewable Energy Revolving Loan Fund? What has come about from the digester projects?
    - PSC cancelled due to it wasn't effective in driving installations, cash incentives is better than low interest loans
    - Biodigesters are complicated…. Was doing well for a bit
        - Best located at large farms with cow manure, other organics can be added to the mix (cheese whey, slaughterhouse renderings)
        - But we hit our 10 percent standard
        - Generally run around the clock, price of power declines significantly overnight, early morn

        - Price differential between weekends/weekdays/holidays
        - Priced 2 cent kwh at sunday 4am, but biodigesters have to keep operating
        - 2013-2016 there was a stagnation in development
        - Phosphorus removal, those who benefit don't pay for that - electricity customers are
        - Now transitioning to making renewable natural gas
- Biogas:
    - Dane County: SE side off of 12/18 into Cambridge
        - Engine generations on the landfill that produce elec with contract with MGE
            - County supports part of budget off sales - MGE said don't expect this good after contract ends (next year)
            - Plan to switch electricity generation, to change to natural gas and injected to interstate gas pipeline, county can capitalize on incentives
        - State of WI is trying to do similar in Brown County
- Can you give you knowledge on what renewable energy credits (RECs) are and how they can be best utilized to achieve maximum clean energy?
    - Utility green pricing programs - contract with entity that produces renewable energy; electricity is sold through utility
        - Systems are around 10-20 years old
        - UW-Stevens Point (UWSP): Wisconsin Public Service (WPS) NatureWise relies on stale renewable energy
            - Your participation doesn't remove fossil fuel generation
        - Madison: Green Power Tomorrow through MGE
            - Same problem - MGE renewable energy elec services have been around for so long
        - Middleton - actually are moving the needle
            - PSC won't allow expansion - claim subscribes won't be paying full costs and it'll pass onto reg energy users
        - Organic Valley: brand new solar arrays
            - Additionality: if purchase doesn't result in new kwh and few fossil kwh, it's money down the drain
            - Organic Valley is directly connected to brand new solar arrays, they'll buy credits for less than 1 cent kwh
            - MGE program premium is 2.4 cents kwh
        - As a customer, you want to save energy in the long run - can't do that with credits, can only get a modest premium on what you pay today
    - Renewable energy rider: MGE brand new service (approved in July)
        - Neither customers or renewable energy sources

        - University (any of them) can participate in this program
        - UW-Madison can because MGE - has enormous energy usage
            - About 15 percent of MGE's load
        - MGE an UW co-own the co-gen facility on Walnut
            - New one generates electricity
- Comment generally about smart grids and applications in WI and on a university setting?
- Some argue that a true smart grid is a microgrid that allows for distributed, decentralized energy generation and storage. Ideally, every place connected to a micro-grid could generate, transmit, store, and use RE. Is it possible to build such a microgrid on the UW campus? In Madison?
    - Campus: solar can be put
        - Any new building should have solar on it
    - What are the obstacles for building a UW campus RE microgrid?
- Besides batteries and storage, what are some other obstacles to implementing more RE on campus?
- Another limitation is the fact that all the University buildings are owned by the state. How can we (as students) pressure the state to increase incentives and decrease regulations?
    - Acquisition of electricity is run through central office of administration - responsibility for all campuses (served by different utilities) Department of Administration (DOA) pays the bills
    - University would have to lobby DOA about sourcing more renewables
        - Has to want it so badly to lobby the state to implement
    - State purchasing with renewable electricity
        - WI passes a law with renewable energy purchase target for state facilities (20 percent by 2011)
            - We're at about 14-15 percent
            - After Scott Walker - decided we didn't have to do anymore
        - 4 contracts for renewable energy
            - MGE has arrangement with state of WI (spring 2008 - 10 years, expires first half of next year)
            - 40,000 kwh of renewables that state gets credit for goes somewhere else
            - Madison goes back down to same percentage as MGE's other customers
                - About 10 percent
            - Wisconsin Energy Corp (WEC): Their contacts are set to decline
- In terms of implementing more renewable energy on campus, where is the best place to start? (who to talk to, where to go, etc.)
    - Student activity is great - very encouraging

- SMC: Mary showed up the day they passed 100 percent in Madison
  - CLEAN: Campus Leaders for Energy Action Now
    - Leader of meeting was Kendall - with Sierra Club Student Coalition on campus
    - Works with state Sierra office and Beyond Coal campaign
    - John Muir Chapter - to get her contact information
    - Lots of fact gathering right now
    - Anna Weinberg and Carly
  - Meetings: 4th Monday of month - open to the public
  - Climate Reality, ASM, Helios, Sierra Club
- State holds the power in these cases
- Need to look at the buildings - age of the roof, shade, what's on the roof, what kind of load does that building have?
  - Helios is starting this,
  - SERF being remodeled - can we do something there?

- Is there room for RENEW to help the University implement more renewables on campus/participate in buying RECs?
  - Has to be much more careful than UWSP
    - Should be utilizing more new solar arrays
- How can the University rework its contract with utilities (currently MGE) to allow for more room for renewables?
  - Push where we can
  - David Daniel: target
  - Chancellors, board of regents - all targets
  - Sustainability Director: target -
- Josh: part of consulting with City of Madison
- Is there anything else you would like to add?

Appendix 9: Ann Terlaak Interview

Professor Ann Terlaak
Interviewed 12/8/17 via email

1. What would it take for UW-Madison to reach 100 percent renewable energy? In other words, what might have to be done in terms of political will, financial investments, technology, and anything else?

"I think looking at why it hasn't been happening (or why we haven't even really been moving t/w it in a meaningful way) can help understand what it would take. I feel one issue is that bandwidth is limited and leadership (bascom) has been dealing with other (equally burning) issues that seem more immediate (diversity and inclusion). As they get a better handle on that issue, my hope is that some bandwidth is freed up to address climate change and the role that UW currently plays (and wants to play in the future) in addressing it.

Another issue that we thus far have not had people in place that are truly assigned to making it happen. Yes, we have OS… but OS has been staffed with professors like me or Cathy, who, really, are paid for attending to their professor job; even the operations folks that we had at OS at some point (and that since have left) have never had more than partial appointments with OS (as far as I know). Making campus run on renewable energy is a very very very (did I say very?) complex undertaking, and it takes folks that can fully dedicate themselves to this endeavor to make it happen. So, in short, Bascom needs to fully commit to OS and staff it appropriately. And this is where limited budgets and funding issues come into play…

Then there is the issue that the state owns UW's building, and capital expenditures for these building (e.g. to upgrade, make more energy efficient, etc) typically require state approval (and funding). The current political climate in WI (and even more broadly on the federal level) does not help here. I sometime feel that UW and higher ed in general is so much attack these days that leadership has to exhaust all its resources just trying to make a case for our existence and continued funding… issues of renewable energy etc easily slip into the background when your whole raison d'etre is being questioned…

Oh geez. Typing all this out really makes for a bleak Friday afternoon…"

2. What can students do to increase the amount of renewable energy used on campus? There are multiple student organizations and individuals that are fighting for this, but meeting roadblocks and limitations. Who do we talk to? How do we draw attention?

"I think it might make sense for the various orgs (and individual) to join forces and align all efforts, rather than each org/individual going out on their own. But other than that I think there likely is no silver bullet. Do what you have been doing, keep bugging Bascom, make clear that climate change and the role that UW should play in addressing it is one of the most important (THE most important?) challenge for your generation – the students that are at UW and that UW should be serving. And remember the one slide that showed in class about social change in general … how it seems that nothing happens forever, despite intensive grass root efforts and campaigns etc… until there suddenly is a tipping point and things change. That tipping point cannot occur unless there is this seemingly "ineffective" activity beforehand…."

Appendix 10: Renewable Energy Site Suitability Maps

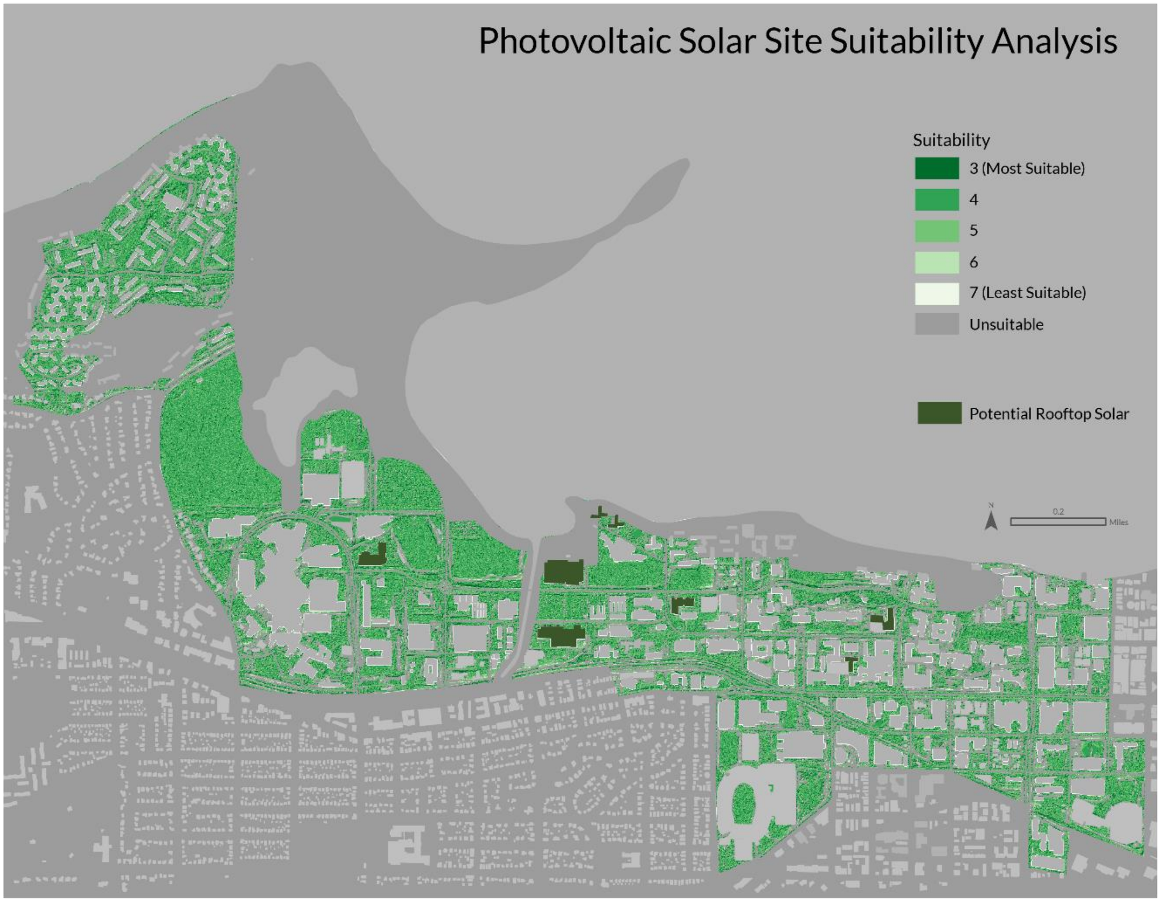

Figure 16: Photovoltaic Solar Site Suitability Analysis Map

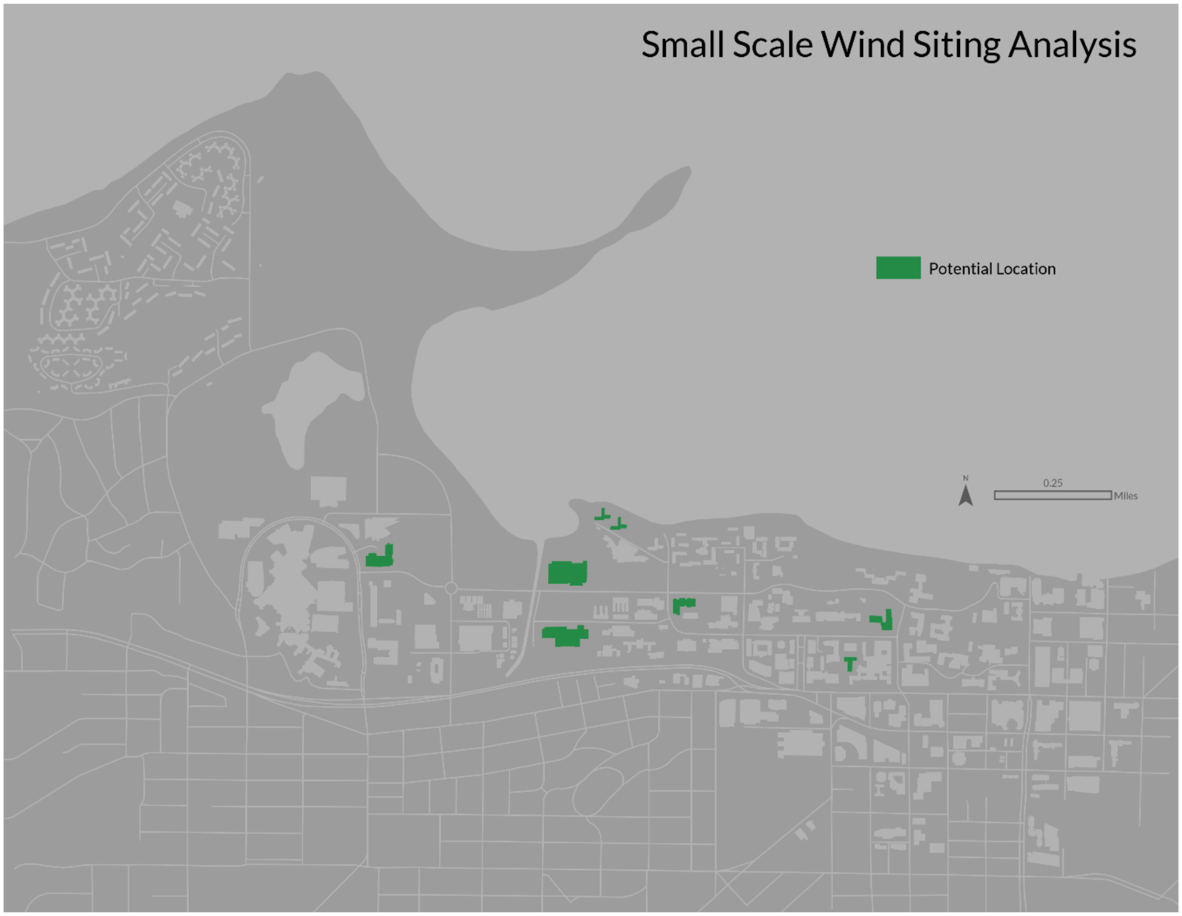

Figure 17: Small-Scale Wind Siting Analysis Map

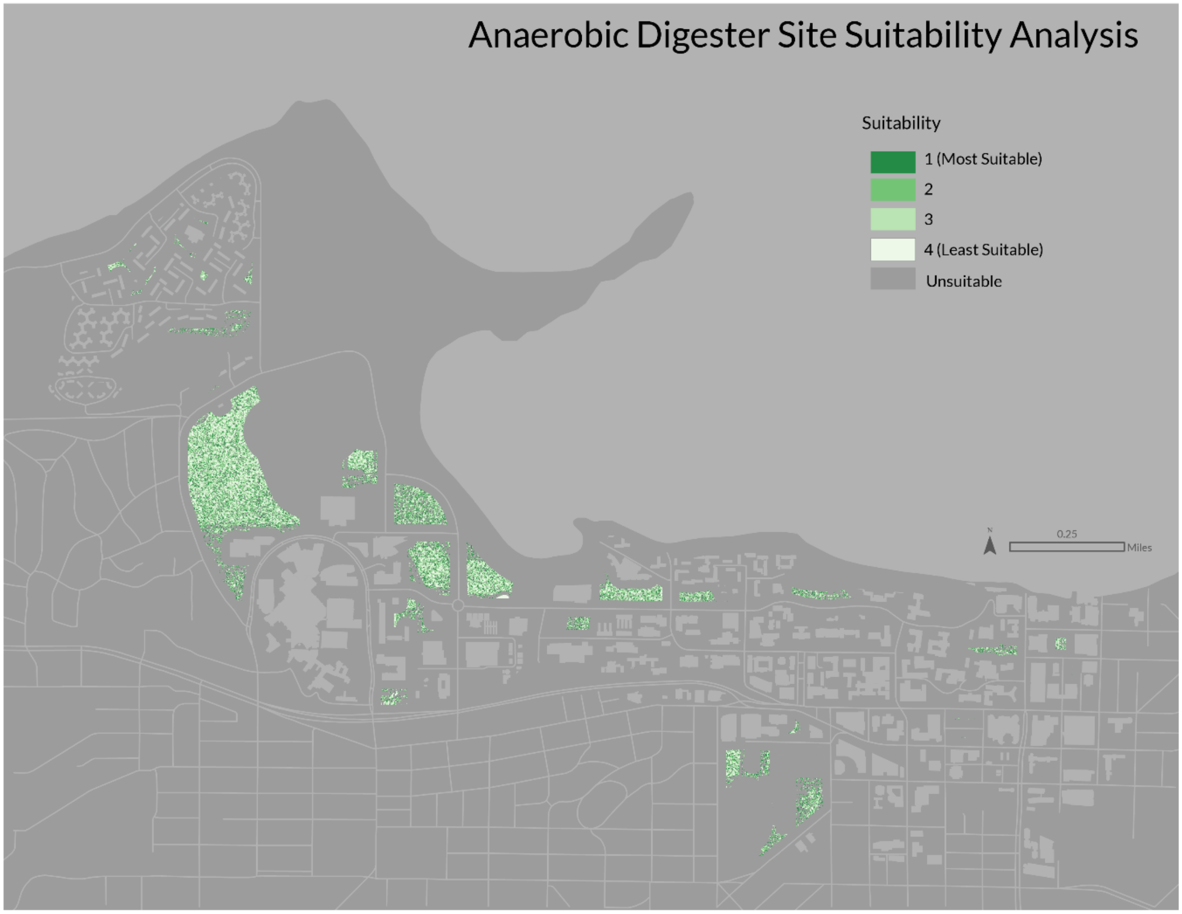

Figure 18: Anaerobic Digester Site Suitability Analysis Map

Appendix 11: Survey Results and Analysis

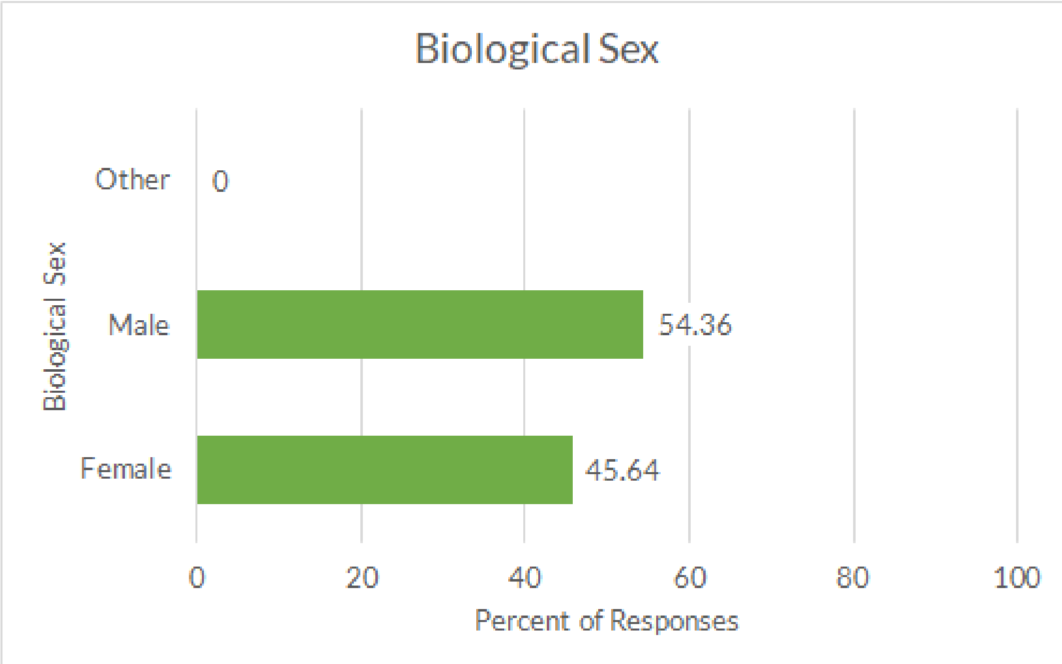

Figure 19: Biological Sex Survey Results

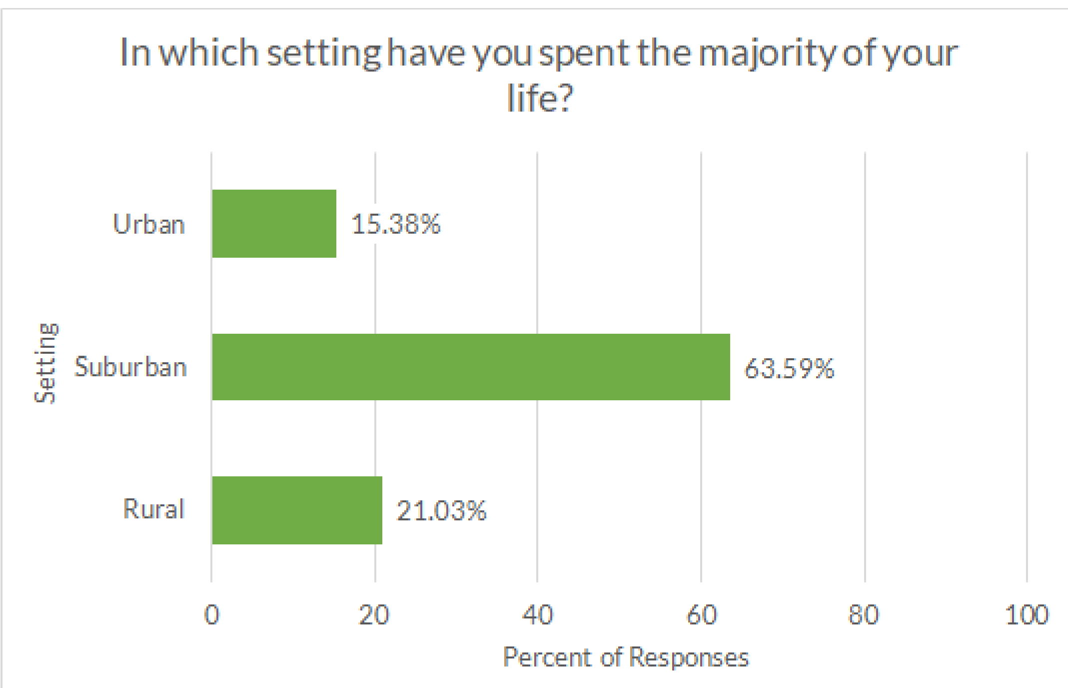

Figure 20: Personal Background Survey Results

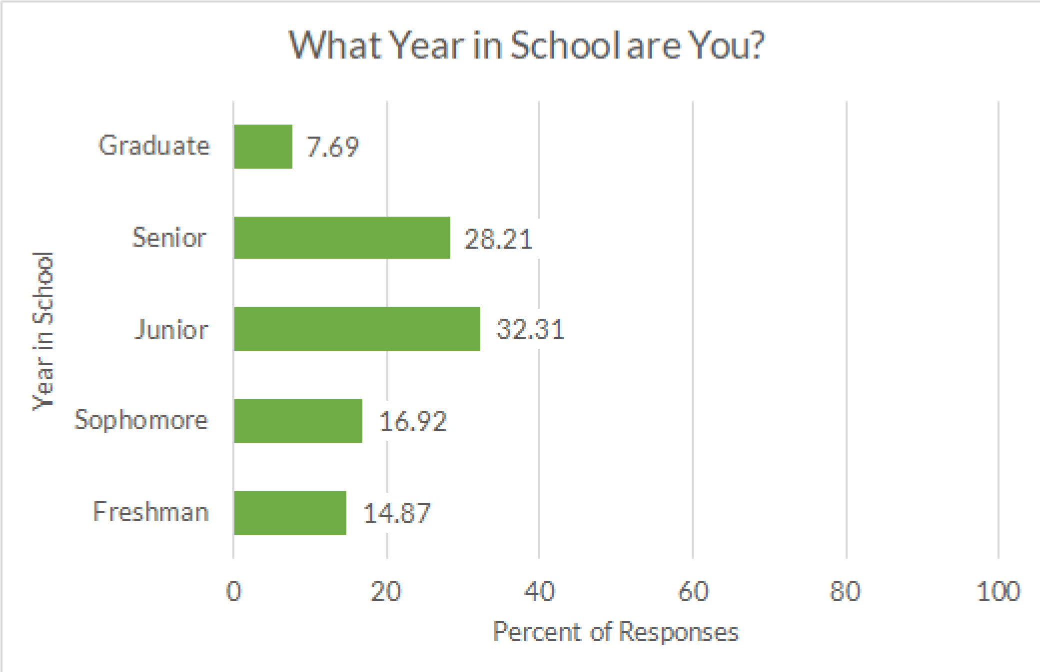

Figure 21: Class Year Survey Results

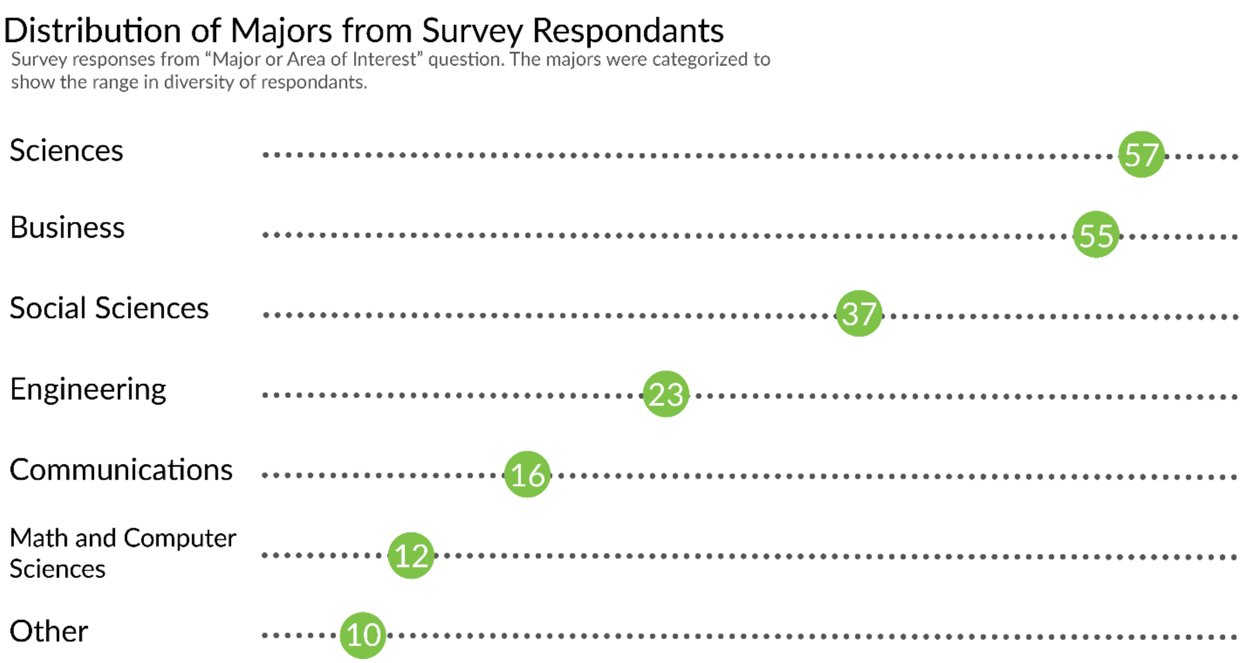

Figure 22: Major Distribution Survey Results

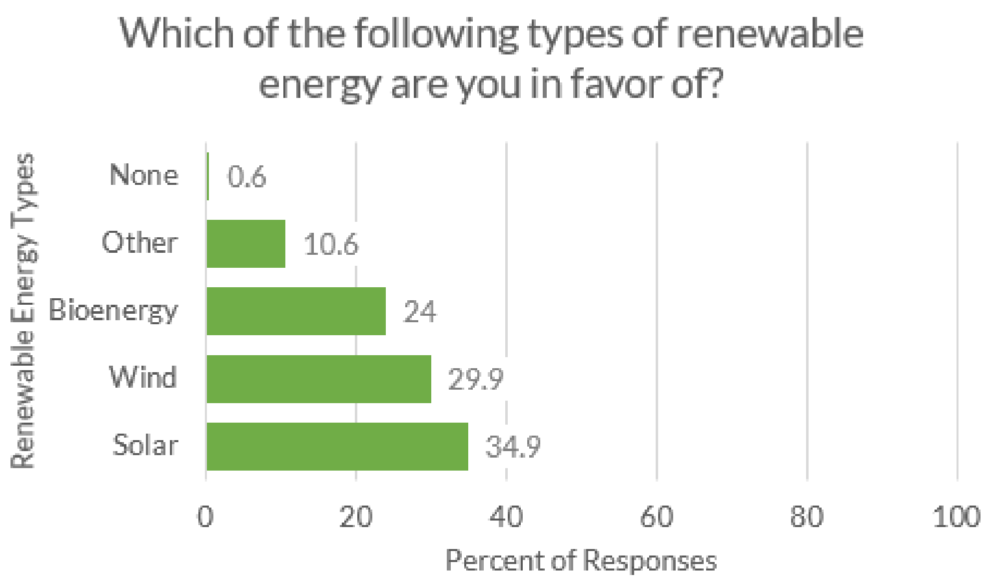

Figure 23: Renewable Energy Favorability Survey Results

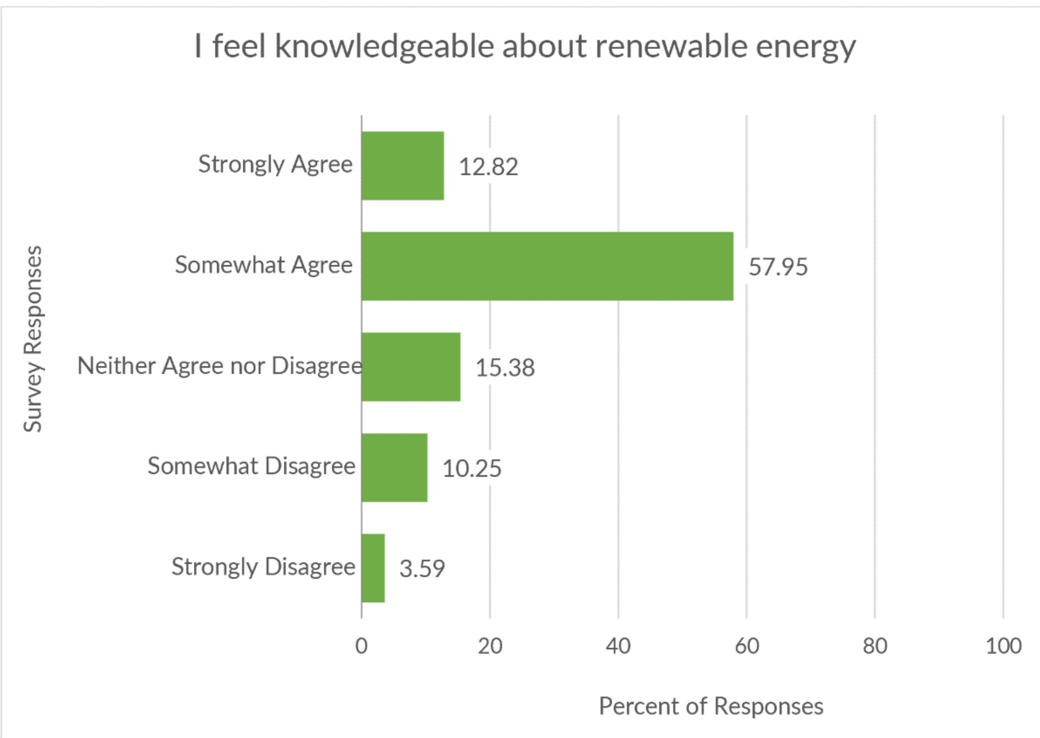

Figure 24: Knowledge of Renewable Energy Survey Results

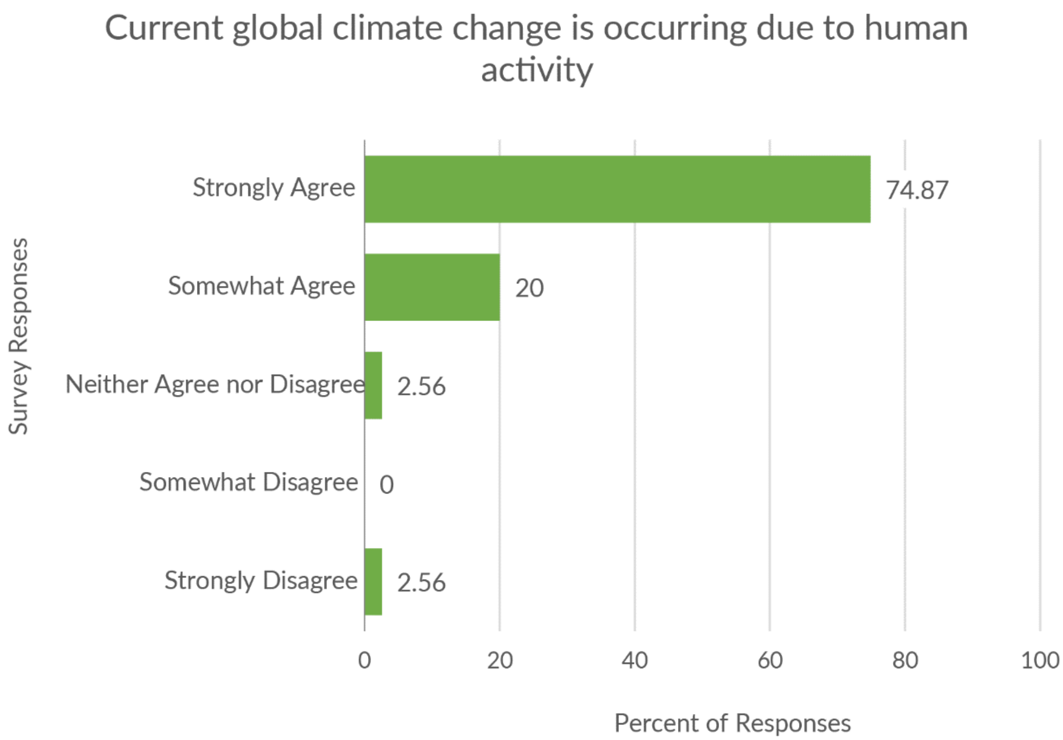

Figure 25: Anthropogenic Climate Change Survey Results

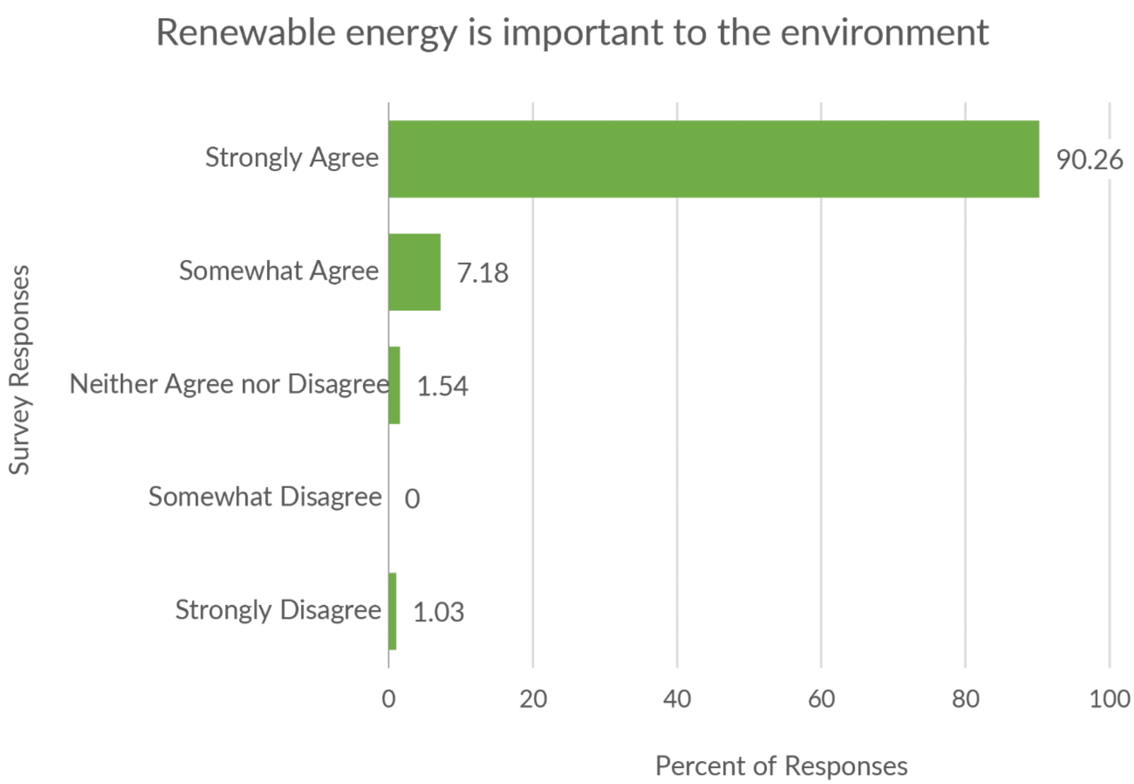

Figure 26: Importance of Renewable Energy Survey Results

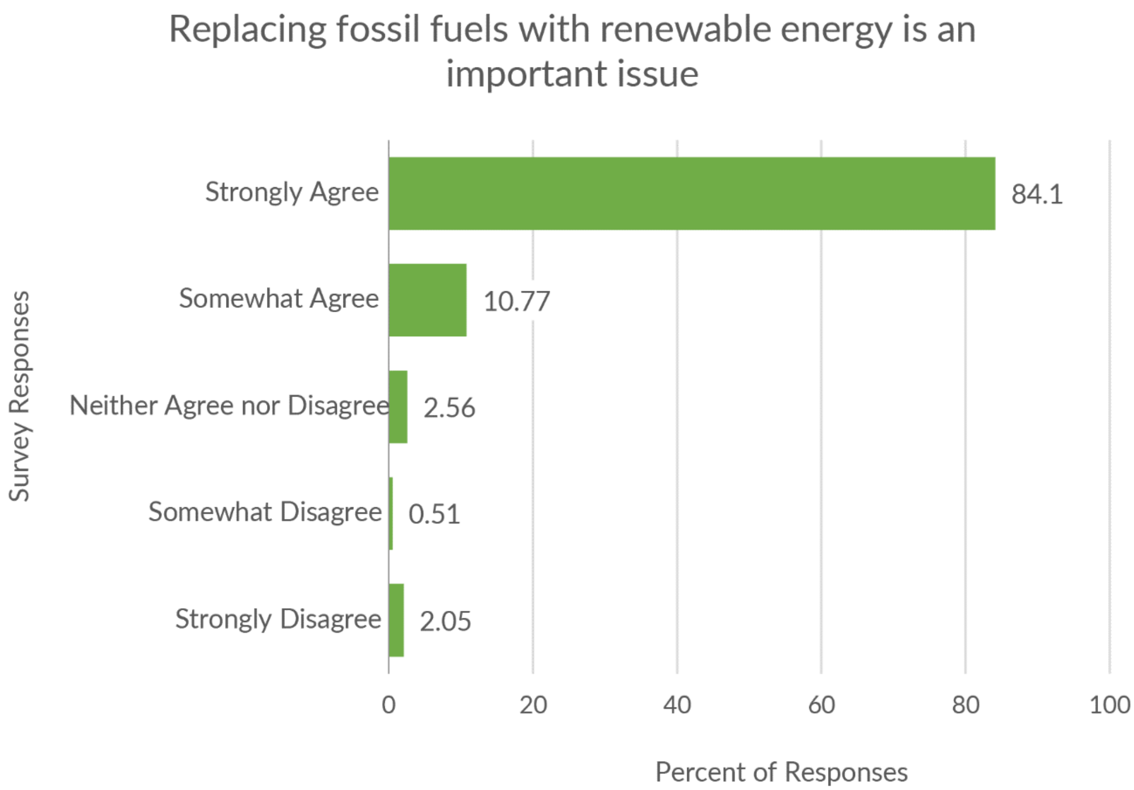

Figure 27: Replacing Fossil Fuels Survey Results

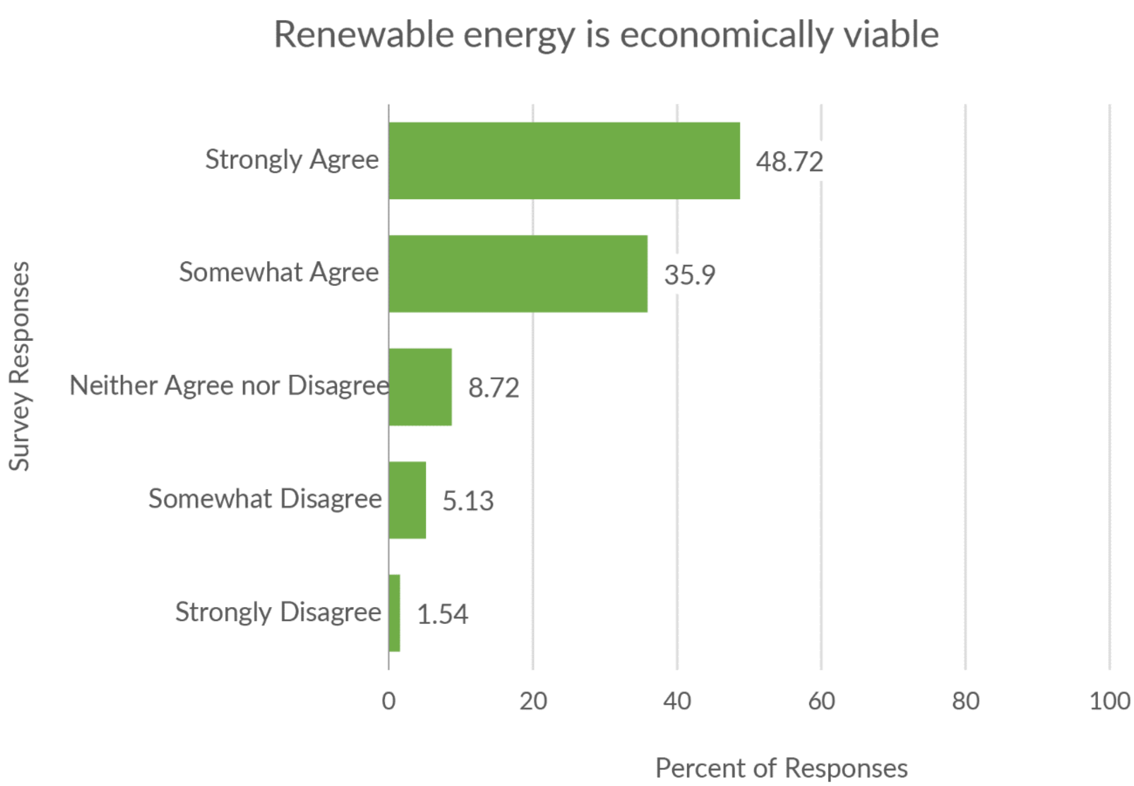

Figure 28: Renewable Energy Viability Survey Results

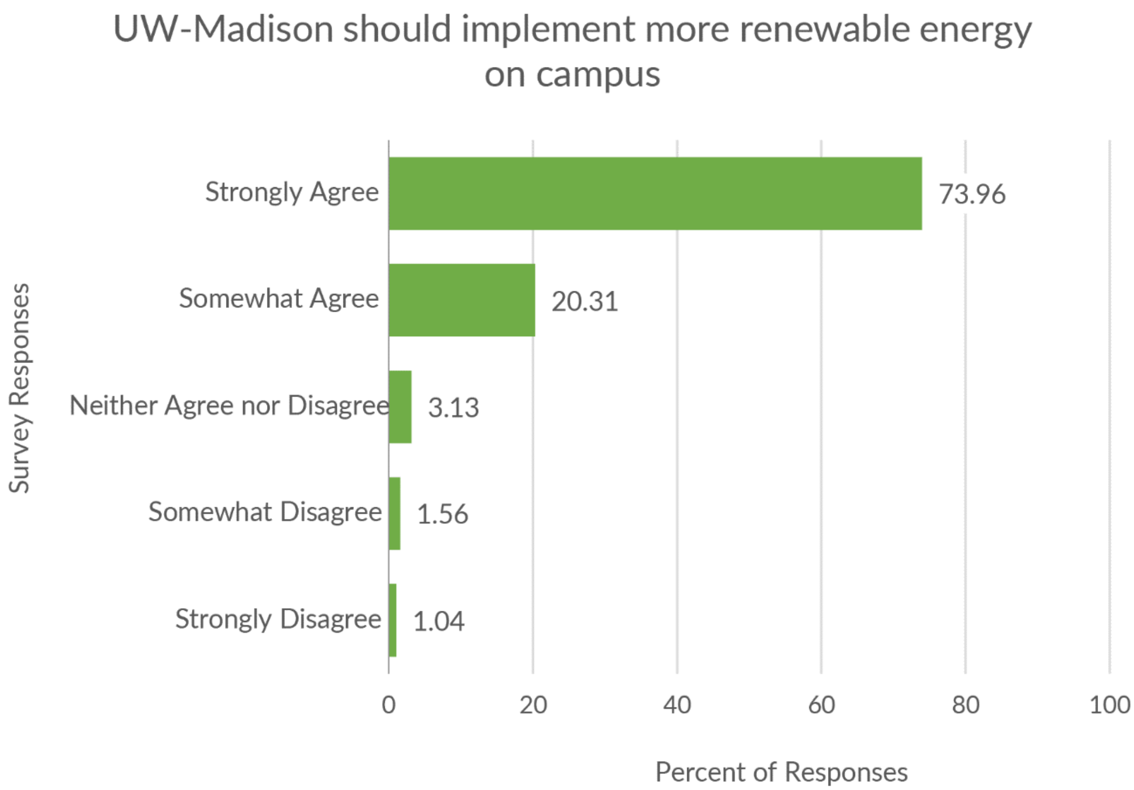

Figure 29: Renewable Energy at UW-Madison Survey Results

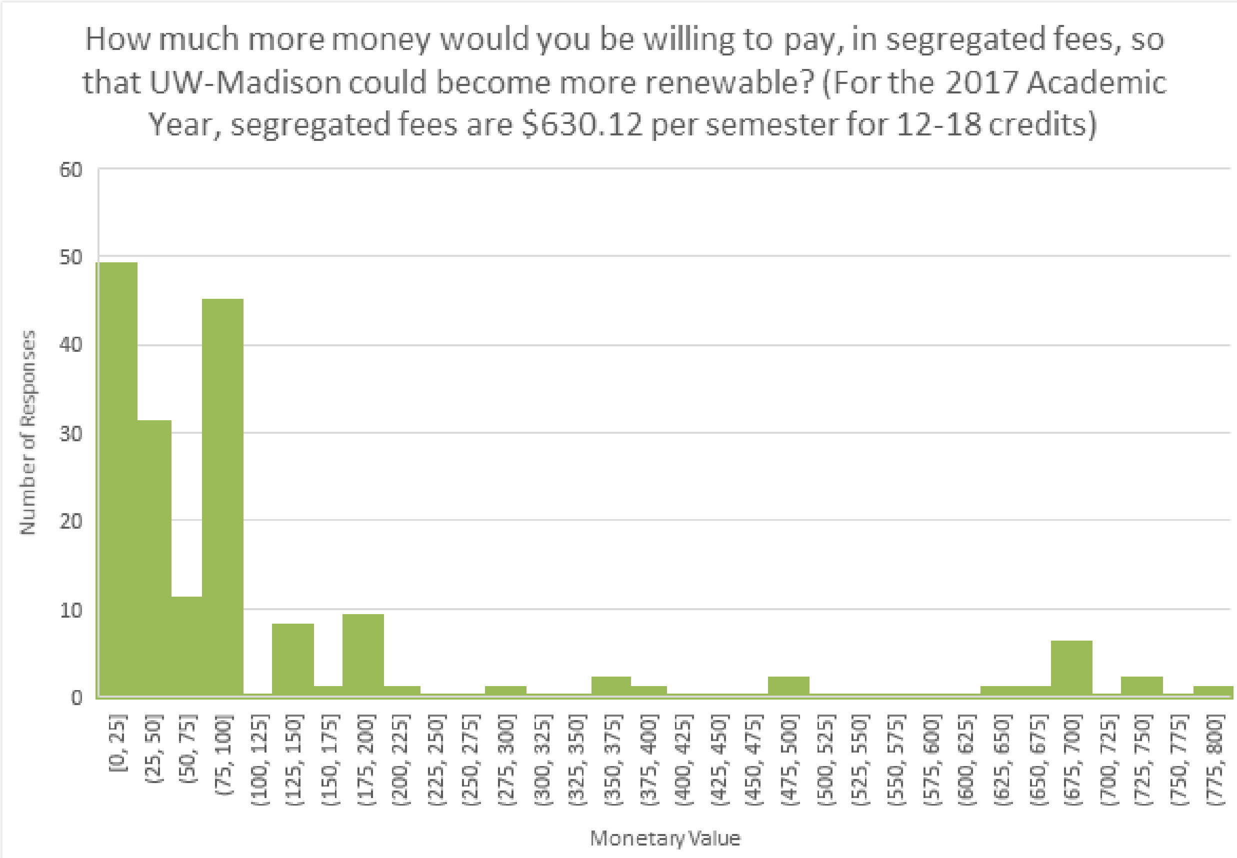

Figure 30: Willingness to Pay Survey Results

Major	# of Respondents	Average $
Accounting	5	170
Actuarial Science	2	85
African Studies	1	0
Agricultural Business	2	134.94
Agronomy	1	50
Animal Science	1	10
Anthropology	1	75
Art History	1	40
Astronomy-Physics	1	15
Biochemistry	3	90
Biological Systems Engineering	2	25
Biology	8	83.75
Biomedical Engineering	4	35.25
Botany	1	100
Business	9	127.21
Cartography	1	100
Chemical Engineering	1	100

Chemistry	2	185
Civil Engineering	2	10
Communication Arts	3	143.33
Computer Engineering	1	100
Computer Science	6	145
Conservation Biology	2	25
Consumer Science	2	100
Dental Hygiene	1	0
Economics	14	144.29
Education	2	75
Engineering Mechanics	1	0
English	4	53.75
Environmental Engineering	3	106.67
Environmental Science	4	400
Environmental Sociology	1	0
Environmental Studies	14	140.35
Finance	11	82.32
French	1	100
Gender & Women's Studies	1	100
Genetics	5	84
Geography	11	129.59
Geology	1	660
History	5	206.31
Human Development and Family Studies	1	0
Industrial Engineering	4	211.25
Interior Architecture	1	0
International Business	1	0
International Studies	3	26.67
IT-Network & Security	1	100
Journalism	4	33.75
Kinesiology	1	369.88
Law	1	0
Legal Studies	2	40
Marketing	8	78.13
Mathematics	2	25
Mechanical Engineering	4	62.50
Molecular Biology	1	100
Neurobiology	1	100
Nuclear Engineering	1	100
Nursing	2	7.50
Other	1	5

Operations & Technology Management	1	75
Personal Finance	1	100
Pharmacy	1	20
Political Science	17	130.94
Psychology	9	125.56
Real Estate	4	31.25
Rehab Psychology	1	50
Religious Studies	1	100
Restoration Ecology	1	0
Retail	2	50
Sociology	2	75
Spanish	2	50
Speech Pathology	2	25
Statistics	2	375
Tuba Performance	1	500
Undecided	4	157.78
Veterinary Medicine	1	20
Vocal Performance	1	0
Wildlife Ecology	1	5
Zoology	1	30

Figure 31: Willingness to Pay by Major