2018-2019

FINAL REPORT

UniverCity Year

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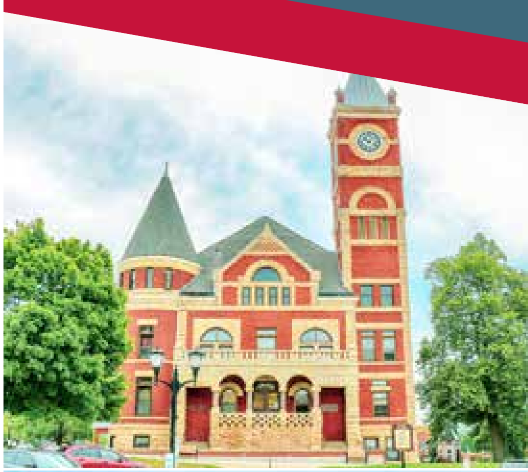
Wind energy recommendations for Juda School District

CIVIL ENGINEERING 421: ENVIRONMENTAL SUSTAINABILITY ENGINEERING



UniverCity Alliance

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Executive Summary

Introduction and Background

The objective of this assessment was to provide the Juda School District, a small school district located in southern Wisconsin, with a sustainability analysis of installing a wind turbine. Considering the effect and impact of climate change, using more clean and renewable energy is a goal of the Juda School District.

To get a better rounded understanding on the environmental, economic, and social sustainability of wind turbines, established literature and information was researched. From this it was found that the positive impacts of using wind energy is that it does not generate any greenhouse gas emission, it uses less water than coal energy production, and that it disturbs the least amount of wildlife and local environments. Negative aspects were also noted. The two most prominent negative impacts was its effects on birds and bat mortality and the sound and visual concerns expressed by local communities. The different kinds of turbines were also looked at to see if any type of turbine was more advantageous.

Scope

The scope of this assessment is to compare and contrast the three different types of wind turbine designs based on several different parameters that include social, environmental, and economic impacts. System bounds in this assessment will only include aspects that meet the Juda School's interests, specifically focusing on parameters such as the wind turbine's construction fee, electricity output amount and cost, education of sustainability influence to school children, safety concerns in nearby communities, and emission reduction.

After considering the three turbine options, the horizontal axis turbine is the most realistic design option in terms of current technology and efficiency. This was in part due to the lack of information on the vertical and urban turbine.

Constraints and Assumptions

There were several constraints and challenges in conducting this study. Previously, Synergy Renewable Systems created a wind site assessment for the Juda School, which provides useful data such as estimated wind speeds, potential construction costs, and energy outputs. However, without specific data for different turbines in the economic analysis, generalized costs found in literature were used. The assessment also mentions various site conditions that could affect the construction process. For example, the Juda school has unknown technical problems with sending electricity back to the electricity grid. The school's electricity trends are also largely inconsistent, making it difficult to estimate the potential amount of economic saving from the turbine. Other social challenges include construction safety and community backlash.

Work Plan

There were different tools used to evaluate the environmental impact that a product or a service has throughout its life. The Life Cycle Assessment (LCA) and System Advisor Model (SAM) were two critical tools used.

The decision on whether to install a wind turbine was eventually based on the quantified numbers of different design alternatives. For a detailed and comparative evaluation of the environmental impacts of each wind turbine, each wind turbine design alternative was run through a life cycle assessment (LCA), looking at the carbon emissions of each kind of wind turbine. The corresponding carbon dioxide emissions to the current energy consumption was compared to the carbon emission with the use of each turbine. The economic analysis was done by conducting a System Advisory Model (SAM) assessment. This gave the power generated and cost associated of each wind turbine. Other economic aspects were looked at such as incentives like tax breaks and credits. For the social sustainability analysis, the concerns of the Juda community were looked at, such as excess noise, shadow flicker, bird collisions, and safety hazards like ice shedding. While these factors will not be quantified in monetary terms they will be considered and addressed in the final recommendation provided.

Results and Recommendation:

The results of the economic and environmental impact assessments are compiled in the table below. When determining which system to recommend, the social impacts were not heavily considered because they are approximately the same for all three turbine designs. Because of this they do not provide a useful basis for comparison.

	Economic Parameters								Environmental Parameters			
	Year 1 Energy Production [kWh]	Year 1 Capacity Factor [%]	Levelized COE [cents/kWh]	Year 1 Net Savings [$]	Net Present Value [$]	Simple Payback Period [years]	Discounted Payback Period [years]	Net Capital Cost [$]	Year 1 Emissions without system [gCO_2e]	Year 1 avoided emissions [gCO_2e]	Year 1 Net Emissions [gCO2e]	Percent Decrease [%]
Greenstorm GS 21 S	311,938	55.6%	4.38	$18,773	$102,841	12.7	15	$224,350	542,974,497	255,061,409	287,913,088	47%
Endurance E4660	374,836	49.9%	4.96	$22,557	$77,264	14.8	18	$300,300	542,974,497	306,630,031	236,344,466	56%
NPS 100C-24	388,300	46.4%	5.36	$23,367	$47,378	16.3	20.4	$334,250	542,974,497	306,491,028	236,483,469	56%

Endurance E4660 has the most cost-environmental balanced value between economics and environmental impact. This 85 kW power turbine has the ability to produce almost the same amount of energy as a 100kW turbine during their lifetime, which means the same GreenHouse Gas emission reduction. At the same time, it has an overall 7.5% cheaper production cost than NPS 100C-24 (100 kW). An 85 kW turbine is the most sustainable option.

Because of its affordable initial cost, which is less than a quarter million, as well as the short payback period, Greenstorm GS 21 S (60kW) is the most suitable type of turbine, based on the current financial condition of Juda public School. Its net present value and energy production cost rate stands out among the three. While it is true that a smaller power turbine will produce smaller amount of energy, GS 21 S can operate with the highest capacity factor under the limited wind speed in the Juda district. So a smaller turbine with power around 60 kW would suit best for Juda Public School.

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1. Introduction

With the growing availability and popularity of renewable energy sources, many school districts are exploring the possibility of incorporating more renewable sources in their school design. The Juda School District is located in southern Wisconsin. It is a very small community. In fact, their school district only consists of a total student population of about 300 people. One of the options that they are considering implementing is the addition of a possible wind turbine. To analyze if the addition of a wind turbine would be sustainable, the Juda School District teamed up with the University of Wisconsin—Madison Civil and Environmental Engineering 421 class. A team, consisting of four team members, will examine the economic, social, and environmental sustainability of various different wind turbines to see which, if any, would be the most beneficial to implement in the Juda School District.

2. Project Significance

This project is significant because of the issues arising with climate change. Global greenhouse gas emissions have increased rapidly since the dawn of the industrial revolution causing the climate to change on a global scale creating a need for change in regards to the current methods used for the generation of energy. Anthropogenic warming surpassed 1°C in 2015 with respect to the average global temperature pre-industrialization and is increasing at approximately 0.2°C per decade (Millar, et al., 2017). Nations came together in 2015, drafting and signing the Paris Agreement, setting a target for greenhouse gas emission reductions that would keep the overall warming to a maximum of 1.5°C. At current rates this threshold would be reached by 2040. The time to act is now as the effects of climate change are already severe. The 2017 hurricanes Harvey, Maria, and Irma, all rank in the top five most costly hurricanes delivering an estimated 265 billion dollars in damage to the United States and 258 official fatalities (Blake & Zelinsky, 2017) (Canglialosi, Latto, & Berg, 2017) (Pasch, Penny, & Berg, 2018). While official statistics are not published, Hurricane Michael (2018) will likely join the 2017 hurricanes near the top of the list for total damages. In 2013, the Intergovernmental Panel on Climate Change published a report concluding that it is “virtually certain” that the frequency and intensity of tropical cyclones in the north Atlantic has increased since the 1970’s (IPCC, 2013). The long term impacts may be more severe as rising sea levels may inundate entire nations, and acidification threatens fisheries around the globe. The community of Juda, Wisconsin, may not be directly affected by these specific disasters due to geography but the atmosphere can be represented as a common resource for all of humanity, meaning everyone must work together to prevent the impending tragedy brought on by climate change.

Although affordable electricity generated by the combustion of fossil fuels allowed the United States to develop an advanced economy in a very short period of time, the emissions generated by the electricity sector represent a large portion of the total greenhouse gas emissions. The electric power sector emitted 36 percent of the U.S. total carbon dioxide from fuel combustion in 2016 (EPA, 2018). The other major carbon emitters responsible for nearly all of the remaining carbon emissions are the transportation and industrial sectors. As electric cars become more common the burden of carbon emission reduction will be passed on to the electricity producers. In the industrial sector the desire to grow our economy makes this an unlikely place to make significant reductions in emission outputs. With far more nuclear power plants being turned off than on, the widespread implementation of renewable electricity generation systems appears to be the most plausible way to combat climate change at this time (EPA, 2018). Despite President Trump withdrawing the United States of America from the agreement, the renewable energy market in this country is rapidly growing in response to several decades' worth of federal investments fueling advancements in technology and compensating installation costs. According to the U.S. Department of Energy, wind and solar energy accounted for over 66% of the total generating capacity installed in 2015 (U.S. Department of Energy, 2016). Although this growth has reduced the total carbon emissions each year since 2007, the atmospheric concentration of carbon dioxide continues to rise meaning further action is required to stop the warming.

Schools within the United States consume a large amount of energy which consumes a significant amount of their yearly budget. Schools are faced with state budget cuts and aging infrastructure coupled with an increasing number of electronic devices available to students making it difficult to reduce consumption. Juda School District is no exception to these trends spending between $70,000 and $80,000 per year on electricity. U.S. school districts spend $6 billion per year on energy ranking second in total expenditure behind teachers' salaries (Xcel Energy, 2007). Another reason schools are at a disadvantage economically is due to the way electricity prices are determined. Utilities designate on-peak and off-peak periods where the price per unit is different.

A premium is charged during on-peak periods which coincide with the hours a typical school is in session. To reduce the overall environmental impact and eventually save money on electricity, schools are looking to construct renewable energy systems on location.

Wind energy is a promising technology for rural Wisconsin schools like the Juda school district; however, the trend in technology is moving away from small turbines and towards much larger turbines, which presents technical and economic feasibility issues. The average nameplate capacity of turbines installed in the U.S. has increased primarily as a function of increasing rotor diameter since 1998, reaching an average capacity of 2.32 MW and rotor diameter of 113 meters. These are increases of 224% and 459% respectively providing context for the scale of the increases (Office of Energy Efficiency & Renewable Energy, 2017 Wind Technologies Market Report, 2018). A resource that many rural schools share is land availability as turbines generate noise that may be distracting to students in the classroom. Even if a school has the ability to site a large turbine, the initial investment would be well over one million dollars, exceeding a reasonable budget for a typical school. A recent report from the University of Texas Energy Institute calculated the cheapest energy source for every county in the U.S. concluding that wind has the lowest full cost of electricity.

Economies of scale applies directly to wind turbine technology as the price per watt of capacity increases significantly as the total capacity decreases, making small turbines far more costly than industrial scale wind machines. The average cost of small wind turbines in 2017 was $10,117 per kW of capacity, which is one hundred times the approximate cost of installing a utility scale turbine. The Department of Energy recently launched the Competitiveness Improvement Project awarding grants to manufacturers in an attempt to make small scale wind competitive with other distributed generation technologies (Office of Energy Efficiency & Renewable Energy, 2017 Distributed Wind Market Report, 2018). A recent report from the University of Texas Energy Institute calculated the cheapest energy source for every county in the U.S. concluding that wind has the lowest full cost of electricity in Green County, Wisconsin (University of Texas at Austin Energy Institute, 2016). As low cost financing, money won through grant programs, and improvements in technology reduce capital costs, an analysis of the feasibility of constructing a small wind turbine for the Juda School District will help determine if this technology is justifiable by weighing the environmental, social, and economic impacts it would have in the community.

3. Background

3.1. Background Literature on Sustainability Impacts

To get a better understanding of what to expect from the environmental, social and economic impacts, published research was looked at. From this, it was seen that wind turbines do have both positive and negative environmental impact.

The positive environmental aspects of wind energy and turbines are often talked about. Wind energy is a clean fuel source. That means that it does not generate any greenhouse gas emissions. According to the American Wind Energy Association, in 2017 wind energy avoided an estimated amount of 189 million tons of carbon emissions (American Wind Energy Association, 2018). It also avoided sulfur dioxide and nitrogen oxides from being emitted into the atmosphere, which are smog causing emissions. In addition, wind energy also helps with water conservation when compared to power plants. An estimated amount of 95 billion gallons of water was saved by using wind energy in 2017 (American Wind Energy Association, 2018). Wind energy also disturbs the least amount of wildlife and local environments. It is estimated that about 98 percent of the land used by wind energy is left undisturbed and can be used for agricultural purposes (American Wind Energy Association, 2018).

Even though wind energy does have all those positive environmental impacts, there are negative environmental and also social impacts associated with it. One of the most prominent environmental concern for wind turbines are their effect on birds and bats. The birds and bats may collide with the spinning wind turbine blades. This is especially a concern in areas with a high bird population and areas on the migration path of certain species (Hutchins, 2017). In addition to the negative environmental impacts, wind turbines also can have a negative social impact due to sound and sight. The spinning of the turbines can cause noise that the nearby community might find a nuisance. Nearby residents have also complained about the shadow flicker that is caused by the spinning of the blades. Some people do not like the aesthetic that a wind turbine brings to their community; they find it disturbing and unsightly (Union of Concerned Scientists, 2013).

3.2. Possible Design Ideas

In addition to looking at the impact of wind turbines, it was important to differentiate between the different kinds of turbines available. There are two main types of wind turbines, horizontal and vertical axis. An alternate wind turbine that can be used for urban settings is a roof-mounted ducted wind turbine. All three types of wind turbines have varying designs, along with different advantages and disadvantages.

3.2.1. Horizontal-axis Turbines

Figure 1: Horizontal-axis wind turbine (Wind Explained: Types of Wind Turbines, 2018)

The most common and efficient type of wind turbine is the horizontal-axis turbine (Wind Explained: Types of Wind Turbines, 2018). These turbines consist of three blades that are rotating on an axis parallel to the ground to stabilize the turbine. Typically, horizontal-axis turbines are designed as tall towers which allows access to the stronger winds in sites with wind shear, while also allowing for placement on uneven landscapes. One main component of this turbine is the rotor, which is designed aerodynamically to capture the maximum surface area of wind in order to spin the most ergonomically. The other components, the blades, are made with lightweight, durable, and corrosion-resistant material such as fiberglass and reinforced plastic. These blades are usually designed to wing warp, which allows them to steer at the best angle of attack when capturing the energy of strong, fast winds. To complement this effect, the rotor blades have the ability to pitch, which refers to the turbine adjusting the rotation speed and generated power in order to control the absorption power. Blade pitching also minimizes damage during a storm. Most horizontal-axis turbines are self-starting (Guzzetta, Myers, & Purse, 2007).

The main disadvantage in this design is difficulty operating in areas where the wind is near the ground. Since the turbine is usually quite large, there are extra transportation, construction, installation, and maintenance costs that need to be considered. In addition, the aesthetics of the large towering design may conflict with the local community (Guzzetta, Myers, & Purse, 2007).

The typical lifespan of this turbine is around 120,000 hours, or 20-25 years. This includes proper maintenance, since the system contains moving components and will need to be replaced during their working life.

3.2.2. Vertical-axis Turbines

Figure 2: Vertical-axis wind turbine (Wind Explained: Types of Wind Turbines, 2018)

The second most common type of turbine is the Vertical-axis design, with the Darrieus wind turbine being the most popular. These turbines have blades that are attached to the top and bottom of a vertical rotor, which are rotating on an axis perpendicular to the ground. The blades in this design work in a similar way to an airplane wing, creating lift in order to power the generator shaft. The greatest advantage with this smaller turbine is easy maintenance, along with much lower construction and transportation costs when compared to the horizontal-axis. These turbines are also not directional, so precise positioning of the turbine along maximum wind streamlines is not a factor. This allows for the turbine to work under turbulent wind conditions from all directions. Because of this versatility, they are primarily used in small wind projects and residential applications where wind conditions are inconsistent. They are also smaller and more quiet, which is ideal for the surrounding the residences (Guzzetta, Myers, & Purse, 2007).

The main disadvantage with the vertical-axis turbine is that it is ultimately less efficient than the horizontal-axis turbine. The reason is that the blades are constantly spinning against the direction of the wind, causing drag. This design also requires an environment with lower, more turbulent winds. With the blade design, these turbines have a low starting torque and require greater energy to start turning (Guzzetta, Myers, & Purse, 2007).

3.2.3. Ducted Wind Turbines

Another less conventional turbine design is the roof-mounted ducted wind turbines (Wind Explained: Types of Wind Turbines, 2018). These turbines are only used in urban areas, and are typically positioned at the edge of the roof of a building. This design operates by utilizing the

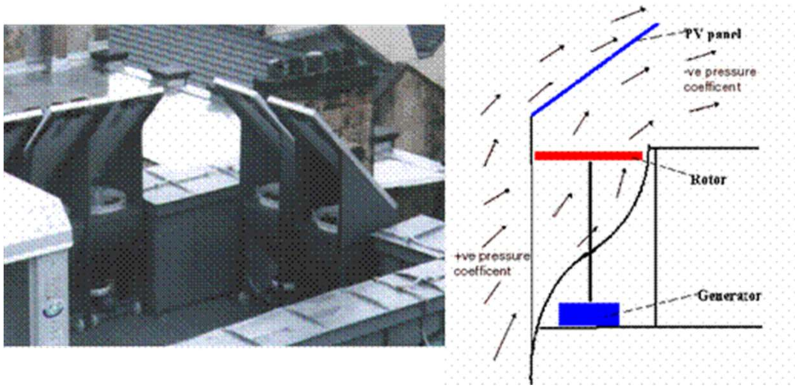

Figure 3: Ducted Wind Turbine (Urban Wind Generation, n.d.)

airflow along the side of a building. As the air flows upwards, the streamlines hug the building wall and enter the front of the duct. This turbine is much smaller than other designs, leaving little visual impact to the building. This can be useful in urban areas as rooftops are typically unused. In addition, the turbine is placed on-site, which avoids transmission losses associated with energy generation (Urban Wind Generation, n.d.).

The problem with this design is that it is relatively new and undeveloped. More research needs to be done with urban wind turbine systems to better determine the energy production potential of the turbine. Also, this turbine is unidirectional, where its fixed position is dependent on wind blowing in the correct direction (Urban Wind Generation, n.d.).

4. Scope of Work

The scope of this assessment is to compare and contrast the three different types of wind turbine designs based on several different parameters that include social, environmental, and economic aspects. A complete system comparison of the selected wind turbines was completed including environmental impact, energy consumption, and energy payback time. While the product life cycle of the wind turbine produces a variety of different impacts during the manufacturing process, transportation, installation, and disposal stages, the life cycle assessment will not consider any product life cycle stages outside of the turbine's actual operation for practical reasons. In Figure 4, the map of flows of the wind turbine is shown as is the bounds of the study. System bounds in this assessment will only include aspects that meet the Juda school's interests, specifically focusing on parameters such as the wind turbine's construction fee, electricity output amount and cost, education of sustainability influence to school children, safety concerns in nearby communities, and the life cycle assessment including carbon reduction and hazardous material release.

After considering the three turbine options, the horizontal axis turbine is the most realistic design option in terms of current technology and efficiency. Efficient vertical axis turbines typically require twice the swept area and four times the material in order to generate the same electricity. Along with the other disadvantages mentioned, it would be difficult to run a proper LCA due to the inconsistencies of the horizontal axis turbine. In addition, there is a lack of information on the urban ducted wind turbines since they are a fairly underdeveloped technology.

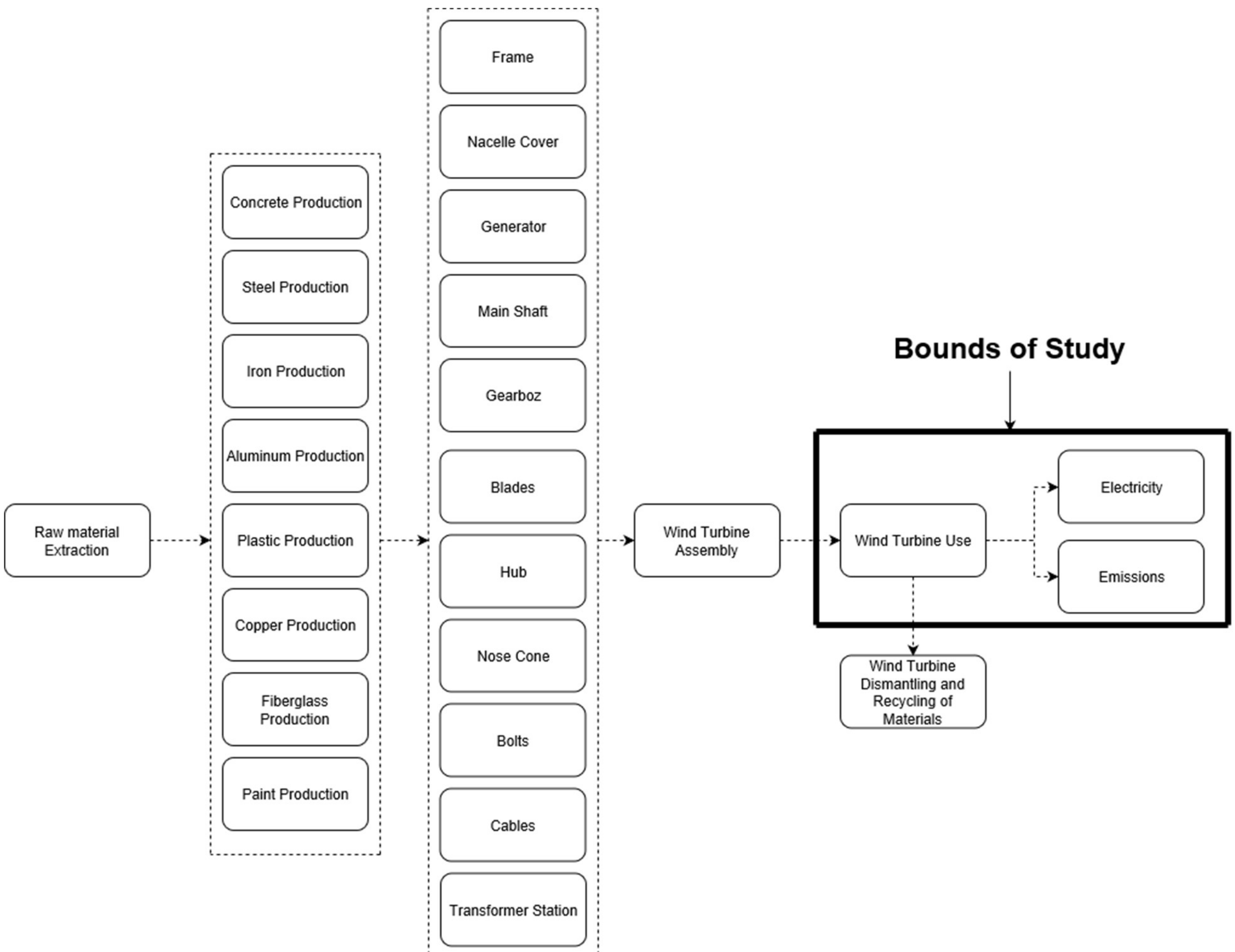

Figure 4: Map of Flows and Bounds of Study in Product Life Cycle of Wind Turbine

5. Constraints and Challenges

The Synergy Renewable Systems, LLC conducted a wind site assessment for the Juda School in 2012, with two possible site locations and five possible models of turbines. The assessment report provides some very useful data including estimated wind speed, possible range of construction cost and possible energy output. However, some important information is missing in order to go through the sustainability assessment.

5.1. Technical

The cost of new wind turbine project consists of the cost of wind turbine, balance of systems costs, the construction fee, and operations and maintenance costs. The Synergy Renewable System (Synergy Renewable Systems, LLC, 2012) said that a potential for subsoil limestone rock exist on site, which may affect the excavation costs and/or foundation requirements. Because of limited expertise regarding the construction of wind turbines, generalized costs found in literature will need to be used which may bring additional error into the analysis.

The wind electricity generated from the turbine can be connected to the energy grid of the Alliant Energy to either send extra electricity to the company or store the electricity in the grid for further use. However, according to Mr. Anderson from Juda School, it was not feasible for them to send electricity back to the grid from the solar panels which the Juda School constructed earlier, due to unknown technical issues with the electricity panel or other transform equipment. Further investigation on the grid system might be needed in order to know if similar problem would happen to the potential wind turbine sets.

5.2. Social

Potential wind farms have already raised concerns among the residents of Green County. The plan to install more than two dozen wind turbines near the town of Juda has not yet been approved by county officials, but several town meetings have been held to discuss the potential project. “My initial reaction was disappointment,” said a local resident, who lives along a stretch of farmland. “You look out your window and instead of seeing a beautiful horizon, sunrise and sunset, you're going to see windmills (Duxter, 2018).” In addition, the Juda public is a K-12 school which contains children from year six to eighteen. As the assessment report suggests, constructing a 80 or 100 feet wind turbine in the school area might cause concerns to children safety in the community. There are also several residential houses within the 500-ft range of the possible turbine sites. These mixed reactions often come with large scale projects such as this one, so more town meetings and conversation will be needed to assess the social value of the wind turbine for the community.

5.3.Economic

The Juda School is looking to reduce its energy cost. In order to achieve this, they made a goal of 10% renewable energy coverage rate and installed solar panels in year 2015 to 2016. In the summer of 2017, the school replaced old incandescent lights and AC system with more energy saving LED lights and new ACs. Although the overall trend is decreasing, as seen in Figure 5 and 6, the School's electricity bills and usages have large fluctuations year by year and makes it difficult to assess the actual contribution of each method. To estimate the potential amount of economic saving due to sustainable energy from the past data, more electricity bill documents are needed for more accurate analysis; in addition, incentives like tax breaks and credits, and electricity charge by peak time differences need to be considered as well.

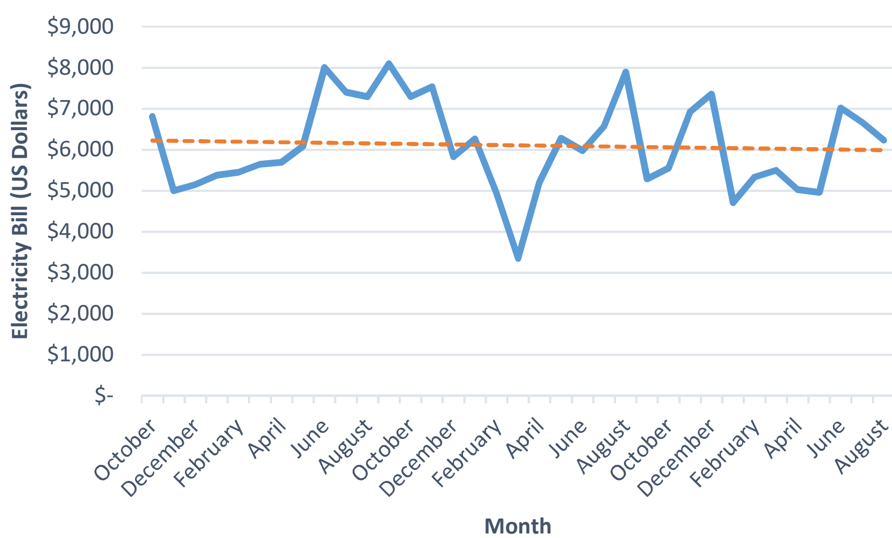

Figure 5: Electricity Bill from October 2015-August 2018 of Juda School District

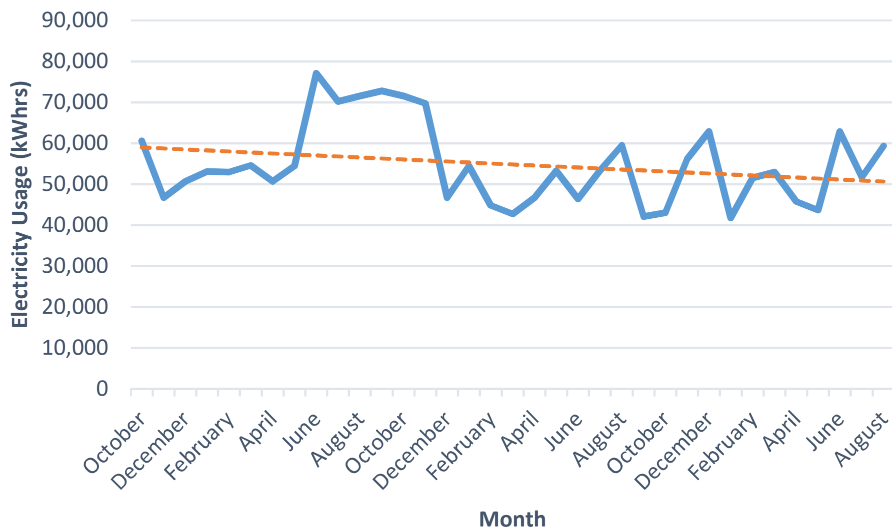

Figure 6: Electricity Usage for October 2015-August 2018 of Juda School District

6. Methods and Work Plan

6.1. Life Cycle Assessment

The basis of this project and environmental analysis is in a Life Cycle Assessment (LCA). This is a tool that is used to evaluate the environmental impact that a product or a service has throughout its life (Hicks, 2018). There are four stages in a LCA. The following are the four stages of LCA and the questions they aim to answer:

1. Goal and Scope definition
   a. What is the study trying to answer overall? What are the boundaries to the study? Is there a functional unit that can be used to compare the results?
2. Inventory Analysis
   a. What are the different inputs and outputs of the product?
3. Impact Assessment
   a. What are the impacts that these various input and output cause?
4. Interpretation

a. What do the impacts mean for the larger community? Can any conclusion be drawn from this?

6.2. System Advisor Model (SAM)

The model used for the economic analysis of this project is the System Advisor Model (SAM). Created by the National Renewable Energy Laboratory, SAM is a life cycle assessment program that makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs. The model requires system design parameters, or specified input variables (Appendix B), in order to describe the performance characteristics of the physical equipment and project costs. SAM also requires a weather data file (Appendix A) to describe the renewable energy resource and the weather conditions at the project site location. Once the input variables are completely specified, the model runs through a simulation and outputs the results. A typical involves running simulations, examining results, revising inputs, and repeating that process until there is confidence in the results.

6.3. Work Plan

The decision on whether to install a wind turbine was eventually based on the quantified numbers of different design alternatives. To quantify these numbers, many different aspects of each design option were considered. In this section, the methods used to quantify will be described in addition to the aspects that were looked at in each of the paradigms of sustainability.

6.3.1. Environmental and Economic Analysis Methods

The first step in analysis different models was to evaluate the current impacts of the energy consumption of the Juda School District. This was done by looking at the electricity bills and seeing the energy consumption listed and then converting that to the corresponding carbon dioxide emissions, which was the main greenhouse gas looked at.

For a detailed and comparative evaluation of the environmental impacts of each wind turbine, each wind turbine design alternative was run through a life cycle assessment (LCA). Since the bounds of the study were the installation and operating stage of the wind turbines, emissions, energy production and consumption, and financial costs were the main outputs from LCA, which are important sustainability indicators. To model some of these outputs, a System Advisory Model

(SAM) assessment was done. This gave the power generated and cost associated of each wind turbine based on the various inputs. The inputs can be seen in Appendix C. The inputs were based on assumptions and research done on each turbine. The assumptions for the wind energy resource, meaning the amount of wind and probability of wind, can be seen in Appendix A. The assumptions made for each turbine can be seen in Appendix B. It was then from the power generated by each wind turbine that the amount of carbon emissions saved was calculated, comparing them to the current carbon emissions of the school.

Other economic aspects were looked at such as incentives like tax breaks and credits. Also, it was determined if there would be a fee for having the wind turbine hooked up to the local electricity grid system. To compact the results, the amount of payback period for each turbine was used. Since, it was assumed that this project will be paid for with a grant, no interest rate or debt accumulation was looked at.

6.3.2. Social Analysis Methods

The final step in the assessment will be addressing the social concerns that the community may have. Juda Public School is located in town meaning many common concerns faced by those attempting to site wind projects are likely to arise. These concerns include but are not limited to excess noise, shadow flicker, bird collisions, and safety hazards like ice shedding. While these factors will not be quantified in monetary terms they will be considered and addressed in the final recommendation provided. This part of the analysis consisted of looking at the news and researching the town and community to see what they have to say about the installation of a wind turbine. This was more qualitative analysis.

7. Wind Turbine Analysis

7.1. Greenstorm GS 21 S

Figure 7: Greenstorm GS-21 Wind Turbine (Greenstorm GS 21 S)

The wind turbine GS 21 S is produced Greenstorm S.r.l., a manufacturer from Italy. The rated power of Greenstorm GS 21 S is 60 kW. The turbine's cut in wind speed is 3 m/s, and the cut-out wind speed is 25 m/s. The rotor diameter of the Greenstorm GS 21-S is 22.3 meters. The rotor area amounts to 386.7 m² and consists of a three blade design (Figure 7). The maximum rotor speed is 50.5 U/min. In the generator, Greenstorm sets to synchronous permanent. The manufacturer has used one generator for the GS 21-S. The maximum speed of the generator is 50.5 U/min. The voltage amounts to 460 V. At the mains frequency, the GS 21 S is at 50 Hz. In the construction of the tower, the manufacturer uses steel tube with paint serving as the mechanism for corrosion resistance. The power curve for this specific turbine can be seen in Figure 8 and represents the turbines output capacity for different wind speeds (Greenstorm GS 21 S, 2017).

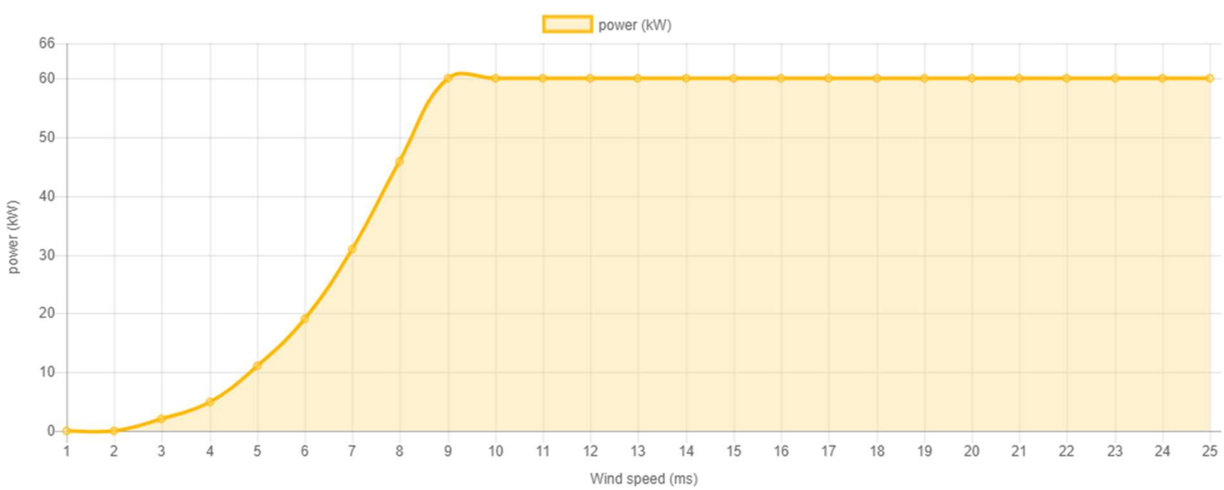

Figure 8: Greenstorm GS-21 Wind Turbine Power Curve (Greenstorm GS 21 S, 2017)

7.1.1. Environmental Impact

One of the first steps in analyzing the environmental impact of this wind turbine was determining the current environmental impact of the energy consumption of the Juda School District. Table 1 shows the average energy consumption and the average carbon emissions of the Juda school district. This was found by finding the annual average all the monthly energy usage data that was provided. Table 1 also shows the conversion factor between energy consumption and carbon emission. This was found by averaging carbon emission values of coal and natural gas power plants per kilowatt-hour (Sovacool, 2008).

Table 1: Average Energy Consumption and Carbon Emissions of Juda School District

AVERAGE ENERGY CONSUMPTION:	664,053	*kWh*
CARBON EMISSION PER KWH OF ENERGY USED:	818	gCO_2e/kWh
AVERAGE CARBON EMISSIONS:	542,974,497	gCO_2e

From the SAM assessment done, the energy production throughout the life of the wind turbine was obtained, which can be seen in Figure 9. The average energy consumption of the Juda School District from 2016-2018 is also shown for comparison.

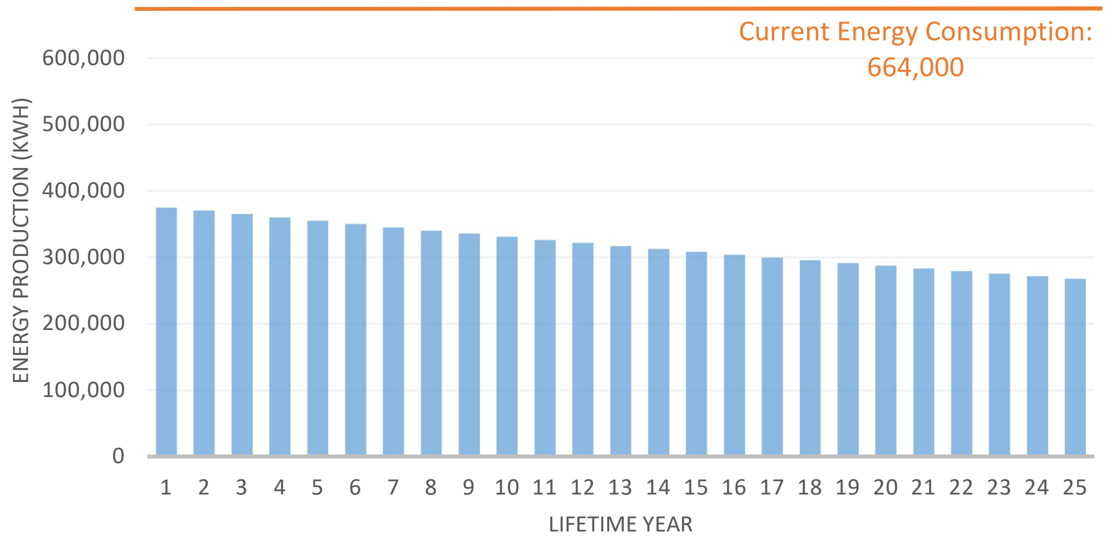

Figure 9: Energy production over lifetime of Greenstorm GS 21 S

In Figure 10 the net carbon emissions with wind energy is shown. This was done by subtracting the carbon emissions saved from the wind energy production from the total current emissions of the Juda School District. Table 2 also shows the percent of carbon emissions saved by using energy for each year of the lifetime use of the wind turbine. The gradual decrease in emission reduction can be attributed to the gradual degradation of the equipment over the project lifetime.

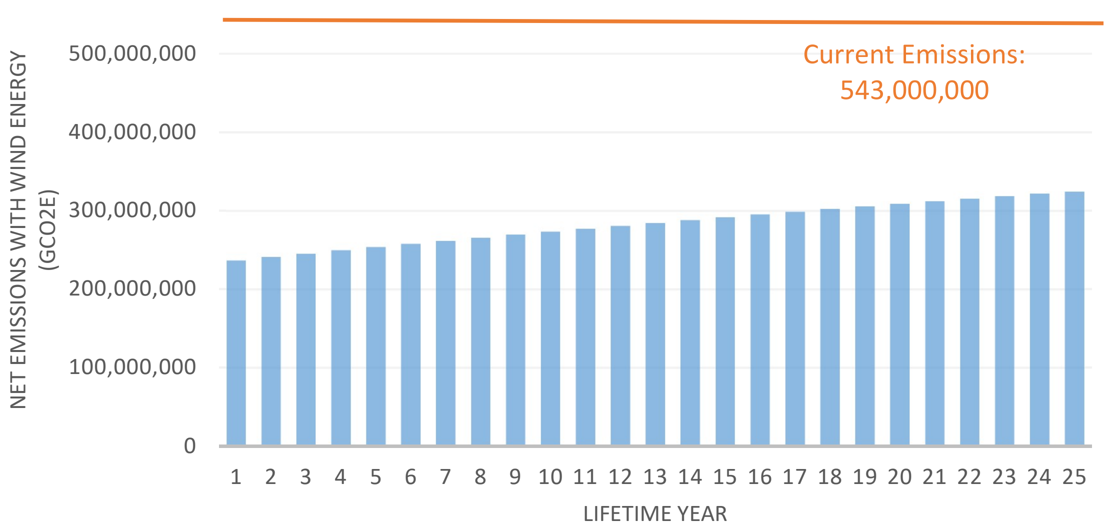

Figure 10: Net emissions over lifetime of Greenstorm GS 21 S

Table 2: Percent of Carbon Emissions Saved with Wind Energy for Greenstorm GS 21 S

Year	*Energy Production (kWh)*	*Carbon Dioxide Emissions Saved with Wind Energy (gCO_2)*	*Net Emissions with Wind Energy (gCO_2)*	*Percent of Carbon Emissions Saved with Wind Energy*
1	311,938	255,061,409	287,913,088	47%
2	307,571	251,490,657	291,483,840	46%
3	303,265	247,969,783	295,004,714	46%
4	299,019	244,497,969	298,476,528	45%
5	294,833	241,075,215	301,899,282	44%
6	290,706	237,700,703	305,273,794	44%
7	286,636	234,372,798	308,601,699	43%
8	282,623	231,091,501	311,882,996	43%
9	278,666	227,855,992	315,118,505	42%
10	274,765	224,666,273	318,308,224	41%
11	270,918	221,520,708	321,453,789	41%
12	267,125	218,419,297	324,555,200	40%
13	263,385	215,361,223	327,613,274	40%
14	259,698	212,346,485	330,628,012	39%
15	256,062	209,373,447	333,601,050	39%
16	252,477	206,442,111	336,532,386	38%
17	248,943	203,552,476	339,422,021	37%
18	245,457	200,702,089	342,272,408	37%
19	242,021	197,892,585	345,081,912	36%
20	238,633	195,122,329	347,852,168	36%
21	235,292	192,390,504	350,583,993	35%
22	231,998	189,697,109	353,277,388	35%
23	228,750	187,041,326	355,933,171	34%
24	225,547	184,422,339	358,552,158	34%
25	222,390	181,840,964	361,133,533	33%

7.1.2. Economic Impact

Table 3: Economic Impacts of Greenstorm GS 21 S obtained from SAM

Metric	Value
Annual energy (year 1)	311,938 kWh
Capacity factor (year 1)	55.6%
Levelized COE (nominal)	5.84 cents/kWh
Levelized COE (real)	4.38 cents/kWh
Electricity bill without system (year 1)	$ 47,276
Electricity bill with system (year 1)	$ 28,772
Net savings with system (year 1)	$ 18,772
Net present value	$ 102,841
Simple Payback period	12.7 years
Discounted payback period	15 years
Net capital cost	$ 224,350

The results of the economic sustainability analysis for the Greenstorm GS 21 S were generated using the SAM modeling software. A summary of important economic considerations is contained within Table 3. The most notable factors from this table are the net present value and the payback period. The results showed that the turbine can be expected to produce an economic benefit to the school after 12.7 years if discounting is not applied, or 15 years if discounting is considered. This specific system would cut the schools electricity bill nearly in half upon connection allowing the school to allocate those funds to different places given that the turbine is funded through grant money or another means that doesn't produce debt for the school.

7.2. Endurance E4660

Figure 12: Endurance E-4660 Wind Turbine

The Endurance E-4660 (Figure 11) is a three bladed turbine with a 23.5 meter diameter rotor produced by Endurance Energy Mftg Ltd from the United Kingdom. The rated power of Endurance E-4660 is 85 kW. The wind turbine's cut in speed is 4 m/s, and the cut-out wind speed is 25 m/s. The rotor area amounts to 434 m². The maximum rotor speed is 33 U/min. The generator used in the E4660 operates via induction and produces an output voltage is three phase 400 VAC at a frequency of 50 Hz. The generator is supported in the air by Free Standing Monopole. The entire exterior is painted to prevent corrosion over time. The power curve for this turbine can be seen below in Figure 12 and represents the expected rating at different wind speeds.

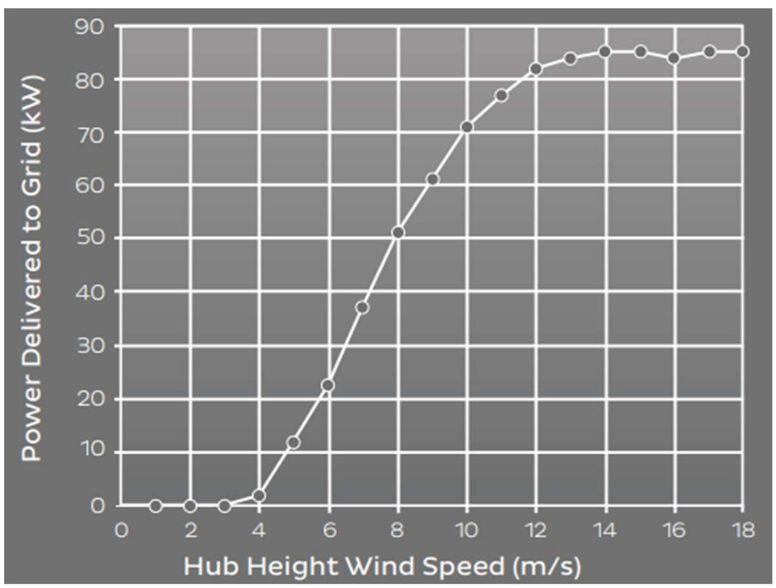

Figure 11: Endurance E4660 Turbine Wind Power Curve

7.2.1. Environmental Impact

The environmental impact for the Endurance E4660 wind machine was calculated using the same method as described in section 7.1.1. The yearly expected energy production (Figure 13) was used to generate the net yearly emissions shown in figure 14. The energy production and emissions saving generated by the E4660 are greater than the GS 21 S which is expected due to this machines higher rated capacity.

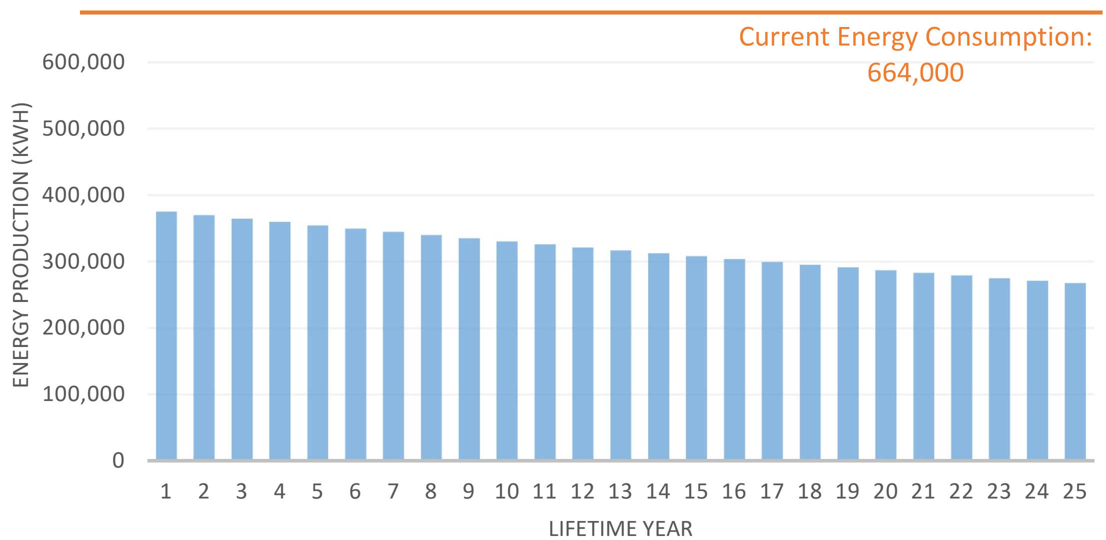

Figure 13: Endurance E4660 Energy Production over Lifetime

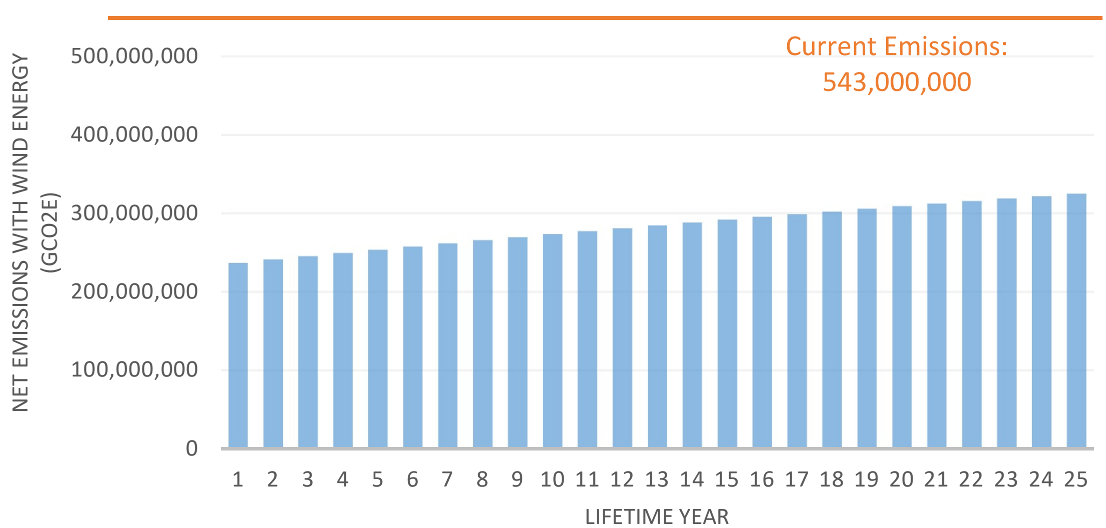

Figure 14: Net Emissions with Endurance E6440 over Lifetime

Table 4 is a reference of the expected yearly carbon savings expected for the Endurance E4660 based on the annual energy production predicted by the SAM model. A year one savings of 56% of gCO_2e shows that this option has the potential to greatly reduce the schools carbon footprint.

Table 4: Percent of Carbon Emissions Saved with Wind Energy with Endurance E4660

Year	***Energy Production (kWh)***	***Carbon Dioxide Emissions Saved with Wind Energy (gCO_2)***	***Net Emissions with Wind Energy (gCO_2)***	***Percent of Carbon Emissions Saved with Wind Energy***
1	375006	306,630,031	236,344,466	56%
2	369756	302,337,279	240,637,218	56%
3	364579	298,104,217	244,870,280	55%
4	359475	293,930,845	249,043,652	54%
5	354443	289,816,344	253,158,152	53%
6	349481	285,759,081	257,215,416	53%
7	344588	281,758,236	261,216,261	52%
8	339764	277,813,811	265,160,686	51%
9	335007	273,924,169	269,050,328	50%
10	330317	270,089,310	272,885,186	50%
11	325692	266,307,601	276,666,896	49%
12	321133	262,579,857	280,394,640	48%
13	316637	258,903,626	284,070,871	48%
14	312204	255,278,908	287,695,589	47%
15	307833	251,704,886	291,269,611	46%
16	303523	248,180,741	294,793,756	46%
17	299274	244,706,474	298,268,023	45%
18	295084	241,280,449	301,694,048	44%
19	290953	237,902,667	305,071,830	44%
20	286880	234,572,309	308,402,188	43%
21	282863	231,287,741	311,686,756	43%
22	278903	228,049,779	314,924,718	42%
23	274999	224,857,607	318,116,890	41%
24	271149	221,709,589	321,264,908	41%
25	267353	218,605,725	324,368,771	40%

7.2.2. Economic Impact

Table 5: Economic Impacts of Endurance E4660 obtained from SAM

Metric	Value
Annual energy (year 1)	374,836 kWh
Capacity factor (year 1)	49.9%
Levelized COE (nominal)	6.62 cents/kWh
Levelized COE (real)	4.96 cents/kWh
Electricity bill without system (year 1)	$ 47,276
Electricity bill with system (year 1)	$ 24,719
Net savings with system (year 1)	$ 22,557
Net present value	$ 77,264
Simple Payback period	14.8 years
Discounted payback period	18.0 years
Net capital cost	$ 300,300
Equity	$ 300,300
Debt	$ 0

The results of the economic sustainability analysis for the Endurace E4660 were generated using the same SAM model as discussed for the GS 21 S with the applicable changes made to make it relevant to this turbine. A summary of important economic considerations is contained within Table 5. The results showed that the turbine can be expected to produce an economic benefit to the school after 14.8 years if discounting is not applied, or 18 years if discounting is considered. The net capital cost for this option is significantly higher than the GS 21 S; however, the model produced an LCOE just under $0.05 per kWh which is cheaper than the price paid for electricity by the school during peak periods. The $77,200 net present value of this technology also suggests that the investment is worthwhile given the input parameters for the model.

7.3. Northern Power NPS 100C-24

Figure 15: Northern Power NPS 100C-24

An early player in the small wind turbine sector based in the United States, Northern Power has been providing turbines for distributed use since 1974. The NPS 100C-24 (Figure 15) is a 3 blade system with a rotor diameter of 24.2 m. The rated capacity at 13 m/s wind speed is 100 kW. The cut in speed for this machine is 3 m/s and the cutout speed is 25 m/s. The generator operates via direct drive meaning there is no gearbox. The generator itself uses synchronous permanent magnets that generate an output voltage of 400 V at a frequency of 50 Hz. The generator and rotor are supported by a freestanding monopole. The system is painted for corrosion resistance. The power curve for this turbine is shown below in Figure 16 representing the output that can be expected for different wind speeds.

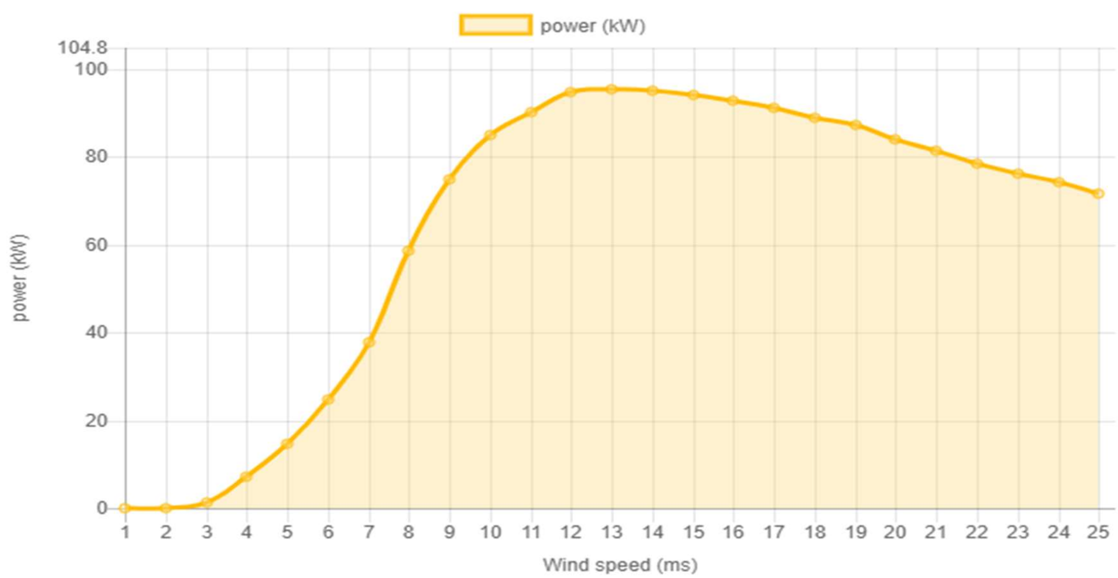

Figure 16: Wind power curve for Northern Power NPS 100C-24 Turbine

7.3.1. Environmental Impact

The environmental impact for the Northern Power Systems 100C-24 wind machine was calculated using the same method as described in section 7.1.1. The yearly expected energy production (Figure 17) was used to generate the net yearly emissions shown in figure 18. The energy production and emissions saving generated by the NPS 100C-24 are greater than the GS 21 S but nearly the same as the E4660. This turbine has the largest rated capacity meaning it should have the greatest environmental benefit; however, the wind resource is too weak to allow this machine to operate in efficient ranges.

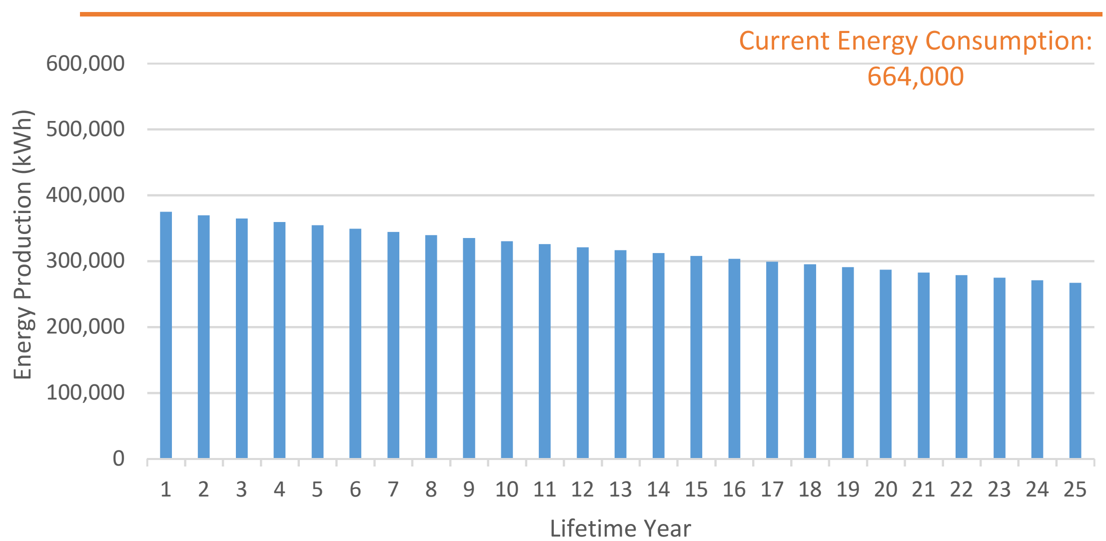

Figure 17: Energy production of NPS 100C-24 over lifetime

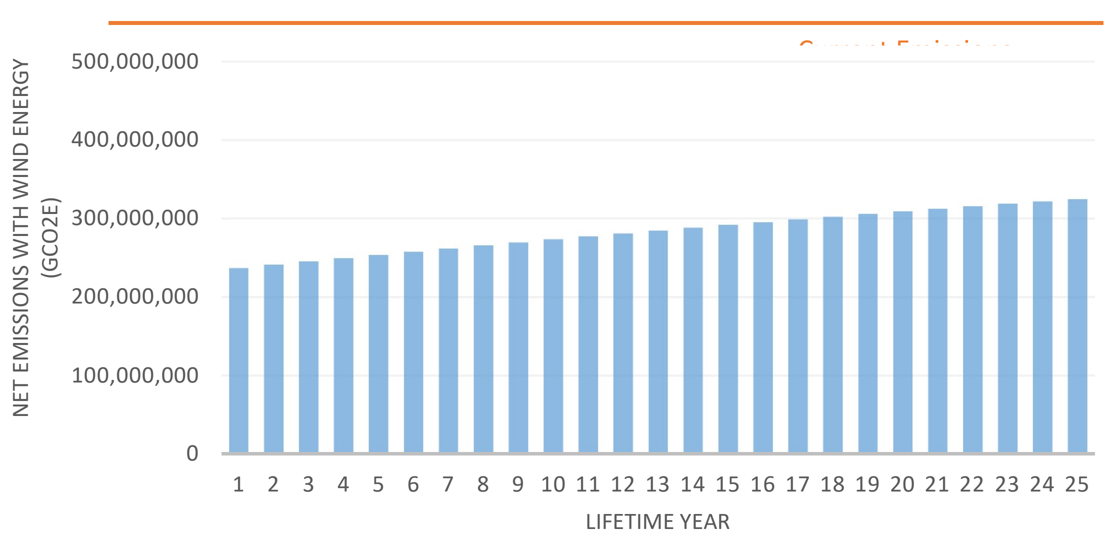

Figure 18: Net emissions with NPS 100C-24 over lifetime

Table 6 is a reference of the expected yearly carbon savings expected for the NPS 100C-24 based on the annual energy production predicted by the SAM model. A year one savings of 56% of gCO_2e shows that this option has the potential to greatly reduce the schools carbon footprint. When compared to table 4 it is noticeable that the results are very similar despite the NPS 100C-24 having an additional 15 kW of rated capacity.

Table 6: Percent of Carbon Emissions Saved with Wind Energy from NPS 100C-24

Year	***Energy Production (kWh)***	***Carbon Dioxide Emissions Saved with Wind Energy (gCO_2)***	***Net Emissions with Wind Energy (gCO_2)***	***Percent of Carbon Emissions Saved with Wind Energy***
1	374,836	306,491,028	236,483,469	56%
2	369,588	302,199,911	240,774,586	56%
3	364,414	297,969,302	245,005,195	55%
4	359,312	293,797,565	249,176,932	54%
5	354,282	289,684,700	253,289,797	53%
6	349,322	285,629,072	257,345,425	53%
7	344,431	281,629,862	261,344,634	52%
8	339,609	277,687,072	265,287,425	51%
9	334,855	273,799,883	269,174,614	50%
10	330,167	269,966,660	273,007,837	50%
11	325,544	266,186,586	276,787,911	49%
12	320,987	262,460,477	280,514,020	48%
13	316,493	258,785,882	284,188,615	48%
14	312,062	255,162,799	287,811,698	47%
15	307,693	251,590,412	291,384,085	46%
16	303,385	248,067,903	294,906,594	46%
17	299,138	244,595,271	298,379,226	45%
18	294,950	241,170,882	301,803,615	44%
19	290,821	237,794,735	305,179,762	44%
20	286,749	234,465,195	308,509,302	43%
21	282,735	231,183,079	311,791,418	43%
22	278,777	227,946,753	315,027,744	42%
23	274,874	224,755,399	318,219,098	41%
24	271,025	221,608,199	321,366,298	41%
25	267,231	218,505,970	324,468,527	40%

7.3.2. Economic Impact

Table 7: Economic Impacts of NPS 100C-24 obtained from SAM

Metric	Value
Annual energy (year 1)	388,300 kWh
Capacity factor (year 1)	46.4%
Levelized COE (nominal)	7.15 cents/kWh
Levelized COE (real)	5.36 cents/kWh
Electricity bill without system (year 1)	$ 47,276
Electricity bill with system (year 1)	$ 23,909
Net savings with system (year 1)	$ 23,367
Net present value	$ 47,378
Simple Payback period	16.3 years
Discounted payback period	20.4 years
Net capital cost	$ 334,250
Equity	$ 334,250
Debt	$ 0

The results of the economic sustainability analysis for the NPS 100C-24 were generated entirely using the SAM model previously discussed for the GS 21 S, and the E4660 with the applicable input changes made to make it fit this turbine. A summary of important economic considerations is contained within Table 7. The results showed that the turbine can be expected to produce an economic benefit to the school after 16.3 years if discounting is not applied, or 20.4 years if discounting is considered. This payback period is the longest of the three designs modeled in this analysis. This turbine produced the lowest capacity factor which ultimately caused the lowest net present value. The NPS 100C-24 does provide the largest expected energy generation producing the biggest decrease in energy cost for the school. This could be considered a positive attribute if the primary goal is to reduce the total cost of electricity.

7.4.Social Impact

The social impacts for all three turbine designs can be assumed the same since all three turbines have similar size characteristics. The primary concern relates to the overall safety of the installation. Ice shedding in the winter would be the primary concern considering the turbines would be installed in the schools recreation area. A fenced off buffer zone around the turbine is recommended to reduce the risk of ice falling on anyone in the area. School personnel supervising outside activities should also be trained to observe the tower and identify potential dangers in the event of high wind days.

Juda School is located within town, making shadow flicker a concern. With the school located directly east of the potential installation locations, shadow flicker would only affect local residents in the morning hours. Those living along Jordan St, Meadow Ln, and Summit Dr are the most likely to be affected. Because the afternoon shadow flicker projected upon the school would be after school hours for the majority of the year, it is not expected that this impact would affect class instruction.

The impact of noise generated by all three turbine designs is determined to be negligible. At a distance of 100 ft from these turbines, the expected sound level is around 50 dBA. A car driving by at a similar distance produces approximately 80 dBA and a refrigerator typically produces 40 dBA. The noise generated by the discussed turbines would more likely than not go unnoticed by both school users and community members.

8. Discussion of Results

Table 8: Comparison of all three wind turbine models

	Economic Parameters								Environmental Parameters			
	Year 1 Energy Production [kWh]	Year 1 Capacity Factor [%]	Levelized COE [cents/kWh]	Year 1 Net Savings [$]	Net Present Value [$]	Simple Payback Period [years]	Discounted Payback Period [years]	Net Capital Cost [$]	Year 1 Emissions without system [gCO_2e]	Year 1 avoided emissions [gCO_2e]	Year 1 Net Emissions [gCO2e]	Percent Decrease [%]
Greenstorm GS 21 S	311,938	55.6%	4.38	$18,773	$102,841	12.7	15	$224,350	542,974,497	255,061,409	287,913,088	47%
Endurance E4660	374,836	49.9%	4.96	$22,557	$77,264	14.8	18	$300,300	542,974,497	306,630,031	236,344,466	56%
NPS 100C-24	388,300	46.4%	5.36	$23,367	$47,378	16.3	20.4	$334,250	542,974,497	306,491,028	236,483,469	56%

In year 1, the Northern Power 100C-24 (100kW) turbine has the highest annual energy generation of 388,300 kilowatt-hours, which is *24.5%* higher than the lowest Greenstorm GS 21.5 (60kW).

This turbine has the highest net savings on the electricity bill in year one of $23,367. Because the NPS 100C-24 would produce the most energy it would also produce the biggest savings to the environment. NPS turbine could help save 56% of the current Greenhouse Gas emission. However, this is also the most expensive turbine, with a net capital cost of $334,250 and the longest simple payback period of 16.3 years. The result is that NPS 100C-24 turbine has the highest energy production cost rate of 5.36 cents/kWh, through the 25-year lifetime period, as well as the lowest net present value. If maximizing energy production is the main goal, this turbine would be a favorable option. Another consideration stems from the fact that this is the only turbine studied that is manufactured in the United States which could results in easier acquisition compared to the other turbines studied.

The Endurance E4660 (85kW) turbine has the second highest annual energy generation of 374,836 kilowatt-hours, which is *20.16%* higher than the lowest turbine, and only *3.47*% lower than the NPS. The first year net saving of this turbine is still high, $22,557. E4660 has a net capital cost of $300,300, 10% lower than the NPS, and a simple payback period of 14.8 years, 1.5 years shorter than the NPS, which are both the second highest among the three turbines. Because of the similar energy production, E4660 has an approximately same GHG emission reduction rate, 56%, as the highest NPS turbine. This turbine has the most cost-effective value between economics and environmental impact among the three, and is the best choice if client would like to spend a little more money on the turbine.

The Greenstorm 21 S (60Kw) has the smallest rated capacity among the three turbines, but the efficiency of this device is greater than the other two options. It is expected to produce the lowest first year energy at 311,938 kWh, and reduce GHG emissions the least at about 47%, comparing to the 56% of other two turbines. However, GS 21 S is the cheapest to install and operate. The net capital cost is the lowest $224,350, which is *32.9%* lower than the highest NPS turbine and *25.3%* lower than the E4660; the simple payback period is also the shortest with a 12.7-year. The LCOE calculated with the SAM model shows that this turbine produces energy at the lowest cost per kWh. Greenstorm's GS 21 S is a favorable choice if the ultimate goal is to produce electricity at the lowest possible cost.

When generating the models used to evaluate each turbine, the specified power curve for a given technology had the largest impact on the final results. The wind resource at the specified location behind Juda School is relatively weak considering most turbines rated capacity is measured at a wind speed of 13 m/s. The average wind speed at Juda was assumed to be 7 m/s based on wind resource map provided by NREL. Given careful consideration of this fact, a maximum capacity factor of 55.6% for the GS 21 S was achieved. This system is optimized for performance in low wind speeds. The other two turbines studied were also selected based on a favorable power curve yet produced a significantly lower capacity factor than the GS 21 S. When selecting a turbine for this application, the technologies effectiveness for the specific site conditions must be considered.

Although Endurance E4660 has the most cost-effective value between economics and environmental impact, Greenstorm GS 21 S (60kW) with the affordable initial cost is the most suitable type of turbine, based on the current financial condition of Juda public School.

9. Conclusion

Based on economic payback period, environmental impact, and power generation, three wind turbines that produced power at different rates were compared. Using a consistent design, the three cases were analyzed by using the life cycle assessment. In addition to economic and environmental aspects, the social impacts of wind turbines on the local area were also analyzed to provide a holistic view of the three major paradigms of sustainability. Based on the analysis of results, the model shows considerable improvements in these aspects and the potential for the application of wind turbines in the Juda school community.

In the future, to enhance the practicality of the life cycle assessment model, the accuracy of the analysis results can be improved by increasing the diversity of the wind data and various economic trends in order to make the simulation process more complete.

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Appendix

Appendix A: Wind Energy Resource Assumptions

Average Annual Wind Speed: The average wind speed found in the Green County area from the NREL Wind Resource Map.

Reference height for wind speed: The height at which the wind speed is measured.

Weibull K Factor: This is the probability of the average wind speed to occur. This is a common assumption made when evaluating wind speed.

Table 9: Assumptions made

Average Annual Wind Speed	7 m/s
Reference height for wind speed	30 m
Weibull K Factor	2.5

Appendix B: Turbine System Assumptions

Rated Output: The maximum power that is typically achieved by the turbine.

Rotor Diameter: Total diameter that the turbine blades cover while spinning.

Hub Height: The distance from the turbine platform to the rotor. Indicates how high the turbine stands above the ground, not including the length of the turbine blades.

Shear Coefficient: Measure of the variation of wind speed with height above the ground, at the turbine installation site.

System Sizing: The number of turbines.

Turbine Losses and Wake Effect: Influence on energy production of a turbine, which results from changes in wind speed caused by the impact of adjacent turbines on each other.

System Degradation Rate: In terms of power generation, the decreasing rate of energy produced by a wind turbine over its lifetime. The degradation rate applies to the system's total annual kWh output for the previous year starting in year 2

Analysis Period: The number of years analyzed in LCA for the turbine lifetime.

Green Storm 60 kW 22.3m	
Rated Output	64.1 kW
Rotor Diameter	22.3 m
Hub Height	40 m
Shear Coefficient	0.15
System Sizing	1 Turbine
Turbine Losses and Wake Effect	0%
System Degradation Rate	1.4%/year
Analysis Period	25 years

Northern Power 100-24	
Rated Output	95.5 kW
Rotor Diameter	24 m
Hub Height	40 m
Shear Coefficient	0.15
System Sizing	1 Turbine
Turbine Losses and Wake Effect	0%
System Degradation Rate	1.4%/year
Analysis Period	25 years

Endurance E4660 85kW 23.5m	
Rated Output	85.8 kW
Rotor Diameter	23 m
Hub Height	40 m
Shear Coefficient	0.15
System Sizing	1 Turbine
Turbine Losses and Wake Effect	0%
System Degradation Rate	1.4%/year
Analysis Period	25 years

Appendix C: Economic Inputs

Sales tax rate: Consumption tax rate imposed by the government on the sale of goods and services to the end-users.

Inflation Rate: The rate at which currency loses its value according to time compared with a standard group of products called consumer price index (CPI).

Normal Discount Rate: The interest rate used in discounted cash flow analysis to determine the present value of future cash flows.

Total Installed Cost: The total cost for the wind turbine installation.

Total Installed Cost per kilowatt: Total installation cost for wind turbine divided by the number of electricity unit [kW].

Weight average cost of capital: The minimum return rate that a company must earn on an existing investment to satisfy its providers of capital, or they will invest elsewhere.

M&O fixed cost by capacity: Annual maintenance and operations cost.

Federal Investment Tax Credit: Amount reduced in the total cost of renewable energy (wind) system by a certain percent with a credit to the federal taxes.

Sell rate for kWh credits remaining: Annual rate for any unused net metering credits.

Annual electricity bill escalation rate: Rate of how electricity cost has risen each year.

Green Storm 60 kW 22.3m	
Capital Costs	
Sales tax rate	5%
Inflation Rate	2.5%/year
Normal Discount Rate	2.5%/year

Total installed cost	$ 224,350.00
Total installed cost per kilowatt	$ 3,500.00/kW
Weight average cost of capital	2.50%
Operation & Maintenance Costs	
Fixed Cost by capacity	$ 37/kW-year
Incentives	
Federal Investment Tax Credit ($200/kW)	$ 20,000.00
Net Energy Metering and Billing	
Sell rate for kWh credits remaining at end of year	$ 0.02/kWh
Annual electricity bill escalation rate	0.1%/year

Northern Power 100-24	
Capital Costs	
Sales tax rate	5%
Inflation Rate	2.5%/year
Normal Discount Rate	2.5%/year
Total installed cost	$ 334,250.00
Total installed cost per kilowatt	$ 3,500.00/kW
Weight average cost of capital	2.50%
Operation & Maintenance Costs	
Fixed Cost by capacity	$ 37/kW-year
Incentives	
Federal Investment Tax Credit ($200/kW)	$ 20,000.00
Net Energy Metering and Billing	

Sell rate for kWh credits remaining at end of year	$ 0.02/kWh
Annual electricity bill escalation rate	0.1%/year

Endurance E4660 85kW 23.5m	
Capital Costs	
Sales tax rate	5%
Inflation Rate	2.5%/year
Normal Discount Rate	2.5%/year
Total installed cost	$ 334,250.00
Total installed cost per kilowatt	$ 3,500.00/kW
Weight average cost of capital	2.50%
Operation & Maintenance Costs	
Fixed Cost by capacity	$ 37/kW-year
Incentives	
Federal Investment Tax Credit ($200/kW)	$ 20,000.00
Net Energy Metering and Billing	
Sell rate for kWh credits remaining at end of year	$ 0.02/kWh
Annual electricity bill escalation rate	0.1%/year

About UniverCity Year

UniverCity Year is a three-phase partnership between UW-Madison and one community in Wisconsin. The concept is simple. The community partner identifies projects that would benefit from UW-Madison expertise. Faculty from across the university incorporate these projects into their courses, and UniverCity Year staff provide administrative support to ensure the collaboration's success. The results are powerful. Partners receive big ideas and feasible recommendations that spark momentum towards a more sustainable, livable, and resilient future. Join us as we create better places together.

GREEN COUNTY WISCONSIN

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