2018-2019

FINAL REPORT

UniverCity Year

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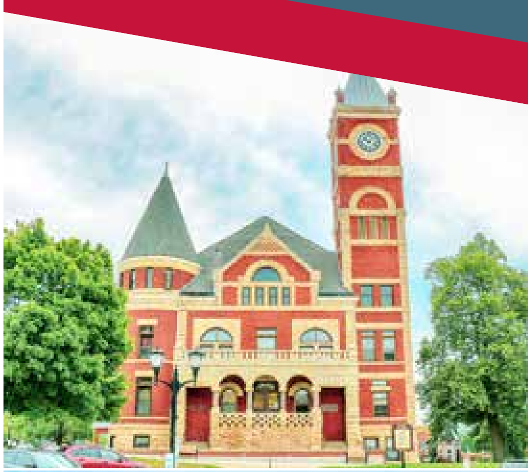
Renewable energy analysis for New Glarus School District

ENGINEERING 601: INTERDISCIPLINARY DESIGN FOR ENERGY & SUSTAINABILITY



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Executive Summary

The New Glarus School District desires to operate more sustainably, and has already made great strides in implementing energy saving methods such as new roofs, energy efficient lights, and better insulation throughout the past five years. Now, NGSD is ready to switch some of its energy sources to renewable technologies. Different renewable energy sources were analyzed for the purposes of supplementing the current energy supply to the school district. It is necessary that a new system is compatible with the current landscape, and is able to be combined with other community projects, such as the construction of a new pool, in order to ensure the town's support. The largest constraints that impact the scope of the design are budget and land area. The client gave no preference of the type of design, and only wished that the design be spatially conservative and fall within a budget of $200,000. Limiting factors also include environmental variables, such as the soil type or the average amount of sunlight and wind the area receives.

The design process consisted of brainstorming efforts followed by evaluation, categorization, and research into chosen topics. After an initial analysis, options were once again evaluated and categorized based on the potential of groups of ideas to reach the energy goal. Although there were a multitude of brainstormed ideas, notable options which were originally researched include solar hot water, geothermal, solar photovoltaic, renewable energy credits and power purchase agreements. Solar hot water was omitted for the reason that the school buildings do not use a substantial amount of water throughout the day, and therefore the resulting energy savings would be insignificant and not worth the installation cost for the system. Geothermal, while logistically viable, was disqualified because there were too many unknowns to proceed forward without spending thousands of dollars just to assess feasibility. It was an option that was

better suited for a customer who knew that they wanted to pursue geothermal as a preferred energy solution, not a curiosity-based inquiry into sustainable design. Eventually, a rooftop solar photovoltaic system was chosen, as it would best fit the constraints of the client by leaving space available for parking and further landscape development projects.

The final design provided options for different tiers of commitment for several system sizes, because of the presently unknown public and committee responses in New Glarus. Three system sizes were explored for the New Glarus Secondary School rooftop. Financing options include school district funding, available cash grants from the state and utility, or a public-private partnership. A public-private partnership would involve third party funding and ownership of the panels, but would guarantee the building of a system large enough to cover the energy needs of the school district. Otherwise, the district could finance the project and build a smaller system within the allotted budget, which could be scaled up yearly as desired. If the latter method is chosen, it is possible to enroll in a renewable energy credit purchase through WPPI, which would ensure that the energy purchased by the school district is sourced from off site renewable energy systems. Power provided from a 250 kW solar photovoltaic system would provide approximately 70% of the school district's energy load, compared to a small system (10kW) which would provide around 3%. The cost for these designs would be approximately $682,000 and $32,000 respectively, with multiple financing options presented to the district.

Problem Definition

Problem Scope

Problem Statement

The New Glarus School District has been implementing energy saving methods, such as new roofs, energy efficient lighting, and higher quality insulation during the past five years, and they are ready to switch some of their energy sources to renewable technologies. We will be exploring different renewable energy sources, such as wind and solar, and evaluating their usefulness to the school district. We will want our project to be compatible with the landscape and budget available. Additionally, the project should be easily combined with another project the community has a strong interest in, such as a pool, to ensure support. The final system should help New Glarus School District reduce its energy bills and decrease its reliance on fossil fuels.

Client Needs and Constraints

The largest constraints that impact the scope of the design are budget and land area. The client, superintendent Jennifer Thayer, gave no preference of the type of design or its aesthetics, and only wishes that the design be practical spatially and fall within an initial budget of $200,000. Limiting factors also include environmental variables, such as the amount of sunlight and wind the area receives on average.

Background/Technical Review

Design Requirements

The most crucial elements considered while formatting the solution were the minimal land area available, school district budget limitations, and energy production optimization. A design matrix, along with modeling technologies, was used to ultimately assess the viability of the options (Figure 1, Appendix). The client requested that in order to maximize land area available for other purposes, the proposed system should not take up any ground space, which immediately narrowed the project scope to rooftop options. In order to fit the requirement to be rooftop mounted, solar photovoltaic or solar hot water systems were the most viable options. Solar photovoltaic panels were chosen as the most advantageous design, because of the insignificant amount of hot water used by the school district. Calculations using System Advisor Model (SAM) and PVWatts were done in order to determine energy production optimization accounting for different placements and orientations on the roof. It was determined that south facing panels on the west half of the roof would both optimize energy and be least visible upon entering the premise of the building, alleviating any aesthetic concerns that would trigger public pushback. The final parameter was the budget limitation. This was the most difficult constraint to properly satisfy because there were a large number of unknown values that had to be considered. The exact time frame in which the changes would be implemented was not defined, which complicated the scope of the project. Because it is not known which, if any, grants could be applied to the project, a tiering system of project sizes was created to account for different scenarios. Small (10kW), medium (100kW), and large (250kW) systems were analyzed in terms of energy production and overall cost with and without potential grants and incentives applied.

Sustainability Goals and Metrics

Implementation of renewable energy in the New Glarus School District will reduce the district's carbon footprint by mitigating greenhouse gas emissions and decrease the fossil fuel dependence of the school buildings. Renewable energy is also an opportunity to better utilize the green, energy efficient engineering that is already in place at the school buildings. A facility study is currently being done at the district which is measuring the school buildings' efficiency. Ideally, this facility study could be repeated once a renewable energy system is implemented to measure the impact of the project.

In terms of social impact, investment in renewable energy for the New Glarus School District promotes the topic of sustainability in the community and will reduce resource scarcity for future generations. Having on-site energy generation will be an engaging experience for New Glarus students to learn about renewable technologies and their impacts. The social impact can be measured through student understanding of sustainability and renewable energies.

Though there will be a significant initial cost to implement renewable energy in the New Glarus School District, savings from energy bills will result in a feasible payback period and saved taxpayer dollars. A financial analysis will be done for the proposed solution to approximate cost savings and the payback period for the school district.

Design Solutions

Overview

Several renewable energy systems were explored using the aforementioned design requirements to determine whether they would be technically feasible and meet the needs outlined by the client. The focus of this study was constrained to widespread and economically proven technologies in order to ensure a safe and profitable investment for the school district. Systems that did not provide a reasonable payback period or otherwise failed to meet client constraints were eliminated from further consideration. Wind energy, although one of the most cost effective forms of renewable energy, was eliminated due to the lack of available land on school grounds. Geothermal and solar heating systems were explored more thoroughly, but both presented disadvantages that proved to be insurmountable for the scope of the project. It was determined that a rooftop mounted solar photovoltaic (PV) system would produce the most effective and economically viable design, and it could produce significant renewable energy without encroaching on current or future land holdings. Moving forward, this design was chosen for a more detailed analysis, where several system sizes and arrangements were explored.

Preliminary Design Analysis

Rejected Designs: Wind and Geothermal

After performing an initial analysis, several conventional renewable energy systems were determined to be impractical for this project due to budgetary and land constraints outlined by the client. Wind energy has drastically fallen in price over the last decade, and is generally considered one of the most cost effective renewable technologies based on levelized cost of electricity (LCOE) [1]. However, the Department of Energy recommends at least one acre of available land for the implementation of a small scale wind system [2], which New Glarus School District cannot feasibly appropriate at this time.

The use of a geothermal heat pump was also examined, with the idea subsequently rejected due to cost and land constraints. This system operates by using the earth to draw in geothermal heat during the winter or to reject heat to cool the building in the summer. Geothermal heat pumps can generally be an effective method of reducing annual heating bills, as well as greenhouse gas emissions from natural gas heating. However, after gaining input from industry personnel, it was determined that the cost of soil testing and permitting, in addition to the excessive land requirements, would make it impractical to implement this on the school district grounds. This technology was also removed from further consideration. After initial options were ruled out, the focus of research turned to more space and cost-effective technologies. It was decided that rooftop solar panels would provide a reliable energy source while only occupying unused roof area.

Roof Mounted Solar Water Heating

A solar water heating (SWH) system, where thermal energy from the sun is harvested to heat water for a building, was analyzed for the New Glarus Elementary School building. SWH systems have been implemented previously in Wisconsin, such as in the Dejope Residence Hall on the UW-Madison campus. This system works by circulating a heat transfer fluid through mounted solar panels, where thermal energy from the sun heats the fluid to a working temperature. The hot fluid is sent into a tank with a coiled heat exchanger, where a stream of domestic water is heated to a sufficient temperature to be used throughout the building (Figure 2, Appendix).

However, several key limitations made it clear that it is not currently feasible to implement solar hot water heating New Glarus schools. In addition to rooftop space, a solar water heating system would require area in the boiler room of the building for a large storage tank where heat transfer could take place. Typically for systems in colder climates such as Wisconsin, propylene glycol is chosen as the heat transfer fluid to avoid freezing [3]. Due to limited space in the boiler room, the New Glarus Secondary School was determined to have insufficient capacity to host a solar water heating system. The elementary school was studied as a potential site, as there is considerably more available space in the building. Heating bills for the past two years were obtained and used with a 2013 study on hot water draw in schools [4] to estimate the average hot water use in the elementary school in order to size the system. National Renewable Energy Laboratory (NREL) benchmarks were used to assess the cost of the system, from which annual savings and payback period could be calculated [5]. From this analysis, it was determined that the system would require 377 ft^2 of panels, and an initial investment of $22,000 to $53,000. The annual savings on the school's heating bill would amount to approximately $762, which would lead to a simple payback period of 36 to 87 years, well past the 25 year lifespan of the system. This unreasonable payback period led to the elimination of SWH as a viable system. This result was mostly due to the relatively low hot water draw for a public school. The potential savings generated even when replacing 100% of the schools hot water load are not sufficient to offset the initial investment.

Roof Mounted Solar Photovoltaic

A roof mounted solar photovoltaic (PV) system was determined to be the most effective and economical renewable energy system given the constraints of this project, and a detailed analysis of several different arrangements and system sizes was conducted in order to provide New Glarus School District with multiple viable options. PV panels utilize the photovoltaic effect to produce direct current (DC) electrical power, which can be converted into a useful alternating current (AC) form using an inverter to meet part or all of a building's electric load. An initial estimate for the potential power output that could be achieved for a rooftop system in New Glarus was determined using the PVWatts® calculator from NREL [6]. The program estimated that a rooftop PV system could generate between 66% and 70% of the electric load for New Glarus Secondary School alone. Additionally, a 2017 report from the International Renewable Energy Agency (IRENA) estimates that the LCOE of solar technologies has fallen to an average value of 10 cents per kilowatt-hour, making the technology competitive with commercial utility-scale fossil fuels [7]. These initial estimates allowed a design matrix to be completed that compares a proposed solar photovoltaic system to other designs that were explored based on the constraints and goals of the project (Figure 1). It is clear from the results of the initial steps in the design process that solar PV panels offer the most advantageous pathway to establishing an on-site renewable energy system in New Glarus School District.

Final Design Solution

Once the focus of this study was narrowed to a rooftop solar photovoltaic (PV) system, the arrangement and location of the equipment had to be determined based on optimizing energy output and aesthetic appeal while minimizing overall cost. Due to the stipulated budget of $200,000, it was prudent to focus on one viable rooftop for this study. The Secondary School rooftop was chosen because of of its large amount of space, lack of shading, and relatively constant roof angle (Figure 3, Appendix). These calculations could also be done on the elementary school, but different effects should be considered, such as the large pine trees shading the roof.

The power output of a PV system is highly dependent on the insolation, or amount of solar radiation reaching the panels, at the location of interest. This value can vary depending on geography, climate, and the arrangement of the solar panels. For locations in the Northern Hemisphere, southern-facing panels produce the highest annual electricity output. However, the Secondary School rooftop is oriented east-west facing, so south facing panels would have to be aligned against the natural angle of the roof, in a “sawtooth” configuration (Figure 4, Appendix). PVWatts® was again used to calculate rough estimates for the energy production of different panel arrangements. A new design matrix was constructed comparing several designs on the basis of energy output, aesthetics, and cost (Figure 5). Utilizing south-facing panels on both sides of the rooftop was found to be most advantageous due to the increased energy output, which overshadowed aesthetic concerns. The client Jennifer Thayer confirmed that the "sawtooth" arrangement would be acceptable. A panel tilt angle equivalent to latitude (42.8°) was chosen due to the abundance of solar insolation data available under this situation, which would lead to more accurate results.

After determining a final rooftop photovoltaic design, the energy output of the system had to be determined relative to the electricity load at New Glarus Secondary School in order to properly size equipment and determine technical and economic projections. Average monthly and annual electricity consumption for New Glarus Secondary School was collected from utility bills provided by the client (Figure 6). The school was found to have an average annual load of 545,184 kWh, which corresponds to a monthly average of 45,432 kWh. A solar insolation chart produced from NREL data (Figure 7) was used to determine the average daily insolation that the Secondary School rooftop receives. This value corresponds to the hourly equivalent of peak solar radiation that reaches the location in a day. New Glarus is estimated to receive approximately 4 hours of "peak sunlight" each day. This value was used with the electricity load to determine the required size of a rooftop PV system. A system generating approximately 370 kW of AC power (after losses) was determined to be sufficient to meet the entirety of New Glarus Secondary School's annual electric needs. This figure provided a reasonable starting point for a more detailed analysis, which could factor in space and cost restraints.

System Modeling and Evaluation

Overview

Using previously determined design parameters, detailed technical and financial projections were produced for several different rooftop photovoltaic systems that could be constructed on the roof of New Glarus Secondary School. Three different system sizes were modeled with different power outputs and financial outlooks in order to give the client several viable options, with the intent for one to be chosen depending on the level of commitment that New Glarus would be willing to make for the project. For each system, annual power outputs were calculated over a 25 year lifespan, and used with utility data to determine the percentage of the school's electricity that would be satisfied. Using utility supplied and literature values for costs and electricity pricing, a detailed financial projection was also made for each system which could be used to assess the viability of each investment. Financial incentives available from the state and local utility were also explored to potentially remove some of the upfront cost burden from the school district.

Modeling Analysis

Methodology

Technical and economic projections were produced for each photovoltaic system using the System Advisor Model (SAM) from the National Renewable Energy Laboratory (NREL) [9]. This software uses geographic and technical data from NREL in conjunction with user-defined inputs in order to estimate energy outputs and economic projections for a specific renewable energy project. It is critical to determine reasonable values and assumptions to input into the program in order to maximize the accuracy of the projections, as small changes to certain parameters can dramatically impact the final result. A full summary of assumptions and inputs for each system can be found tabulated in the Appendix (Figures 8 and 9). Information on the modules and inverter for each system was determined using model equipment found in the NREL database, which provided detailed voltages and efficiency curves. Each system utilized SunPower SPR-E18-305-COM photovoltaic modules with 18.7% efficiency, as these are commercially available and recommended for space-limited projects [10]. A single central inverter was used with data modeled by equipment from Ingeteam Energy which offered inverters at rated AC power outputs consistent with all system sizes [11]. PV panels were arranged south facing at latitude tilt. Default losses were assumed to occur due to self-shading, annual degradation (0.5% per year), and typical central inverter losses supplied by the SAM program. With this information, technical projections over the lifespan of three photovoltaic systems could be determined, and an initial design could be proposed.

System 1: 250 kW

The largest system analyzed was sized at 250 kW of AC power generation, which would account for approximately 70% of New Glarus Secondary School's annual electricity load. This system would require 6 rows of 5 x 30 module panels, with total surface area of approximately 245 m^2 (about 2638 square feet) each. The spacing between each row was determined by SAM to be 27.8 m (91.2 feet) to minimize self-shading, with 3 rows on each side of the Secondary School roof (Figure 10).

System 2: 100 kW

The next system was sized at 100 kW of AC power generation, which would account for approximately 27% of New Glarus Secondary School's annual electricity load. This system would require 6 rows of 3 x 20 module panels, with total surface area of approximately 97.8 m^2

(1053 square feet) each. The spacing between each row was determined by SAM to be 16.7 m (54.8 feet) to minimize self-shading, with 3 rows on each side of the Secondary School roof (Figure 11).

System 3: 10 kW

The smallest system was sized at 10 kW of AC power generation, which would account for approximately 3% of New Glarus Secondary School's annual electricity load. This system would require 4 rows of 2 x 5 module panels, with total surface area of approximately 16.3 m^2 (146.4 square feet) each. The spacing between each row was determined by SAM to be 11.1 m (36.4 feet) to minimize self-shading, with 2 rows on each side of the Secondary School roof (Figure 12).

Available Financial Incentives

Prior to producing economic models in SAM, financial incentives available from the state government and local utilities were explored in an attempt to mitigate some of the upfront cost the school district would be required to take on for each project. This was especially crucial as the district would be unable to take advantage of the typical 30% federal tax credit offered to private solar projects, which can greatly reduce overall costs, especially for a large system [12]. Several available incentives were found for which New Glarus School District would be a good candidate. The Focus on Energy Program in Wisconsin offers a direct cash grant called Prescriptive Renewable Incentives (PRI) which pays for 10% of the cost of a new solar project up to $4,000 [13]. Focus on Energy also provides a larger direct cash grant of 50% of the project cost up to $400,000 through the Renewable Energy Competitive Incentive Program (RECIP), however, this cannot be used in conjunction with the PRI grant [14]. Finally, WPPI Energy, the parent utility for New Glarus, offers a renewable energy grant for non-profits called RFP, which will pay for up to 50% of the project (including other grants and incentives) up to $100,000 [15]. This grant is more applicable to larger systems, as it requires connection to a member distribution system. For each project, a model was completed with and without financial incentives applied. For the two largest systems (250 kW and 100 kW), it was assumed that 50% of the project cost could be recuperated with a combination of the RECIP and WPPI grants. For the smallest system (10 kW), a model was made for using the RECIP grant as well as the PRI grant separately. This process allowed several projections to be constructed, from which the district could choose the most viable path depending on the ability to earn grants.

Modeling Economic Projections

Just as with the technical modeling, accurate inputs and assumptions had to be determined for financial projections in the System Advisor Model. Reasonable costs for each system on a $/W_{DC}$ basis were determined from the 2017 U.S. Solar Cost Benchmark produced by NREL [16], as well as pricing specific to the state of Wisconsin compiled by SolarReviews [17]. The total installed cost per Watt was significantly lower for the largest system compared to a modest 10kW system. Operation and maintenance costs were fixed at $20/kW-year for each system (the default SAM value). A 2.5% inflation rate and 5% discount rate were applied over the lifespan of the project with linear depreciation. As New Glarus Secondary School is a public school, federal tax credits and accelerated depreciation could not be applied for this project. Electricity rates were obtained from the New Glarus Utility, and a net-metering assumption was made for excess electricity generated by the system, although this was a fairly insignificant factor for the tested systems. A simulation was produced for each project using self-financing as well as available grants. A detailed summary of financial inputs and assumptions can be found in Figure 9 in the Appendix. These inputs allowed metrics such as the payback period, LCOE, and net present value of the project to be calculated in order to assess the feasibility and sustainability of each system.

Results and Discussion

System 1: 250 kW

The 250 kW rooftop PV system was determined to be financially viable for New Glarus School District with the aid of direct cash grants that could offset 50% of the cost of the system, but did not present a good investment opportunity if the district would be forced to self-finance the project. The energy generated by the system (AC) over the first year is presented in Figure 13 of the Appendix alongside the electricity load for New Glarus Secondary School.

The 250 kW system will provide approximately 70% of the annual electricity used at New Glarus Secondary School. This reduction in usage corresponds to an estimated $38,575 in savings over the first year of operation. However, there would be a substantial upfront cost to the project, making it difficult to finance while staying within the stipulated budget. Figure 14 summarizes the financial outlook for the 250 kW system, either by self-financing or taking advantage of available grants.

If the district were to self-finance the 250 kW system, the project cost would be more than triple the stipulated budget, and the investment would produce a large negative net present value. However, by taking advantage of available grants, the project becomes significantly more reasonable. At a cost of $342,319, the system would still exceed the original budget but the remaining funds would present a much more viable case to the voters. In this situation, the system would produce electricity at a LCOE of 8.97 cents/kWh, which falls below the current price offered by the New Glarus Utility. Additionally, the project would yield a net present value of $53,600 and a simple payback period of 10.5 years. Under these circumstances, the district could justify exceeding the original project budget by pointing to the increased payback produced by the larger system.

System 2: 100 kW

The 100 kW rooftop PV system was determined to be financially viable for New Glarus School District with the aid of direct cash grants that could offset 50% of the cost of the system, and would present a more reasonable investment closer to the original budget compared to the larger system. The energy generated by the system (AC) over the first year is presented in Figure 15 alongside the electricity load for New Glarus Secondary School.

The 100 kW system will provide approximately 27% of the annual electricity used at New Glarus Secondary School. This results in approximately $15,063 in savings over the first year of operation. This project is significantly less expensive compared to the 250 kW system, and with the aid of grants New Glarus could finance the project within the original budget of $200,000. Figure 16 summarizes the financial outlook for the 100 kW system, either by self-financing or taking advantage of available grants.

If the district were to self-finance the 100 kW system, the project would cost $80,000 more than the original budget, and would still provide a negative net present value. Using available grants, the project cost immediately falls to $139,989, well within the original budget. This would allow the district to finance the system without raising additional funds from the voters. This project would provide a positive environmental impact while proving to be a sustainable and profitable investment. The 100 kW system would produce electricity at a LCOE of 11.93 cents/kWh, which is reasonably close to the current New Glarus Utility rates. Additionally, the project would yield a net present value of $12,600 and a simple payback period of 11.1 years. The 100 kW system, financed with available direct cash incentives, presents the most advantageous investment for New Glarus School District while remaining within the original budget.

System 3: 10 kW

The 10 kW rooftop PV system was determined to be the only system size that New Glarus School District could completely self-finance, but did not present a profitable investment unless direct cash grants could be obtained to offset 50% of the cost of the system. The energy generated by the system (AC) over the first year is presented in Figure 17 alongside the electricity load for New Glarus Secondary School.

The 10 kW system will provide only 3% of the annual electricity used at New Glarus Secondary School. This results in approximately $1,707 in savings over the first year of operation. Although these savings are substantially less than the larger systems, the project cost for the 10 kW arrangement is small enough to be completely self-financed by the district. Figure 18 summarizes the financial outlook for the 10 kW system, either by self-financing or taking advantage of available grants. For this project, the WPPI grant was deemed not to apply, so two situations were explored with the grants available from Focus on Energy.

If the district were to self-finance the 10 kW system, the project would cost $32,867, well within the original budget. However, the project would present a negative net present value and high LCOE, and the district could easily end up losing money on the venture. The 10% PRI grant would reduce these values somewhat, but the project still does not present a wise investment even with this aid. By incorporating the RECIP grant, the project cost falls to a reasonable $16,433, and the simple payback period drops to 11.5 years. The project would generate a net present value of $900, and the LCOE would be less than the utility price at 9.61 cents/kWh. Although the overall value and savings for this project are significantly less than the larger systems, the 10 kW system represents an investment that the district could easily justify and finance. This system would also leave a significant amount of roof space for additions in later years. If the district is unable to acquire the necessary grants to finance the 100 kW project, this system would present the best opportunity for New Glarus School District to generate renewable energy.

Next Steps and Recommendations

The next necessary step moving forward with this project is highly dependent on the client decision. In order to make this project fiscally beneficial, grants must be considered as a funding source. Before grants and partnerships can be pursued, clear project metrics must be determined. Key parameters that must be decided by the client for grant applications include system size in kilowatts, the location the system will be placed, estimated project cost, and a time frame for the construction project. Locations, recommendations, and cost estimates have been calculated for three different system sizes listed previously. Many grants appear to have a submission date around September, so application timing should be planned accordingly.

New Glarus Utilities offers incentives to to commercial properties pursuing renewable energy. Once a system size is decided on, the utility company can be contacted for available incentives that correspond to the size of the system. Beth Carlson is the energy representative at New Glarus Utilities that can provide information on incentives and net metering, assuming a large enough system size is built. Her contact information is listed in the appendix (Figure 19).

From here, solar companies will need to be contacted to determine the best construction price. Although contacting solar companies was not the focus of this project, among the few contacted, H&H Group Holdings was particularly helpful and responsive. Paul Perkins, the director of business development, is the company representative. The company was eager to pursue future consulting and provide professional advice free of charge. His contact information is listed in the appendix (Figure 19). H&H has previously installed solar panels on the New Glarus Wastewater Treatment Facility in 2010.

The final step in the process is to build the system. It is important to note that system sizing may need to be reconsidered in the situation that funding does not turn out as planned. Additionally, it is possible to add both modules and inverters to the overall system as time progresses, or as money becomes available. This is a viable option if funding falls through and a small system is initially the only affordable option. The findings of this report should be taken as a useful starting point for the implementation of a solar photovoltaic system for the New Glarus School District.

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Appendix

	Category Wt	Geothermal	Solar Hot Water	PV- Large	PV- Medium	PV- Small
Efficiency of space	4	1	5	4	5	5
Usefulness to school	5	3	1	5	4	3
Energy production	4	4	3	5	4	2
Cost of installation	5	1	4	2	3	5
Ease of maintenance	2	5	3	4	4	5
Looks	1	4	4	3	4	5
Total		39	67	82	83	83

Figure 1: Decision matrix used to assess various renewable energy systems using key factors provided by the client. A solar photovoltaic (PV) clearly provides the most advantages for this project.

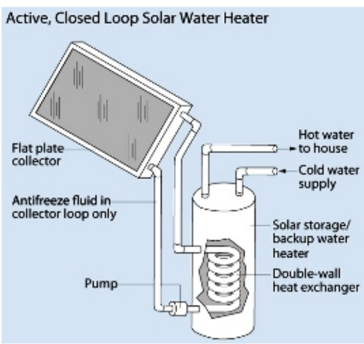

Figure 2: Schematic for a solar water heating (SWH) system. A heat transfer fluid such as glycol is normally used in circulation in order to avoid freezing in cold climates. Image obtained from ARC Mechanical [3].

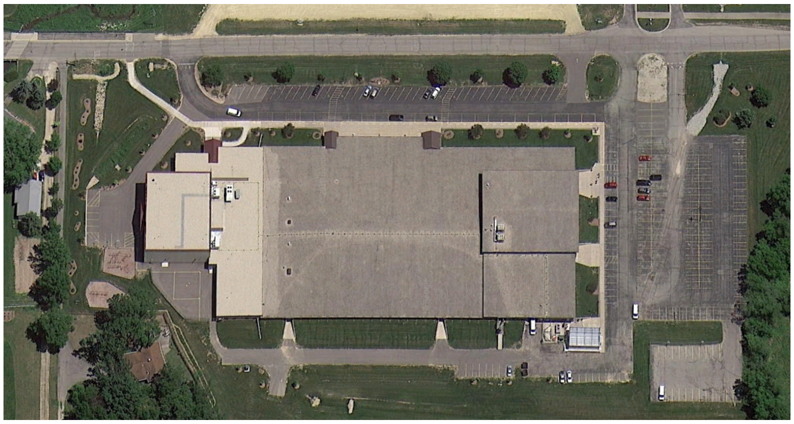

Figure 3: The rooftop of New Glarus middle and Secondary Schools, which was chosen as the location for a proposed solar PV energy system.

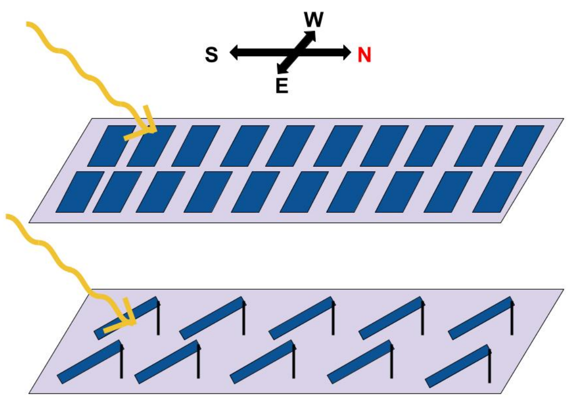

Figure 4: A schematic of the "sawtooth" arrangement of south facing panels compared to panels aligned with the angle of the roof.

	Category Weight	East-West	South-South	East-South
Energy Production (% of current)	4	0.661	0.752	0.706
Aesthetics	1	1	0.8	0.8
Cost of Installation	1	0.5	0.5	0.5
	TOTAL	**4.144**	**4.308**	**4.124**

Figure 5: Decision Matrix used to assess alternative arrangements of rooftop solar photovoltaic panels. The arrangements were rated based on energy output, aesthetic appeal, and installation cost. From this analysis it was determined that south facing panels provided the most advantageous design.

Month	On Peak Average (kWh)	Off Peak Average (kWh)	Average Total (kWh)
June	26208	21168	47376
July	16848	16992	33840
August	27792	23328	51120
September	36288	20016	56304
October	28944	16128	45072
November	26352	18576	44928
December	24480	17136	41616
January	26928	18864	45792
February	26640	16416	43056
March	27216	17712	44928
April	24192	14976	39168
May	33840	18144	51984
ANNUAL TOTAL (kWh)	**325728**	**219456**	**545184**

Figure 6: Average monthly and annual electricity usage for New Glarus Secondary School. Data was collected for a two year time period from New Glarus Utility bills provided by the client.

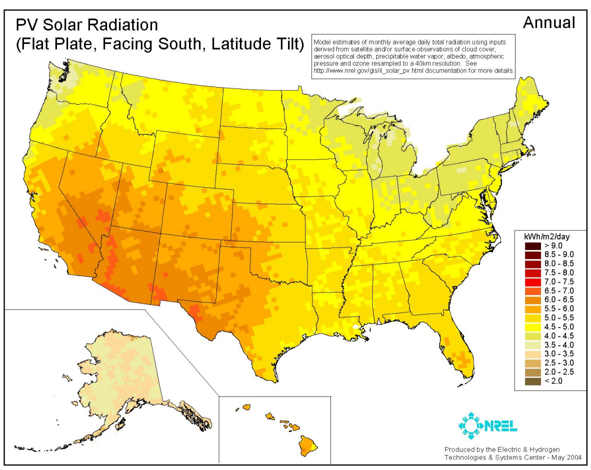

Figure 7: Average solar insolation in the United States, using a flat plate collector, south facing with latitude tilt [8]. New Glarus is estimated to receive approximately 4 hours of “peak sunlight” per day.

Technical Parameters	250 kW System	100 kW System	10 kW System
Module	SunPower E18-305	SunPower E18-305	SunPower E18-305
Inverter	INGECON 250TL	INGECON 100U	INGECON 10TL
Modules/String	12	8	5
Strings in Parallel	75	45	8
DC Power	274.7 kW	110 kW	12 kW
AC Power	250 kW	100 kW	10 kW
Estimated Rooftop Area	1.2 acres	0.5 acres	0.1 acres
Modules in Panels	5 x 30	3 x 20	2 x 5
Row Spacing	27.8 m	16.7 m	11.1 m
Total Rows	6	6	4

Figure 8: Technical inputs for the System Advisor Model used for each photovoltaic system.

Financial Parameters	250 kW System	100 kW System	10 kW System
COSTS ($/$W_{DC}$)			
Modules	0.40	0.45	0.50
Inverter	0.11	0.12	0.12
Equipment	0.30	0.30	0.33
Labor	0.19	0.19	0.19
Installer Overhead	0.70	0.70	0.70
Contingency	5%	5%	5%
Permitting	0.05	0.05	0.10
Engineer Overhead	0.65	0.65	0.66
Total [17]	**2.48**	**2.55**	**2.69**
ANALYSIS			
Analysis Period	25 years	25 years	25 years
Debt Percent	0%	0%	0%
Tax Rates (Fed, State)	0%	0%	0%
Insurance Rate	0.5%	0.5%	0.5%
Salvage Value	10%	10%	10%
INCENTIVES			
PRI Grant	0	0	10%
RECIP Grant	-	-	50%
RECIP+WPPI Grants	50%	50%	0

Figure 9: Financial inputs for the System Advisor Model used for each photovoltaic system.

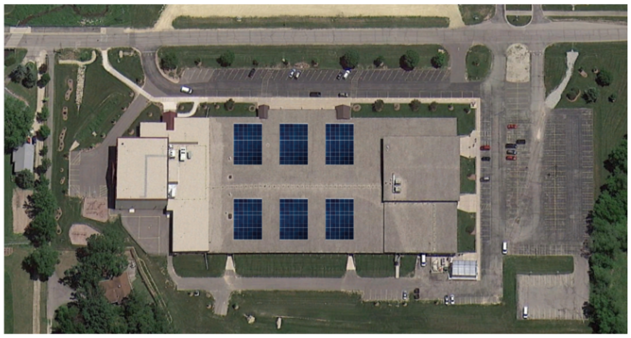

Figure 10: The general rooftop arrangement for a 250 kW photovoltaic system. The system contains 6 rows of 5 x 30 module panels, which would be directed south at latitude tilt.

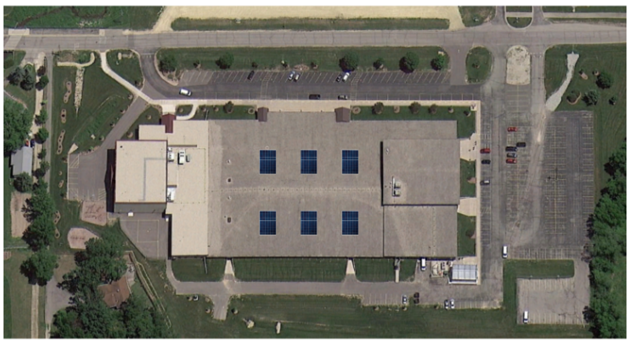

Figure 11: The general rooftop arrangement for a 100 kW photovoltaic system. The system contains 6 rows of 3 x 20 module panels, which would be directed south at latitude tilt.

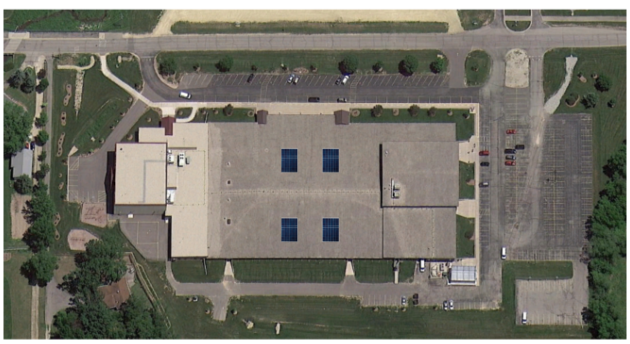

Figure 12: The general rooftop arrangement for a 10 kW photovoltaic system. The system contains 4 rows of 2 x 5 module panels, which would be directed south at latitude tilt.

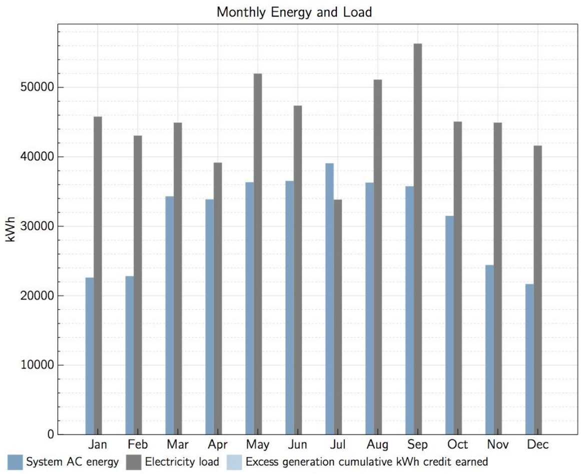

Figure 13: Monthly energy production and load for the first year of operating the 250 kW system. The blue bars represent the energy (AC) generated by the PV system, and the gray bars represent the electricity load of the school.

	Self Financed	**Financed with Grants (50% w/ RECIP, WPPI)**
School Cost	$682,638	$341,319
Simple Payback Period	19.4 years	10.5 years
LCOE (real)	15.73 cents/kWh	8.97 cents/kWh
Net Present Value	**-$287,700**	**$53,600**
Estimated Year 1 Savings	$38,575	$38,575

Figure 14: Financial projections for the 250 kW rooftop PV system. In order to achieve a positive net present value, the project financing would have to be assisted by a combination of RECIP and WPPI grants which could supply 50% of the cost.

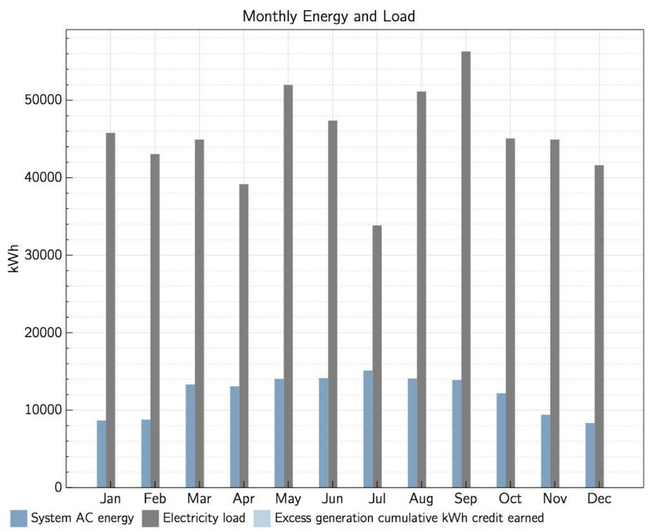

Figure 15: Monthly energy production and load for the first year of operating the 100 kW system. The blue bars represent the energy (AC) generated by the PV system, and the gray bars represent the electricity load of the school.

	Self Financed	**Financed with Grants (50% w/ RECIP, WPPI)**
School Cost	$279,978	$139,989
Simple Payback Period	20.4 years	11.1 years
LCOE (real)	16.49 cents/kWh	11.93 cents/kWh
Net Present Value	**-$127,200**	**$12,600**
Estimated Year 1 Savings	$15,063	$15,063

Figure 16: Financial projections for the 250 kW rooftop PV system. In order to achieve a positive net present value, the project financing would have to be assisted by a combination of RECIP and WPPI grants which could supply 50% of the cost.

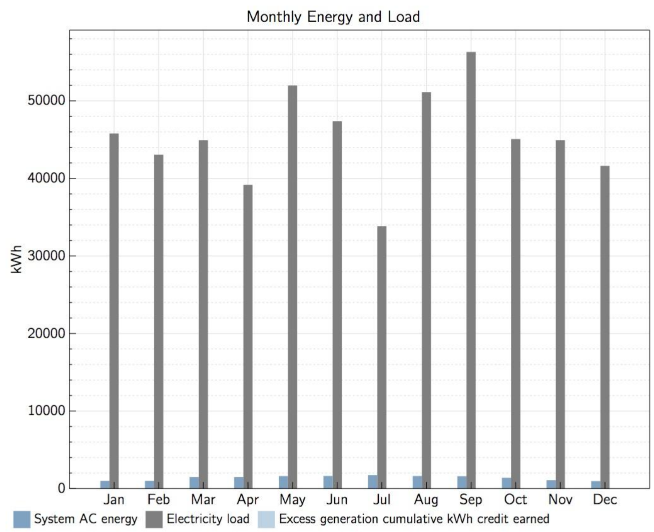

Figure 17: Monthly energy production and load for the first year of operating the 10 kW system. The blue bars represent the energy (AC) generated by the PV system, and the gray bars represent the electricity load of the school.

	Self Financed	**Financed with 50% RECIP Grant**	**Financed with 10%PRI Grant**
School Cos	$32,867	$16,433	$29,580
Simple Payback Period	20.9 years	11.5 years	19.1 years
LCOE (real)	16.94 cents/kWh	9.61 cents/kWh	15.47 cents/kWh
Net Present Value	**-$15,400**	**$900**	**-$12,100**
Estimated Year 1 Savings	$1,707	$1,707	$1,707

Figure 18: Financial projections for the 10 kW rooftop PV system. In order to achieve a positive net present value, the project financing would have to be assisted by the RECIP grant providing 50% of the project cost. The PRI grant alone would be insufficient to produce a reasonable investment opportunity.

Name of Contact	Company	Phone Number	Email
Beth Carlson	New Glarus Utilities	608-834-4500	bcarlson@wppienergy.org
Paul Perkins	H&H Group Holdings	-	pperkins@hhgroupholdings.com

Figure 19: Contact information for Beth Carlson from New Glarus Utilities and Paul Perkins from H&H Group Holdings.

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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