University of Michigan - School of Natural Resources and Environment

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BRINGING RENEWABLE ENERGY TO CAMP MICHIGANIA

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by

Tim Dobson
Kellie Donajkowski
Andrew Heairet
Betsy Riley
Caitlin Sadler
Tirumalai Tejas
Rex Zhang

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Faculty advisors:
Dr. Gregory Keoleian (SNRE/CSS)

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Abstract

Camp Michigania is a family camp for University of Michigan alumni and has been operating in Boyne City, Michigan since 1963. In order to become more sustainable, Michigania wanted to assess the feasibility of installing renewable energy at camp. It was important that there be a focus on creating educational materials and connecting campers to sustainability issues in order to have broader impacts both inside and outside Camp Michigania. To achieve this goal, the team was divided into two sections; educational and technical. The educational team conducted a comprehensive survey, created an outreach program for campers and donors, produced a website to track the progress of the project, designed child and adult educational resources, and built educational displays. The technical team obtained and analyzed energy use data, performed site analyses, solicited quotes and performed vendor reference visits, researched zoning ordinances, built energy and financial models, and identified the best renewable energy technology. The results of these analyses led the team to focus on a roof-mounted solar photovoltaic system. Solar vendors were then compared on price, technology, and level of experience. The team recommends Sunventrix as the vendor and that a 19.76kW solar photovoltaic system be installed on the south-facing Dining Hall roofs.

Acknowledgements

The team would like to thank the following people for their contributions to this project:

Client – Mitch Rosenwasser, Executive Director, Camp Michigania

Mitch impressed team members from the very first meeting by effectively conveying his passion for Michigania, the campers that attend each summer, and the present and future sustainability goals of the camp. Over the course of the project he made sure we had access to staff members, camp sites, food and a place to stay during visits, transportation when needed, and added team members to energy vendor accounts to allow for more direct access to data. Mitch also made himself available for in-person meetings with the group in Ann Arbor during the school semesters, and always asked a question near the end of each meeting: “What else do you need from me?” His goal was to make sure the team was successful so that all had a good learning experience while also providing Michigania with a first step renewable energy project recommendation that would be a success both educationally and technically.

Advisor – Greg Keoleian, Ph.D., Director of the Center for Sustainable Systems, Professor at the School of Natural Resources and Environment, Professor at the College of Engineering

Professor Keoleian has spoken at Michigania’s Faculty Forum for several years, where U-M faculty and staff provide insight into their areas of expertise through evening discussions and informal gatherings in the mornings. During these times, he has stayed at the camp during the week, enjoying the activities, environment, and interactions with other campers. Professor Keoleian’s direct experience at camp, plus extensive experience with sustainable energy systems, enabled team members to place great confidence in his advice and direction. He made himself available during his stay at camp to meet with a team member to review progress, walk the camp for a preliminary site analysis, and advise on next steps. Throughout the project, Professor Keoleian continued to emphasize having the appropriate scope, with the emphasis on ensuring the team do a few things well, focusing on quality of work rather than quantity. This enabled the team to work more effectively and efficiently.

Michigania Staff Members, Campers, and Other University of Michigan Faculty

A number of staff members provided data, camp-specific insight, and access to sites throughout the time of this project. This assistance enabled more detailed analyses of data and better survey preparation to provide the basis for more robust recommendations. A number of campers provided frank and constructive feedback during team member visits, and some even provided technical analyses of solar systems they installed where Michigania could take advantage of lessons learned. Finally, various members of the University of Michigan faculty provided feedback to both the education and technical teams, with one faculty member meeting a team member at camp to review the team’s progress and offer suggestions while doing a preliminary site analysis.

1 Introduction

1.1 Background

Camp Michigania is a family camp for University of Michigan alumni. The camp has been housing families, couples, and single individuals for the summer since 1963 when it opened on the shores of Walloon Lake, located in Boyne City, a small town in northern Michigan. During the summer months, Michigan alumni come to camp to enjoy the lake, food, and each other for a one week stay. Currently, Michigania is able to accommodate over 4,500 people throughout the summer.

The camp sits on 417 acres, and the total square footage of all buildings is about 150,000 ft^2 (Rosenwasser, 2013). Buildings at Michigania consist of staff housing, camper cabins, the Education Center, the Nature Center, the Dining Hall (built in 2010), and maintenance facilities. Each of these facilities are wired with electricity and working plumbing. Accommodating the high number of campers Michigania houses with these amenities as well as providing three meals a day results in high energy usage; approximately $100,000 was spent for electricity and propane during 2012.

Michigania has been passionately pursuing sustainability initiatives on site for the past several years; strong recycling efforts are underway, food gardens have been added, and there has been a greater focus on local food sourcing. Michigania has also retained university students to analyze a portion of the camp from a sustainability perspective and provide recommendations; this master's project group being the third group in the last three successive semesters.

In the spring of 2011, the first group provided a report titled "Camp Michigania Cabin Sustainability Report". This report focused on a sustainable cabin design, analyzing several renewable energy systems before providing final recommendations of a photovoltaic solar system, tankless water heaters, and low-flow showerheads. The following Fall term, the second group provided a report titled "Sustaining Camp Michigania" and focused on sustainable practices, such as recycling, and sustainable education programs for campers.

In an effort to become more sustainable, Camp Michigania has decided to invest in various energy efficiency and renewable energy strategies as a third student-led project. While many options are available, Camp Michigania is conscious of how change will be perceived by its community of campers and supporters. Camp Michigania's stakeholders are accustomed to an aesthetic that has been maintained for generations of campers and therefore, successful energy solutions will need to embrace and enhance this aesthetic through stakeholder engagement, and education throughout the project.

Our team brought together experience in social, educational, technical, and environmental perspectives to holistically evaluate sustainability options for Camp Michigania. This approach offered significant advantages over traditional single-dimensional analysis by better engaging all relevant stakeholders and by offering more comprehensive solutions throughout the process.

Over the course of the past year, our team evaluated different solar photovoltaic technologies using a framework that achieves financial, environmental, technical, and stakeholder objectives. Solar thermal heating was also assessed as a possible energy efficiency strategy for camp. At the conclusion of the project, best-fit strategies were proposed and will be implemented soon. An educational program was developed to promote continual camper engagement throughout the process and to promote in sustainability issues at camp and in the home.

1.2 Project Objectives

The research question being answered for this project was:

> What renewable energy technology would be a good first step for Michigania to help promote sustainability at camp while also providing an opportunity for educating campers so they can apply it at home and within their local communities?

It was just as important for the project to succeed in educating campers on the costs and benefits of renewable energy as was the recommendation of the most applicable renewable energy system for the camp itself. Based upon these considerations, the overall project objectives were:

- Determine the optimal renewable energy system for Camp Michigania, placing a value not only on financial return on investment (ROI), but also camper perception and aesthetic fit.
- Develop a communication strategy and create educational resources to engage campers in the process.

1.3 Organization of Report

This report is divided into two major sections. The first documents the actions by the education team that conducted a comprehensive survey, created an outreach program for campers and donors, produced a website to track the progress of the project, designed child and adult educational resources, and built educational displays. The second section documents the action of the technical team that obtained and analyzed energy use data, performed site analyses, solicited quotes and performed vendor reference visits, researched zoning ordinances, built energy and financial models, and identified the best renewable energy technology. An appendix is provided at the end providing detailed educational resources and listing detailed technical information and analyses.

2 Education and Communication Considerations

Camp Michigania plays host to a wide variety of campers, who are all intensely invested in what happens to the camp. Many of these families have been going to the camp for not only many years, but also for several generations, and because of that, have strong opinions about what should happen there. As our client Mitch Rosenwasser put it at the beginning of this project: "We know we don't own the camp—the campers do."

For this reason, a major part of the project has been communication. This has taken the following forms:

- Extensive initial outreach
- Presentations to governing boards of Camp Michigania
- Fundraising outreach materials
- Child and adult education programs
- Post-installation information boards

Great attention was put into outreach style and content. Our audience was homogeneous in two key ways: they are highly educated (Camp Michigania is an alumnae camp) and generally are upper middle class. Early visits to camp were designed to determine how these specific characteristics translated into camper preferences.

We discovered a highly interested audience that asked specific questions and listened intently to the answers. It was readily apparent that with such an engaged audience, our outreach material would need to take place in the form of an information exchange—rather than an information gathering—and our materials reflect this conclusion.

3 Communication Strategies

3.1 Website

At the onset of the project, a website was created in order to provide updated information regarding the project for campers who were interested in learning more and staying informed. It was created using Wix.com and the domain purchased from the same site. The website is located at www.sustainablemichigania.com (originally www.renewablemichigania.com) and contains the following pages:

- Homepage
- Current status of the project
- Master's Project team member information
- Project Feedback
- What a Master's Project is and how it works
- Camp Michigania's energy use

The website address was made available on all initial outreach material, as well as later material, such as an article in the *Gania Gossip*, the camp's official newsletter.

3.1.1 First Summer Info

At the beginning of the project, it was critical to make sure that campers received accurate information about the project and that they had ample opportunity to provide feedback. One of the best ways to make campers aware of the project was by using multiple channels to distribute the information. This included announcements about the project at the beginning of camp, informational displays, brochures, and an updated website. All of these materials mentioned the survey to encourage more campers to provide feedback on the project. In addition, an email address was given out to better engage with campers, but over eighty percent of feedback from the campers was given through the survey and not through email.

3.2 Survey

As an integral part of the communication team's initial outreach project, a survey was developed to determine the depth and breadth of camper thoughts and opinions on the subject of renewable energy installations at Camp Michigania.

The survey was approached with a specific set of questions, designed to guide our work with the renewable energy choice and installation as well as the outreach and education materials:

1.) How important do people see the aesthetics of the camp? Energy efficiency? Renewable Energy? Sustainability?

In order to get a feel for the camp, we were interested in knowing just how much campers thought about these different environmentally related themes and their general opinions towards them. In addition, one of Camp Michigania's biggest draws is its beautiful landscape, and past work with renewable energy (in particular wind energy, which has caused controversy across the nation, especially with regards to offshore installations) indicated that many people may consider renewable energy projects as taking away from this natural beauty. For this reason, we were interested in comparing across these different aspects to determine how these different values interrelate.

2.) How do campers feel about sustainability while at home versus at Camp Michigania?

This question was specifically requested by our client in order to determine if campers had different standards for their camp than for their homes. This can help determine if feelings of sustainable use are something that campers associate with the camp (i.e. the camp currently has an undercurrent culture of sustainability) or if ideas around sustainability vary with the individual camper, rather than the location. This allows us to better understand the current culture of the camp and the cognitive link between the camp itself and feelings of sustainability.

3.) Do campers feel as though sustainability is a burden? Is there resentment?

This question is highly relevant because Camp Michigania is a camp—a place people go to for vacation. If current negative feelings exist in regards to sustainability, this is important to understand and address when hoping to bring in additional technology related to sustainability. For this question, we took advantage of a recent program that's been undertaken by the sustainability coordinator—a recycling program—to understand camper feelings and gauge their interest in related, sustainability-themed programs.

4.) What are campers' favorite activities?

This question pertains to the development of educational programs. Understanding camper activity preferences helps in the development of educational activities that fit in with what campers already like to do, making them more interesting and engaging.

5.) How likely would campers be to attend informational sessions? Educational activities?

Informational sessions seem almost a requirement for adult education programs; however, creating such an information session would not be worthwhile if campers were not interested in attending.

6.) What types of activities do parents enjoy having their kids do? Physical things? Educational things? Creative/artsy?

This question was a requirement for the children's educational programs in order to determine what sorts of activities should be designed to best appeal to campers and their children.

7.) What types of renewable energy technology do campers most support?

This question gets to the heart of the project. If campers have strong preferences one way or the other with regard to renewable energy technology, this information is invaluable to the decision making of the project.

8.) Would campers be willing to donate money to bring renewable energy to Camp Michigania?

This question is important in understanding what sort of funding options will be available for the project by understanding camper willingness to contribute. In addition, it provides a helpful indicator for the level of support we can expect from campers—a high willingness to donate would reveal strong positive feelings towards the project, while a general unwillingness would reveal a disinterest or dislike on the part of campers.

3.2.1 Design

Due to high camper engagement with the project, the survey was designed to not only ask questions, but make sure that campers knew why we were asking them. It was felt that asking a question without an understanding of why it was being asked could lead to a high amount of missing information, due to the high engagement of campers and reported camper reluctance towards changes in the camp.

The survey design was created with reference to expert literature on questionnaire construction (SPSS, Inc., 1995) (Fowler, 1998) in an effort to best capture camper information. Basic relevant demographic information was collected, including number of years of being a camper and who they come with to camp. The survey was kept brief with 29 individual questions combined into a

12-question format, with tables created to facilitate comprehension. The full survey is available in Appendix I.

3.2.2 Distribution

Surveys were self-administered and presented in the form of both an online survey and paper copies. Online surveys were created and administered through Qualtrics and could be found via a link, which was included in a follow up email from the camp that was sent to all Camp Michigania families, as well as available on the website.

3.2.3 Results

There were a total of 349 surveys were collected, with 289 campers using the online survey and 60 using paper copies. Of the campers sampled, 132 (38.5%) had attended Camp Michigan over 20 times, with 22% having attended 11-20 times, 16% 6-10 times, and only 8% reporting this as their first year at Michigania. In addition, 71% reported coming with their significant other, 85% came with their children, 26% came with a friend, and 3% attended alone.

Demographics, such as age, gender, race, etc., were not considered relevant for the purposes of this survey.

Data was downloaded to excel, filtered for qualitative data, and uploaded into .dta format for use with the Stata statistical software, which was the source of the following statistics. The .do file listing the functions ran is included in Appendix II.

3.2.4 Question Specific Results:

1.) How important do people see the aesthetics of the camp? Energy efficiency? Renewable Energy? Sustainability?

To answer these question, we used a 5-point scale (1=not at all important, 5=very important) to look at camper opinion towards aesthetics (mean=4.46), sustainability (mean=4.46), energy efficiency (mean=4.31), and renewable energy (mean=4.12). Sustainability was defined in the survey as "use of camp resources in a way that allows them to continue being used into perpetuity." The means from these categories were calculated and compared against each other with the results listed in the table below.

Table 1. T-test Results Comparing Means. Results shown as “tscore (*p*--value)” with *n* below.

	Sustainability	Energy Efficiency	Renewable Energy
Aesthetics	0.16 (0.870) 336	3.02 (0.003)* 337	6.06 (<0.001)** 337
Sustainability	-	3.62 (0.0003)** 339	8.16 (<0.001)** 339
Energy Efficiency	-	-	6.60 (<0.001)** 341

Asterisks indicate a significant difference at the 0.01* and the 0.001** level.

The results in **Table 1** show significant differences between camper preference for renewable energy and every other measure. Because the mean preference for renewable energy is relative low compared to these other measures, the data indicates that campers on average see renewable energy as less important than either aesthetics or the other environmental measures, scoring even lower than energy efficiency, which was also significantly lower than aesthetics and sustainability.

It should be noted that while significant differences exist, all these means are quite high—a score of 4 indicates the feeling that the variable being measured is “important” with 5 being “very important.”

2.) How do campers feel about sustainability while at home versus at Camp Michigania?

A paired t-test between home and camp revealed a t-score of -2.07 and a *p*-value of 0.039, making the difference in means (4.27 for home and 4.35 for camp) statistically significant at the α=0.05 level, showing that indeed, campers seem to relate Camp Michigania with sustainability more so than they do their homes.

3.) Do campers feel as though sustainability is a burden? Is there resentment?

The responses on this section of the questionnaire are extremely straightforward, as seen in **Figure 1**:

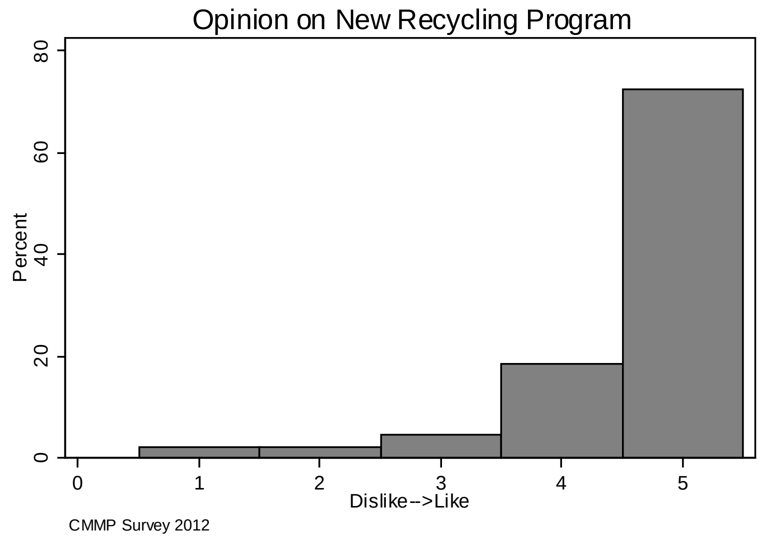


Figure 1. Opinion on New Recycling Program. Response by campers displaying like/dislike of recycling program. A score of one was chosen by campers who did not like the recycling program and did not want any more like it, while a score of five indicated that the camper liked the program and wanted more like it. A score of 0 was not an option. *N* = 310.

It was found that 73% of respondents liked both the current program and were hoping to see more programs like it started in the future, compared to approximately 4.5% of campers who did not like the program, 4.5% who were indifferent, and 18.4% who liked the current program, but did not want more like it.

4.) What are campers' favorite activities?

As in Question 1, we used a 5-point scale (1=strongly avoid, 5=very much prefer) to look at camper opinion towards information sessions (mean=3.54), family activities (mean=4.05), individual activities (mean=3.86), hands-on activities (mean=4.13) and educational activities (mean=3.84). The means from these categories were calculated and compared against each other with the results listed in **Table 2** below.

Table 2. T-test Results Comparing Means. Results shown as "tscore (*p*-value)." *N* values are shown beneath.

	Family Activities	Individual Activities	Hands-on Activities	Educational Activities
Information Sessions	-8.02 (<0.001)** 279	-5.15 (<0.001)** 280	-9.74 (<0.001)** 280	-6.65 (<0.001)** 275
Family Activities	-	3.99 (0.0001)** 279	-1.58 (0.115) 281	3.79 (0.0002)** 275
Individual Activities	-	-	-6.15 (<0.001)** 280	0.38(0.76)275
Hands-on Activities	-	-	-	5.32 (<0.001)** 277

Asterisks indicate a significant difference at the 0.01* and the 0.001** level.

The results show that information sessions are the least popular form of activity, by a significant difference in each case. Hands-on activities were on the opposite end of the spectrum, being significantly more popular than all other activities besides family oriented activities. T-tests were run to determine if interest in hands-on activities varied by whether or not a family brought their child along, and while the results approached significance (p=0.08) there was not a statistically valid difference. This lack of a children/no children distinction held true for the other variables as well, with the exception of family oriented activities, in which those who did not bring children were significantly less interested in family activities than those who did (p=0.018).

5.) How likely would campers be to attend informational sessions? Educational activities?

Based on the information collected as part of question 4, it seems evident that campers are not altogether enthusiastic about attending information sessions when other options are available. For this reason, information sessions may need to be reframed as education activities, which were rated significantly higher than information sessions. In addition, educational resource designs need to be more than simply a lecture format, with more emphasis on hands-on activities and audience involvement; this could increase camper participation and enjoyment.

6.) What types of activities do parents see their kids doing? Physical things? Educational things? Creative/artsy?

Using the slider function for the online survey, and a fill-in-the-space technique on paper copies, families that brought children were asked to identify what percentage of time they believe their children spend doing a specific activity. Because a single activity can fall into multiple categories (it can be hands on, education, and family oriented, for example), campers were asked to not worry about having percentages equal 100%. The following figure shows the mean time percentages, looking only at families that brought children with them to camp. All differences are significant at the 0.001 level, with the exception of the difference in means between physical and peer activity.

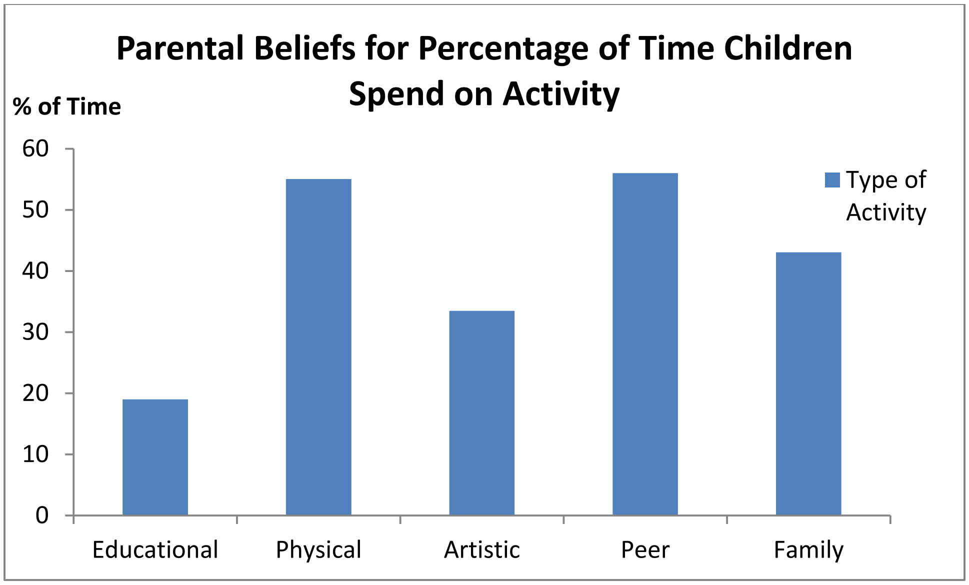


Figure 2. Parental Beliefs for Percentage of Time Children Spend on Activity. Numbers will not add up to 100%, since many activities fall into multiple categories. N = 272. Families that reported coming to camp without children were excluded from analysis.

The results in **Figure 2** show a substantial difference in mean beliefs in a number of areas. The data show that families bringing children do not expect their children to engage in educational activities over physical and/or peer activities. Manipulation of the data produced mixed results when attempting to discern whether campers believe physical *and* peer activities or physical *or* peer activities are more popular, with only 54% of campers similarly rating these two activities. Therefore, while both activities are rated highly, it is not possible to conclude that campers believe their children prefer physical activities *and* peer activities equally.

7.) What types of renewable energy technology do campers most support?

Because this question is so central the heart of the project, the Dislike-Like Likert scale used was expanded to seven, rather than five choices, ranging from “Dislike Very Much” to “Like Very Much” with a neutral option in the middle. The mean results are presented in the figure below:

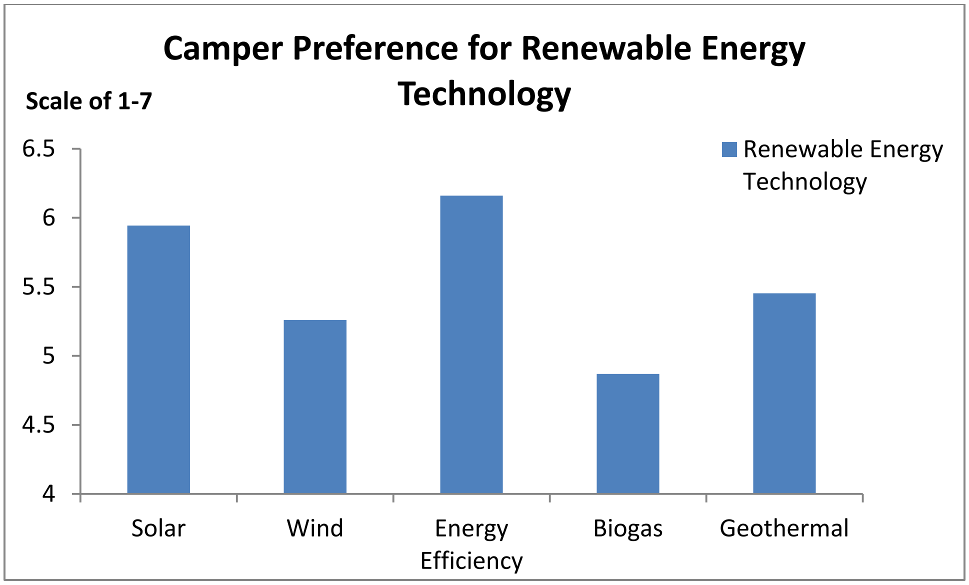


Figure 3. Camper Preference for Renewable Energy Technology. Lowest like of biogas, highest like of energy efficiency. *N* = 339 (solar), 335 (wind), 338 (energy efficiency), 321 (biogas), and 322 (geothermal).

The results in **Figure 3** reveal general support for renewable energy of all kinds. Only biogas fell below an average score of 5 (Like), and only barely at 4.8, which is still well within the "Like Slightly" range. These results are extremely promising for the project as it shows an overall positive association from campers with renewable energies, sampled from the self-selected campers with interest enough in the project to complete the survey.

The 0.2-point difference between camper preference for energy efficiency and solar technology is statistically significant (p=0.0009), making energy efficiency the preferred sustainable technique for campers. Because the project is focused specifically on a renewable energy technology, energy efficiency practices are not an option for this project specifically, but the option was included after visits to the camp revealed that many campers had ideas about energy efficiency techniques. This information could be helpful in guiding future Master's Project teams, because Camp Michigania is looking to host another group in the future.

Solar, then, had the most support of all the available renewable energy technologies. It is this option that the Camp Michigania Master's Project pursued.

8.) Would campers be willing to contribute money to bring renewable energy to Camp Michigania?

Only one question was used at the end of the survey to determine interest in contributing money and it asked the question in a very straightforward manner. The results are shown below in **Figure 4**, equaling a total of 100%:

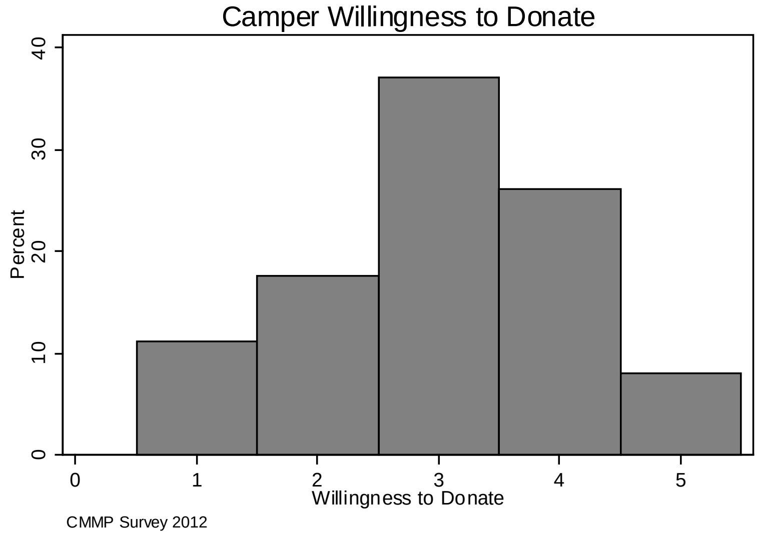


Figure 4. Camper Willingness to Donate. A score of "1" signifies a response of "unwilling" while a score of "5" signifies "very willing." A score of "0" was not an option. *N* = 340.

These results reveal slightly more support for the project than lack of support, but the largest category was from campers who did not have a preference (Group 3).

3.2.5 Written Questions

In addition to the quantitative data obtained from the surveys, several occasions were given for campers to type or write in additional information that they thought would be useful to the project. Some of this information (such as the "What three words would you use to describe Camp Michigania?") were used for outreach purposes. Other questions provided information more specific to the project and were used to help understand and interpret our findings.

3.2.6 Limitations

An effort was made to ensure that all campers had access to the survey, which means that the campers who chose to take the survey were self-selected, rather than randomly selected. This method was chosen because random selection of campers would risk missing the strongest opinions towards renewable energies, while the self-selection method ensured that these voices were heard, since it is these opinions that we have the most interest in addressing. This does, however, allow us to only speculate on the prevalence of such opinions—we can't conclusively determine how representative these opinions are of the general Camp Michigania population.

However, the advantages of this method far exceed this drawback. Based on the results of the survey, we have determined that strong opposition towards all renewable energy technology is extremely rare. Instead, strong opinions tend towards the type and placement of renewable energy technology, which we were able to accommodate without sacrificing our designs.

Another misstep in the survey creation was a single mismatch between the online and the paper surveys. The surveys went through many drafts before being distributed and each time the questions had to be updated on both copies. In the final versions sent to campers, there were slight discrepancies between the two surveys. Questions that could be interpreted different ways by campers were recoded or thrown out as deemed appropriate.

3.3 Focus Groups

In order to further assess campers' opinions on renewable energy at camp Michigania, focus groups were run once a week for an hour for five weeks during the summer of 2012. A focus group was initiated to get a more in depth understanding of campers' feelings and desires for camp, having in person interviews allows for further understanding about statements or opinions made by campers.

Participants were recruited through advertisement of the event in the dining hall and in the weekly schedule that each camper receives. Focus groups took place on Friday afternoons and were scheduled for an hour.

The focus group sessions started off with a welcome and thank you followed by a brief introduction to the project. After the project was explained we took campers through a series of questions, below are the questions and any main concerns that came about during the discussion.

- What do you think campers will like about a project like this?
- What do you think about renewable energy coming to Camp Michigania?
- What concerns do you think campers will have if these changes occur?
- What concerns do you have?

Campers liked and thought others would like the initiative that Camp Michigania was taking by changing some of their energy usage to a renewable source. Campers were also ok with Camp Michigania obtaining solar panels as long as their concerns were addressed. People were very concerned about what type of renewable energy would be chosen because they were very against having a wind turbine installed. The campers had negative opinions about the turbines because they did not want their view disrupted or the lake altered at all.

The idea of installing solar panels also resulted in several concerns from campers. Campers were concerned that the payback period for solar was just not there yet and that the solar panels would not benefit camp financially. Another concern was location; where were the solar panels going to be placed? The main concern here was that the panels would be an eyesore on the camp.

Finally, campers were concerned about where the money was going to come from to finance this project, they did not want funding taken away from programs at camp and they did not want the cost of camp to increase because of this. All of these concerns were taken into account during the assessment of the project.

3.3.1 Limitations

The set-up and nature of Camp Michigania made it difficult for focus group sessions to be successful. Every week at Camp there are about 100 families present but on average the focus groups only received five participants if people showed up at all. On two occasions no campers showed up to the focus group and so the session was cancelled for that day. Camp Michigania is a place where families go to vacation so during that time people want to partake in the activities that camp offers. Another issue that hindered the focus groups was that they were only able to be worked in on Fridays which is the last full day campers have at Michigania, making them even less likely to partake in an indoor activity.

3.4 Presentations

One of the biggest challenges with any outreach plan for a project of this nature is getting started. It can be hard to get access to important groups of stakeholders in order to gain insights into the organization. Having the opportunity to present to and meet with the Michigania Alumni Board was very beneficial, especially since this meeting occurred within the first few weeks of the project. This board is comprised of camp leaders from each session of camp and they were able to give our team prospective on what some of the concerns of campers might be in the future. In addition, this group gave key insights into the unique culture that has shaped Camp Michigania for decades. Their feedback heavily influenced the creation of the outreach materials.

3.4.1 Fundraising (Support / Resources)

Camp Michigania has a long tradition of campers donating to projects at camp. Our team prepared information for donors that provided data about the impact that donations of different amounts would have on the amount of energy produced. This helps to make each contribution more tangible and helps guide donors to different levels of financial contribution. In addition to providing campers with information about the impact of their donations, the packet also included definitions of the available technologies. The information tied the solar installation in with other camp values, such as sustainability and being a leader. The packet was designed to fully explain the project to those who were not aware, and intrigue campers to stay updated with the project by visiting our website or contacting the team.

3.5 Educational Components

3.5.1 Kids Educational Resources

A solar activity booklet was produced for the sustainability coordinator or the nature staff to use with camper children ages seven and up. This activity booklet contains four different lessons/activities that the staff can do with groups of children; *Hot Water Never Seemed so Easy, Michigania's Solar System, Renewable Races, and Monitoring Our Energy – the TED way* (Appendix III). The activities are specifically tailored towards Michigania and the solar system that we have recommended. Each activity gives instructions and background information for the staff member running the program.

The four activities are interactive and use the learning cycle in order to ensure that kids are getting the most out of the programs as possible. According to the 5E learning cycle there are five steps to ensure that learning occurs in students. The five-stage process consists of *engagement, exploration, explanation, extension, and evaluation* (Bybee, et al., 2006). In each activity, the participants become *engaged* when they learn about what the activity is and what they are going to be doing. They then are able to *explore* when they actually do the activity, example: using TED to see real-time energy usage of different appliances, racing cars that are solar powered, and measuring water temperatures. After the activity has taken place, each lesson runs through a series of discussion questions in order to get participants to *explain* what was happening in the activity, example; in *Renewable Races* they are asked why the different racecars go at different speeds. This discussion allows the participants to think about what they have just done. In this particular activity they are also asked to think about the limitations of solar, this provides *extension* to the knowledge they have just gained, they are able to apply it to other topics. The last step of the 5E learning cycle, *evaluation*, is not used in these activities because while learning and retaining that knowledge is always important, the objective at Camp Michigania is to have fun activities that campers can enjoy. Another reason the *evaluation* stage is not used is because the activities were developed to stand alone and not build on one another, this was done in order to make the lessons flexible. Each activity can be used for multiple age groups and can be used in any order.

Each activity was also created keeping the survey results in mind. Adults expect that their children would be spending the majority of their time with their peers and doing physical activities, anticipating that their children would spend less than 20% of their time on educational activities. While this is not a perfect indicator of what the children will be doing or participating in at camp, activities were geared towards groups of campers and included a high level of activity.

Monitoring Our Energy – the TED way, is an activity that needs a special purchase; the TED Energy Monitor. While the TED Energy Monitor is needed in order to run the activity; *Monitoring Our Energy – the TED way*, it is up to Camp Michigania to decide whether or not they would like to purchase the device. As can be seen in the proposal from Sunventrix, TED is an optional addition to the system that they can install for $469. The activity cannot be conducted without the TED Energy Monitor, the device shows real time energy use and this is a great means of showing campers just how much energy and money is used and spent by leaving lights on and using other appliances. TED can also be used to record weekly energy usage which can be turned into a competition between weeks by the sustainability coordinator.

3.5.2 Kids Educational Displays

As part of the children's education program our team designed a set of interactive boards that will be displayed in the nature center at Camp Michigania. The nature center is a place that helps campers connect to their surroundings and teaches campers about environmental issues (Winther, 2010). This made it a great location for displays about sustainable choices and renewable energy options. Each of the boards contains pictures and information as well as an interactive game (see Appendix IV). The game includes questions about information that is not directly stated on the board. This allows campers to apply what they learned from the poster to similar questions; therefore this requires applying the information that has been acquired to a new situation. Overall, this strategy helps to reinforce the information (Jacobson, 2006). This way of learning is especially important for information regarding sustainable lifestyle choices, because these are choices that people make quickly and do not have time for lots of evaluation.

The boards were also designed to appeal to campers with different learning styles. The pictures and design of the boards help visual learners, while the interactive doors cater to more tactile learners (Jacobson, 2006). Additionally, children can either explore them on their own or they can serve as the basis for a lesson led by counselors. The overall purpose of the children's education program is to help teach campers about sustainability, and give them information that they can use at home.

The first board is about sustainable choices and includes tasks that children can do to reduce their impact on the environment. The purpose of this display is to engage children with everyday activities they are already familiar performing. While some of the activities on the board are items campers would do at camp, others are tasks that are only done at home. Each camper is only at camp for one week, which is why focusing on information that they use at home is even more important. This was the reasoning behind adding a QR code that takes campers to an online quiz about their CO_2 emissions. This particular quiz was developed by "Cool the World" and allows for campers to evaluate the impact that their family's lifestyle has on the planet (Cool the World). This serves as another way to connect what they are learning at camp to their habits at home.

The renewable energy board is geared towards slightly older children. It focuses on successful renewable energy solutions including solar panels, wind turbines, biomass and geothermal energy (Alliant Energy). This display provides basic information and fun facts that are meant to get campers interested in learning more about renewable energy. This particular board also ties in with the renewable energy adult programs to help provide some overlap between what children and adult campers are learning about. Also, the interactive questions on this board are more difficult, which encourage children to task their counselors and parents about renewable energy.

3.5.3 Solar Photovoltaic Energy Interface

Once the system is installed at Michigania it is important to keep campers involved in the system and its impact. By keeping campers aware and engaged in the project we hope to increase the likelihood of additional sustainability initiatives taking place at Camp. In order to keep campers engaged in the project after its completion it is suggested that an interface medium, such as an iPad, be purchased and mounted in an area of high foot traffic like the dining hall. Once mounted, the interface can display the instantaneous energy gain from the panels showing how much each panel is producing. In order to be able to view this information, an Enphase Metering and Management Solution device needs to be installed along with the system. The Sunventrix proposal prices this at $545 for the device and the installation. This would be a great tool to show camp's energy progress and accumulation and should be purchased alongside the recommended solar system.

3.5.4 Adult Educational Programs

As part of the educational outreach portion of the Camp Michigania Master's Project, adult education materials were developed to provide a way for interested adults to learn more about renewable energy technology options. While a complete educational program is outside the scope of this project, two small programs were developed in order to provide a jumping off point for discussion, and to serve as a basis for future sustainability coordinators or SNRE Master's Project teams to develop more fully later on.

3.5.4.1 Program details

These programs took the form of a multimedia presentation, to be presented by the sustainability coordinator. The program meets two key needs: 1.) providing enough information that campers who are unfamiliar with the subject can gain a basic knowledge of the material to facilitate discussion, and 2.) the material is clearly designed and instructed so as to make a sustainability coordinator (who will likely have no training in this field) comfortable presenting to campers.

The program is not a comprehensive overview of the prepared topics. Such a task would be impossible in the short time frame allotted for presentation and discussion. In addition, it is not intended to serve the needs of campers who are already experts in this field, as the information contained in the presentations is extremely basic and does not delve deeply into any one aspect of renewable energy technology. More advanced campers may be interested in the handouts that are available with each program, more than the presentation, as the handouts are those developed by SNRE's Center for Sustainable Systems and updated regularly. Within the package materials is a link to CSS's website, with instructions for the sustainability coordinator to ensure that the most up-to-date materials are being used.

3.5.4.2 Program Topics

- Solar Technology
- Wind Technology

3.5.4.3 Program Materials

Each program comes with the following materials:

- Instructions for the Sustainability Coordinator
- Fact Sheets developed by the CSS for distribution to interested campers
- PowerPoint presentation, including notes for the Sustainability Coordinator's reference

These materials are included in Appendix V of this report.

3.5.4.4 Program Outline

Each program has the same coordinator instructions, with slight variations to fit the specifics of the program. Fact sheets should be printed off and available to participants when they arrive, and the PowerPoint downloaded and prepared. The entire program is intended to be one hour, with the presentation taking up 20-25 minutes. The remaining time is intended as an opportunity for discussion in order to engage participants, rather than a straight informational session. The program can then continue as the campers see fit, ending early if they are not interested in discussing or lasting longer if the discussion is engaging.

3.5.4.5 Limitations

As with all things technology related, these programs will likely quickly become outdated. A few safeguards have been put into place to extend the life of these programs (such as the recommendation to ensure the most updated fact sheets are used), but ultimately technology will advance beyond the point where these presentations are useful. For this reason, they are being put forth as a guide more than a complete educational program, to be edited and expanded as the sustainability coordinator sees fit.

3.5.5 Staff Educational Letter

A letter should be constructed in order to inform incoming staff about the sustainable changes made at Camp Michigania. This letter is to be distributed during staff training week and staff should do their best to memorize the information. There is constant interaction between campers and staff and campers use staffers as a source of information, because of this, it is important that staff is able to provide correct information when questioned or at least be able to refer campers to where they may find information on the project. The letter should contain the type and size of system that camp decides to go with along with information about when the system went up. This letter should also contain information on who campers can talk to if they are interested in donating to the project.

3.6 Key Findings

In order to increase energy awareness and understanding of the new solar system at Camp Michigania, it is recommended that the education materials, including the adult programs and children's activity booklet, be put to use by the sustainability coordinator. By using these materials, the sustainability coordinator role can become more of an educational role, potentially producing greater understanding of sustainability issues and more positive outcomes and participation in the current sustainability initiatives at camp.

There are two purchases that we recommend Camp Michigania to make in order to increase effectiveness of energy understanding and to promote positive camper feedback: TED energy monitor and a Solar Photovoltaic Energy Interface.

3.6.1 Education Conclusions

The installation of a solar photovoltaic system at Camp Michigania is more than just an opportunity to reduce Camp Michigania's CO_2 emissions and to become less energy dependent; it is a chance to reach a widespread audience. This allows an opportunity for an increase in knowledge and understanding about energy issues and choices, as well as potential options for changes they could make in their own homes and communities.

4 Technical Considerations and Analysis

4.1 Energy Demand

In helping to understand what type of renewable energy application to use and where to site the system, an important step was to collect the energy demand data of the camp. The local utilities were contacted in order to obtain detailed reports showing use and cost for the last several years at Michigania. Great Lakes Energy (GLE) provides electricity to the camp and Petoskey Propane provides propane for water heaters and some appliances. One caution taken with the data is the understanding that Michigania continues to grow and some activities have been shifted from one building to another. For instance, a new Dining Hall was constructed in early 2010, so the data was analyzed with that in mind. Also, a new Arts & Crafts building was built in 2008. More recently, the West Pole Barn was built in 2009 and the maintenance staff reported that the plan is to move more work from the current maintenance shop, located in the Maintenance Barn near the Dining Hall, to the West Pole Barn, so an increase in electricity is likely to be seen there in future years.

4.1.1 Michigania Electricity Use

Great Lakes Energy was able to provide electricity use and cost information invoiced since January of 2007 through 2012 for the 23 meters located around the camp. During a visit to camp in May, 2012, team members were able to locate and identify all 23 meters and match the meter number to the account on the invoice. **Table 3** highlights the electricity use for 2011 and 2012. Through this data, it was found that during 2012 and over the past six years total, three locations total 60% of the total camp's electricity use: the Dining Hall, Education Center, and Arts & Craft Building.

Table 3: Summary Electricity Use Data for 2011 and 2012. More detailed information can be found in Appendix VI.

Location	2012 Electricity Used (kWh)	2011 Electricity Used (kWh)	% of 2012 Total Electricity	% Change Full Year 2012 vs. 2011
Dining Hall	122,360	109,360	31%	12%
Education Center	85,160	71,880	22%	18%
Arts & Craft Bldg (New in 2008)	24,080	24,120	6%	0%
All Other Locations	156,929	116,324	40%	35%
Total	**388,529**	**321,684**	**100%**	**21%**

Focusing on the largest user, when the new Dining Hall was constructed, the use of electricity during the summer camp season of 2010 increased by 55% compared to 2009. Note that this computation removed the construction phase of the new Dining Hall as that was performed prior to the camping season. Also of note is the increase of electricity use of 2012 compared to 2011. For only the camping season (June – August), use increased by 15% for 2012. For the entire year, use increase by 12%.

Figure 5 shows a slight steady increase in electricity use from camp seasons 2007 through 2009, then a significant increase from 2009 to 2010 when the new Dining Hall was built. The 2011 camp season was similar to 2010, but 2012 showed a 12% increase. Staff has indicated part of this increase in 2012 may be due to air conditioning added in 2012 to the exercise room in the lower level.

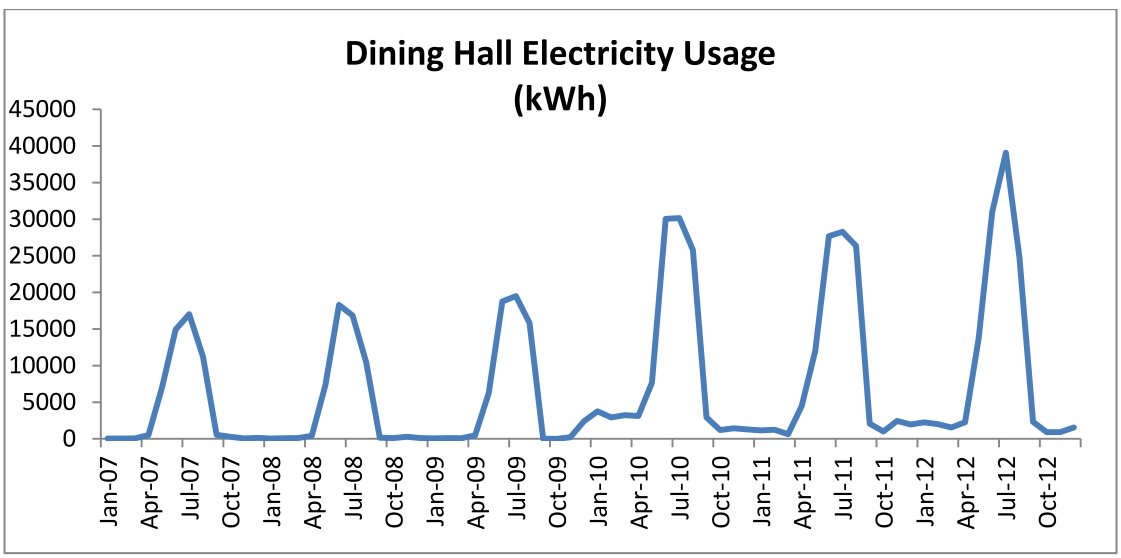


Figure 5: Dining Hall Electricity Usage.

It was found that during the off season (September – March) the new Dining Hall averages 1600 kWh in electricity use per month. Since the Dining Hall is totally shut down during these months, a maintenance person investigated the energy usage, but the preliminary investigation only turned up the electric heater in the water room and a computer. It was reported that the temperature is supposed to stay around 45 degrees in the water room, so further investigation is warranted to understand if the electric heater is causing such a large draw of electricity, as the computer will not pull a significant amount of electricity. There may be other sources drawing electricity and this represents a savings opportunity through better understanding.

Table 3 above shows that overall electricity use at camp increased by 21% from 2011 to 2012. Michigania continues to grow from a physical building standpoint, and with that growth comes additional use of electricity. The West Pole Barn used for maintenance was added in 2009 and two staff cabins were added in 2012, just to list a couple additions. Although the camp is physically growing, over the last six years the population at camp has remained steady. Staff population has numbered around 110 people all six years, and total camper population was 4,438 in 2007 and 4,530 in 2012 (Rosenwasser, 2013). In looking at other reasons for the significant increase, one might consider temperature variation from summer to summer, but for the majority of camp that is not a consideration because there are very few locations (e.g., Education Center, Director's house, etc.) where air conditioning is used. Detailed graphical and tabular electricity information can be found in Appendix VI and VII.

4.1.2 Michigania Propane Purchases

Petoskey Propane was able to provide propane delivery and cost information invoiced since January 2007 through July 2012 for 19 Michigania accounts. During a visit to camp in May 2012, team members were able to locate 23 propane tanks and map their location (see Appendix VIII). However, a tank number was unable to be associated with an account during this visit. Months later the Michigania staff was able to provide location information for some of the accounts, with the Dining Hall being one of those. **Table 4** summarizes propane purchase information for 2010 and 2011. Since 2012 was a partial year, a comparison between 2010 and 2011 was performed.

Table 4: Summary Propane Purchase Data for 2010 and 2011.

Location	2011 Propane Purchases (gallons)	2010 Propane Purchases (gallons)	% of 2011 Total Propane Purchased	% Change Full Year 2011 vs. 2010
Dining Hall	5,094	6,764	19%	-25%
Education Center	3,612	9,488	13%	-62%
South Cabin 6 & 7	2,780	2,814	10%	-1%
All Other Locations	15,661	14,707	58%	6%
Total	**27,147**	**33,774**	**100%**	**-20%**

Focusing on the Dining Hall as the largest propane user, it uses propane for heating the two 125 gallon Lochinvar water tanks that provide the majority of hot water to the Dining Hall. There is a small electric hot water heater near the bathrooms. Propane is also used for some of the appliances in the kitchen. On a positive note, propane use decreased from 2010 to 2011 by 25%. When comparing the old and new Dining Halls, it is too difficult to determine when the propane was actually used in 2010 for standard camp activities versus used for building the new building. Therefore a comparison between 2009 and 2011 is a better approach and shows that propane use went down by 31% (7,375 gallons in 2009 versus 5,094 gallons in 2011). The exact reason for this reduction is unknown, but a likely cause is the increased efficiency of the new water heaters and appliances that were purchased for the new Dining Hall. **Figure 6** shows a varied purchase pattern for the Dining Hall over the last 5 & ½ years, with overall purchases declining in the years since the new Dining Hall was built in 2010. More detailed information for all Michigania propane sites can be found in Appendix VIII and IX.

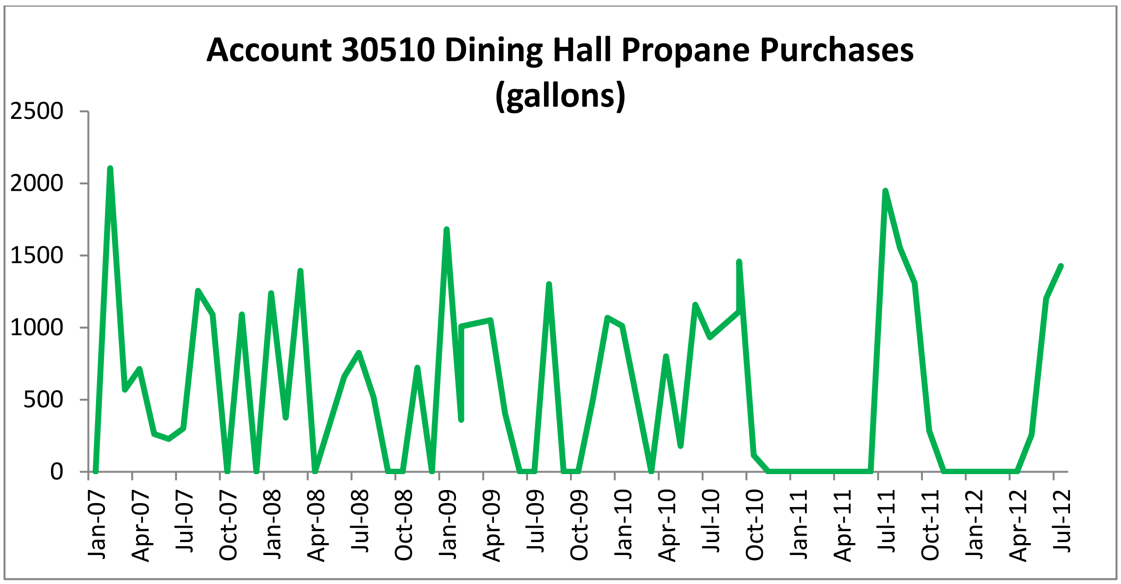


Figure 6: Dining Hall Propane Purchases.

4.2 Siting

4.2.1 Site Assessment

One of the principle objectives of this project was to assess the solar resource availability at Camp Michigania. Site solar insolation data was retrieved from the National Renewable Energy Laboratory (NREL); however more information was needed to fully assess renewable energy options for camp. Multiple data collection assessments were made at camp over the course of a year to determine how site-specific factors would impact solar photovoltaic performance.

4.2.1.1 Assessment Criteria

The conversion efficiency of solar panels (how well the panels convert sunlight into electricity) depends on four factors, the strength of sunlight penetrating the atmosphere, the orientation of the panels with respect to the rays of incoming solar radiation, panel shading, and the cleanliness of the surface of the panel. Since it is impossible to control sunlight availability at a site, our analysis focused on optimizing the remaining three factors.

4.2.1.2 Panel Orientation

To collect as much sunlight as possible, it is best to orient a solar panel to maximize the area normal to (facing) the direction of the sun's rays. The efficiency of a solar panel is proportional to the cosine of the angle between the incident rays of sunlight and the panel surface as shown in **Figure 7**. Consequently, to optimize the output of the panels at any given moment, the panel should be oriented orthogonal (normal) to the incoming sunlight.

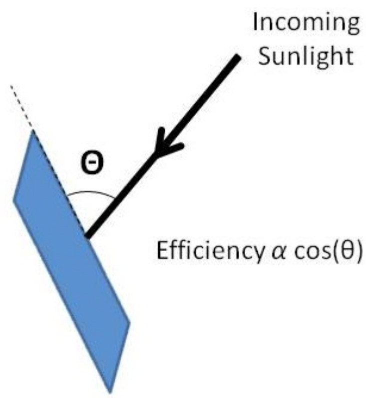


Figure 7: Panel efficiency is proportional to the cosine of the angle of incidence.

This would be easily achieved if the sun stayed in a fixed position when viewed from a point on earth, but obviously this is not the case. To account for the moving source of incident light, tracking systems can be employed. One axis tracking systems rotate the panel on a vertical axis to point the panel at a different compass heading throughout the day to keep the panel pointed at the sun. Two axis tracking systems also account for the elevation of the sun (the angle of the sun in the sky relative to the horizon), which is shown in **Figure 8**. These tracking systems tilt the panel on a horizontal axis to keep the panel pointed at the sun. This second axis of rotation is particularly useful in regions with large differences in solar elevation among seasons (closer to the earth's poles where the solar elevation is high in the summer but low in the winter). Because of the weight and size of the hardware needed to rotate and tilt the panels, solar panels that employ tracking systems are typically ground mounted.

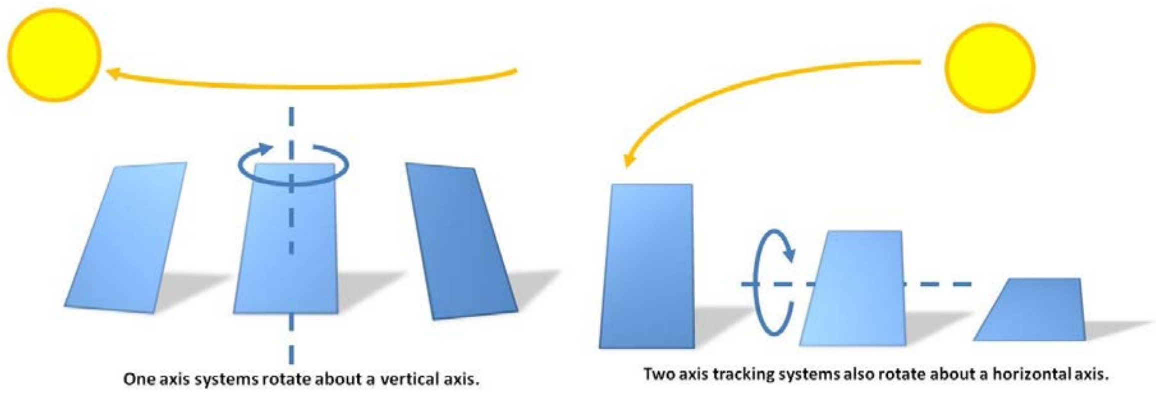


Figure 8: One axis and two axis tracking systems rotate panels to face the sun.

Though tracking systems improve the panel efficiency, they add significant cost to the solar installation. This cost needs to be weighed against the monetary value of the extra electricity produced verses a non-tracking system. If tracking systems are uneconomical (or there is not sufficient space for them), solar panels can be roof-mounted. Typically, panels should face south and should be mounted at an angle equal to the latitude of the site to maximize efficiency. This orientation theoretically maximizes the area of the panel orthogonal to incoming sunlight (**Figure 9**). However, empirical data from NREL showed that for Traverse City, MI (the closest city to Camp Michigania for which data was available), a 30° mounting angle is optimal for non-tracking PV systems despite having a latitude of 45° (**Figure 10**). Fortunately 30° is the angle of many of Camp Michigania's roofs, allowing the panels to be mounted directly on the roof to maximize output while simultaneously negating the cost of pitch angle adjustment hardware.

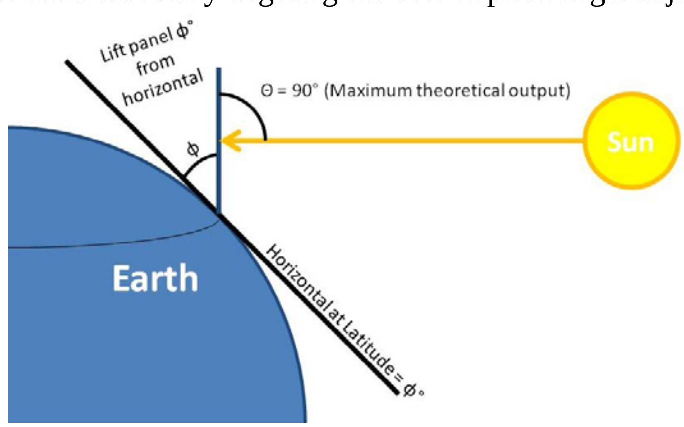


Figure 9: Maximize panel output by tilting at angle equal to site latitude.

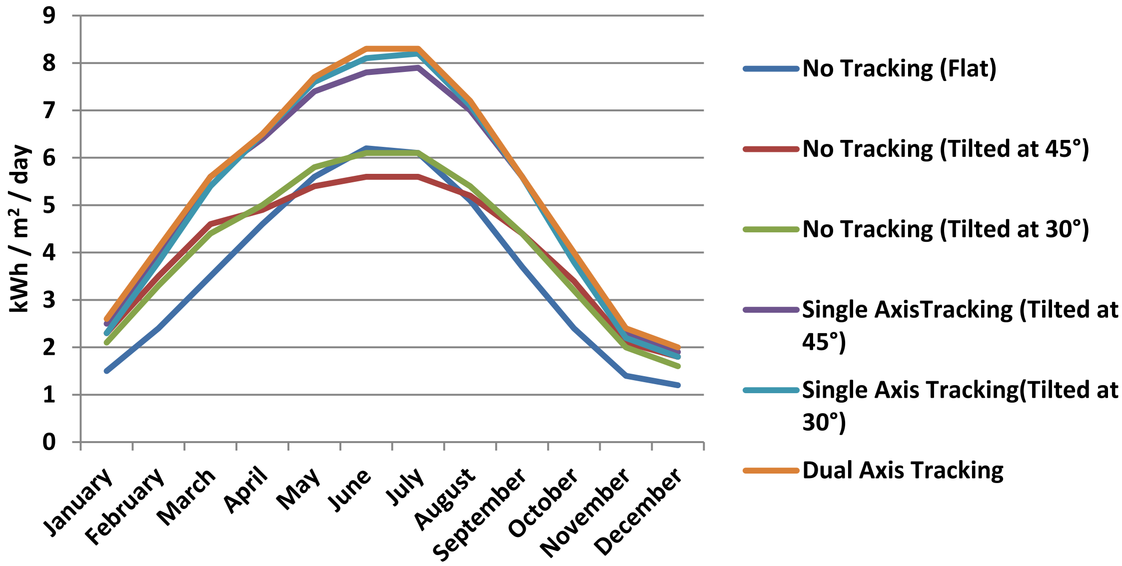


Figure 10: 30 year average solar insolation for Traverse City, MI for various system configurations. Adapted from (NREL, 1990)

4.2.1.3 Panel Shading

Panel shading can be a serious problem if proper design criteria aren't considered. When obstructions such as trees and buildings cast shadows on solar panels, electric output is significantly diminished. Because of the way the solar cells in an individual panel are wired, shading a small fraction of a panel can reduce panel output by more than the fraction of the panel area that is shaded (**Figure 11**). The effects of individual panel power reduction can be limited by the use of bypass diodes (that direct current around the shaded panel) for systems that use a central inverter. Another strategy to overcome shading problems is by using microinverters on each panel. With microinverters, power is collected individually from each panel and inverterted before being centrally collected. In this configuration, one panel's performance does not affect the performance of other panels in the system. However, it is important to select sites that are not partially or fully shaded for a significant portion of the day to maximize electricity generation.

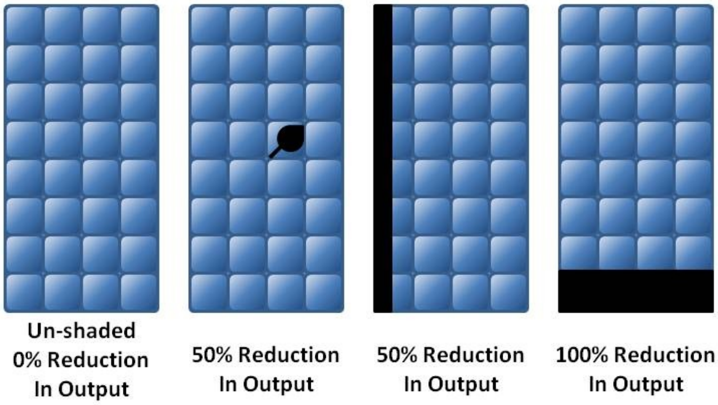


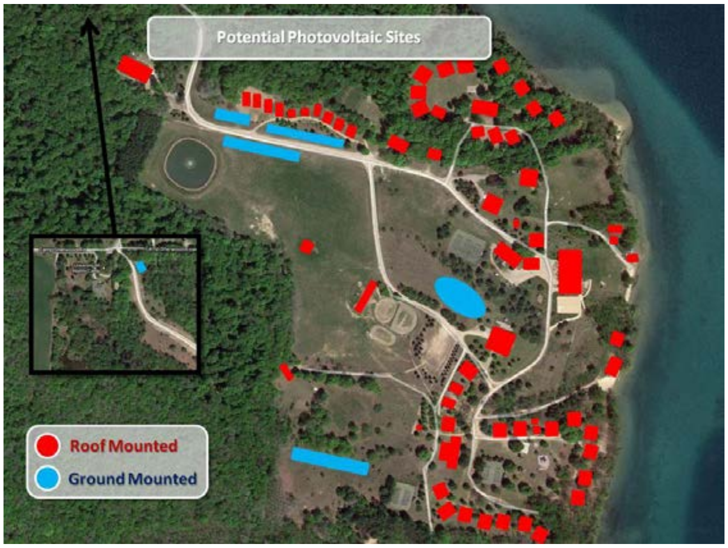
Figure 11: Disproportionate single-panel reduction in power from partial shading. Using microinverters or bypass diodes prevents this problem from adversely affecting the whole PV array. Adapted from (Wholesale Solar)

4.2.1.4 Panel Cleanliness

The surface of a solar panel needs to be kept clean to ensure maximum performance. Dirt, leaves, snow, and bird droppings decrease the panel's performance by shading small portions of the panel's surface. As shown in **Figure 11**, small blemishes on the panel's surface (local shading) can have disproportionately large impacts on power output. Thus it is important to consider factors that affect panel cleanliness when siting a solar photovoltaic system. Proximity to dirt roads can cause dirt to accumulate on panels. Proximity to trees increases the chances that leaves will fall on the panels (in addition to overall shading from tree shadows). Panels that are mounted at a shallow angle can accumulate snow which shades the cells and significantly diminishes power output from the shaded panels. Panel cleanliness issues can be addressed by regular maintenance (washing with clean water), and by mounting the panels at an angle sufficiently large enough to cause snow to slide off. Rain can also be useful for keeping the surface of solar panels clean.

4.2.1.5 Site Assessment

Using aerial data and ground verification, potential solar panel sites were selected for Camp Michigania. An inventory of all roofs and open areas were collected and then systematically eliminated based on failure to meet the assessment criteria outlined in the previous section (pitch angle, excessive shading, or proximity to sources that would make the panels dirty). Remaining sites that were too small to be economical or too distant from electricity loads were also eliminated. **Figure 12** shows the process of elimination used in order to define realistic potential sites.


Potential Photovoltaic Sites
Roof Mounted
Ground Mounted

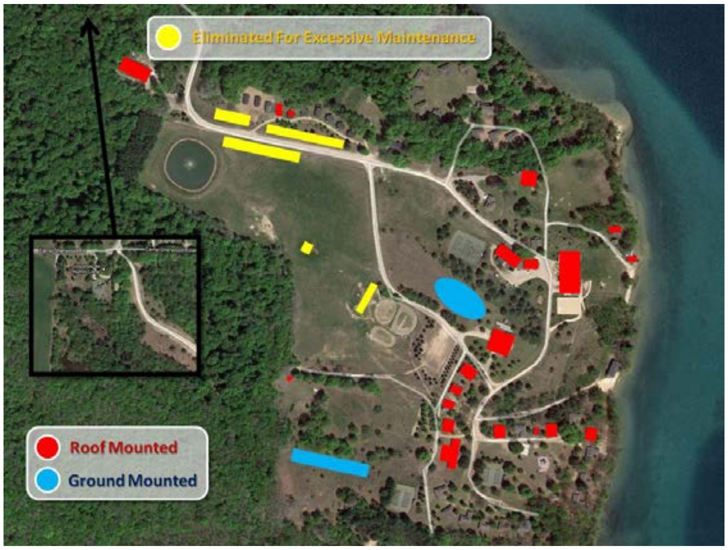
A)


Eliminated For Too Much Shade
Roof Mounted
Ground Mounted

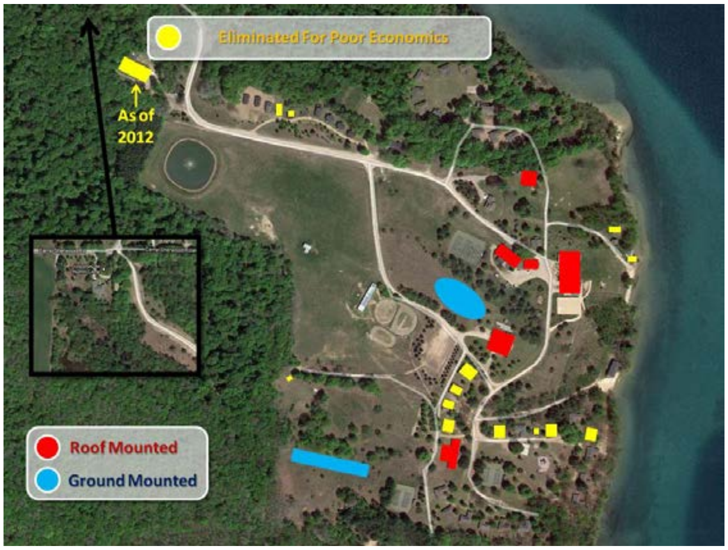
B)


Eliminated For Poor Roof Alignment
Roof Mounted
Ground Mounted

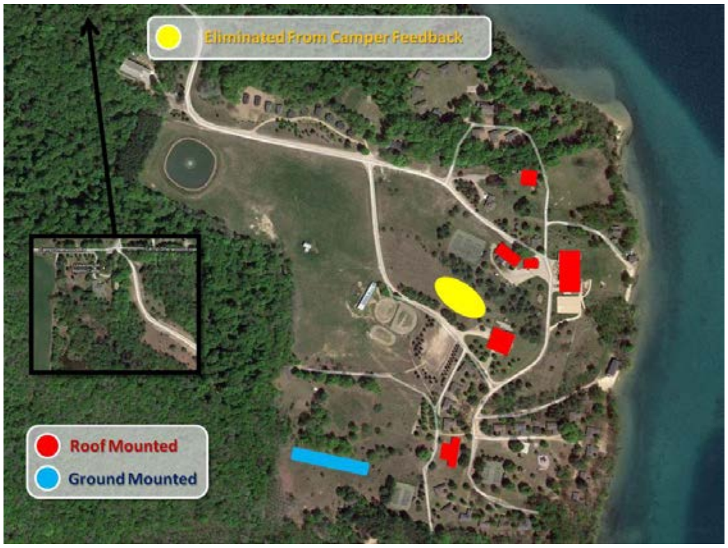
C)


Eliminated For Excessive Maintenance
Roof Mounted
Ground Mounted

D)

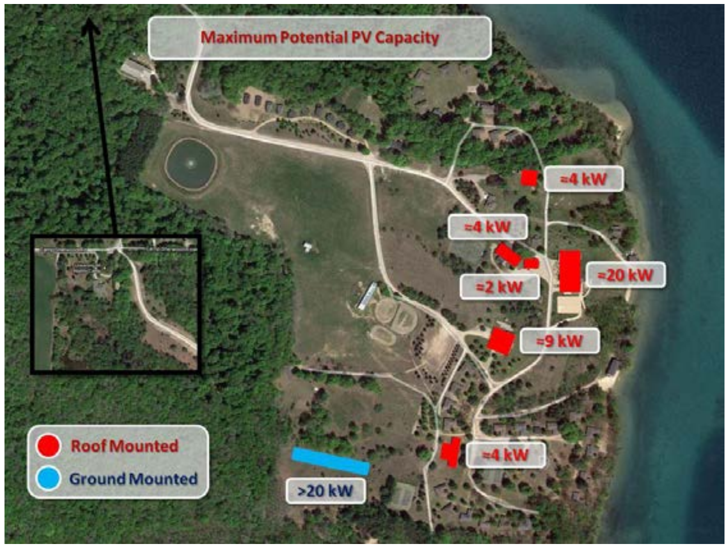

Eliminated For Poor Economics
As of
2012
Roof Mounted
Ground Mounted

E)


Eliminated From Camper Feedback
Roof Mounted
Ground Mounted

F)

G)



H)

Figure 12: Solar Panel Site Selection and Elimination. A) Potential solar PV sites, B) Sites eliminated for excessive shading (yellow), C) Roof sites eliminated for poor roof angle (yellow), D) Sites eliminated due to potential dust problems (yellow), E) Sites eliminated for economic reasons (yellow), F) Sites eliminated due to camper perception (yellow), G) Remaining viable solar PV sites with approximate capacities, H) Sites saved for future analysis (yellow). This project only focuses on the two remaining sites (red).

4.2.2 Zoning

Camp Michigania is located in Bay Township within Charlevoix County. Per the Charlevoix County website (Charlevoix County, 2013), the local communities have zoning authority. So the zoning administrator of Bay Township, Ron VanZee, was contacted to ask about any specific zoning ordinances related to renewable energy and specifically solar, and his e-mail response is copied below:

> Bay Township Planning Commission is currently working on wind energy (turbine) ordinances but (has) not completed them as of now. Solar energy collectors are considered structures if they are independent of a principal structure and would fall under the total lot coverage and setback requirements in section 5.4 of the ordinance. If they are independent they would also fall under the accessory structure section. (VanZee, E-mail: Zoning 1, 2013)

A follow up question regarding solar panels on an existing structure (e.g., roof of the Dining Hall) was posed and below was his response:

> The maximum height of any structure is 30'. As long as that height is not exceeded, you should be fine. (VanZee, E-mail: Zoning 2, 2013)

So based on these responses, there are no zoning ordinances that will represent a roadblock for Michigania to install solar. Appendix X provides additional information obtained from a Michigania camper who lives in the nearby area and installed a solar energy system in late 2012; he reported no zoning problems.

4.3 Selected Technology (PV)

4.3.1 Predicted Performance / Solar Model

Based in the selection criteria outlined in the Site Assessment, the performance analysis for this project was focused on solar panels without single or multi-axis tracking hardware. Fixed (non-tracking) solar panel performance is a function of many factors, namely material type, quality, size, site, shading, orientation, pitch angle, and age. These factors were compiled into a performance model that was used to conduct economic analysis on each contractor-proposed solar photovoltaic system.

As mentioned in the Site Assessment section, solar panels should be oriented as closely to geographic south as possible. Also, panels should not be placed in areas with excessive shading. The selected sites at Camp Michigania allow for near optimal performance on these criteria so their effects were excluded from the model. To determine the solar resource availability at the site (near Traverse City in the northern part of Michigan's Lower Peninsula), solar insolation data from the National Renewable Energy Laboratory (NREL) was studied. NREL has compiled daily insolation data for many decades at a reference site less than 70 miles from camp. This data gives a long term expected insolation for northern Michigan and would surpass the accuracy of manually collected data at the site for the duration of this project. Our research did not find any factors that would indicate a significant variation in solar insolation between NREL's reference site and camp, and consequently this data was used. Average daily insolation data from NREL is shown in **Table 5**. Values are given for surfaces at pitch angles ranging from 0°, 30° (the pitch angle of the roofs of the selected camp buildings), and 45° (the latitude of camp).

Table 5: Average Daily Insolation Data. Values given are in average kWh / m^2 / day. Source: NREL.

Pitch Angle	January	February	March	April	May	June	July	August	September	October	November	December
0° (Flat)	1.5	2.4	3.5	4.6	5.6	6.2	6.1	5.1	3.7	2.4	1.4	1.2
30° (Roof)	2.1	3.3	4.4	5.0	5.8	6.1	6.1	5.4	4.4	3.2	2.0	1.6
45° (Latitude)	2.3	3.5	4.6	4.9	5.4	5.6	5.6	5.2	4.4	3.4	2.1	1.8

As **Table 5** shows, the optimal pitch angle for the solar insolation happens to be the angle of the roofs at camp. This allows for maximum output for solar panels mounted directly to the roof without needing hardware to optimize pitch angle which saves system costs. With the insolation data from **Table 5**, it is possible to predict the average annual electricity generation from a solar panel with the following formula:

$$\boldsymbol{E_{gen} = \sum_{month=1}^{12} F_{\theta,month} * A * \eta_{panel} * \eta_{inverter} * t}$$

$$E_{gen} = Energy\ generated\ \left(\frac{kWh}{year}\right)$$

$$F_{\theta} = Radiant\ energy\ on\ surface\ at\ angle\ \theta\ \left(\frac{kWh}{m^2 day}\right)$$

$$A = Area\ of\ panel\ (m^2),$$

$$\eta_{panel} = Panel\ Conversion\ Efficiency$$

$$\eta_{panel} = Inverter\ Efficency$$

$$t = time\ \left(\frac{days}{month}\right)$$

Often, the conversion efficiency of a panel (η_{panel}) is not explicitly stated from the manufacturer. However, because the peak power rating of a solar panel is defined as the power output when exposed to 1000 W/m^2, the efficiency can be calculated with the following formula:

$$\eta_{panel} = \frac{P_{peak}}{A * 1000 \frac{W}{m^2}}$$

$$\eta_{panel} = Panel\ Conversion\ Efficiency$$

$$P_{peak} = Peak\ Power\ (W)$$

$$A = Area\ (m^2)$$

Thus a 220 W-peak 1.6 m^2 panel has a conversion efficiency of about 14%. Assuming an inversion efficiency of 98%, the expected first year electricity generation for this solar panel (given the insolation data shown in **Table 5**) is shown in **Table 6**.

Table 6: The expected first year electricity generation from a 220W solar panel.

Pitch Angle	First Year Panel Output (kWh)
0° (Flat)	339
30° (Roof)	383
45° (Latitude)	378

As with any electrical system, a solar panel's performance fades with age. Typically manufacturers state a first year peak power rating and guarantee a certain fractional performance over the expected lifetime of the panel (eg. 75% of original power after 25 years). To model lifetime system output, panels were assumed to last for the exact duration of the warranty (any output after the warranty period can be considered a bonus). It can be shown that a panel that linearly degrades to 75% of its first year output after 25 years will produce 21.9 times the first year output over the life of the panel. With these assumptions the model can predict expected system generation. An example for the 220-W panel is shown in **Table 7**.

Table 7: The expected lifetime electricity generation from a 220W solar panel.

Pitch Angle	Lifetime (25 year) Panel Output (kWh)
0° (Flat)	7,422
30° (Roof)	8,383
45° (Latitude)	8,279

4.3.1.1 System Payback

Using the expected electricity generation from the photovoltaic array, the system's complete installation cost, the cost of electricity, and inflation & depreciation rates, the net present value of installing the system can be calculated (for calculations on specific examples see Appendix XI). Inflation rates were calculated from the long term price trends in electricity to predict the value of avoided electricity purchases for each year of the system's lifetime. Values were depreciated to present dollars using an optimistic contemporary annualized savings rate. These present value calculations determine whether or not the system makes economic sense and also gives a payback period (the length of time before the system reduces energy bills in present dollars by an amount equivalent to the complete installation costs). This price model was used in negotiations with solar panel vendors to verify energy generation claims and to compare quotes for systems with differing performance characteristics.

4.3.2 Net Metering

It is important to note that the performance and cost models assume that electricity generation will have the same monetary value to the client as an equivalent amount of electricity purchased from the local utility. Deviations from this assumption change the payback period of the PV system dramatically. In some areas, customers receive feed-in tariffs for electricity generation that are worth more than the purchase price of electricity. In other areas, customers are limited to selling electricity back to the utility at wholesale prices. However, Camp Michigania's local utility (Great Lakes Energy) employs net metering (the customer is billed for the difference between consumption and on-site generation). In the event that on-site generation exceeds electric demand in any given month, the difference in price is credited to future billing cycles. However, Great Lakes Energy imposes 2 rules on their net metering customers:

- Photovoltaic systems connected to a single meter must be less than 20 kW-peak to be compensated for electricity generation at a rate equal to the customer's typical purchase price. Larger systems are divided into tiers (based on peak power) with larger system receiving a successively smaller fraction of the customer's typical purchase price per kWh.
- A system cannot be sized to regularly generate more energy than the demanded energy on that meter (seasonal variability may allow for net generation billing cycles but these should overall be balanced by net consumption billing cycles).

To achieve maximum sustainability performance, Camp Michigania's leadership team would like to construct as large of a system as budgets and regulations allow. Systems smaller than 20 kW-peak receive the maximum credit per kWh. Since Michigania's proposed photovoltaic sites are connected to meters that far exceed the expected output of a 20 kW photovoltaic array, the second constraint is not applicable. Thus any systems smaller than 20 kW/meter would be appropriate for camp's goals.

4.4 Selection and Vetting Process

To ensure the cost-effectiveness of implementing solar PV at Camp Michigania, reviews were conducted to assess all proposals from four selected Michigan solar PV vendors, namely, The Green Panel, Greenlife, Michigan Energy Works, and Sunventrix. The assessment process is described in Figure 13.

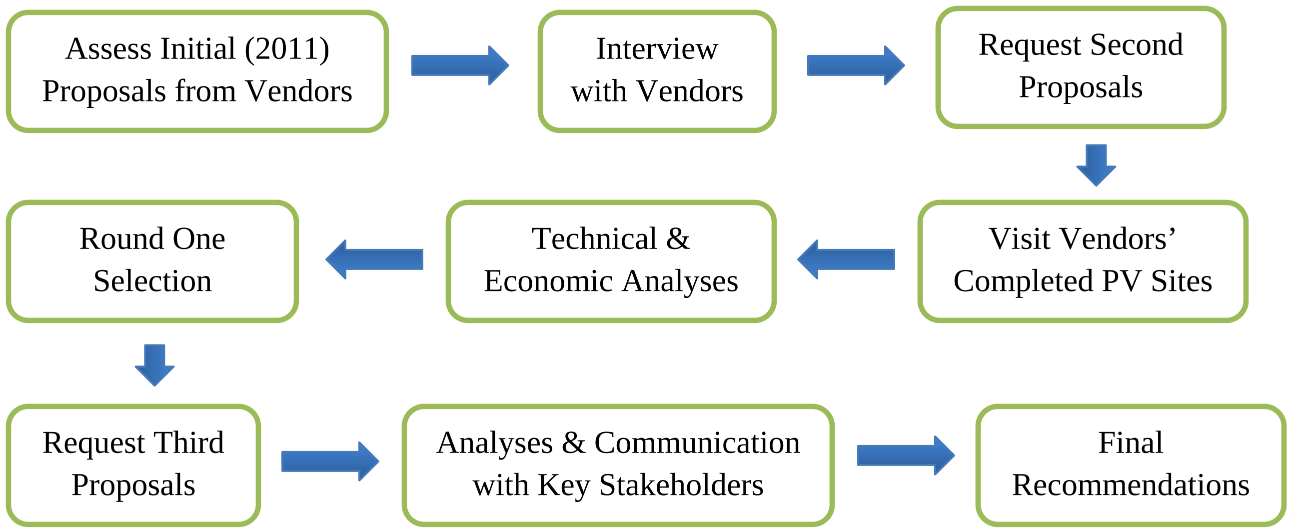


Figure 13: Selection & Vetting Process.

4.4.1 Results of Selection

After the interviews with all the vendors in June 2012, Michigan Energy Works was phased out because the company never responded to the request. All the other vendors demonstrated great interests in continuing the work with Camp Michigania and agreed to submit secondary proposals before October 2012 based on the assessment results and suggestions from the technical team.

The technical team finished the assessment of secondary proposals in October 2012 by analyzing technical specifications of proposed solar products (PV panels, inverters and solar thermal panels) and by using a developed spreadsheet to calculate the present value and payback time of each proposal.

The Green Panel was phased out after this round due to the long payback time, panel brand choice (non-U.S.), inflexibility with the system size and major change within its management team. Greenlife was required to submit a third proposal to decrease its cost of SunPower panels, the most efficient panels among the proposals.

The technical team updated the analyses based on Greenlife's new proposal, which lowered the cost by sacrificing high-efficiency SunPower panels. **Figures 14** & **15** show the final solar PV system Net Present Value (NPV) analysis results of Sunventrix and Greenlife. Appendix XI shows the detailed analyses.

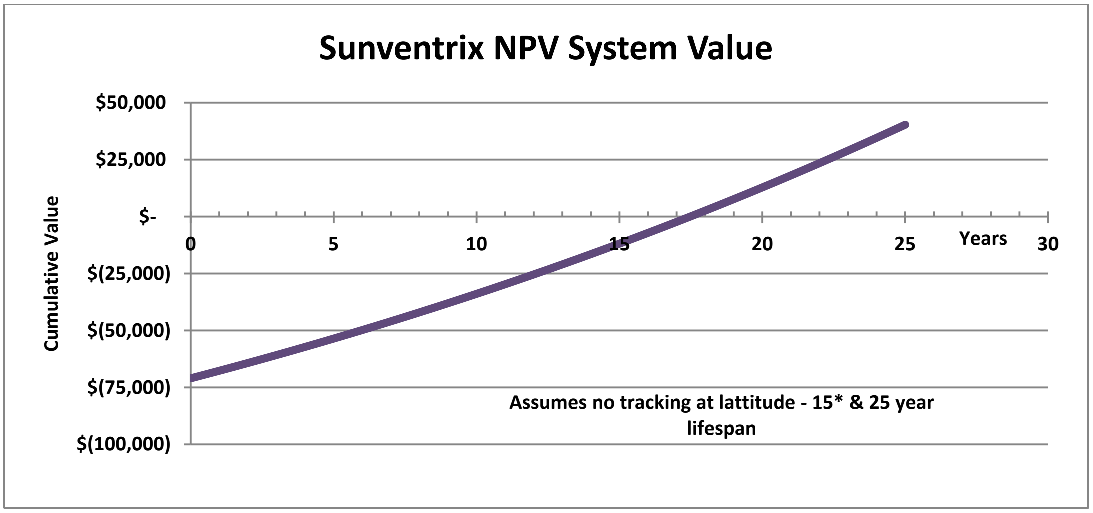


Figure 14: Sunventrix NPV System Value.

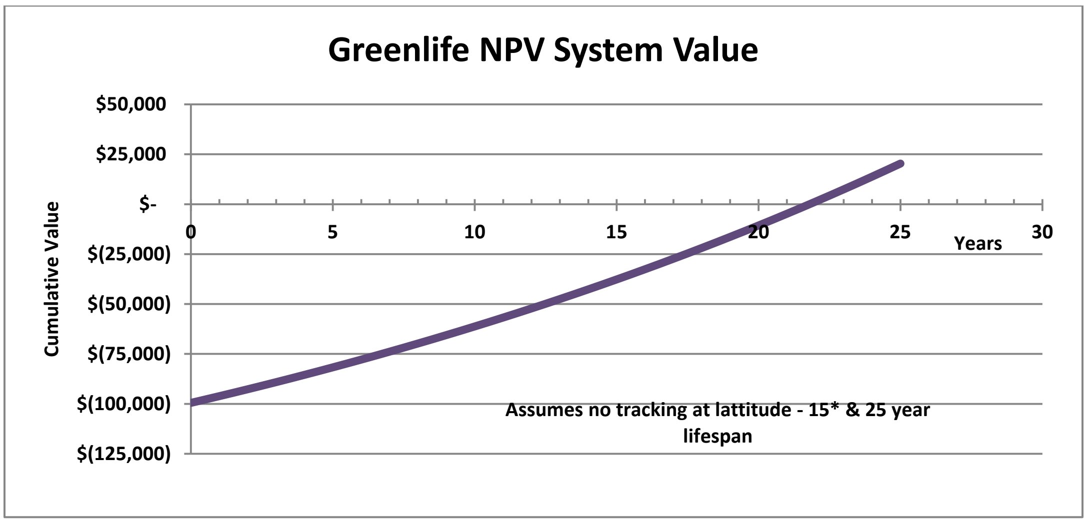


Figure 15: Greenlife NPV System Value.

A solar thermal system was also eliminated because of its long payback time and potential maintenance burden for camp staff. Detailed discussions are presented in a later section.

The team exchanged ideas with the client and the advisor, and made final suggestions that Sunventrix should be considered the primary vendor for Camp Michigania's solar PV project. **Figure 16** provides information about Sunventrix and lists positive and negative aspects that were considered.

Sunventrix

General Profile:

Mark Hildebrandt, the owner of Sunventirx, is a first-year camper. Sunventrix is a three-year old solar vendor based in Southeast Michigan. Mark has solid experience in residential solar projects and a couple of commercial projects, including the 19.6 kW project on McKinley center in downtown Ann Arbor.

Proposal Summary:

Various proposals for solar PV and one proposal for solar thermal

Site Visit:

Multiple residential PV sites and McKinley center

Pros:

- Very detailed proposals
- Mark is a great guy to work with and he is a camper himself
- Competitive cost
- Enphase micro-inverters

Cons:

- No solar thermal experience
- Relative limited experience of commercial projects
- Self-employed

Figure 16: Qualitative Analysis of Sunventrix.

The final proposal from Sunventrix is presented in Appendix XII.

4.5 Other Sustainable Strategies

4.5.1 Solar Thermal (Solar Hot Water)

Of all the other renewable energy systems considered and not recommended, solar thermal was the technology we invested the most time in. We met with two solar thermal vendors and spent extensive time finding reliable factors to use in calculations, performing analysis, and double checking calculations.

4.5.1.1 Technology Overview

Solar Thermal, or the term Solar Hot Water that more aptly describes what was investigated for Michigania, is a technology that has been around for centuries. The sun’s radiation is able to heat up water that can either be used directly as potable water, or the fluid in the tubes can be used to heat up water through a heat transfer process. Solar power replaces the need for propane to heat the water. Operation steps are listed below and **Figures 17** and **18** show a brief pictorial representation of a system. A more detailed pictorial representation can be found in Appendix XIII.

Step 1: The absorber coating on the inner glass tube absorbs sunlight and converts it into heat.

Step 2: Steam forms inside heat pipe which transfers heat rapidly up to the manifold.

Step 3: A pump circulates water or heat transfer fluid through the header pipe, carrying heat back to the storage tank. Gradually throughout the day the tank is heated up.

The tank can be boosted by an electric element, gas/oil boiler, or the solar tank can simply feed an existing water heater tank with solar pre-heated water. (Apricus, 2013)

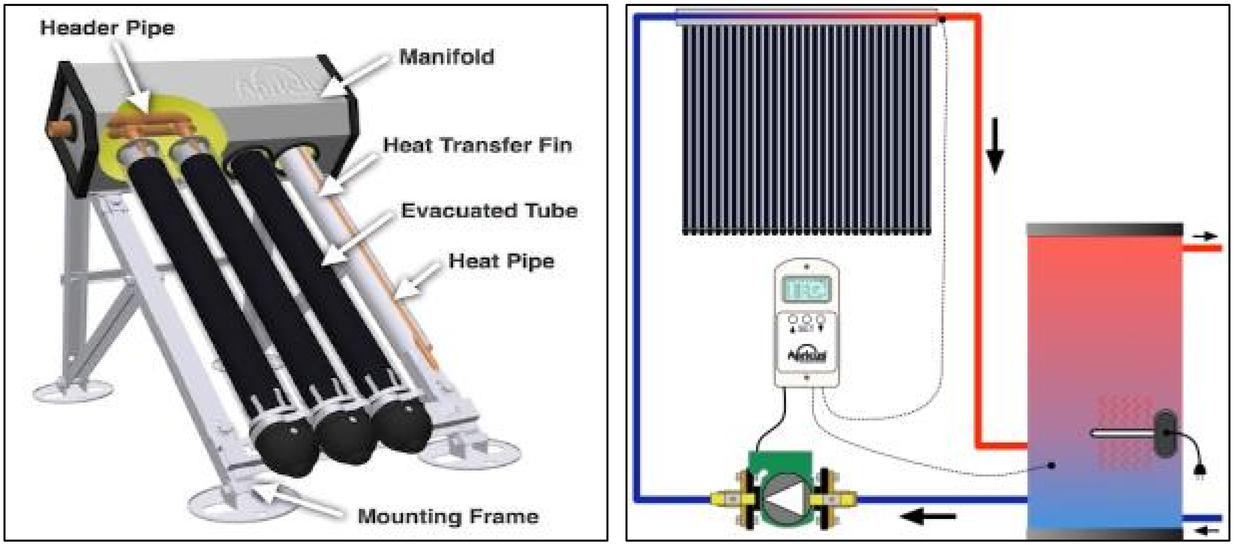


Figure 17: Construction (left) and Operation (right) of an Apricus solar collector (Apricus, 2013).

Figure 18: Front (left) and side (right) views of a mounted Apricus solar collector. Right picture shows where fluid is piped through the roof line (Apricus, 2013).

4.5.1.2 Siting

During a visit to camp in May 2012, team members looked at various roofs to understand both their compass direction and roof angles. The Dining Hall and Education Center used the most propane as seen above in the Michigania Propane Purchases section of this report, so those two buildings became the focus. The Education Center has two main problems. One is that the roof is quite high off the ground with no flat roof nearby, so any maintenance would be dangerous. Second is that although the roof faces in a somewhat southwest direction which is good, there are two trees growing near the area that will start to shade the roof line likely within the next 5 years and initial feedback indicates an unwillingness to cut them down. The one benefit of the Education Center is that it is used all year long.

The Dining Hall has excellent south facing roofs, with plenty of flat roofs surrounding the angled roofs, allowing easy and safe access for maintenance. There are also no trees in the area so shading would not be a problem. Another positive is that two of the roof sections are close to the drop-down shaft that runs to the water heaters, so installation would be easier and somewhat less costly. Therefore it was decided that vendors would use the Dining Hall for their bids.

4.5.1.3 Resource Availability / Calculations

The resource available for solar thermal is the same as that available for solar PV, and that is explained in the solar PV section. As mentioned above, we chose the Dining Hall for vendors to place their bids, but on significant obstacle from a payback standpoint is the fact that the Dining Hall is only used from May 1 through September 15.

For the first solar thermal quote given by Greenlife's subcontractor using an Apricus solar thermal system, they attempted to get around the partial year use of hot water by also providing heat to the water room during the off-season, thereby reducing electricity usage. After running a detailed analysis, the Apricus system would provide 32% of the hot water needed for the Dining Hall and the payback period came back as 33 years for a propane only scenario and 27 years when including heat for the water room during the off-season. See Appendix XIV for the detailed analysis.

For the second solar thermal quote given by Sunventrix' subcontractor using a Caleffi solar thermal system, they did not quote heating the water room in the off-season. Their system would provide 29% of the hot water needed for the Dining Hall, but due to their lower price the payback period would be 25 years. Note that there were questions about how many actual BTUs the Caleffi system could provide but those questions were never answered by the vendor. Since the payback period was longer than solar PV and the vendor was unresponsive, the team decided to no longer pursue further answers as solar thermal would be eliminated as described below. See Appendix XV for the detailed analysis.

4.5.1.4 Criteria for Elimination

Two primary factors were used to eliminate solar thermal from consideration. First, the payback period was greater than solar PV by about 7 to 9 years for both vendors. This was a surprise initially as numerous articles have listed solar thermal payback periods in the 4 to 8 year range. Two known factors contributed to longer payback periods for Michigania. One factor is that the Dining Hall is only used from May 1 through September 15, so they don't have the full twelve months each year to realize savings. Second is since Michigania is a non-profit, they do not qualify for the 30% tax credit and there are no other significant incentives they can get at the writing of this report.

The secondary factors used to eliminate solar thermal was the additional maintenance involved and the hesitancy on the part of the maintenance staff to take on such work when comparing to solar PV where very little maintenance is required.

4.5.2 Wind

4.5.2.1 Technology Overview

Wind is caused by the uneven heating of the earth's surface by incoming solar radiation. This uneven heating results in motion of air masses due to the thermal gradients on the earth's surface.

The kinetic energy of wind is converted to electrical energy by a wind turbine. The component within the turbine is an electrical generator, which consists of electrical windings surrounded by magnets. Other important components of a wind turbine are the blades, nacelle and shaft. The blades are aerodynamically designed to capture as much of the incoming wind energy as possible, and spin. The spinning wind turbine then spins the electrical generator through a gearbox (which simply increases the speed of rotation). This electrical energy generated can then be connected to the grid or to a standalone load. See figure below for a visual representation of a wind turbine. Wind power at a site can be quantified into different classes based on wind speed, as shown in **Figure 19**.

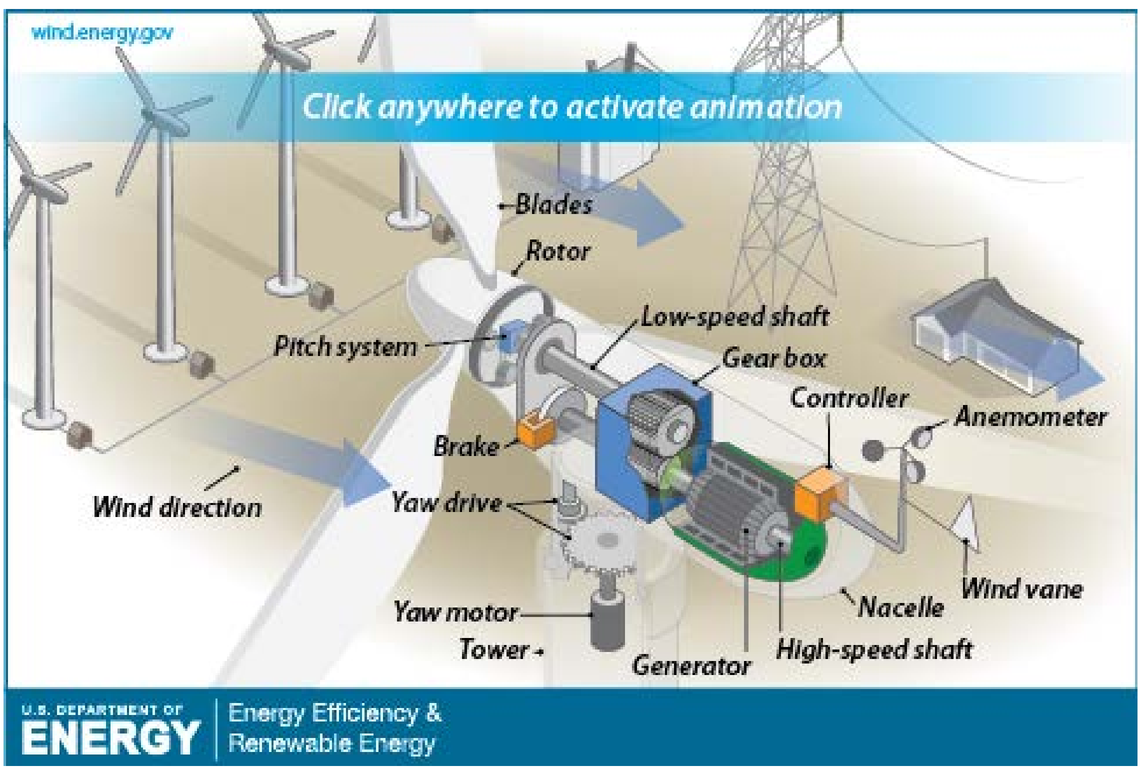


Figure 19: The different parts of a wind turbine. (US DOE EERE)

Table 8: Wind Power Classification (NREL 2001)

Wind Power Class	Resource Potential	Wind Power Density at 50 m (W/m2)	Wind Speed at 50 m (m/s)	Wind Speed at 50 m (mph)
2	Marginal	200 to 300	5.6 to 6.4	12.5 to 14.3
3	Fair	300 to 400	6.4 to 7.0	14.3 to 15.7
4	Good	400 to 500	7.0 to 7.5	15.7 to 16.8
5	Excellent	500 to 600	7.5 to 8.0	16.8 to 17.9
6	Outstanding	600 to 800	8.0 to 8.8	17.9 to 19.7
7	Superb	800 to 1600	8.8 to 11.1	19.7 to 24.8

4.5.2.2 Factors Affecting the Power Output from a Wind Turbine

- The main factor affecting the output of a wind turbine is the prevailing wind speed. **Table 8** shows how wind power is classified based on wind speed. **Figure 21** shows the wind speeds across different parts of Michigan at a height of 80 m.
- The wind speed is affected by the height of the wind turbine. This is because wind speeds tend to be higher at higher altitudes. Unfortunately, due to physical (sizing) and financial constraints, only 'small' wind turbines were considered for Camp. These operate at a height of about 30 m. **Figure 20** shows a wind turbine similar to one that was considered for Camp.
- The length of the turbine blades (and hence the cross-sectional area swept by the spinning blades) also affects the output from the turbine.
- The air density in a given area also affects the power output. The greater the air density, the higher is the power output.
- Sufficient open land area is also required to properly place the turbine.

Figure 20: An image of a small wind turbine. (Cascade Engineering)

4.5.2.3 Environmental Benefits of Wind Power

- Power produced from wind is carbon free.
- Life cycle CO_2 emissions from a wind turbine are the lowest of all existing energy generation sources.
- The Net Energy Ratio of wind is much higher than other sources of energy generation. Net Energy Ratio is a metric used to quantify the 'sustainability' of an energy source. It is the ratio of delivered energy in a useable form (normally electricity) to the energy input obtained from fossil fuels across the entire life cycle of the source. (Price & Kendall, 2012)

4.5.2.4 Criteria for Elimination

- Camp Michigania has plenty of trees, which greatly reduce the number of viable sites for placing wind turbines.
- Small wind turbines (of about 30 m height) were considered, but the outputs from these were found to be insufficient.
- The wind speeds at these heights (~ 30 m) at Camp during the summer months were found to be insufficient (shown in **Table 9**).

Table 9: Wind Speeds at Camp Michigania during different seasons (National Renewable Energy Laboratory)

Season	Average Wind Speed at 30 m height (m/s)
Summer	5.5
Fall	6.7
Winter	7.25
Spring	6.7

- Campers' responses from surveys indicated a strong dislike/aversion to wind power.
- The Camp Michigania management team's primary objective was to ensure that any renewable energy options considered fit with the camp's aesthetics. Campers' input was considered extremely important.
- Finding reliable small wind turbines was difficult. An investigation of various appropriately sized small wind turbines showed that there were several complaints about the standard brands used.
- The best location to put up small turbines was in front of Walloon Lake, which was something the campers would be vehemently opposed to.
- After speaking to Mark Clevey (Michigan Energy Development Commission), it was found that wind turbines required a significant amount of zoning and permitting, which would delay completion of the project.

- The Michigania management team was worried about pushback from the Boyne City community about the presence of wind turbines (for fear that these turbines would lower property value).
- Campers were extremely concerned about the noise that would be generated by a small wind turbine, and how this would affect the aesthetics of camp.
- Our project team wanted to introduce campers to renewable energy in small doses in order to gain acceptance. Wind turbines were considered too ‘intrusive’ to start with.

4.5.2.5 Conclusion

For reasons listed above, wind power was not chosen as an option at Camp Michigania. After a preliminary analysis, it was determined that significant deployment of wind energy was not viable from a technical standpoint for Camp Michigania. However, resistance from the campers was the primary reason why wind was not chosen.

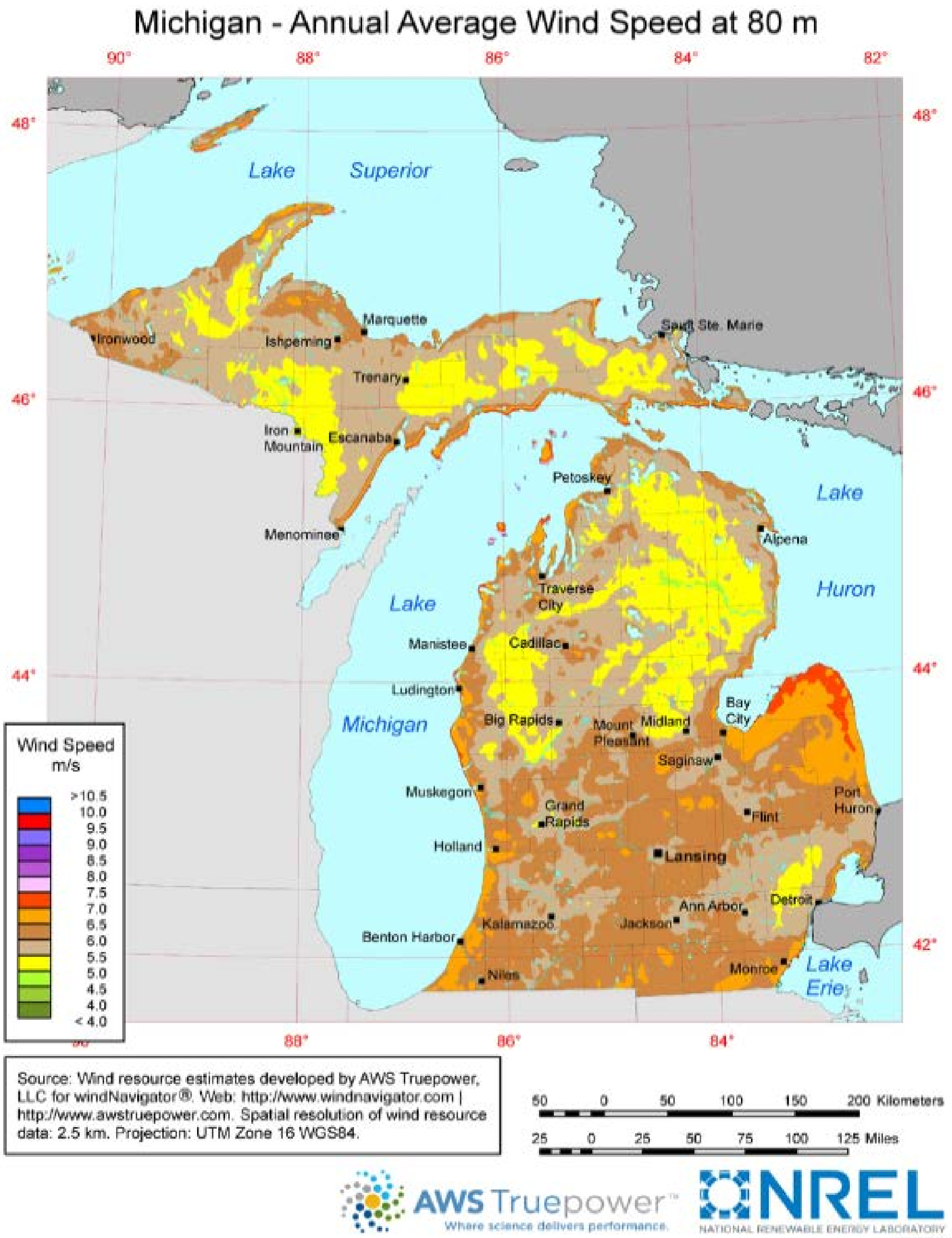


Figure 21: Wind speeds in different regions of Michigan

Image Source: (NREL)

4.5.3 Biogas Energy

4.5.3.1 Technology Overview

Biomass is defined by the Energy Information Administration as “organic nonfossil material of biological origin constituting a renewable energy source”. This biomass can be combusted in a boiler to produce steam. This steam can then be used to turn a generator to produce electricity. Alternately, biomass could be put into a biogas digester. This digester contains microorganisms that convert the biomass into biogas and solid slurry. The biogas can be used to produce heat and electricity. The slurry can be used as fertilizer as it is very rich in nutrients.

Different sources of biomass can be used. Some of the commonly used biomass crops are switch grass, willow and poplar. For biogas production, any kind of organic waste is suitable.
At Camp, potential sources of biomass are:

i) Food waste from the dining hall
ii) Horse manure from the stables

Figure 22 explains how a potential biomass system at Camp would operate.

Waste from the kitchens and stables would be put in a collection tank. This waste material would then be sent to the anaerobic digester. Anaerobic digestion (Burke, 2001) is the breakdown of organic material in an environment free from oxygen. The outputs of this process are primarily methane and carbon dioxide gas, with some hydrogen sulfide. (Burke, 2001)

These gases together are referred to as biogas. The biogas can be used to generate electricity or produce heat. As a result of this anaerobic breakdown, the quantity of solid waste in the digester is greatly reduced. The residual waste is referred to as slurry. This slurry is rich in organic material and can be used as a fertilizer for crops. This can also be a potential source of income for Camp.

4.5.3.2 Environmental Benefits of Biomass as a Source of Energy/Heat

- Biomass energy has a fairly high Net Energy ratio.
- The process of producing electricity from biomass is nearly carbon free (i.e. emissions associated with energy production from biomass are nearly zero).

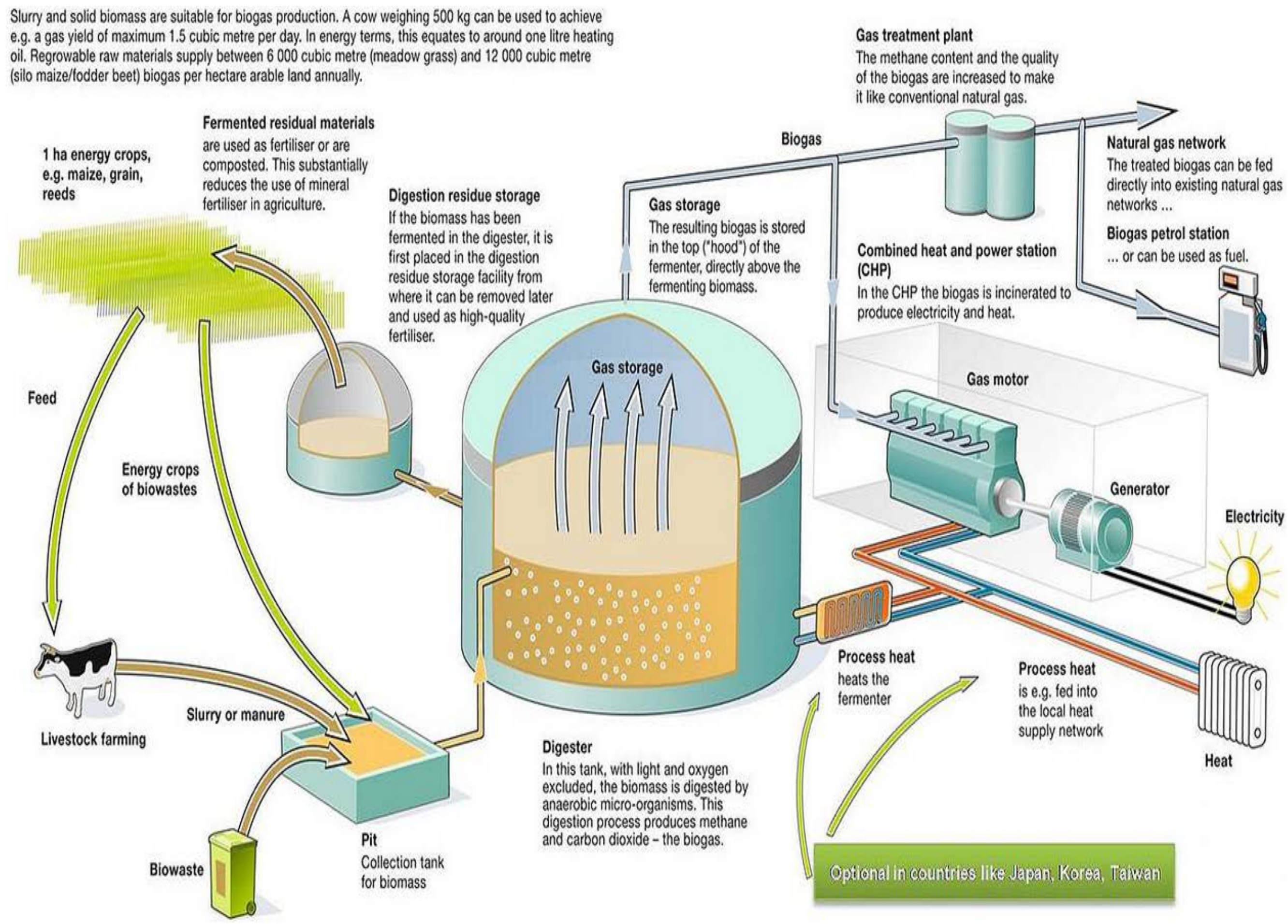


Figure 22: How a biogas digester operates (Biotec Asia Living Energy)

4.5.3.3 Criteria for Elimination

Since Camp is in operation only for a few months in the year, the digester would not have a steady source of input. One of the deciding factors in choosing a renewable energy option at Camp was the amount of maintenance the system would require. The intention was to choose a system that would be easy for the staff to use and operate. (Ideally the staff would be able to watch the system operate independently). A biomass system would require staff to physically transport the food waste and horse manure to the digester and also transport the slurry that the digester would output which adds more work for staff that are already fully occupied.

After just a preliminary analysis, it was concluded that biomass energy in the form of an anaerobic digester was not the ideal way to introduce campers to renewable energy. Siting of the digester was a major concern in light of the aesthetics at Camp. A detailed analysis of digester sizing was not conducted, so there are no numbers to show the actual footprint of the digester.

However, it was assumed that the digester would ideally have to be kept as far away from the main camp as possible, so as not to be an ‘eyesore’.

4.5.4 Geothermal

4.5.4.1 Technology Overview

There is energy stored in the earth’s surface in the form of trapped heat. This heat energy exists as hot water and steam, and is found in porous reservoirs. This hot water and steam can be used either to generate electricity, or to heat water or buildings. Additionally, the temperature below the earth’s surface is nearly constant and can be used as reservoir for heating and cooling spaces. This application is referred to as a ground source heat pump.

There are three ways in which this energy from the earth’s surface can be used (NREL)

- Directly using the hot water and steam
- Generating electricity by using the hot steam to turn a turbine
- Using a geothermal heat pump to keep spaces warm in winter and cool in summer

Geothermal works on the principle that temperature below the earth’s surface is nearly constant. Depending on latitude, the temperature under the earth is in the range of 45 F-75 F (7 C- 21 C). An easy way to imagine this is to think of an underground cave. It is always reasonably cool in a cave, irrespective of the season. **Figure 24** shows the variation of geothermal resources across the United States. It is important to note that a majority of Michigan falls under the ‘Least Favorable’ category.

For Camp Michigania, geothermal heat pumps were considered. A pump essentially transfers heat either to or from the room/space depending on the need (heating or cooling). These pumps essentially use a region under the earth as a reservoir of heat. During winter, the above surface temperature is very low. However, the temperature under the earth’s surface is much warmer in comparison. As a result, heat can be transferred from this reservoir under the earth to the room/space which is above the earth’s surface. In summer, the temperatures above the earth’s surface are higher than those below the earth’s surface. A pump can then transfer heat from the room/space to be cooled to this underground reservoir. Thus, it is clear that such pumps require a thermal gradient (i.e. two regions with different temperatures) to operate effectively. **Figure 23** shows how a geothermal heat pump operates for space heating and cooling.

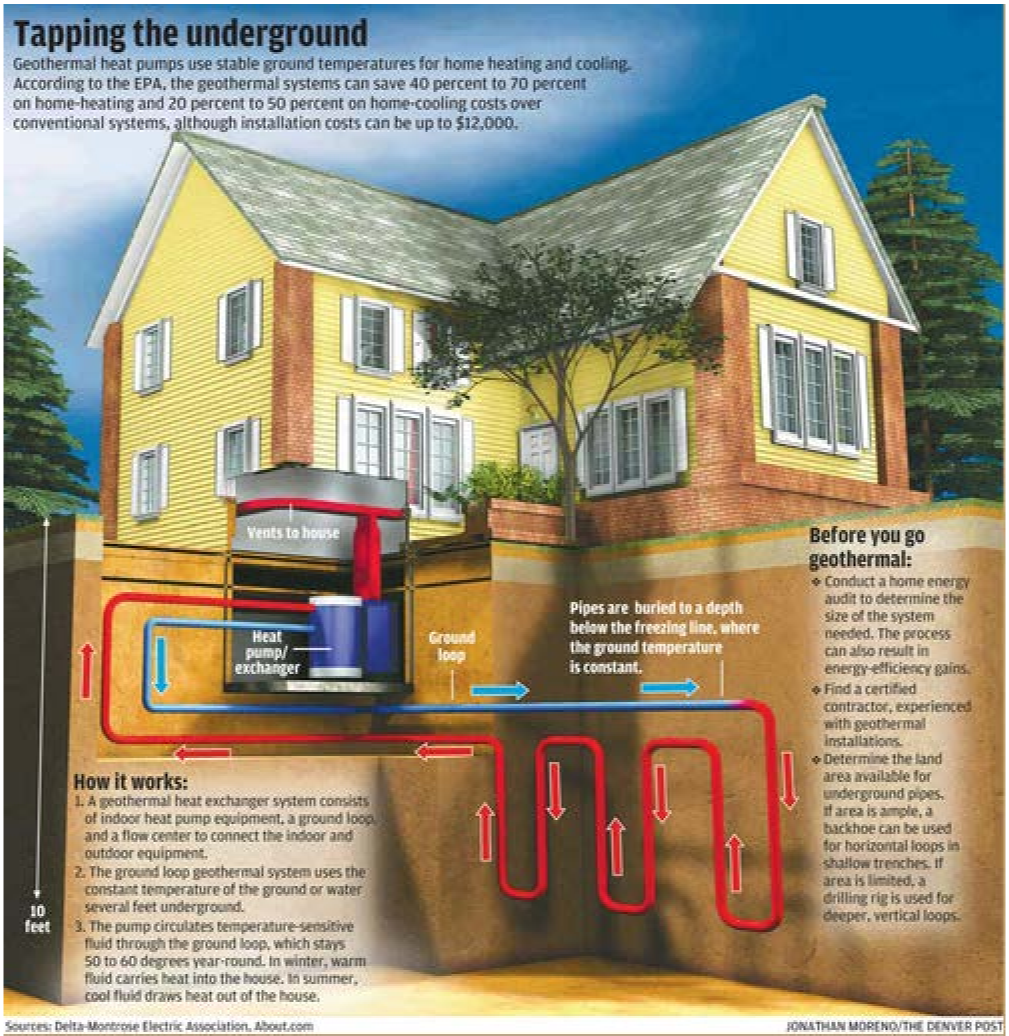


Figure 23: Working of a geothermal heat pump for space heating and cooling (THB Energy Solutions)

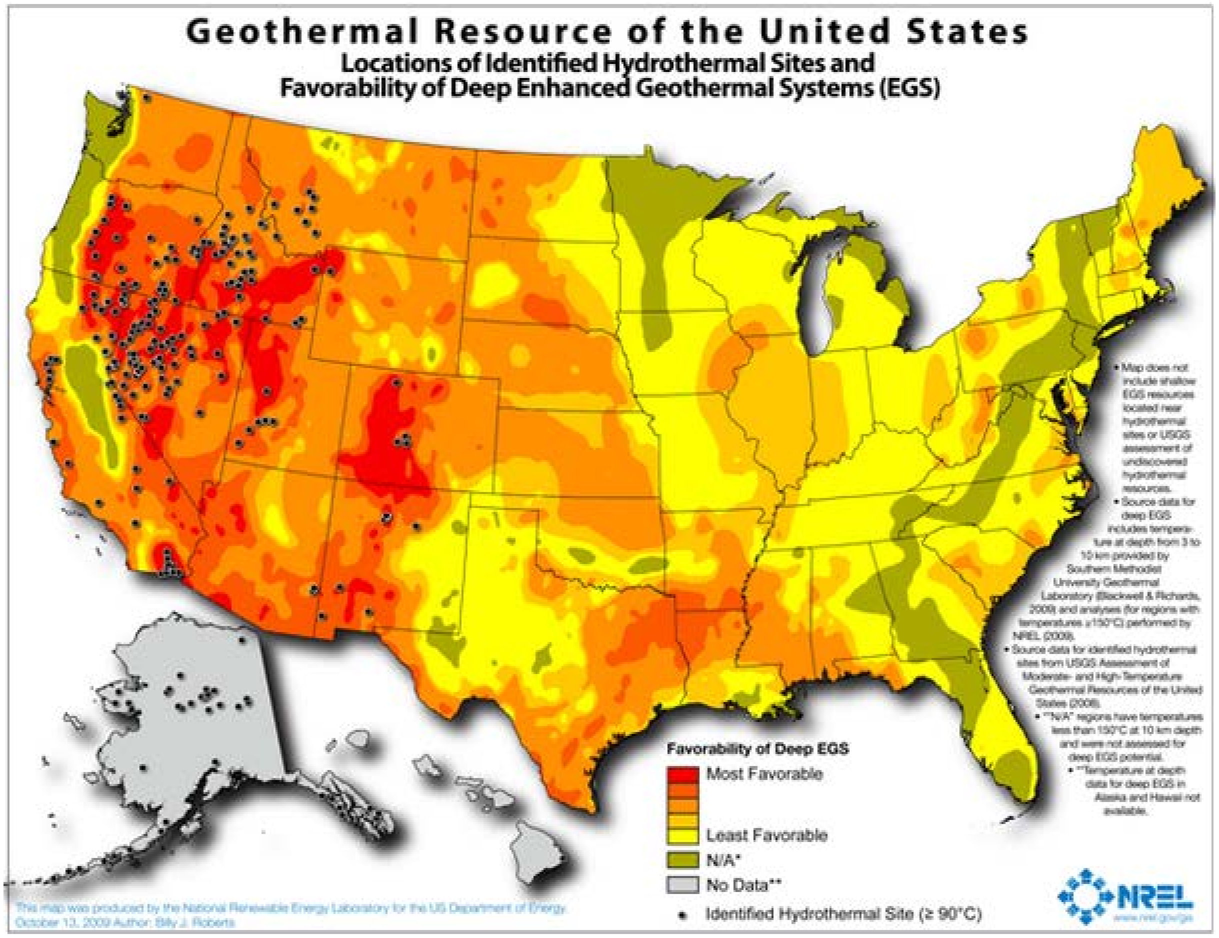


Figure 24: Variation in geothermal resources across the United States
Image Source: (Midwest Energy News)

4.5.4.2 Environmental Benefits of Geothermal Energy

- It is a carbon free source of energy/heat.
- When used as a heat pump, some amount of electricity is consumed in operating the pump.

4.5.4.3 Criteria for Elimination

Camp is in session only in the summer months when there is no heating requirement. A geothermal heat pump would be most useful only in the winter months when there are no campers. As a result, it is difficult to justify allocating funds to a geothermal heat pump system, when these funds can be effectively used for a more appropriate and valuable renewable energy system for Camp. Maintenance and repair of these pipes would be difficult as well.

4.5.5 Energy Efficiency

Energy efficiency was originally selected as one of the viable areas for improving sustainability metrics at Camp Michigania. Energy efficiency is a broad term that describes technologies that could improve the efficiency of energy usage of a built environment. Major energy efficiency technologies include LED lighting, high insulation value building materials, smart building controls, and efficient HVAC systems.

After several preliminary site investigations, the team decided not to pursue energy efficiency for this particular project due to two major reasons. First, the dining hall was retrofitted to LEED Silver standard in 2010, so budget is limited for new projects. Second, the camp does not track its energy consumption to the extent required for a detailed energy efficiency analysis. However, we suggest incorporating a real-time energy monitoring system into the solar PV project to lay the ground work for future energy efficiency analysis. Additionally, we highly recommended that a later project further investigate this area as a priority, because energy efficiency has been proven in many cases to be the most cost-effective means to reduce energy consumption.

4.6 Potential Follow-on Projects at Camp Michigania for Other SNRE Master's Project Teams

Camp Michigania is committed to making its operations more sustainable, while educating campers about how they can make their lives more sustainable. Since a number of the campers have positions of influence in various organizations, they have the potential to create the most change, by educating their co-workers, employees and families.

Our group focused on renewable energy options at Camp. However, through our research, we learned that there are significant gains to be had in electricity and natural gas conservation. Therefore, our group concluded that a potential follow-on SNRE Master's project team could focus on energy efficiency at Camp. Some of the activities that this project would involve are listed below:

- Determine energy saving measures (both electricity and natural gas) for the existing site, with the aim of decreasing overall energy usage.
- Determine camper views toward the implementation of various energy efficiency measures. (In order to maintain the aesthetics of camp and get support/funding from campers).
- Provide optimum energy efficiency solutions, by analyzing technical, financial and aesthetic requirements.
- Create an implementation plan for the measures recommended, which would specify the type, location and size of system(s). This would also include providing detailed ROI calculations to justify these measures to campers.
- The dining hall provides the single greatest source of potential energy savings at Camp, and so a significant amount of research time would be spent on analyzing energy consumption patterns at this location.
- Create educational materials for Camp Michigania's Nature Program.
- Create an on-site educational experience for campers, to aid their understanding of the benefits of energy efficiency.

5 Conclusion

Over the course of the last year, the team had numerous interactions with campers and staff at Michigania allowing for a solid grasp of what is important to a majority of those whom spend significant time at camp. Surveys conducted during this time showed that sustainability is either somewhat or very important to over 90% of respondents, and solar energy and energy efficiency had the highest likability rating at 90% of all renewable energy options. From an energy standpoint, the camp spends about $100,000 a year on electricity and propane, with the Dining Hall and Education Center being the two highest users over the last six years. Due to their high energy use and good site characteristics, the Dining Hall and Education Center were found to be the best candidates for a solar photovoltaic system after extensive site analyses and discussions with potential vendors. Based upon these findings, the team recommends the following:

<u>Education</u>

- Educational Programs
    - Include the educational materials designed by our team in the overall environmental education programs at camp.
    - Incorporate adult education programs side by side with children's programs about renewable energy.
- Create a Visual Interface for the Solar Array
    - This interface should show real time data for the array.
    - Provide context for the impact that the energy produced will have.
- Increasing the Educational Role of the Sustainability Coordinator
    - Providing the coordinator with a teaching session in the morning to work with the kids programs at camp.

<u>Technical</u>

- Install a 19.76kW solar photovoltaic system on the south-facing Dining Hall roofs. **Figure 25** shows the two roofs where the system would sit.
- Use Sunventrix as the vendor and install Suniva solar modules and Enphase microinverters for an installed cost of $3.96/W.

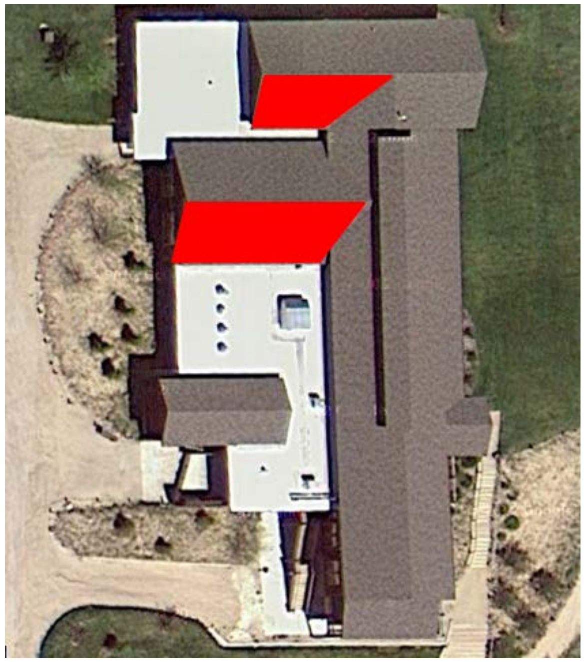


Figure 25: Location of Recommended 19.76 kW Solar Photovoltaic System. Area for solar modules indicated in red.

Additionally, based on campers' feedback, the team recommends that a follow-on student project at Camp focus on energy efficiency in the Dining Hall. This should involve conducting technical analyses to determine the best strategy to reducing the dining hall's energy consumption, and developing educational material that will help campers understand the benefits of improving energy efficiency.

6 Bibliography

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7 Appendix

Appendix I: Online Survey Taken by Campers

qualtrics.com

All responses to these questions are totally anonymous and will be used only for the continuing improvement of Camp Michigania.

Please answer the following questions about yourself only. There will be time later in the survey to answer questions regarding children and/or family.

How long have you been going to Camp Michigania?

- ○ It's my first time!
- ○ 1-5 years
- ○ 6-10 years
- ○ 11-20 years
- ○ 21+ years

Please rate how important you believe the following items are in relation to your experience at Camp Michigania. You should not feel compelled to rank these things against each other. They can all be equally important, or of varying importance.

	Not at all Important	Unimportant	Neither Important nor Unimportant	Somewhat Important	Very Important
Sustainability*	○	○	○	○	○
Aesthetics	○	○	○	○	○
Energy Efficiency	○	○	○	○	○
Renewable Energy	○	○	○	○	○

*Sustainability has hundreds of definitions. For the purpose of this survey, consider the term to mean, "use of camp resources in a way that allows them to continue being used into perpetuity."

Any renewable energy project has to go somewhere. This could mean solar panels on a roof, a windmill on the lake, a solar array by the education center, or a hundred other places. Our goal is to ensure that whatever and wherever the project ends up, we are able to minimize its impact on the things campers hold most important, including camp aesthetics and camper safety. If there's something or someplace in particular that you want us to be aware of going forward, let us know in the box below.

In addition to a renewable energy project, the Camp Michigania Master's Project team will be creating activities and educational programs centered around the project. How much do you enjoy the following types of activities when you're at Camp Michigania?

	Very Strongly Avoid	Avoid	Indifferent	Prefer	Very Strongly Prefer

Informational sessions	○	○	○	○	○
Family activities	○	○	○	○	○
Individual activities	○	○	○	○	○
Hands on activities	○	○	○	○	○
Educational activities	○	○	○	○	○

What three words would you use to describe Camp Michigania?

Who comes with you to Camp Michigania? Knowing how preferences vary with demographics helps us to tailor programs and activities to the groups who would be most interested. (Select all that apply)

- ☐ Significant other
- ☐ Children
- ☐ Friends
- ☐ Just me!

The next question pertains to those families bringing children to Camp Michigania. If you don't have children or aren't bringing them, feel free to skip it!

What percentage of time do you think your child(ren) will spend doing the following activities? (Many activities fall into more than one category, so don't worry if your total is larger than 100%)

	0	10	20	30	40	50	60	70	80	90	100
Educational activities											
Physical activities											
Arts and Crafts											
Activities with their peers											

Activities with their family	

Recently, Camp Michigania introduced a new recycling program, and continues to add new sustainability initiatives. What are your thoughts on this program and the potential for other programs like it?

- I like the program! We should have more like it!
- I like program, but I'd rather not have more, similar programs in place.
- I dislike the program, but I would be interested in other sustainability programs.
- I dislike the program and would rather not have more, similar programs in place.
- I have no feelings about the program.
- Other

How important do you see sustainability...

	Not at all Important	Unimportant	Neither Important nor Unimportant	Important	Very Important
At home	○	○	○	○	○
At Camp Michigania	○	○	○	○	○

How much would you like to see the following energy options explored at Camp Michigania?

	Dislike Very Much	Dislike	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like	Like Very Much
Solar Power	○	○	○	○	○	○	○

Wind Energy	○	○	○	○	○	○	○
Energy Efficiency	○	○	○	○	○	○	○
Biofuels	○	○	○	○	○	○	○
Geothermal	○	○	○	○	○	○	○

How willing would you be to contribute to a renewable energy project at Camp Michigania?

- ○ Unwilling
- ○ Some Willingness
- ○ Neutral
- ○ Willing
- ○ Very Willing

Is there anything else you'd like us to know, but we didn't ask about?

>>

Appendix II: .do File Showing the Functions Ran in Statistical Software

```
clear all
set more off
capture log close
cd "M:\Michigania"
use "michigania.dta"

* For information on how the data has been coded, see michigania_cleanup.do

* Demographics
tab yrs_going
tabstat join_sig join_child join_friend join_me, stat(mean)


* How important do people see the aesthetics of the camp? Energy efficiency? Renewable Energy? Sustainability?
tabstat imp_*, stat(mean)

ttest imp_aeth==imp_sus
ttest imp_aeth==imp_eneff
ttest imp_aeth==imp_renew
ttest imp_sus==imp_eneff
ttest imp_sus==imp_renew
ttest imp_eneff==imp_renew

* How do campers feel about sustainability while at home versus at Camp Michigania?

tabstat impsus_home impsus_camp, stat(mean)
ttest impsus_home==impsus_camp

* Do campers feel as though sustainability is a burden? Is there resentment?
recode op_recyc (1=5)(2=4)(4=2)(5=1)
label define op_recycle 1 "dislike, no more" 2 "dislike, more" 3 "indifferent" 4 "like, no more" 5 "like, more"
label values op_recyc op_recycle
tab op_recyc
histogram op_recyc, discrete percent title(Opinion on New Recycling Program) note(CMMP Survey 2012)
xtitle(Dislike-->Like) scheme(s1mono)

* What are campers' favorite activities?

tabstat ed_*, stat(mean)
ttest ed_info==ed_fam
ttest ed_info==ed_individ
ttest ed_info==ed_hands
ttest ed_info==ed_ed
ttest ed_fam==ed_individ
ttest ed_fam==ed_hands
ttest ed_fam==ed_ed
ttest ed_individ==ed_hands
ttest ed_individ==ed_ed
ttest ed_hands==ed_ed

* Difference here in campers who brought children vs. those who did not?
ttest ed_info, by(join_child)
ttest ed_fam, by(join_child)
```

```
ttest ed_individ, by(join_child)
ttest ed_hands, by(join_child)
ttest ed_ed, by(join_child)

* How likely would campers be to attend informational sessions? Educational activities?
*See information gleaned as part of previous question.

* What types of activities do parents enjoy having their kids do? Physical things? Educational things? Creative/artsy?
tabstat per_* if join_child==1, stat(mean)

ttest per_ed==per_phys if join_child==1
ttest per_ed==per_ac if join_child==1
ttest per_ed==per_peers if join_child==1
ttest per_ed==per_fam if join_child==1
ttest per_phys==per_ac if join_child==1
ttest per_phys==per_peers if join_child==1
ttest per_phys==per_fam if join_child==1
ttest per_ac==per_peers if join_child==1
ttest per_ac==per_fam if join_child==1
ttest per_peers==per_fam if join_child==1

* Question with this data: do families that prefer children to do physical activities the same ones who prefer peer
activities?

recode per_phys (min/33.33=1) (33.34/66.67=2) (66.68/max=3) if per_phys!=., gen(physpref)
recode per_peers (min/33.33=1) (33.34/66.67=2) (66.68/max=3) if per_phys!=., gen(peerspref)
gen pref_compare=1 if physpref==peerspref & !missing(physpref, peerspref)
recode pref_compare (.=0) if !missing(physpref, peerspref)


*What types of renewable energy technology do campers most support?

tabstat like_*, stat(mean)
ttest like_solar==like_eneff


* Would campers be willing to donate to a cause like this?

tab donate
histogram donate, discrete percent title(Camper Willingness to Donate) note(CMMP Survey 2012) xtitle(Willingness to
Donate) scheme(s1mono)
```

Appendix III: Kids Activity Booklet

Dear Sustainability Coordinator,

At Camp Michigania, stewardship is one of the core values that staff strive to achieve. Recently Michigania has made some efforts towards that value and has had solar panels installed. This packet includes four educational activities that can be done with campers to increase their knowledge about solar and Michigania's solar system in particular. All of the activities are standalone lessons but much of the same information is conveyed in multiple programs. Two of the activities depend on having a sunny day while the other two are not constrained by this.

Each lesson contains several sections: purpose, background, getting ready, and doing the activity. The purpose section explains what the activity should accomplish. The background section provides the instructor with the background knowledge to be able to answer the questions that are suggested as talking points with the students. The 'getting ready' section gives you an explanation of any preparations that need to be done before the start of the activity. Finally, the 'doing the activity' section provides a step-by-step procedure on how to run the activity.

This booklet will help you break into the educational arena at camp giving you four ready-to-go activities.

Good Luck!

Camp Michigania Masters Project

Hot Water Never Seemed So Easy!

It is amazing what the sun can do and how useful it can be to us! In this activity, campers will conduct an experiment and explore what conditions attract and hold the sun's rays.

Ages: 5+

Time: 45min

Location:

Outdoors

Weather: Sunny

Materials:

- 4 plastic cups
- Black & white paper
- 4 thermometers
- Saran wrap
- 2 Rubber bands
- Scissors
- Water

<u>Purpose:</u> Campers will see how the sun can be used to heat the water that we use. They will also gain skills in the scientific method.

Background

The sun has always been a source of great power to people. It provides light and heat by giving off shortwave radiation which includes visible and UV light. The UV light that is emitted from the sun travels to the earth and hits objects. These objects then interact with the UV light and convert the radiation to heat. This heat allows us to keep warm, heat our homes, and cook food. With the right infrastructure, the sun can be used as a free source of energy.

Different materials have different albedos. Albedo is known as the reflection coefficient which describes how much of the incoming radiation (visible and UV radiation) is reflected off of surfaces it comes into contact with. An albedo of 50% or 0.5 means that 50% of incoming radiation is reflected back into the atmosphere. Objects that have low albedos are dark in color while lighter colors tend to have higher albedos. For example places like the oceans and forests have low albedos while the ice caps and deserts have high albedo. This concept is important because the radiation that is not reflected off an object gets absorbed and converted to heat. People have learned to use this knowledge to their advantage and have changed their behavior accordingly, we see this all the time with peoples' daily clothing choices; during hot sunny days people choose to wear lighter colors in order to stay cool.

Solar thermal energy has become commonplace in building houses these days. For example; solar thermal system consists of several rows of connected black tubes that are located (usually) on a rooftop. The water is then continuously pumped through the tubing and can result in warm or even hot water.

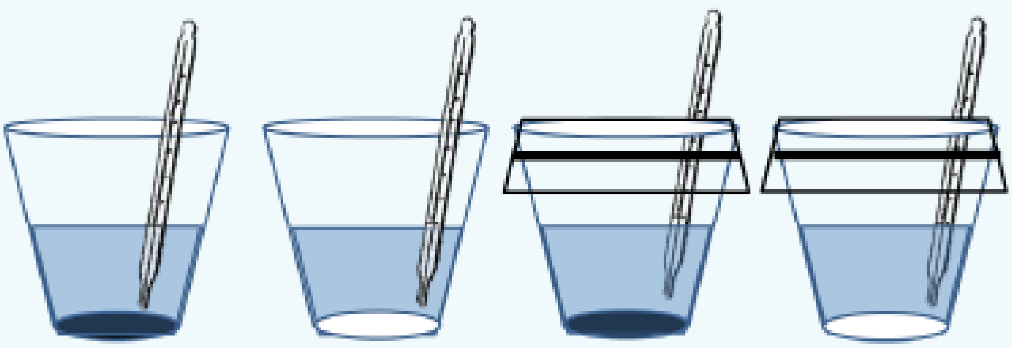
Getting Ready

Before the experiment there are two things you need to make sure to do:

1. Collect all necessary materials. Water should be set aside inside in order to reach room temperature before the experiment begins.
2. Find an area outside in direct sunlight that can be used for the experiment.

Doing the Activity

1. Explain the experimental set-up to campers and follow the steps to construct the experiment. (see visual below for set-up help)
   A. Use the cups to trace two circles on the black construction paper and two circles on the white construction paper. Cut out the circles and place one circle at the bottom of each cup.
   B. Place 100mL of the water that has been sitting at room in each cup and measure the starting temperature of the water. Record this number on the handout.
   C. Take one black bottomed cup and one white bottomed cup and cover the tops with plastic wrap and hold in place with a rubber band.
   D. Place containers in direct sunlight and leave for 15 minutes, after that time record the new temperatures of the water.



Doing the Activity continued...

2. During the 15 minutes ask the campers what they think will happen to the water in each cup; form a hypothesis; will the temperature increase, decrease, stay the same? What are the differences in the cups in relation to each other? (Which cup do they think will have the greatest increase?)
3. After the final temperatures are recorded, make the difference calculations and determine what conditions absorb and retain the most heat.
4. Ask campers why the temperatures varied and why were certain containers hotter than others.
5. Ask campers how they could use this knowledge, is there any way that this would be useful? When and where could you use this?

Adapted from National Energy Education Development Project

Data Collection

	White No cover	Black No cover	White With cover	Black With cover
Original temperature – C				
Temperature after 15 min – C				
Temperature difference - C				

<--- Cut along dashed line --->

Data Collection

	White No cover	Black No cover	White With cover	Black With cover
Original temperature – C				
Temperature after 15 min – C				
Temperature difference - C				

Michigania's Solar system

Camp Michigania is going green! A solar panel system has been installed on the dining hall in order to have a percentage of Michigania's energy be from renewable energy. This tour will give campers a chance to explore and learn about the newly installed solar panel system at Camp Michigania.

Ages: Tour can be tailored for any age group (recommend 7+)

Time: 30-60 minutes depending on age group

Location: Dining Hall (both inside and outside)

Weather: Activity works best when sunny but can be run effectively as long as there is no precipitation.

Materials: No materials needed for this activity.

<u>Purpose:</u> Campers will be able to see a real solar system and see the real-time energy-gain from solar panels and the sun. Campers will also be able to assess pros and cons about solar panels. Allows campers to explore a new and innovative area of camp.

Background

FILL IN BLANKS ONCE SYSTEM IS CHOSEN.

Camp Michigania has decided to install a solar photovoltaic system on the roof of the dining hall at camp. This decision has been made in order to decrease the dependence on non-renewable energy, lower camp's CO_2 emissions as well as provide a learning opportunity for campers to gain knowledge and understanding about renewable energy and solar energy in particular.

Camp has decided to purchase a ___kW system that consists of ____panels that each produce ____kW.

There are many factors that can affect the effectiveness of solar panels: lack of sunlight, shade, dirtiness, and age. Panels are most effective when they are new and clean and when they receive 100% direct sunlight. This means that on cloudy days or at night, the panels are unable to produce energy which can severely limit its total output.

Even with these issues, solar panels are a great technology that allows us obtain energy from a renewable source while helping to lower CO_2 emissions into the air.

Getting Ready:

1. Choose a location to start your tour from.
2. Locate the area around the dining hall that has the best view of the solar panels on the roof.

Doing the Activity:

1. Ask campers if they can tell you the difference between renewable and non-renewable resources, if they are unable to produce a proper definition, provide one for them. Ask them to name some examples of each.
2. Tell the group that today they will be taking a tour to see Michigania's solar system. Lead the group out to the south side of the dining hall where panels are most visible. Point out the panels to the campers and have them count them. Tell them how much energy each panel can produce and ask them to calculate how much energy Michigania gets from the system.
3. Lead the group inside the dining hall to the solar energy display. Give campers a brief description of what information is being displayed and how they can read and understand the device. Allow campers to explore the device for several minutes.
4. Lead a discussion about what they see.
   a. What do you notice about the panels?
   b. Are they all producing the same amount of energy?
   c. Which panel produces the most?
   d. Which panel produces the least?
   e. What could be the reason that the numbers differ?
   f. Shade, low amount of sunlight (clouds), dirty panels (dust, bird droppings, leaf coverage), etc.
   g. Do the actual energy numbers come close to the theoretical amount of energy the panels should produce?
   h. If no, why not?
   i. Why are solar panels good?
   j. What benefits are gained by using solar instead of gas?
   k. Finish the tour by recapping what they have learned and seen and take them back to the location of the start of the tour.

Renewable Races

In this activity campers get to play with solar powered toys while they learn about the pros and cons of solar power. Campers will get the chance to race each other with either racecars or Viking ships.

Ages: 5+ can be tailored to be age group appropriate.

Time: 45-60 minutes

Location: Outside

Weather: This activity can only take place on a clear sunny day with little to no cloud cover or the racecars/Viking ships will not work.

Materials:

- Completely smooth 5ft surface (can be constructed out of poster board)
- 5 solar racecars or
- 3 Viking ships
- Tape
- Markers
- Ruler

<u>Purpose:</u> Campers will experience a fun side of solar energy. Campers will also get to observe the immediacy and the draw backs of solar.

Background

Solar panels are being used for all types of things these days including, as your campers will find out, toys. Solar toys are being used these days in order to help educate children about solar and renewable energy in general. These toys are a great interactive resource to get kids to engage and develop interest in sustainability. While solar toys are great to spark interest there are also problems associated with solar.

These solar toys cannot be played with indoors or when there are clouds. They are most effect when used in direct sunlight and when the weather has little or no clouds. The racecars also work best on a completely flat surface and those can be hard to find. Some other issues with these toy solar panels are that they can be easily scratched or damaged and they will lose their effectiveness.

Getting Ready:

In order to do this activity it needs to be a sunny day with little or no cloud cover.

1. Prepare materials; around camp it is difficult to find a completely flat area that the cars can move across. In order to circumvent this problem you can get 2-3 poster sheets from CAC and very carefully tape them together to form a smooth racing surface. Add a start and finish line to the race track along with five lanes.
2. Once you have your track, it is important to find an extremely smooth area in direct sunlight to lay your track down in (the platform off of the Nature center tends to work well).
3. Make sure that all racecars are properly constructed and if you are doing the alternative activity make sure to construct the Viking ships. You might also want to write a number on the racecars so that it is clear which car is the winner.

Doing the Activity:

Get set...

1. Before letting campers dive into the races, set the stage. Ask campers how cars are able to move. If they do not respond with answers like 'electricity' or 'gas', prompt them by asking what fuel source or type of energy their cars use, using your knowledge of energy sources have a discussion about what types of energy is out there.
2. Next, explain that right now Michigania is getting energy from solar power and that our racecars are also going to be getting their power from the sun.
3. There are five racecars and three Viking ships so depending on the amount of campers there are either have them get into teams or give them their own car.

Go!

1. Have them race their cars. All cars should start behind the start line and you should count down so that all cars are released at the same time. If someone releases their car early you can either restart or disqualify the racer for that round depending on the age group.
2. After campers have raced several times, ask them why some cars were faster than the others. Talk about and discuss:
    a. Human error: both in construction and in release
    b. Quality of solar panels: there may be scratches of scuffs
    c. Shade: were there any clouds or did the car get covered by a shadow?
    d. Ground Surface: is one lane smoother than the others?
3. Finally see if you can get them to conclude some pros and cons of solar power and solar panels.
4. Campers will probably want to play around with the cars after the activity, you should allow them to race as long as possible

Variation:

1. On particularly warm days you might want to do the alternate version of this activity; Viking ships. You should not do this version if you have a large amount of campers.
2. Take the campers to north beach and set some ground rules; they will be playing in the water and since there is no lifeguard they need to be restricted in where they can go and what they can do.
3. Consider wind and water movement when you decide where you will have the start and finish lines (you could have one camper stand where you wanted the start and finish line so there is a reference)

Monitoring our energy – the TED way

Explore the energy usage of different objects by using The Energy Detective (TED).

Ages: 7+

Time: 30-45 minutes

Location: Dining Hall

Weather: No weather restrictions

Materials:

- TED energy monitor
- Computer with TED software installed.

Additional resources: http://www.theenergydetective.com/

Purpose: Campers will see instantaneous changes in energy usage with the activation of different appliances. Campers will see the relative energy usage of several everyday actions.

Background

Kilowatt hour is power by time which gives you the energy usage. The TED energy monitor is a device that allows the owner to assess the kWh and dollar amount of using different appliances. The device is hooked up to the dining hall and when you turn it on it will tell you the current energy usage of everything in the building. The kWhs might be fluctuating depending on what is happening in the building, if other people are turning appliances and lights on, the usage will shift accordingly. The device will allow you to test different objects and observe the change in total energy being used by the building. Go to this website: http://www.theenergydetective.com/ and watch the video clip in order to better familiarize yourself with the device and the online interface.

Getting Ready:

1. Make sure to watch the video about TED energy monitor so that you are aware of all the features and displays.
2. Practice using the device beforehand so that you are comfortable with the functions and information.
3. Evaluate different appliances, electronics, and light so that you know what will be good examples to show the campers.

Doing the Activity:

1. Ask campers to think about what things use energy. Then ask them to point out what things in the room use energy. Talk about what is better – using a lot of energy or saving energy, why do we want to save energy? Here you can try to get them to talk about money, a loss of resources, wastefulness, etc.
2. Take out TED and explain to the campers what TED tells us and how we can use it. Make sure to explain what kilo watt hours are and to talk about how we have to pay for electricity and the more that we use the more our bill will be.
3. Once the campers understand what TED is and what it shows go around the room turning different things on and off to see how much energy they use (note the device gives you the kWh and $/hour on the display). Let the campers explore different appliances, try lights, vacuum, TV, other objects that plug in, etc.
4. Have the campers record the different values and make the difference calculations. The values can also be converted into $/min.
5. Discuss what items cost the most and what items cost the least. Talk about how individual items might not seem like they cost much but when you take into account all the items that are working over the month, the cost can really build up.
6. Use the computer to log onto Michigania's energy account. Once there, take them on a tour of the set up and explain what all the different parts mean. Using this site demonstrate Michigania's average usage and how much money they spend and show where they could save money.
7. Talk about energy efficiency and how that is an important first step to reducing energy dependency.

Appendix IV: Kids Educational Displays

Appendix V: Adult Education Activities, Solar and Wind

Renewable Energy Talks

Instructions for the Sustainability Coordinator

Solar Energy

<u>Included:</u>

- ✓ These instructions
- ✓ Solar Energy Fact Sheet—2013 version
- ✓ Solar PowerPoint Presentation with Notes

Instructions:

1.) The Solar Energy Fact Sheet is regularly updated by SNRE's Center for Sustainable Systems, under "Photovoltaic Energy." Before working with these documents, check that you have the most up-to-date version available. All updated versions are here: http://css.snre.umich.edu/publications/factsheets
2.) Print off updated copies of the Solar Fact Sheet. 10-15 should suffice, with more or less depending on anticipated attendance. These sheets should be made available to participants when they enter.
3.) Prepare the Solar PowerPoint Presentation. There are 2 videos in this presentation. Ensure that both are working properly before participants arrive. It would be exceedingly helpful to familiarize yourself with the PowerPoint and the Solar Fact Sheet before performing the activity.
4.) While the audience is filtering in, put the first slide, labeled "SOLAR ENERGY" on the projector.
5.) When the audience arrives, introduce the program using the following, or your own words:

"Welcome to Renewable Energy Talks: Solar Edition. One page factsheets are available for anyone who didn't get one when they came in, and you can take those with you after the presentation.

Tonight/Today I'm going to present to you a general overview of where solar energy currently stands. I am personally not an expert in solar energy, and the point of the presentation isn't to make anyone an expert—it's just designed to provide general information for campers who are interested, and to spark discussion on the topic. The presentation will last 20-25 minutes, and we'll use the rest of the time to discuss what we heard and thought. Any questions?"

6.) Answer any questions you can and proceed with the presentation.
7.) At the end of the presentation, let them know that it's time for discussion. Lead the discussion or let the campers discuss among themselves, as per your judgment.

Center for Sustainable Systems

University of Michigan
440 Church Street, Ann Arbor, MI 48109-1041
phone: 734-764-1412 fax: 734-647-5841
email: css.info@umich.edu
http://css.snre.umich.edu

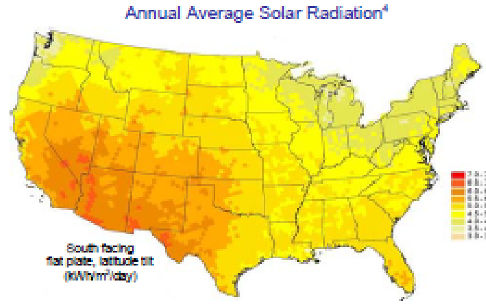
factsheets

Photovoltaic Energy

Solar energy can be harnessed in two basic ways. First, *solar thermal* technologies utilize sunlight to heat water for domestic uses, warm building spaces, or heat fluids to drive electric generating turbines. Second, *photovoltaics* (PVs) are semiconductors that convert sunlight to electricity. Only 0.04% of U.S. electricity is generated with solar technologies, in part because direct costs are high.[1]

Solar Resource

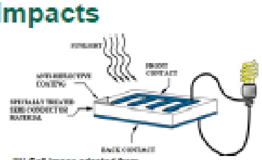
Annual Average Solar Radiation[4]



- On average, 1.05×10^5 terawatts (TW) of solar radiation reach the Earth's surface, while global electricity demand averages 1.98 TW.[2,3]
- Solar resource availability is very well correlated with daily patterns of electricity demand. However, the sun is not always shining; energy storage is needed to serve all electric loads with solar energy.
- PVs can be installed where electricity is used and can reduce stress on electricity distribution networks, especially during peak demand.
- PV *conversion efficiency* – percentage of incident solar energy that a PV converts to electricity – is 6% to 21% for production modules.[5]
- Assuming intermediate efficiency, PVs covering 0.4% of U.S. land area would generate as much electricity as the nation uses.[6]
- The roof area needed for PVs to power a house is modest. Most residential systems require as little as 50 sq. ft. and up to 1,000 sq. ft. A typical 1 kW system would occupy 80-360 sq. ft., depending on its efficiency.[7]
- According to one assessment, with a $420 billion investment in PVs, solar concentrators, transmission infrastructure, and compressed air energy storage over 40 years, solar power could generate 69% of U.S. electricity by 2050.[8]

PV Technology and Impacts

PV Cells



PV Cell image adapted from http://science.nasa.gov/headlines/y2002/solarcells.htm

- *PV cells* are semiconductors that produce electrons when photons strike the surface.
- Most PV cells are square or rectangular, several inches on a side, and produce a few watts of direct current (DC) electricity.
- PV cells also include electrical conductors called *contacts*, to collect electrons, and surface coatings to reduce light reflection.
- A variety of semiconductor materials can be used for PVs; common types and their production efficiencies are listed in the table.
- Although PV conversion efficiency is an important metric, for most power applications the cost per watt of power – also known as cost efficiency – is more important. Some very cost efficient cells do not have high area efficiencies.

PV Technology Types, Conversion Efficiencies and Production

		Production conversion efficiency†		Manufactured quantity in 2006[11]	
		cell (%)[9]	module(%)[10]	(MW)	(%)
Crystalline	monocrystalline silicon (Si)	24	13.8 - 17.7	958	38
	polycrystalline Si	18.2	12.8 - 14.2	1174	47.1
	string ribbon Si		12.7	68	2.7
	Gallium arsenide (GaAs)	25 - 30		n/a	n/a
	Other crystalline Si			150	6
Thin film	amorphous Si (a-Si)	13	4.9 - 6.3	98	3.9
	Cadmium telluride (CdTe)	16	9.4	68	2.7
	CIS / CIGS	18.8	8.1 - 11	5	0.2
				2,521	(Total)

† Module conversion efficiency is generally lower than cell conversion efficiency primarily because cells are not directly adjacent to one another and the resulting gaps, of course, cannot produce energy.

PV Modules and Balance of System (BOS)

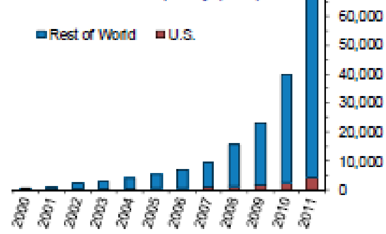
1 MW PV system, General Motors distribution center in Rancho Cucamonga, California

- *PV modules* typically comprise a rectangular grid of 72 or more cells, connected in several parallel circuits and laminated between a transparent front surface and a protective back surface. They usually have metal frames for strength and capacity of 175 to 300 watts.
- A *PV array* is a group of modules, connected electrically and fastened to a rigid structure.
- *BOS components* include wires that connect modules in series, junction boxes to merge the circuits, mounting hardware, and power electronics that manage the PV array's output.
- An *inverter* is a power electronic device that converts DC PV output to alternating current.
- Another power electronic device is a *charge controller*, used to manage energy storage in batteries.
- *Building Integrated PV* (BIPV) replaces building materials to improve PV aesthetics and costs.[12] Photo (right) shows a BIPV roof tile.[13]
- Some PV arrays track the sun's daily movement to generate up to 46% more energy than fixed systems.[14]

PV Installation, Manufacturing, and Cost

- Global cumulative capacity of PV systems grew 49-fold between 2000 and 2011, reaching nearly 70 GW. The U.S. installed 1,855 MW of PV in 2011, more than twice the capacity installed in 2010. Total U.S. PV capacity is approximately 4 GW.[15]
- PV module prices, the largest part of system cost, fell 74% from 1995 to 2011.[3,16]
- Global investment in solar R&D – $4 billion in 2011, which was higher than any other renewable energy technology – should further reduce PV production costs.[17]
- PV systems or components are manufactured in 61 factories across 21 states.[18]
- Between 2000 and 2010, U.S. market share of PV cell and module production dropped from 30% to 7%.[19]
- PV energy costs range from 15¢ to 64¢/kWh in the U.S., depending on system size.[20] Retail electricity averages 10¢/kWh for all users and 12¢/kWh for residential.[1]

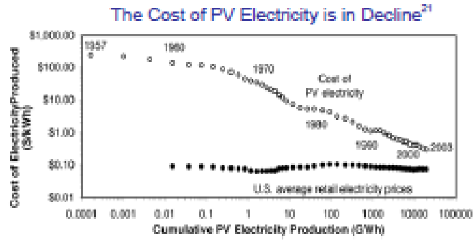
World Cumulative Installed PV Capacity (MW)[15]



Energy Performance and Environmental Impacts

- Net energy ratio compares the life cycle energy output of a PV system to its life cycle primary energy input; one study showed that amorphous silicon PVs generate 3 to 6 times more energy than is required to produce it.[22]
- Recycling multi-crystalline cells reduces manufacturing energy over 50%.[23]
- Pollutants and toxic substances may be emitted during PV manufacturing, but life cycle emissions are low. For example, per unit of energy delivered Cd-Te life cycle emissions are 95-98% less for all major pollutants (Cd included) as compared to the grid.[24]
- PVs can dramatically reduce environmental impacts associated with fossil-fueled electricity generation – 470 gal fresh water/MWh of electricity are evaporated by thermoelectric plants.[25] U.S. air pollutant emissions were 826.7 kg CO_2/MWh, 1.8 kg SO_2/MWh, and 0.8 kg NO_x/MWh, for the 2.87×10^9 MWh of electricity generated from fossil fuels in 2010.[1]

The Cost of PV Electricity is in Decline[21]



Watts are units of power, or rate of energy flow.
1 TW = 1,000 GW = 1,000,000 MW = 1,000,000,000 kW
kWh = kilowatt hour = unit of energy
1 kWh = electrical energy required to light a 100 watt bulb for 10 hours.

Solutions and Sustainable Actions

Policies Promoting Renewables

- The price consumers pay for electricity does not cover externalities, such as the cost of health effects from air pollution, environmental damage from resource extraction, or long-term nuclear waste storage. Policies that support PVs can address these externalities.
- PV policy incentives include renewable portfolio standards (RPS), feed-in tariffs (FIT), capacity rebates and net metering.
  - An RPS requires electricity providers to obtain a minimum fraction of their energy from renewable resources by a certain date.
  - A FIT sets a minimum per kWh price that retail electricity providers must pay renewable electricity generators.
  - Capacity rebates are one-time, up-front payments for building renewable energy projects, based on installed capacity (in watts).
  - With net metering, PV owners get credit from the utility (up to their annual energy use) if their system supplies power to the grid.
- For a listing of current U.S. policies by state, see the DSIRE database at http://www.dsireusa.org.
- Proposed carbon cap-and-trade policies would work in favor of PVs by increasing operating costs for fossil-fuel fired generators.

What Can You Do?

- Look for ways to make your lifestyle more energy efficient – this will reduce the total amount of energy you use in the first place.
- Consider installing your own PV system, especially if you live in a state that has capacity rebates or a net metering policy. For consumer information, see the U.S. Department of Energy's website at www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10710.
- Purchase "green power" from your utility. Green power allows you to pay a premium for every unit of electricity generated from a green source. For example, Unisource Energy in Arizona sells electricity generated from PVs for a 2¢/kWh premium.[26]
- Buy Green Tags – also known as carbon offsets or Renewable Energy Certificates or RECs. A REC represents the environmental attributes – separate from the actual electrons – associated with a unit of renewably-generated electricity.[27]
- Write your elected officials to support renewable energy policies.

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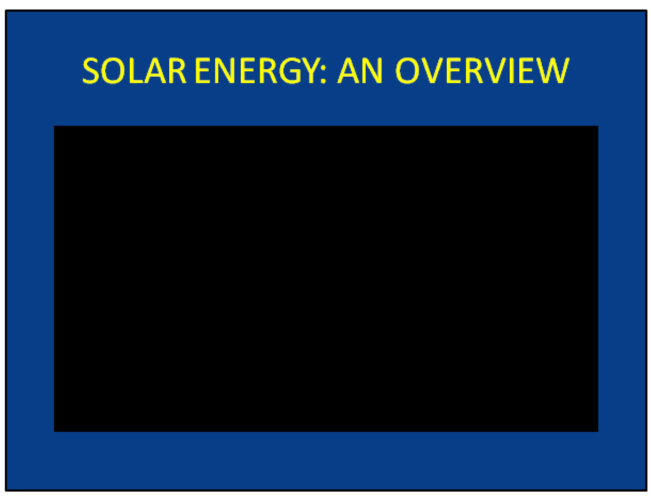
[1] U.S. DOE, Energy Information Administration (EIA) (2012) *Annual Energy Review 2011.*
[2] Goswami, Y. (2007) "Energy: The Burning Issue." *Refocus* 8 (3): 22-25.
[3] U.S. EIA (2012) *International Energy Statistics.*
[4] U.S. DOE, National Renewable Energy Lab (NREL) (2004) "Solar Maps."
[5] NREL (2012) "SunShot Vision Study."
[6] NREL (2004) "PV FAQs - How much land will PV need to supply our electricity?"
[7] EERE (2009) Solare Energies Technology Program "So you want to put PV on your roof…"
[8] Zweibel, K., J. Mason and V. Fthenakis (2008) "A Solar Grand Plan." *Scientific American* 298 (1): 64-73.
[9] Deb, S. K. (2000) Recent developments in high-efficiency PV cells. NREL/CP-590-28060.
[10] NREL (2007) Manufacturers' spec-sheet ratings compilation.
[11] Maycock, P. and T. Bradford (2007) "PV market update: Demand grows quickly and supply races to catch up." *Renewable Energy World* (2007) 10(4): 60-74, July-August.
[12] NREL (2007) "Building Integrated Photovoltaics."
[13] Photo is of Atlantis Energy System's SUNSLATE product, http://atlantisenergy.com/?page_id=255.
[14] Mousazadeh, et al. (2009) "A review of principle and sun-tracking methods for maximizing solar systems output." *Renewable and Sustainable Energy Reviews* 13:1800-1818.
[15] European Photovoltaic Industry Association (2012) *Global Market Outlook for Photovoltaics until 2016.*
[16] U.S. EIA (2012) *Solar Photovoltaic Cell/Module Shipments Report 2011.*
[17] Bloomberg New Energy Finance (2012) Global Trends in Renewable Energy Investment 2012.
[18] Solar Energy Industry Association and Greentech Media Research (2012) U.S. Solar Market Insight 1st Quarter 2012.
[19] NREL (2011) "PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry."
[20] Solarbuzz (2012) "Solar Electricity Prices: March 2012." http://www.solarbuzz.com/SolarPrices.htm. Prices are calculated by dividing life cycle expenditures on the system by total energy produced, excluding sales tax and savings from government incentives. Assumes site receives 5.5 hours sunlight/day throughout year (typical for U.S. sunbelt states).
[21] Nemet, G.F. (2006) "Beyond the Learning Curve: factors influencing cost reductions in photovoltaics," *Energy Policy* 34 (2006) 3218–3232.
[22] Pacca, S.A., D. Sivaraman and G.A. Keoleian (2007) "Parameters affecting life cycle performance of PV technologies and systems." *Energy Policy* 35: 3316 – 3326.
[23] Muller, A., K. Wambach and E. Alsema (2006) "Life cycle analysis of solar module recycling process." *Materials Research Society Symposium Proceedings* 895.
[24] Fthenakis,V. and H.C. Kim (2006) "Cd-Te Photovoltaics: Life cycle environmental profile and comparisons." *Thin Solid Films* 515: 5961-5963.
[25] Torcellini, P., N. Long and R. Judkoff (2003) *Consumptive water use for U.S. power production.* NREL/TP-550-33905.
[26] Energy Efficiency and Renewable Energy (EERE) (2012) "Green Pricing: Utility Programs by State."
[27] EERE (2012) "Green Power Markets: Renewable Energy Certificates." *The Green Power Network.*

PowerPoint Presentation with Notes: Solar

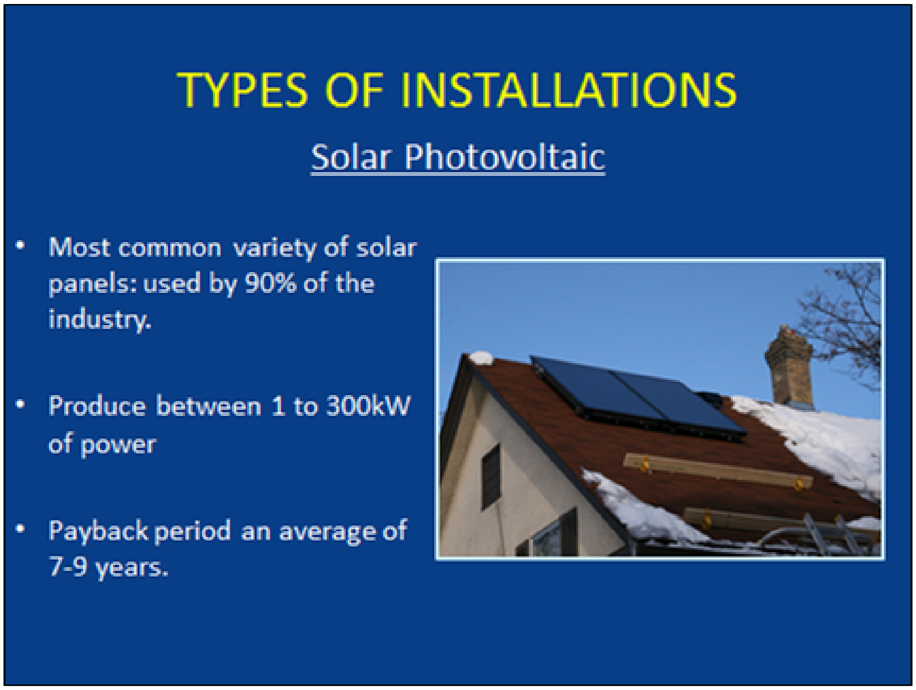
This is the Title Page. Have this up on the projector when your camper group is filtering in. After you've finished reading the introduction in the instructions, or after you've introduced the program in your own way, start the presentation. This packet is intended as a guide. The information contained here is likely much more than 20-25 minutes. It is recommended that you practice the presentation beforehand, in order to present most effectively. Information not used in the presentation may prove useful during discussion.

References:
Dennis Schroeder. NREL. 12/19/11. NREL Image Gallery: Solar Energy: Photovoltaics: 20287.JPG. Retrieved 2/2/13. Electronic Source: http://images.nrel.gov/viewphoto.php?&albumId=207405&imageId=6322680&page=2&imagepos=35.



The slide has a video from the Department of Energy that provides a brief overview of what solar power is and how it works. The video is slightly under 4 minutes.

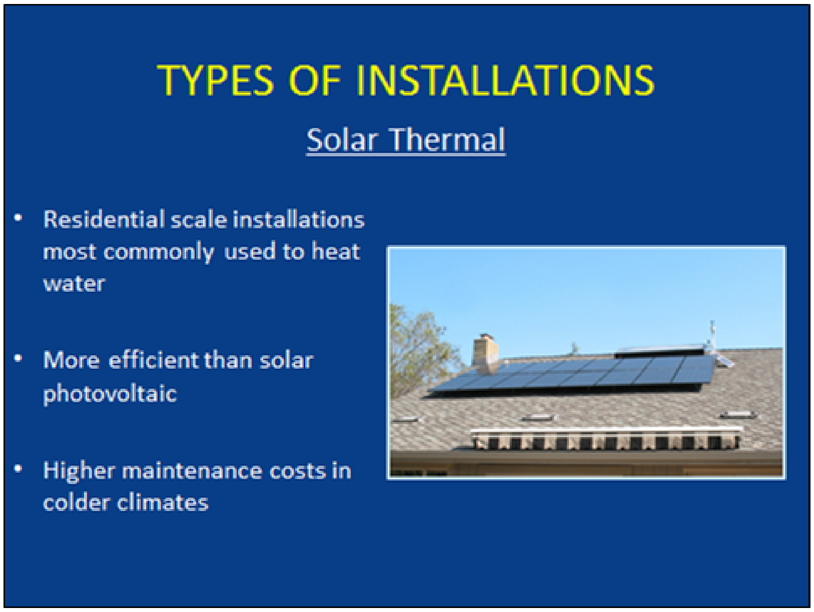
References:
Department of Energy. National Renewable Energy Laboratory. Jamie Krutz. Copyright 2010. Video: Solar Power Basics. Retrieved 2/2/13. Electronic Source: https://www.eeremultimedia.energy.gov/solar/videos/solar_power_basics.



"Solar Photovoltaic (pronounced fo-to-vol-TAE-ic)installations are what is most commonly thought of when people think of a "solar panel." These can be large or small installation that convert the sun's energy into usable energy to power households and household devices.

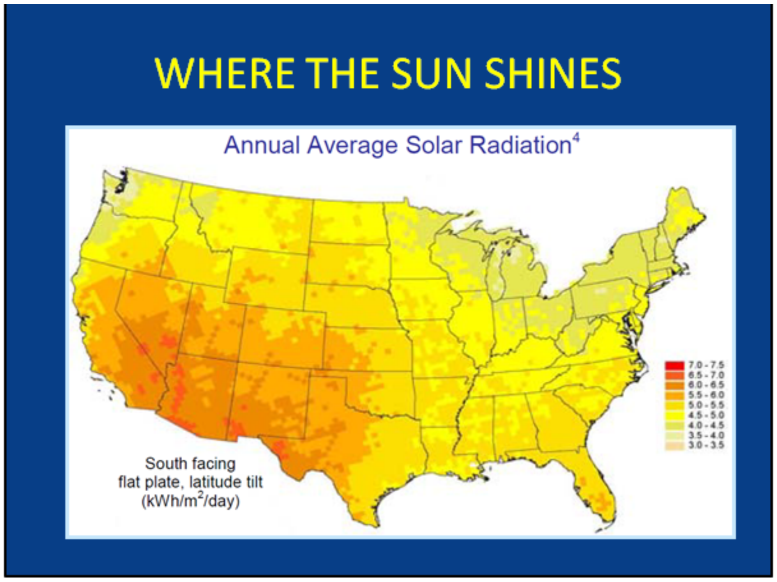
"Solar Photovoltaic systems produce from 1kW to 300kW of power—the latter of which is easily enough to power a home and store or sell the excess. The average return on investment of these types of installations is between 7-9 years, but can range from as little as 2 ½ to 15, depending on a variety of factors including electricity rates in grid-tied systems."

References:
Michigan Solar Solutions. Product Types: Solar Panels. 2010. Retrieved 2/4/2013. Electronic Source: http://www.michigansolarsolutions.com/solar_panels.html.
Applied Energy Innovations. NREL. 12/19/10. NREL Image Gallery: Solar Energy: Photovoltaics: 18699.JPG. Retrieved 2/4/13. Electronic Source: http://images.nrel.gov/viewphoto.php?&albumId=207405&imageId=6322515&page=5&imagepos=21.
The Solar Foundation. "National Solar Jobs Census 2011." October 2011. Electronic Source: http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF_JobsCensus2011_Final_Compressed.pdf.



"Solar thermal installations are far more efficient than their photovoltaic cousins. Some solar thermal designs concentrate the sun's light to create heat, which it then runs through an engine to generate electricity. In the version pictured here, however, the installation is designed around the household's water tank. Rather than converting anything to electricity (a highly inefficient process) this solar thermal installation absorbs the heat from the sun in order to simply heat the water of the house, saving a great deal of money on water heating. Such an installation is slightly more difficult in colder climates, where the pipes are in danger of freezing during the winter months and maintenance costs are higher."

References:
Solar-thermal.com. 2008. An Industry Report on Solar Thermal Energy. Solar Thermal vs. PV. Retrieved 2/4/2013. Electronic Source: http://www.solar-thermal.com/solar_vs_pv.html.
Lieko Earle. NREL. 2/17/10. NREL Image Gallery: Solar Energy: Thermal: 19615.JPG. Retrieved 2/4/13. Electronic Source: http://images.nrel.gov/viewphoto.php?&albumId=207407&imageId=6323523&page=1&imagepos=23.

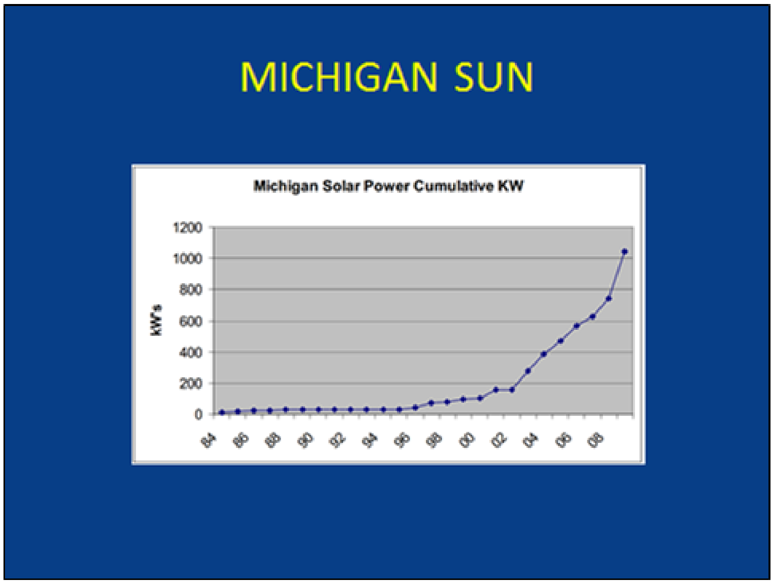


"On the screen is a map of solar power capacity in the United States. As you can see, the main concentration of solar radiation is concentrated in the Southwest of the country. While this area is, in many ways, ideally placed for solar power installations, it is not the only place that such installations can go. Solar installations can be placed wherever the sun shines, and there are many such installations in Michigan, whose climatic conditions produce more voltage per sunlight hour than hotter climate, where the installations become too hot and lose efficiency."

References:

Michigan Solar Solutions. Useful Resources: Fun Facts: Sun Facts. 2010. Retrieved 2/4/2013. Electronic Source: http://www.michigansolarsolutions.com/sun_facts.html.

Center for Sustainable Systems, University of Michigan. 2012. "*Photovoltaic Energy Factsheet.*" Pub. No. CSS07-08.

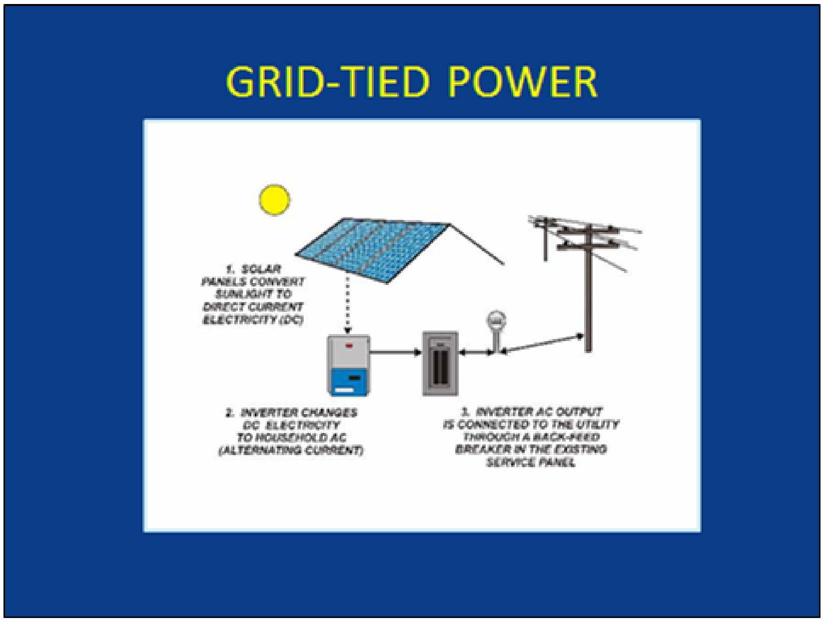


"Solar energy installations have been increasingly rapidly in Michigan. With Michigan's colder climate proving extremely conducive to energy production via solar, industry is springing up all over the state as supply increases to meet rising demand.

Michigan companies such as Hemlock Semiconductor are moving from away from the electronics business and into the solar world, believing that the growth in this industry will continue to be profitable. These companies hire where they are—from universities and colleges in Michigan.

Nevertheless, Michigan still lags behind many other states in solar energy jobs and installations. States such as Colorado, Pennsylvania, New York, and Oregon are all ahead of Michigan in these areas."

References:
Michigan Energy Office. "Solar Power Installed in Michigan." Retrieved 2/4/2013. Electronic Source:
http://www.michigan.gov/documents/dleg/Solar_Chart_309619_7.pdf
The Solar Foundation. "National Solar Jobs Census 2011." October 2011. Electronic Source:
http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF_JobsCensus2011_Final_Compressed.pdf.

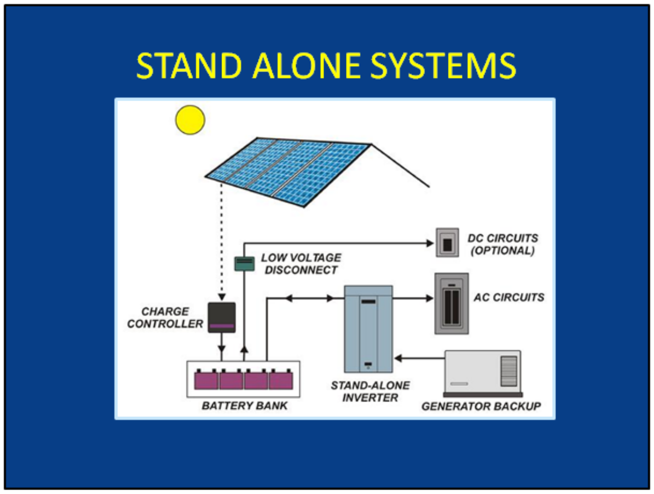


"The grid-tied power system allows a household to use as much energy as it needs, while selling the rest back to the power grid at the going electricity rate. In addition, if the system is underproducing due to weather or other conditions, the grid can serve as a backup without a disruption or power loss.

This is one of the more logical choices for systems that have a reliable connection to the grid, due to its ability to actually earn money when the household is using less energy than it is producing. This results in a significant decrease in the payback period of the installation.

A downside to the system, however, is its inability to continue supplying power if the grid is down. Because it has no battery system to store power during these periods, the electricity demands of the household cannot be met. A battery system IS available, though it adds complications in terms of cost and maintenance, as well as losing some of the payback benefits of being tied to the grid."

References:
Aladdin Solar, LLC. 2008. "PV (Photovoltaic) Systems." Retrieved 2/4/2013. Electronic Source: http://www.aladdinsolar.com/pvsystems.html.

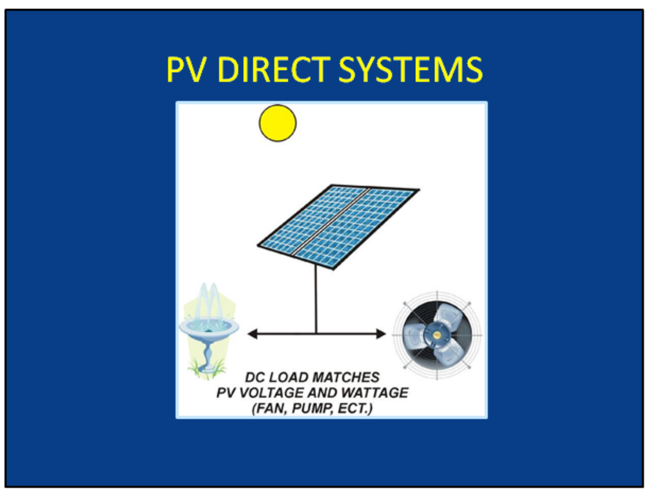


"A stand alone system has no connection to the grid and is instead connected to a battery operated system that stores extra energy directly on the premises, for use on the premises. The system stores enough energy to power an installation for several days and nights if the panels are disrupted or there is little no sun.

This type of system generally requires a backup power source of some kind, such as hydroelectric power or wind. Miniature versions of this type of installation are those seen on remote road signs and radio towers."

References:

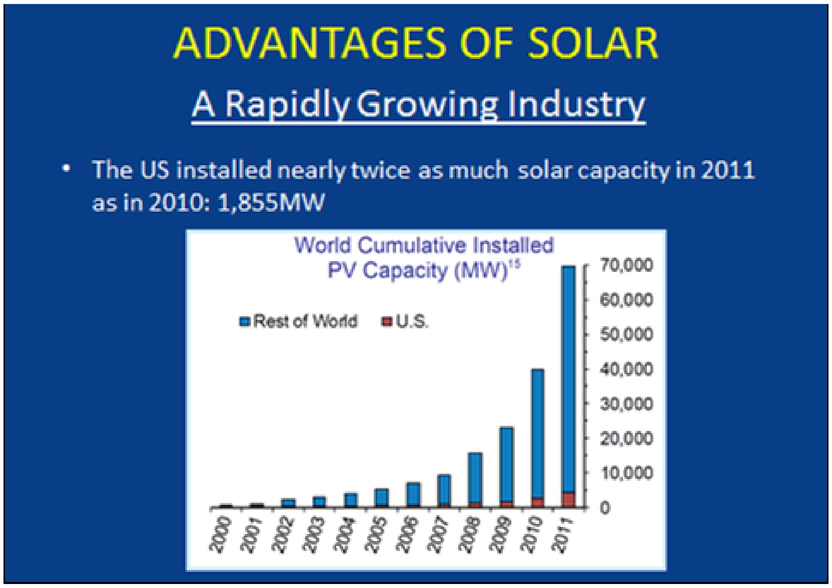
Aladdin Solar, LLC. 2008. "PV (Photovoltaic) Systems." Retrieved 2/4/2013. Electronic Source: http://www.aladdinsolar.com/pvsystems.html.



"The PV Direct Systems are the most simplistic solar installations available, and are used for much smaller purposes, such as powering a fan or a pump for a garden fountain, as shown here. The system is straight forward: the energy produced is used immediately for the purpose it's been designed for. There is no conversion of energy types, and little to no power transmission required. And when the sun stops, the system stops, too."

References:

Aladdin Solar, LLC. 2008. "PV (Photovoltaic) Systems." Retrieved 2/4/2013. Electronic Source: http://www.aladdinsolar.com/pvsystems.html.



"That's means a lot of new jobs. The installation of solar panels creates jobs in installation, manufacturing, salds and distributions, as well as work in the research sector as scientists and engineers work to make the technology cheaper and more efficient. In 2012, the solar industry employed almost 125,000 American workers in these areas—a growth rate of 24% over 2011 numbers.

The US is definitely increasing in its PV capacity, but is still lagging behind the rest of the world. Currently, Germany, Italy, and the Czech Republic are the world leaders in solar, producing over 1GW each (Germany producing around 8GW. The United States was 5th world wide in the market, coming in behind Japan as well, as of 2010."

References:
Center for Sustainable Systems, University of Michigan. 2012. "*Photovoltaic Energy Factsheet.*" Pub. No. CSS07-08.
http://exploringgreentechnology.com/solar-energy/advantages-and-disadvantages-of-solar-energy/
The Solar Foundation. "National Solar Jobs Census 2011." October 2011. Electronic Source: http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF_JobsCensus2011_Final_Compressed.pdf.
Solarbuzz. NPD Group. 2010. "Global PV Market." Solar Market Research and Analysis. Retrieved 2/10/13. Electronic Source: http://www.solarbuzz.com/facts-and-figures/market-facts/global-pv-market.

ADVANTAGES OF SOLAR

- Allows individual initiative
- Only costs are upfront costs, and maintenance. The power source itself is free.

Unlike traditional energy, and many types of renewables, solar energy is unique in amount of interest it has created on a small scale. Before the prevalence of solar, the energy market has been difficult to break into, with high upfront costs and highly specialized knowledge. With solar panels available, it's becoming easier for individuals to break away from power companies, whether because they do not support their practices, they prefer to be self sufficient, or any number of reasons.

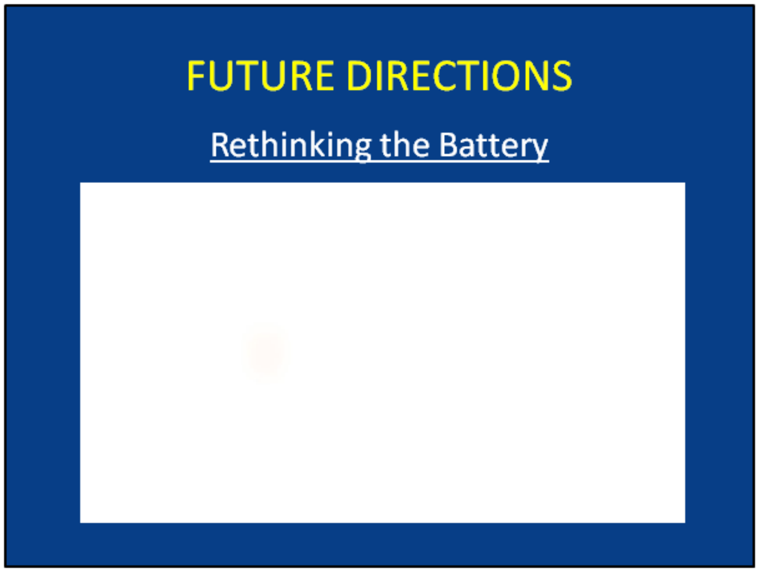
While currently produced on this smaller scale, larger scale solar installations provide an opportunity for stabilizing energy prices. While the upfront costs are significant (like any power company's), once solar has been installed, the costs are minimal, only fixed costs such as leasing payments, and limited variable costs in the form of regular maintenance. Unlike fossil fuel plants, there is no need to buy the energy source—the sun is free. This could allow energy companies to lock in prices for decades into the future."

DRAWBACKS

- "Off the grid" isn't quite off the grid…
- Batteries may offer a solution, but current technology isn't up to the job for utility scale units.

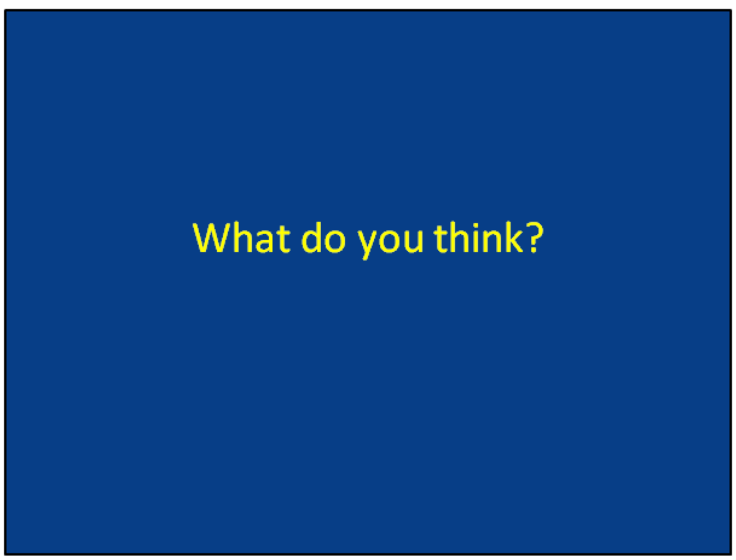
"Many people invest in solar in order to 'get off the grid' and decrease their reliance on industrial power companies. While the the most common grid-tie system provides many advantages, however, these solar customers are still vulnerable to power outages, since their extra energy is all sold back into the system.

Proponents of solar energy believe that this issue can be resolved using large scale, industrial batteries. Batteries would be used to store excess energy when the household is underconsuming what is generated, and to provide energy when the household is overconsumer—removing the need to tie into the system. Currently, however, battery technology is expensive with higher long term maintenance costs, and a grid-tie system has monetary advantages."



"One of the biggest challenges facing renewable energy is energy storage. Fortunately, the field isn't stagnant. This video has some interesting information on where technology is headed with regards to battery storage."

Play video (less than 3 minutes).



"That's the end of the presentation. The rest of the time has been set aside for discussion on the presentation and solar energy in general—whether it's thoughts you had during the presentation, or something you've been wondering. Again, I'm not an expert, but I'll answer anything that I can. Does anyone want to start us off?"

To be displayed upon the end of the discussion, or upon request.

Renewable Energy Talks

Instructions for the Sustainability Coordinator

Wind Energy

Included:

- ✓ These instructions
- ✓ Wind Energy Fact Sheet—2013 version
- ✓ Wind PowerPoint Presentation with Notes

Instructions:

1.) The Wind Energy Fact Sheet is regularly updated by SNRE's Center for Sustainable Systems. Before working with these documents, check that you have the most up-to-date version available. All updated versions are here: http://css.snre.umich.edu/publications/factsheets
2.) Print off updated copies of the Wind Fact Sheet. 10-15 should suffice, with more or less depending on anticipated attendance. These sheets should be made available to participants when they enter.
3.) Prepare the Wind PowerPoint Presentation. There are two (2) videos in this presentation. Ensure that both are working properly before participants arrive. It would be exceedingly helpful to familiarize yourself with the PowerPoint and the Wind Fact Sheet before performing the activity.
4.) While the audience is filtering in, put the first slide, labeled "WIND ENERGY" on the projector.
5.) When the audience arrives, introduce the program using the following, or your own words:

"Welcome to Renewable Energy Talks: Wind Edition. One page factsheets are available for anyone who didn't get one when they came in, and you can take those with you after the presentation.

Tonight/Today I'm going to present to you a general overview of where wind energy currently stands. I am personally not an expert in wind energy, and the point of the presentation isn't to make anyone an expert—it's just designed to provide general information for campers who are interested, and to spark discussion on the topic. The presentation will last 20-25 minutes, and we'll use the rest of the time to discuss what we heard and thought. Any questions?"

6.) Answer any questions you can and proceed with the presentation.
7.) At the end of the presentation, let them know that it's time for discussion. Lead the discussion or let the campers discuss among themselves, as per your judgment.

Center for Sustainable Systems

University of Michigan
440 Church Street, Ann Arbor, MI 48109-1041
phone: 734-764-1412 fax: 734-647-5841
email: css.info@umich.edu
http://css.snre.umich.edu

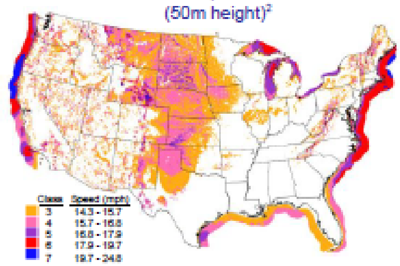
factsheets

Wind Energy in the U.S.

The Wind Resource and its Potential

Approximately 2% of the solar energy striking the Earth's surface is converted to kinetic energy in wind.[1] The distribution of wind energy is heterogeneous, both across the surface of the Earth and vertically through the atmosphere. Wind turbines convert the wind's kinetic energy to electricity without emissions. Class 3 winds (annual average speed of 14.3 - 15.7 mph at 50m) are generally the minimum needed for a commercially viable project. Although only 2.9% of U.S. electricity was derived from wind energy in 2011[3], wind capacity is increasing rapidly.

U.S. Wind Resources, Onshore and Offshore (50m height)[2]



- Wind power is proportional to the cube of wind speed.
- Because wind speeds are lower close to the earth's surface – a phenomenon called "wind shear" – more wind power is available higher off the surface. The hubs of most modern wind turbines are 70-100 meters off the ground.
- Potentially, global onshore and offshore wind power at commercial turbine hub heights could provide 840,000 TWh of electricity each year, while total global electricity consumption from all sources in 2009 was about 17,300 TWh.[4,5] Similarly, the U.S. annual potential of 68,000 TWh (lower 48 states) well exceeds annual U.S. electricity consumption of about 3,700 TWh.[3,4]
- A 2008 study found wind could feasibly provide 20% of U.S. electricity by 2030.[6]
- Many studies have shown wind's variability would increase the cost to operate the grid by less than 0.7¢/kWh of electricity (for up to 40% electricity from wind).[7]
- Detailed state wind maps can be found under 'Maps & Data' at: http://www.windpoweringamerica.gov/

Wind Energy Technology and Impacts

Horizontal Axis Wind Turbines

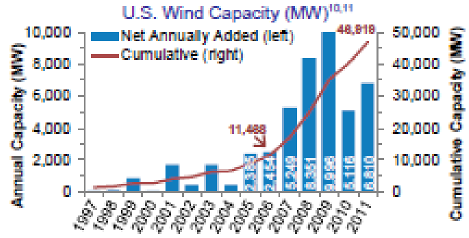
2.5MW Clipper, Medicine Bow, WY[8]

This factsheet focuses on horizontal axis wind turbines (HAWT) because they are predominant. The HAWT rotor comprises blades (usually three) symmetrically mounted to a hub. The rotor is connected via a shaft to a gearbox, and the generator is housed within the turbine's nacelle.The nacelle is mounted atop a tower that is connected to the ground with a concrete foundation.

- HAWT come in a variety of sizes, ranging from 2.5 meters in diameter and 1 kW for residential applications up to 100+ meters in diameter and over 3.5 MW for offshore applications. The theoretical maximum efficiency of a HAWT is ~59%, also known as the Betz Limit. Most HAWT extract about 50% of the energy from the wind that passes through the rotor area.[6]
- The *capacity factor* of a wind turbine is its average power output divided by its maximum power capability. Capacity factor depends on the quality of the wind at the turbine. Higher capacity factors imply more energy generation.
- On land, capacity factors in the range of 0.24 to 0.50 are typical.[9]
- Offshore winds are generally stronger than on land, and capacity factors can exceed 0.50, but offshore wind farms are more expensive to develop and maintain.[9] Most offshore turbines are currently placed in depths of 30m or less.

Installation, Manufacturing and Cost

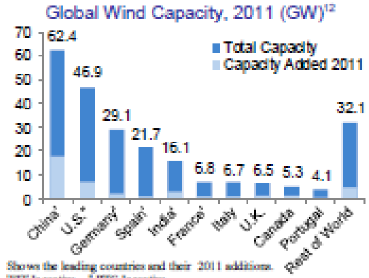
U.S. Wind Capacity (MW)[10,11]



- More than 39,000 utility-scale wind turbines are installed in the U.S.[10,11]
- U.S. installed wind capacity increased by 309% between 2006 and 2011, a 33% average annual increase; [10,11] global installed capacity has grown 27% each year, on average, since 2000 and reached 237 GW in 2011.[12]
- U.S. average turbine size was 1.97 MW in 2011, up from 0.89 MW in 2000.[7]
- Average capacity factor has increased from 0.25 for projects installed through 1998 to around 0.33 for recent projects. Higher capacity factors tend to lower power prices.[7]
- Installed wind project costs declined by roughly $2,700/kW between the early 1980's and 2001.[13] In 2011, costs were $2,100/kW.[7]
- Since 2003, commercial wind energy has cost 3-6¢/kWh wholesale.[7] The 2011 average U.S. residential electricity price was 11.8¢/kWh.[3]
- A small (3-10 kW) turbine on an 80 ft. tower with an inverter and batteries would cost $15,000-$50,000 installed.[14]

- The leading wind states, by total capacity, are Texas (10,377 MW), Iowa (4,322 MW) and California (3,927 MW).[11] South Dakota generated the greatest percentage of electricity from wind – 22.3%.[15]
- Wind turbines and components are manufactured at more than 470 U.S. facilities.[16]
- In 2011, an estimated 75,000 full-time workers were employed in the U.S. wind industry.[7]
- In a multi-turbine wind project, ≈60 acres of land are needed per MW of installed capacity, but 5% or less of this total area is actually occupied by roads, turbine foundations, or other equipment – 95% of this area is available for other uses.[17]
- For farmers, annual lease payments provide a stable income of $2,000 to $5,000/MW of turbine capacity (depending on the number of turbines on the farmer's property, the value of the power generated, and lease terms).[18] For a 250-acre farm, with income from wind at about $55 an acre, the annual income from a wind lease could be $14,000.[19]

Global Wind Capacity, 2011 (GW)[12]



Shows the leading countries and their 2011 additions.
'FIT Incentive + PTC Incentive

Energy Performance and Environmental Impacts

- Wind turbines can reduce environmental impacts associated with electricity generation – 470 gal fresh water/MWh of electricity are evaporated by thermoelectric plants.[20] U.S. air pollutant emissions were 826.7 kg CO_2/MWh, 1.8 kg SO_2/MWh, and 0.8 kg NO_x/MWh, for the 2.87×10^9 MWh of electricity generated from fossil fuels in 2010.[3]
- Each year, U.S. wind capacity installed through 2011 will avoid an estimated 75 million tons of carbon dioxide emissions and conserve about 27 billion gallons of water that would have otherwise been consumed as steam or for cooling in conventional power plants.[12]
- According to a 2008 study, if 20% of U.S. electricity was wind-generated by 2030, annual CO_2 emissions would decrease by 825 billion kg, 7.6 trillion kg of CO_2 would be cumulatively avoided by 2030, and electricity generation-based water usage would decrease by 17%.[6]
- A 2005 study of two U.S. wind farms found net energy ratios (energy generated/energy invested) of 47 and 65.[21]
- Avian mortality due to collisions with wind turbines is much lower than for other human structures, but the best way to minimize mortality is careful siting – picking sites with low bird use.[22]
- Bat mortality due to wind turbines is less well studied and research is ongoing (as it is with avian issues). A large percentage of bat collisions occur during the fall migratory period.[23]
- Noise, in dB(A), from a typical wind farm at 350m is 35-45. For comparison, a quiet bedroom is 35; a 40 mph car 100 m away is 55.[24]

Solutions and Sustainable Actions

Policies Promoting Renewables

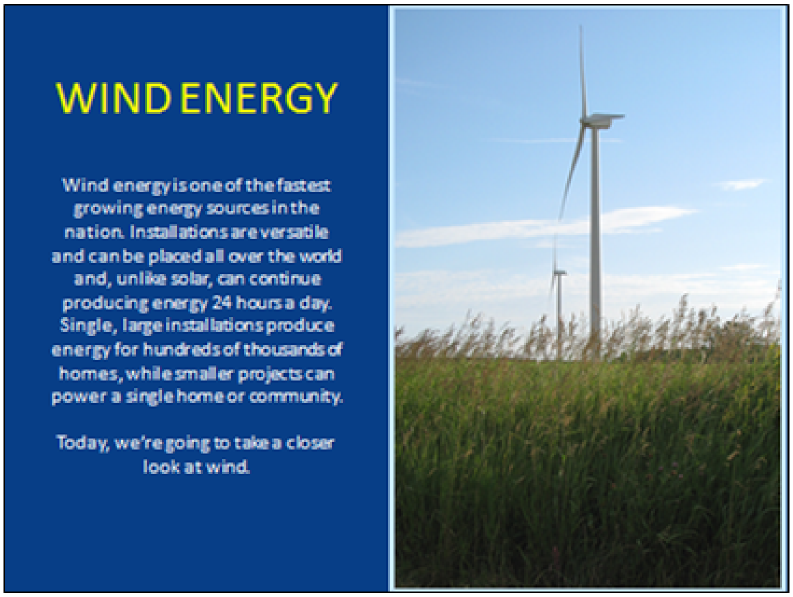
The price consumers pay for electricity generated with conventional fuels does not include externalities such as the cost of health effects from air pollution, environmental damage from resource extraction, or long-term nuclear waste storage. The following are examples of policies that support wind and other renewables and address these externalities.

- A *renewable portfolio standard* (RPS) schedules electricity providers to obtain a minimum fraction of their energy from renewable resources.
- *Capacity rebates* are one-time up-front payments for building renewable energy projects, based on the capacity (in watts) installed.
- *Feed-in tariffs* set a minimum per kWh price paid to renewable electricity generators by retail electricity distributors.
- *Production tax credit* (PTC)- the American Recovery and Reinvestment Act (2009) extended the federal PTC, which provides a 2.2¢/kWh benefit for the first ten years of a renewable energy facility's operation, through 2012 for wind. Small wind installations (<100 kW), can also receive tax credits for 30% of the purchase and installation cost.[25]
- *Qualified energy conservation bonds* are an interest-free financing option for state and local government renewable energy projects.[25]
- *Section 9006 of the Farm Bill* is the renewable energy and energy efficiency program that funds grants and loan guarantees for agricultural producers and rural small businesses.[26]
- *System benefits charges* are paid by all utility customers and create a fund for low-income support, renewables, efficiency, and R&D projects that are unlikely to be provided by a competitive market.
- *Net metering*, offered in 43 states and DC, requires retail utilities to credit customers who generate more electricity than they consume.[27]
- For a listing of current U.S. policies by state, see the DSIRE database at http://www.dsireusa.org/

What Can You Do?

- Invest in non-fossil electricity generation infrastructure by purchasing "green power" from your utility.
- Buy carbon offsets, also known as Green Tags or Renewable Energy Certificates (RECs). A REC represents the environmental attributes – separate from the actual electrons – associated with a unit of electricity generated from renewable sources.[28]
- Consider installing your own wind system, especially if you live in a state that provides financial incentives or has a net metering policy.
- Visit the U.S. Department of Energy's small wind website at http://www.windpoweringamerica.gov/small_wind.asp

[1] Gustavson, M.R. (1979) "Limits to Wind Power Utilization," *Science* 204 (4388): 13-17.
[2] U.S. Department of Energy, National Renewable Energy Lab (2009) "US Wind Resource Map."
[3] U.S. DOE, Energy Information Administration (2012) *Annual Energy Review 2011.*
[4] Lu, Xi et al. (2009) "Global potential for wind-generated electricity" *Proc. of Natl. Acad of Sci.* 106 (27).
[5] U.S. EIA (2012) "Electricity Consumption." *International Energy Statistics.*
[6] U.S. DOE, Energy Efficiency and Renewable Energy (2008) "20% Wind Energy by 2030."
[7] NREL (2012) *2011 Wind Technologies Market Report.*
[8] Image courtesy of DOE/ NREL – Credit – Clipper Liberty.
[9] NREL (2012) "Transparent Cost Database: Capacity Factor" *Open Energy Information.*
[10] AWEA (2011) *U.S. Wind Industry Annual Market Report, Year Ending 2010.*
[11] AWEA (2012) *U.S. Wind Industry Fourth Quarter 2011 Market Report.*
[12] Global Wind Energy Council (2012) *Global Wind Report: Annual Market Update 2011.*
[13] U.S. DOE. (2008) *Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007.*
[14] EERE (2007) "Small wind electric systems: A U.S. consumer's guide."
[15] U.S. EIA (2011) *Electric Power Monthly, February 2012.*
[16] AWEA (2012) "Industry Statistics."
[17] AWEA (2007) "How much land is needed for a utility-scale wind plant?"
[18] U.S. Government Accountability Office (2004) "Renewable Energy, Wind Power's Contribution to Electric Power Generation and Impact on Farms and Rural Communities." Report #GAO-04-756.
[19] AWEA (2009) "Resources: Wind Energy and the Economy."
[20] Torcellini, P., et al. (2003) "Consumptive Water Use for U.S. Power Production." NREL/TP-550-33905.
[21] Spitzley, D.V. and G.A. Keoleian (2005) "Life cycle environmental and economic assessment of willow biomass electricity." Center for Sustainable Systems Report #CSS04-05R.
[22] National Wind Coordinating Committee (2001) "Avian collisions with wind turbines."
[23] National Wind Coordinating Committee (2004) "Wind turbine interaction with birds and bats."
[24] British Wind Energy Association (2000) "Noise from wind turbines: The facts."
[25] N.C. Solar Center, IREC (2012) "Federal Incentives/Policies for Renewables & Efficiency." *DSIRE.*
[26] U.S. Department of Agriculture (2007) "2002 Farm Bill Initiative: The Renewable Energy and Energy Efficiency Program." USDA Farm Bill Section 9006.
[27] N.C. Solar Center and IREC (2012) "Net Metering Policies." *DSIRE.*
[28] U.S. EPA's Green Power Network (2008) Renewable Energy Certificates.



This is the Title Page. Have this up on the projector when your audience is filtering in. After you've finished reading the introduction in the instructions, or after you've introduced the program in your own way, start the presentation. This packet is intended as a guide. The information contained here is likely much more than 20-25 minutes. It is recommended that you practice the presentation beforehand, in order to present most effectively. The other information may prove useful during discussion.

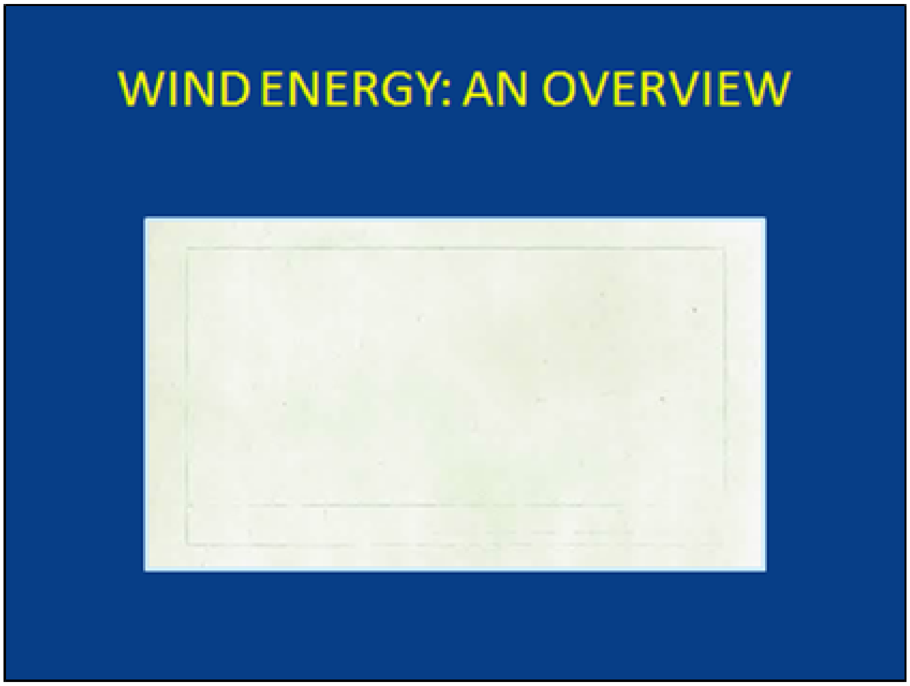
"Wind energy is one of the fastest growing energy sources in the nation. The number of megawatt hours per day that the US capacity can generate has been steadily increasing since 2001, with almost 60,000 megawatts projected to be generated in 2013. Already able to generate 50,000 megawatts, the wind energy sector has the ability to make up 20% of all U.S. energy consumption by 2030.

Wind energy installations are versatile and can be placed all over the world, in cold climates and warm climates, and unlike solar installations, wind energy projects work for 24 hours a day. Large installations can produce enough electricity to power hundreds of thousands of homes, offsetting hundreds of millions of tons of carbon emissions per year. Small installation have the versatility to power a single home, or entire communities.

In this program, we're going to take a closer look at wind."

References:

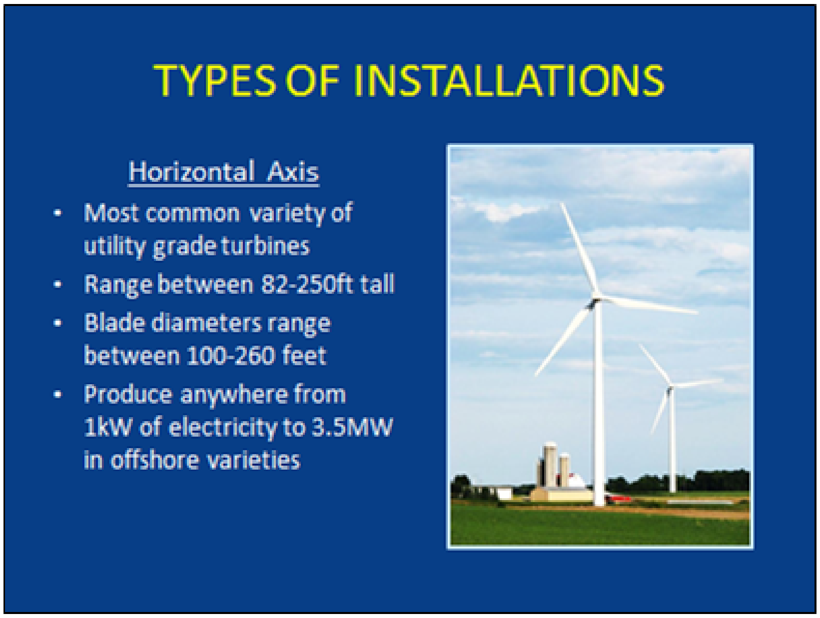
U.S. Every Information Administration. December 2012. Analysis and Projections: Short-Term Energy Outlook. Retrieved 12/11/12. Electronic Source: http://www.eia.gov/forecasts/steo/query/
U.S. Department of Energy: Energy Efficiency and Renewable Energy. Wind Program Accomplishments. September 2012. Electronic Source: http://www1.eere.energy.gov/wind/pdfs/wind_accomplishments.pdf.



The slide has a video from the Department of Energy that provides a brief overview of what wind turbines are and how they work. The video is slightly over 2 minutes. You may deem the video sufficient, or you can explain further, as below.

"Wind turbines are actually fairly simple in their construction. Turbine blades are connected to a generator, which generates energy as the wind spins the blades. These blades are specifically designed to maximize the efficiency of the wind that the blows across them, by creating air pressure differences that make the blades spin in a circle, rather than fighting against the direction of the wind. The blades are then connected to a rotor shaft and a series of gears, which increase the rate of rotation to make energy generation possible. More advanced versions of wind technology, such as that shown below, contain a wind vane to measure the wind's direction and move the turbine with the wind in order to maximize electricity generation.

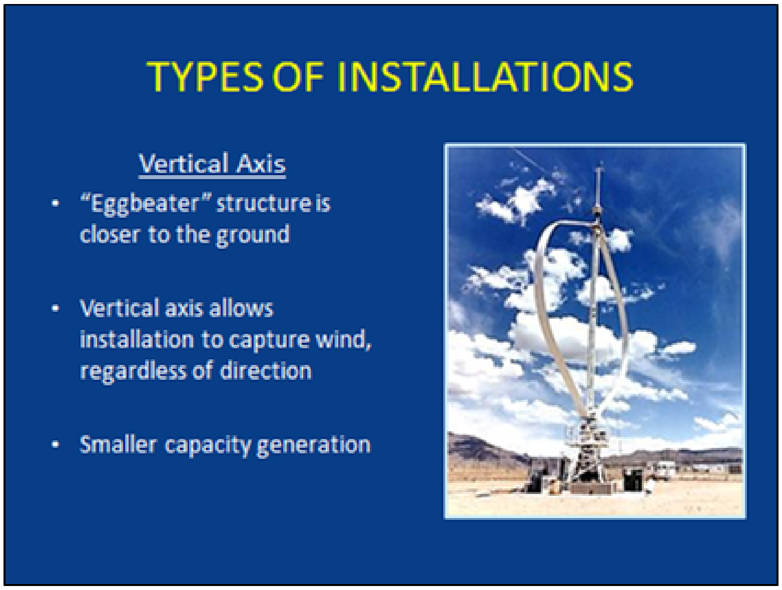
The energy produced by the turbine must then be transmitted via physical means to where it is stored or used. Most large scale systems connect to the nation's electricity grid via transmission cables, while other types of installations store the energy produced in a battery, for use when the wind speed is low."



"These are the most commonly recognized form of wind turbine here in the United States, using blades (that resemble airplane propellers) to turn around a single horizontal axis. These turbines are usually exceptionally tall, in order to capture the higher velocity winds in the higher atmospheres. Horizontal axis turbines are the most commonly used turbines in today's market, comprising almost all utility grade turbines globally.

The towers can range anywhere from around 82 to 250 feet (~25-75 meters). They boast 1-3 massive rotating blades that range from around 100 to 260 feet (30-80 meters) in diameter. The longer the blades, the faster the revolutions per minute going into the gear box and ultimately the more energy generated."

References:
American Wind Energy Association. Learn about Wind Power: What is a Wind Turbine and How Does it Work? Retrieved1/19/13. Electronic Source: http://www.awea.org/learnabout/faq/windturbine.cfm.
RenewableUK. Renewable Energy: Wind Energy: How it Works. Retrieved 1/19/13. Electronic Source: http://www.renewableuk.com/en/renewable-energy/wind-energy/how-it-works.cfm.



“The vertical axis variety of windmill involves two blades, rotating on a vertical axis, usually referred to as an “eggbeater” structure. The style is closer to ground than the horizontal variety, which increases the energy produced per unit construction material purchased. In addition, its vertical nature allows the structure to capture wind energy from whatever direction the wind is blowing, without the use of extra technologies.

However, due to its location closer to the ground, vertical axis varieties don’t reach high enough up to capture the higher velocity winds that the horizontal variety reach, leading to smaller voltage generation per unit. The turbine in the photo to the left has a nameplate capacity (maximum generation under ideal conditions) of 60KW, much smaller than many of the horizontal units that have nameplate capacitys that average 1.78MW.”

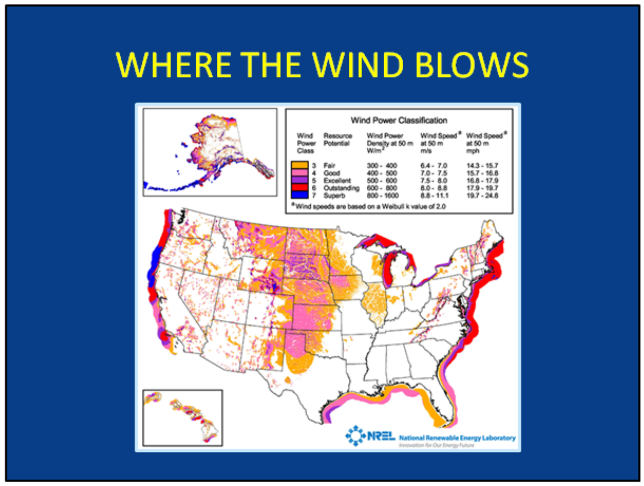
References:
Department of Energy Photo. The 60 KW Darrieus Wind Turbine at the Test Site at Sandia Laboratories. Digital Photo Archive. Retrieved 1/19/13. Electronic Source: http://www.doedigitalarchive.doe.gov.
U.S. Department of Energy: Energy Efficiency and Renewable Energy. Wind Program Accomplishments. September 2012. Electronic Source: http://www1.eere.energy.gov/wind/pdfs/wind_accomplishments.pdf.

"Smaller scale installations come in a large variety of shapes and sizes. The American Wind Energy Association currently recommends a 5KW system for an average American home. An installation of this size would have a diameter of about 18 feet (~9 feet/blade) and average about 80 feet tall. Smaller units that produce around 2KW would be slightly smaller, while units that produce more energy would require a larger diameter.

Such installations cost an average of $30,000 run from around $4,000 for a <1KW system, to much larger, 100KW turbines that could run an entire community, for $350,000. These numbers are current as of January 2013, and vary based on type and size of installation. The payback period for these sorts of installations also varies greatly, depending on a variety of factors, such as type of turbine, wind conditions, local incentive programs, and electricity rates. The American Wind Energy Association places the payback period anywhere from 6 to 30 years.

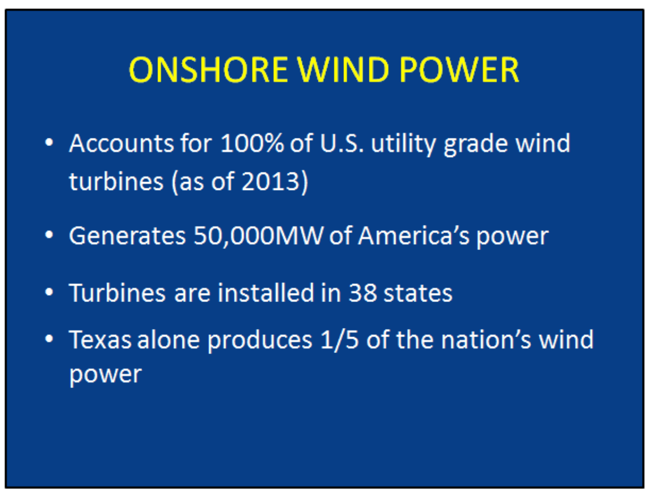
To see what sort of government incentive programs are available in your state, check out the Database of State Incentives for Renewables and Efficiencies website at http://dsireusa.org/."

References:
American Wind Energy Association. Wind Energy Basics Fact Sheets: FAQ for Small Wind Systems. Electronic Source: http://www.awea.org/learnabout/publications/factsheets/factsheets_windenergybasics.cfm.



"On the screen is a map of wind power in the United States. As you can see, a lot of the areas that have great wind power resources are taking advantage of them. Texas currently leads the country in the amount of wind power generated, with most of its installations in the panhandle. Iowa and California come in next, but as the map shows, they have only limited resources in their states.

Indeed, the darkest areas on the map are the coasts, not just the marine coasts, but the coasts along the Great Lakes as well. After seeing where the real capacity is currently located, it's not difficult to understand why wind energy companies are pushing so hard to an offshore wind energy installation up and running."



"Onshore wind power has proven extremely successful in the United States. Current energy generation accounts for 50,000MW of America's power, as of August 2012, with utility grade wind turbines installed in 38 states. Texas is the largest producer, generating over 1/5 of total wind production and producing more than California and Iowa (the next two largest producers) combined.

Onshore wind power has been an enormous step forward for renewable energy production in the United States, but as the figure above shows, the areas in the US with the strongest wind quality is just off the coasts, rather than on land. In addition, wind farms face strict legal regulations in some states on how tall they can be and in what locations, meaning not all the sites shown on the map are available for wind farms, even if they look like viable options. It's likely that in the coming years, wind developers will increasingly look towards the coasts."

"While offshore wind installations have been constructed around Europe, the US companies has thus far been unsuccessful in their attempts to erect similar structures here. In terms of energy generation, offshore wind turbines makes a lot of sense. Current offshore wind generation capacity is estimated to be 1,000 *gigawatts* off the Atlantic coast alone, roughly equivalent to the nation's current electricity generating capacity from all sources. Offshore systems can be much larger, and much taller than those currently feasible or allowed onshore, and a large diameter and better access to fast moving winds in the upper atmosphere means faster energy generation in higher quantities.

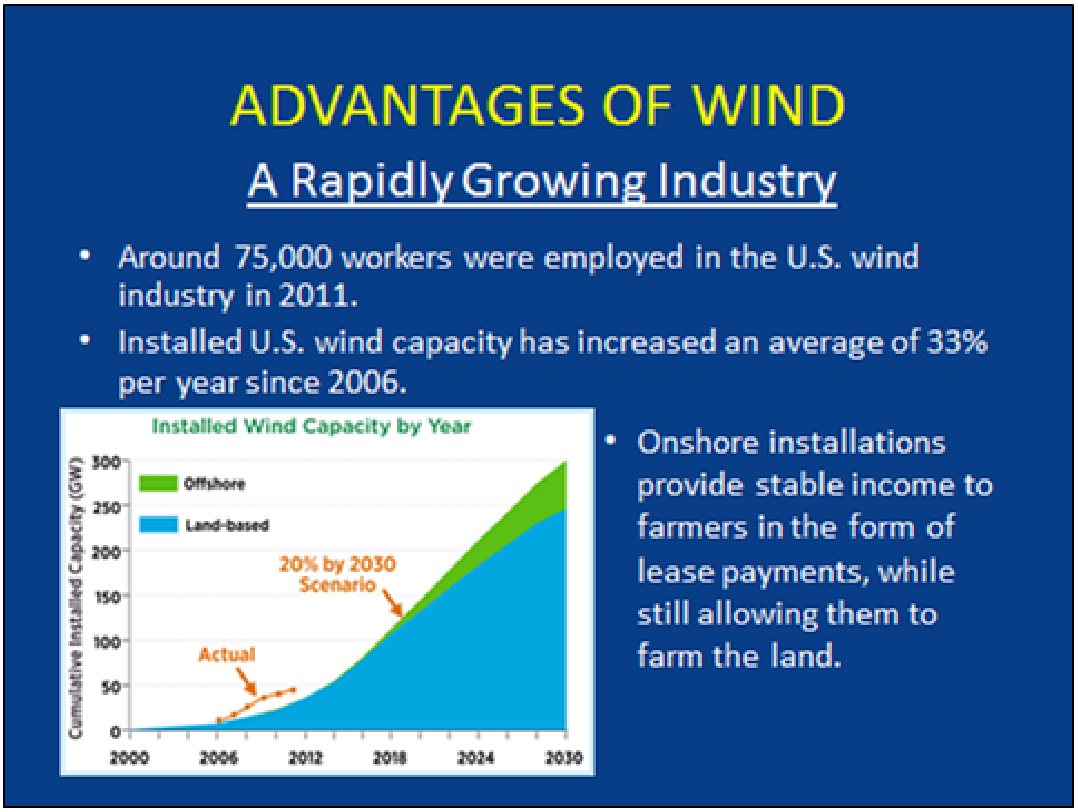
In addition, offshore wind power has not been shown to disrupt marine habitats, and can provide direct power to America's largest coastal cities because the power generated by offshore turbines would be directly adjacent to the people who needed it. This increased efficiency reduces energy lost during transmission, meaning that more of the energy that gets produced gets used.

References:
Department of the Interior. 2/7/10. Overview: Offshore Wind Energy Development off the Atlantic Coast. Press Release. Electronic Source: http://www.doi.gov/news/pressreleases/upload/02-07-10-wea-fact-sheet.pdf.

"While there are many extremely useful aspects of offshore wind power, there remain very serious drawbacks to implementation. Offshore wind technology is much less firmly established than onshore wind installations, and being built in much less friendly environmental conditions. Constructing a turbine to stand in deep water to withstand intense storms is no easy task. This leads to a certain amount of uncertainty around the feasibility and longevity of offshore installations, making economic gains uncertain, even for interested companies.

In addition, offshore wind power faces powerful pockets of political opposition. By the very nature of their location in popular coastal locations, local residents and other invested interests have become seriously concerned about the effects that offshore wind turbines will have on the aesthetics of these locations and the property value of adjacent land. Several installations that seemed sure to move forward were interrupted and ultimately scrapped due to the power of these alternative interests."

References:
American Wind Energy Association. Offshore Wind. Retrieved 1/19/13. Electronic Source: http://www.awea.org/learnabout/offshore/index.cfm.

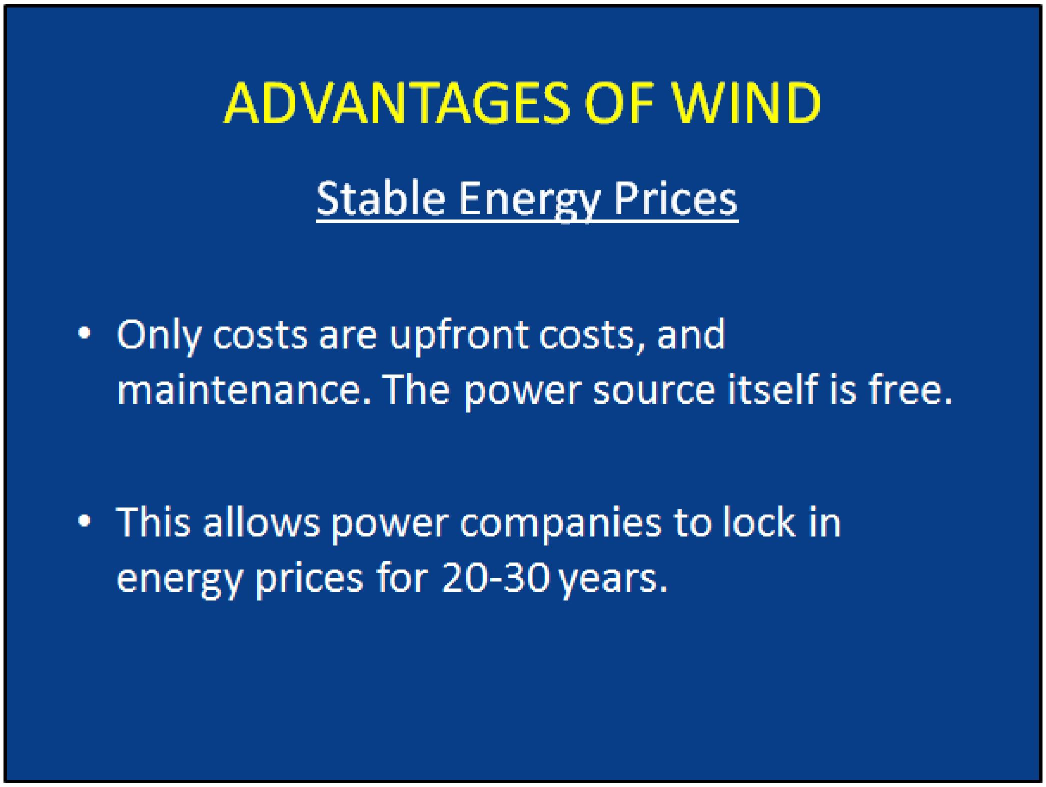


"Today over 75,000 workers are employed in the U.S. wind industry, working in manufacture, construction, siting, regulating, and dozens of other related careers. With the White House's decree that America should receive 20% of its energy from wind by 2030, state governments and businesses are working together to make it happen. The industry is booming so much, that we as a nation are ahead of schedule, headed towards meeting out deadline ahead of schedule.

That's means a lot of new jobs."

References:

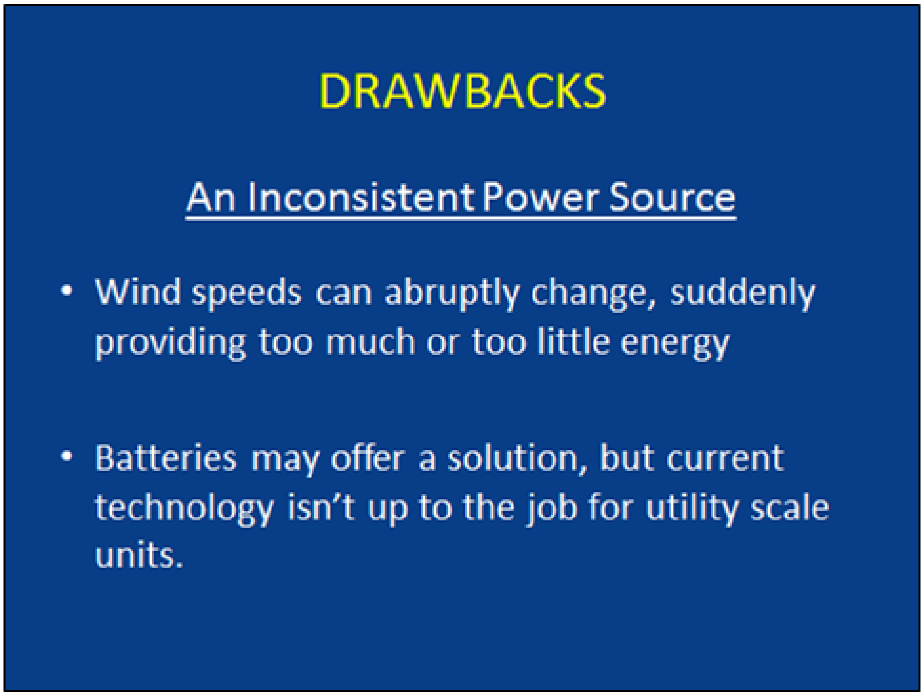
U.S. Department of Energy: Energy Efficiency and Renewable Energy. Wind Program Accomplishments. September 2012. Electronic Source: http://www1.eere.energy.gov/wind/pdfs/wind_accomplishments.pdf.



Wind energy provides an incredible opportunity for stabilizing energy prices. While the upfront costs are significant (like any power company's), once the wind farm has been installed, the costs are minimal, only fixed costs such as leasing payments, and limited variable costs in the form of regular maintenance. Unlike fossil fuel plants, there is no need to buy the energy source—the wind is free. This allows energy companies to lock in prices for decades into the future."

References:

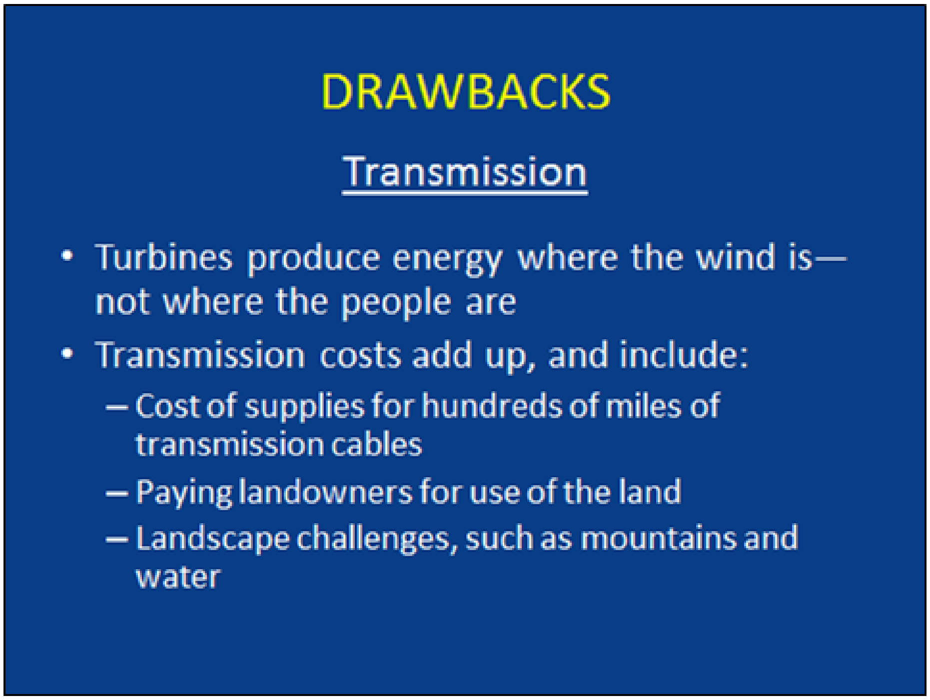
American Wind Energy Association. Learn about Wind Power. Utilities and Wind Power. Costs and Benefits of Wind Energy. Retrieved 1/27/13. Electronic Source: http://www.awea.org/learnabout/utility/index.cfm.



"Wind energy faces a number of challenges, the most serious from a business standpoint being the unpredictability wind. Instances such as that in Texas in 2008 when one wind utility company's production suddenly dropped from 1700MW to 300MW in under 3 hours, highlights the suddenness at which wind energy can turn. Alternatively, if wind speeds suddenly pick up, turbines have to be shut down or risk overloading the grid.

Proponents of wind energy believe that this issue can be resolved using large scale, industrial batteries. Batteries would be used to store excess energy when the wind is moving at a high velocity, and provide energy when wind is moving more slowly. Currently, the US energy grid from all energy sources produces energy as fast as it is being consumed, leading to scrambling by the energy companies if supply or demand change suddenly. A battery powered system would help to solve this problem for the entire grid, making it a viable step towards future energy security. Currently, however, battery technology is not cost effective for this sort of system on such a large scale."

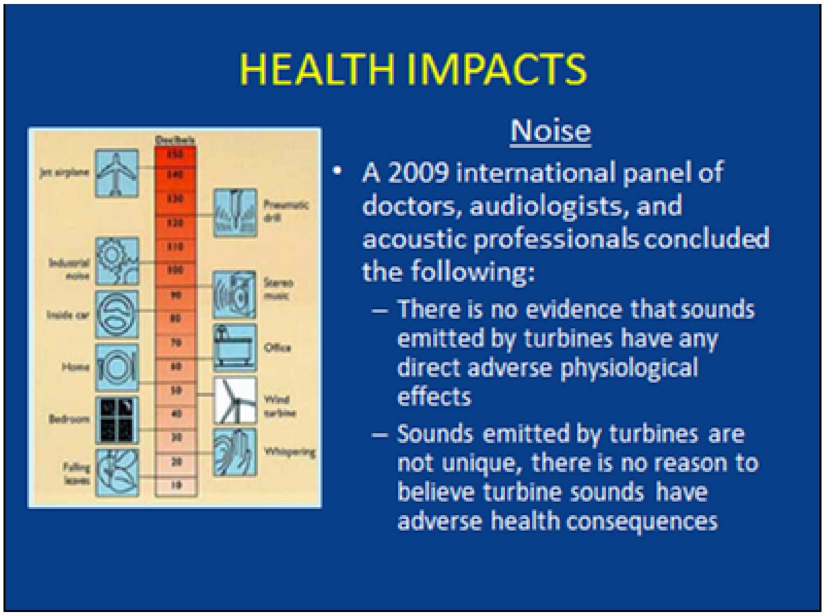
References:
Texas Comptroller of Public Accounts. The Energy Report 2008. Chapter 11: Wind Energy. Available: http://www.window.state.tx.us/specialrpt/energy/renewable/wind.php.



"Unlike traditional fossil fuel energy sources, which can be moved via pipeline or train to its desired location, wind energy is produced exactly where the wind turbine is standing—usually quite a distance from the consumer who ultimately hopes to use it. In order to get the power from the turbine to the consumer, transmission lines have to be strung from the power generation site to a location where it can be hooked into the grid.

This can be extremely expensive, and different locations have different obstacles. A 2008 estimate in Texas put the cost of such transmission lines at $1.5 million per mile—a calculation based mainly on the costs associated with paying landowners for access to their land. Offshore wind installations must battle with nature to find a way to run transmissions through constantly changing water. As the scale of wind power installations increase, transmission issues are becoming one of the largest hurdles to address."

References:
Texas Comptroller of Public Accounts. The Energy Report 2008. Chapter 11: Wind Energy. Available: http://www.window.state.tx.us/specialrpt/energy/renewable/wind.php.

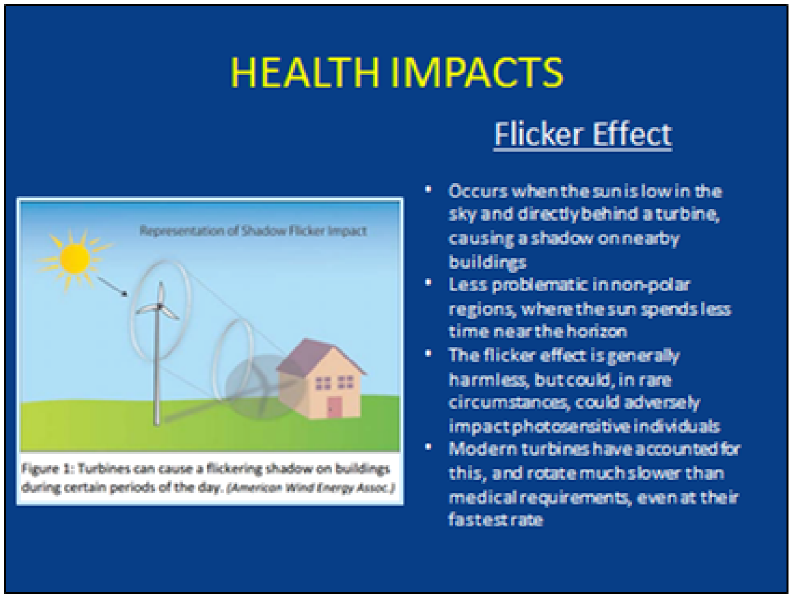


"No discussion of wind power is complete with addressing the health impacts of the technology. The two main complaints, those of noise and the flicker effect, are most certainly valid complaints and will be addressed here.

Noise is emitted from wind turbines from two areas: the turbine blades as they cut through the air, and mechanical sounds from the gearbox or yaw drive. Current turbine designs use sound proofing to muffle the mechanical sounds inside the turbine, making the aerodynamic sounds from the blades themselves the most easily heard sound from the ground level, usually in the range of 35-45 decibels at a distance of 350 meters.

In 2009, a panel was convened to study the noise effects of wind turbines. The panel was convened at the request of the American Wind Energy Association and the Canadian Wind Energy Association and was comprised of medical doctors, audiologists, and acoustic professionals from four countries. They reviewed the most recent scientific literature on the potential adverse effects of turbine noise pollution on speech interference, noise-induced hearing loss, task interference, annoyance, sleep disturbance, and vibration exposure. The results will be discussed here, but the full findings are still available online at http://awea.org/_cs_upload/learnabout/publications/5728_1.pdf. The panel reached consensus on the following conclusions, listed on the slide.

References.:
American Wind Energy Association. Wind Energy Basics Fact Sheets: Utility Scale Wind Energy and Sound. Electronic Source: http://www.awea.org/learnabout/publications/upload/Utility-Scale-Wind-Sound-Fact-Sheet_WP11.pdf.
Colby, W. David; Dobie, Robert; Leventhall, Geoff; Lipscomb, David M.; McCunney, Robert J.; Michael, Seilo, Michael T.; Sondergaard, Bo. Wind Turbine Sound and Health Effects: An Expert Panel Review. December 2009.

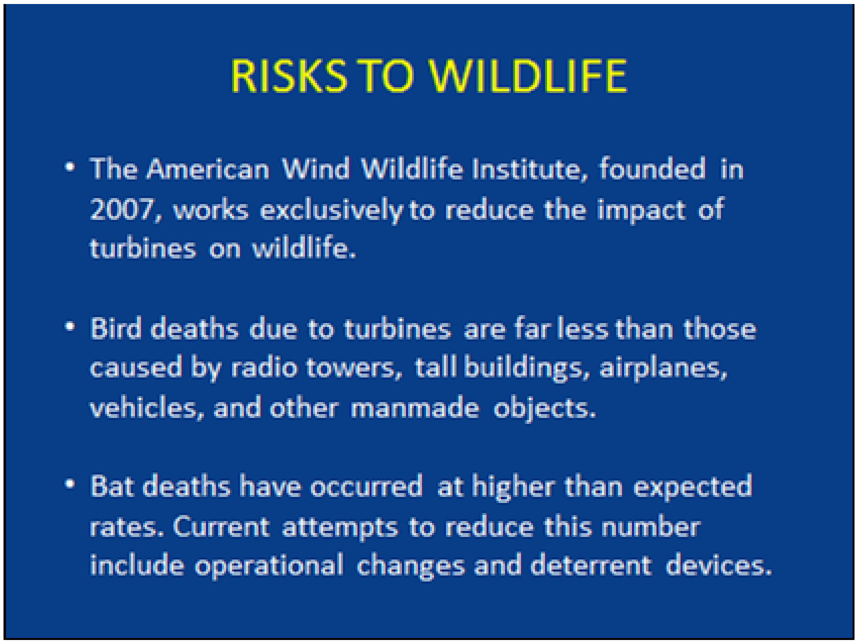


"The flicker effect of wind turbines occurs when the sun is low in the sky and the turbine casts a shadow on nearby homes or buildings. Due to its rotating blades, the turbine's shadow appears to flicker through windows, to the disgruntlement of the building's occupants.

The flicker effect can be larger or smaller depending on wind speed, and geographic locations. Those living closer to the poles experience greater flicker effects than those in the middle or equatorial latitudes due to longer periods of time in which the sun is near the horizon, lengthening the turbine's shadows. Here in Michigan, the turbine's shadow does not fall on a single building for more than a few minutes a day, and the flicker effect is not often sited as a complaint.

To most people, this flicker effect is harmless, even if it is considered a nuisance. However, it should be noted that those people suffering from photosensitive epilepsy , or have seizure due to environmental triggers might increase their likelihood of suffering an incident in the presence of a rapid flicker effect. Such a condition affects approximately 1 in 4,000 people, and occurs when flickering occurs at a rate faster than 3 flickers per second. Modern turbines, at their fastest, rotate at a rate of 20 rotations per minute, or 1 rotation every 20 seconds—much slower than the medical requirements.

References:
West Michigan Wind Assessment. Wind Power and Human Health: Flicker, Noise, and Air Quality. West Michigan Wind Assessment Issue Brief #2. Michigan Sea Grant. August 2010. Electronic Source: http://www.miseagrant.umich.edu/downloads/research/projects/10-733-Wind-Brief2-Flicker-Noise-Air-Quality2.pdf.



"In 1994, it was discovered at Altamont Pass in California—one of the first wind farms ever built—that the rate of raptor deaths due to wind farms was much higher than expected. This lead to serious concern among the environmental community with how wind turbines were affecting avian populations. In 2007, the American Wind Wildlife Institute was founded as a coalition between wind companies and conservation groups to address the problem.

Today, bird deaths as a result of turbines are much lower than many other manmade objects, such as those on the slide. Methods of protecting avian populations, such as operational changes, siting regulations and deterrent devices, are proving effective in reducing the death count even more. In addition, many wind companies have devoted resources to help fund research for White-Nose Syndrome, an unrelated disease that is currently devastating bat populations in the Northeast."

References:
American Wind Energy Association. May 2011. Wind Energy and Wildlife. Retrieved 1/27/13. Electronic Source: http://www.awea.org/learnabout/publications/upload/Wind-Energy-and-Wildlife_May-2011.pdf

FUTURE DIRECTIONS

Rethinking the Battery

"One of the biggest challenges facing renewable energy is energy storage. Fortunately, the field isn't stagnant. This video has some interesting information on where technology is headed with regards to large scale energy storage."

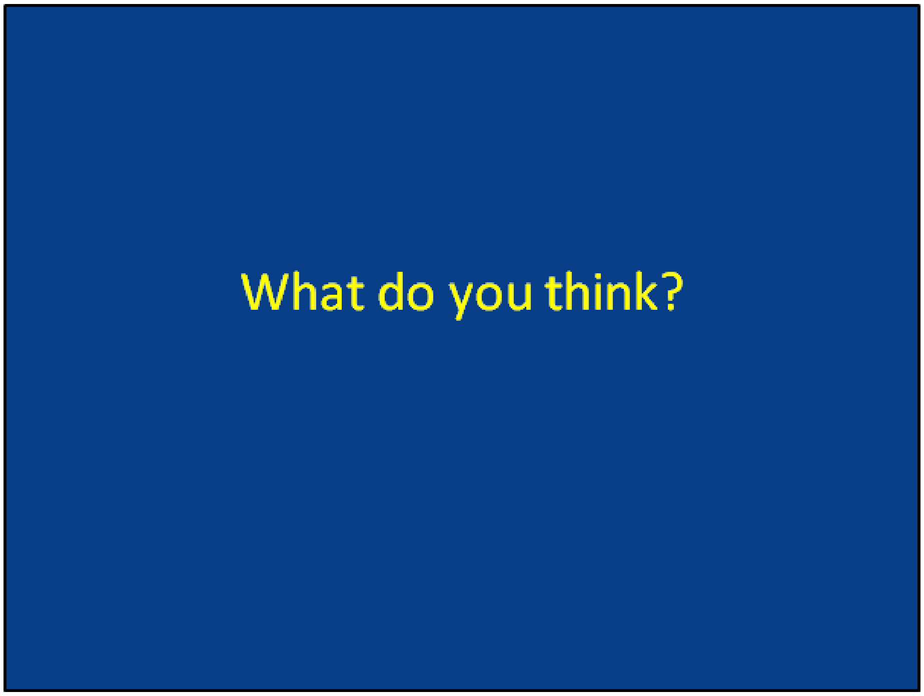
Play video (less than 3 minutes).

FUTURE DIRECTIONS

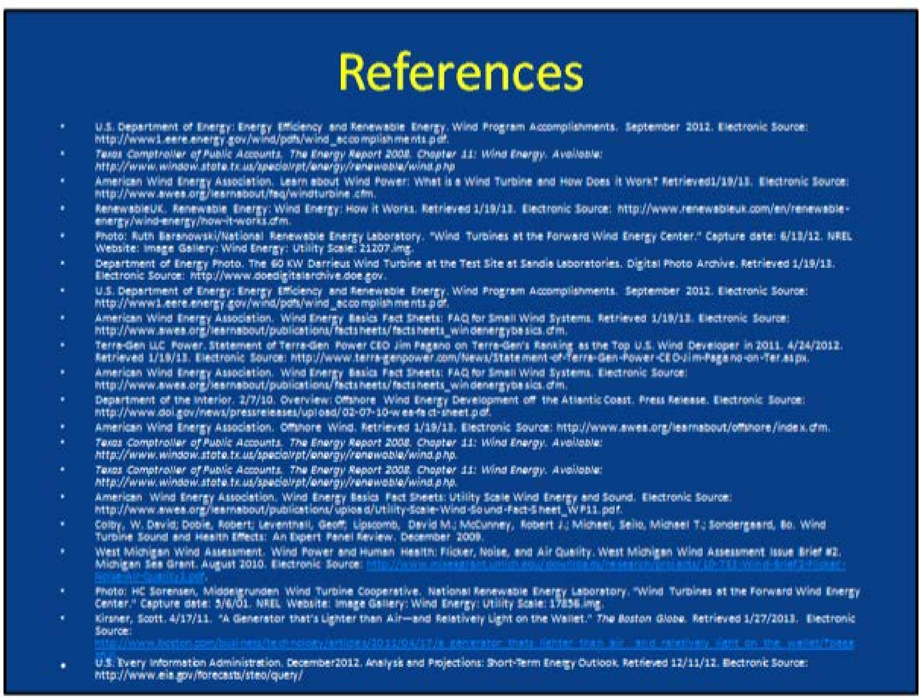
Bringing the Sky to the Turbine

Altaeros Energies, Inc. offers one of several ideas to create an airborne version of the turbine, in this case using helium to lift the blades (located in the hollow center) as high as regular turbines, accessing the high wind velocities, while significantly reducing the costs of getting there.

"In addition to energy storage, there have been some interesting new ways of rethinking the turbine, including designs that increase energy generation at lower wind velocities, and designs such as the one pictured here, which simply floats the turbine into higher altitudes without the high costs associated with building a permanent infrastructure. While all projects such as this one are in their beta testing stage, the field is full of innovation and technology is continuing to improve."



“That’s the end of the presentation. The rest of the time has been set aside for discussion on the presentation and wind energy in general. Again, I’m not an expert, but I’ll answer anything that I can. Does anyone want to start us off?”

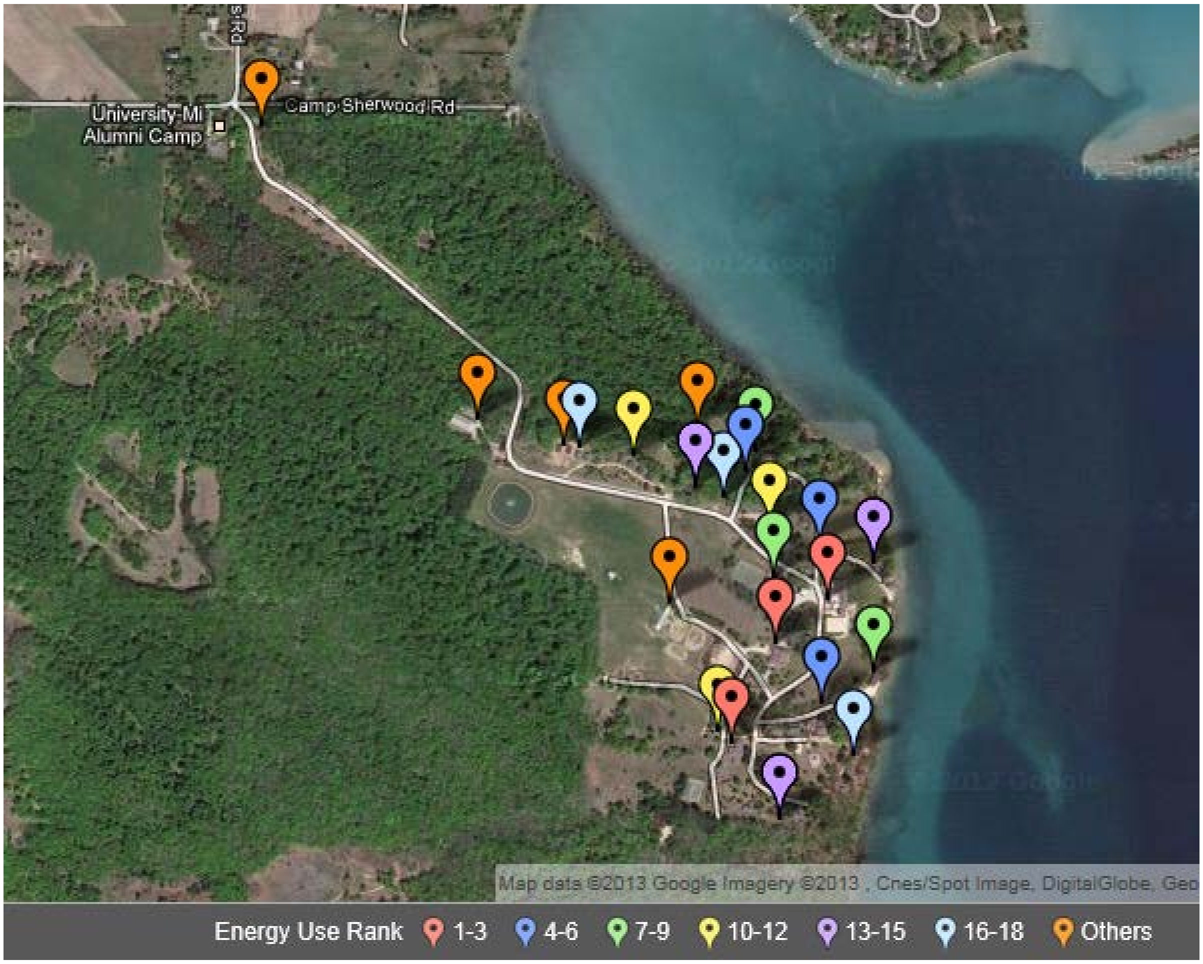


To be displayed upon the end of the discussion, or upon request.

Appendix VI: Electricity Use Data, Costs & Map (Great Lakes Energy, 2007-2012)

Account	Meter	Service Address/Description	Electricity Used (kWh)						
			2012	2011	2010	2009	2008	2007	Total
20314-001	632400435	Director's House	4,660	6,689	4,068	5,376	5,034	5,418	31,245
20314-002	34098369	South Cabins 14,15,16,17,18,19 (also Art & Craft in 2007)	6,501	5,555	5,272	5,653	7,836	14,134	44,951
20314-004	33772345	Nest Building - Swim Beach	6,359	7,129	10,312	10,131	10,316	11,534	55,781
20314-005	34098363	Farmhouse (not there now)	11,087	12,451	17,265	15,229	12,055	12,629	80,716
20314-006	33772202	Riding Stables	260	168	337	507	290	244	1,806
20314-007	34863949	Lake Cottage	2,129	4,346	5,620	4,337	4,505	10,748	31,685
20314-008	34098367	Maintenance Barn	11,964	10,587	11,418	12,369	11,665	10,312	68,315
20314-009	34447035	Dining Hall	122,360	109,360	113,560	63,719	54,250	51,922	515,171
20314-010	34098366	South Cabins 5,6,7,8	5,495	3,516	3,433	4,702	4,681	6,876	28,703
20314-011	34098405	South Cabins 1,2,3,4, South Laundry	11,613	10,881	15,981	19,594	20,751	23,445	102,265
20314-012	34098368	South Cabins 9, 10,11,12,13, & Pump Station	9,769	2,614	2,999	3,805	2,992	7,761	29,940
20314-013	34447043	Education Center	85,160	71,880	78,800	81,160	74,240	119,000	510,240
20314-014	632404791	Roadhouse Cabin	14,800	3,423	1,371	1,042	2,271	2,898	25,805
20314-015	31625914	Sign at Gate	276	207	302	371	467	597	2,220
20314-016	34098354	Staff Cabins - East	8,790	7,420	7,821	7,408	8,423	10,012	49,874
20314-023	24961146	Nature Center Bldg	7,894	8,704	9,228	8,516	7,594	8,800	50,736
20314-024	34098471	North Cabins 1,2,3,4, North Laundry	33,872	14,073	7,270	6,956	7,178	10,905	80,254
20314-025	24755174	North Cabins 9, 10, 11, 12, 13	2,490	2,731	2,060	1,927	1,872	-	11,080
20314-026	33772292	Staff Cabins - West	4,257	4,513	3,437	1,402	1,139	2,532	17,280
20314-027	24669027	Food Service Director's House	12,079	10,894	8,204	4,523	3,114	4,357	43,171
20314-028	37460407	Arts & Craft Bldg (New in 2008)	24,080	24,120	26,400	26,320	27,640	-	128,560
20314-029	38494662	West Pole Barn (Maintenance)	1,786	423	272	4	-	-	2,485
20314-030	36639718	Staff Cabins 4, 5 (New in 2012)	848	-	-	-	-	-	848
Totals			388,529	321,684	335,430	285,051	268,313	314,124	1,913,131
% Change from Prior Year			21%	-4%	18%	6%	-15%	N/A	
	= All data not given by Great Lakes Energy								

Account	Meter	Service Address/Description	Total Costs ($) 2012	2011	2010	2009	2008	2007	Total
20314-001	632400435	Director's House	$ 781	$ 948	$ 708	$ 749	$ 738	$ 762	$ 4,686
20314-002	34098369	South Cabins 14,15,16,17,18,19 (also Art & Craft in 2007)	984	830	795	783	1,030	1,640	6,062
20314-004	33772345	Nest Building - Swim Beach	969	992	1,315	1,206	1,290	1,364	7,136
20314-005	34098363	Farmhouse (not there now)	1,490	1,552	2,033	1,731	1,478	1,479	9,762
20314-006	33772202	Riding Stables	297	263	281	275	244	240	1,601
20314-007	34863949	Lake Cottage	503	700	828	644	689	1,283	4,647
20314-008	34098367	Maintenance Barn	1,585	1,359	1,434	1,433	1,424	1,251	8,486
20314-009	34447035	Dining Hall	13,737	11,714	12,014	6,604	5,939	5,373	55,381
20314-010	34098366	South Cabins 5,6,7,8	873	615	602	690	698	908	4,387
20314-011	34098405	South Cabins 1,2,3,4, South Laundry	1,546	1,389	1,902	2,131	2,387	2,558	11,914
20314-012	34098368	South Cabins 9, 10,11,12,13, & Pump Station	1,353	519	556	600	527	997	4,551
20314-013	34447043	Education Center	9,636	7,817	8,446	8,151	7,892	12,146	54,087
20314-014	632404791	Roadhouse Cabin	1,902	619	428	327	454	504	4,233
20314-015	31625914	Sign at Gate	299	267	278	263	262	276	1,645
20314-016	34098354	Staff Cabins - East	1,237	1,023	1,056	939	1,101	1,211	6,566
20314-023	24961146	Nature Center Bldg	1,137	1,161	1,205	1,059	999	1,100	6,661
20314-024	34098471	North Cabins 1,2,3,4, North Laundry	3,976	1,757	999	895	971	1,299	9,896
20314-025	24755174	North Cabins 9, 10, 11, 12, 13	543	531	459	411	357	54	2,355
20314-026	33772292	Staff Cabins - West	744	759	636	379	348	489	3,355
20314-027	24669027	Food Service Director's House	1,630	1,479	1,169	711	570	692	6,252
20314-028	37460407	Arts & Craft Bldg (New in 2008)	2,922	2,944	3,167	2,944	3,226	-	15,202
20314-029	38494662	West Pole Barn (Maintenance)	473	307	291	23	-	-	1,094
20314-030	36639718	Staff Cabins 4, 5 (New in 2012)	281	-	-	-	-	-	281
Totals			$ 48,896	$ 39,544	$ 40,604	$ 32,946	$ 32,625	$ 35,625	$ 230,240
% Change from Prior Year			24%	-3%	23%	1%	-8%	N/A	
(yellow)	= All data not given by Great Lakes Energy								

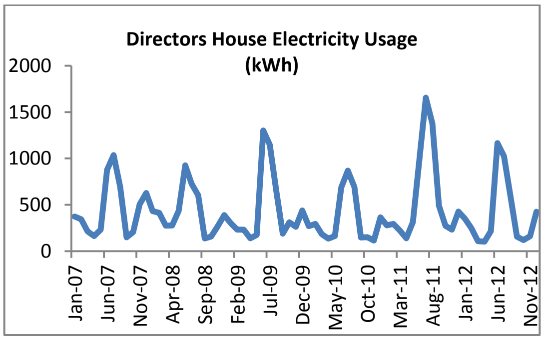


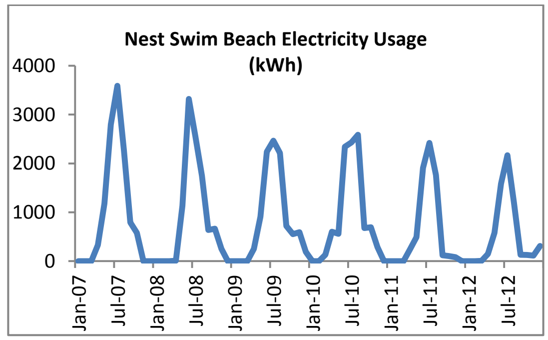
Map above produced using Great Lakes Energy data compiled by Tim Dobson; used http://batchgeo.com/ to map.

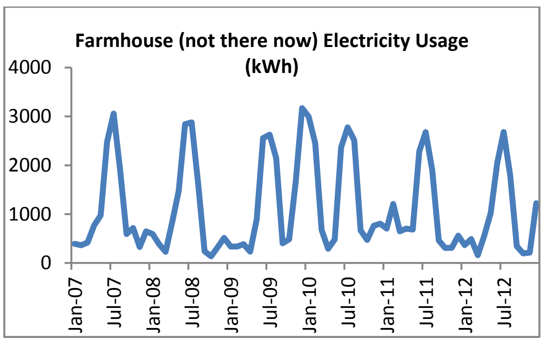
Appendix VII: Electricity Use Charts (Great Lakes Energy, 2007-2012)

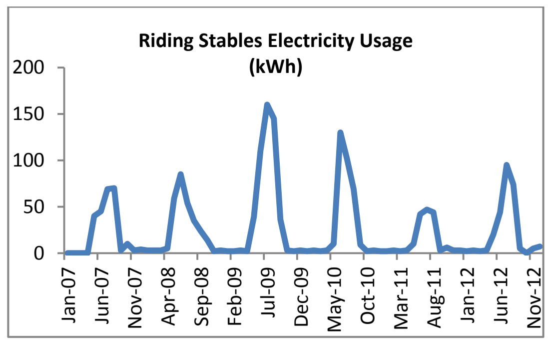
Note 1: As of 2012, Camp Michigania has 23 electric meters on site

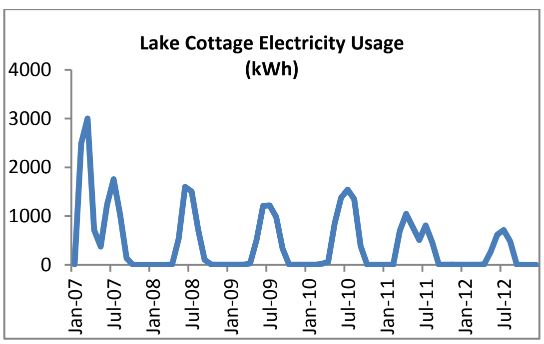
Note 2: Vertical axis may be different for below charts to help see trends better

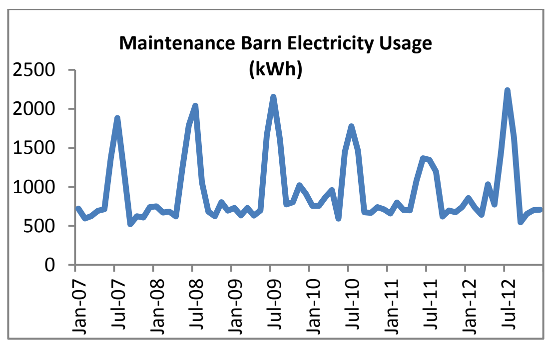


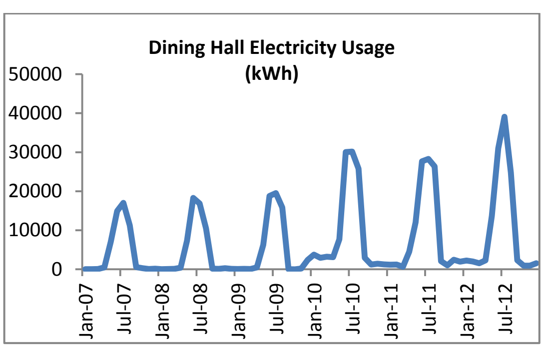


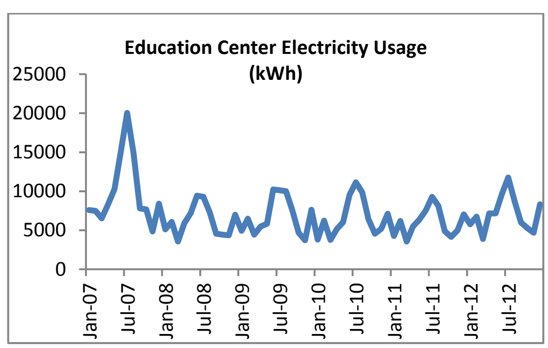


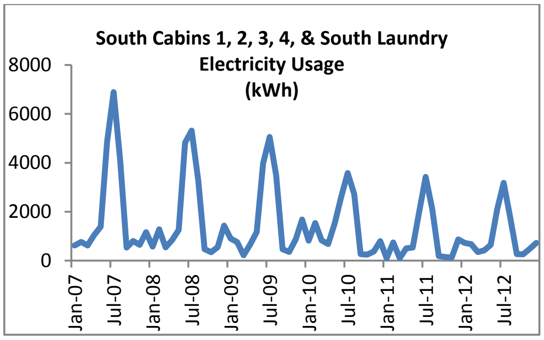


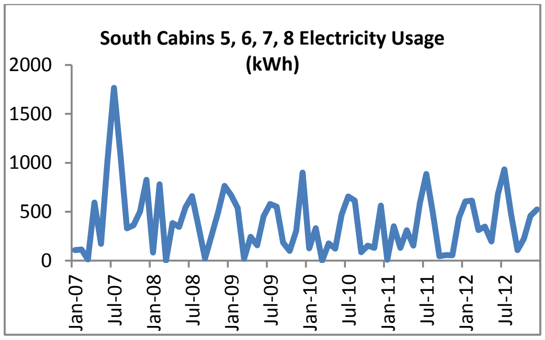


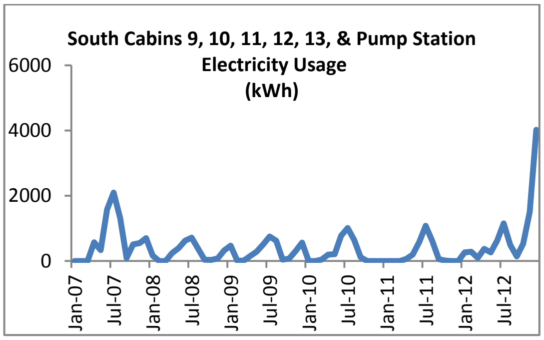


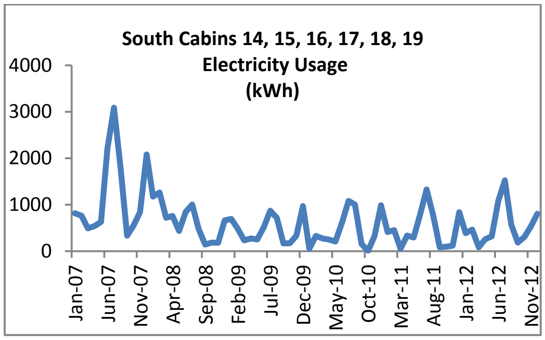


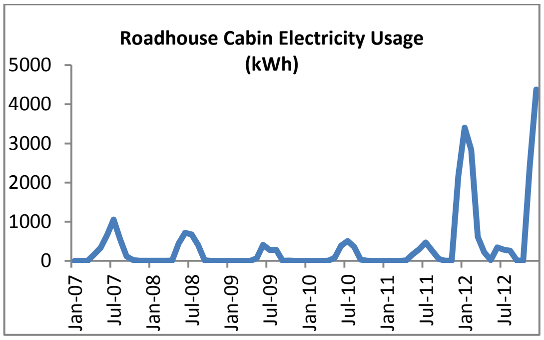


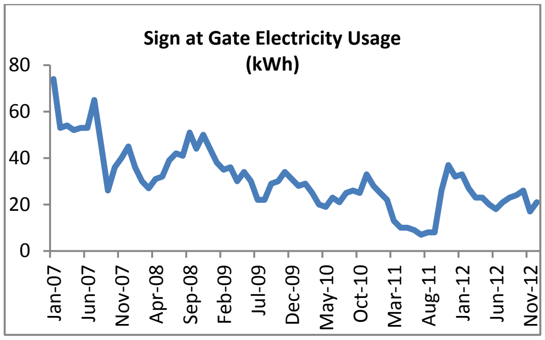

South Cabins 1, 2, 3, 4, & South Laundry Electricity Usage (kWh)
8000
6000
4000
2000
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12

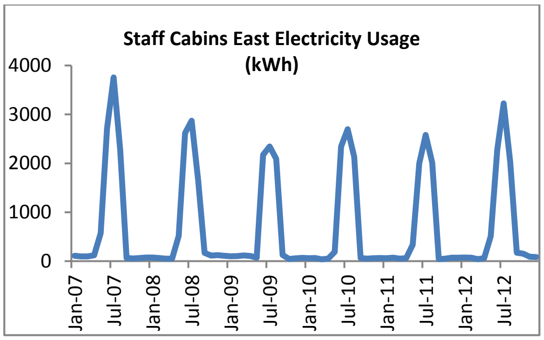

South Cabins 5, 6, 7, 8 Electricity Usage (kWh)
2000
1500
1000
500
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12

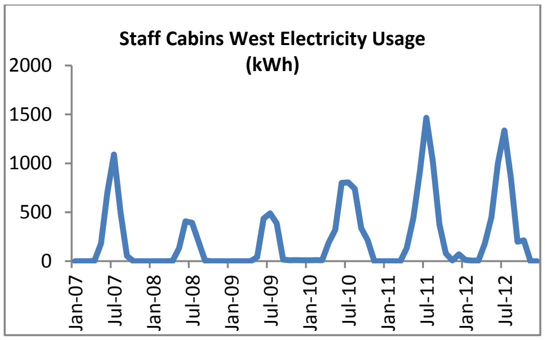

South Cabins 9, 10, 11, 12, 13, & Pump Station Electricity Usage (kWh)
6000
4000
2000
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12

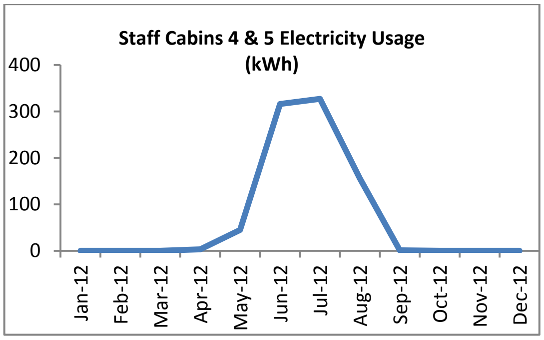

South Cabins 14, 15, 16, 17, 18, 19 Electricity Usage (kWh)
4000
3000
2000
1000
0
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10
Mar-11
Aug-11
Jan-12
Jun-12
Nov-12

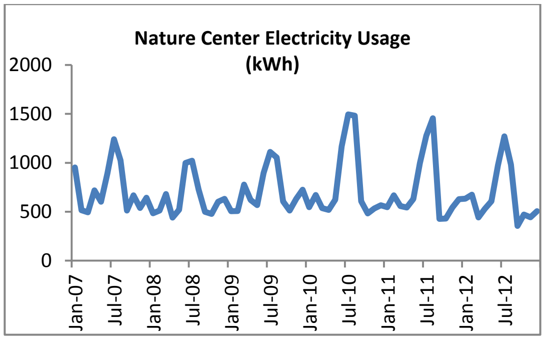

Roadhouse Cabin Electricity Usage (kWh)
5000
4000
3000
2000
1000
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12

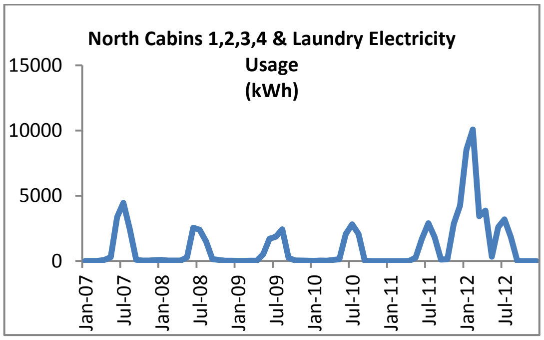

Sign at Gate Electricity Usage (kWh)
80
60
40
20
0
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10
Mar-11
Aug-11
Jan-12
Jun-12
Nov-12

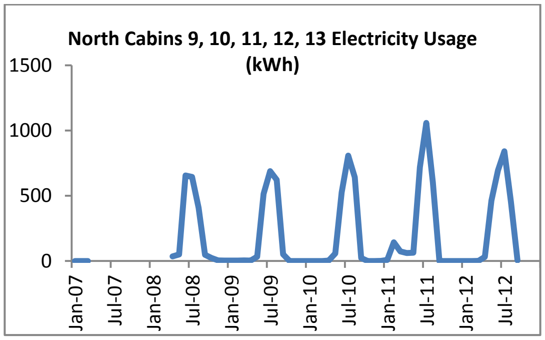

Staff Cabins East Electricity Usage (kWh)
4000
3000
2000
1000
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12

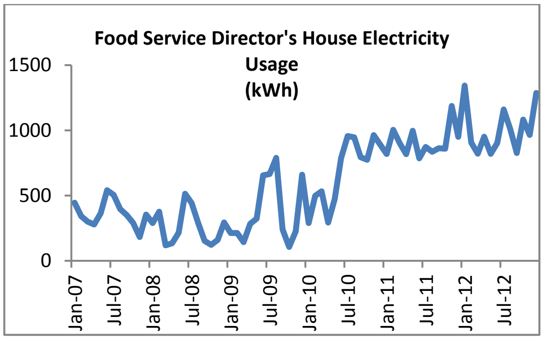

Staff Cabins West Electricity Usage (kWh)
2000
1500
1000
500
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12

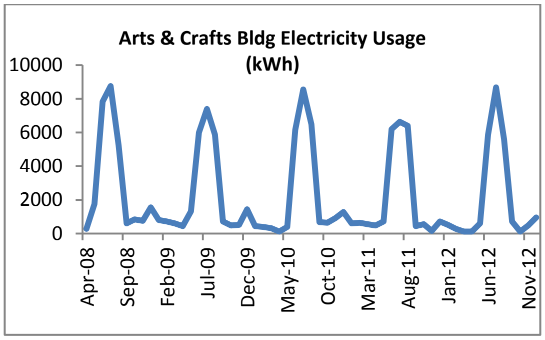

Staff Cabins 4 & 5 Electricity Usage
(kWh)
400
300
200
100
0
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12

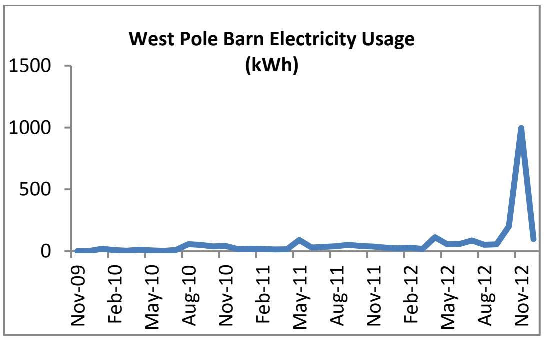

Nature Center Electricity Usage
(kWh)
2000
1500
1000
500
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12


North Cabins 1,2,3,4 & Laundry Electricity
Usage
(kWh)
15000
10000
5000
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12


North Cabins 9, 10, 11, 12, 13 Electricity Usage
(kWh)
1500
1000
500
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12


Food Service Director's House Electricity
Usage
(kWh)
1500
1000
500
0
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12

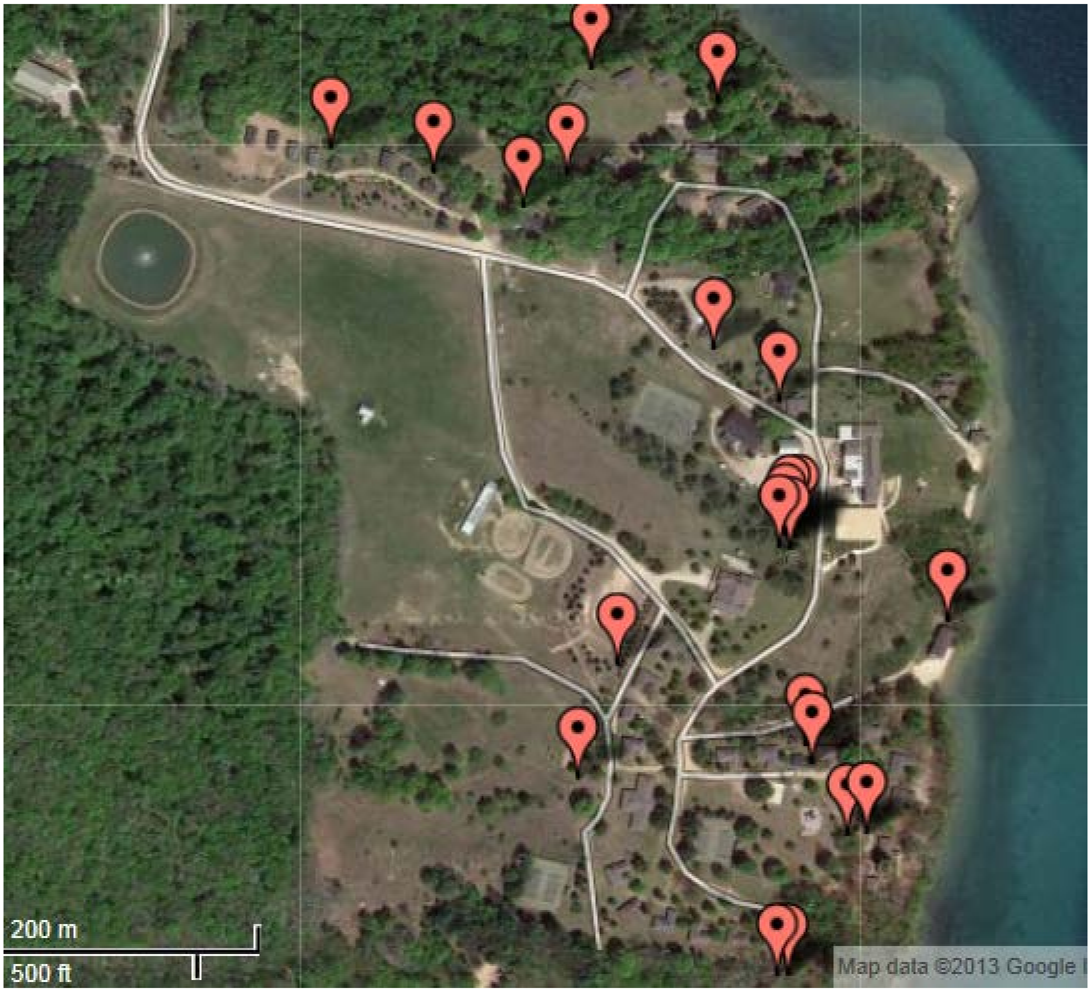

Arts & Crafts Bldg Electricity Usage
(kWh)
10000
8000
6000
4000
2000
0
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10
Mar-11
Aug-11
Jan-12
Jun-12
Nov-12


West Pole Barn Electricity Usage
(kWh)
1500
1000
500
0
Nov-09
Feb-10
May-10
Aug-10
Nov-10
Feb-11
May-11
Aug-11
Nov-11
Feb-12
May-12
Aug-12
Nov-12

Appendix VIII: Propane Purchase Data, Costs & Map (Petoskey Propane, 2007-2012)

Account	Identification	Propane Purchased (gallons)						
		2012 (Partial)	2011	2010	2009	2008	2007	Total
30490	Director's Residence (Gray House) - Tank # 613241	532	1,058	910	1,265	1,060	922	5,746
30491	569090: 613151 S 9 & 10	1,382	1,384	2,048	1,705	2,497	2,412	11,427
30492	007075: 008001 Ed Center	2,206	3,612	9,488	4,203	2,891	3,407	25,807
30493	Food Service Director's Residence - Tank # 542059	459	907	863	567	781	927	4,503
30494	613154 N 2	2,963	2,576	2,886	3,267	3,094	2,782	17,568
30495	601496 15-NC 9	132	157	191	229	267	180	1,156
30496	549892 17/V2	280	552	469	676	517	583	3,077
30497	571181 18-NC 7	224	472	422	519	558	491	2,687
30498	030777: 620481 SC 1 Laundry	1,310	1,318	1,441	2,242	1,878	1,463	9,652
30500	SC Parking - Tank # 899624	1,740	2,307	2,125	3,354	720	-	10,247
30505	07298	629	1,178	657	1,291	1,396	-	5,152
30506	No name given	-	-	324	371	-	-	695
30507	002107: 002359 SC 6-7	3,289	2,780	2,814	4,580	3,896	2,737	20,096
30508	No name given	-	458	-	-	-	303	761
30509	No name given	138	570	446	610	510	551	2,825
30510	530677: 577211: 613153: 613155 Dining Hall	2,888	5,094	6,764	7,375	6,393	7,615	36,129
30515	No name given	142	226	157	186	178	97	986
30517	007086 NC Laundry	287	587	656	826	753	657	3,766
30518	601481 Brown House	820	1,911	1,113	1,005	1,023	902	6,774
Totals		19,418	27,147	33,774	34,270	28,413	26,029	169,051
% Change from Prior Year		Partial Yr	-20%	-1%	21%	9%	N/A	

Account	Identification	Total Costs ($)						
		2012 (Partial)	2011	2010	2009	2008	2007	Total
30490	Director's Residence (Gray House) - Tank # 613241	$ 1,223	$ 2,196	$ 1,716	$ 2,618	$ 2,298	$ 1,544	$ 11,595
30491	569090: 613151 S 9 & 10	3,178	2,867	3,863	3,297	5,489	4,146	22,840
30492	007075: 008001 Ed Center	5,071	7,427	17,164	7,189	7,224	5,777	49,852
30493	Food Service Director's Residence - Tank # 542059	1,055	1,897	1,606	1,252	1,654	1,554	9,017
30494	613154 N 2	5,895	5,254	5,390	6,912	6,802	4,693	34,947
30495	601496 15-NC 9	304	313	381	400	668	315	2,380
30496	549892 17/V2	644	1,165	937	1,167	1,291	992	6,196
30497	571181 18-NC 7	514	981	843	897	1,359	841	5,435
30498	030777: 620481 SC 1 Laundry	3,012	2,728	2,792	4,476	4,262	2,454	19,724
30500	SC Parking - Tank # 899624	3,039	4,689	4,017	7,053	1,800	-	20,598
30505	07298	1,445	2,356	1,182	2,842	3,091	-	10,916
30506	No name given	-	-	583	667	-	-	1,250
30507	002107: 002359 SC 6-7	7,560	5,686	5,319	9,546	8,715	4,730	41,556
30508	No name given	-	915	-	-	-	500	1,414
30509	No name given	316	1,180	891	1,054	1,275	940	5,656
30510	530677: 577211: 613153: 613155 Dining Hall	6,639	10,660	13,123	15,420	14,142	12,954	72,938
30515	No name given	326	474	314	325	445	160	2,044
30517	007086 NC Laundry	659	1,219	1,311	1,424	1,882	1,122	7,618
30518	601481 Brown House	1,885	3,909	2,113	2,087	2,246	1,522	13,762
Totals		$ 42,765	$ 55,915	$ 63,546	$ 68,626	$ 64,644	$ 44,243	$ 339,739
% Change from Prior Year		Partial Yr	-12%	-7%	6%	46%	N/A	



Red indicators on map above show the location of propane tanks at Camp Michigania. Locations were found by Tim Dobson and Andrew Heairet during a site assessment at camp in May, 2012 and subsequently mapped using [http://batchgeo.com/.](http://batchgeo.com/)

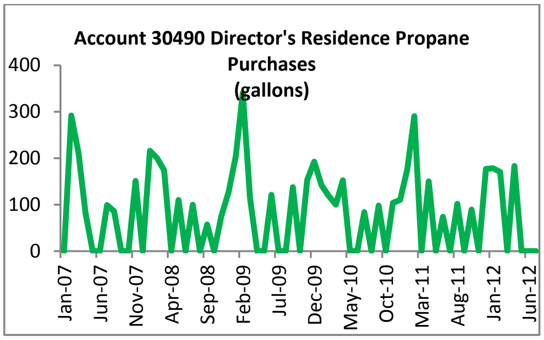
Appendix IX: Propane Purchases Charts (Petoskey Propane, 2007-2012)

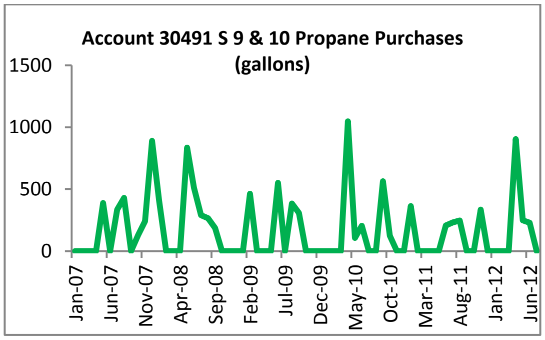
Note 1: As of 2012, Camp Michigania has 19 propane accounts with Petoskey Propane

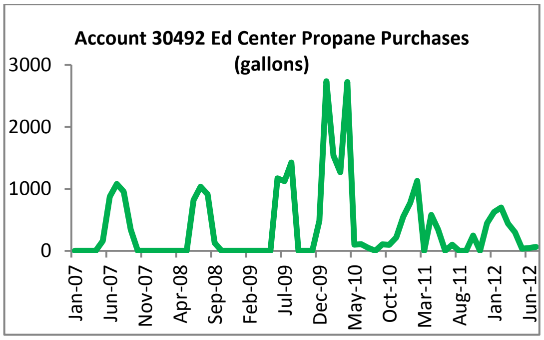
Note 2: A search of propane tanks on site in May, 2012 found 23 tanks

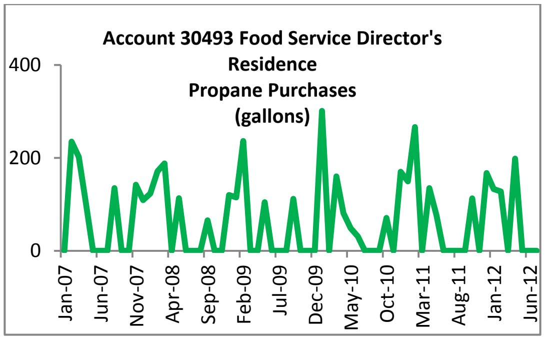
Note 3: Vertical axis may be different for below charts to help see trends better

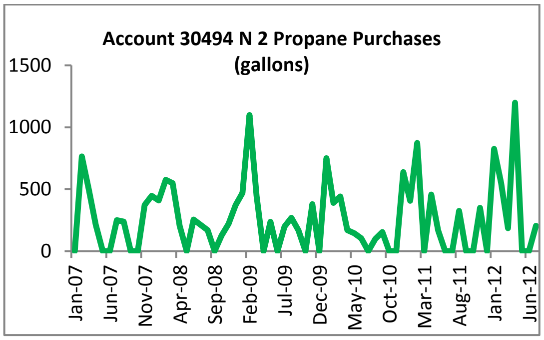
Note 4: For 2012, only data through July 2012 could be obtained

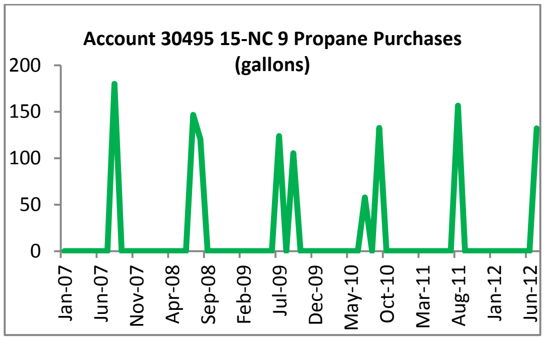


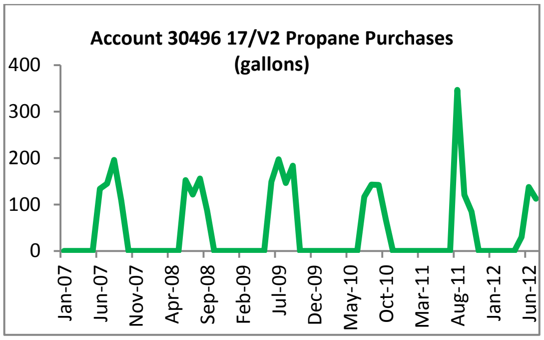


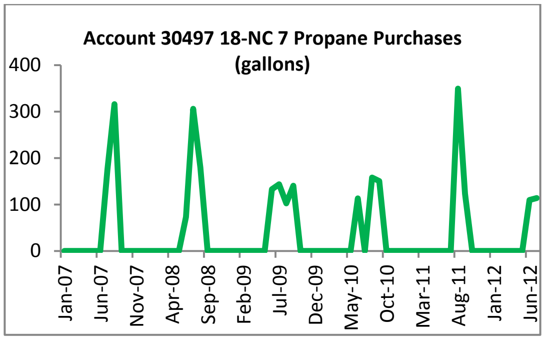


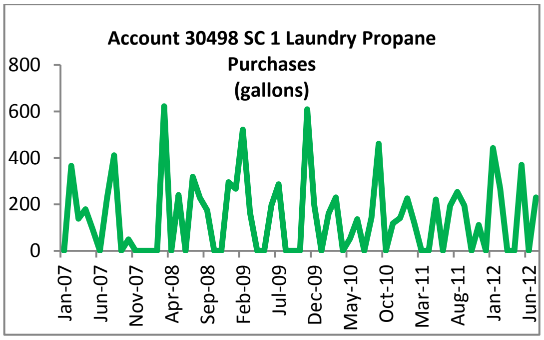


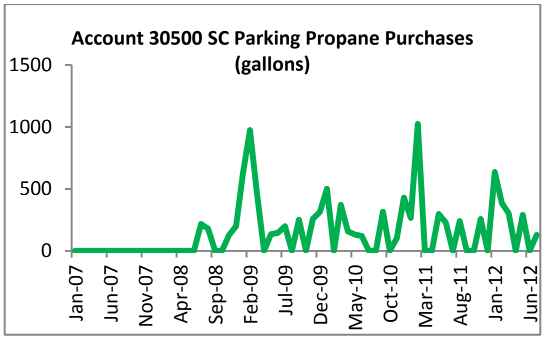


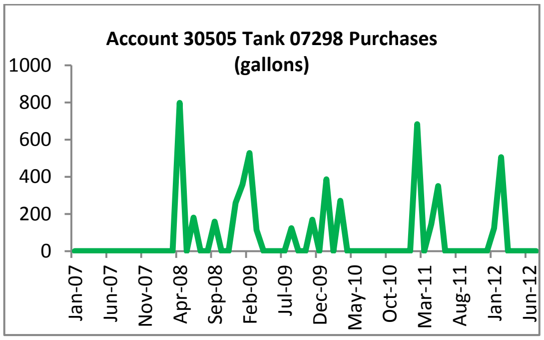


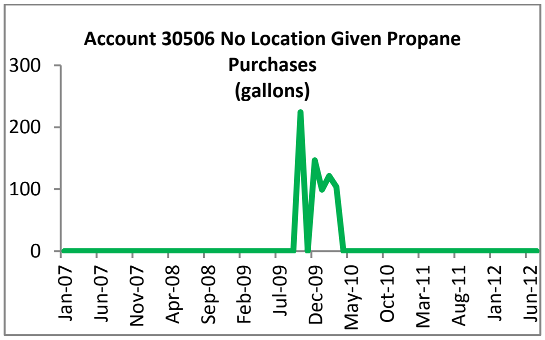


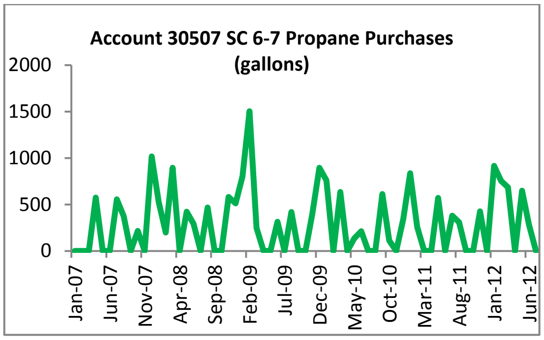


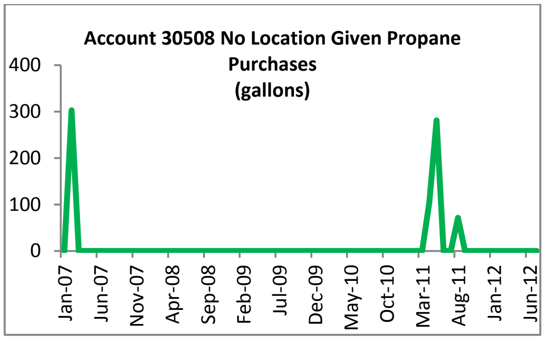

Account 30498 SC 1 Laundry Propane Purchases (gallons)
800
600
400
200
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12

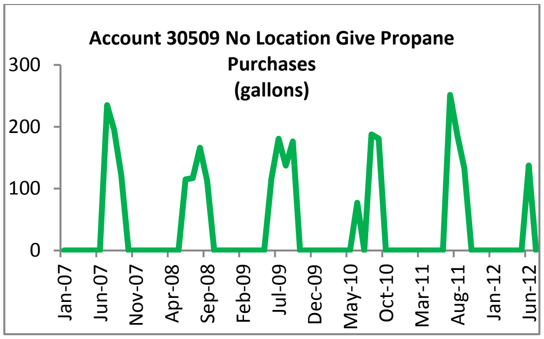

Account 30500 SC Parking Propane Purchases (gallons)
1500
1000
500
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12

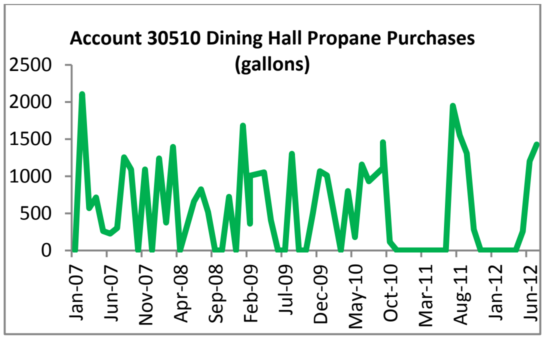

Account 30505 Tank 07298 Purchases (gallons)
1000
800
600
400
200
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12

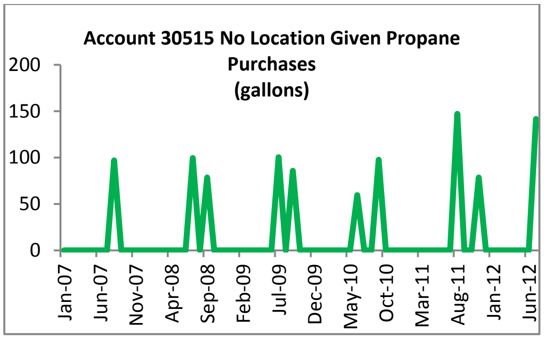

Account 30506 No Location Given Propane Purchases (gallons)
300
200
100
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12

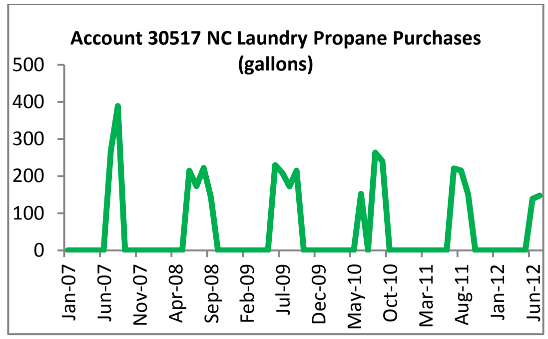

Account 30507 SC 6-7 Propane Purchases (gallons)
2000
1500
1000
500
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12

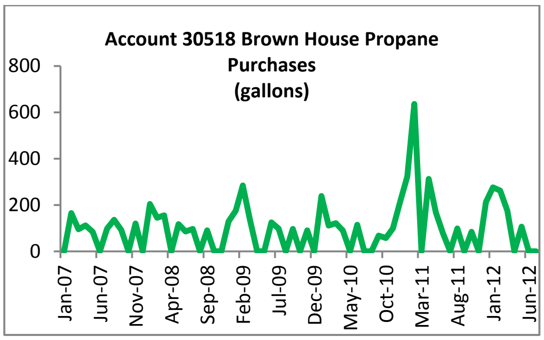

Account 30508 No Location Given Propane Purchases (gallons)
400
300
200
100
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12


Account 30509 No Location Give Propane Purchases (gallons)
300
200
100
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12


Account 30510 Dining Hall Propane Purchases (gallons)
2500
2000
1500
1000
500
0
Jan-07 Jun-07 Nov-07 Apr-08 Sep-08 Feb-09 Jul-09 Dec-09 May-10 Oct-10 Mar-11 Aug-11 Jan-12 Jun-12


Account 30515 No Location Given Propane Purchases (gallons)
200
150
100
50
0
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10
Mar-11
Aug-11
Jan-12
Jun-12


Account 30517 NC Laundry Propane Purchases (gallons)
500
400
300
200
100
0
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10
Mar-11
Aug-11
Jan-12
Jun-12


Account 30518 Brown House Propane Purchases (gallons)
800
600
400
200
0
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10
Mar-11
Aug-11
Jan-12
Jun-12

Appendix X: Zoning Information and Technical Feedback

Below is feedback on January 3, 2013 from a Michigania camper, who recently installed solar trackers at a location about 20 miles from Michigania, regarding zoning and other technical information. Note that the camper describes some technical problems that will be good for Michigania and the solar vendor to be aware of for the future. All were notified in January, 2013 but it is important to document here as well to maintain that record.

> Yesterday was a milestone of sorts for my solar installation as it's now delivered 1.0 megawatt-hour of energy to the grid. Due to start-up issues, though, that's only 61% of the estimated energy generation. All known issues are now resolved, and the system has generated 248 kWh over the last 7 days (with estimated generation being 246 kWh per PVWatts v2.0 http://www.nrel.gov/rredc/pvwatts/grid.html).
>
> To reiterate, I had no zoning issues with Hudson Twp or Charlevoix County whatsoever. As evidence, the Charlevoix building inspector called my ground mount array a 160 foot "fence" and charged me $42 for the structural permit (required only because it was over 8 feet high). No zoning permit was required by Hudson Twp as they had no regulation on the books regarding solar modules.
>
> During construction, we had trouble excavating for the foundation footings. The soil is very sandy here and ended up requiring 24" diameter sonotubes for the concrete footings to prevent cave-ins below about 5 feet of depth. I had originally planned to use a Bobcat-mounted auger and pour concrete directly into 18" holes, but the holes got very wide during excavation due to continuous cave-ins.
>
> I anticipated and designed for a myriad of problems, but did not suspect that power quality (or lack thereof, specifically excess harmonic distortion) would end up being the main startup problem that has impacted my system. I want to take a moment and express my complete satisfaction with Great Lakes Energy's superb level of service and expertise in helping resolve my issues. The day after the power quality issue was identified, Great Lakes Energy put 4 of their 5 engineers to work on my problem and deployed several more techs out into the field to do research on my behalf. The head engineer (Gus Paz) stayed in direct phone contact with me all through the resolution process. He personally took ownership of all problems, even extending to a billing issue with the net metering where I was charged instead of credited with my monthly generation (due to a new billing system). I don't suspect that a bigger power company would be nearly as responsive or as thorough.
>
> So the lesson learned regarding power quality is to measure the total harmonic distortion on each leg of the split phase 240 VAC and attempt to drive it down under 3.7% to keep the

Enphase M215 microinverters from repeatedly being knocked off-line. This should happen even before construction begins since it can be a long process to identify, correct, and/or filter whatever excess distortion is present in the AC wave form.

My symptom was the repeated disconnection and re-connection of microinverters to the grid. This was happening many times per hour per microinverter. The net result was that the microinverters were spending a fair amount of time off-line during the day. I was seeing about a 50% reduction from the estimated power generation. Enphase support used their remote control capability through the internet to identify the problem as a heavily distorted AC sine wave (their L1/L2 raw data wave forms are attached to this email). The microinverters use a built-in pure sine wave table as a reference and were unable to fully track the distorted sine wave all the time.

The day after receiving this report from me, Great Lakes Energy (GLE) assembled a team of 4 engineers to discuss the problem and sent a tech out to my site to measure total harmonic distortion (THD). They reported a THD of 4.2% on L1 (leg 1) and 4.1% THD on L2 at the service entrance. Enphase Energy's recommendation was to limit the THD to 3%.

Now, a little background information on THD to put the data in perspective. IEEE Standard 519,“RECOMMENDED PRACTICES AND REQUIREMENTS FOR HARMONIC CONTROL IN ELECTRICAL POWER SYSTEMS” provides suggested harmonic values for power systems: “Computers and allied equipment, such as programmable controllers, frequently require AC sources that have no more than 5% harmonic voltage distortion factor [THD], with the largest single harmonic being no more than 3% of the fundamental voltage. Higher levels of harmonics result in erratic, sometimes subtle, malfunctions of equipment that can, in some cases, have serious consequences.” The limits on voltage harmonics are thus typically set by utilities at 5% for THD and 3% for any single harmonic. It is important to note that the suggestions and values given in the IEEE 519 standard are purely voluntary. Great Lakes Energy guidelines dictate even more strict levels of THD: 3% maximum for residences. Thus, they accepted responsibility for the high levels of THD and began a search of powerlines in the area for the source of the THD. As such sources are found, they are required to filter out their distortion or face being disconnected from the grid.

Based on the "fingerprint" of excessive 3rd, 5th, and 11th harmonics, GLE knew right where to look. The sources of this distortion are the more than 4,000 gas wells in and around Charlevoix county. Each uses variable frequency motors to pump the liquefied gas. These drive systems have a non-linear power draw from the grid that distorts the pure AC sine wave for those customers connected to the same transmission leg. In prior years, such harmonic issues had been identified and solved by requiring the pipeline companies to add filters to the most egregious sources of distortion, and GLE suspected that one or more of these filters may have developed problems. None were found. The elevated THD was caused by many gas wells in the aggregate, but no individual well was responsible, and thus no additional action could quickly be enforced.

GLE's next step was to measure the distortion of all three phases on their transmission system. One phase of the three had a slightly lower distortion of 3.9%, but it was not the phase to which I (and all of my neighbors for miles around) were connected. GLE decided to swap phases at the substation to provide me (and hundreds of neighbors) the phase with the cleaner AC wave form. This not-insignificant effort and temporary power interruption to my neighbors during the swap over demonstrates how seriously GLE wanted to solve the problem. Immediately after the swap, the number of microinverter "events" dropped from many/minute to several/hour. Clearly the reduction in THD from 4.2% to 3.9% was helping the inverters track the AC sine wave more accurately, but the disconnections were still causing about a 25% loss of generation capacity.

Recognizing that GLE was not going to be able to further reduce the THD of the new phase anytime soon, I knew that my site was going to need a filter to reduce the incoming THD down to acceptable levels. Specifically, a low pass filter was needed to remove the higher order harmonic distortion caused by the gas wells (3rd, 5th, 11th order). Filters that can handle 400 amps are not cheap! But I also knew that transformers act as low pass filters, and the larger the transformer (impedance), the more it filters. My service entrance had a 25 kVA transformer which, for residential service, is already quite large. The rule of thumb is to double or triple the transformer rating to get a noticeable additional filtering effect, and I was unsure if GLE would increase the size of an already large transformer for free. I suggested to GLE that they swap my transformer out for a 50 kVA model and they agreed without complaint or cost to me. More kudos to GLE!

This investigation started on November 12, 2012. By December 14, 2012, the new 50 kVA transformer was installed, and immediately the microinverters became stable. I may have seen 1 or 2 individual events that day, but even those went away after a few days. I was finally making expected power! But the final test had to wait for a "full power" day since THD typically increases at higher current (power) levels. December 18th had a brilliant blue sky and the system peaked at 17.08 kW with no sign of microinverter instability.

The combination of actions taken by GLE had reduced the THD to acceptable levels, but what was the final THD at my site? GLE also wanted to know and scheduled a tech to return to my site to measure it. A major snowstorm on December 20th put 20" of snow on my panels which was not to melt off until January 5th. So on January 8th, with the system generating 17 kW, GLE came out and took a THD reading. The final readings were 3.7% (L1) and 3.7% (L2).

Appendix XI: Solar PV Proposal Assessments for Sunventrix and Greenlife

Sunventrix Solar Model

Fill in green boxes (blue boxes will automatically be calculated)

Panel Rated Power:	260	Watts				
Panel Dimensions:	65.0	Inches x	38.7	Inches =	1.62	Square Meters
Number of Panels:	76				19.76	kW System Total
Expected Lifetime (Years):	25	Remaining Output At End Of Life Relative To New System:				75%
Technology Efficiency:	16.0%	(Lifetime Output / First Year Output) Ratio :				21.9

Price Per Panel	$ -	If panel prices aren't listed individually, include the cost in balance of system (BOS)
Single Axis BOS	-	
Dual Axis BOS	-	
No Axis BOS	$ 71,000.00	

Array Output (kWh/month or total)	First Year Output	Average Annual Output	Lifetime Output	System Cost	Cost / kWh
No Tracking Flat	26,312	23,023	575,584	$ 71,000	$ 0.123
No Tracking at Lattitude	29,350	25,681	642,021	$ 71,000	$ 0.111
No Tracking at Lat - 15*	29,719	26,004	650,104	$ 71,000	$ 0.109
Single Axis at Lattitude	37,489	32,803	820,065	#VALUE!	#VALUE!
Single Axis at Lat - 15*	37,556	32,861	821,534	#VALUE!	#VALUE!
Dual Axis	38,694	33,857	846,432	#VALUE!	#VALUE!

Greenlife Solar Model

Fill in green boxes (blue boxes will automatically be calculated)

Panel Rated Power:	250	Watts				
Panel Dimensions:	64.7	Inches x	39.1	Inches =	1.63	Square Meters
Number of Panels:	80				20	kW System Total
Expected Lifetime (Years):	25	Remaining Output At End Of Life Relative To New System:				85%
Technology Efficiency:	15.3%	(Lifetime Output / First Year Output) Ratio :				23.1

Price Per Panel	$ -	If panel prices aren't listed individually, include the cost in balance of system (BOS)
Single Axis BOS	-	
Dual Axis BOS	-	
No Axis BOS	$ 99,500.00	

Array Output (kWh/month or total)	First Year Output	Average Annual Output	Lifetime Output	System Cost	Cost / kWh
No Tracking Flat	26,632	24,635	615,865	$ 99,500	$ 0.162
No Tracking at Lattitude	29,706	27,478	686,951	$ 99,500	$ 0.145
No Tracking at Lat - 15*	30,080	27,824	695,600	$ 99,500	$ 0.143
Single Axis at Lattitude	37,944	35,098	877,455	#VALUE!	#VALUE!
Single Axis at Lat - 15*	38,012	35,161	879,028	#VALUE!	#VALUE!
Dual Axis	39,164	36,227	905,668	#VALUE!	#VALUE!

Appendix XII: Final Solar PV Proposal from Sunventrix

Grid Tied Solar PV System Proposal

For

Camp Michigania

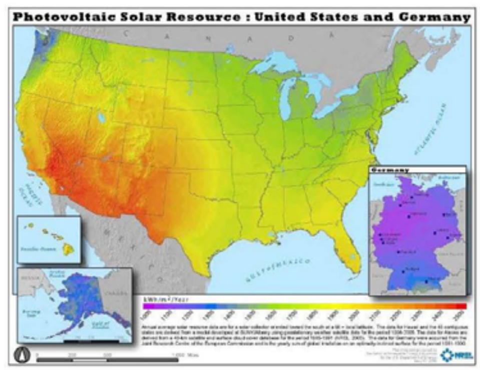
01/22/13

Mark Hildebrandt, '94 MS
Sunventrix, LLC
Ann Arbor / Saline
734-478-2606
markh@sunventrix.com
sunventrix.com

sunventrix solar

Save With Solar in Michigan!

True net metering – your Sunventrix solar PV system is eligible for true net metering which means you get credit for the electricity you don't use when your system is working (slows or stops your meter) and for any surplus that's sent back into the grid (spins your meter backward)! And most importantly, you get control over your electricity rates for 25+ years, especially in this era of ever increasing electric bills! There may also be Renewable Energy Credit programs that can help you save even more!



The sun shines in Michigan – contrary to popular belief, we get a lot of sun in Michigan, even more than Germany, one of the world's largest producers of solar energy.

Real time energy monitoring – Sunventrix solar PV systems are available with lifetime secure monitoring of your system on smart phone, computer, or tablet showing system performance and environmental benefits.

Reduce your carbon footprint – every kWh your clean energy system produces saves ~2lbs of greenhouse gas CO_2. And since our utilities import their coal and use it for up to 75% of electricity generation, your system reduces the burning of dirty fossil fuels for generation and transportation.

Reliable – systems work day in day out, even some on cloudy days to make you clean energy. All components were chosen for their innovation, performance and quality.

Durable with no maintenance – tempered glass modules and aluminum construction can sustain direct contact with hail, snow, and rain. Systems last 25+ years, and rain and snow helps keep them clean.

2

Notes

1. This proposal provides three options for solar PV on the dining hall roof. After taking final measurements, and using higher output panels, we confirmed that we could get nearly a 20kW system on just two roofs (gift shop and serving area) which reduces costs due to close proximity and still provides great solar output.
2. Due to amortizing fixed costs like architect and engineering fees, most electrical work, etc. over a larger number of panels, the largest savings occur with the largest system. Per your request to provide a few other system size options that were expandable, these separate options are treated as separate installs right now and do not reflect a future expansion price that would be less due to less fixed costs already paid for in the initial installation.
3. The analyses of the systems do not include any savings due to REC aggregation now becoming available, or additional solar incentive programs. Participation in a REC aggregation program or other incentive program may shorten payback. Also, future additional energy efficiency consumption reductions will allow solar to offset a higher % of the overall use.
4. These solar PV systems are designed to provide high output, have minimal intrusion on building aesthetics, and provide an educational component through visibility and monitoring with minimal intrusion on building aesthetics.
5. We updated the system outputs with on-site insolation data.
6. We selected ARRA black on black solar modules and black racking to best blend with the aesthetics of the building. American compliant modules are available at extra cost.
7. Since true net metering limits the size to 20 kW at full retail electricity rate, option 1 is the largest system possible on the dining hall's meter at retail rate. However, other meters on the grounds can have their own 20kW systems.
8. With each option, Sunventrix provided a preferred discount for minimal system branding. Sunventrix is also happy to lead educational seminars on solar during a camp week, especially using actual camp results. Finally, thank you for the opportunity to install a solar PV system at Camp Michigania!

sunventrix solar

Builder's License No. 2102198819 3886 West Garden Court Saline MI 48176	SOLAR PV CONTRACT PROPOSAL - COMMERCIAL SUNVENTRIX, LLC	Telephone:734-478-2606 Email: markh@sunventrix.com Website: www.sunventrix.com
PROPOSAL SUBMITTED TO OWNER Alumni Association of The University of Michigan	PHONE 734-764-0384	DATE 01/23/13
STREET 200 Fletcher St	OWNER'S AUTHORIZED REPRESENTATIVE (If other than Owner) Steve C Grafton	
CITY, STATE AND ZIP CODE Ann Arbor MI 48109-1007	JOB SITE & PROPERTY ("Property") 3006 Camp Sherwood Rd	

Sunventrix, LLC, a Michigan limited liability company ("Sunventrix"), proposes to provide all labor and material required to install the following solar PV system (Work) at the above Property. All references to Property shall include any structure on which the Work is taking place:
SEE ATTACHED FOR DETAILS

Install a grid tied solar photovoltaic (PV) system on Camp Michigania dining hall roof using Suniva solar modules, Enphase Energy microinverters, SnapNrack roof racking, & all related electrical work for utility interconnection including disconnect, and connection of Enphase gateway.

This Proposal incorporates by reference Sunventrix's attached General Terms and Conditions ("GT&C") and the following additional documents together referred to as the "Contract:"
Plans - See attached for proposed location to capture the most sunlight
Specifications – See attached for solar PV system materials and components

Sunventrix proposes to furnish material and labor per the referenced plans, specifications, etc., for the following sum ("Contract Sum") subject to the GT&C for a **Fixed Price** of:

	Option 1	Option 2	Option 3	Additional options:	
System cost	$81,499	$60,841	$39,000	TED energy management system	$469 installed
				Easy Sun solar generator	$1999 installed
Preferred discount	$(3260)	$(2434)	$(1950)	Suniva American compliant modules	$.04/watt extra
Total cost of	**$78,239**	**$58,407**	**$37,050**	Suniva 265W modules	$.02/watt extra

Subject to change orders or other additions or deductions per the Contract.

PAYMENT SHALL BE MADE PER THE FOLLOWING SCHEDULE

Cash Payments To Be Made	Due Date of Payments	Option 1	Option 2	Option 3
Payment No. 1 (Initial Payment) – 50%	Due Upon Execution of Contract by Owner	$39,119.50	$29,203.50	$18,525.00
Payment No. 2 (Final Payment) – 50%	Due upon completion of the Work	$39,119.50	$29,203.50	$18,525.00
Total of Required Payments (excluding change orders)		$78,239.00	$58,407.00	$37,050.00

The Contract Sum and Final Cash Payment shall be adjusted to the extent required by the Contract including any agreed change orders.

Estimated Start Date: Spring 2013	Estimated Completion Date: Spring 2013 subject to weather

Special Instructions: None

LEGAL NOTICE: A residential builder or a residential maintenance and alteration contractor is required to be licensed under article 24 of the occupational code, 1980 PA 299, MCL 339.2401 to 339.2412. An electrician is required to be licensed under the electrical administrative act, 1956 PA 217, MCL 338.881 to 338.892. A plumbing contractor is required to be licensed under the state plumbing act, 2002 PA 733, MCL 338.3511 to 338.3569. A mechanical contractor is required to be licensed under the Forbes mechanical contractors act, 1984 PA 192, MCL 338.971 to 338.988.

NOTE: This proposal may be withdrawn by Sunventrix without liability prior to Sunventrix's final approval below. Quote is valid for 30 days from date indicated.

Authorized Signature: ______________
Sunventrix's representative
Dated: 01/23/13

Owner's Acceptance of Proposal - The above terms of the Contract including the Contract Sum and any documents referenced therein are satisfactory and are hereby accepted and agreed upon. You are authorized to do the Work as specified. Payment will be made as outlined above. We are authorized to engage Sunventrix to provide the above Work on the Property. This proposal becomes a binding contract upon Sunventrix's approval of this Contract at the bottom of this page.

Authorized Signature(s): ______________
All Owner(s) or authorized representative(s) Dated

Printed name(s): ______________
All Owner(s) or authorized representative(s)

THIS CONTRACT IS NOT BINDING UNTIL APPROVED BELOW BY SUNVENTRIX'S AUTHORIZED REPRESENTATIVE:

Date of Acceptance: ______________ Authorized Signature: ______________
Sunventrix representative
Name: ______________

4

GENERAL TERMS AND CONDITIONS OF SUNVENTRIX SOLAR PV CONTRACT

1. Scope of Work; Subcontractors. The scope of work for this Project is limited to the plans and specifications agreed upon by Owner and Sunventrix in writing as further detailed in the Contract. Sunventrix may use trained subcontractors to perform any portion of the Work. Owner shall not provide instructions or directions to said subcontractors relating to the Work and all communications relating to the Work shall be directed by Owner to Sunventrix and not to its subcontractors or suppliers, except when required in an emergency to avoid property damage or bodily injury. Owner is prohibited from engaging any such subcontractors for any purpose until after all Work is complete and Sunventrix has been fully paid all sums due under the Contract.

2. Time; Excuse of Performance; Special Orders. Sunventrix shall begin the Work per the Contract, but not before all permits are obtained and Owner has fulfilled all conditions for starting work. Sunventrix is not responsible for delays or increased expenses arising from circumstances not within its reasonable control, for example, Acts of God such as inclement weather or natural disasters, fire, theft, windstorms. labor shortages or strikes, custom order delays, disasters, vandalism, terrorism, Owner's actions or delays, actions or misfeasance of other contractors of Owner, or similar causes or events.

3. Workmanship; Construction Means and Methods; Limited Warranty. Sunventrix will perform its services in a good and workmanlike manner in accordance with the Contract. In addition, Sunventrix warrants that its services will be free from defects for a period of **TWO (2) YEARS** ("limited warranty period") from the date of substantial completion of its services and agrees to remedy any material defects reported in writing by Owner to Sunventrix during the limited warranty period at Sunventrix's expense. Sunventrix shall have the sole right to select whether to repair or replace defective work. Sunventrix shall not be responsible for repair or replacement of items caused by the acts or omissions of Owner or others including, but not limited to, Owner's subcontractors or resulting from abnormal use, wear or tear, or lack of proper care of the items by Owner. Owner's duty to correct defects is conditioned upon Owner's reporting the defect to Sunventrix in writing within the limited warranty period. Owner's sole remedy with respect to any goods, material or equipment installed by Sunventrix, is the warranty provided by the manufacturer and Sunventrix's liability to Owner is limited to that arising from defects in the installation of said goods, however, under no circumstances shall Sunventrix's liability extend beyond the limited warranty period specified herein. Sunventrix shall have no liability arising from the prior condition of the Owner's Property including, but not limited to, defects in the roof or any other portion of the Property where the installation is occurring or any water leakage arising from the prior condition of the Property. Also, because each property has different energy use and property conditions and each owner has a different personal situation, Sunventrix does not guarantee that the Owner will achieve a certain level of electricity or other energy savings and makes no warranties or representation regarding energy or tax savings. Owner waives any claims based on the amount of energy or tax savings achieved. THIS LIMITED WARRANTY IS OWNER'S EXCLUSIVE REMEDY AND THERE ARE NO OTHER WARRANTIES MADE BY Sunventrix EXCEPT THE LIMITED WARRANTY CONTAINED IN THIS SECTION. ALL IMPLIED, EXPRESS OR OTHER WARRANTIES OF WHATEVER KIND OR NATURE INCLUDING BUT NOT LIMITED TO FITNESS FOR A PARTICULAR PURPOSE OR HABITABILITY ARE EXCLUDED BY THIS LIMITED WARRANTY. NO OTHER AMOUNTS SHALL BE DUE TO OWNER FROM Sunventrix REGARDLESS OF THE CAUSE OR CIRCUMSTANCE EXCEPT AS OTHERWISE SPECIFICALLY PROVIDED IN THE CONTRACT AND ALL CLAIMS FOR INCIDENTAL, CONSEQUENTIAL, OR INDIRECT DAMAGES ARE WAIVED BY OWNER. The warranty contained in this provision is not transferable or assignable and may only be enforced by the Owner. This warranty automatically becomes void if Owner fails to pay Sunventrix in accordance with the Contract. Service calls that are outside the limited warranty period or that do not involve improper installation shall involve a service charge that is in addition to the Contract Sum.

4. Change Orders. Michigan law requires all contract changes on residential projects including change orders to be in writing. Sunventrix is not obligated to make any change requested by Owner unless the parties have executed a written change order. All change orders shall be paid by Owner prior to ordering material and commencement of work per the change order.

5. Insurance. Sunventrix maintains commercial general liability insurance appropriate for the project and other insurance to the extent required by law.

6. Payment; Late Charge, Interest, and Costs of Collection. Upon receipt of Sunventrix's invoice, Owner shall pay Sunventrix the sum required by the agreed schedule contained on page 1 of the Contract. Final payment of all amounts due to Sunventrix shall be made by Owner upon completion of the Work. Except as otherwise provided below, in the event that Owner fails to pay any amount within fifteen (15) days of the date it is due, Owner shall pay to Sunventrix a **LATE PAYMENT CHARGE** equal to one (1%) percent per month on the unpaid balance which the parties agree is reasonable or the highest amount permitted by law, whichever is less. If the balance remains past due for thirty (30) days or more, then Owner shall also pay to Sunventrix any collection or related costs incurred by Sunventrix including attorneys' fees and expenses, without limitation. The foregoing late payment charge and collection expenses are not applicable to amounts determined not to have been due pursuant to Section 9 below. Timely payment by Owner is a condition precedent to Sunventrix's warranty and other obligations under this Contract. The above remedies are in addition to any other remedies provided by applicable law.

7. Owner's Duties; No Withholding of Payment; Hazardous Materials. Sunventrix is better able to economically, expeditiously, and safely perform its work if the Owner cooperates with Sunventrix in providing certain information and approvals. Therefore, the Owner agrees to timely provide to Sunventrix any information, documents or approvals reasonably requested by Sunventrix or otherwise required by law including any association or any architectural review committee. In addition, prior to commencement of Sunventrix's work, the Owner agrees to advise Sunventrix of any hazardous, unsafe, or other condition of the Property that could affect Sunventrix's work or cause bodily injury or property damage to Sunventrix. Owner is solely responsible for any damage, injury or repairs arising from the physical condition of the Property prior to Sunventrix's work and indemnifies and holds harmless Sunventrix relating to any property damage, personal injury or other claims or circumstances arising from the prior condition of the Property including payment of Sunventrix's attorney's fees and expenses. Owner shall provide to Sunventrix any utilities required to perform its services and will cooperate with Sunventrix regarding all aspects of its work including providing reasonable access to the Property and removing any fragile, valuable or vulnerable personal property from any work area. Owner is responsible for compliance of Property and Work with all zoning, building and use restrictions, and with any association or other requirements or approvals. Owner warrants and represents that it is the owner of the Property on which the improvements are to be made or that it is the lessee or land contract vendee of the Property acting with the Property owner's written consent and that its representative is authorized to act on behalf of Owner. All references to the Owner shall also refer to the lessee or land contract vendee, if applicable. Owner covenants that it will act in good faith and fairly deal with Sunventrix at all times. Owner shall not withhold payment to Sunventrix for any reason without Sunventrix's prior written consent as long as Sunventrix is not in material default of its obligations to perform work, and in such event, shall only withhold the amount actually in dispute as reasonably determined by Sunventrix. If pursuant to Section 7 or 9, it is determined that Owner wrongfully withheld amounts due to Sunventrix, Owner shall pay all amounts due under Section 6 of this Contract and any other amounts permitted by law.

8. Hidden Conditions. Sunventrix is not liable for or responsible to undertake any additional work that becomes necessary due to concealed or hidden conditions of any kind or nature. Concealed or hidden conditions are defined as any situation that Sunventrix could not reasonably determine by a

general visual inspection. Sunventrix is not responsible for ascertaining any conditions not readily observable by visual inspection and not directly relating to its work.

9. Claims and Disputes; Waiver of Certain Damages. In the event of any claim or controversy between the parties arising from the Contract, its breach or relating to any proceeding before the State of Michigan or any of its divisions or departments, the parties shall first attempt to resolve the matter by nonbinding mediation (facilitated settlement negotiation) and in such event each party shall be equally responsible for the expense of the neutral mediator. If mediation is unsuccessful or is not completed within thirty (30) days of written notice to the other party of a claim or dispute, the claim or dispute shall be resolved by binding arbitration to the extent permitted by law. These dispute resolution procedures shall be conducted in accordance with the Construction Industry Dispute Resolution Rules of the American Arbitration Association and the arbitrator(s) shall have the power to award legal and equitable remedies. Judgment upon the award may be entered in any court having jurisdiction thereof. Nothing herein shall prevent or delay Sunventrix from perfecting or otherwise enforcing its lien rights in accordance with Michigan law in an appropriate court. Sunventrix and Owner waive their right, if any, to incidental and consequential damages for claims, disputes or other matters arising out of or relating to this Contract or its performance. In the event of any dispute between Owner and Sunventrix, Sunventrix including its subcontractors, suppliers, agents or designees shall be entitled to inspect, photograph or test the Property or Work as needed upon 72 hours prior notice to Owner at Sunventrix's sole cost. Owner's failure to permit Sunventrix to do so voids Sunventrix's obligations or liability under the Contract including the obligation to complete its Work and any warranty but does not release Owner of its obligations under the Contract including payment. The arbitrator(s) regarding any dispute may award attorney's fees and expenses to the prevailing party in any dispute.

10. Termination/Suspension; Third Parties. Sunventrix may suspend or terminate performance in the event of nonpayment by Owner or other material breach of the Contract by Owner upon delivery of written notice to the Owner. In the event of termination by Sunventrix or in the event of Owner's wrongful termination, Owner shall pay to Sunventrix all amounts required by the Contract or applicable law including, but not limited to, the cost of all unreimbursed labor and material including any material that cannot be returned for a refund, and any overhead, administration costs, and profit due to Sunventrix, i.e. not less than 30% of the Contract Sum. Owner is prohibited from engaging any third party to perform some or all of the work covered by this Agreement, unless first agreed upon in writing by Sunventrix, and any such action by Owner is a breach of this Contract, is grounds for Sunventrix to terminate this Contract, and voids all obligations of Sunventrix under this Contract. In addition, Sunventrix may terminate this Contract any time for Sunventrix's convenience and without cause which shall be effective upon delivery of written notice to the Owner. In such event, (a) Sunventrix shall be entitled to payment from Owner of any costs incurred through the date of termination by Sunventrix and Sunventrix's overhead and profit through the date of termination including Sunventrix's *pro rata* share of any fee due to it under the Contract; and (b) the Owner shall not be required to pay Sunventrix any sums that otherwise would be due to Sunventrix for portions of the Work not yet performed.

11. No Amendment or Waiver. No amendment or waiver hereunder shall be effective except as expressly made in a writing signed by Sunventrix, and no waiver of any obligation or default shall operate as a waiver of any other obligation or default or of the same obligation or default on a future occasion No single or partial exercise by Sunventrix of any right or remedy, nor any delay or forbearance in the exercise thereof, shall preclude other or further exercise of such right or remedy by Sunventrix and no amendment or waiver shall be construed as creating a custom of deferring any obligation, including but not limited to payment or as modifying in any way the terms of this Contract.

12. Copyright. Owner indemnifies and holds harmless Sunventrix with respect to any claim for copyright or other infringement relating to Owner's or Sunventrix's use, copying or modification of any plans, drawings, or specifications relating to the Work which are supplied by Owner, Architect, or agent, including payment of Sunventrix's attorney's fees, expenses or damages relating to any such claim. If the plans and specifications are prepared by or at the direction of Sunventrix, Sunventrix shall be deemed the author of them and shall retain all common law, statutory or other related rights. In such event, unless otherwise agreed in writing by Sunventrix, neither the Owner nor their agents shall use said plans or specifications for any purpose except relating to the Work, and then, only if Sunventrix has been paid all sums due to it or upon written consent of Sunventrix. Owner is prohibited from modifying the foregoing plans or specifications without Sunventrix's prior written consent. If Owner terminates this Contract without paying to Sunventrix all amounts due under this Contract, Owner is prohibited from using, copying, or modifying said plans or specifications for any purpose and Sunventrix may withdraw said plans and specifications from any building department or other governmental authority and prohibit use of said documents except with Sunventrix's prior written consent.

13. Entire Agreement. This Contract includes any documents specifically referenced herein and together, these documents constitute the full, final and entire understanding and agreement of the parties and supersede any prior or other oral or written representations or promises to the contrary. The term Owner shall encompass any lessee or land contract vendee acting with Owner's authority. Instructions of one Owner shall be binding on all other owners. All references in the Contract to the Proposal, the GT&C or any written Addendum to the Contract shall include all of said documents. Payment to Sunventrix shall not be contingent on the approval of any architect, engineer or third party.

14. Approvals; Maintenance; Grid. Owner agrees to maintain the system installed by Sunventrix in accordance with the manufacturer's instructions. Owner's failure to properly use or maintain the system automatically voids Sunventrix's warranty including, but not limited to, any tampering, modification, or unauthorized repair or improvement to the system. Owner acknowledges that a PV system tied to the grid will not operate when the grid loses power and repairs are being made to the system. This shut-down minimizes injuries to power line workers.

15. Forms and Filings; Disclaimer. Upon request, Sunventrix can assist Owner with the preparation of forms and filings to obtain certain reimbursements from energy companies or tax benefits arising from the installation of its solar PV system, however, the Owner is solely responsible for completing and submitting any such forms or information and Sunventrix will have no liability or responsibility to Owner regarding the results of any such submissions.

16. Miscellaneous. In the event any or a portion of the provisions of this Contract shall be held invalid, illegal or otherwise unenforceable by a Court, the remaining provisions of this Contract shall remain in full force and effect as if the invalid provision were not in existence. This Contract shall be governed by the laws of the State of Michigan. This Contract and all of its terms and provisions shall be binding upon the heirs, representatives, successors and assigns of the parties and may only be assigned by the parties upon their written consent which shall not be unreasonably withheld, delayed, or conditioned. The headings of the several articles and subdivisions of this Contract are inserted solely for the convenience of reference and shall have no further meaning, force or effect. In the event of a conflict among the documents which are part of the Contract, the specifications shall be controlling. No third party shall be a beneficiary of any provision of this Contract. For purposes of this Contract, any signed document sent by facsimile transmission or e-mail shall be treated in all manner and respects as an original document, provided, however, that either party may require the other to re-execute any such document in original form. Sunventrix shall have the right to place appropriate signage or advertising on the Property during the work.

Specifications

General description

Install a commercial grid tied solar photovoltaic (PV) system. The system will be installed using a roof mounted system including attachment feet, racking, solar modules, microinverters, cabling, conduit and other electrical components.

Scope of work

To design, supply and install a solar PV system including:

Suniva 260 watt modules (or equivalent) with tempered glass and black back sheet and black aluminum frame.

Enphase Energy M215 microinverters.

Enphase Enlighten Communication Gateway.

SnapNrack black aluminum PV mounting system mounted on roof.

Balance of system AC wiring, connection into existing load center with applicable circuit breaker(s), generation meter (for potential future use), and utility disconnect per utility requirements.

All required electrical and building permits and scheduling of inspections.

Complete all electrical work and grounding and bonding to code.

GEC system grounding with Midnight Solar surge suppression.

Engineering studies and approval for placing solar PV system on roof.

Lifetime monitoring of your system's performance using the Enphase Enlighten monitoring system.

Notes

This is a turnkey system with all paperwork, installation, interconnection, and commissioning of the solar PV array by Sunventrix including required inspections. Additional services include initial Enphase enlighten monitoring setup and training, but does not include making Enlighten available on dedicated monitors or embedding Enlighten onto Camp Michigania/etc. website(s), although on-line info is available to do this. For specific options selected, installed price includes initial setup and operation testing.

Warranty

Ten year product warranty by Suniva for the solar panels, and a 25 year performance warranty.

Twenty-five year product warranty by Enphase Energy for the microinverters, and a 100% uptime performance reimbursement guarantee per Enphase agreement.

Two year labor and installation warranty by Sunventrix for the solar PV system.

One year product warranty on the Easy Sun solar generator by Suburb Solar

One year product warranty on the TED by The Energy Detective

sunventrix solar

Solar PV Array Location

Option 1
19.76kW array on serving area and gift shop roofs, 76 Suniva OPT 260W BOB modules, estimated 20% building offset

Option 2
13.52kW array on serving area roof, 52 Suniva OPT 260W BOB modules, estimated 13% building offset

Option 3
6.24kW array on gift shop roof, 24 Suniva OPT 260W BOB modules, estimated 6% building offset with clean solar energy

Solar modules mounted parallel to roof for great output and aesthetics
Solar modules and racking are black colored to match dark roof and dark features of building
High efficiency Suniva modules and Enphase M215 microinverters carry 25 year warranties
Tie in to building electrical and utility interconnection at service entrance

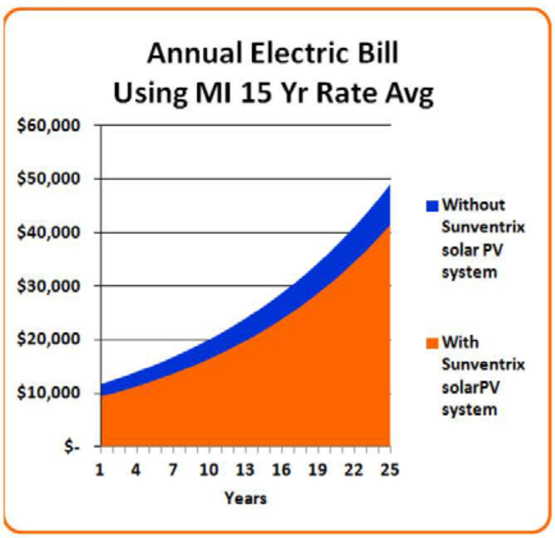
Analysis – Option 1

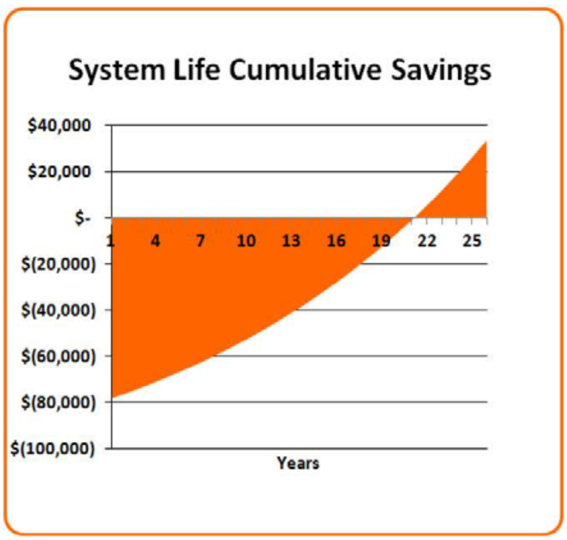
Description	
Customer average annual electric usage (kWh)	109,360
Proposed system size (kW)	19.76
Estimated system output (kWh/yr)	21,631
Solar generation of average annual electric usage (%)	20%
DC rating of solar module (STC watts)	260
Number of panels based on DC rating and system size	76.0

Investment		
Cost per watt for system installation	$	3.96
Total cost for system installation	$	81,499
Preferred discount	$	(3,260)
Commercial system net cost	$	78,239

Savings		25 Year System Life
First year electric bill savings	$	2,317
Average yearly electric bill savings	$	4,474
Average monthly electric bill savings	$	373
Cumulative energy production (kWh)		480,595
Greenhouse gases prevented (lbs)		**817,011**
- equivalent to trees planted		**9,214**
- equivalent to gallons of gas not consumed		**41,431**

Estimated values using on-site measurement, utility info, PV Watts, Enphase Energy data. Savings based on 20 year program life, but systems designed to last 25+ years. Electricity costs including overhead. Annual electric bill escalation of 6.25% minus annual solar output degradation of 1.0% (industry standard) = 5.25% factor used per year.





Analysis – Option 2

Description

Customer average annual electric usage (kWh)	109,360
Proposed system size (kW)	13.52
Estimated system output (kWh/yr)	14,638
Solar generation of average annual electric usage (%)	13%
DC rating of solar module (STC watts)	260
Number of panels based on DC rating and system size	52.0

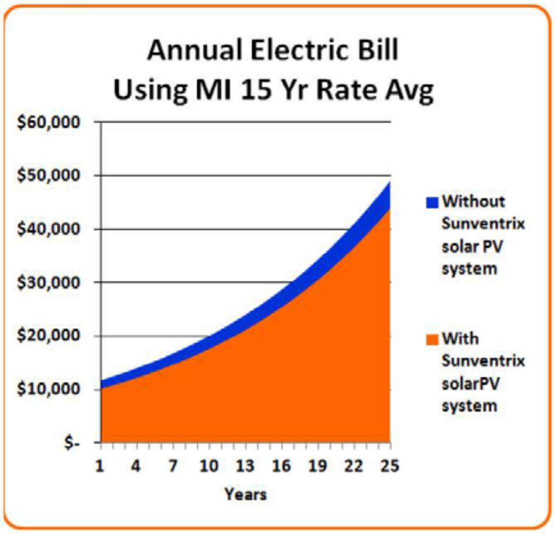
Investment

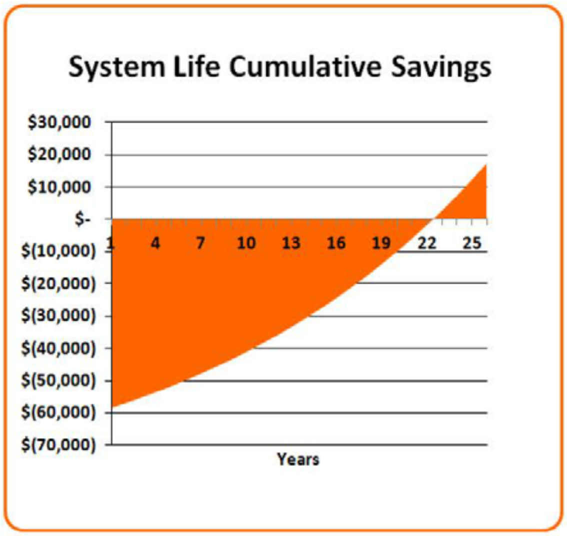
Cost per watt for system installation	$	4.32
Total cost for system installation	$	60,841
Preferred discount	$	(2,434)
Commercial system net cost	$	58,407

Savings

		25 Year System Life
First year electric bill savings	$	1,568
Average yearly electric bill savings	$	3,028
Average monthly electric bill savings	$	252
Cumulative energy production (kWh)		325,225
Greenhouse gases prevented (lbs)		**552,883**
- equivalent to trees planted		**6,235**
- equivalent to gallons of gas not consumed		**28,037**

Estimated values using on-site measurement, utility info, PV Watts, Enphase Energy data. Savings based on 20 year program life, but systems designed to last 25+ years. Electricity costs including overhead. Annual electric bill escalation of 6.25% minus annual solar output degradation of 1.0% (industry standard) = 5.25% factor used per year.





Analysis – Option 2

Description

Customer average annual electric usage (kWh)	109,360
Proposed system size (kW)	13.52
Estimated system output (kWh/yr)	14,638
Solar generation of average annual electric usage (%)	13%
DC rating of solar module (STC watts)	260
Number of panels based on DC rating and system size	52.0

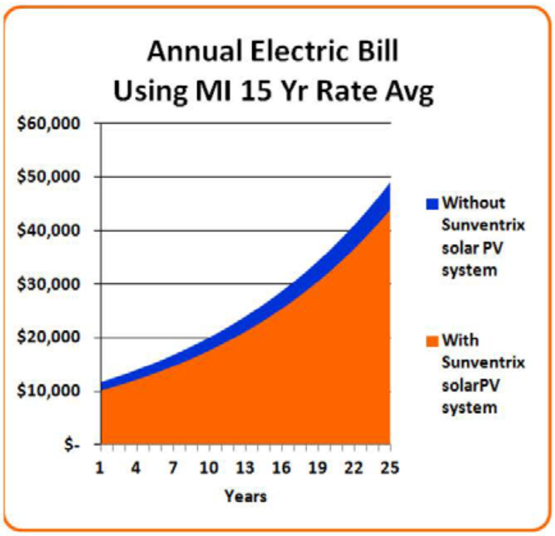
Investment

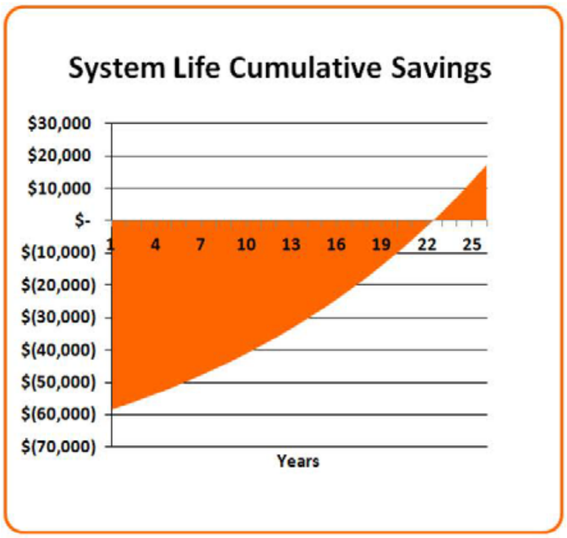
Cost per watt for system installation	$	4.32
Total cost for system installation	$	60,841
Preferred discount	$	(2,434)
Commercial system net cost	$	58,407

Savings

		25 Year System Life
First year electric bill savings	$	1,568
Average yearly electric bill savings	$	3,028
Average monthly electric bill savings	$	252
Cumulative energy production (kWh)		325,225
Greenhouse gases prevented (lbs)		**552,883**
- equivalent to trees planted		**6,235**
- equivalent to gallons of gas not consumed		**28,037**

Estimated values using on-site measurement, utility info, PV Watts, Enphase Energy data. Savings based on 20 year program life, but systems designed to last 25+ years. Electricity costs including overhead. Annual electric bill escalation of 6.25% minus annual solar output degradation of 1.0% (industry standard) = 5.25% factor used per year.





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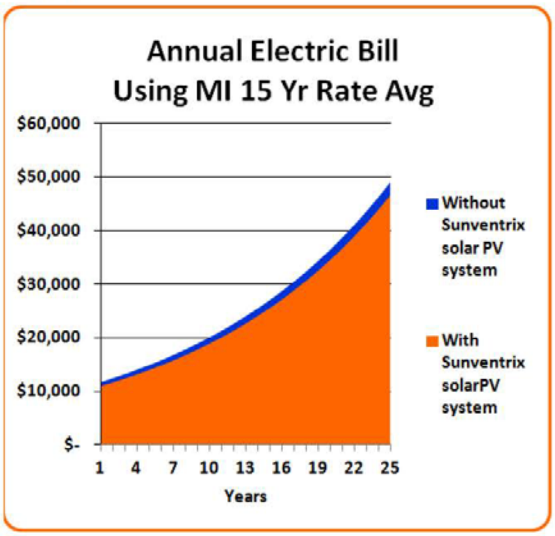
Analysis – Option 3

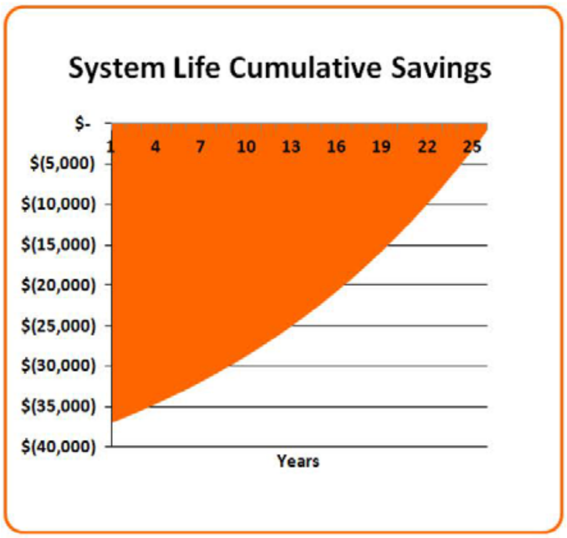
Description	
Customer average annual electric usage (kWh)	109,360
Proposed system size (kW)	6.24
Estimated system output (kWh/yr)	6,993
Solar generation of average annual electric usage (%)	6%
DC rating of solar module (STC watts)	260
Number of panels based on DC rating and system size	24.0

Investment		
Cost per watt for system installation	$	5.94
Total cost for system installation	$	39,000
Preferred discount	$	(1,950)
Commercial system net cost	$	37,050

Savings		25 Year System Life
First year electric bill savings	$	749
Average yearly electric bill savings	$	1,446
Average monthly electric bill savings	$	121
Cumulative energy production (kWh)		155,370
Greenhouse gases prevented (lbs)		**264,128**
- equivalent to trees planted		**2,979**
- equivalent to gallons of gas not consumed		**13,394**

Estimated values using on-site measurement, utility info, PV Watts, Enphase Energy data. Savings based on 20 year program life, but systems designed to last 25+ years. Electricity costs including overhead. Annual electric bill escalation of 6.25% minus annual solar output degradation of 1.0% (industry standard) = 5.25% factor used per year.





Products

Suniva Modules

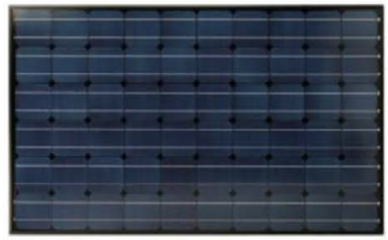
260 watts, very high efficiency, great lifetime output

Extremely durable, meet all hail requirements

Black backsheet, black frame

10 year parts warranty, 25 year performance warranty

US company, over 80% US content, meets ARRA requirements



Enphase Microinverter M215

Highest efficiency @ 96%, plus max power tracking

Longest warranty @ 25 years, plus 100% uptime guarantee

Converts DC to AC at each module for higher output

Works great with some shading or snow cover; plus turns on earlier and stays on later in low light conditions

Safe with low voltage DC, arc fault protection, and no single point of failure like with string inverters

Available monitoring on computers, smart phones, tablets

US company

SnapNrack PV Roof Mounting System

All aluminum construction with stainless steel hardware

Black anodized

Minimal penetrations and attractive design

10 year warranty, 50 year expected life

Made in USA

Quickmount or DPW or equivalent roof system attachment

All aluminum construction

Silver aluminum / black anodized

Stainless steel hardware for rust resistance

Code-compliant, watertight roof mounts

10 year warranty, 50 year expected life

Made in USA

12

Options

TED Energy Monitor ($469 installed)

System shows real time consumption, generation & net

Residential users save an average of 12% on their monthly bill through increased awareness

Accessible via web, display or mobile device

Displays dollar, kilowatt and CO_2 readings

EasySun Solar Generator ($1999 installed)

Portable design lets you wheel it where you need it

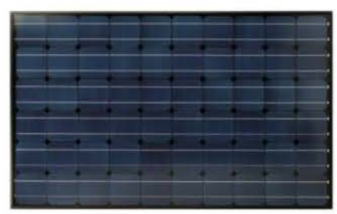
Charges via sunlight, simply place in the sun!

Easy to use - simply turn it on, plug appliance in

Silent operation with no emissions, no gas, no fuel

Runs AC and DC electrical loads up to 1500 watts

Made in Michigan



American Compliant Suniva 260W Modules ($.04/watt extra)

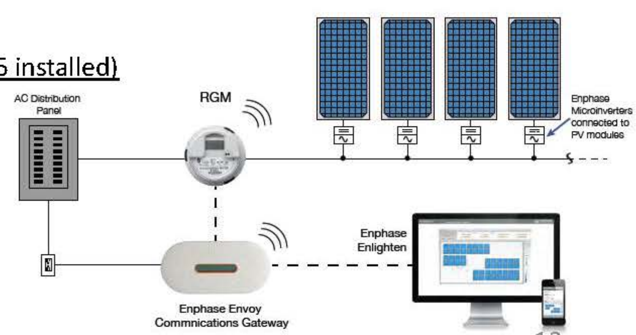
Final assembled in the US w/ 86% domestic content (std modules meet ARRA requirements with 80% content)

Longer lead time required

Suniva 265-60-4-1BO Modules ($.02/watt extra)

Highest bin class of OPTIMUS BO series - 16.33% efficiency

Recent Enphase study shows "right sizing" of higher wattage modules with M215 microinverters can result in higher kWh even with multi year cold weather power clipping (highest differences shown compared to 250W module)



Enphase Metering & Management Solution ($545 installed)

Single platform for SREC monetization

Enphase compatible, GE i210 meter

Revenue grade accuracy to within .2%

Robust Zigbee encryption & enlighten interface

24/7 monitoring and analysis

20 year offsite data retention

sunventrix solar

Why Sunventrix?

Professional Site Assessment and Solar PV Design – We assess your site using the latest tools and technology and engineer your solar PV system for best output, safety, and aesthetics that fits your needs and budget.

Experienced Installers - We use licensed electricians and installers with years of experience.

Made in Michigan and the US – Sunventrix sources Michigan and US made components for our installations and uses Michigan labor and suppliers to help our economy and jobs in the US.

Turnkey - We handle all of the paperwork for you. This includes the utility interconnection application, engineering studies, permits (building and electrical departments), inspections, everything right through to interconnection.

Safety First Policy - We follow safety requirements for installations, we carry liability and WC insurance, and we properly ground and inspect electrical work to code.

Member of Associations - Sunventrix keeps up to date with information, technologies and training.

Dedicated Project Managers - We offer a single point of contact to ensure safe, efficient, and professional design, installation and follow up.

Written Limited Warranty - our products and work are backed by and subject to a written contract and limited warranty.

Last but not least...we're green ourselves!
Sunventrix receives 100% of its electricity from clean solar energy. We also follow energy efficient measures at our business where we've adopted a majority of Energy Star recommended improvements and practices to save energy and reduce our carbon footprint.

Residential 7.52kW installation

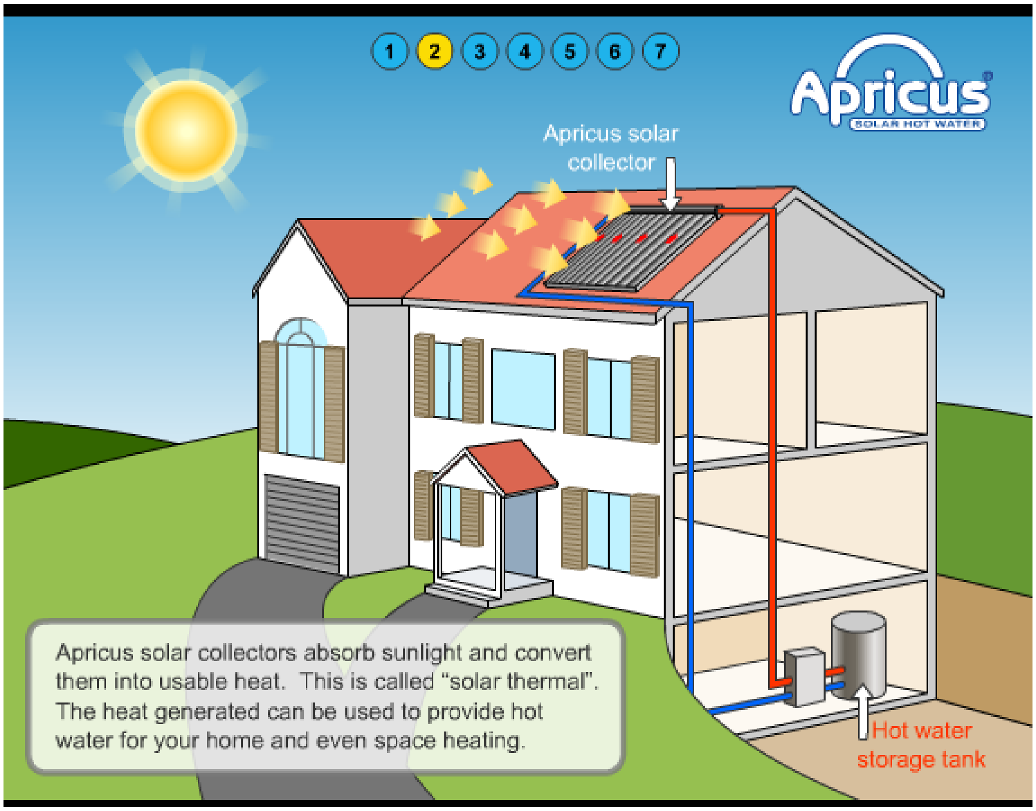
Commercial 19.78kW installation

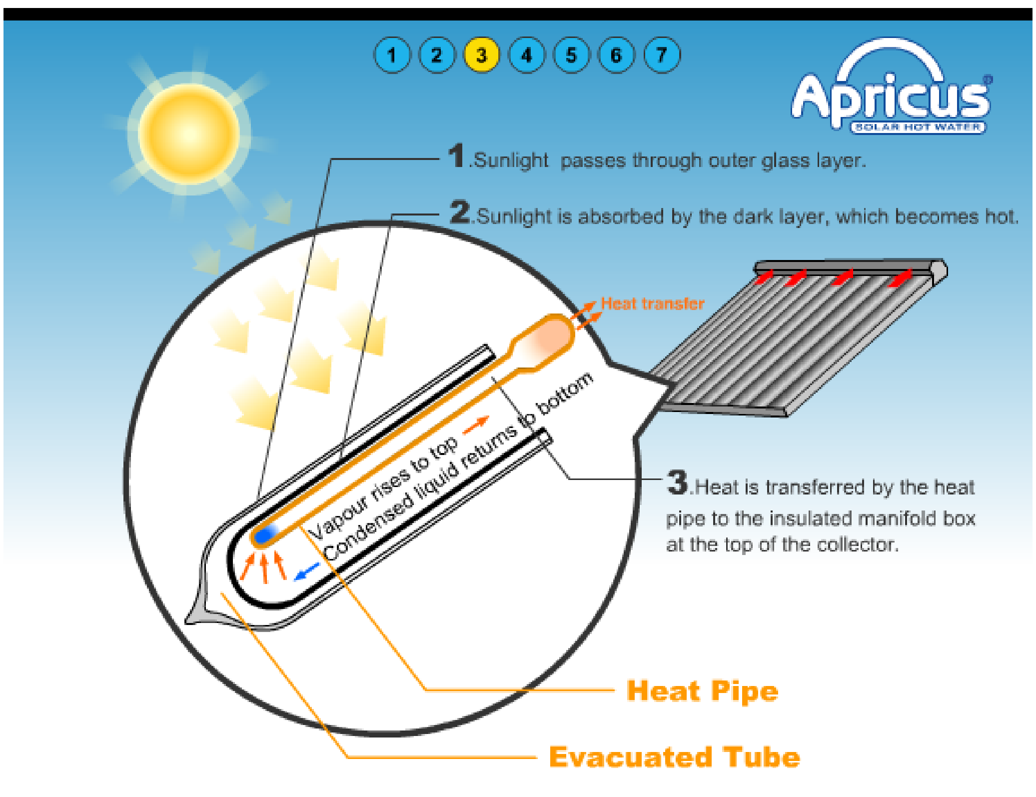
Commercial 11.75kW installation

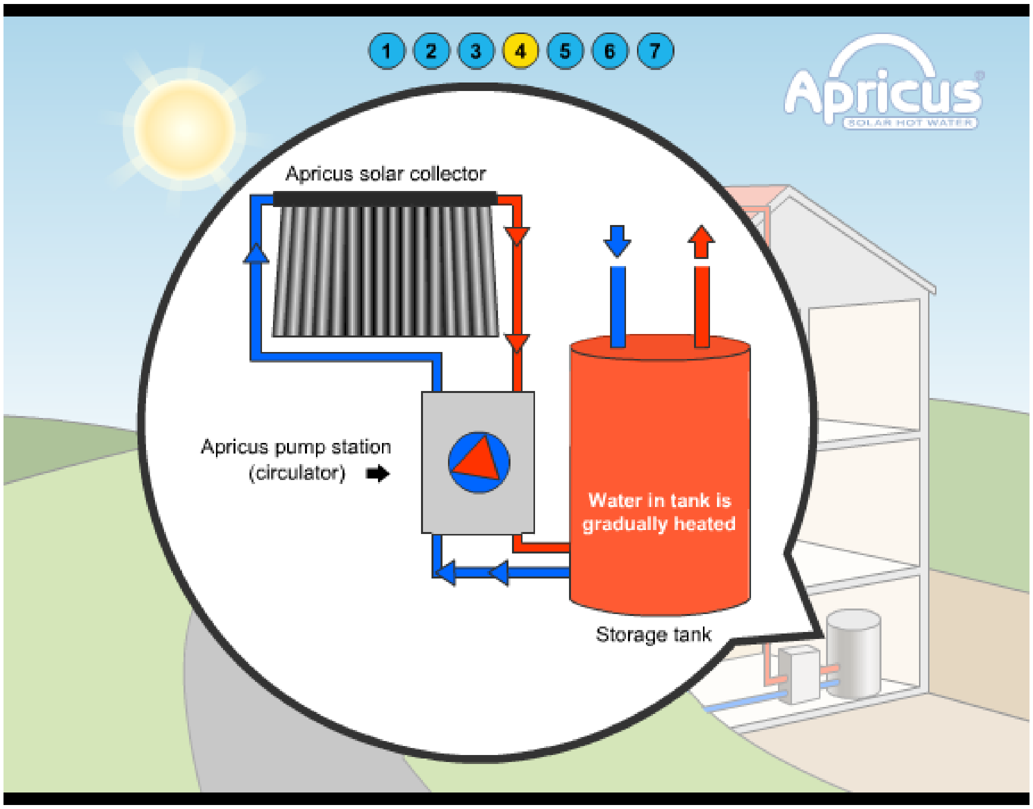
AMERICAN SOLAR ENERGY SOCIETY

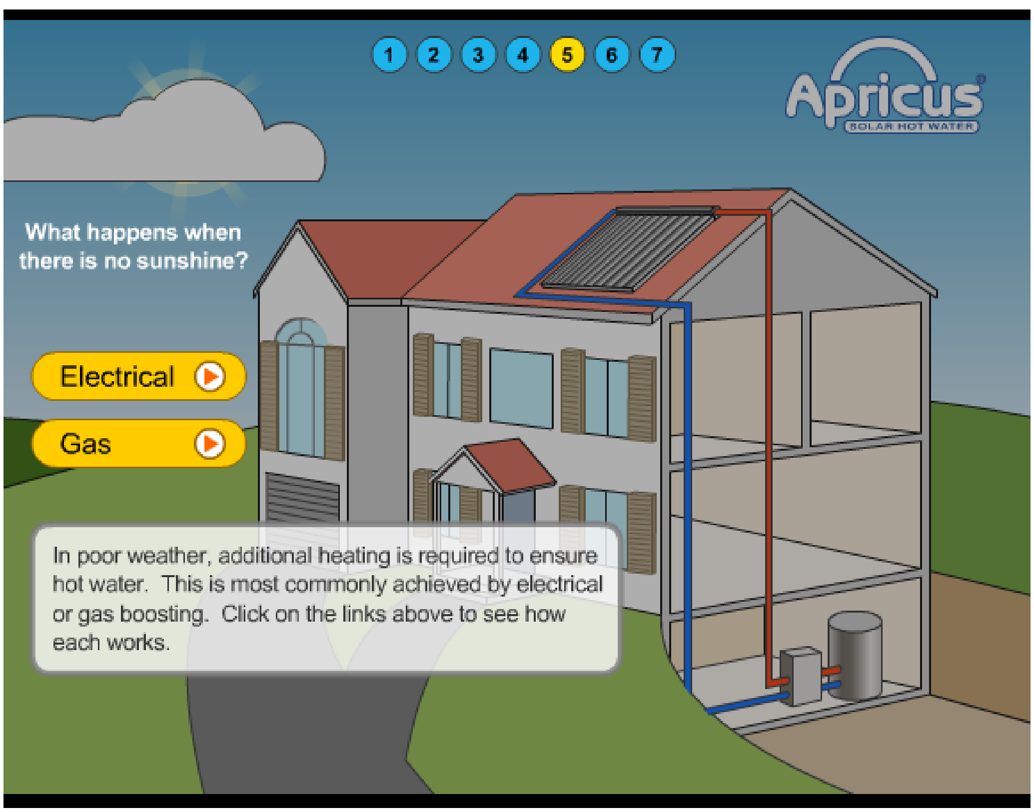
GLREA GREAT LAKES RENEWABLE ENERGY ASSOCIATION

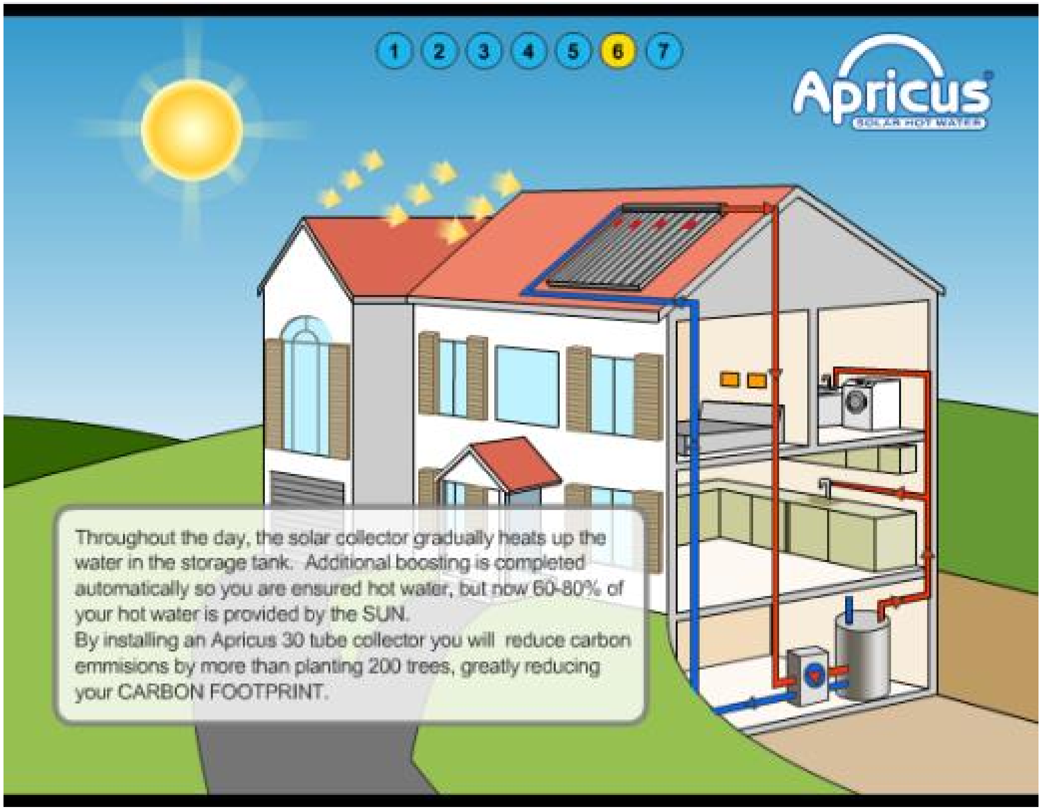
Appendix XIII: Solar Thermal Pictorial Step-by-Step (Apricus, 2013)






1 2 3 4 5 6 7
Apricus
SOLAR HOT WATER
Apricus solar collector
Apricus pump station
(circulator)
Water in tank is
gradually heated
Storage tank


1 2 3 4 5 6 7
Apricus
SOLAR HOT WATER
What happens when
there is no sunshine?
Electrical
Gas
In poor weather, additional heating is required to ensure hot water. This is most commonly achieved by electrical or gas boosting. Click on the links above to see how each works.


1
2
3
4
5
6
7
Apricus
SOLAR HOT WATER
Throughout the day, the solar collector gradually heats up the water in the storage tank. Additional boosting is completed automatically so you are ensured hot water, but now 60-80% of your hot water is provided by the SUN.
By installing an Apricus 30 tube collector you will reduce carbon emmisions by more than planting 200 trees, greatly reducing your CARBON FOOTPRINT.

Appendix XIV: Detailed Solar Thermal System Calculations – Apricus System

Estimated Propane Use for Heating Water (Inputs = black, Computed values = **blue**)

Description	Values	Reference	Source / Formula
Estimated water temp in ground (degrees F)	52	A	Solar thermal contractor estimate
Ave water temp observed during visits (degrees F)	135	B	On site observations
Temp rise required (degrees F)	83	C	B - A
Ave water gallons/day (from softener readout)	5095	D	Lester from maintenance read the water softner display
% hot water of total water used	40%	E	Industry std per Roger Peters, Solar Solutions of Michigan
Hot water used per day (gallons/day)	2038	F	D * E
Propane conversion factor (BTU/1 gal propane)	91,648	H	Energy star document (EPA)
kWh conversion factor (BTU/1 kWh)	3412	I	Energy star document (EPA)
Mass (m) of water (lbs/1 gal)	8.343	J	U.S. Geological Survey
Heat capacity / Specific heat (c) of water (BTU/1 °F lb)	1	K	Fundamentals of Classical Thermodynamics, 4th Ed., p 810, Table A.9E
Formula used to find energy to heat water: mcΔT (BTU/1 gal water	692	L	J * K * C
Energy needed to heat ave hot water use at camp (BTU/day)	1,411,252	M	L * F
Water heater efficiency	96%	N	Lochnivar website document
Energy needed to heat ave hot water use at camp (BTU/day)	1,470,054	O	M / N
Propane needed to heat water (gallons/day)	16.04	P	O / H
2012 cost of propane ($/1 gallon)	$ 2.30	Q	Petosky Propane
Annual days propane used (days)	138	R	Per maintenance personnel, May 1 - Sep 15
Annual cost of propane to heat water ($)	$ 5,089	S	P * Q * R
Sealsonal solar thermal production (BTU)	64,913,290	T	See solar thermal vendor's sheet to the below
Daily solar thermal production (BTU/day)	470,386	U	T / R
% energy proposed solar thermal system provides	32%	---	U / O (10 Apricus AP-30 modules)

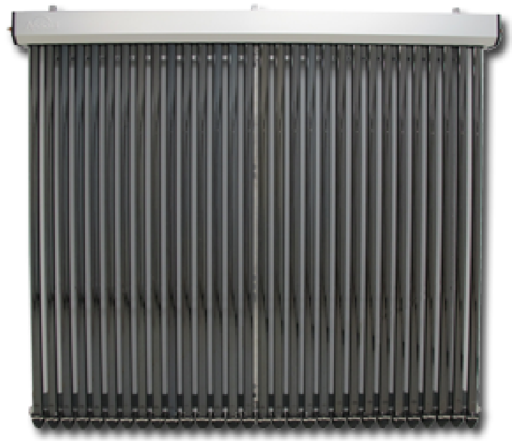
Project	Camp Michigania (10)		Legend:	AD = Average Day		30 tubes are the number of tubes per module. See picture below.					
	03006 Camp Sherwood R%d			BD = Best Day							
	Boyne City, Mi 49712			WD = Worst Day		Note: All items in black from solar thermal vendor (Roger)					
1-30 Evacuated Tube Collector				Collect = Colletor							
Location:				Req = Required							
Latitude 42.37 / Longitude -83.12				Fur = Furnished			AVERAGE BTU PER DAY REQUIRED				
								1,155,790			
Month	AD/ BTU 30 TUBE	BD/30- TUBE	WD 30 TUBE	# COLLECT	AVE BTU REQ	AVE BTU FUR	% CONTRIB	BD TOTAL	WD TOTAL	Days in Month	Total BTU in Month
January	21,344.0	36,880.0	2,670.0	10		213,440.0	#VALUE!	368,800.0	26,700.0		
February	26,456.0	47,102.5	3,102.5	10		264,560.0	#VALUE!	471,025.0	31,025.0		
March	34,502.5	58,015.0	5,425.0	10		345,025.0	#VALUE!	580,150.0	54,250.0		
April	37,550.0	63,170.0	7,562.5	10		375,500.0	#VALUE!	631,700.0	75,625.0		
May	46,788.0	64,805.0	10,187.5	10	1,155,790	467,880.0	40.48%	648,050.0	101,875.0	31	14,504,280
June	48,967.0	64,847.5	13,852.5	10	1,155,790	489,670.0	42.37%	648,475.0	138,525.0	30	14,690,100
July	47,644.0	64,630.0	16,077.5	10	1,155,790	476,440.0	41.22%	646,300.0	160,775.0	31	14,769,640
August	46,872.0	57,845.0	16,525.0	10	1,155,790	468,720.0	40.55%	578,450.0	165,250.0	31	14,530,320
September	42,793.0	53,920.0	10,800.0	10	577,895	427,930.0	74.05%	539,200.0	108,000.0	15	6,418,950
October	35,267.0	51,100.0	6,465.0	10		352,670.0	#VALUE!	511,000.0	64,650.0		
November	24,176.0	42,565.0	2,415.0	10		241,760.0	#VALUE!	425,650.0	24,150.0	138	64,913,290
December	20,876.0	27,377.5	1,275.0	10		208,760.0	#VALUE!	273,775.0	12,750.0		
Year	36,103.0	xxx	xxx	10		361,030.0	#VALUE!	XXX	XXX		

AP-30

The **Apricus AP-30 (30 tube) collector** is designed to be used in a wide variety of solar thermal applications in almost any climate. The evacuated tube and heat pipe technology provides very efficient and reliable solar thermal production in an easy to install, low maintenance design.

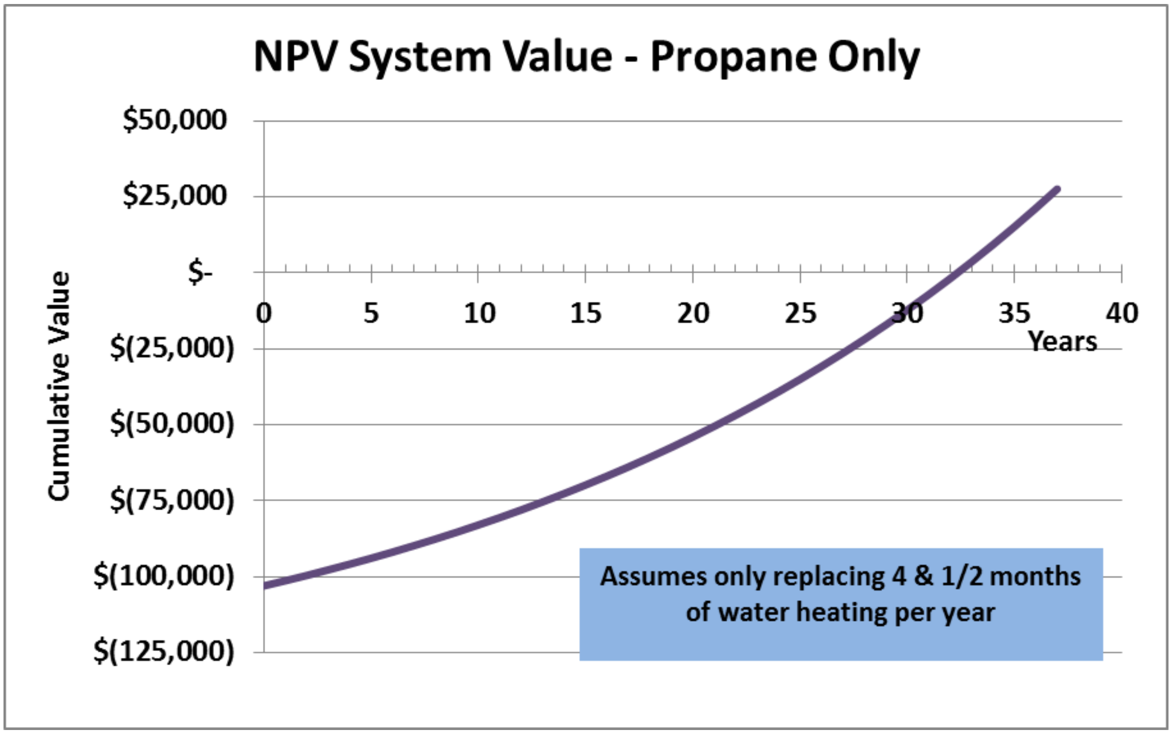
Key Features

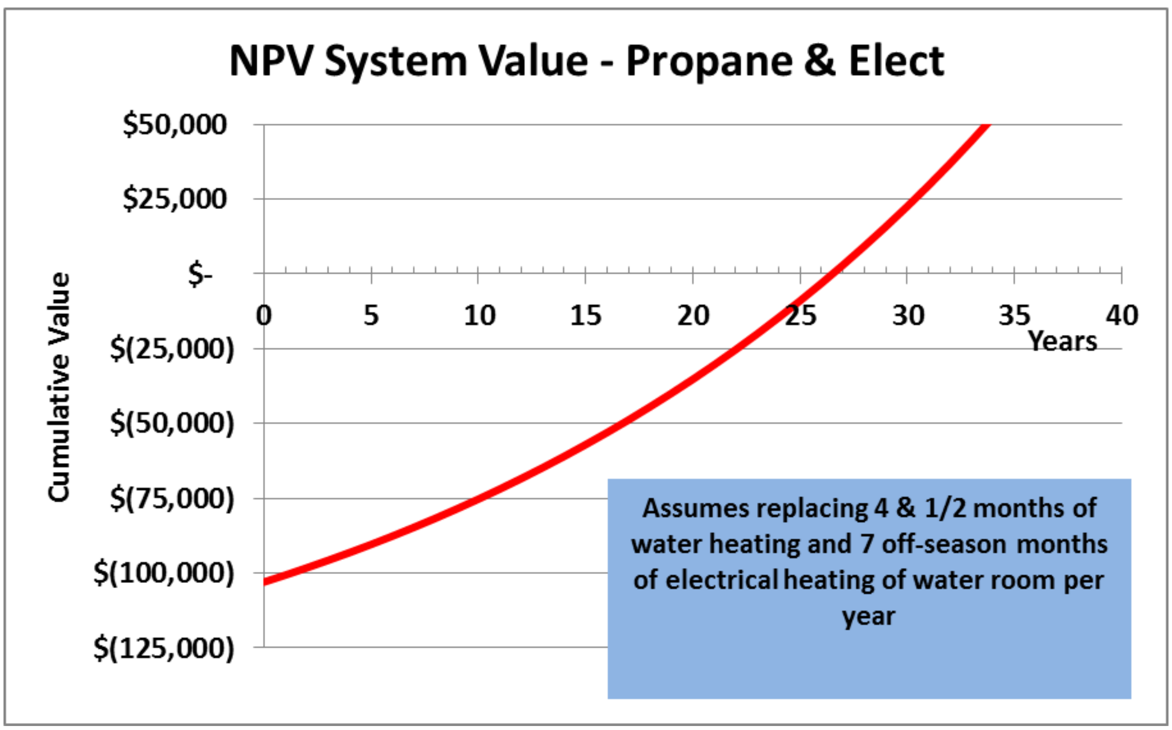
- Efficient performance at high differential temperatures
- Round absorber coating passively tracks the sun throughout the day
- Individual tubes easily replacable without disrupting the system
- Standard sized pipe connections
- Drainback compatible
- Flexible mounting options: roof, ground, awning
- Hail resistant in accordance with EN12975-2 and designed to sustain up to 130mph winds
- 10-year warranty on tubes and heat pipes, 15-year on copper header and frame



(Apricus, 2013)

Solar Thermal Payback (Inputs = black, Computed values = **blue**)			
Description	**Values**	**Reference**	**Source / Formula**
Propane conversion factor (BTU/1 gal propane)	91,648	H	Energy star document (EPA)
2012 cost of propane ($/1 gallon)	$ 2.30	Q	Petosky Propane
Annual days propane used (days)	138	R	Per maintenance personnel, May 1 - Sep 15
Sealsonal solar thermal production (BTU)	64,913,290	T	See solar thermal vendor's sheet above
Daily solar thermal production (BTU/day)	**470,386**	U	T / R
Gal/propane per day saved (gal/day)	**5**	V	U / H
Cost/day saved, propane ($/day)	**$ 12**	W	V * Q
Cost/year saved, propane ($/year)	**$ 1,628**	X	W * R
Total cost of system ($)	$ 102,985	Y	Vendor quote (Greenlife - see separate tab for copy)
Simple payback - **propane savings only** (years)	**63**	Z	Y / X
NPV payback - **propane savings only** (years)	**33**	Graph below	Using 4% inflation rate and 0.25% discount rate
Added in potential electric savings below			
Electricity used 9-14-2010 through 4-13-2011 (kWh)	9,880	AA	Great Lakes Energy Invoices
Electricity used 9-13-2011 through 4-11-2012 (kWh)	13,280	AB	Great Lakes Energy Invoices
Average electricity used per year in off-season (kWh)	**11,580**	AC	(AA + AB) / 2
Estimated % of electricity used for heating water room	50%	AD	Estimate
Estimated electricity used for water room heater off-season (kWh)	**5,790**	AE	AC * AD
Cost of electricity / kWh, 2012 ($/kWh)	$ 0.108	AF	Great Lakes Energy Invoices
Cost/year saved, electricity by heating with solar thermal ($/year)	**$ 625**	AG	AE * AF
Total cost/year saved, propane and electricity ($/year)	**$ 2,254**	AH	AG + X
Simple payback - **propane & electric savings** (years)	**46**	AI	Y / AH
NPV payback - **propane & electric savings** (years)	**27**	Graph below	Using 4% inflation rate and 0.25% discount rate





Note: Above graphs produced from Excel spreadsheets using appropriate inflation and discount rates to perform net present value computations to determine payback periods. Spreadsheets were verified independently by second technical team member who is an electrical engineer familiar with net present value computations.

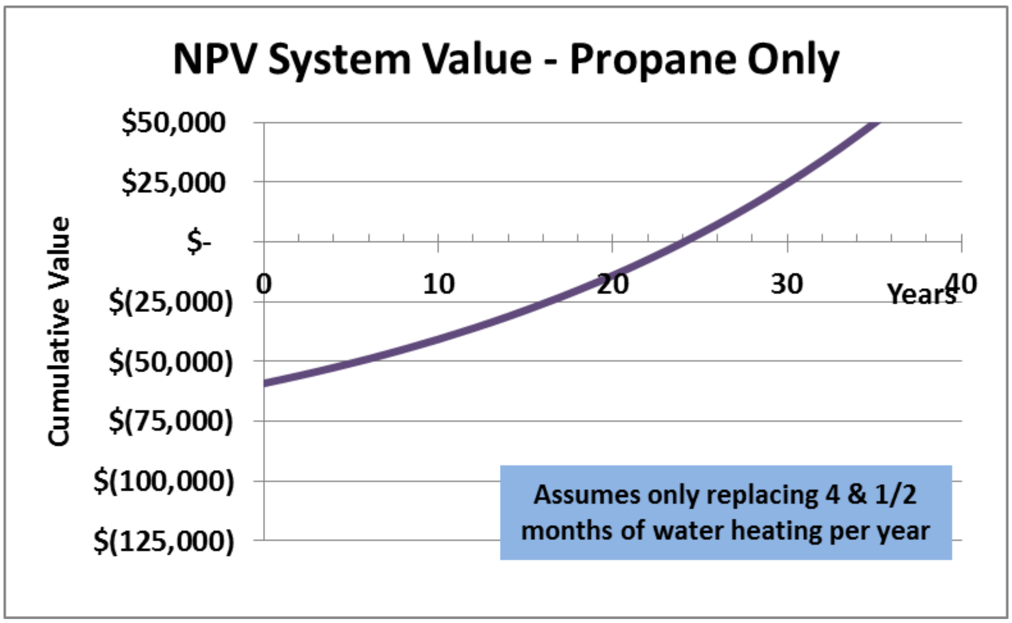
Appendix XV: Detailed Solar Thermal System Calculations – Caleffi System

Estimated Propane Use for Heating Water (Inputs = black, Computed values = blue)			
Description	**Values**	**Reference**	**Source / Formula**
Estimated water temp in ground (degrees F)	52	A	Solar thermal contractor estimate
Ave water temp observed during visits (degrees F)	135	B	On site observations
Temp rise required (degrees F)	83	C	B - A
Ave water gallons/day (from softener readout)	5095	D	Lester from maintenance read the water softner display
% hot water of total water used	40%	E	Industry std per Roger Peters, Solar Solutions of Michigan
Hot water used per day (gallons/day)	2038	F	D * E
Propane conversion factor (BTU/1 gal propane)	91,648	H	Energy star document (EPA)
kWh conversion factor (BTU/1 kWh)	3412	I	Energy star document (EPA)
Mass (m) of water (lbs/1 gal)	8.343	J	U.S. Geological Survey
Heat capacity / Specific heat (c) of water (BTU/1 °F lb)	1	K	Fundamentals of Classical Thermodynamics, 4th Ed., p 810, Table A.9E
Formula used to find energy to heat water: mcΔT (BTU/1 gal water)	692	L	J * K * C
Energy needed to heat ave hot water use at camp (BTU/day)	1,411,252	M	L * F
Water heater efficiency	96%	N	Lochnivar website document
Energy needed to heat ave hot water use at camp (BTU/day)	1,470,054	O	M / N
Propane needed to heat water (gallons/day)	16.04	P	O / H
2012 cost of propane ($/1 gallon)	$ 2.30	Q	Petosky Propane
Annual days propane used (days)	138	R	Per maintenance personnel, May 1 - Sep 15
Annual cost of propane to heat water ($)	$ 5,089	S	P * Q * R
Sealsonal solar thermal production (BTU)	59,800,000	T	Vendor's RET Screen Energy Model output
Daily solar thermal production (BTU/day)	433,333	U	T / R
% energy proposed solar thermal system provides	29%	---	U / O (8 Caleffi modules)

Solar water heater		
Type		Glazed
Manufacturer		Caleffi
Model		SolarFlat NAS10410
Gross area per solar collector	ft²	39.78
Aperture area per solar collector	ft²	37.47
Fr (tau alpha) coefficient		0.71
Fr UL coefficient	(Btu/h)/ft²/°F	0.86
Temperature coefficient for Fr UL	(Btu/h)/ft²/°F²	0
Number of collectors		8
Solar collector area	ft²	318.27
Capacity	kW	19.49
Miscellaneous losses	%	3.0%
Balance of system & miscellaneous		
Storage		Yes
Storage capacity / solar collector area	gal/ft²	1
Storage capacity	gal	320.0
Heat exchanger	yes/no	Yes
Heat exchanger efficiency	%	85.0%
Miscellaneous losses	%	3.0%
Pump power / solar collector area	W/ft²	0.87
Electricity rate	$/kWh	0.110
Summary		
Electricity - pump	MWh	0.6
Heating delivered	million Btu	59.8

(Bartlette, 2012)

Solar Thermal Payback (Inputs = black, Computed values = **blue**)			
Description	**Values**	**Reference**	**Source / Formula**
Propane conversion factor (BTU/1 gal propane)	91,648	H	Energy star document (EPA)
2012 cost of propane ($/1 gallon)	$ 2.30	Q	Petosky Propane
Annual days propane used (days)	138	R	Per maintenance personnel, May 1 - Sep 15
Seasonal solar thermal production (BTU)	**59,800,000**	T	**Vendor's RET Screen Energy Model output**
Daily solar thermal production (BTU/day)	**433,333**	U	T / R
Gal/propane per day saved (gal/day)	**5**	V	U / H
Cost/day saved, propane ($/day)	**$ 11**	W	V * Q
Cost/year saved, propane ($/year)	**$ 1,500**	X	W * R
Total cost of system ($)	$ 59,121	Y	Vendor quote
Simple payback - **propane savings only** (years)	**39**	Z	Y / X
NPV payback - **propane savings only** (years)	**25**	Graph below	Using 4% inflation rate and 0.25% discount rate



Note: Above graph produced from Excel spreadsheet using appropriate inflation and discount rates to perform net present value computations to determine payback period. Spreadsheet was verified independently by second technical team member who is an electrical engineer familiar with net present value computations.