Northport 100% Renewable Energy Feasibility Study

On behalf of Northport Energy Action Taskforce
Based in Northport, Michigan

by

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Abstract

Situated in northern Michigan, Northport and Leelanau Township comprise a small community with a significant tourist industry, agricultural presence and natural beauty. A local non-profit, Northport Energy Action Taskforce (NEAT) has articulated a goal to transition their community to 100% locally-generated renewable energy. This feasibility study focused on electricity and included research on the disposition of the community as well as technical analyses of renewable energy systems that would be suitable for attaining the goal. The team created a household survey, followed by resource assessments for wind and solar power, as well as site identification for renewable energy systems. The survey results showed that the community is open to the possibility of increasing the share of renewable energy in the Township, with 71% of respondents expressing support to the initiative. Based on the resource assessment results, we concluded that the resource availability in the location is enough to provide the required electricity to meet the 100% goal. Land availability makes feasible the deployment of large-scale systems needed for the plan. Additional analyses of energy-efficiency potential and energy policies were conducted to inform the development of three scenarios for achieving 100% local renewable energy.

Acknowledgements

Our client, Northport Energy Action Taskforce
This group of volunteers has been an inspiration for us, dedicating their time and energy toward an ambitious 100% renewable energy goal. The pursuit of the larger goal hasn't come at the expense of the day-to-day efforts needed to tackle renewable energy and efficiency projects. We hope that our (future) children will be able to visit Northport some day to see Michigan's first renewably-powered town.

Our advisor, Kim Wolske, Ph.D.
Kim's willingness to give us a crash course on survey methodology was but one of her contributions to the quality and integrity of our research.

Our advisor, Greg Keoleian, Ph.D.
Greg's extensive knowledge of renewable energy systems and overall experience in the field of sustainability were foundational for the development of our project.

Leelanau Township Community Foundation
The foundation provided funding for us to conduct a comprehensive household survey that served as a basis for the rest of the study.

Electric Utilities, Consumers Energy and Cherryland Electric Co-op
Both utilities contributed electricity consumption data for Leelanau Township. That was essential for our analysis of renewable energy feasibility.

Leelanau Township Treasurer
The treasurer supplied the address database used for the survey. The accuracy of this database allowed us to obtain a higher participation rate.

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Executive Summary

The objective of this project was to determine the feasibility of Leelanau Township, Michigan, generating 100% of its electricity needs from local, renewable sources. The project was initiated by the non-profit Northport Energy Action Taskforce (NEAT), which focuses on renewable energy and energy efficiency initiatives in that area. Specifically, this study examines variables that are likely to impact achievement of this goal. The first phase of the project involved collecting information on the local community's perspective toward renewable energy through a series of community meetings and a household survey. For the second phase, the team looked at potential energy-efficiency measures that could reduce overall energy demand and assessed available solar and wind resources in the Township. Finally, the third phase examined different scenarios for achieving the 100% renewable electricity goal in the Township.

Phase I - Community Engagement

The first phase involved engaging the community about a potential transition to100% local, renewably-generated electricity. First, we designed a household survey with the goal of better understanding the orientation of the community toward renewable energy and a potential renewable energy plan. We wanted to understand residents' perspectives regarding energy and the environment and their reasons for either supporting or opposing a community renewable energy plan. Additionally, the survey included some questions related to household energy-efficiency measures. Ultimately 2,012 surveys were mailed and a total of 668 responses where received, resulting in a response rate of 33%. Second, the team participated in two community events organized by NEAT in July 2014. These events were focused on educating the public on renewable energy generally and highlighting existing renewable energy projects in the community. The meetings also provided an opportunity for dialog about the broader goal. At the conclusion of the project, findings were presented to NEAT and the community on April 11, 2015.

Phase I Findings

When respondents were asked about how supportive they would be of a plan to achieve 100% renewable energy in Leelanau Township, 71% indicated that they were somewhat to very supportive. In addition, around 40% of respondents expressed a willingness to participate in the development of the renewable energy plan (**Figure 1.**).

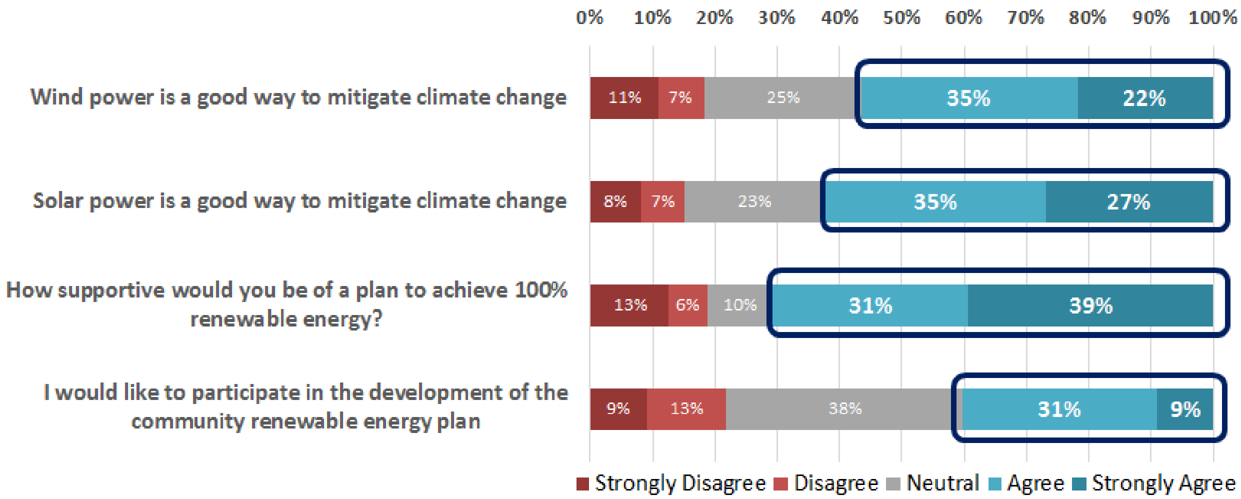


Figure 1. Respondents' perception regarding renewable energy

Phase II - Energy Efficiency and Resource Assessment

Energy efficiency and conservation are often the least expensive way to reduce fossil fuel use, and complement renewable energy generation. Some energy-efficiency measures require little effort or cost, and some can lead to significant savings. Two energy-efficiency measures were analyzed to determine their potential impact in Leelanau Township. First, the savings from switching from incandescent lightbulbs to energy-efficient light bulbs was examined on a household and community scale. Energy savings from lowering the thermostat during winter for electric heaters was also analyzed.

Because NEAT's stated goal is for locally-generated renewable energy, we performed a resource assessment to determine the feasibility of meeting net annual electricity needs through renewable generation. PV solar and wind energy systems were modeled to estimate electricity generation for these systems. Community input and land availability were also considered when determining the potential siting for the different large-scale systems.

Phase II Findings

Using survey responses to help gauge potential, we estimated that savings through energy-efficiency measures would be minor in the scheme of transitioning to 100% renewable energy. More than two-thirds of Northport and Leelanau Township residents indicated that they have already undertaken some energy-efficiency measures. Plus, we estimated that about half of homes may be used seasonally, reducing their potential for conservation and efficiency-based savings. However, energy efficiency and conservation efforts could keep consumption essentially flat over time. We estimate annual savings of 0.5% through employing those strategies, lessening the need for additional generation in future years.

Based on electricity consumption data, we made a projection for electricity consumption in year 2035, which resulted to be 23,500 MWh/year approximately.

After evaluating the results from the resource assessment, we concluded that Leelanau Township has sufficient solar radiation and wind speeds to supply the totality of its electricity consumption via renewable energy sources. Although this area does not have exceptional wind and solar resources, both are adequate for meeting the goal, partly because of the low population density. Targeting the projected electricity demand mentioned above, we estimated that the modeled renewable energy systems would be able to provide about 9,600 MWh/year of electricity from wind turbines and around 14,000 MWh/year from a series of small and large-scale PV solar installations.

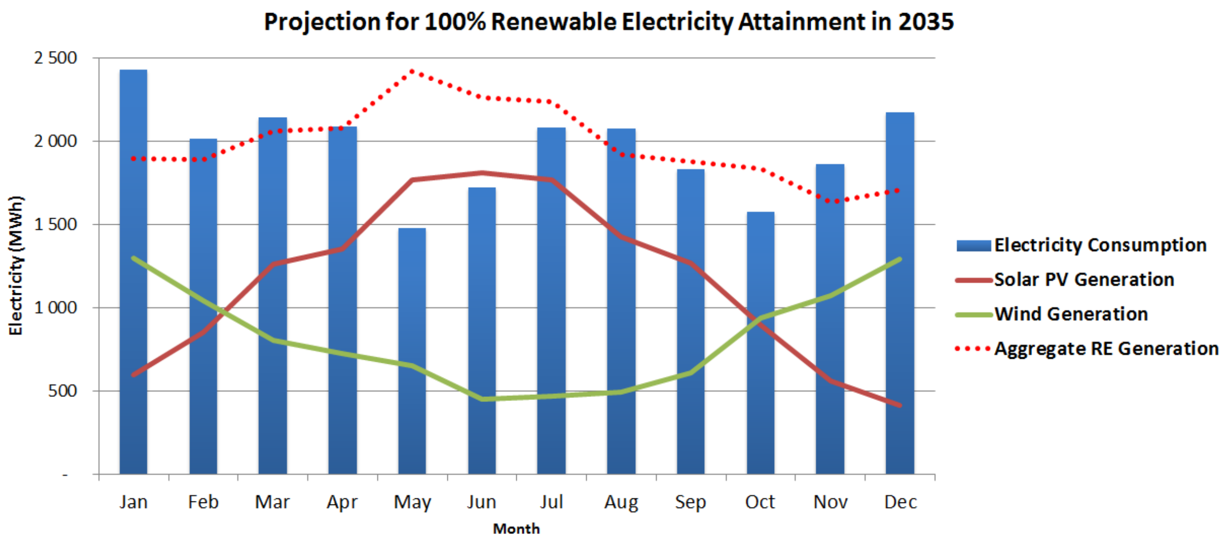


Figure 2. Projection for 100% Renewable Electricity Attainment in 2035. A total installed capacity of 3 MW of wind power and 7.5 MW of large-scale solar PV would meet the net annual electricity needs for Leelanau Township.

Phase III - Renewable Energy Plan

In the final phase, we integrated the information gathered and the results obtained from the previous phases to develop three scenarios to illustrate different schedules for transitioning to renewable-generated electricity. They included a base scenario considering middle-of-the-road assumptions, in which the 100% goal would be achieved in 20 years; a rapid renewable energy adoption scenario, assuming extended policy incentives and subsidies; and a stalled renewable energy adoption scenario, where future low fossil fuel prices would hinder the rate of adoption of renewables. These scenarios were intended to demonstrate alternative pathways to NEAT for a 100% renewable energy plan.

Phase III Findings

Each scenario has large step-wise increases in renewable energy generation. These correspond with large project installations. Because we assumed that only 15% of residences and commercial properties would adopt PV solar, the majority of generation would need to be provided by larger-scale projects.

Residents of Leelanau Township are somewhat sensitive to the appearance of wind turbines, as reported in the community survey. Using that as a consideration for turbine siting, we expect that an additional 3 MW (or about one-sixth of the total needed) of wind capacity may be the approximate upper limit for that generation type. The generation mix chart for the base scenario, below, shows that the difference is made up by large-scale PV solar. Meanwhile, smaller-scale PV systems on residences and businesses make up a relatively small slice, totaling about 1.5 MW (approximately 8% of the total needed).

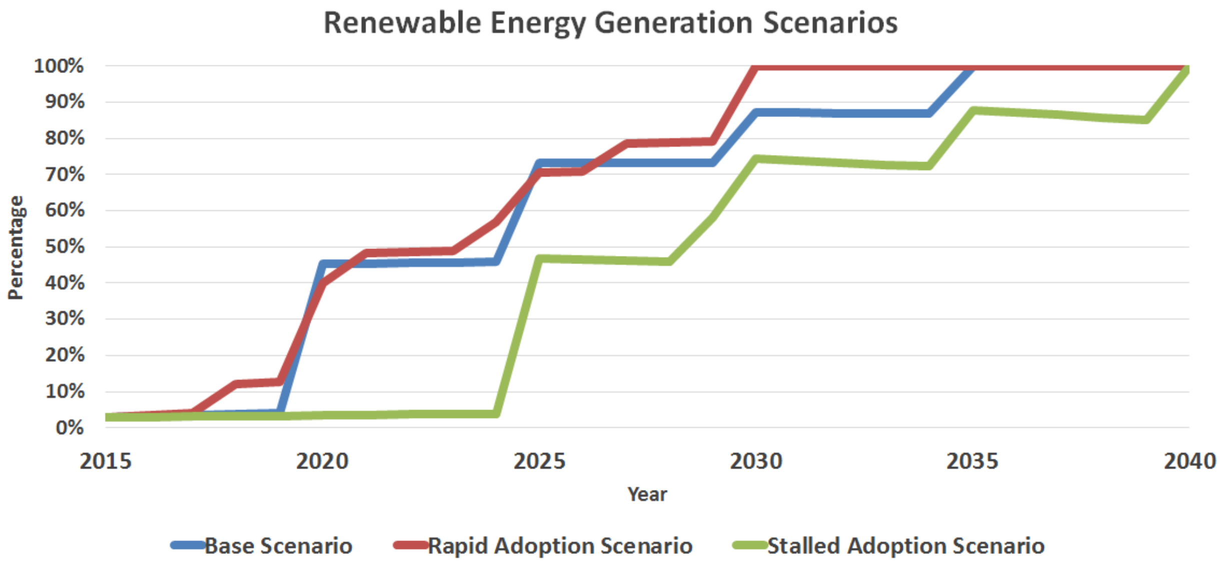


Figure 3. Renewable Energy Generation Scenarios

Introduction

Today the global energy industry is undergoing a dramatic transformation. Clean, renewable energy has an increasingly important role to play as the world faces the threat of climate change and the likelihood that finite fossil fuels will become depleted or become uneconomic to retrieve. Renewable energy technologies have a much lower environmental impact than fossil energy sources and can contribute to energy security. Deploying renewable energy technologies while simultaneously reducing energy consumption at the local community level could significantly decrease the fossil energy use both in the U.S. and worldwide.

Several communities in the U.S. have already set 100% goals for renewable energy generation. For instance, the city of Aspen has set a 100% renewable power goal by 2015 and as of 2014 the city reached 86%, mostly through hydropower, though also including wind. The project was inspired by the idea of reducing both operational and community-wide greenhouse gas (GHG) emissions 30% below 2004 levels by 2020 and 80% below 2004 levels by 2050. Another U.S. city, Burlington, the largest city in Vermont with the population of about 42,000, proved that the goal of generating 100% of electricity from renewable sources such as wind, water and biomass is achievable (Burlington, VT - 100% Renewable Public Power, n.d.).

Communities that adopt grid-integrated renewable energy resources are protected against energy price rises and can employ local labor for installation and maintenance. In concert with renewable generation, energy-efficiency measures can reduce electricity costs for households and businesses. Despite these advantages, a transition to 'clean' resources faces barriers such as high initial capital costs and inadequate policies to facilitate the implementation of renewable energy projects. Most importantly, such community-based projects require support of local community members.

Northport Energy Action Taskforce (NEAT), a non-profit organization whose main goal is the advocacy for energy efficiency and the use of renewable energy, reached out to University of Michigan's School of Natural Resources and Environment (SNRE) in order to develop a renewable energy feasibility study for the Village of Northport and Leelanau Township, located in northern Michigan. The objective of this study was to research the feasibility of a 100% renewable energy community-based plan for electricity on a net annual basis. The project team was formed in February 2014 and the project concluded in April 2015. A team of six students conducted the study aimed at providing information and support to NEAT for development of a renewable energy plan for Leelanau Township. The team brought expertise in various fields such as building energy efficiency, environmental resource assessment, and statistical analysis.

The following sections provide additional detail about the community, the project and research methodology.

Background

Michigan has a growing renewable energy industry, with renewable electricity generation coming predominantly from biomass, a lesser amount from hydroelectric power and a small but rapidly growing contribution from wind energy. Michigan's Renewable Energy Standard (RES), which was passed into law in October 2008, helped to accelerate a transition to a clean energy economy by requiring 10% renewable electricity generation by 2015. As a result, electricity production derived from renewable energy sources has increased from about 4% in 2009, to nearly 10% by early 2015 (Michigan Energy Overview, n.d.). However, Michigan's Renewable Portfolio Standard (RPS) is among the least stringent nationally of states that have standards (Michigan Energy Overview, n.d.). Additionally, Michigan lacks other incentives to encourage advanced energy development and increase its RPS target beyond 10%[1].

Michigan's wind resources are ranked 18th in the nation according to U.S. Energy Information Administration (Michigan State Energy Profile, n.d.). While not possessing the best wind resource nationally, Michigan has been among the top states in percentage increase in wind capacity from turbines in recent years (cf. Figure 4). As of 2014, there were 887 wind turbines in the state with a peak capacity of 1,531 MW[2]. They provided 2.4% of the state's electricity in 2013, equating to enough energy to power approximately 233,000 homes[3]. Michigan has about 20 utility-scale wind farms.

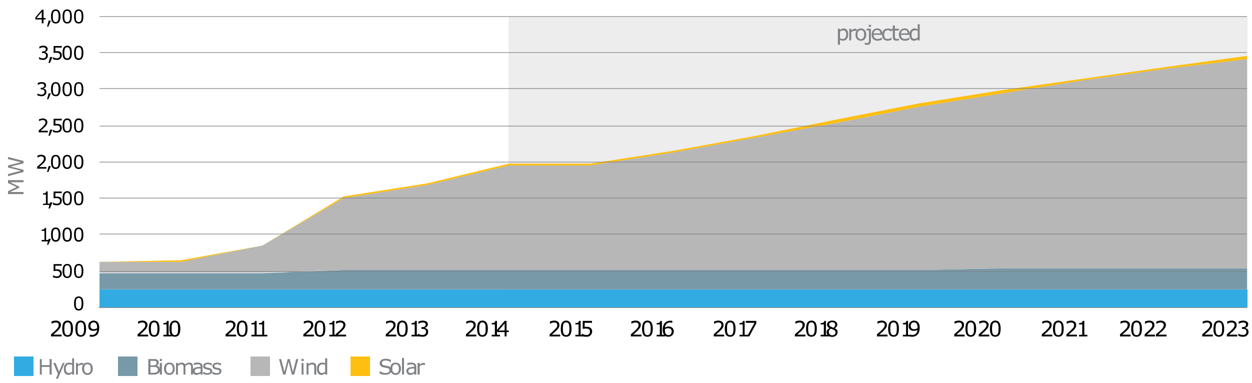


Figure 4. Clean energy capacity, by sector and year

Source: (Trusts, 2014)

Despite modest annual solar radiation, the number of photovoltaic (PV) solar installations has increased in recent years in Michigan. Solar development has been aided by a variety of regulatory actions and financial incentives – particularly a 30% federal tax credit that is available through 2016 for any size project. Upfront-costs for PV solar have also fallen substantially in recent years, allowing systems to compete with retail electricity in areas with lower solar radiation like Michigan. Michigan's grid-connected PV installed capacity has rapidly increased since 2007, from 0.4 MW to 22.2 MW in 2013. Despite those gains, less than 1% of Michigan's renewable energy is generated from solar power.

[1] Barriers to advanced energy in Michigan. Institute For Energy Innovation. (January 2015). Retrieved March 19, 2015 from
[2] http://www.michigan.gov/documents/mpsc/wind_farm_summary_407660_7.pdf?20131218143923
[3] http://awea.files.cms-plus.com/FileDownloads/pdfs/Michigan.pdf

Stakeholders

Developing and implementing a renewable energy plan is a complex process, and understanding the motivations and concerns of stakeholders is critical to its success. The main stakeholders for this project are described below.

NEAT

Formed in 2008, the community's 'men discussion group' started addressing energy and environmental issues, officially evolving into the Northport Energy Action Taskforce (NEAT) in January 2010. NEAT's approximately two-dozen members come from diverse vocational backgrounds and include farmers, scientists, engineers, economists and energy experts. Their work includes projects in energy efficiency, as well as wind and solar system promotion and installation. NEAT is our client and the group that developed a vision for a community-based 100% renewable energy plan.

The Community and the Village of Northport / Leelanau Township

Leelanau Township consists of the northernmost portion of Michigan's Leelanau Peninsula (**Figure 5**). Its southern boundary is approximately 20 miles northwest of Traverse City. The population of Leelanau Township is about 2,000 people, with 931 households, including the Village of Northport. The Village has an area of 1.65 square miles (4.27 km^2) and population density of 318.8/square mile (123.1/km^2). As of 2010, the Village had a median household income of $49,643 (U.S. Census Bureau, 2010). About 20% of the population is comprised of retired professionals and the population approximately doubles from winter to summer.

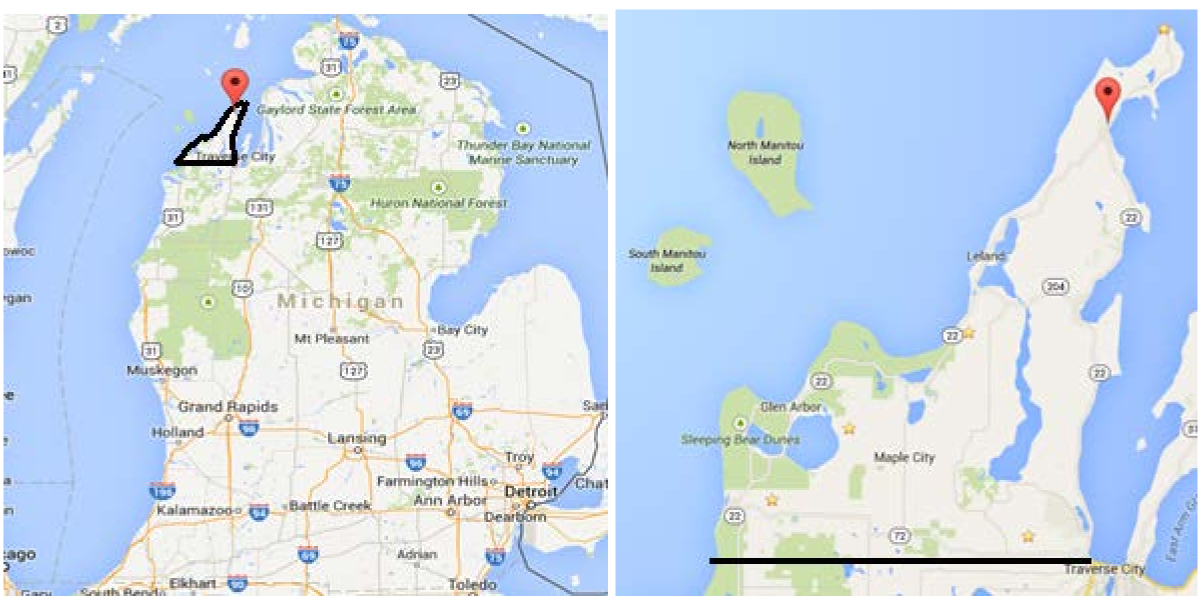


Figure 5. Location of the Village of Northport

The region is famous for its cherry industry, which began in 1853 and is still prevalent today. Northport is a popular tourist destination during summer along with other towns in Northern Michigan such as Traverse City, Elk Rapids and Harbor Springs, among others.

The area already has a number of renewable projects installed. Leelanau Community Energy (Leelanau Community Energy LLC.), a for-profit organization that was founded to fund, build, and operate wind energy systems in Michigan, completed the state's first community wind project — a 120 kW wind turbine that went online in November 2012 — and provides the energy for the Northport/Leelanau Township wastewater treatment plant. Northport is also home to the first 100% solar-powered golf course in Michigan. Additionally, several residents have photovoltaic solar panels installed on their homes, farms and businesses.

Electric Utilities

Even though participation of local utilities in achieving the renewable energy goal was outside the scope of our project, it is important to acknowledge that their future response to NEAT's renewable energy goals could either boost or stall the implementation and eventual completion of the plan. There are two utilities that serve Leelanau Township:

- Cherryland Electric Cooperative: A rural cooperative comprised of about 33,000 members that provides electricity services to six counties in the state of Michigan: Leelanau, Grand Traverse, Benzie, Kalkaska, Wexford, and Manistee (Cherryland Electric Cooperative, 2015). Cherryland serves some of the more rural areas in Leelanau Township.

- Consumers Energy: An investor-owned utility and one of the largest utilities in the nation, it provides electric and natural gas services to nearly 6.6 million Michigan residents (Consumers Energy, 2015). Consumers Energy serves most of the population in Leelanau Township, including the village of Northport.

Project Objectives & Methodology

The project was designed to encompass technical as well as social research, recognizing that a successful community-based plan requires broad support of implementable solutions. Our study consists of three broad areas: (1) Understanding residents' perceptions of renewable energy and interest in a renewable energy plan; (2) analyzing the amount of sun and wind that can be harnessed by renewable energy systems and potential sites for them, and (3) developing scenarios for attainment of the 100% renewable energy goal.

We conducted a household survey to provide a statistically-valid basis for our conclusions and to assist NEAT with future efforts. In addition to gathering information about residents' environmental views, the survey questionnaire included questions about awareness of NEAT as well as efforts they have undertaken, plus demographics and characteristics about respondents' homes.

Evaluating the potential for the sun and wind to be harnessed by renewable energy systems was a follow-up step to the survey. Michigan is not known for high levels of solar radiation, meaning that the right combination of system components and siting – along with financing and incentives that were evaluated later – are needed to make PV solar projects financially viable. The situation for wind power is similar, though with different challenges and constraints with regard to siting.

While NEAT has articulated a goal of 100% renewable energy of all types, this project only considered electricity delivered over the grid due to time and resource constraints. We evaluated the level of renewable electricity attainment based on annual generation compared with annual consumption. In other words, the electricity grid is assumed to provide electricity when renewable generation is lower than is being demanded by electricity users in the township, and to transport excess generation to other areas when the situation is reversed.

In the final phase, we integrated the information gathered and the results obtained from the previous phases to develop three scenarios to illustrate different schedules for transitioning to renewable-generated electricity. They included a base scenario considering middle-of-the-road assumptions, in which the 100% goal would be achieved in 20 years; a rapid renewable energy adoption scenario, assuming extended policy incentives and subsidies; and a stalled renewable energy adoption scenario, where future low fossil fuel prices would hinder the rate of adoption of renewables. These scenarios were intended to demonstrate alternative pathways to NEAT for a 100% renewable energy plan.

Survey

One of NEAT's main interests was to make community engagement an essential part of the study. A plan created without it would be unlikely to have broad support or become part of the community's identity. The first major effort of the project was to design a household survey, with the goal of better understanding the community's general attitudes toward renewable energy and the potential implementation of a community renewable energy plan. Additionally, we wanted to gather information about heating sources in residences to provide input to the energy efficiency portion of the project. Survey responses and analysis were later used to define several assumptions and variables for the development of 100% renewable energy scenarios. In the following sections more detail about the design of the survey is provided.

Questionnaire

The survey questionnaire was designed as a four-page booklet on one tabloid sheet. The intent was to balance survey length with content, while preserving readability. The questionnaire was mailed with a one-page cover letter, a half-page insert that provided contact information for NEAT and a postage-paid return envelope (cf. Appendix I.). The cover letter also provided an option to take the survey online.

Methodology

The survey was implemented using a modified version of the Dillman Total Design Method (Babbie & Dillman, 1982). In order to achieve a higher response rate, the Dillman method uses an advance notification mailing, plus multiple follow-up mailings to encourage recipients to respond to the survey. To keep costs manageable, we scaled back the number of mailings to one before and one after the survey questionnaire itself. The mailings were sent about two weeks apart in an attempt to keep the survey fresh in recipients' minds without being intrusive. Once the survey method was defined, the following timeline was established for the different activities related to the survey. The next section describes the survey process in more detail.

Survey Timeline

- Notification letter mailed August 1, 2014
- Survey questionnaire mailed August 13, 2014
- Reminder postcard mailed August 28, 2014
- Survey responses accepted until September 30, 2014

Distribution

The modest population of Northport and Leelanau Township made it feasible to distribute the questionnaire to all households by postal mail. While the cost of postage and printing was considerably more than web-only distribution, two primary factors influenced this decision: (1) finding postal mail addresses was much more straightforward than e-mail addresses, and (2) we assumed that the retiree population would be more likely to respond to a paper survey than one in an electronic format.

An address database of property owners, used for tax purposes, from Leelanau Township was used a starting point. We filtered addresses to remove suspected businesses, since our survey was designed for households. We also limited mailing to U.S. addresses, which excluded a handful of entries. The address database provided by the Township contained very few address errors. Of the 2,012 mailings, 21 were returned as undeliverable.

The survey questionnaires were mailed to property owners in Leelanau Township, which covered most of the population since over 90 percent of the occupied housing units were owner-occupied according to the 2013 American Community Survey (ACS) data (U.S. Census Bureau, 2013). We received a total of 668 questionnaires, including both paper copies and web submissions, resulting in a response rate of approximately 33% (among deliverable surveys).

Survey Content

The questionnaire consisted of 65 questions divided into ten categories, which are further described below. Many of these questions used a 5-point Likert rating scale where 1 indicated low endorsement or strong disagreement with the item and 5 indicated high endorsement or strong agreement with the item.

Community identity

Northport is a small community and the last town while traveling north on the Leelanau Peninsula. We wanted to understand how strongly residents identify with their community, and what community attributes would be important to them in the future, ranging from natural and scenic beauty to economic growth to affordable housing. Recipients were asked to select three attributes from among 12 options, including a write-in "other" option. The attributes question was intended to gather information about the compatibility of residents' wishes for the future of Leelanau Townships and locally-installed renewable energy systems. For example, being a tourist destination could be mutually reinforcing with a community identity that includes local renewable energy. Or, the opposite could be true if a high value is placed historic preservation and renewable energy systems would be broadly visible.

In addition, three statements on a Likert scale were used to gauge community identity. These statements were intended to inform the level of engagement that might be tapped for creation of a community renewable energy plan.

Environmental attitudes

This section consisted of 16 statements on a Likert scale from 1 = *strongly disagree* to 5 = *strongly agree*. These statements were intended to assess the respondents' general views on environmental topics, as well as more specific positions on personal vs. institutional responsibility for addressing environmental problems:

- Economic growth vs. energy problems
- Personal habits regarding energy conservation
- Concern about energy costs
- Motivation for reducing energy use: money vs. environment
- Responsibility for taking environmental action at personal, household, community, state and national levels
- Interest in using renewably-generated electricity

Energy efficiency practices

These statements asked respondents to rate how likely they would be to try six different energy efficiency actions on a scale from 1 = *not at all* to 5 = *already doing*. Behaviors included lowering the thermostat to 68°F in winter, installing a programmable thermostat, installing high-efficiency lighting, sealing heating and cooling ducts, and two items about upgrading to efficient appliances.

Attitudes regarding wind turbines

Respondents were asked to what extent they agreed or disagreed with eight statements about wind turbines. These included potential negative aspects of wind turbines such as noise disturbances, danger to wildlife, and unreliability, as well as positive attributes like increasing property values, providing a safe source of energy, and allowing multiple land uses.

Attitudes regarding PV solar panels

As with the previous section, we sought to know how respondents felt about solar panels. The statements were thematically similar to the ones used for the previous section. Negative aspects included high upfront costs and unreliability, while positive comments included climate change mitigation and protection against rising energy prices.

Awareness of existing renewable energy projects in Leelanau Township

This section asked whether respondents were aware of the existing wind turbine at the wastewater treatment plant, and if so, what their opinion was of it. There was also an open-ended question that asked whether respondents were aware of other renewable energy projects in the Township. These were intended to gauge awareness of existing renewable energy installations in the community. We also wanted to provide NEAT with representative feedback about the wind turbine that their organization installed.

Attitude regarding NEAT

After a brief summary of what NEAT is, a series of questions asked respondents how familiar they were with the organization and their opinion of it. This was intended to evaluate how successful NEAT has been in reaching out to the community and how they are viewed. To provide feedback to NEAT about their marketing efforts, the final question asked whether respondents attended either of two community events that were held in July 2014.

Support for a renewable energy plan

To gauge whether respondents would be open to the idea of a community plan to achieve 100% renewable energy, we presented a paragraph that outlined NEAT's 100% renewable energy goal, followed by a question regarding the respondent's support level, ranging from "very opposed" to "very supportive." Next was an open-ended question asking why the respondent felt that way. Finally, five related statements were presented about the plan that used a Likert scale from 1 = *strongly disagree* to 5 = *strongly agree*. They included statements about interest in solar panels for the respondent's house, whether Michigan gets enough sun to make solar panels worthwhile and whether the responded would be willing to participate in the development of a 100% renewable energy plan.

Home heating and water heating sources

Three questions covered home heating fuels, hot water heater type and renewable energy technologies installed at the home. This section was designed for evaluating the energy efficiency potential in the community as well as estimating the prevalence of existing renewable energy systems. These responses may be useful for NEAT's future efforts to transition other energy types to renewable sources.

Demographics

The final section of the survey covered standard demographic questions including gender, age, employment status, business ownership, household size, and dwelling type. We also asked how long respondents have lived in the Township, how much time they spend there annually and whether they expect to live there a decade from now. These questions were important given that the implementation of the renewable energy plan would likely require a decade or more. Understanding residents' time horizons can help in creating a renewable energy plan with provisions that match their goals and interests. The final question was open-ended, asking for any additional comments.

Results

Key survey results and analyses are described below. The complete survey, with responses broken out by percentage, is available in Appendix I.

Sample

Of all the respondents, excluding those who chose not to answer, the survey showed that slightly less than half (47%) of them were female. In contrast, the most recent American Community Survey (ACS) data estimated that 52% of the Township population is female. In terms of education, our sample appeared to be more highly educated than the population of Leelanau Township, with 79% of survey respondents having a four-year college degree or higher compared to 54% of the township population (U.S. Census Bureau, 2013). Educational levels are shown in more detail in Figure 6. More than half of the respondents were retired (57%), while 40% worked full-time or part-time. These results were fairly consistent with the ACS data that 52% of the population in Leelanau Township was not in labor force (U.S. Census Bureau, 2013).

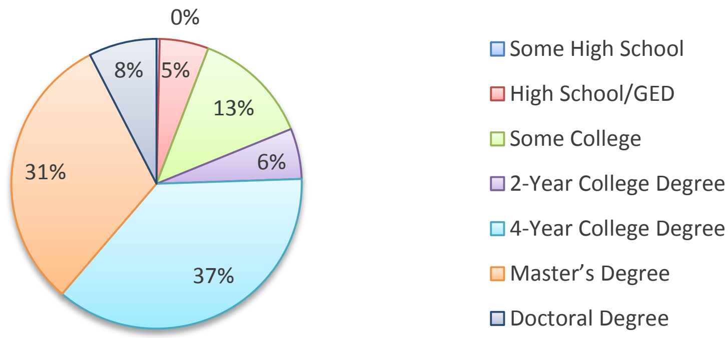


Figure 6. Education level of survey respondents

Housing Characteristics

Respondents' housing types are also fairly representative of the housing types in Leelanau Township. The survey indicated that the vast majority of respondents (90%) lived in single-family houses, while the ACS data estimates that 96% of the total housing units are one-unit detached houses (U.S. Census Bureau, 2013). Meanwhile, up to 51% of the respondents reported being seasonal residents, meaning that they might get reduced benefits from installing renewable energy systems. This will be discussed further in the Regression Analysis section.

For space heating, 44% of the respondents reported using propane, making it the primary heating fuel. About 23% heat their houses using wood, 21% use natural gas, and 25% have heat pumps. Some homes have multiple heating methods, so heating types will not total to 100%. As for water heaters energy source, electric was most common at 62%, followed by propane (20%) and natural gas (14%). Detail heating and water heater types are shown in Figure 7.

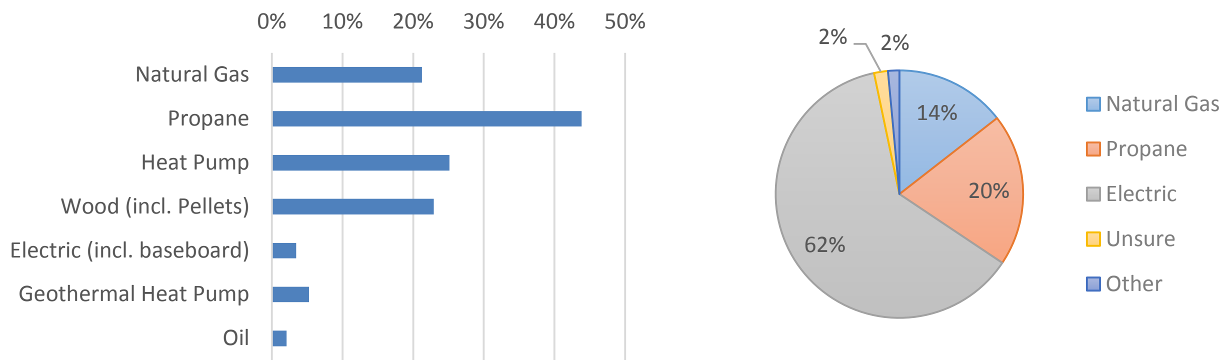


Figure 7. Household heating systems (left) and water heater (right). Note that individual house could have multiple heating systems installed.

Energy Efficiency Practices

It is worth mentioning that over half of the respondents indicated that they have already taken some action with energy-efficiency measures, such as installing efficient light bulbs, purchasing efficient appliances, or sealing heating/cooling ducts to reduce energy use. If we include those who would try these actions in the future, there would be over 80% positive responses to the questions about improving energy efficiency. While energy conservation is fairly common in Leelanau Township, only 4% of the respondents have solar or wind power installed at their homes.

Attributes of Leelanau Township

Understanding how residents thought about their community could help NEAT make the community renewable energy project more favorable to the community. When the respondents were asked to select the three most important attributes that they would like Leelanau Township to have 15 years from now, "Natural and Scenic" (74%), "Environmentally Healthy" (57%) and "Small Town" (34%) were the three most commonly selected. "Natural and Scenic" being the most important attribute suggests that the wind turbines proposed in the project should be carefully sited so that the view shed impact would be minimized. Moreover, environmental benefits from the renewable energy projects should be emphasized when promoting them to appeal to the "Environmentally Healthy" attribute. We also observed a high degree of identification with the local community among most respondents. It is possible that they would possess non-negative views on the Northport community energy plan since a township supported entirely by renewable energy is definitely an admirable achievement, which makes the residents proud to be members of the community.

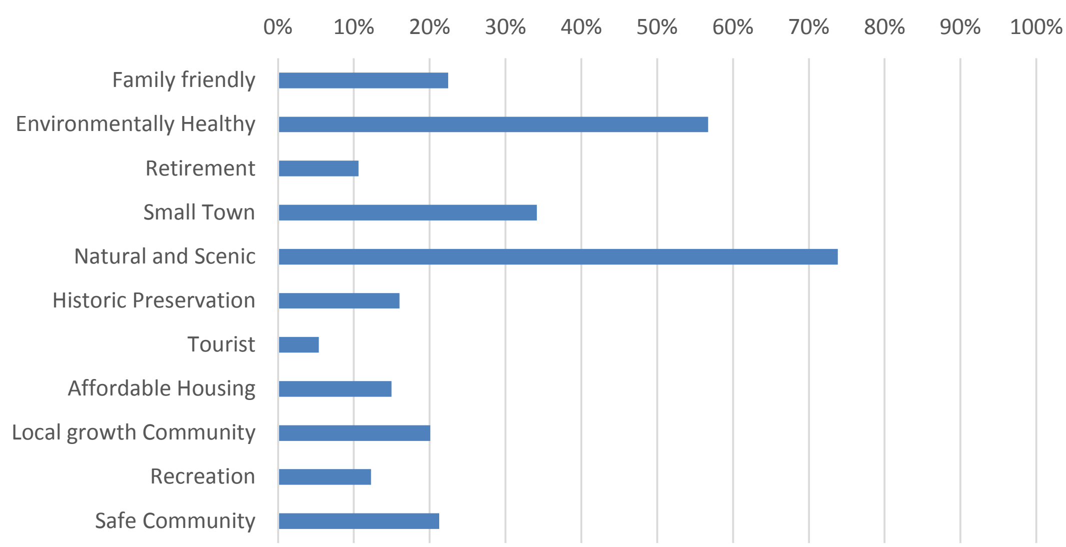


Figure 8. Frequencies of attributes that are selected by the respondents as three most important attributes of the Leelanau Peninsula 15 years from now.

Local Perspectives of Wind and Solar Photovoltaic Power

Respondents' opinions toward wind turbines and solar PV panels were mixed. Over 50% of respondents agreed that wind turbines are a good way to mitigate climate change, and around 60% thought similarly about solar panels. On the other hand, roughly one-third (35%) of respondents still felt doubtful about the reliability of solar and wind energy. The proportion that agreed that wind turbines are dangerous to wildlife is about the same as the proportion who disagreed it. Similarly, respondents were split on whether solar panels are unattractive. Furthermore, while respondents thought that PV solar provides insurance against rising electricity prices, they also believed that they are expensive to purchase and install. As for the existing renewable energy projects, about three-quarters of respondents were aware of the wind turbine at the wastewater treatment plant, and 61% among them held a favorable opinion of it. As mentioned earlier, this gives a sense of the level of awareness in the community about existing renewable energy systems in the region.

Despite the diversity of responses toward wind and solar power, the overall opinion about the proposed Northport community renewable energy plan was mainly positive. When respondents were asked how supportive they would be of a plan to achieve 100% renewable energy in Leelanau Township, about 71% indicated that they were somewhat to very supportive. In terms of project participation, around 40% respondents showed willingness to participate in renewable energy project development. A slightly larger proportion (48%) showed interest in learning whether their homes are suitable for solar panels.

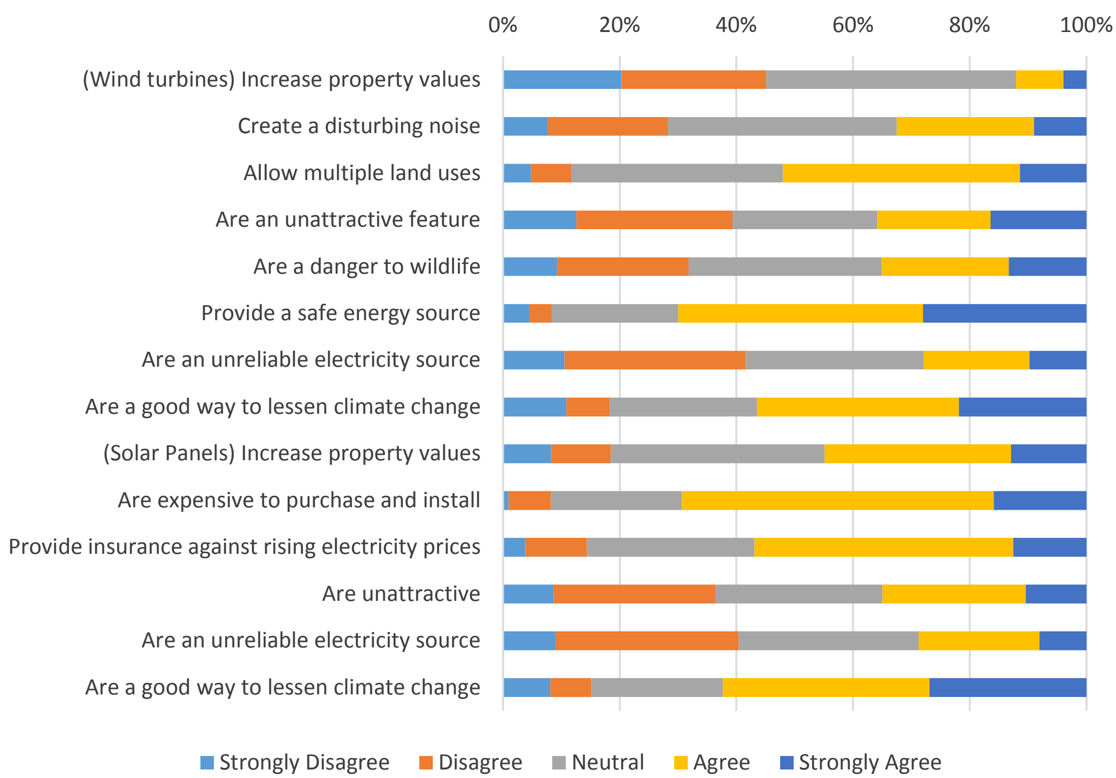


Figure 9. Respondents' thoughts on wind turbines and solar PV panels.

Factor analysis

Originally introduced in psychological studies, factor analysis is a statistical technique to categorize variables into groups, so that the complexity of data can be reduced. We used this method to determine the underlying dimensions of respondents' perspectives on environmental and energy issues (cf. Question 3 in Appendix I.). In general, factor analysis looks at the correlations among the answers to each individual question to reveal how they are related to each other. The result is a set of derived groupings or "factors" that give us insight into how people think about these issues. Our factor analysis on the environmental attitude questions yielded three factors:

- Support renewable energy development and fossil fuel phasing out
- Concerns about energy costs
- Norms around energy conservation and environmental impact reduction.

This three-factor solution explained about 71% of the total variance among views on environmental and energy issues. Table 1 lists the three-factor solution with descriptive statistics of each factor.

The first factor consisted of eight questions, which are mainly related to phasing out conventional fossil fuels, and supporting renewable energy development. The mean value of all variables in the first factor is 4.00, with standard deviation 1.26. Namely, the average response for questions in this factor is "Agree". Note that the question about the threat of environmental problems and whether the current life style is wasteful of resources are also belongs to this factor, meaning that survey respondents think of it together with energy transformation. It might suggests that the threat of environmental issues are fairly attributed to fossil fuel usage, and respondents interpreted "resources" as non-renewable energy sources.

The second and third factors reflect concerns about energy costs and norms about reducing environmental impacts, with mean values 3.88 and 4.12, respectively. The average answers to these two factors are also around "Agree". The third factor also indicates that the respondents regard environmental impact and energy usage in a single category. In other words, the respondents might have recognized that energy conservation is one of the approaches to reduce environmental burdens from modern civilization.

Support for the Community Renewable Energy Plan

In Question 12 of the survey questionnaire, respondents were asked how supportive they would be for a plan to achieve 100% renewable energy, and in Question 14-1, they were asked their willingness to participate in the development of the community renewable energy plan (cf. Appendix I.). The survey results show that overall, the Northport community renewable energy plan received firm support from the respondents, and may have fair amount of participants. Mean value of the responses of Question 12 is slightly below "Agree" (mean = 3.78, standard deviation =1.35), while the average answer to Question 14-1 is just above "Neutral" (mean = 3.18, standard deviation = 1.07). Understanding which sub-groups of residents are more or less supportive of the plan could help NEAT better target its outreach efforts. We used multiple linear regression to investigate the relationships between a respondent's attitude toward the renewable energy plan and socio-demographic status. The models focused on two dependent variables: (1) support for a plan to achieve 100% renewable energy and (2) willingness to participate in the

Table 1. Factor loadings for environmental and energy issues

	Factor		
	1	2	3
Factor 1. Support renewable energy development and fossil fuel phasing out			
The U.S. needs to put more effort into developing renewable energy sources (e.g. solar, wind)	0.93		
The threat of environmental problems has been greatly exaggerated‡	−0.83		
If we continue our high levels of fossil fuel use, future generations will not enjoy the same standard of living as ours	0.82		
We should reduce fossil fuel use in the U.S. to help preserve our natural environment	0.81		
Electric utilities should promote renewable energy programs in MI	0.80		
My local government should facilitate the development of renewable energy projects in my area	0.69		
I am interested in getting at least some of my electric power from renewable energy sources	0.68		
Our present way of life is much too wasteful of resources	0.66		
Factor 2. Concerns about energy costs			
I would do more to reduce my energy consumption if I knew it would save me money		0.67	
I'm concerned about rising energy costs		0.58	
Factor 3. Norms around energy conservation and environmental impact reduction			
I feel a personal obligation to reduce my impact on the environment			0.86
Our community needs to do its share in reducing energy use			0.66
Energy conservation is part of my daily routine			0.66
Households should do what they can to reduce their carbon dioxide (CO_2) emissions			0.60
% Explained variance	54.58%	9.96%	6.31%
Cronbach's alpha	.96	.54	.87
Mean†	4.00	3.88	4.12
SD	1.26	.89	.86

† 1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly agree
‡ The answers to this question is deducted from 6 to reverse the negative orientation.

development of the plan. In each model we regressed the dependent variable on

- Education level
- Business ownership
- Retirement status
- Gender
- Amount of time spent in the township each year
- Length of residency in the township
- Expectation to live in the township ten years from now.

The results may provide NEAT information to identify community residents who may be less supportive or interested in the project. Future outreach events could be designed to address the concerns of these groups.

Respondents' support for 100% renewable energy

The regression model indicated that respondents have similar levels of support regardless of whether they expect to live in Northport/Leelanau in the future, their education level, or whether they own a business. Similarly, the length of time that respondents spend living in town each year does not affect their support. In other words, part-time residents showed similar support as full-time residents did. The results showed that female respondents tended to be more supportive of the plan, as did respondents who are relatively new residents. Retired respondents tended to be less supportive. These results show that statistically, demographics are not a major factor in whether respondents support the plan or not.

When the factors of the respondents' attitude toward environmental and energy issues (Question 3) are also selected as predictors, the data fits the new model considerably well, where R^2 significantly increases (cf. Table 3.). In other words, more variation in the support for 100% renewable energy is explained by the predictors. Gender is no longer significant, indicating that other predictors outweighed its influence. The retirement status remains a marginally significant negative predictor. The new model suggests that the more a respondent supports development of renewable energy (in general), phasing out fossil fuels, and energy conservation, the more likely he or she would support the 100% renewable energy plan. No significant relationship was found between concerns about energy costs and support for the plan.

The willingness to participate in the community energy plan development

A similar analysis revealed that respondents' demographics had little influence on their willingness to participate in developing the plan. Respondents who had lived in Leelanau Township longer showed less interest in participation. Likewise, respondents who were more likely to live in Leelanau Township in the next ten years were also less inclined to participate in the development phase of the project. Meanwhile, retirement status had a marginally significant negative effect ($b = -.19, p = .06$), indicating that retirees were less willing to participate in the plan's development than non-retirees (cf. Table 4.).

Similarly, we create a new linear regression model by taking attitudes toward environmental and energy issues into consideration, as shown in Table 5. These predictors accounted for more variation in the dependent variable ($R^2 = .39$). We observe that the more a respondent has favorable attitudes toward renewable energy in general and energy conservation, the more like he/she would be willing to be a participant in the renewable project development. In addition, intention to live in the township 10 years from now and length of residency in the township remain significant with negative slopes. An interesting fact is that gender becomes significant in this new model. Male respondents show less inclination to participate in the community energy project development than female respondents do.

Discussion

Regression analysis reveals that respondents' socio-demographic characteristics have no significant effect on their attitudes toward a plan aiming 100% renewable energy, except gender and retirement status. The survey suggested that people believed solar energy may be expensive. Due to fixed income, retirees may therefore be less supportive to the project. Respondents who have lived in Leelanau Township longer not only showed less support for the plan but also showed less interest in participating.

By taking the attitude toward environmental and energy issues into consideration, we find that respondents concern about the development of renewable energy and the environmental impact caused by conventional energy may affect their support and involvement of the community renewable energy plan. In contrast, their socio-demographic characteristics play minor roles. Respondents who have lived in town longer still express less willingness in participating, but their support to the plan becomes similar to newer residents. It is worth noticing that the concern about energy costs is insignificant in these two models, which might be a sign that respondents still consider renewable energy as an expensive solution. Based on the results, we would suggest that NEAT should focus on the environmental benefit, and the replacement of fossil energy brought by this renewable energy plan, as well as the economic feasibility when outreaching or promote this community energy plan.

Table 2. Predictors of support to achieve 100% renewable energy goal

	Estimate slope (b)	Std. Error	t value	p value
(Intercept)	4.37	0.49	9.00	< .001
Anticipate living in the township 10 years from now	−0.04	0.07	−0.53	0.60
Education level	0.02	0.04	0.62	0.54
Business ownership	−0.21	0.18	−1.17	0.24
Months spent in Northport each year	−0.02	0.06	−0.39	0.70
Retired*	−0.26	0.13	−2.06	0.04
Gender‡	0.52	0.11	4.59	< .001
Length of residency in the township	−0.01	0.00	−3.66	< .001

$R^2 = .07$
‡ With *Male* as reference group
Variables in bold indicate significant with 95% confident interval

Table 3. Multiple regression model for respondents' interest in participating in the development of the community energy project.

	Estimate slope (b)	Std. Error	t value	p value
(Intercept)	3.93	0.40	9.92	< .001
Anticipate living in the township 10 years from now	−0.14	0.06	−2.27	.02
Education level	0.03	0.03	1.01	.32
Business ownership	−0.15	0.14	−1.05	.29
Months spent in Northport each year	−0.01	0.05	−0.28	.78
Retired	−0.19	0.10	−1.92	.06
Gender‡	0.10	0.09	1.05	.30
Length of residency in the township	−0.01	0.00	−4.44	< .001

$R^2 = .06$
‡ With *Male* as reference group
Variables in bold indicate significant with 95% confident interval

Table 4. Multiple regression model of support for 100% renewable energy plan with additional predictors of factors in the view on environmental and energy issues

	Estimate slope (b)	Std. Error	t value	p value
(Intercept)	−0.11	0.38	−0.30	.76
Anticipate living in the township 10 years from now	0.00	0.04	−0.05	.96
Education level	0.00	0.02	−0.15	.88
Business ownership	−0.08	0.11	−0.78	.44
Months spent in Northport each year	0.01	0.03	0.19	.85
Retired	−0.14	0.08	−1.83	.07
Gender‡	0.02	0.07	0.25	.80
Length of residency in the township	0.00	0.00	−1.07	.29
Support renewable energy development and phasing out fossil fuels	0.75	0.03	22.83	.00
Concerns about energy costs	0.02	0.04	0.45	.65
Norms around energy conservation and environmental impact reduction	0.27	0.05	5.51	.00

$R^2 = .67$
‡With *Male* as reference group
Variables in bold indicate significant with 95% confident interval

Table 5. Multiple regression model for the respondents' interest in participate in the development of the community energy project with additional predictors of factors in the view on environmental and energy issues

	Estimate slope (b)	Std. Error	t value	p value
(Intercept)	1.14	0.41	2.74	0.01
Anticipate living in the township 10 years from now	−0.11	0.05	−2.17	0.03
Education level	0.01	0.03	0.58	0.57
Business ownership	−0.09	0.12	−0.80	0.42
Months spent in Northport each year	0.01	0.04	0.33	0.74
Retired	−0.12	0.08	−1.47	0.14
Gender‡	−0.19	0.08	−2.50	0.01
Length of residency in the township	−0.01	0.00	−2.99	0.00
Support renewable energy development and fossil fuel phasing out	0.45	0.04	12.53	0.00
Concerns about energy costs	0.07	0.05	1.44	0.15
Norms around energy conservation and environmental impact reduction	0.14	0.05	2.57	0.01

$R^2 = .39$
‡With *Male* as reference group
Variables in bold indicate significant with 95% confident interval

Participant Comments

In Question 13 of the survey, respondents were asked to explain why they would or would not be supportive of a plan to achieve 100% renewable energy. This open-ended question received 454 recognizable responses. After reading these comments, we categorized them into eleven primary themes:

- More info desired ($N = 55$)
- Supports in principle ($N = 174$)
- Too expensive ($N = 57$)
- Government overreach ($N = 9$)
- Environmental preservation ($N = 29$)
- Community pride ($N = 11$)
- Inadequate solar resource in the township ($N = 10$)
- Appearance of renewable energy projects ($N = 29$)
- Intermittency of renewable energy ($N = 8$)
- Unrealistic goal ($N = 46$)
- Miscellaneous ($N = 26$)

Many comments showed firm support for increasing renewable energy in the community:

> *"In 2010 I traveled in Germany. It seemed every house, barn, outbuilding are solar why are we so far behind?"*

> *"The greatest source of renewable is wind. There should be an opportunity to harness this valuable resource."*

> *"It is important for communities to find ways to increase renewable energy sources"*

> *"Because I am an idealist, and I believe it can be done. If achieved, we would all be proud."*

> *"It is the right move. We've become a 'throw-away society' or a global scale. They build thing, now so you can't fixed them, instead you buy a new one. Why not make total use of 'throw-away' into renewable energy"*

> *"We cannot wait. Killing ourselves and destroying our world with fossil fuel use -this is the right thing to do for ourselves and future generations."*

> *"Renewable energy is the way of the future it has the potential to save money and spur economic growth"*

> *"The US population is like an energy alcoholic. Recovery require that we stop drinking (wasting energy) and then work the steps of recovery (alternative)."*

Several comments are supportive, but suggests that 100% renewable energy might not be realistic:

> *"I suggest a goal of 25% renewable energy."*

> *"I don't think we could ever achieve 100%, but any & and all steps are import to save the environment"*

> *"Not very likely, but is a good goal!"*

Part of the respondents would like to have more detail, such as project agenda or costs:

> *"I don't know enough of the plan details to be more supportive."*

> *"Need more information on wind and solar energy costs."*

> *"I'm generally favorable to energy conservation and the use of renewable energy technologies whenever they make sense. I would need to understand at least the*

general outline of a 100% renewable energy plan for Northport/Leelanau Township before I could be "very supportive".”

“I don't know enough about the cost for the local residents.”

“Need more information on what is being proposed.”

Environmental burdens from using traditional energy is also mentioned in some comments:

“We have to reduce our carbon footprint for future generations.”

“We have very serious environmental problems and we love that a group in our community is tackling this issue!”

“I believe we are doing great damage to our environments and to the wildlife that shares these environments with us. We are polluting our waters and overdeveloping our land. Not to mention this new fracking craze, which I feel is highly invasive and wildly unregulated.”

However, some respondents were concerned about the downsides of renewable energy projects, such as costs, the impact to the view shed caused by wind turbines and solar panels. Furthermore, the intermittency issue of solar and wind power, as well as the demand for base load electricity are addressed.

“Would love to help, but it may be too costly for us to participate.”

“It is counterproductive and expensive. The object should be most economical for business and family”

“I would not want my property taxes to increase if I did not participate in solar panels.”

“Wind turbines can take away from the natural beauty of the county if not managed properly.”

“Leelanau Peninsula is a beautiful place. I do not want to see wind turbines dotting the landscape”

“Biggest issue is turbines - I think they ruin the landscape and are loud, threaten wildlife.”

“Most residents are retired, elderly people who would not be supportive of the sight of solar panels or turbines in the Township because they would rather see the natural beauty of the area instead of a view obstructed by panels or turbines.”

“This is totally unrealistic. Solar & wind power is intermittent and there is no current method of storage or long distance transmission of electricity available.”

“Renewable energy can be fickle. Base load capacity is important. At present, base load capacity is best met by traditional means.”

“Renewable energy (wind and solar) is expensive and intermittent. Wind and solar require idling base load power plants or combustion turbines on standby to provide power when the wind drops off. So there is much less reduction in greenhouse gases than people assume. Investment in fossil fuel power plants is still required to provide power when there is no wind or when the sun is not shining, like at night, when it’s cloudy, and when the sun is low in the sky. I am all for individuals putting up wind turbines and solar panels for their own use and back feeding to the utility--they either know the extra costs they are going to pay or are about to find out. I object to forcing utilities to install renewable energy sources, because I will end up paying significantly more for power with little benefit to the environment.”

A few respondents thought that the solar insolation in the township is not sufficient to supply the entire electricity demand:

“Takes years to be economical. This is not FL or CA where it makes more sense. Take advantage of our natural gas. Open Keystone Pipeline. Frack. Drill.”

“I'm skeptical of solar energy because we are socked in clouds all winter.”

“This place we do not have enough sunny days for solar to be effective, wind energy will be more effective.”

From the comments made by respondents, we observed that there are concerns about the disadvantages of renewable energy, the economic feasibility of the 100% goal, and the aesthetic issues of wind turbines even though the overall rate of support to the plan is over 70%. As renewable energy technologies, especially wind and solar photovoltaic power, have significantly improved and dropped in price, NEAT may want to tackle perception problems with the viability of PV solar in Michigan through marketing and education.

Leelanau Township Electricity Demand

Utilities play an important role helping Michigan to meet both its current and future energy needs. As key providers of energy, utilities are in a unique position to expand energy access in a sustainable way by engaging in actions that would increase business value, and contribute to a sustainable future by improving social, environmental and economic benefits for their customers. The utilities serving Leelanau Township are Cherryland Electric Cooperative and Consumers Energy. Cherryland is a rural electric co-op that serves several counties in Michigan, including Leelanau County, while Consumers is an investor-owned utility that serves the more populated areas along the M-22 corridor, including Northport.

Consumers Energy along with the Michigan Public Service Commission (MPSC) launched the Clean Energy Plan in 2007 to meet the energy needs of customers for the next 15 years. Currently, the utility provides its customers with approximately 5% of the electricity coming from renewable sources with plans to increase this number to 10% by 2015 (Consumers Energy, 2015). A few years later, in 2013, Cherryland Electric Cooperative launched Solar Up North (SUN) Alliance, a community solar program that offered solar panels located at the community solar array. Now fully subscribed, customers could lease a 235-watt solar panel for $470 with a 25-year term (Cherryland Electric Cooperative, 2015).

Before determining the feasibility of a renewable energy plan, it was first necessary to establish a baseline for Township electricity demands. By quantifying the total amount of electricity consumed on a baseline year, it was possible to size the different systems so that the same amount of electricity would be generated throughout the year.

Electricity consumption data for Leelanau Township were provided by Consumers Energy and Cherryland Electric Cooperative. Appendix IV. contains the aggregated electricity consumption from residential and commercial and industrial buildings from May 2013 to April 2014. These datasets served as our reference for electricity consumption, which were multiplied by an annual escalation factor – depending on the scenario – to account for future growth in electricity demand.

The total annual electricity consumption for Leelanau Township was 22,600 MWh. **Figure 10** and **Figure 11** provide a more detailed breakdown of electricity use throughout the year in Leelanau Township and the share of both residential and commercial consumption:

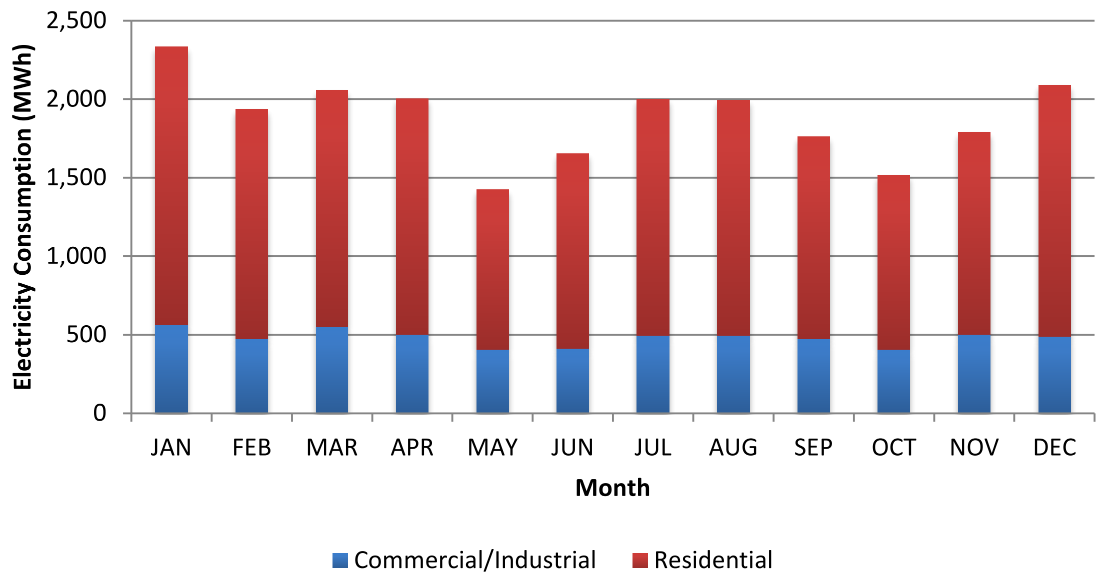


Figure 10. Monthly Electricity Consumption

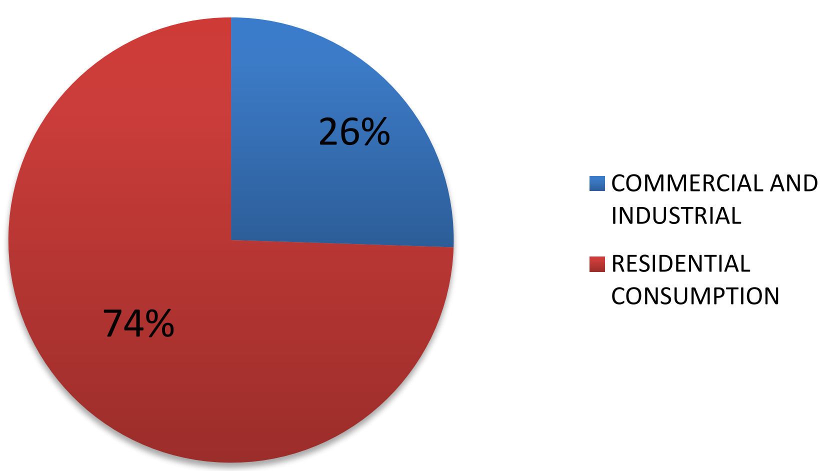


Figure 11. Share of Total Consumption by Sector

With this information, it is possible to conduct the renewable resource assessment to determine the wind and solar generation potential and estimate the number of systems that would be required to meet the total electricity demand.

Energy Efficiency

Energy efficiency and conservation are almost always the least expensive way to reduce fossil fuel use, and can complement renewable energy generation. Advances in lighting technology, appliance efficiency and electronic controls have enabled straightforward and economically viable energy-efficiency options, regardless of the electricity generation source. This analysis focused on residential energy efficiency because residential electricity use is about three-quarters of the total electricity in the township. In addition, residential customers may not be aware of the devices that use the most energy, or which ones could save them money if upgraded (Attari, DeKay, Davidson, & Bruine de Bruin, 2010). Enhancing the awareness of residential energy-efficiency strategies is an area where NEAT can help their community realize a reduction in fossil-based energy in the near term and on an ongoing basis. These changes are some of the cheapest ways to help make the community energy independent because they lower energy generation requirements. This section investigates the potential for energy-efficiency measures in Northport and Leelanau Township as they relate to residential electricity use.

There are a variety of ways that residents can reduce their household energy use that range from cost-free changes in behavior to expensive system and building envelope upgrades. This section focuses on inexpensive changes that are within reach of the average homeowner. We have identified changes and upgrades that have potential for a quick return on investment and are relevant to Leelanau Township. The areas that were analyzed in detail included savings from switching to high-efficiency lightbulbs and lowering the thermostat in colder months.

Lightbulbs

Lighting is a feature that is necessary in every home and is taken for granted, but there are potential savings available if high efficiency bulbs are used. Although incandescent bulbs are much cheaper than the more efficient types, they use four to ten times as much electricity of energy-efficient bulbs and have a much shorter lifespan. The annual electricity use for lighting was estimated by using Leelanau Township residential usage in conjunction with national statistics (How much electricity is used for lighting in the United States?, n.d.). We also took into account the percentage of households who indicated on the community survey that they had already purchased and installed energy-efficient light bulbs. Lighting estimates using baseline data for the Township can be seen in **Table 6** and **Table 7** below.

Table 6. Township Electricity Use

Annual residential electricity used	15,385,170	kWh
Annual Township Lighting	658,998	kWh
Hourly Township lighting	75	kW
Electricity cost	0.12	$/kWh

Table 7 Bulb Data

	Incandescent	LED	CFL
Lifetime (hours)	1,200	50,000	8,000
Watts/bulb	60	8	13
Cost/bulb ($), no rebate	$0.66	$9.97	$2.00
Rebate/bulb ($)	0	6	1

We developed an energy savings model for lighting based that was informed by our survey results. Sixty-seven percent of respondents had already purchased energy-efficient light bulbs, though we did not know the proportion of total bulbs that were energy efficient for a given residence. To account for this, we tested four combinations where the proportion of energy-efficient bulbs was 25%, 50%, 75%, or 100%.

In each scenario, changing to energy-efficient bulbs caused lighting-related electricity use to drop by 50%. Detailed results can be seen in Appendix II.

Thermostats

Next the savings from lowering the thermostat was examined. Only savings from lowering the thermostat during the winter were considered because of the cold climate, cooling needs are relatively minimal. One convenient way to reduce heating energy use is by installing a programmable thermostat that raises and lowers the temperature on a schedule. Although savings will occur no matter what method is used to heat the home for this analysis only those who use heat pumps will be examined since they require electricity. Using data from the Department of Energy, the savings from lowering the thermostat was found (Heating costs for most households are forecast to rise from last winter's level, n.d.). Then using the number of homes in Northport and the amount of people who already lower the thermostat from the survey results, 67%, the potential savings from lowering the temperature 1°, 2°, 3°, 4°, and 5° F was found. According to the EIA, the average annual heating bill is about $900 (Heating costs for most households are forecast to rise from last winter's level, n.d.). From the survey it was determined that about one quarter of the town uses a heat pump or electric resistance heat baseboards to heat their home.

The data for the Township is shown below in **Table 8** while the results are in **Table 9**. Overall, by lowering the thermostat by 5 degrees there can be a savings of between 5 and 10% for each household depending on various characteristics of the home (U.S. Department of Energy, n.d.).

Table 8. Basic Heating Data

Estimated homes occupied during the winter	930
Average annual electricity costs	$900
Savings/degree/8 hours	1% of energy bill
Average annual Electricity used by heating pumps	7500kwh

Table 9. Lowering the Thermostat

Amount lowered (ºF)	Annual Savings/household (kWh)	Annual Town Savings (kWh)
1	75	4359
2	150	8719
3	225	13078
4	300	17438
5	375	21797

However, these savings apply only to houses that are occupied in the winter. Based on data from our survey, we estimate that 1100 houses are unused during the winter, and most likely are fully winterized or heated minimally to prevent pipes from freezing. Those houses likely have little, if any, potential for energy savings. In addition, since a large portion of the community is retired, we assumed that a larger percentage of people would be at home for portions of the work week. Lowering the thermostat set point is likely less feasible for that group of residents.

Energy Star Appliances

Some energy-efficiency measures have significant upfront costs that require several years before the initial deposit is returned via savings. One such measure is to select Energy Star products when purchasing new appliances. From the survey we learned that about 70% of people are already selecting Energy Star appliances when they are purchasing new appliances. Large appliances, including refrigerators, washing machines and dishwashers that are at least 10 years old are good candidates for replacement because the energy savings should be recouped over the life of the appliance. For example, an 18 cubic foot refrigerator that is 10 years old likely uses 840 kWh annually while a new one of the same size will only use 490 kWh (U.S. Department of Energy, n.d.). This trend holds true for most large appliances because new technology has allowed new appliances to provide the same service while using less energy than their predecessors. Rebates may be available for Energy Star products. For example, Consumers

Energy provides them for clothes washers and refrigerators as well as one for recycling a secondary refrigerator (Molina, 2014). NEAT could educate the community about the rebates as part of their broader effort regarding energy efficiency.

Conclusions

Residents in Leelanau Township have indicated an awareness of energy-efficiency measures and conservation habits through the household survey. We encourage NEAT to continue to work with willing households on making straightforward upgrades with brief payback periods, such as lighting retrofits and programmable thermostats. While engaging with households on those items, other larger upgrades could be discussed, such as building envelope improvements and HVAC upgrades. Because the survey indicated that residents tend to be loyal to the area, they may be good candidates for energy-efficiency upgrades that have a longer payback period. However, the gains from energy-efficiency measures will likely be modest in the overall scheme of moving to 100% renewable energy, since more than two-thirds of residents have already taken steps in that area. Additionally, many houses are unoccupied for portions of the year, meaning in most cases that their energy use is minimal. The Energy Information Administration estimates that future rounds of appliance efficiency standards and building codes will trim 0.5% off annual residential electricity growth, as compared to stagnated standards and codes (U.S. Energy Information Administration, 2014). While energy efficiency alone may not substantially contribute to NEAT's goal, it can help to put energy use on a downward trend, relieving generation and distribution needs in the future.

Renewable Resource Analysis

Having established the annual electricity demand for the Township, this section starts by discussing the renewable resources to be analyzed and the estimation of the total available resource based on modeling tools and historical weather information. In this context, we refer to the resource availability as the energy that can be harnessed from natural sources such as the sun and the wind. Once the resource availability was determined, the next step was to estimate the number of renewable systems that are required to generate enough electricity to match the demand for the Township.

Wind Resource Assessment

In order to develop a wind power project, it is important to assess and characterize available wind resources at the sites under consideration. The quality of a wind resource is commonly classified by its spatial scale, speed and wind power density (WPD) (Brower, 2012)[4]. The National Renewable Energy Laboratory (NREL) classifies wind into classes based on the WPD at several heights, usually 50m, 80m and 100m. A larger WPD calculation leads to a higher class rating. These classes range from Class 1 (the lowest) to Class 7 (the highest). Class 3 winds (annual average speed of 14.3 to 15.7 mph at 50m) are generally the minimum needed for a commercially viable project[5]. Michigan has good and excellent onshore wind resource areas (classes 3-5) concentrated in a few exposed coastal areas and islands (U.S. Department of Energy, n.d.). For instance, **Figure 12.** Michigan – Annual Average Wind Speeds at 80m**Figure 12** shows the wind resource map for Michigan with the predicted mean annual wind speeds at an 80m height in Michigan with average wind speeds ranging from 7.0 m/s to 8.5 m/s in Leelanau Township.

This report primarily focuses on wind resources analysis at 80m wind turbine hub height, as an average value between other 'traditional' wind turbine hub heights: 50m and 100m.

Methodology

In order to perform wind resources assessment of the area of research, we reviewed available literature on previous works and methodology, collected available weather data, conducted a site visit and performed calculations of the wind resource potential.

Data Collection[6]

Since wind resource highly varies year to year, short-term (< 5 years) onsite measurements can result in highly inaccurate energy estimates. Therefore, wind speed data from nearby longer term weather stations are used to adjust the onsite data.

Thus, in order to assess wind resources in Leelanau Township, we obtained the following data:

[4] Calculation relating to the effective force of the wind at a particular location, frequently expressed in terms of the elevation above ground level over a period of time. It takes into account wind velocity and mass.
[5] U.S. DOE, NREL (2011) "Wind Data Details"
[6] It was not possible to obtain accurate wind data from the existing wind turbine at the waste water treatment plant for more than two years, so our analysis does not take that location into account.

- Historical wind data from the NOAA Lighthouse Station, GTLM4, owned and maintained by National Weather Service Central Region, which is located on the tip of Leelanau peninsula. The data represent 10-min records for the period of 2006 - 2014.
- NREL Eastern Wind Dataset with three years (2004-2006) of 10-minute wind speed data.

The Eastern Wind Dataset was created by AWS Truepower with oversight and assistance from NREL and includes plant output values for 1,326 simulated wind plants (National Renewable Energy Laboratory, n.d.). For further analysis of wind resources in Leelanau Township we chose the simulated[7] NREL plant #5579, which is located in closer proximity to the potential sites than other three stations also located in Leelanau (Figure 13) (National Renewable Energy Laboratory, n.d.). For weather station locations refer to Appendix V.

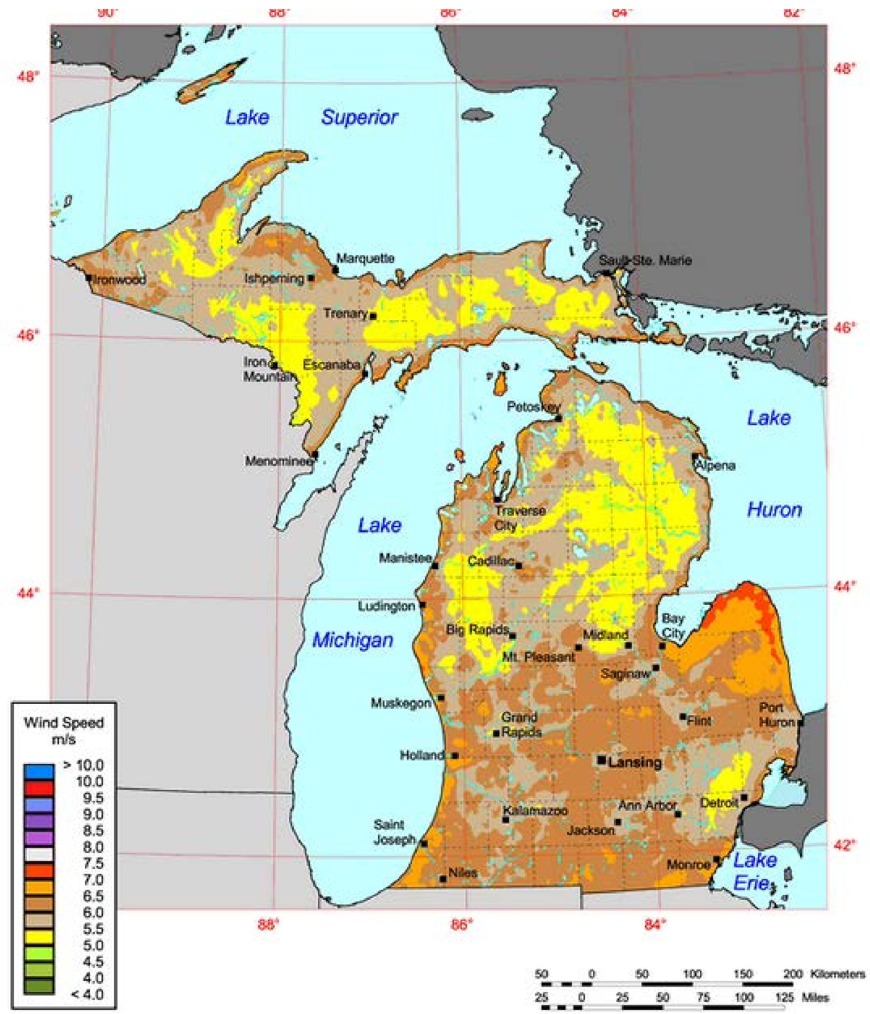


Figure 12. Michigan – Annual Average Wind Speeds at 80m

Source: Wind resource estimates developed by AWS Truewind LLC for windNavigator. Web: hhttp://navigator.awstruewind.com| www. Awstruewind.com. Spatial resolution of wind resource data: 2.5 km. Projection: UTM Zone 16 WGS84.

[7] Land-based sites composed of many nearby grid points that have similar wind characteristics.

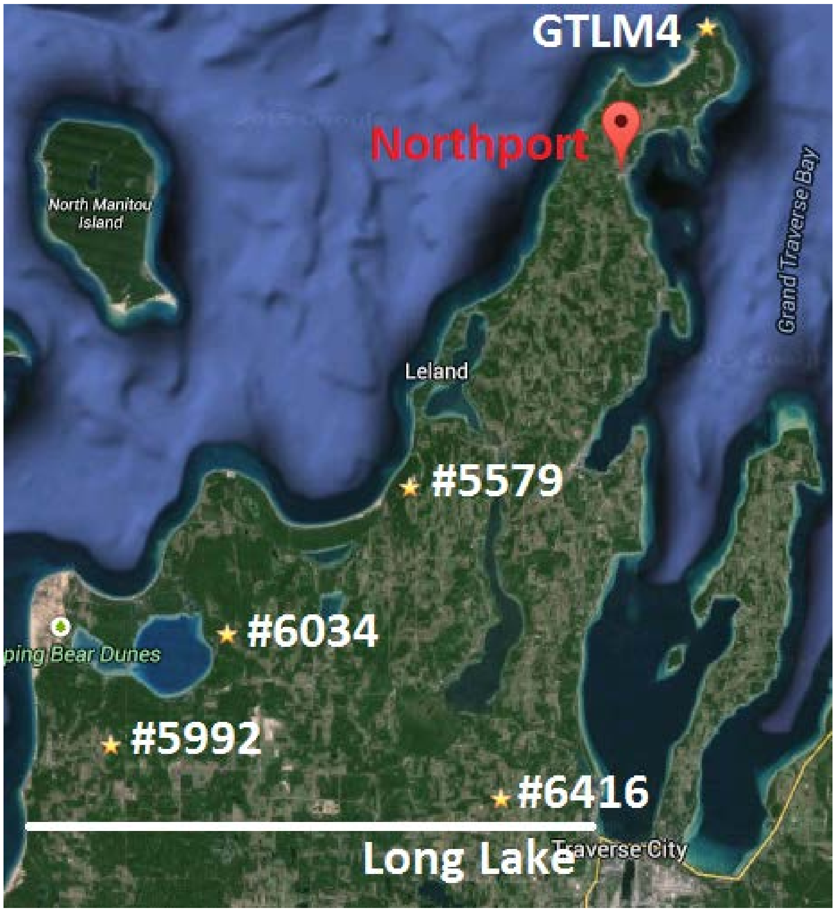


Figure 13. Location of the data sources, Leelanau Township

In addition, we referred to the Wind Resource Study of the Grand Traverse Region prepared by Tripod Wind Energy ApS Consulting Engineers to verify our results. The study evaluates wind resources from four different sites located around Traverse City: Grand Traverse (GT) Resort, Long Lake, Traverse City Airport and Pellston Airport. We correlated our results with Long Lake site, since it is closer to the potential sites in Leelanau Township (U.S. Department of Energy, 2008).

Power calculations

The wind energy resources for the simulated NREL station #5579 were calculated by use of the System Advisor Model (SAM) Version 2015.1.30, developed by the Natural Renewable Energy Laboratory (NREL). We considered Power Purchase Agreement[8] for a single owner (utility) option in the software in order to estimate the potential energy generation from available wind resources. We used the Eastern Wind Dataset as an input in the SAM to find the potential energy generation for each wind turbine for the period of 2007 to 2012. Once we determined the values for each year, we found the average wind speeds and generation.

[8] contract between two parties, one who generates electricity for the purpose (the seller) and one who is looking to purchase electricity (the buyer)

In order to find the potential energy generation from the GTLM4 wind data we used a slightly different approach: we calculated wind power density (WPD) for each turbine. First, we corrected air density for temperature at GTLM4 to make our assessment more accurate. Then, since wind speed increases with height, we calculated wind speeds at the height of the turbine hub for each of the turbines in our evaluation set in order to compute estimated power generation. The equation showing the relationship between wind speed and height is the wind shear equation:

$$v = v_0 \left(\frac{h}{h_0}\right)^a,$$

where v_0 is the speed at some reference height h_0, and v is the speed to be calculated at the desired height h. The wind shear exponent α reflects how the speed increases with height and depends on the surface roughness at the location. Given that the area of research represents a wooded countryside with complex terrain, we assumed wind shear to be 0.25 (Table 10). The value perfectly corresponds with the wind shear exponents obtained for the Long Lake site from the Grand Traverse study, which was in the range of 0.20 – 0.25 based on the terrain roughness.

Table 10. Wind shear coefficient for various terrain characteristics

Terrain Characteristics	Wind shear
Smooth hard ground, calm water	0.10
Tall grass on level ground	0.15
High crops, hedges and shrubs	0.20
Wooded countryside, many trees	0.25
Small town with trees and shrubs	0.30
Large city with tall buildings	0.40

Once we determined the wind speed at each turbine's hub height, we were able to find the wind energy production potential for GTLM4 weather station. We calculated it in the following way:

$$\text{WPD} = \frac{1}{2N}\sum_{i=1}^{N} \rho_i v_i^3 \quad (\text{w/m}^2)$$

where
N = the number of records in the period;
ρ_i = the air density (kg/m3);
v_i = the wind speed for record i (m/s)
w/m^2 = Watts per meter squared.

Finally, once we got the values for potential energy generation for both GTLM4 and NREL #5579 stations, we determined the average generation. We performed the analysis assuming that at least one wind turbine will be installed. **Table 11** shows the estimated potential annual electrical energy generation from wind resource of each of the turbines in our assessment.

Table 11. Estimated potential annual energy production for each turbine

Parameters	Mitsubishi MWT-1000-61	Vestas90	Suzlon88	GE2.5xl-2.0MW	Siemens SWT-3.0-101 MW
Estimated mean speed at hub height (m/s)	7.8 m/s	8.0 m/s	8.0 m/s	8.0 m/s	8.3 m/s
Capacity factor, %	34.2	36.0	36.0	40.0	37.6
Annual Energy Production (Mwh)	2993	6414	6482	7170	9890

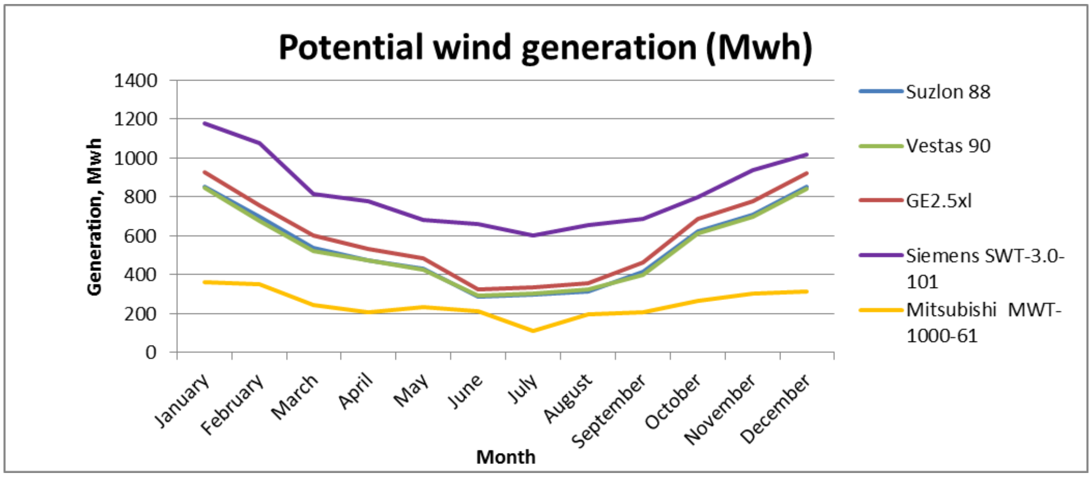


Figure 14. Potential wind generation (MWh) for selected wind turbines.

Wind turbines GE2.5xl and Siemens2.3 have higher generation throughout the year due to larger rotor diameter than the other turbines. Overall, the SAM model proved to be more conservative than the wind data for GTLM4 due to higher wind speeds at the lighthouse's location.

Additional details about the wind resource analysis are available in (Appendix [X]), including:

- Correlations between long-term weather station and simulated NREL plants in Leelanau Township;
- Wind Power Density;
- Extrapolating of the wind speed for 50m, 80m and 100m wind turbine hub heights;
- Selection of wind turbine class as per IEC standard;
- Energy production using a wind turbine manufacturer's power curve;
- Energy losses

The wind assessment showed that average wind speeds at both locations are in a range of 7.9 – 8.1 m/s. With this in mind, in order to assess the wind energy resources at both stations, we chose IEC II and III wind turbines for potential installation in Leelanau Township. In order to provide recommendation on the best hub height selection, we assessed wind resources at 50m, 80m and 100m wind turbine hub heights (cf. Appendix V.)

Site Selection

Sites for potential large-scale solar PV and wind turbine installations were selected with the assistance from NEAT and through a visit to Leelanau Township. The team has identified five potential sites (Figure 15). The list of potential sites is not included in this report to protect the local landowners' privacy. It is important to note that this list simply illustrates that adequate land is available, and that changes or additions are likely to take place over time.

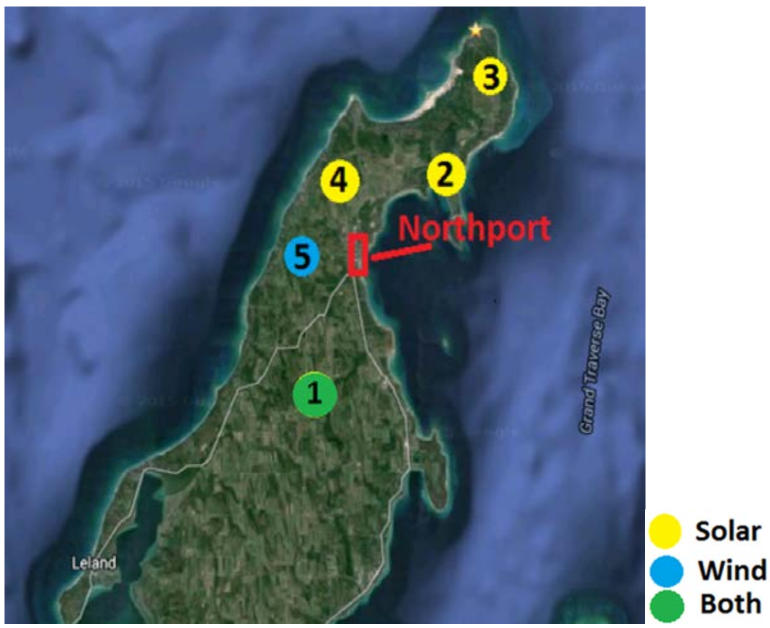


Figure 15. Potential sites for large-scale solar PV installations and wind turbines

Potential large-scale PV installations

Given that residential and commercial installations were assumed to be located on rooftops with south-facing surfaces, only the large-scale systems were considered when determining and evaluating land requirements. From the results obtained in the previous section, it was established that the required area for large-scale PV installations is about 40 acres (161,874 m^2).

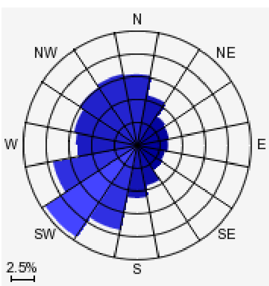
NEAT provided information on land availability based on feedback by some community members who were interested in being part of the renewable energy plan. When evaluating these sites it was important to consider accessibility to the site, total land area, and proximity to existing three-phase electric transmission lines to allow for interconnection to the grid. Four total potential sites were identified based on the parameters previously described. We concluded that with the current proposed sites for PV solar development it would be possible to deploy the total large-scale systems needed to achieve the 100% renewable electricity goal. Although it is hard to currently determine the distribution and configuration of these systems, land availability should not be a limitation to their deployment over the duration of the plan.

Potential wind turbine installations

Wind resources assessment showed that Leelanau Township has adequate wind resources. Wind turbines with a hub height of 80m would be suitable for the area, given expected turbine and rotor sizing. Using a hub height of 100m is not recommended due to potential shadow impacts. The shadow created by the wind turbine blades is dependent on the sun trajectory for the specific location of the area of research. Therefore, not every location can be suitable for a wind turbine, as residents might oppose them on the grounds of shadow impact. Currently, there are two sites that suit the requirements for the installation of a wind turbine. These sites are located in areas close to both Cherryland and Consumers Energy transmission lines.

Given the fact that there are no wind records for the these specific sites, we based our recommendations for potential wind generation on the results received from the GTLM4 and NREL #5579 wind data analysis. Wind roses created in AWS TruePower software correspond with average wind directions for Leelanau region. Hence, we have confidence in our results. **Figure 16** shows how wind speed and direction are typically distributed at Sites 1 and 5.

Site #1



Site #5

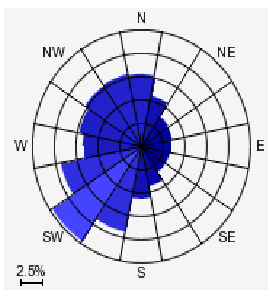


Figure 16. Wind rose for Site 1 and 2, AWS TruePower

Solar Resource Assessment

According to the 2011 Solar Energy Perspectives Report by the International Energy Agency,

> *"…the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared." (International Energy Agency, 2011)*

The successful design and deployment of solar energy systems depends substantially on characteristics of the solar resource for the location being evaluated. Installing PV systems close to the point of electricity use is also important to minimize transmission losses.

Because the scope of the project covers electricity generation, we only evaluated the potential energy generation as it relates to solar photovoltaic systems, as opposed to other types of solar technologies such as solar thermal.

Conducting an adequate solar resource assessment helps to ensure the identification of the most cost-effective ways to incorporate PV power systems. The following sections explain the way that the solar energy availability for Leelanau Township was calculated.

Methodology

The National Solar Radiation Data Base (NSRDB) provides the starting point to determine the available solar resources at a certain location through the use of Typical Meteorological Year (TMY) datasets. A TMY data file provides an annual data set that contains hourly meteorological values (referring to expected weather conditions) for a specific location over a period of up to 30 years. These data sets are extensively used by industry for modeling renewable energy conversion systems. These monthly data sets contain actual time-series meteorological measurements and modeled solar values.

In the creation of a TMY data set, using a larger collection of yearly datasets allows for smaller differences between selected data months and long-term monthly characteristics. Conversely, the smaller the pool of years from which to determine climate characteristics, the less likely the selection represents the actual climate (Hubbard, DeGaetano, Kunkel, & Redmond, 2005).

The average monthly solar insolation is estimated using the hourly measurements from the TMY weather file. The average monthly solar insolation is a measure of the solar energy received on a given surface area in a given time and is commonly expressed in kilowatt-hours per square meter (kWh/m^2). Key tables used for this estimation are presented in 93Appendix IV.

The modeling tool used to estimate the available solar resource and the potential energy generation from different PV systems for this project is the System Advisor Model (SAM) Version 2015.1.30, developed by the Natural Renewable Energy Laboratory (NREL). SAM makes performance predictions and energy cost estimates for grid-connected power projects based on installation and operating costs and system design parameters that are specified as inputs to the model (Blair, et al., 2014).

To evaluate the potential energy generation from PV solar systems, we considered three different types of systems based on their size and application:

- Residential: Systems aimed at supplying electricity for individual households.
- Commercial: Larger systems intended to supply energy for large commercial buildings and high-energy consuming businesses.
- Large-Scale: These systems would provide electricity for a larger proportion of the community and will require larger areas to be installed.

After system parameters are defined (e.g. orientation, tilt, capacity, etc.), they are introduced as inputs into the SAM modeling tool to determine the potential energy generation for each system type. The modeling tool assumes that the renewable energy system delivers power either to an electric grid or to a grid-connected building to satisfy the electricity needs. A typical analysis involves running simulations, evaluating results, revising inputs, and repeating the process until there is enough confidence in the results based on the system simulation performance, which for this analysis, was reached by comparing the results with similar existing PV systems in Leelanau Township, as provided by NEAT (Blair, et al., 2014).

All PV systems that were modeled were assumed to be connected to the electric grid. However, grid-connected systems can be divided into two categories based on which side of the electric meter the systems are placed. Small-scale systems that feed power directly to the customer's meter are known as "behind-the-meter" systems. They compete against the retail price of grid electricity through net energy metering, and are typically sized to not generate more electricity than the customer uses on a net annual basis. Alternately, larger-scale systems typically have their own meter, allowing their owners sell power into the wholesale electricity market through power purchase agreements (PPAs). Considering the total capacity of PV systems that will be required to achieve the project goals, both types of metering systems will be considered in our analysis.

Several assumptions were made regarding system characteristics in order to better adapt the simulation models to the actual conditions of the location where the systems will be installed. These assumptions, technical in nature for the most part, are described in Appendix IV. It is important to emphasize that these assumptions may not match every potential PV site, given the high variability in parameters such as orientation, available area, and shading elements.

Once the potential electricity generation was calculated, a comparison of the energy generated from existing PV systems in Leelanau Township and the energy generation obtained from the simulations was conducted to validate the results. This comparison was done by correlating the total kWh generated to the solar resource availability, resulting in a ratio between the kWh generated and the kW of capacity. The correlation results obtained from the existing model were then compared to the correlation results obtained from the simulation model. The validity of these comparisons is detailed in the analysis section for the PV solar systems.

Finally, it is important to mention that a series of scenarios were developed to account for different variables that could impact the deployment process such as policy changes, fossil fuel prices, and so on. These scenarios will be explained in more detail in the scenario analysis section.

Solar Resource Analysis and PV Modeling

Available Solar Resource in Leelanau Township

In order to develop accurate and reliable PV solar models, it was necessary to use a data set that is representative of the location's historical weather conditions. Given that there are currently no TMY weather files available for Leelanau Township, we decided to use the nearest TMY dataset, which is located in Traverse City, Michigan, (Station ID: 726387) as an approximation to the actual solar resource available in Leelanau Township. **Figure 17** shows the solar resource availability map for Michigan. As indicated in the map, Leelanau Township has an average solar resource of about 4.00 to 4.15 $kWh/m^2/day$.

Source: NREL and Michigan Geographic Data Library (2014).

Figure 17. Solar Resource Availability

PV Solar Systems Modeling

After determining the solar resource availability for Leelanau Township, the next step was to conduct the modeling process for each system type: Residential, Commercial, and Large-Scale PV Solar.

Residential PV Solar

The system sizing for an average residential PV solar array was assumed to be 5 kW_{DC} (kilowatts of direct current power), based on the average size of a residential PV system in the U.S. (Solar Energy Industries Association, n.d.) With this basic assumption it was possible to perform the residential system simulation with the modeling tool. The simulation resulted in the monthly estimated electricity generation values contained in Table 12:

Table 12. Monthly Estimated Residential PV System Generation

Month	Electricity Output (kWh)
January	330
February	445
March	659
April	641
May	770
June	739
July	721
August	666
September	621
October	473
November	294
December	237
TOTAL	**6,596**

More detailed information regarding the residential PV model results and configuration can be found in Appendix IV.

The SAM model for residential installations results in an annual electricity generation of about 6,600 kWh per household. The average residential electricity consumption for the state of Michigan is 8,112 kWh/year (Electricity Local, 2015), which means that the proposed PV installation would offset about 80% of the electricity consumption of an average Michigan household.

The validation of the model was conducted through a correlation analysis and then compared to a similar existing system in the community. The kWh/kWc ratio (amount of energy generated per generation capacity installed) for the existing PV system is 99.12, while the simulation model correlation results in 101 kWh/kWc. The closeness of these results serves to justify the model's validity. Details of the validation analysis are found in Appendix IV.

In order to determine the potential for the deployment of residential PV systems, the survey results (Question 14, cf. Appendix I.) were used as a reference. These results show that 48% of the surveyed individuals would be interested in learning if their homes would be suitable for PV solar installations. We assumed a conservative uptake of residential installations, considering values ranging from 0% to 15% of the households installing 5 kW_{DC} PV systems.

The number of households in Leelanau Township is 931, according to the 2010 census data (U.S. Census Bureau, 2010). It was possible to generate different deployment estimates for residential PV systems, resulting in different potential electricity generation scenarios shown in **Table 13.**

These results were used as inputs for the scenarios that are detailed later in the document.

Table 13. Total Residential PV System Potential Generation

Percentage of Households installing 5 kW_{DC} PV systems	Number of Households installing 5 kW_{DC} PV systems	Estimated Electricity Generation from Residential Systems (MWh/year)	Share of Total Electricity Consumption in 2013 (22,600 MWh/year)
10%	93	613.8	2.71%
15%	139	917.4	4.06%
20%	186	1,223.2	5.41%

Commercial PV Solar

The PV system reference size for commercial buildings was 20 kW_{DC}. The commercial simulation was conducted similarly to the process used for the residential simulation. The monthly estimated electricity generation from the array is reported in **Table 14:**

Table 14. Monthly Estimated Commercial PV System Generation

Month	Electricity Output (kWh)
January	1,162
February	1,526
March	2,241
April	2,216
May	2,700
June	2,603
July	2,547
August	2,348
September	2,178
October	1,660
November	1,037
December	838
TOTAL	**23,056**

More detailed information regarding the model results and configuration can be found in Appendix IV.
The SAM model for installations aimed for commercial buildings results in an annual electricity generation of about 23,000 kWh per building. In context, that amounts to approximately 0.1% of total energy used in the Township annually.

Similar to the residential PV modeling, a validation process was conducted for the commercial systems. The existing system correlation resulted in 108.25 kWh/kWc while the simulation model correlation was 103.83 kWh/kWc. The similarity of the results serves to validate the model. More details can be found in Appendix IV.

Estimating the number of PV systems that can be deployed for commercial buildings was more difficult given the lack of electricity consumption information for individual commercial buildings. Based on the electricity consumption dataset, the total commercial and industrial electricity use for Leelanau Township is 5,755 MWh/year. In order to estimate the potential PV solar electricity generation for commercial and industrial buildings, a similar assumption to the residential PV system potential was made, in which we considered different scenarios about the share of commercial buildings adopting PV solar systems. The results obtained are shown in **Table 15**

Table 15. Total Commercial PV System Potential Generation

Percentage of Commercial Consumption Supplied by 20 kWdc PV Systems	Estimated Electricity Generation from Commercial Systems (MWh/year)	Share of Total Electricity Consumption (22,600 MWh/year)
10%	575.6	2.54%
15%	863.4	3.82%
20%	1,151.2	5.09%

As with the residential PV systems, these values will be used to determine the different scenarios to be used when modeling the renewable energy plan.

Large-Scale PV Solar

To determine the required large-scale PV solar array size, we decided to first aggregate the total electricity that could be generated by the proposed wind turbines and the residential and commercial PV systems, and then subtract that amount from the actual electricity consumption. The resulting amount was used to determine the required capacity for large-scale PV solar systems.

As previously stated, the purpose of this project is to help NEAT develop a plan to achieve a 100% electricity generation from renewable sources for Leelanau Township. Considering the already estimated generation from wind and small-scale solar PV systems, it was determined that the large-scale PV solar systems to be deployed would require an aggregate capacity of approximately 7.5 MW. This is shown in more detail in Appendix IV.

Before proceeding with the simulation, it is important to mention that given the difference between these large-scale projects and the previous smaller systems considered, two additional assumptions were made, the first considers these systems to have 2-axis tracking capabilities, and the second one estimates lower shading losses. These are detailed in Appendix IV. (assumptions 5 and 6).

The monthly estimated electricity generation from this simulation can be seen in **Table 16**

Table 16. Monthly Estimated Large-Scale PV Systems Generation

Month	Electricity Output (kWh)
January	534,969
February	763,333
March	1,127,550
April	1,211,420
May	1,585,220
June	1,620,370
July	1,584,240
August	1,275,910
September	1,132,780
October	802,050
November	499,609
December	370,895
TOTAL	**12,508,346**

More detailed information regarding the model results and configuration can be found in Appendix IV.

Based on the results, the large-scale PV solar installations would be capable of generating about 12,500 MWh per year, requiring an area of nearly 40 acres. Aggregating this amount of electricity to the total generation from wind turbines and residential and commercial PV solar installations results in a total renewable energy generation that matches the total electricity consumption for Leelanau Township.

Having defined the total large-scale PV solar systems that will be required to achieve the 100% renewable electricity generation target, it was necessary to make sure that there would be enough land available to successfully deploy these systems. In the next section we provide information on how the site selection process was conducted to determine the best alternatives for the installation of these PV systems.

Site Selection

Given that residential and commercial installations were assumed to be located on rooftops with south-facing surfaces, only the large-scale systems were considered when determining and evaluating land requirements. From the results obtained in the previous section, it was established that the required area for large-scale PV installations is about 40 acres (161,874 m^2).

NEAT provided information on land availability based on feedback by some community members who were interested in being part of the renewable energy plan. When evaluating these sites it was important to consider accessibility to the site, total land area, and proximity to existing three-phase electric transmission lines to allow for interconnection to the grid. Four total potential sites were identified based on the parameters previously described. The list of potential sites is not included in this report to protect the local landowners' privacy. It is important to note that this list simply illustrates that adequate land is available, and that changes or additions are likely to take place over time. Nevertheless, we concluded that with the current proposed sites for PV solar development it would be possible to deploy the total large-scale systems needed to achieve the 100% renewable electricity goal. Although it is hard to currently determine the distribution and configuration of these systems, land availability should not be a limitation to their deployment over the duration of the plan.

Policy and Regulation

Federal and state policies are significant factors that affect the time horizon for completing the 100% local renewable energy goal. Specifically, they are important drivers for energy efficiency promotion and renewable technology adoption. Policies are also essential parameters to be considered in financial modeling and scenario development later in this study. Since many of the current policies do not yet have extensions after 2015 or 2016, the time horizon to achieve 100% renewable energy is dependent on future policy extensions, at least for the near term. The likelihood of their extension is unclear, so some assumptions were made to estimate the extension or phase-out of renewable energy policies based on the analysis of the current policy environment on state and federal levels.

The main policy mechanisms that apply to renewable energy generation for Leelanau Township are summarized in Table 17 below:

Table 17. Policy Mechanisms for Renewables and Energy Efficiency with Expiration Years

Technology	Michigan RPS	Residential Incentive	Commercial Incentive
Solar Photovoltaics	Renewable Energy Standard (2015)	Net metering [b] Residential Renewable Energy Tax Credit (2016) [a]	Net metering [b] Investment Tax Credit [a]
Wind	Renewable Energy Standard (2015)	Net metering [b] Residential Renewable Energy Tax Credit (2016) [a]	Net metering [b] Investment Tax Credit (2016) [a] Production Tax Credit (2014) [a]
Energy Efficiency	Energy Optimization Standard (2015)	Residential Energy Efficiency Tax Credit (2014) [b]	Energy Efficiency Grants [b]
Loan Program (renewable energy & energy efficiency)		Home Energy Loan – Michigan Saves [b] FHA PowerSaver Loan [a]	Business Energy Financing – Michigan Saves [b] Loan Guarantee Program [a]

[a] Federal
[b] State of Michigan

Source: Database of State Incentives for Renewables & Efficiency at http://www.dsireusa.org/

Renewable energy-related regulations and incentives are expected to be important for the growth of renewable generation in the next several years, since they help those technologies compete with conventional generation sources. Because PV solar, in particular, has dropped substantially in cost over the past five years, subsidies are becoming less important to make the economic argument for renewable sources.

Renewable Portfolio Standards (RPS) in Michigan

In October 2008, Michigan enacted the *Clean, Renewable, and Efficient Energy Act (Public Act 295 of 2008)*, requiring "certain providers of electric service to establish renewable energy programs" and "to establish energy optimization programs",[9] so as to "promote the development of clean energy, renewable energy, and energy optimization".[10] Under Public Act 295, the state of Michigan also developed its renewable portfolio standard (RPS), the Michigan Renewable Energy Standard, details of which are shown below.

The Michigan Renewable Energy Standard requires certain utilities to generate 10% of total electricity sales from renewable energy resources by the year 2015 (U.S. Department of Energy, n.d.). And eligible renewable technologies include PV solar and wind.

Although Michigan has relatively modest Renewable Portfolio Standard, at 10% by 2015, among participating states (Leon, 2013), Governor Snyder has recently announced his interest in increasing renewable energy adoption in the state. In early 2015, he laid out a proposal to increase renewable generation and energy efficiency to between 30% and 40% of electricity consumption by 2025. However, Snyder's proposal does not include binding targets (Governor Snyder's 2015 Energy Special Message: The calls to action, n.d.). Some anticipate that a future RPS could require 20% renewable energy by 2022 (Brandt, n.d.).

Because Governor Snyder was recently re-elected, and his proposal does not include binding targets, we do not expect an RPS or other state mandates to be significant factors for development of a community renewable energy plan. If Snyder's successor and the state legislature adopt binding goals for Michigan, they will likely take effect more than five years in the future. In that case, state mandates would likely be more of a course correction to a renewable energy plan, rather than a primary consideration.

Renewable Technology Incentives

Apart from regulatory standards, there are also market-based instruments available in Michigan that include incentives such as tax credits, grants and statewide loan programs. The residential and commercial sectors usually have different incentives or loan programs for both renewable upgrades and efficiency improvements. Financial incentives help to reduce a portion of the up-front costs for renewable energy systems, making the adoption of renewable technologies accessible to more homeowners and businesses.

Renewable technology incentives are important parameters for estimating the cost of electricity. Notable incentives include net metering and the Renewable Energy Tax Credit, both of which are detailed in the following sections.

Net Metering

Net metering is a service provided by utilities to electricity consumers in which any electricity generated by a customer (usually via renewable energy sources) is used to offset the electricity delivered by the utility during a certain billing period.[11] (6 H.R. § 1241) This service is applicable for both residential and commercial/industrial sectors, and eligible systems include solar, wind and other renewable technologies capable of generating electricity.

[9] Clean, Renewable, and Efficient Energy Act of 2008, MCL §§ 460.1001.
[10] Clean, Renewable, and Efficient Energy Act of 2008, MCL §§ 460.1001.
[11] Energy Policy Act of 2005, 6 HR §§ 1241.

Net metering is of particular importance to renewable energy modeling because it would directly impact the cost-effectiveness of smaller-scale renewable energy systems to be deployed in Leelanau Township. Details about the different net metering schemes available in Michigan can be found in **Table 18**.

Table 18. Net Metering Categories

Category	System Range (kW)	Pay Rate	Approximate Pay Rate[12]	Received Credits	Approximate Credit Received
1	0 – 20	Full retail rate	$0.1276	Full retail rate	$0.1276
2	20 – 150	Full retail rate	$0.1276	Generation portion of retail rate	$0.0838

Currently, Category 1 net metering customers receive a bill credit for the full retail rate of electricity for excess generation. Larger Category 2 systems forgo the distribution portion of the electric rate for excess generation, which amounts to about one-third of the total.

Renewable Energy Investment Tax Credit (ITC)

This incentive consists of a 30% federal tax credit available when purchasing and installing solar PV and small wind systems (less than 100 kW) (Residential Renewable Energy Tax Credit, n.d.). Currently, this policy instrument is set to decrease to 10% for solar commercial PV installations and will expire for wind energy systems on December 31, 2016. The ITC will be phased out entirely for residential PV solar at that time (Business Energy Investment Tax Credit (ITC), n.d.). Detailed information about the ITC and its sunset date can be found in Appendix III.

Renewable Electricity Production Tax Credit (PTC)

This incentive provides financial support for the development of renewable energy installations by providing tax credits on a per-kWh basis to the owners of renewable energy systems. The PTC is only applicable to wind power systems, providing a benefit of $0.023 per kWh for the first 10 years of operation (Renewable Electricity Production Tax Credit (PTC), n.d.). The PTC mechanism expired on Jan 1, 2015, meaning that projects starting their construction process after January 1, 2015 are ineligible for this credit.

The potential extension for both the ITC and PTC remains unknown, since currently there is no bill proposing to extend the tax credits for renewables after 2016 at the time of this writing.

Energy Efficiency Regulations & Incentives

The Michigan energy bill (PA 295) that authorized the Renewable Energy Standard also included an Energy Optimization Standard for the state's largest utilities. It requires a 1% reduction in electricity sales for every year after 2012. (MCL § 460.1001) Federal programs also

[12] Consumers Energy Company. Rate Book for Electric Service (p. 136). (2014, July 22). Retrieved February 27, 2015, from http://www.consumersenergy.com/uploadedFiles/CEWEB/SHARED/Rates_and_Rules/electric-rate-book.pdf

provide incentives for efficiency upgrades in residential, small business, and nonprofit sectors. For example, the Energy Efficiency Tax Credit is applicable for the residential sector to improve energy efficiency by new equipment purchase, and Energy Efficiency Grants provide up to $50,000 to small business and nonprofit organizations taking action to improve energy efficiency. More information about these incentives can be found in Appendix III.

Loan Programs

Complementing the mechanisms described above are federal and state loan programs for both renewable and energy efficiency projects. For example, Michigan Saves offers a loan program with favorable terms for homeowners and businesses. A summary of Michigan Save's programs can be found in Appendix III. And examples of federal loan programs include FHA PowerSaver Program, Energy-Efficient Mortgages, and Clean Renewable Energy Bonds, etc. These programs are relevant because they can be used to encourage the adoption of both renewable energy projects and energy-efficiency measures.

Summary

The trajectory of various policy instruments for renewable energy systems and energy efficiency will affect the timetable for NEAT's 100% renewable energy plan. Existing tax credits have a rapidly approaching sunset date and may retroactively look relatively generous if phased out or eliminated.

Uncertainties regarding the future status of renewable energy policies serve as a motivator for the development of different scenarios for reaching 100% renewable energy, and are described later in this report.

Incentives aimed at promoting energy efficiency measures are also relevant to these project because they would have a direct impact on the rate of adoption of these measures, which in turn would impact the amount of electricity to be generated from renewable sources to reach the 100% goal.

Scenarios for Renewable Energy

The resource assessment sections of this report showed that there is sufficient renewable energy potential to generate 100% of the Township's electricity on a net annual basis. Additionally, the siting analysis validated that enough land area is available to locate a mix of PV solar and wind turbines to achieve this goal. That still leaves a number of variables that would affect the rollout of renewable energy systems, such as incentives, conventional energy price and community preferences. Three scenarios were developed to provide NEAT with an idea of what reaching their goal might look time in terms of generation mix and timeline. The base scenario used middle-of-the-road assumptions, while the other two represented rapid adoption and stalled adoption, respectively.

Methodology

A base scenario was developed to both demonstrate middle-of-the-road assumptions, and to serve as the reference point for total cost over a 25-year period, 2016-2040. The 25-year period corresponds with EIA projections for electricity consumption, and is the approximate lifespan of a renewable energy system. The total base scenario cost was used for the other two scenarios. In other words, the total electricity cost (conventional and renewable) for the Township is fixed for all scenarios. This was done to show the impact of variables other than total cost. The cost of renewable energy systems and associated financing costs will undoubtedly be important to the success and time line of the project. However, a comprehensive financial analysis is a significant undertaking on its own and outside the scope of this study. Our assumption, corroborated with NEAT, is that renewables will be implemented as they near or achieve parity with grid electricity costs. Different trajectories — and target years — for achieving 100% net annual electricity generation are mapped out by adjusting assumptions about annual electricity rise, cost escalation and renewable energy subsidies, among others.

Residents of Leelanau Township are somewhat sensitive to the appearance of wind turbines, as reported in the survey section. Using that as a consideration for turbine siting, we expect that an additional 3 MW of wind capacity may be the approximate upper limit for that generation type. The generation mix for each scenario can been seen in the charts that follow.

Base scenario

The base scenario assumes that renewable energy technologies will continue to improve, resulting in lower prices and better competitiveness with conventional sources. However, this scenario assumes that incentives would be phased out over time, meaning that adoption of renewable generation would increase at a steady but not rapid rate due to falling costs for PV solar over time. Electricity use is assumed to rise only gradually over time due to regular tightening of appliance efficiency standards and adoption of high-efficiency light bulbs as they become less expensive. We also assumed that conventional energy prices will continue to rise in the base scenario, helping to promote energy-efficiency measures.

Rapid Adoption Scenario

Many of the assumptions for the base scenario carry over to the rapid adoption scenario. The primary difference is that subsidies remain in place, and that other regulatory mechanisms, such as a renewable portfolio standard, are used to promote renewable energy.

Stalled Adoption Scenario

Finally, the stalled adoption scenario assumes that fossil energy prices remain low, lessening the appeal of renewable generation for those who are primarily motivated by cost. Subsidies for renewable energy are assumed to be phased out, while low energy prices discourage conservation and energy efficiency measures.

Table 19 provides more detail about the incentives used in each scenario**.** In the base scenario and the Stalled adoption scenario, the Federal Investment Tax Credit is expected to drop from 30% to 10% at the year 2017, and the Federal Production Tax Credit (PTC) is never extended. For the Rapid Renewable Energy scenario, the 30% Federal ITC is extended throughout the entire period analyzed, and the PTC extension will be made at 2015. It is also assumed that net-metering will remain effective in the base and rapid scenario, but will end at 2020 in the stalled scenario.

Table 19. Assumptions of renewable energy incentives and electricity consumption escalators for each scenario

	Net Metering	Federal Tax Credits	Electricity Consumption Escalator
Base	yes	2015-2016: 30% ITC 2017-2040: 10% ITC	0.2%/year
Rapid RE adoption	yes	30% ITC PTC	0.2%/year
Stalled RE adoption	ends 2020	2015-2016: 30% ITC 2017-2040: 10% ITC	0.7%/year

ITC: Investment tax credit
PTC: Production tax credit

In each scenario, the capital costs for wind projects are assumed to be constant in 2015 dollars throughout the entire analysis period. For solar photovoltaic, on the other hand, the capital costs for are projected to decrease each year. Using the future forecasting from Black & Veatch, we estimated the cost trend for residential, commercial, and large scale solar PV project from 2015 to 2040, respectively as shown in Figure 18, Figure 19, and Figure 20 (Black & Veatch Corporation, 2012).

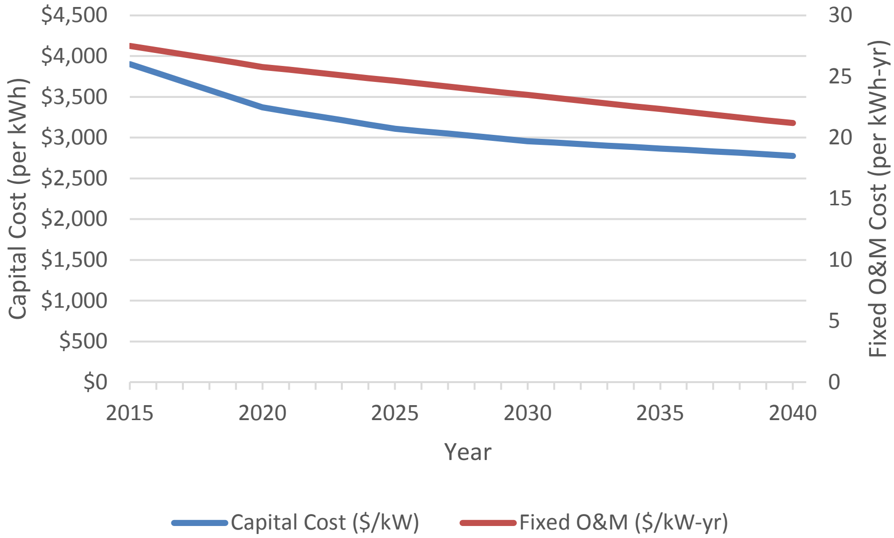


Figure 18. Projected capital costs for installing solar PV residential roof-top systems.

The adoption of renewable energy systems is assumed to increase over time, and the entire renewable systems are consisted of residential and commercial roof-top solar photovoltaic systems, large scale dual-axis tracking solar photovoltaic systems, and large wind turbines. In order to achieve 100% renewable energy supply, smaller solar photovoltaic systems, such as residential or commercial roof-top systems, are added each year. Larger projects, such as wind or large scale solar PV systems are added in certain years during the entire analyzed period. We calculated the levelized cost of energy (LCOE) for newly installed renewable energy projects each year based on the costs trends and incentives.

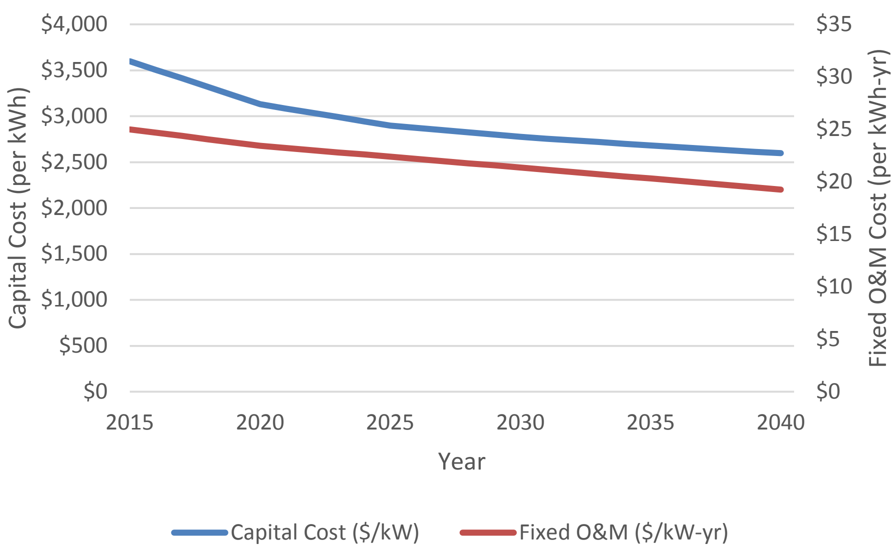


Figure 19. Projected capital costs for installing solar PV residential roof-top systems.

Model Development and Financial Structure

The scenarios were developed in NREL's Cost of Renewable Energy Spreadsheet Tool (CREST) for and large scale solar PV projects, as well as in NREL's System Advisor Model software tool for residential and commercial solar PV systems. First, we built pro forma financial models for the three types of solar PV projects and wind projects using the financial variables of the first year. These models were simulated twenty five times for each year of the analyzed period by scripts. The models were designed to be adaptable to changing conditions and assumptions, therefore, the capital costs, fixed O&M costs, net-metering, and federal ITC or PTC were changed for each model simulation. As a result, we obtained the LCOE for newly installed renewable energy systems each year throughout the entire analyzed period. Costs were adjusted to real 2015 dollars.

Parameters other than the scenario assumptions mentioned above are set to be the same for each scenario. All projects are assumed to utilize project-level debt in order to lower the initial costs. For residential and commercial solar projects, the debt fractions are set to 100 percent, while the debt fractions for large scale solar and wind projects are adjusted to maintain 1.3 average annual debt service coverage ratio (DSCR) and 1.2 minimal annual DSCR. For commercial and large scale solar and wind projects, the five-year modified accelerated cost recovery system (MACRS) schedule is considered. The key financing parameters are shown in Table 20.

Table 20. Main financing variables by project types

Analysis Parameters	Residential PV	Commercial PV	Large Scale PV	Wind
Project life	25 years	25 years	25 years	25 years
Inflation rate	3%	3%	3%	1%
Real discount rate	7%	7%	7%	7%
Debt fraction	100%	100%	35%	30%
Debt Term	10 years	5 years	10 years	15 years
Debt Rate	4%	5.9%	5.5%	7%
Federal income tax	15%/year	34%/year	35%/year	35%/year
State income tax	4.25%/year	4.5%/year	4.5%/year	0%
Sales tax	6%	6%	6%	6%
Federal ITC/PTC*	30% or 10%	30% or 10%	30% or 10%	Varies
Federal Depreciation	None	5-yr MACRS	5-yr MACRS	5-yr MACRS

* Value varies in different scenarios

These scenarios represent a simplified view of how renewable energy projects might contribute to NEAT’s 100% goal for Leelanau Township. They were developed from a residential rate payer's perspective and do not consider costs that would be incurred to change transmission and distribution lines, along with other grid infrastructure, to accommodate a high proportion of renewable energy. Energy storage was also excluded from scenario development because that technology — especially when battery-based — does not have a track record and cannot easily be valued for this exercise. We expect that energy storage will play a role in enabling a high proportion of intermittent generation resources to be added to the grid, though it will come at an added cost.

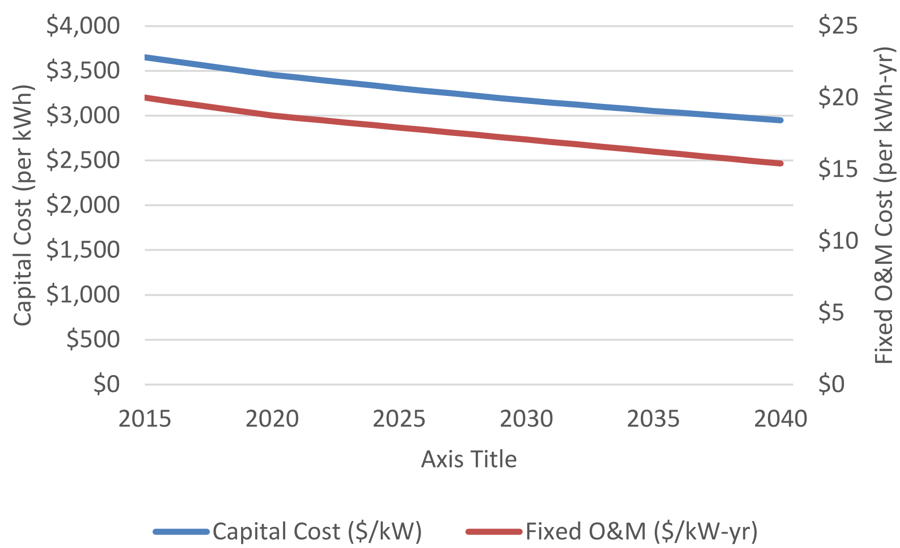


Figure 20. Projected capital costs for installing solar PV large scale dual-axis tracking systems.

Results

Our analysis yielded the following attainment years and energy costs for 100% renewable electricity, by scenario:

Table 21. Total energy costs and the year that 100% renewable energy is achieved

	Base Scenario	Rapid Scenario	Stalled Scenario
100% RE achieved	2035	2030	2040
Average Cost per MWh	$170.58	$146.93	$235.19

In order to obtain the total electrical energy costs for each scenario, we summed up the total life cycle costs for each renewable energy projects, such as residential, commercial, large scale solar PV, and wind, scheduled to be installed in each scenario, and the costs for conventional energy. These costs then be divided by the total electricity consumption in each scenario to obtain the average costs of electricity consumed. The results show that the Rapid scenario has the lowest costs, while the Stalled scenario has the highest. Since the Rapid scenario is the first to achieve

100% renewable energy, the conventional electricity costs for the remainder of the analyzed period would be negligible. Therefore, the costs per megawatt-hour would be minimized.

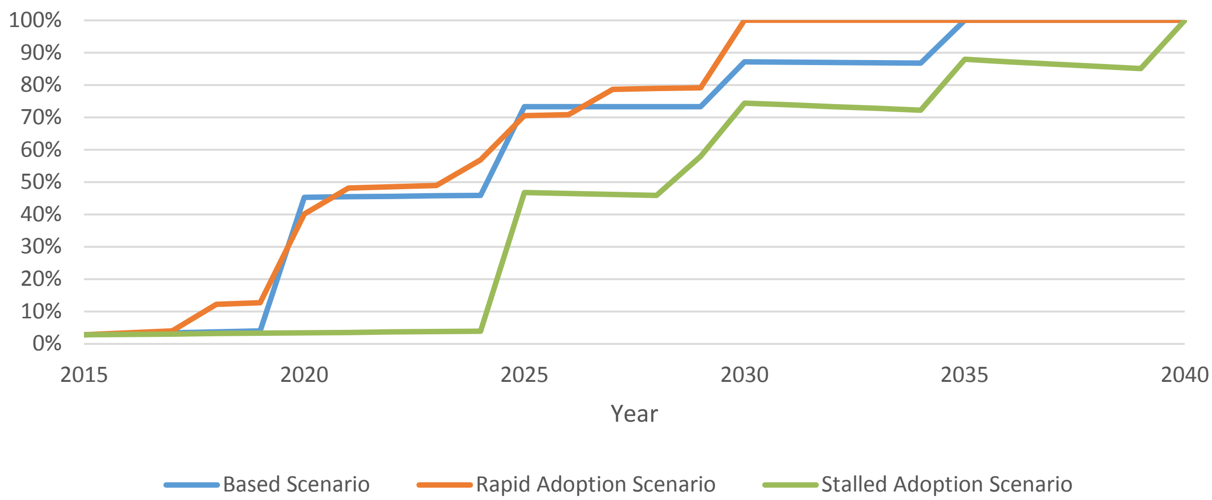


Figure 21. Renewable generation proportion for the three scenarios throughout the analysis period.

As Figure 21 shows, each scenario has large step-wise increases in renewable energy generation. These correspond with large project installations. Because residential and commercial PV adoption was assumed to be 15%, the majority of generation must come from larger-scale projects.

The generation mix for each scenario are presented below.

Base Scenario

The generation mix chart for the base scenario, below, shows that the difference is made up by large-scale PV solar. Meanwhile, smaller-scale PV systems on residences and businesses make up a relatively small slice, totaling about 1.5 MW. The chart represents peak generation power for each technology, which reflects installation costs indirectly. The actual percentage of time that wind and solar systems produce energy different.

Among all renewable technologies, wind power has the lowest LCOE, as shown in Figure 23. Commercial solar systems has the lowest LCOE than other solar systems since commercial projects benefit from both net-metering and the 5-year MACRS depreciation schedule. For the LCOE trends, the solar photovoltaic systems experience sharp increase at the year 2017 due to the Federal Investment Tax Credit decreases from 30 percent to 10 percent. It takes more than twenty years for the LCOE of residential and commercial solar projects to return to pre-2017 levels. The LCOE of large scale solar projects never return to what it is before ITC drops during the analyzed period. It seems that the solar projects should be installed as many as possible before the ITC drops at 2017 to avoid costs from rising. However, the actual install prices for solar PV systems might not follow the projection precisely. It is still possible that the capital costs decrease significantly in the future so that the additional costs due to ITC drops could be compensated.

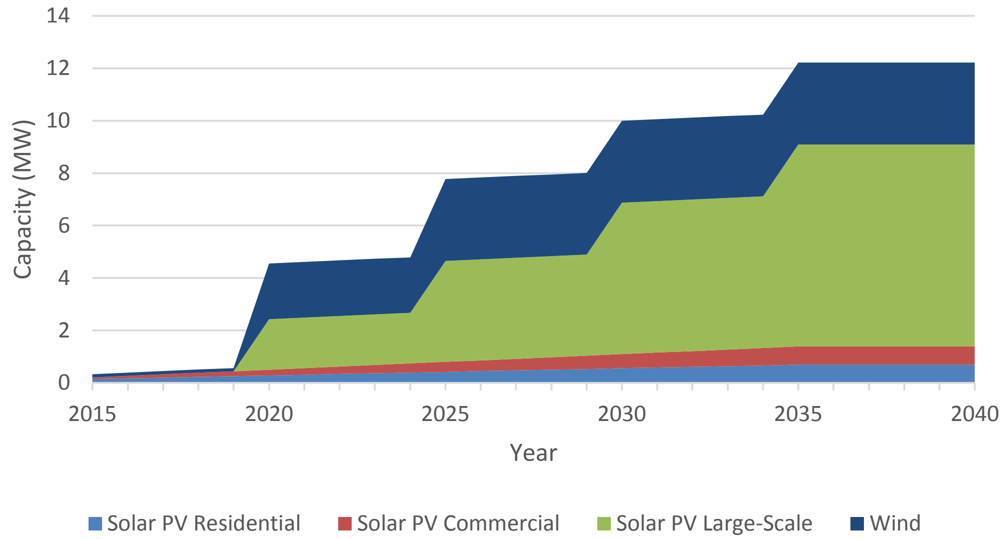


Figure 22. Renewable energy generation mix in the Base scenario

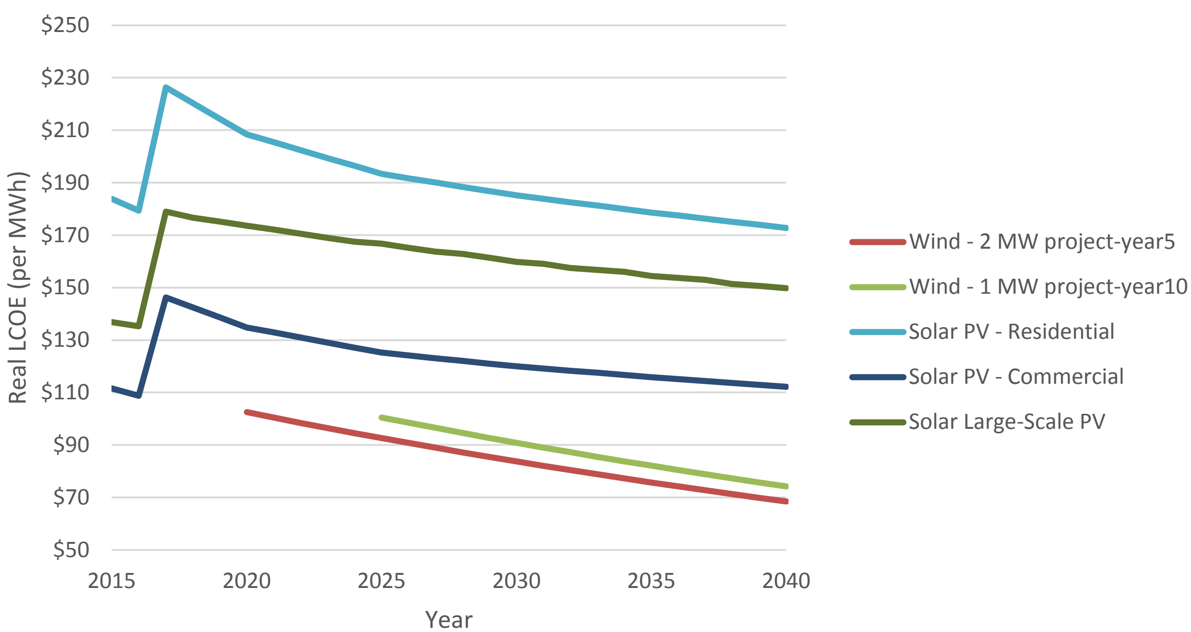


Figure 23. Levelized costs of energy for different types of renewable energy system installed at each year in the Base scenario

Rapid Adoption Scenario

This scenario shows renewable energy systems coming online sooner than the base scenario, with shorter intervals between large system installations. That reflects greater incentives being available for renewable systems and state-level commitment to a higher Renewable Portfolio Standard.

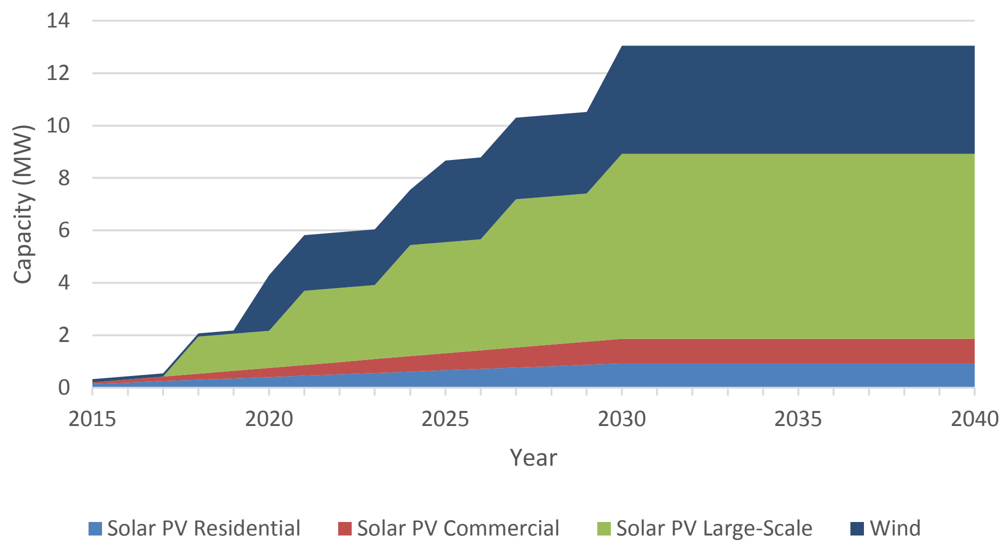


Figure 24. Renewable energy generation mix in the Rapid scenario

In this scenario, the Federal ITC is assumed to be continued as 30% throughout the entire analyzed period, resulting much smoother decreasing trend for the solar LCOE. Commercial solar systems are still the cheapest solution among all solar systems. In fact, the commercial solar projects installed in 2040 have similar LCOE as the 2MW wind project does at 2020. Compare with the Base scenario, the results show that Federal ITC plays a fairly important role in the prices of solar PV systems even though the prices drop considerably over time. Whether the 30% ITC would be continued is still unknown, this scenario represents the most optimistic case in terms of government incentives.

Stalled Adoption Scenario

The higher rise in electricity use over time can be seen in the “stalled” line in the Figure 21 above, where the proportion of renewable energy is eroded between large projects coming online. This scenario has no large-scale projects for nearly a decade, though smaller projects continue to be implemented at a modest rate. From that point, the renewable energy systems would need to be installed over the next 15 years in order to meet the goal.

Similar to the Base scenario, the Federal ITC drops from 30% to 10% at year 2017 in the Stalled scenario. Moreover, net-metering phases out at year 2020, resulting the renewable energy projects in this scenario to be least subsidized. The LCOE curves in the Base and Stalled scenarios are in fact identical. Since the residential and commercial solar systems are designed to meet the demand closely, met-metering generate very little revenue annually. As a result, the expiration of net-metering has almost no effect on LCOE for residential and commercial solar systems.

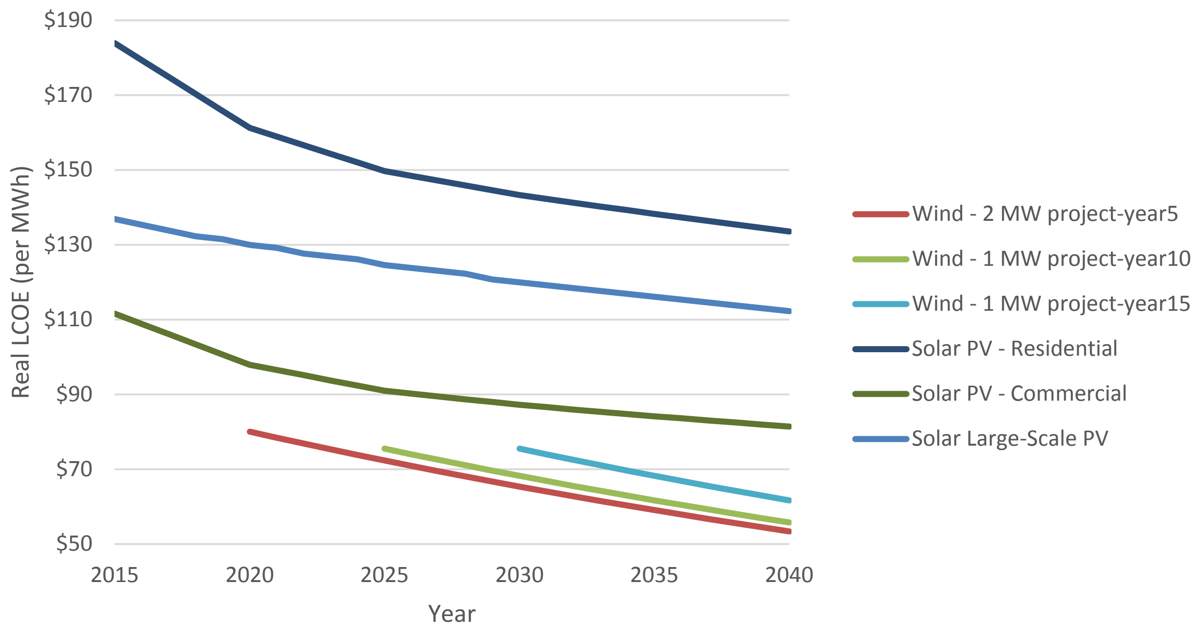


Figure 25. Levelized costs of energy for different types of renewable energy system installed at each year in the Rapid scenario

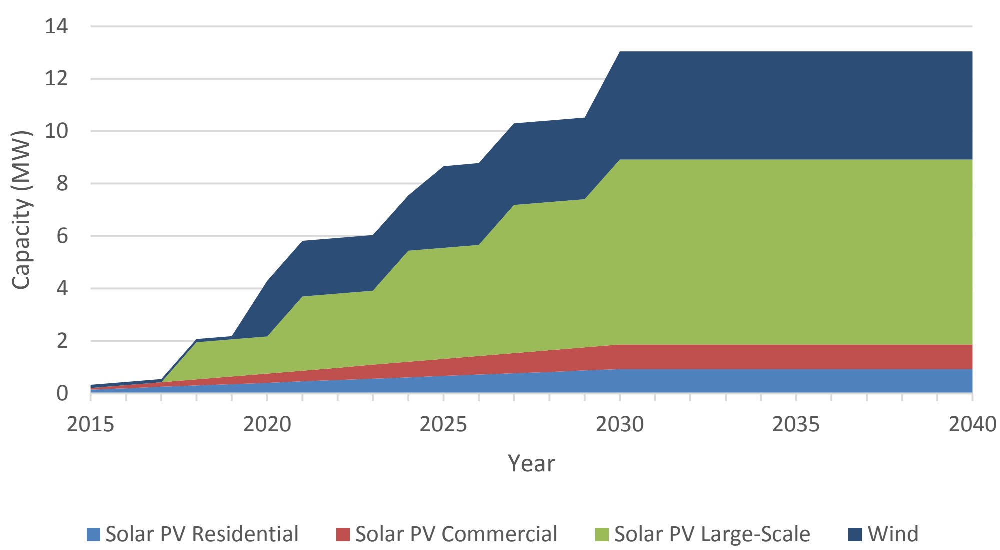


Figure 26. Renewable energy generation mix in the Rapid scenario

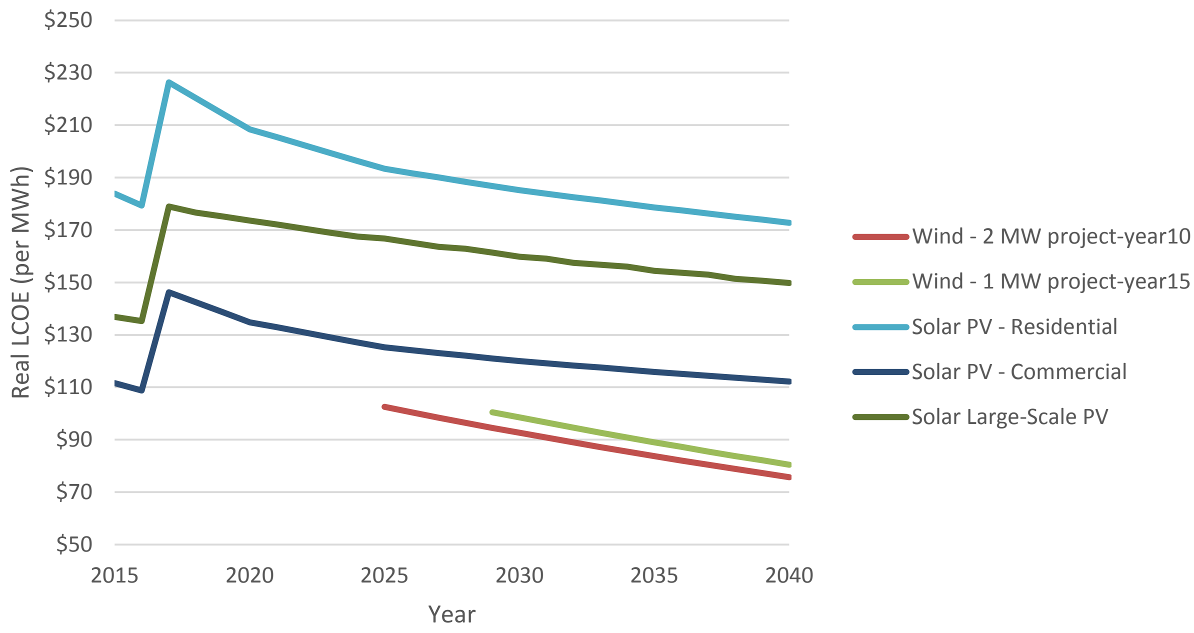


Figure 27. Levelized costs of energy for different types of renewable energy system installed at each year in the Rapid scenario

Conclusion

Key Findings

The primary goal of this project was to determine the feasibility of a community-based plan to achieve 100% renewable electricity for Leelanau Township. Our analysis had three major components:

- community perceptions and interest,
- renewable energy resources, and
- siting and scenarios development.

Our key findings follow, organized by area.

Community Perception

Results from our survey show that community members are generally open to the idea of increasing renewable energy in Northport and Leelanau Township. The majority of respondents (70%) expressed that they would support the plan to reach the 100% renewable energy goal. The relatively high response rate (33%) is a good sign of community engagement, which is an essential element of this plan. NEAT should continue to engage with their community during the development of a plan due to avoid unfounded opposition. The survey indicated that some residents suspect that a plan would be mandated by the government and increase their taxes. Others appeared to be skeptical based on outdated cost data regarding renewable generation.

Renewable Energy Resource

Based on the resource assessment conducted for both solar and wind resources, we conclude that Leelanau Township has sufficient wind and sun energy to supply the totality of its electricity consumption. Although the wind and solar resources available in Leelanau Township are not as robust as in other regions of the country, the 100% goal could be met by deploying several large scale systems. The available land would be more than enough to meet the systems' land requirements of about 80 acres. The identified sites are by no means definite and could be expanded as further efforts are conducted to bring the plan to realization.

Scenarios

Drawing from the other project components allowed creation of three scenarios to serve as examples for renewable energy plan creation. The greatest unknown in the implementation of the plan will be the time to reach the goal. Policy and market uncertainties were identified to have great impacts on the costs of solar PV and wind turbines, in turn affecting the feasibility of reaching the plan goal. The growing implementation of energy efficiency measures and its effect on electricity use increase was another important variable to consider when developing the different scenarios. The base scenario was modeled to reach the implementation goal in a 20-year period. Using different assumptions for renewable energy incentives and consumption rise, it was possible to also provide a "rapid" scenario and a "stalled" scenario, in which the goal would be reached in 15 and 25 years respectively. Because these scenarios are most likely not final representations of the future, the scenario model is also being provided to our client in order to be able to assume different parameters to develop other potential scenarios.

Recommendations

NEAT has embarked on a challenging project to generate all of the energy used within the boundaries of Leelanau Township from local, renewable sources. Even when considering only electricity, this is an ambitious goal. We have developed a set of recommendations for NEAT as they pursue their goal:

Set Intermediate Goals

There is an established track record for renewable energy projects in the Township, along with more in the pipeline. These are positive indicators, though are not yet at the scale that will be needed to achieve 100% within two decades. We recommend setting intermediate goals at five-year intervals (or shorter) as a way to maintain community interest and engagement in between larger projects that necessarily have longer development times than residential PV installations.

Balance Large- and Small-Scale Projects

It is important to take into account the fact that the 100% renewable energy goal cannot be reached by just deploying residential and commercial systems, and that large-scale systems will be necessary. The plan relies more heavily on large-scale solar PV systems than large-scale wind turbines because of residents' sensitivity about the appearance of wind turbines.

However, the team would also like to emphasize the importance of encouraging smaller scale projects regardless of the plan's heavy dependence on large-scale systems to achieve its goal. Small renewable energy systems are important to increase community participation and ownership of renewable electricity sources.

Promote Conservation & Community Education

We recommend continued efforts in the community with regard to conservation, energy efficiency and education about renewable energy incentives and costs. Helping homeowners and businesses with lighting retrofits and payback calculations for efficient appliances can help promote awareness about energy-related topics, while saving money and reducing emissions. While efficiency and conversation represent a small proportion of a transition to renewable energy, they are concrete and part of residents' daily routines. Finally, incentives can greatly affect the net cost of renewable energy systems. Raising residents' awareness of their availability and significance should aid renewable energy uptake.

Purchase Renewable Energy Credits

NEAT has placed a high value on local renewable energy generation, and the resource analyses have shown that goal to be feasible in terms of land area. Recognizing that it will take several years to develop large-scale projects in particular, we recommend purchasing renewable energy credits (RECs) in the short-to-medium term. Consumers Energy, which provides about three-quarters of the electricity to the Township, offers a Green Generation rate. It adds 1¢/kWh to residential retail rates for 100% renewable generation from within Michigan. Purchasing RECs or signing up for the "green" rate program sends a signal to the utilities that renewable generation is important, even at a small premium.

Future Research

This feasibility study is one part of a much larger effort that NEAT is undertaking. We believe that this study establishes some foundational elements for a 100% renewable electricity plan, including community support and adequacy of land area to support renewable energy systems with enough capacity to serve the Township's electricity needs. In the interest of advancing community renewable energy plans for Leelanau Township — and potentially other small communities — we suggest these areas for future research:

Grid Impacts

This study is predicated on the availability of an electric grid that can accommodate a large proportion of intermittent renewable generation. Considerable changes to physical infrastructure may be needed to accommodate that, with attendant changes in regulation and utility models. An assessment of the grid requirements for high levels of distributed generation would be a worthwhile companion to this study and would help to round out the total cost of a 100% renewable electricity plan.

Financial Analysis

The broad adoption of renewable energy is significantly dependent on its cost. Renewable generation is competitive with conventional energy with the right financing options and incentives (at least for the short term). Closer examination of the financing requirements and vehicles would bolster a renewable energy plan, along with in-depth analysis of technology and cost trends for PV solar, in particular.

Energy Storage

Energy storage presents a partial solution to the problem of intermittent renewable resources. Though not cost-competitive today for grid-tied renewable energy systems in Michigan, this could change over the course of NEAT's renewable energy plan. Research on the conditions needed for energy storage would complement a renewable energy plan and help to establish a path for implementing a high level of local renewable generation.

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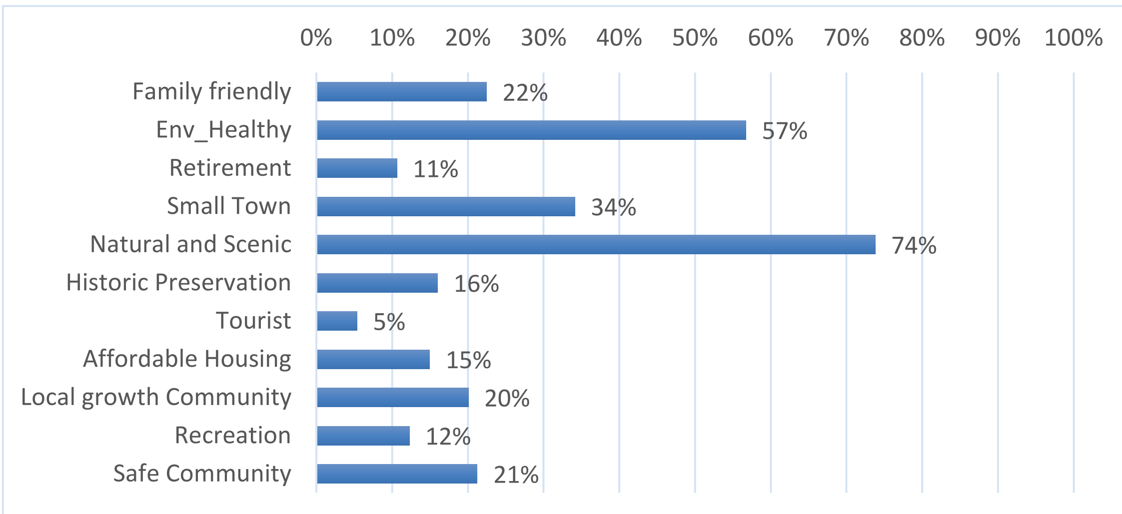
Appendices

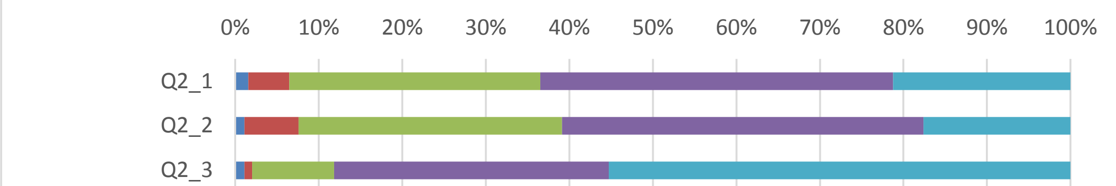
Appendix I. Northport & Leelanau Township Community Renewable Energy Survey

We would like to know your thoughts about Leelanau Township

1. Imagine the Leelanau Peninsula as you would like to see it 15 years from now for you and future generations. What are the **3 most important** attributes of the Leelanau Peninsula 15 years from now? *Please mark only three items.*



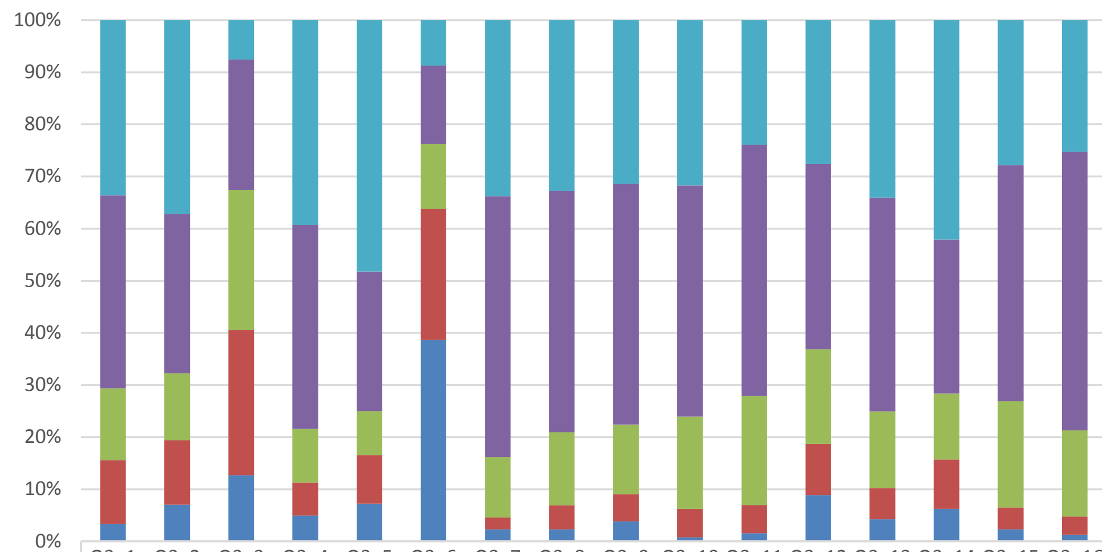
2. To what extent do you agree or disagree with the following?



	Q2_3	Q2_2	Q2_1
Strongly Disagree	1%	1%	2%
Disagree	1%	6%	5%
Neutral	10%	32%	30%
Agree	33%	43%	42%
Strongly Agree	55%	18%	21%

Q2_1	I strongly identify with the local community in Leelanau Township
Q2_2	Being an engaged community member is important to me
Q2_3	I am proud to be a resident of Leelanau Peninsula

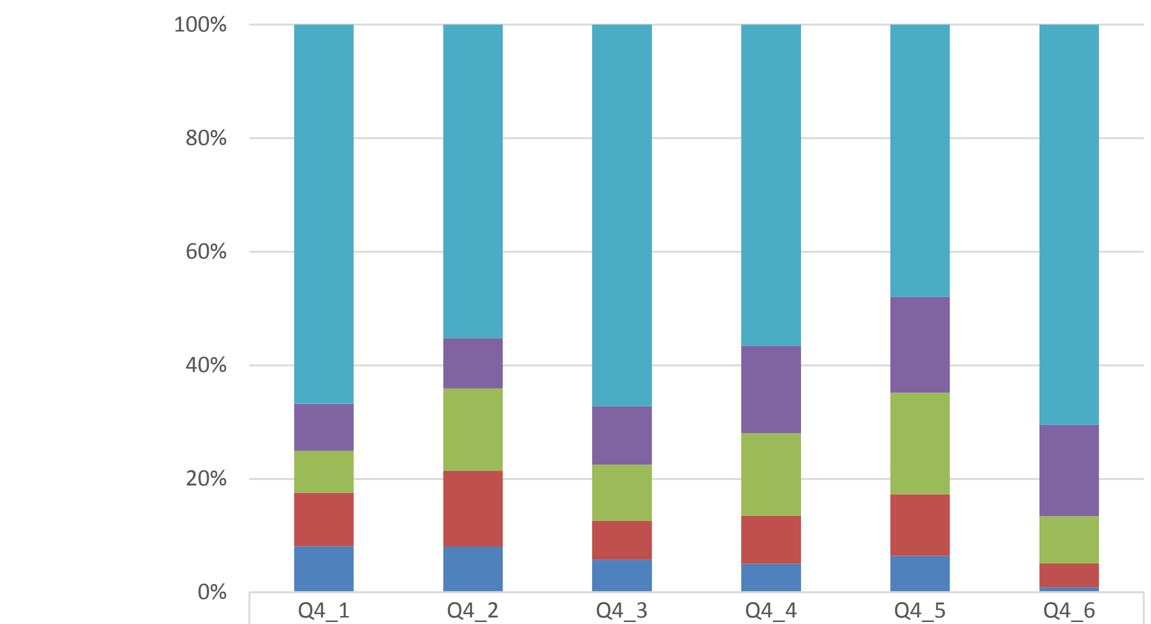
We would like to know a little about your views on environmental and energy issues
3. To what extent do you agree or disagree with the following statements?



	Q3_1	Q3_2	Q3_3	Q3_4	Q3_5	Q3_6	Q3_7	Q3_8	Q3_9	Q3_10	Q3_11	Q3_12	Q3_13	Q3_14	Q3_15	Q3_16
Strongly Agree	34%	37%	8%	39%	48%	9%	34%	33%	31%	32%	24%	28%	34%	42%	28%	25%
Agree	37%	31%	25%	39%	27%	15%	50%	46%	46%	44%	48%	36%	41%	30%	45%	53%
Neutral	14%	13%	27%	10%	8%	12%	12%	14%	13%	18%	21%	18%	15%	13%	20%	17%
Disagree	12%	12%	28%	6%	9%	25%	2%	5%	5%	5%	5%	10%	6%	9%	4%	4%
Strongly Disagree	3%	7%	13%	5%	7%	39%	2%	2%	4%	1%	2%	9%	4%	6%	2%	1%

Q3_1	Our present way of life is much too wasteful of resources
Q3_2	If we continue our high levels of fossil fuel use, future generations will not enjoy the same standard of living as ours
Q3_3	Energy problems must not stand in the way of economic growth
Q3_4	Electric utilities should promote renewable energy programs in MI
Q3_5	The U.S. needs to put more effort into developing renewable energy sources (e.g. solar, wind)
Q3_6	The threat of environmental problems has been greatly exaggerated
Q3_7	I feel a personal obligation to reduce my impact on the environment
Q3_8	Our community needs to do its share in reducing energy use
Q3_9	Households should do what they can to reduce their carbon dioxide (CO_2) emissions
Q3_10	I'm concerned about rising energy costs
Q3_11	I would do more to reduce my energy consumption if I knew it would save me money
Q3_12	My local government should facilitate the development of renewable energy projects in my area
Q3_13	I am interested in getting at least some of my electric power from renewable energy sources
Q3_14	We should reduce fossil fuel use in the U.S. to help preserve our natural environment
Q3_15	I would do more to reduce my energy consumption if I knew it would help the environment
Q3_16	Energy conservation is part of my daily routine

Please tell us about your interest in these energy efficiency practices
4. How likely would you be to try the following actions?



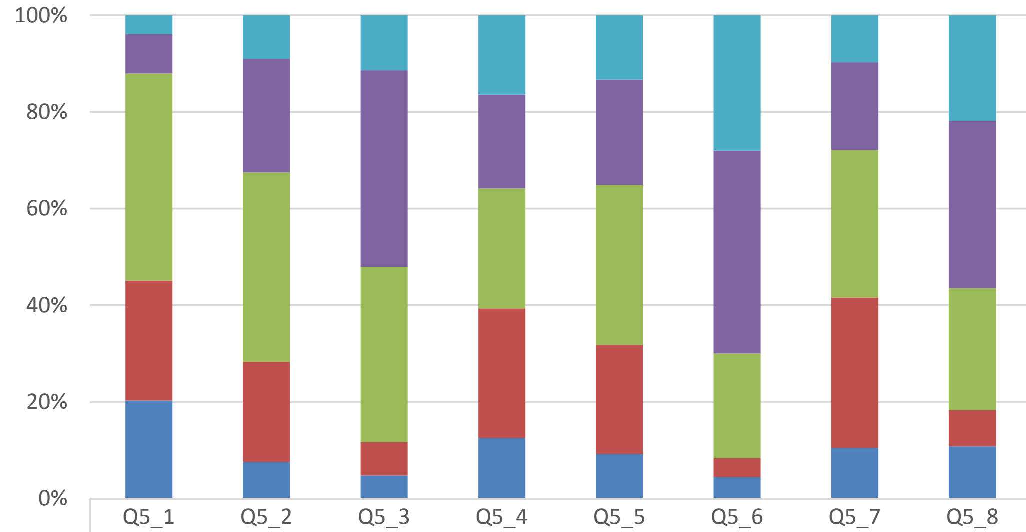
	Q4_1	Q4_2	Q4_3	Q4_4	Q4_5	Q4_6
Already Doing	67%	55%	67%	57%	48%	70%
Will Definitely Try	8%	9%	10%	15%	17%	16%
Likely to Try	7%	14%	10%	15%	18%	8%
Might Try	9%	13%	7%	8%	11%	4%
Not at All	8%	8%	6%	5%	6%	1%

Q4_1	Keep my thermostat at or below 68ºF during the winter
Q4_2	Install a programmable/smart thermostat
Q4_3	Install high-efficiency light bulbs (LED or CFL)
Q4_4	Replace an old furnace or water heater with a high efficiency model
Q4_5	Seal heating and cooling ducts
Q4_6	Select Energy Star appliances when purchasing

We would like to know more about your thoughts on wind turbines

5. To what extent do you agree or disagree with the following statements?

Wind turbines…

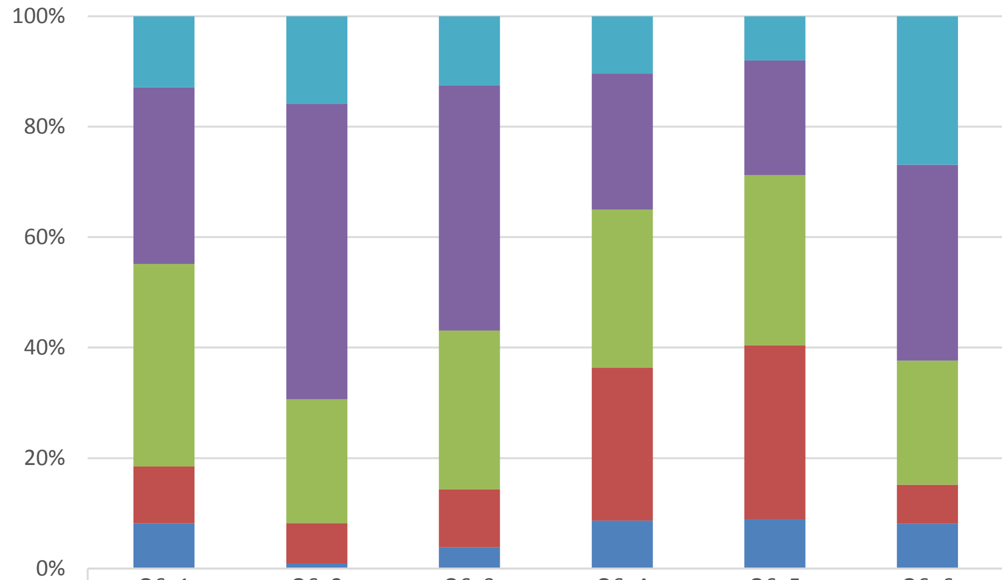


	Q5_1	Q5_2	Q5_3	Q5_4	Q5_5	Q5_6	Q5_7	Q5_8
Strongly Agree	4%	9%	11%	16%	13%	28%	10%	22%
Agree	8%	24%	41%	19%	22%	42%	18%	35%
Neutral	43%	39%	36%	25%	33%	22%	30%	25%
Disagree	25%	21%	7%	27%	23%	4%	31%	7%
Strongly Disagree	20%	8%	5%	13%	9%	4%	11%	11%

Q5_1	(Wind turbines) Increase property values
Q5_2	Create a disturbing noise
Q5_3	Allow multiple land uses
Q5_4	Are an unattractive feature
Q5_5	Are a danger to wildlife
Q5_6	Provide a safe energy source
Q5_7	Are an unreliable electricity source
Q5_8	Are a good way to lessen climate change

We would like to know more about your thoughts on solar panels

6. To what extent do you agree or disagree with these statements? *Solar Panels…*

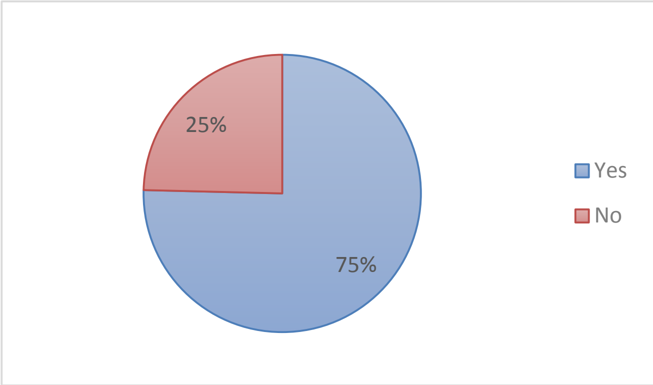


	Q6_1	Q6_2	Q6_3	Q6_4	Q6_5	Q6_6
Strongly Agree	13%	16%	13%	10%	8%	27%
Agree	32%	53%	44%	25%	21%	35%
Neutral	37%	22%	29%	29%	31%	23%
Disagree	10%	7%	11%	28%	31%	7%
Strongly Disagree	8%	1%	4%	9%	9%	8%

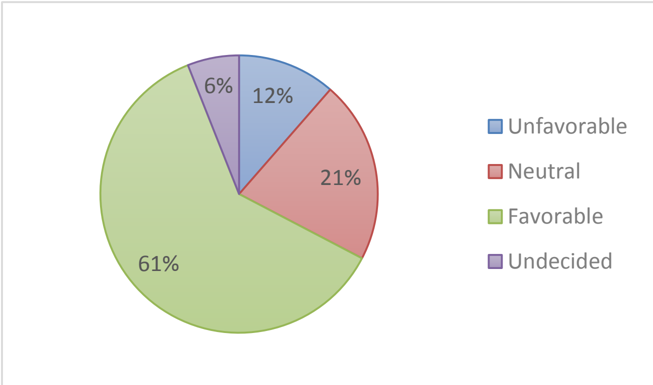
Q6_1	(Solar Panels) Increase property values
Q6_2	Are expensive to purchase and install
Q6_3	Provide insurance against rising electricity prices
Q6_4	Are unattractive
Q6_5	Are an unreliable electricity source
Q6_6	Are a good way to lessen climate change

Renewable Energy in Leelanau Township

7. Are you aware of the wind turbine at the Waste Water Treatment Plant in Northport?



If Yes **→ 7a. What is your opinion of it?**

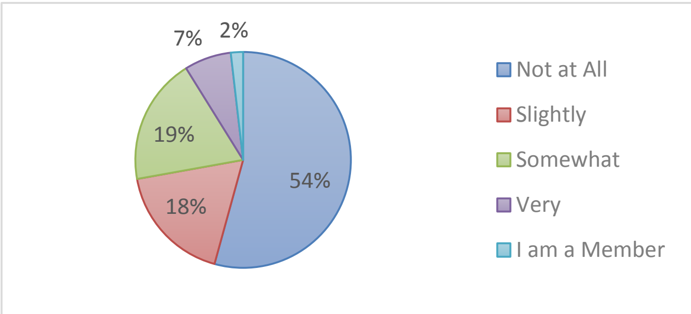


About Northport Energy Action Taskforce (NEAT)

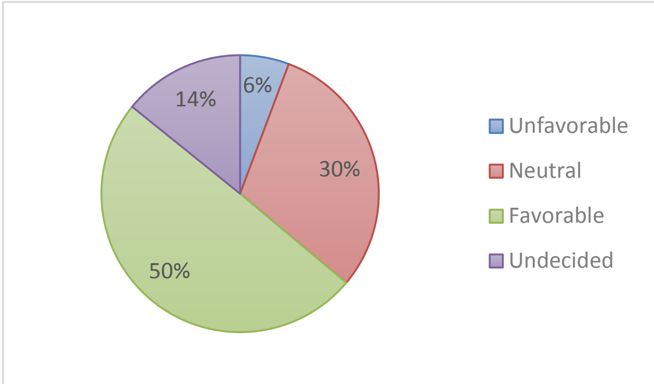
8. What other renewable energy projects are you aware of in Leelanau Township/Northport?

Written comments.

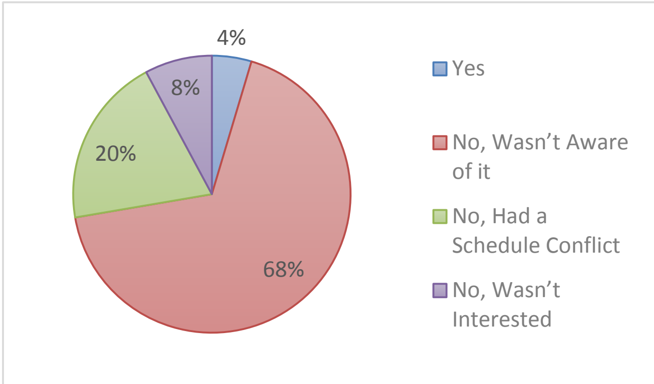
9. Before receiving this survey, how familiar were you with the Northport Energy Action Taskforce (NEAT)?



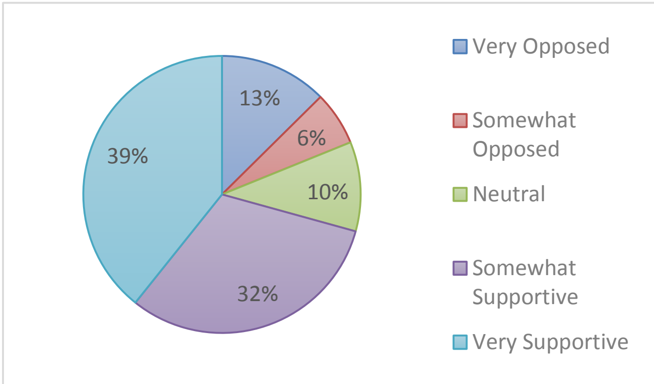
10. What's your opinion of NEAT?



11. Did you attend the NEAT Community Event on either July 16th or July 30th?



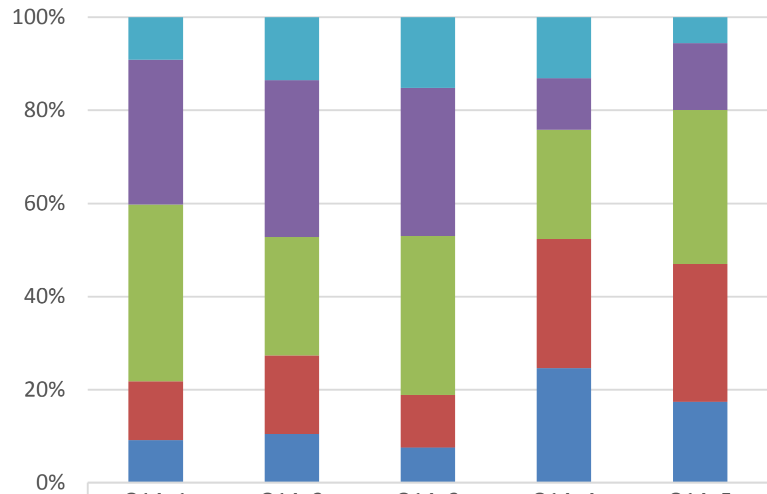
12. How supportive would you be of a plan to achieve 100% renewable energy?



13. Why do you feel that way?

Written comments.

14. Based on what you read above, to what extent do you agree or disagree with the following statements?

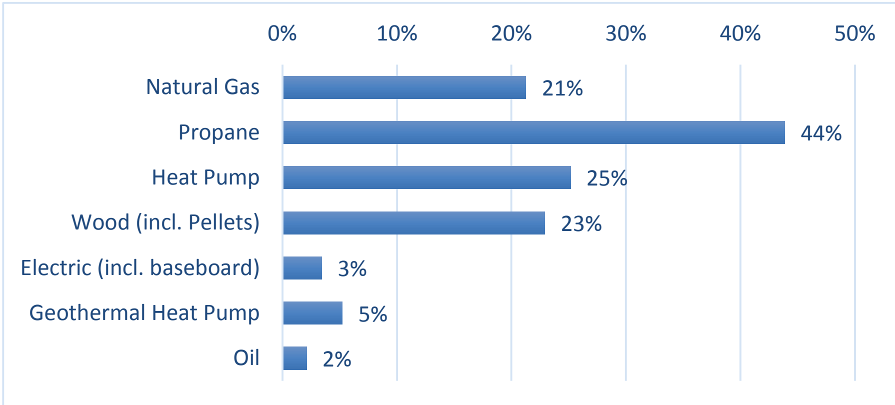


	Q14_1	Q14_2	Q14_3	Q14_4	Q14_5
Strongly Agree	9%	14%	15%	13%	6%
Agree	31%	34%	32%	11%	14%
Neutral	38%	25%	34%	24%	33%
Disagree	13%	17%	11%	28%	30%
Strongly Disagree	9%	10%	8%	25%	17%

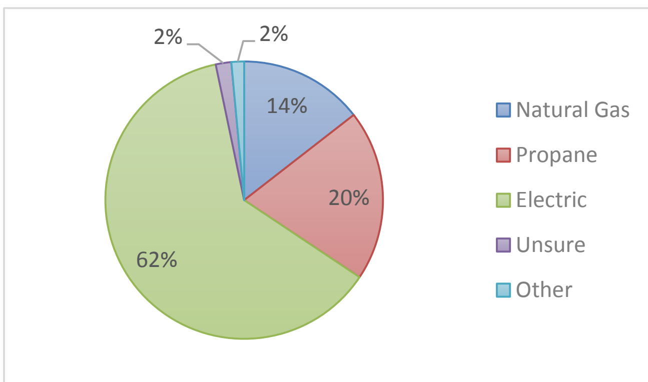
Q14_1	I would like to participate in the development of the community renewable energy plan
Q14_2	I am interested in learning whether my home is suitable for solar panels
Q14_3	My friends and family would respond positively if I installed solar panels at my residence
Q14_4	Residential wind turbines should not be used for the production of electricity within the Township
Q14_5	Michigan doesn't get enough sun to make solar panels worthwhile

Please tell us a little about your home in Leelanau Township

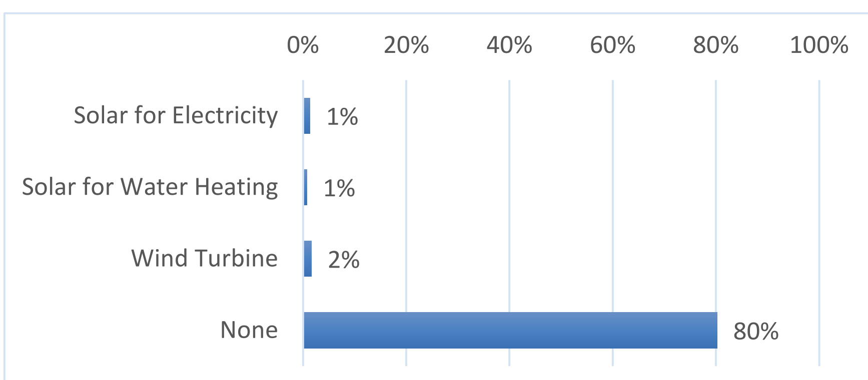
15. Which of the following do you use to heat your home?



16. What type of hot water heater do you have?

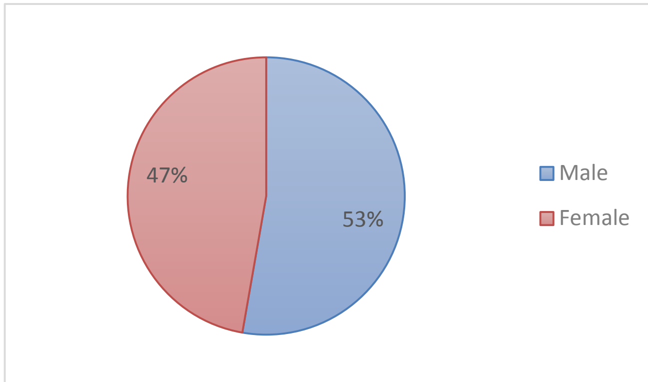


17. What, if any, renewable energy technologies do you have installed at your home?

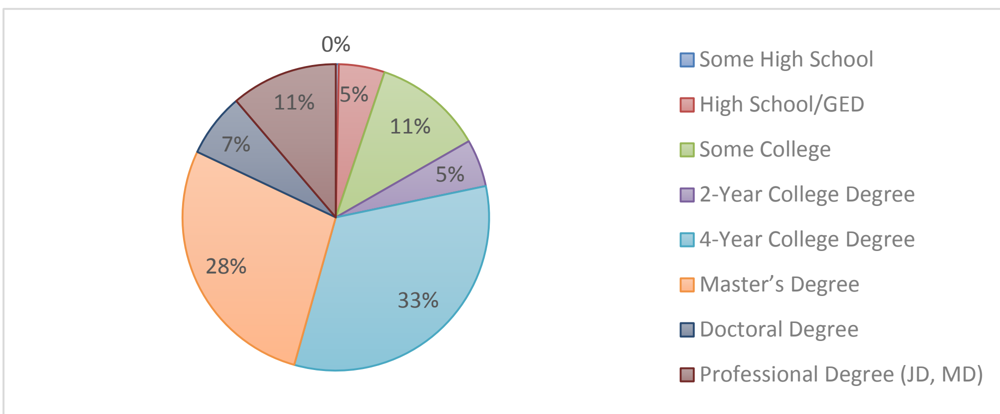


Please tell us a little about yourself

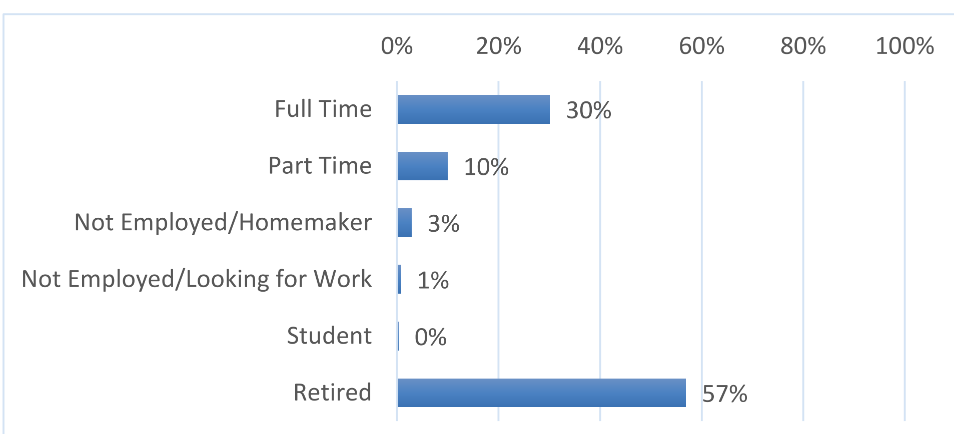
18. What is your gender?



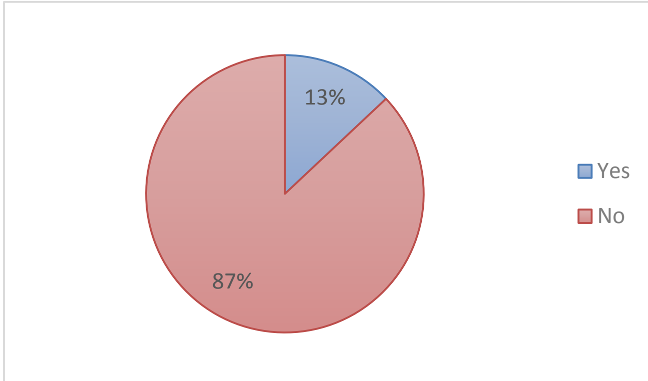
19. What is the highest level of education you have completed?



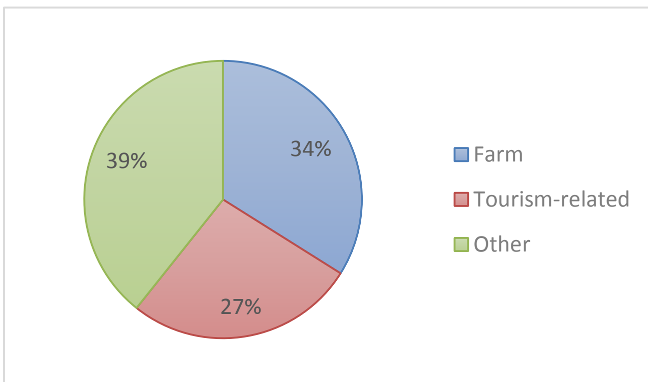
20. What is your employment status?



21. Do you own or operate a business in Leelanau Peninsula?



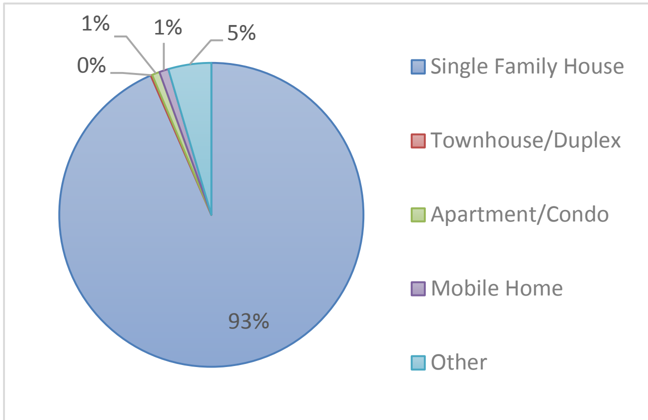
If Yes → 21a. What type of business?



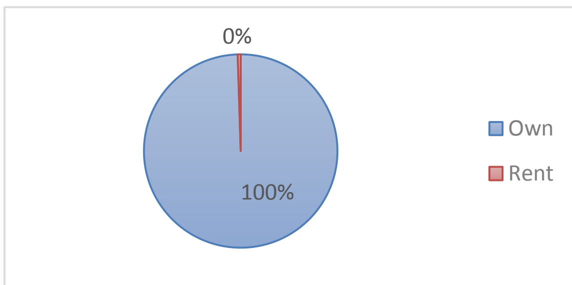
22. How many people are there from each age group in your household?

	Under 18	18-34	35-50	51-65	Over 65
Selected	60	73	55	251	314
Min	1	1	1	1	1
1st Q	1	1	1	1	1
Median	2	2	2	2	2
Mean	1.9	1.841	1.61	1.602	1.61
3rd Q	2	2	2	2	2
Max	5	10	4	6	3

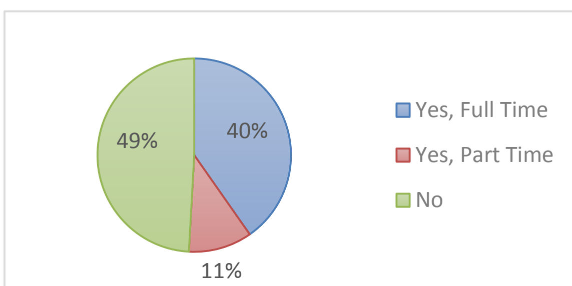
23. How would you describe your home in Leelanau Township/Northport?



24. Do you own or rent your home in Leelanau Township/Northport?



If Own → 24a. Is your home ever used as a vacation rental?

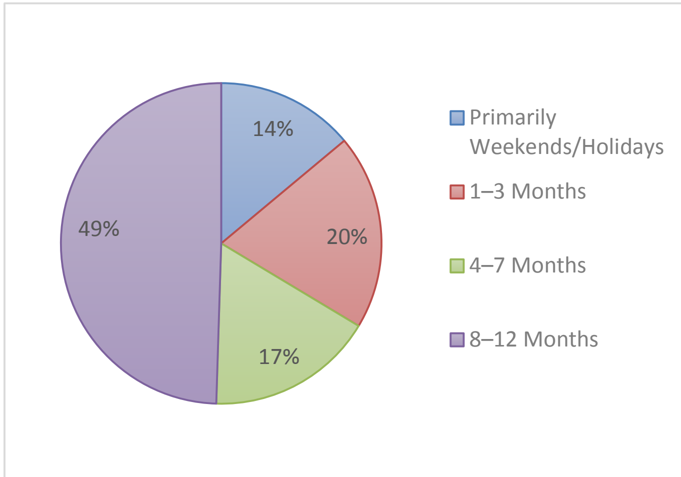


25. How long have you lived in Leelanau Township/Northport?

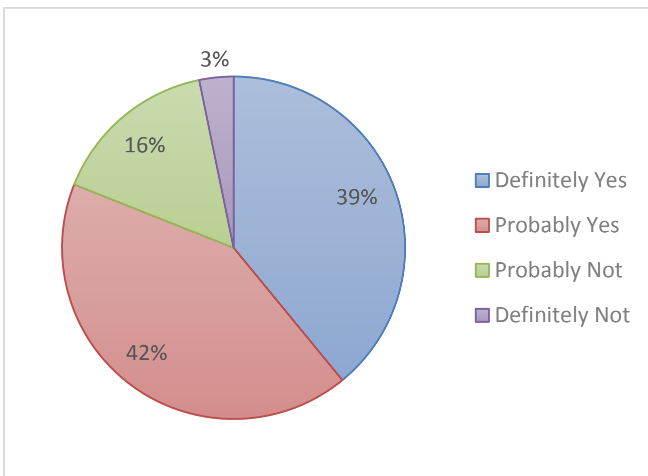
Min	1st Q	Median	Mean	3rd Q	Max	Std. Dev.
0	9	20	22.83	34	88	18.42

(Years)

26. How much time do you typically reside in Northport/Leelanau Township each year?



27. Do you expect to live in Leelanau Township 10 years from now?



Appendix II. Energy Efficiency Calculations

degrees lowered	Annual savings/household	Annual town savings
1	$7	$406.88
2	$14	$813.75
3	$21	$1,220.63
4	$28	$1,627.50
5	$35	$2,034.38

homes in town	930
average heating cost	$700
savings/degree/8 hours	1%
% of town with heat pump	25%

Table 22 Current Use

residential electricity used	15385170	kWh
ave. lighting use	658998.1	Kwh
town	75.1766	kW each hour
electricity cost	0.12	$/kWh

Table 23 Calculations

	Incandescent	LED	CFL
# bulbs needed	2225	2225	2225
cost	$140,404.58	$18,720.61	$30,420.99
# bulbs/yr	7.31	0.18	1.10
cost/bulb	$0.66	$9.97	$2.00
cost for bulbs	$1,468.22	$22,179.03	$8,898.31
rebate $/bulb		$0.00	$0.00
savings		$0.00	$0.00
bulb cost w/rebate		$22,179.03	$8,898.31
total cost	$140,404.58	$40,899.64	$39,319.30

No rebate 100% high efficiency bulbs

Table 24 Initial Conditions

	Incandescent	LED	CFL
% of total bulbs	0.3	0.21	0.49
current bulbs	878	614	1433

Table 25 All CFL costs

A new amount of bulbs	0	614	2311
cost for new bulbs	$0.00	$0.00	$3,510.19
cost of electricity		$5,169.42	$31,601.14
rebate savings			$0.00
total cost	$0.00	$5,169.42	$35,111.33 A
current electricity cost	$55,386.61	$5,169.42	$19,600.71

Table 26 All LED

new amount of bulbs	0	1492	1433
cost for new bulbs	$0.00	$8,749.15	$0.00
cost of electricity	$0.00	$12,554.30	$19,600.71
rebate savings	$0.00	$0.00	$0.00
total cost	$0.00	$21,303.45	$19,600.71

Table 27 Half CFL half LED

new amount of bulbs	0	1053	1872
cost for new bulbs	$0.00	$4,374.58	$1,755.10
cost of electricity	$0.00	$8,861.86	$25,600.92
rebate savings	$0.00	$0.00	$0.00
total cost	$0.00	$13,236.43	$27,356.02

Table 28 no rebate 100% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	76	$80,156.74	0.1693	$178.13
all CFL	35	$40,280.75	0.0777	$89.51
all LED	31	$40,904.16	0.0679	$90.90
half of each	33	$40,592.45	0.0728	$90.21

Table 29 no rebate 75% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
Current	101	$106,273.06	0.2245	$236.16
all CFL	36	$43,136.08	0.0794	$95.86
all LED	29	$44,123.15	0.0639	$98.05
half of each	32	$43,629.61	0.0717	$96.95

Table 30 no rebate 50% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
Current	126	$132,389.39	0.2797	$294.20
all CFL	36	$45,991.41	0.0811	$102.20
all LED	27	$47,342.14	0.0600	$105.20
half of each	32	$46,666.78	0.0705	$103.70

Table 31 no rebate 25% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	151	$158,506	0.3348	$352
all CFL	37	$48,847	0.0828	$109
all LED	25	$50,561	0.0560	$112
half of each	31	$49,704	0.0694	$110

Full rebate

Table 32 Full rebate 100% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	76	$80,156.74	0.1693	$178.13
all CFL	35	$39,403.20	0.0777	$87.56
all LED	31	$36,516.42	0.0679	$81.15
half of each	33	$37,521.04	0.0728	$83.38

Table 33 Full rebate 75% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
Current	101	$106,273.06	0.2245	$236.16
all CFL	36	$41,746.63	0.0794	$92.77
all LED	29	$35,786.44	0.0639	$79.53
half of each	32	$38,766.54	0.0717	$86.15

Table 34 Full rebate 50% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	126	$132,389.39	0.2797	$294.20
all CFL	36	$44,090.06	0.0811	$97.98
all LED	27	$35,934.01	0.0600	$79.85
half of each	32	$40,012.04	0.0705	$88.92

Table 35 Full rebate 25% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	151	$158,506	0.3348	$352
all CFL	37	$46,433	0.0828	$103
all LED	25	$36,082	0.0560	$80
half of each	31	$41,258	0.0694	$92

50% rebate

Table 36 50% rebate 100% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	76	$80,156.74	0.1693	$178.13
all CFL	35	$39,403.20	0.0777	$87.56
all LED	31	$38,710.29	0.0679	$86.02
half of each	33	$39,056.74	0.0728	$86.79

Table 37 50% rebate 75% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	101	$106,273.06	0.2245	$236.16
all CFL	36	$41,746.63	0.0794	$92.77
all LED	29	$39,954.79	0.0639	$88.79
half of each	32	$41,198.08	0.0717	$91.55

Table 38 50% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	126	$132,389.39	0.2797	$294.20
all CFL	36	$44,090.06	0.0811	$97.98
all LED	27	$41,638.07	0.0600	$92.53
half of each	32	$43,339.41	0.0705	$96.31

Table 39 50% rebate 25% high efficiency bulbs

	Electricity use (kW)	Cost	Electricity use (kW)/household	Cost/house
current	151	$158,506	0.3348	$352
all CFL	37	$46,433	0.0828	$103
all LED	25	$43,321	0.0560	$96
half of each	31	$45,481	0.0694	$101

Appendix III. Policies & Regulations

Investment Tax Credit Amount

Below is the table about the amount of ITC of different time periods. And we can find that after December 31, 2016, the credit drops significantly to 10% for solar and expires for wind.

Table 40 Amount of Investment Tax Credit for Solar PV and Wind

Renewable Property	Time Placed in Service	Amount of Tax Credit
Solar[13]	Before Jan 1, 2017	30%, no maximum
	After Dec 31, 2016	10%, no maximum
Small wind turbines (up to 100 kW)	Oct 3, 3008 – Dec 31, 2008	30%, maximum $4,000
	Jan 1, 2009 – Dec 31, 2016	30%, no maximum
	After Dec 31, 2016	Expires

Energy Efficiency Incentives

There are a number of incentives for energy efficiency upgrades in residential, small business and nonprofit sectors. Primary ones consist of Residential Energy Efficiency Tax Credit (federal) and Energy Efficiency Grants (Michigan).

Residential Energy Efficiency Tax Credit

The Residential Energy Efficiency Tax Credit is a federal incentive that provides benefits for homeowners to improve energy efficiency in their houses by purchasing new more efficient equipment. Eligible equipment includes water heaters, furnaces, boilers, heat pumps, central air conditioners, building insulation, windows, roofs, circulating fans used in a qualifying furnace. Meanwhile, the aggregate amount of the credit is limited to $500 for purchases made in 2011 – 2014; and that for technologies placed in service in 2009 – 2010 is limited to $1,500. However, the credit expires on December 31, 2014, which means that purchases made after December 31, 2014 are not eligible for the credit.

Energy Efficiency Grants

For small businesses and nonprofit sectors, the statewide Energy Efficiency Grants range from $25,000 to $50,000 are available to cover costs of energy efficiency upgrades. Eligible upgrades

[13] Eligible solar energy property includes equipment that uses solar energy to generate electricity, to heat or cool a structure, or to provide solar process heat. Source: http://programs.dsireusa.org/system/program/detail/658

include water heaters, lighting, lighting controls/sensors, chillers, furnaces, boilers, heat pumps, central air conditioners, heat recovery, programmable thermostats, systems/building controls, duct/air sealing, building insulation, windows, siding, roofs, led exit signs, energy management, LED street lighting, and electric vehicle charging stations. Facility costs are only considered when it can be proven that infrastructure improvements are required to launch the clean-energy technology manufacturing process.

Michigan Saves Loan Program

Home Energy Loan Program (Michigan Saves)

The Home Energy Loan Program (Michigan Saves) is available for owner-occupied, single family homes for energy efficiency improvements as well as renewable energy system adoption, with funding from the Michigan Public Service Commission. Eligible renewable technologies for Residential Michigan Saves include solar water heat, solar thermal electric, photovoltaics, geothermal heat pumps, daylighting. And eligible efficiency technologies include clothes washers, dishwasher, refrigerators, dehumidifiers, ceiling fan, water heaters, furnaces, boilers, heat pumps, central air conditioners, duct/air sealing, building insulation, windows, siding, roofs, room air conditioners, tankless water heaters, heat pump water heaters.

Under the Home Energy Loan Program, "participating lenders offer an unsecured loan for amounts between $1,000 and $30,000, at a fixed annual percentage rate (APR) no higher than 7%, without prepayment penalty". In addition loan terms vary – one year added for every $1,000 up to $4,999; for loans $5,000 and higher, an optional 10-year terms are available.

Business Energy Financing (Michigan Saves)

The Business Energy Financing Program provides loans to some renewable technologies including solar thermal electric and a large number of the energy efficiency improvement for commercial and nonprofit sectors, including solar water heat, solar thermal electric, geothermal heat pumps, and equipment insulation, water heaters, lighting, lighting controls/sensors, chillers , furnaces , boilers, heat pumps, central air conditioners, steam-system upgrades, programmable thermostats, duct/air sealing, building insulation, windows, siding, roofs, room air conditioners, commercial refrigeration equipment, tankless water heaters, heat pump water heaters, infrared heaters, and cool roof. It offers negotiated fast financing up to $250,000 as low as 5.9% for up to 5 years. Also, additional incentives may apply for businesses in the food sector.

Appendix IV. Solar Resource Assessment

Typical Meteorological Year Dataset Elements

The 12 selected typical months of a TMY dataset are determined using statistics defined by considering five elements:

- Global Horizontal Irradiance (GHI) – Represents total solar radiation. It is the sum of the direct normal irradiance (DNI), diffuse horizontal irradiance (DHI), and ground-reflected radiation.
- Direct Normal Radiation (DNR) – Also known as beam radiation, it is the amount solar radiation from the direction of the Sun.
- Dry-Bulb Temperature – Air temperature measured with a thermometer, similar to ambient temperature. The term "dry-bulb" distinguishes it from the wet-bulb temperature used to determine relative humidity.
- Dew Point Temperature – The temperature at which the water in the atmosphere will condense as drops on a surface.
- Wind Speed – Speed measured by the horizontal motion of air near the surface of the Earth.

The data format for TMY files has two file header lines of 8,760 lines of data (representative of the total number of hours in a year), each with 68 data fields. The different elements conforming a TMY file are detailed in the following tables:

Table 1. TMY data header (line 1)

Field	Element	Unit or Description
1	Site identifier code	USAF number
2	Station name	Quote delimited
3	Station state	Two-letter U.S. postal abbreviation
4	Site time zone	Hours from Greenwich, negative west
5	Site latitude	Decimal degree
6	Site longitude	Decimal degree
7	Site elevation	Meter

Source: (Wilcox & Marion, 2008)

Table 1.2 TMY data header (line 2)

Field	Element
1-68	Data field name and units (abbreviation or mnemonic)

Table 1.3 TMY data fields

Field	Element	Unit or Range	Resolution	Description
1	Date	MM/DD/YYYY	--	Date of data record
2	Time	HH:MM	--	Time of data record (local standard time

3	Hourly extraterrestrial radiation on a horizontal surface	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation received on a horizontal surface at the top of the atmosphere during the 60-minute period ending at the timestamp
4	Hourly extraterrestrial radiation normal to the Sun	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation received on a surface normal to the Sun at the top of the atmosphere during the 60-minute period ending at the timestamp
5	Global horizontal irradiance	Watt-hour per square meter	1 Wh/m^2	Total amount of direct and diffuse solar radiation received on a horizontal surface during the 60-minute period ending at the timestamp
6	Global horizontal irradiance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates
7	Direct normal irradiance	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation (modeled) received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
8	Direct normal irradiance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates
9	Diffuse horizontal irradiance	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
10	Diffuse horizontal irradiance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates
11	Global horizontal illuminance	Lux	100 lx	Average total amount of direct and diffuse illuminance received on a horizontal surface during the 60-minute period ending at the timestamp
12	Global horizontal illuminance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates
13	Direct normal illuminance	Lux	100 lx	Average amount of direct normal illuminance received within a 5.7” field of view centered on the Sun during 60-minute period ending at the timestamp
14	Direct normal illuminance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates
15	Diffuse horizontal illuminance	Lux	100 lx	Average amount of illuminance received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
16	Diffuse horizontal illuminance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates

17	Zenith luminance	Candela per square meter	10 cdm/m^2	Average amount of luminance at the sky's zenith during the 60-minute period ending at the timestamp
18	Zenith luminance uncertainty	Percent	1%	Uncertainty based on random and bias estimates
19	Total sky cover	Tenths of sky	1 tenth	Amount of sky dome covered by clouds or obscuring phenomena at the time indicated
20	Opaque sky cover	Tenths of sky	1 tenth	Amount of sky dome covered by clouds or obscuring phenomena that prevent observing the sky or higher cloud layers at the time indicated
21	Dry-bulb temperature	Degree C	0.1°	Dry-bulb temperature at the time indicated
22	Dew-point temperature	Degree C	0.1°	Dew-point temperature at the time indicated
23	Relative humidity	Percent	1%	Relative humidity at the time indicated
24	Station pressure	Milibar	1 mbar	Station pressure at the time indicated
25	Wind direction	Degrees from north (360° = north; 0° = undefined, calm)	10°	Wind direction at the time indicated
26	Wind speed	Meter/second	0.1 m/s	Wind speed at the time indicated
27	Horizontal visibility	Meter*	1 m	Distance to discernible remote objects at the time indicated (7777 = unlimited)
28	Ceiling height	Meter*	1 m	Height of the cloud base above local terrain (7777 = unlimited)
29	Precipitable water	Centimeter	0.1 cm	The total precipitable water contained in a column of unit cross section extending from the Earth's surface to the top of the atmosphere
30	Aerosol optical depth, broadband	[unitless]	0.001	The broadband aerosol optical depth per unit of air mass due to extinction by aerosol component of the atmosphere
31	Albedo	[unitless]	0.01	The ratio of reflected solar irradiance to global horizontal irradiance
32	Liquid precipitation depth	Milimeter*	1 mm	The amount of liquid precipitation observed at the indicated time for the period indicated in the liquid precipitation quantity field
33	Liquid precipitation quantity	Hour*	1 hr	The period of accumulation for the liquid precipitation depth field

*Value of -9900 indicates the measure is missing

Source: (Wilcox & Marion, 2008)

Appendix V. Wind Resource Assessment

Turbine evaluation set

Since some sites are windier than others, manufactures design their wind turbines for specific 'wind classes' designated by the International Electrotechnical Commission (IEC. IEC 61400-1 Standard applies to wind turbines design requirements and categorizes them into different classes according to typical mean wind speeds and turbulence intensities (Table XX). These parameters can be generally used during the design process of wind turbines and do not represent specific sites.

Table . Wind turbine classes according to IEC 61400-1

Wind turbine class	I	II	III	IV
V (m/s)	10	8.5	7.5	6
Class A turbulence intensity	0.16			
Class B turbulence intensity	0.14			
Class C turbulence intensity	0.12			

According to the U.S. Department of Energy's 2013 Wind Technologies Report, Class III wind turbines have become very popular in recent years, with more than 90% of turbines installed in the U.S. in 2013 being Class III units. Class II turbines are generally designed for medium-wind-speed sites and Class III turbines are suited for lower-wind-speed sites.

The wind assessment showed that average wind speeds at both locations are in a range of 7.9 – 8.1 m/s. With this in mind, in order to assess the wind energy resources at both stations, we chose IEC II and III wind turbines for potential installation in Leelanau Township, available in the SAM software package.

- Mitsubishi MWT-1000-61 – 1 MW
- Vestas 90m – 2.0MW
- Suzlon88
- GE 2.5xl
- Siemens SWT-3.0-101 MW

A summary of important specifications of the turbines is provided in:

Table . Wind turbine parameters

Parameters	Mitsubishi MWT-1000-61	Vestas 90-2.0 MW	Suzlon 88	GE 2.5xl	Siemens SWT-3.0-101 MW
Wind turbine class	IEC-III	IEC-IIIA	IEC-IIA	IEC-IIB	IEC-IIB

Rated Power (kW)	1,000	2,000	2,100	2,500	3,200
Hub height (m)	50	80	80	80	99.5
Rotor Diameter (m)	61.4	90	88	100	101
Cut-in/Cut-off Speeds (m/s)	3.0 /25	4 / 25	3.9 / 25	3.0 / 25	3.0 / 25
Rated Wind Speed (m/s)	12.5	12	13	12.5	12

Turbulence

Turbulence is an important parameter to estimate while performing a wind assessment of a site, since it indicates how gusty a wind site is, or, in other words, how often the site gets sudden, brief increases in the speed of the wind. Turbulence is a cause of a wind's flow disruption by local obstructions like trees and buildings and can be defined as rapid fluctuations in wind speed and direction. Turbulence intensity is defined as the ratio between the standard deviation and mean value of the wind speed during a 10-minute period. We considered the Turbulence Intensity factor (TI) of 16%, since the Township has complex terrain with crops fields and hilly areas at the same time. The Grand Traverse Region study provides the values of 15.3% and 16.2% for average turbulence intensity for GT Resort and Long Lake sites respectively. In addition, we assumed that the hilly areas are well exposed and that taller towers will significantly reduce wind shear and turbulence.

Wind losses

We estimated the electricity generation with availability, electrical, turbine performance and environmental losses. Since it is difficult to accurately estimate these losses, we assumed the typical value for the loss rate. Furthermore, since we assumed that wind turbines would not be installed in transmission-constrained area, the curtailment had a 0% value. In addition, we assumed that wind turbines would not be installed in proximity to each other; hence the loss for the wake effect is 0%. However, it is important to keep in mind that losses can change over time due to weather fluctuations and specific turbine characteristics.

Table . Loss categories and typical values

Loss category	Low	Typical	High
Wake effects, %	3	6.7	15
Availability, %	2	6.0	10
Electrical, %	2	2.1	3
Turbine performance, %	0	2.5	5

Environmental, %	1	2.6	6
Curtailments, %	0	0	5
Total losses, %	7.8	18.5	37.0

Source: Brower

Analysis

We analyzed the available wind data in order to determine the correlations between the measurements, the monthly variations and the wind distributions.

Measure-Correlate-Predict (MCP) Regression

We used the binned linear regression Measure-Correlate-Predict method to estimate long-term behavior of the wind resource. We correlated the data from GTLM4 weather station with data from NREL #5579 station over the years 2007 to 2014.

The analysis showed that there are strong correlations between the daily mean wind speeds at GTLM4 and NREL simulated station #5579 (R^2=0.81). That gave us confidence to proceed with further analysis. We assumed that all sites are exposed to the same general wind climate.

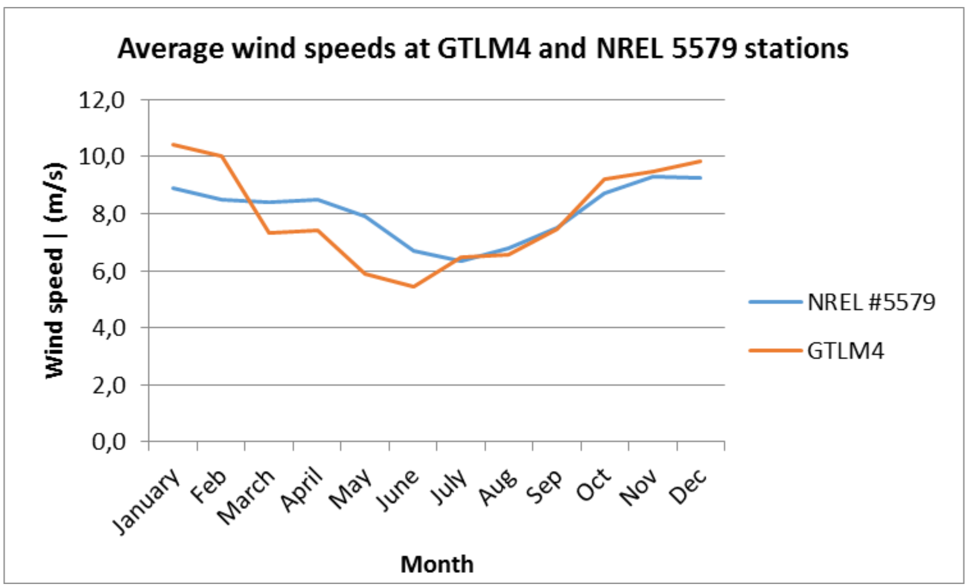


Figure . Average wind speeds at GTLM4 and NREL #5579 stations

Wind distributions

The measured wind data at 80 m from two stations was transformed into the Weibull distributions and is presented in Figures [X]. Weibull distribution represents a family of probability distributions commonly used within the wind industry and describes how the wind speed varies over time at a particular location. It can be seen that GTLM4 weather station has a better agreement between measured wind distributions and the Weibull fits than a simulated NREL #5579 wind results.

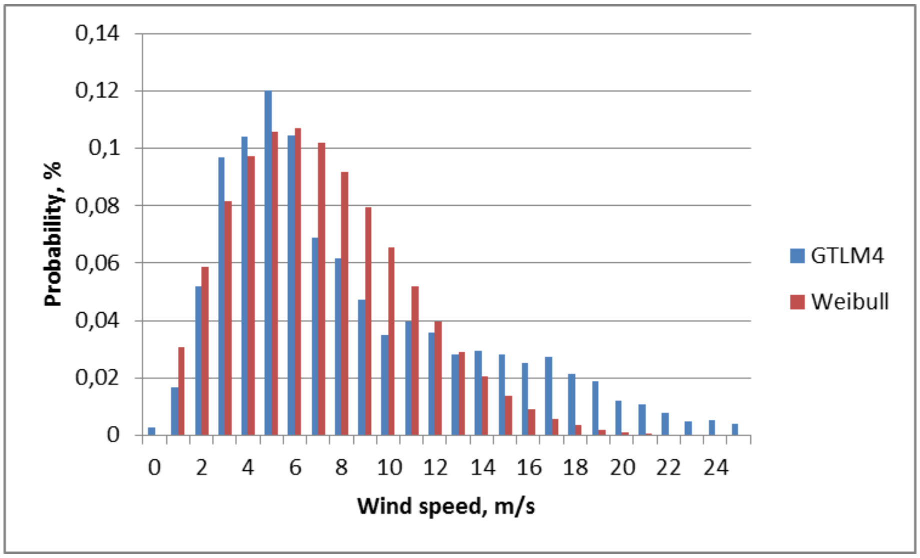


Figure . Weibull distribution for GTLM4 station, k = 2, A = 8 m/s

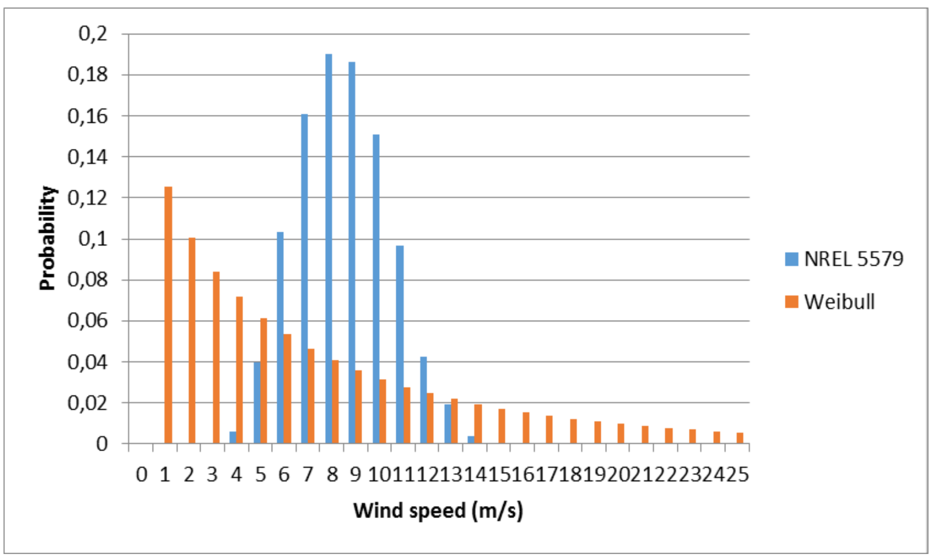


Figure . Weibull distribution for NREL #5579, station, k = 0.9, A = 7.5m/s