Bringing Wind Power to Local Communities

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ABSTRACT

Center for Sustainable Community Development (CSCD) has been working with three local communities to advance their wind power initiatives; the Grand Portage Indian Reservation, Proctor School District, and the city of Duluth. All three of the communities were working toward the installation of a community-owned wind turbine. At the time the CCRR money was awarded, each community was at a different stage of the process, some just beginning and some further along. The CSCD assisted these communities by working with community partners and providing technical assistance. We gathered wind speed data, conducted wind analyses, selected sites for the turbines, and researched turbines to determine the best fit for their wind resource.

INTRODUCTION

The mission of the Center for Sustainable Community Development (CSCD) is to help communities transition from global dependence to community self reliance by designing and implementing economically attractive as well as socially and environmentally sustainable local energy production systems. These efforts include a detailed analysis of the technical capabilities and economic potential associated with many emerging renewable energy production technologies as well as the sociopolitical aspects tied to community decision making and implementation. In our work with these new technologies and communities the practical and academic results come in an integrated fashion as demonstrated by the three community wind projects described below.

Grand Portage Reservation has been measuring their wind speed for over 2 years. They originally measured the wind on Mt. Maud with a grant from the National Renewable Energy Lab (NREL). After the data was collected, the CSCD assisted them in conducting a feasibility study and wind analysis. We found their wind to be very promising, with an average wind speed of 14 mph. However, when we began the process of researching and choosing a turbine, we encountered some problems with the site. Mt Maud is one of the highest points on the Reservation, however it is difficult to access and is 6 miles from an existing power line. This information led us to measuring the wind on another peak that is not as prominent, but is easier to access and closer to an existing power line. We will compare the costs and benefits of installing at each location.

We were measuring the wind at 5 locations around the city of Duluth at the start of the CCRR project. We had anemometers installed at Enger Tower, Park Point Fire Hall, the Duluth Aerial Lift Bridge, Chester Bowl Ski Jump and Spirit Mountain. During the study, we determined Enger Tower to be the best location, due to wind speeds, accessibility, height and local community support. We have been measuring the wind at Enger Tower for over a year and are collecting promising data.

At the time we received our grant from the CCRR, Proctor High School had measured the wind, chosen a turbine, and was ready to install. Throughout the next several months, the CSCD assisted them in the installation of Jacobs 20 kW turbine. Furthermore, the CSCD, along with Susan Santone of Creative Change Solutions, has been working with teachers from the Proctor School District to integrate renewable energy concepts into their curriculum. In the Fall of 2006, they installed a 20 kW wind turbine on their school’s campus. The CSCD will continue working with Proctor to provide content and work along side teachers while they develop new curriculum to incorporate renewable energy and conservation concepts into their teaching.

RESEARCH OBJECTIVES

This project was designed to achieve three main objectives. These three objectives are described in further detail below.

1) Measuring the Wind

The first objective was to obtain an accurate measure of the wind speed at Proctor, Duluth and Grand Portage. Currently, there exists only wind maps produced by the State Department of Commerce, which do not provide site-specific wind information. The wind speeds on State maps are extrapolated over several miles and therefore, not as accurate. Providing communities with a precise description of their wind resource will empower them and enable them to make more-informed decisions.

2) Determining Economic Feasibility

The second objective was to conduct an economic feasibility study to determine the wind development potential at each site. Once we obtain a sufficient amount of wind data at each site, we conduct an economic feasibility study to determine the upfront and long-term costs and benefits of developing the wind resource. We work with each community to decide which turbine will work best with their wind resource, consumption patterns and budget (ie. Proctor decided to install a 20 kW turbine while Grand Portage has decided to install a 1-2 MW turbine).

3) Involving Community Partners

The final objective was to attract and involve local partners from each community. We believe it is extremely important to rally community support for the wind projects we are working on. In order to alleviate resistance to the installation of a wind turbine, it is important not only to educate the community, but also to involve them in every step of the process. This way they feel ownership over the project and are invested in the final outcome.

METHODOLOGY

1) Measuring the Wind

Literature Review

We began by conducting a literature review. We thought it would be a good way to gain perspective into the equipment, methodology, and software used in previously performed wind resource studies. We reviewed case studies of projects conducted using a similar methodology, which is to measure the wind on-site and extrapolate the data across a region. Our goal was to gain an understanding of the practices and techniques that are most widely-used and effective in measuring and analyzing the wind.

The National Renewable Energy Lab (NREL) and Windustry have many resources and case studies available on measuring the wind. Throughout our project, we often referenced the *Wind Resource Assessment Handbook: Fundamentals for Conducting a Successful Monitoring Program* that was put out by NREL. It describes the industry standards that should be followed when measuring site specific wind.

Site Selection

The first step in measuring the wind is site selection. The National Renewable Energy Lab (NREL) suggests that when selecting sites, there are three steps to consider. First, identify potential wind development sites, then inspect and rank the potential sites, and lastly, select the actual tower location(s) from the candidate sites. Other steps to consider in the site selection process include the use of existing wind data and the analysis of topographic maps

When measuring site-specific data, the following should be determined and considered: station location, local topography, anemometer height and exposure, type of observation (instantaneous or average), and the duration of record. Data is more representative of the surrounding area where the terrain is generally flat. When complex terrain is present, it is difficult to extrapolate the information beyond the station with a high degree of reliability. For example, airport data near runways is more reliable than rooftop measurements, where nearby buildings can interfere and influence the wind data.

Equipment Installation

The necessary tools for this project include anemometers to measure the wind speed and data loggers to record the data. For this equipment, the CSCD used Vortex Inspeed anemometers and MadgeTech Pulse 110 data loggers. The method of installation varies depending on the size and shape of the structure on which we are mounting the equipment.

For our project, the Vortex Inspeed anemometers were typically installed on an existing structure at the maximum height possible. If measuring for the installation of a specific wind turbine, the anemometer would be mounted at the hub height of the prospective turbine. In order to avoid disturbance or obstruction of the wind speeds, anemometers should be 10 feet above any surrounding structures, such as trees or buildings. If mounted off the side of an existing tower they should be placed a minimum of three times the tower diameter away from the tower. The CSCD mounted anemometers on towers ranging from 85 to 120 feet and extended the anemometers approximately 10 to 15 feet above the roof, and 6 feet off the side.

The MadgeTech Pulse 110 data loggers are wired to the anemometers and dropped down the tower to an easily accessible location. The data loggers are securely fastened to the towers and protected from the elements of wind, cold and rain.

Data Retrieval

At each site location, data is retrieved from the field once or twice a month. At least two members of the CSCD work together to collect the data by either climbing a tower or gathering the data from a logger attached at the ground. A new data logger is programmed to begin collecting data. The CSCD then removes the old data logger and replaces it with a new one. The old, data-filled logger is brought back to the office for analysis.

Data Analysis

The data loggers are set at to record data at 10 minute intervals, which is the international standard for wind measurement. The loggers record the number of pulses (complete rotation of the anemometer) in a 10 minute interval. The minimum recommended time period for monitoring the wind energy potential of a site is one year (NREL). One year of data is necessary to capture the seasonal variations of the wind.

After the data loggers are retrieved from the field, we download, print a validation sheet, and save the data using MadgeTech software. Then the data is exported to Microsoft Excel. Once in Excel the number of pulses is converted to miles per hour using the following equation supplied by MadgeTech. Daily averages are then calculated by summing the 10-minute interval averages and dividing by the number of these 10 minute intervals in a day.

$$MPH = \# \text{ of pulses} / \# \text{ of seconds in the interval} * 2.5$$

For 10 minute intervals, the equation would look like this:

$$MPH = \# \text{ of pulses} / 600 * 2.5$$

Wind speed and directional data are then collected from regional airports for validation. For this project, the Duluth International Airport and Grand Marais Airport were used. The airport data was retrieved using the National Oceanic and Atmospheric Association (NOAA) website (www.noaa.gov/). Each site has corresponding airport daily averages that serve as a comparison and verification for our data. At the end of each month, the data is presented and analyzed by the project team, who try to assess and isolate any problems in the data. As the NREL Wind Resource Assessment Handbook suggests, we are aiming for a 90% data recovery or no more than 3 days of missing data per month.

2) Determining Economic Feasibility

The community economic feasibility studies will cover the following:

Estimating Potential Revenues:
1. Analyze wind data ('binning' wind speeds, calculating power density adjusting for hub height and wind shear etc..), and calculate wind potential (annual kWh per square meter of swept area)
2. Quantify expected output (kWh per year) from several different wind turbines
3. Determine price per kWh (current rates and purchase agreements with utility)
4. Determine applicability of incentives (green credits, CBED, CREBS etc..)
5. Determine total project revenues (including net present value calculations)

Estimating Project Costs:
1. Wind turbine and tower costs
2. Site prep and installation costs
3. Explore possible interconnect options/costs (demand charges, standby fees, transmission lines etc…) with each communities utility
4. Estimate any insurance, MISO and legal costs
5. Determine total project costs (including net present value calculations)

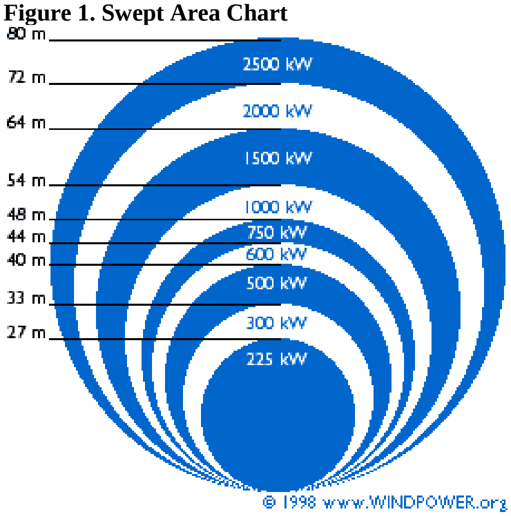
Analyzing the Energy in the Wind

Once we have calculated the daily average wind speeds, we use another method to determine the energy potential in the wind. This method accounts for many different factors influencing the power in the wind. Influential factors include air density, the area intercepting the wind (swept area), wind speed and terrain.

Selecting a Turbine

When choosing a turbine, there are many different issues to consider. How much of a community's total consumption do they want to cover? What size turbine is best suited for their project? Do they need a turbine that operates best with low average wind speeds or high average wind speeds? Once we get all these preliminary questions answered, we can focus on the specifications of potential turbines. The most important feature to consider in a turbine is the rotor diameter, which in turn gives you the "swept area" or the area of the turbine intercepting the wind and capturing the power. (See Figure 1 below) It is also important to know the efficiency of the turbine, or what percentage of the total energy captured is processed into usable energy. There are many other elements to look at when selecting a turbine, including generator size, number of blades, tower type, height and cost.

Figure 1. Swept Area Chart



3) Involving Community Partners

The CSCD has engaged several community stakeholders and empowered them to accomplish major local economic development and educational initiatives in the area of renewable energy. The process is a perfect example of the benefits of partnerships between the community and the university. Within the communities, numerous and diverse stakeholders came together around these projects and grew increasingly excited about their potential. As a result of these projects many bridges were built between partners in ways that will launch similar initiatives within these communities and in many other communities across NE MN.

At all three of our sites, we have a base of local support and it is our hope that the community will begin generating action around the installation of wind turbines. The CSCD realizes that there is only so much we can do to move these wind projects forward. Once we have measured the wind and conducted an economic feasibility study, we will continue to act as a resource and information-provider for the communities. However, in order for these projects to be a success, we need to build leaders within the community. This will ensure the sustainability of the project. A wind turbine is a long-term investment that would best be managed by the community, not an outside entity.

We are learning the value of involving the community from the first step of the process and keeping them involved throughout. This way they feel ownership over the project and are more invested in seeing it through. Community involvement from the start could also help to mitigate local resistance to the project.

The CSCD has researched the communities that we will be working with throughout the wind study. We determined a few key points to focus on while we were doing our research to give us an idea of the community profiles. We will attempt to achieve some or all of the following tasks for each community:

1) Identify the key contacts in each community. Who are the power players in the community? Who supports renewable energy / environmental issues?
2) Develop relationships with community members. Who do we already know? How will we make contact with people?
3) Gather census data / demographic information for the community. What socio-economic statistics will be relevant to our study? (ie. income, unemployment, education, etc.)
4) Identify the major energy consumers in the region. Are there businesses or industries using large amounts of energy? Does the residential sector contribute significantly to the total energy demand?
5) Collect energy consumption data. What utility company services that region? Is it possible to get access to their records?

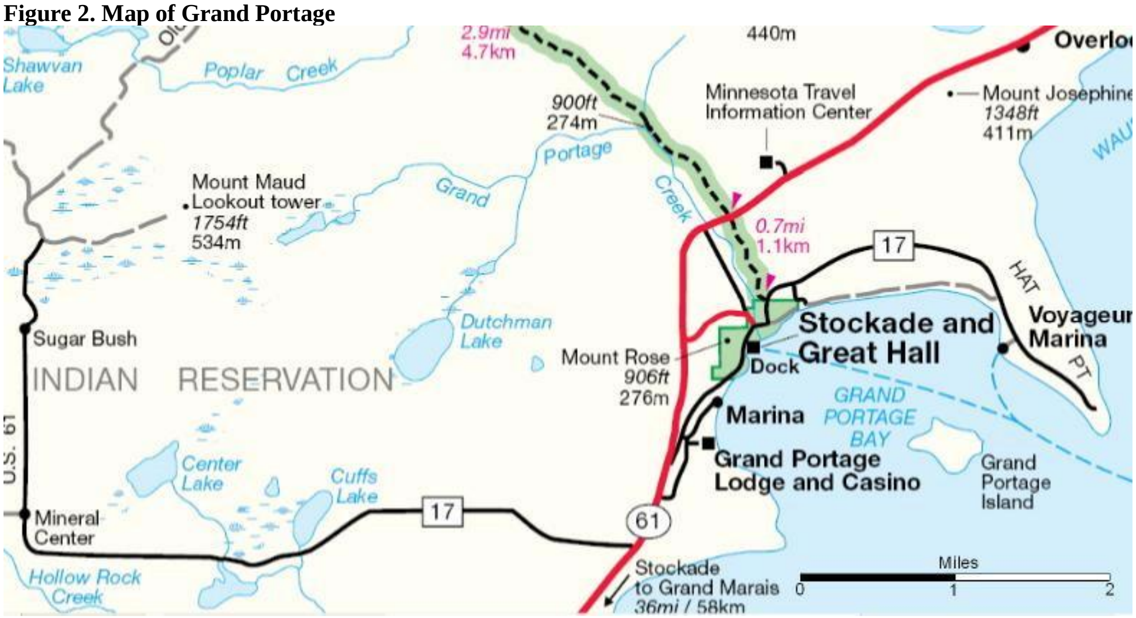
RESULTS / ANALYSIS

1) Grand Portage Reservation

Measuring the Wind

Grand Portage received an anemometer on loan from the National Renewable Energy Laboratory. The anemometer (an NRG Wind Explorer) was installed on Mount Maud in January of 2004, and remained in place for 13 months. According to data gathered during that time period, the location has proven to be a viable wind site. The anemometer was mounted on an existing lookout tower that will be removed if a turbine is implemented. Grand Portage is currently in the process of re-measuring their wind on the WDIO tower on Mt. Maud to rule out any interference the original readings may have experienced due to tower shadowing. They will use three anemometers, spaced 10 m apart, to get a more accurate reading. Mt. Maud is located within the Flaming Maple Ridge and has an elevation of 1754 feet. To access Mt. Maud there are a few miles of unpaved gravel road. The nearest power line is approximately three miles away. The originally measured average annual wind speed was 14.3 mph at 20 meters.

Figure 2. Map of Grand Portage



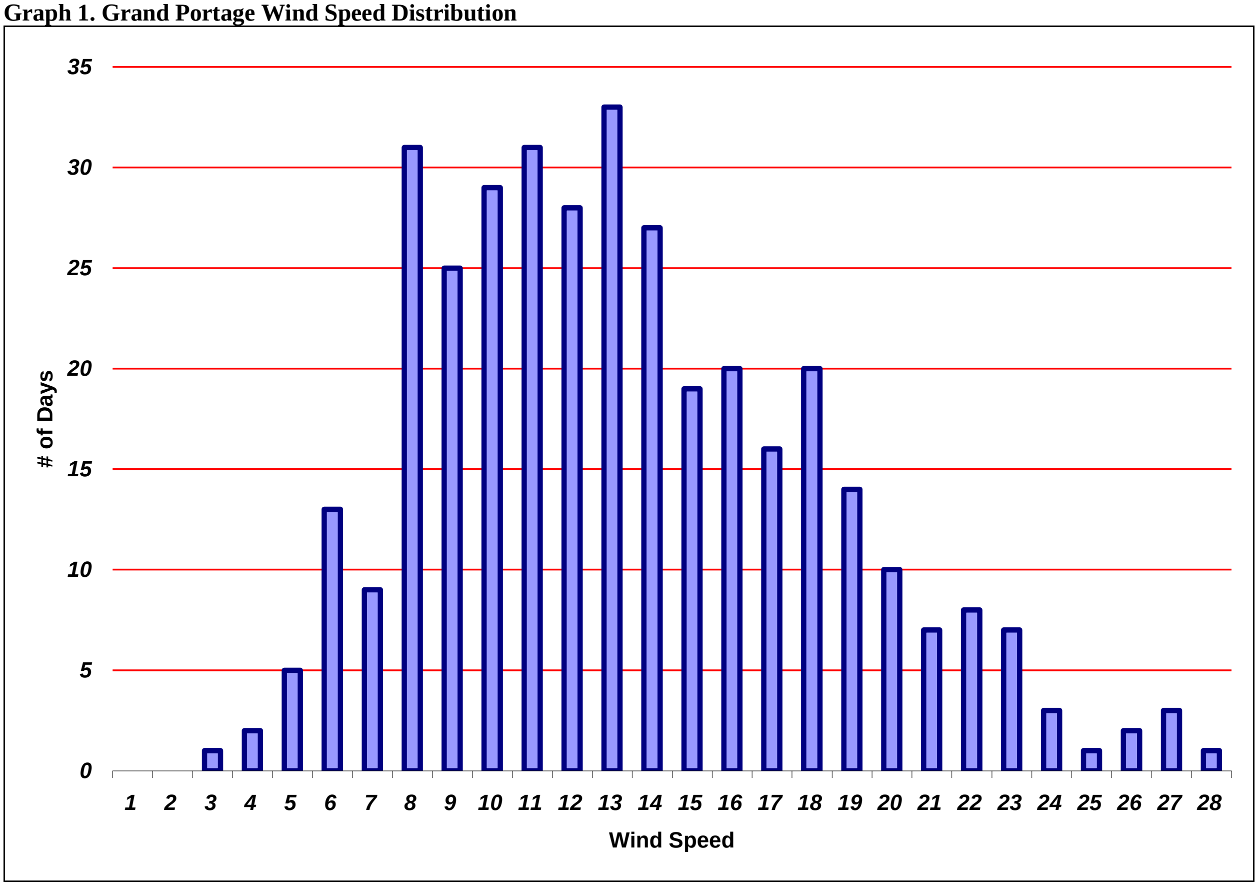
Source: www.nps.gov/applications/parks/grpo/ppmaps/GRPOmap1.pdf

Determining Economic Feasibility

The CSCD completed an economic feasibility study for the Grand Portage Reservation. We used the wind data collected by NREL to determine the amount of energy produced from their wind speeds, as well as the costs and benefits of harnessing that energy by installing a 1-2 MW turbine. The process of conducting the study is described in detail below.

The initial phase of the study was determining Grand Portage's energy potential by analyzing the average wind speeds. The first step is to group an annual set of wind data into wind 'bins.' Wind speeds are sorted into 'bins' of 0.5-1.5 mph, 1.5-2.5 mph, 2.5-3.5 mph, etc. This tells us the number of days in each wind bin. Graph 1 illustrates the distribution of the number of days in each wind speed bin.

Graph 1. Grand Portage Wind Speed Distribution



We then take the percentage of the total days that fall into that particular wind bin and multiply it by the power density (the cube of the wind speed multiplied by air density) and sum these numbers for a total Power Density (W/m²). Examples from three wind bins are shown below in Table 1.

Table 1

Wind Speed Bin	**Number of Days**	**Percentage of Year**	**Power Density** (PD) .5pV^3	**PD*Percentage of Year**
(mph)		*(%)*	*(W/m²)*	
1.5 – 11.5	…	…	…	…
12.5	28	0.076712329	117.1875	8.989726
13.5	33	0.090410959	147.6225	13.34669
14.5	27	0.073972603	182.9175	13.53088
15.5 - 28.5	…	…	…	…
Sum				221.218

Next, we must adjust the Summed Power Density by extrapolating from the original height at which the wind was measured (20 m) to the projected hub height of the wind turbine (60 m). It is also necessary to adjust this number by the wind shear according to the surface roughness of the terrain. The wind sheer exponent for Mt. Maud is approximately .2, given the area's rolling forested terrain. We then multiply the adjusted power density by the number of hours per year (8760) and divide by the number of watts in a kW (1000) to get our final electricity output number in units of kWh/yr/m². This number tells us the annual electrical output we can expect from a turbine, depending on the swept area and efficiency of the turbine. The overall calculation is shown in Table 2.

Table 2

Summed PD	**Orig. Ht.**	**Hub Ht.**	**Wind Sheer**	**Adj. PD** (H/Ho)^(3*α)*Po	**Output/m²**
(W/m²)	*(m)*	*(m)*	*Exp (α)*	*(W/m²)*	*(kWh/yr/m²)*
221.218	20	60	0.2	442.4360137	3875.7395

Finally, using an example of a turbine with a 60 meter blade diameter and a swept area of 2826 m², we estimate the output. To determine the turbine output, we multiply the swept area by the output/m². In order to determine the Net Turbine Output, we multiply the turbine output by the efficiency of the turbine, in this case 25%. The calculation is shown in Table 3.

Table 3

Turbine Diameter	**Swept Area** Π(.5d)²	**Turbine Output**	**Turbine Efficiency**	**Net Turbine Output**
(m)	*(m²)*	*(kWh/yr)*	*(%)*	*(kWh/yr)*
60	2826	10,952,839.8	0.25	2,738,209.943

The second phase in the study was to determine the costs and benefits of installing a turbine on the Reservation.

Cost

Using the Suzlon 1.25 MW turbine as an example, we divided the costs into Upfront Costs and Annual Costs. The Upfront costs are one-time payments to cover equipment, shipping, infrastructure, labor, and legal fees. The Annual Costs are figured over 20 years and include insurance, operation and maintenance, utility charges, and finance. Below, Table 4 displays the Upfront Costs and Table 5 displays the Annual Costs.

Table 4. Upfront Costs

	Suzlon 1.25 MW
Turbine & Tower	$1,100,000
Shipping	$50,000
Transformer	$17,500
New Power Line ($13/ft x 3 mi. – 6 mi.)	$200,000 - $400,000*
Electrical Labor	$15,000
Concrete & Rebar	$30,000
Foundation Labor	$15,000
Tower Imbeds/Bolts	$15,000
Crane	$100,000 – $200,000*
Labor – Erection	$30,000
Legal	$10,000
Total Cost	**$1,582,500 - $1,882,500**

*cost will be determined by location of site

Table 5. Annual Costs

Insurance	$12,000
Operation & Maintenance	$40,000
Standby charge ($1.39/kW/mo)	$20,850
Finance ($1.5 million, 6%, 20yrs)	$129,241
Total	**$202,091**

Revenue

To calculate the annual revenue, we multiply the net output of the turbine by the cost per kWh. To determine the Net Turbine Output, we used the method described above. We multiplied the output/m² by the swept area of the turbine and by the efficiency of the turbine. Below is an example of the equation used for the Suzlon 1.25 MW.

⇒ 3875.7395 kWh/yr/m² (Output/m²) x 3421 m² (Swept Area) x .30 (Efficiency) = **3,977,671 kWh/yr**

In order to determine the annual revenue, we first had to estimate a savings per kWh. This number is dependent on many factors, including the wind data, the size of the turbine, the pattern of energy use versus wind pattern, and the agreement with the utility. Grand Portage's savings will be $0.07/kWh when they are consuming electricity directly from the turbine and $0.03/kWh when they are selling their excess electricity back to the utility. Therefore, at any given point in time, the savings will be in the range of $.0.03-$0.07. For the purpose of this example, we assumed a revenue of $0.05/kWh or $0.06/kWh to calculate two different scenarios for the Annual Revenue. Table 7 illustrates these calculations, with the annual kWh's rounded up to 4 million.

Table 6. Annual Revenue

Turbine Output: 4 mil kWh/yr @$.05/kWh	**$200,000**
Turbine Output: 4 mil kWh/yr @$.06/kWh	**$240,000**

Community Involvement

In Grand Portage, we worked directly with key members of the tribal council, and several tribal employees responsible for the direction of their various environmental programs (air, water, wetlands, etc.). In addition, we have engaged a representative from the local utility company, several wind turbine manufacturers, and an expert in financing from Native Energy to assist the tribe in their remaining questions. Finally, the members of the council and/or employees of the Reservation have met with the general community in the past to explain the project, and plan to continue this basic community education component as the project moves forward.

The following are the results from our research to determine Grand Portage's community profile:

1) Identify the key contacts in each community.
The CSCD has been working with Grand Portage reservation for many years assessing the feasibility of various renewable energy systems. During this time we have developed strong working relations with various individuals. One significant partnership is our work with the Tribal Government, specifically John Morrin, Vice Tribal Chair. John's role in this project cannot be understated. He is identified as a key contact because he knows how things work within their community, he is well respected by the community and he shares the goals of our project. Morrin has been interested in having Grand Portage's wind measured for many years in an effort to update a study that was done many years ago.

2) *Develop relationships with community members.*
We also work with several of the reservation's employees, including: Air Quality Specialists, Victor Aba and Shannon Judd, Water Quality Specialist, Margaret Watkins and reservation Grant Writer, Dave Danz. We consider these contacts to be of key importance, since they understand the daily business of the Reservation. Being that it is a very small community, they also have open dialog with community members. These employees are quickly becoming educated on several wind energy issues and as the project moves forward, they will serve educator for the local community.

3) *Gather census data*.
<u>Grand Portage</u>

Population:	308
Unemployed:	26.5%
Per capita income:	$10,808

4) Identify the major energy consumers in the region.
The major energy consumers on the Reservation are the Grand Portage Lodge and Casino, the Community Center, the Tribal Council Offices, and the Residential (household) Sector.

5) Collect energy consumption data. At this time we have full access to Grand Portage's electric utility bills. They are serviced by Arrowhead Electric

2) City of Duluth

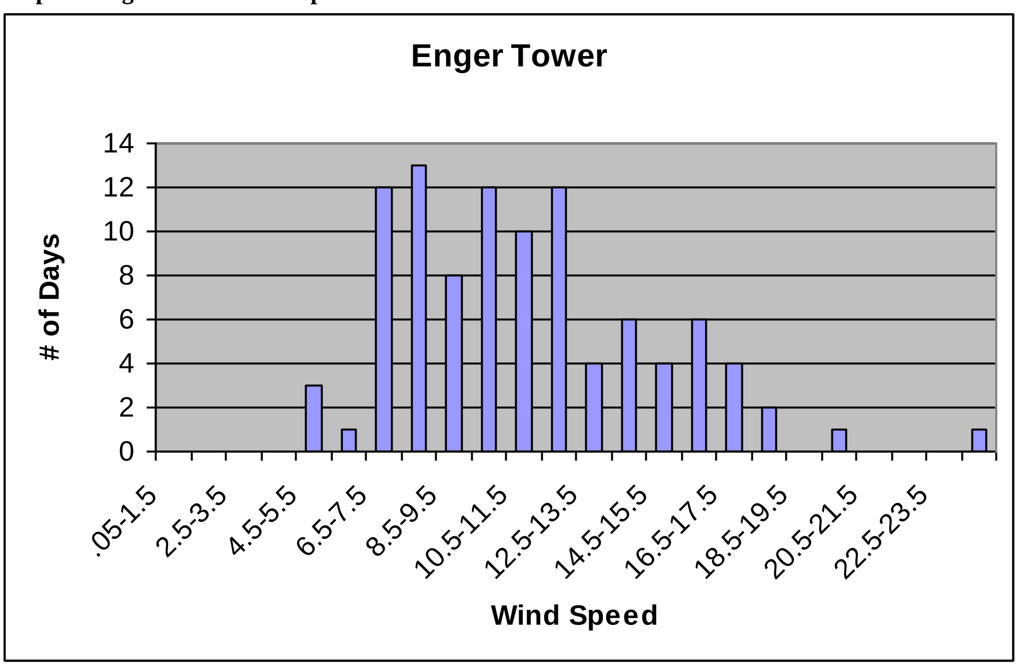
Measuring the Wind

When selecting a site, the CSCD considers four key factors for proper anemometer placement: location, elevation, existing structures, and permission/access to those structures. Using these four variables, we assessed the potential sites in Duluth. After sampling several sites, including Enger Tower, Park Point Fire Hall, the Duluth Aerial Lift Bridge, Chester Bowl Ski Jump and Spirit Mountain, we decided Enger Tower was the best due to the height and accessibility of the tower. We installed permanent monitoring equipment on the Enger Tower in December of 2005 and have been measuring the wind ever since.

Determining Economic Feasibility

In order to determine Enger Tower's wind energy potential, we analyzed the average wind speeds. As with Grand Portage, the first step was to group an annual set of wind data into wind 'bins.' Graph 2 illustrates the distribution of the number of days in each wind speed bin at Enger Tower from January 29, 2006 to April 12, 2006.

Graph 2. Enger Tower Wind Speed Distribution



We have not yet determined costs and benefits associated with installing a wind turbine in these wind speeds due to the fact that we do not know the size and number of turbines Duluth is interested in putting up.

Community Involvement

The following are the results from our research to determine Duluth's community profile:

1) *Identify key contacts in the community*.
In the search for an appropriate wind-monitoring site, we connected with several key players in Duluth. We initially considered Spirit Mountain and Chester Bowl as potential sites. In doing so, we talked to and met with people each site. Although they were supportive of our project, we decided against using either site due to issues of height, access and safety. We ultimately decided on Enger Tower and met with several city employees, including Dan Green, Director of Facilities Management for the City of Duluth, Tony Livingston, Maintenance Employee for City of Duluth, and Scott Nelson, Electrician for the City of Duluth. Everyone we have worked with so far has been fully supportive of the study and would like to see wind development in the region.

2) *Develop relationships with community members*.
The CSCD has been networking with other renewable energy and environmental groups in the Duluth. Dr. Mageau is on the steering committee for Duluth's Cities for Climate Protection and has developed several significant relationships with other community members in the group. We are also involved in the Clean Energy Resource Teams, where we have met many other people and organizations working on renewable energy initiatives.

3) *Gather census data*.

Duluth	
Population:	76,918 (2005)
Labor force:	63.5%
Unemployed:	6.9%
Per capita income:	$22,627 (in 2005 inflation-adjusted dollars)
High school or higher graduate:	87.7%

4) *Identify major energy consumers*.
This will be a difficult task with a city as large as Duluth. There are many large businesses and industries contributing to Duluth's energy consumption. The residential sector is also very large and difficult to measure. We will probably wait until more specific wind project ideas are developed, and then do a localized study of energy consumption (i.e. West Duluth, Lakeside, Piedmont, etc.) depending on where the turbine would be installed.

5) *Collect energy consumption data.*
We have accessed the "Greenhouse Gas Inventory and Forecast Report" prepared by and for the City of Duluth in 2001. This report provides a breakdown of emissions by sector (residential, commercial, industrial, transport and waste) as well as by fuel type (electricity, natural gas, gasoline, fuel oil, steam, etc). This report will prove to be extremely useful in the future. We have also made contact with Bill Mittlfehldt (Sustainable Duluth) who has quantified the costs, fuel types and consumption area for the City of Duluth as recently as 2006.

3) Proctor School District

Measuring the Wind and Determining Economic Feasibility

The CSCD joined the Proctor Community Wind Power team mid-way through the project. They had already assessed their wind resource by consulting nearby airport data. They decided their wind was adequate for the installation of a small wind turbine. The Proctor Wind team had also decided to go forward with the installation even if the payback time was as long as 20 years. Therefore, the CSCD's main role in Proctor's project was to help develop renewable energy curriculum.

The end results for Proctor changed slightly from the beginning goals. Due to complications with the original manufacturer, the school installed a Jacobs 20 kW turbine instead of the intended Next Generations 37 kW turbine. Proctor now has the convenience of working with a local (Prior Lake) manufacturer, which is ideal for operation and maintenance needs. The Jacobs 20 kW turbine was installed at the high school in mid-October.

Community Involvement

At Proctor High School, the project was initially developed by teachers, administrators and students. Along with interested community members, they worked to plan, implement and evaluate the installation of the wind turbine and integration of the experience into their curriculum. The project team remained in contact through quarterly meetings of the entire group as well as several phone calls and emails between sub-groups. Progress was also communicated with parents, students, the school board, the county board and the general public. They held meetings and made themselves available to concerned citizens worried about issues like noise, aesthetics, bird kills, etc. The project team maintained an open dialog with the community on issues regarding the turbine.

The curriculum development portion of the project would fall under the community involvement part because teachers and students are part of the community and the concepts that are integrated into their curriculum will have a ripple effect on the families of Proctor.

In November 2005, the CSCD teamed up with Susan Santone of Creative Change Solutions to lead a full-day meeting with the project team focused on integrating renewable energy into the curriculum. The process went as follows:

- We introduced renewable energy as an integrating context for the curriculum.
- Teams of teachers worked by discipline (i.e., all science teachers, K-12) and by grade level (science, economics, language arts, etc. for a single grade) to fully identify "entry points" for integrating renewable energy
- School district administration introduced longer-range goals for the wind project and how they relate to the school's overall mission. These goals include
    - Increasing student awareness of global issues and their impacts
    - Involving students in practical projects that enable them to make a positive different

    - Ensuring students understand how disciplines relate to each other
    - Working inside the school and the community to begin making responsible choices today

In January of 2006, we held a second full-day meeting for the team of teachers to begin developing specific units and projects based on the curriculum integration opportunities identified in November. Additional time was reserved to continue linking the overall wind project to long-term district goals. The process went as follows:

- Teachers reviewed existing curricula and materials on renewable energy and related areas.
- Teachers identified how these materials and topics could supplement their existing curriculum goals. Then, working from their existing curriculum, teachers began developing plans for “units makeovers” that would integrate the targeted content. The teams decided that units will be implemented in the 2006-07 school year.
- The team developed strategies to link the academic goals of their individual units to the district’s larger goal of strengthening school-community relations.
- After taking an inventory of potential school-community strengthening opportunities and projects, the team created a timeline that mapped out goals and measurable benchmarks for a 3-5 year period.
- Finally, the team of teachers discussed their roles as ‘ambassadors’ to other staff and the community. The team understood the importance of evaluating the pilot projects connected with the wind turbine, communicating the impacts, and articulating how the district intends to build on the activities to meet long-term educational and community goals.

DISCUSSION

Grand Portage Reservation

Our work with Grand Portage has led to several issues of further consideration. Below is a list of issues that must be determined before Grand Portage continues with the installation of a turbine:

1) Site – Mount Maud is a ridgeline of solid rock. Installing in bedrock raises another issue to be addressed. Although it can be done, additional time and money are necessary for the intensity required. Running a 3-phase power line from Mount Maud to the Casino is another issue to consider with the site. There are two feasible routes the line could travel. One is three miles long with limited road access and would be difficult and timely to service, especially in the winter. The estimated line cost for this route would be $200,000. The other route is six miles long on existing roads with better accessibility. The estimated line cost would be $400,000. We are currently measuring the wind at another peak on the reservation that is not as prominent as Mt. Maud, but would be easier to access and is closer to an interconnection site.
2) Maintenance – The issue of service and maintenance needs to be considered in respect to Grand Portage's remote location. Several manufacturers have local area service providers in Minnesota; however, most of them are located in the Southwest region of the state. Grand Portage will need to take into account the possible delay in service when turbine maintenance or repair is needed.
3) Insurance – It is highly recommended that turbine owners purchase insurance to protect themselves from incidents like mechanical damage, lightening strikes, fire, and liability. Some utilities might even require the power producer to purchase liability insurance on their turbines in case of an accident. This adds another substantial cost that must be considered.
4) Interconnection – Grand Portage was faced with two options when connecting their turbine. The first option is to tie in to the grid, and buy and sell all their electricity through the utility. This would require a power purchase agreement with the utility to set the rate at which they will buy the power (lower than retail). The second option would be to connect the turbine directly to the end user, in Grand Portage's case, the casino. This type of interconnection is called 'behind the meter.' After research and conversations with the utility, we have found the second option to be the most efficient and beneficial way of interconnecting. The casino will use all the available electricity (saving their retail rate) and then sell any excess to the utility (typically at a rate much lower than retail). This is a viable option due to the fact that the casino is using electricity almost 24 hours/day. The casino does not experience the usual "down time" during the overnight hours, therefore probably won't produce much excess power. We are currently looking into the option of aggregating loads. If it is possible, Grand Portage could aggregate their casino, community center, tribal office, and trading post loads into one and power them all with the turbine. This would allow for the installation of a larger turbine.

5) MISO – According to Don Stead of Arrowhead Electric, Grand Portage will not need to apply to the Midwest Independent Transmission System Operator (MISO). A study done by MISO is required when entities want to transmit large loads of electricity through the grid. Due to the fact that Grand Portage will be connecting 'behind the meter', they will not have to go through the timely and costly process of applying for a MISO study.

City of Duluth

Since the complete of the CCRR project, we have continued measuring the wind at Enger Tower. We have upgraded our equipment and mount and have raised the anemometer to a significant height where the wind is less disturbed by surrounding obstructions. The more recent data collected from the site has greatly improved. The current winds speeds we are collecting are very promising, with daily average as high as ____ mph. With average wind speeds at this level, Duluth would benefit greatly from harnessing the power in the wind. The CSCD will continue measuring until we have a complete year's data set in order to capture the seasonal variations.

Our work at Enger Tower has inspired us to explore the wind energy potential along the entire North Shore of Lake Superior. The CSCD has taken on a new project, funded by the Department of Natural Resource's Coastal Zone Program, in which we have installed anemometers at seven locations along the North Shore. We currently have anemometers in Duluth, Clover Valley, Finland, Lutsen, Grand Marais, Hovland and Grand Portage. After gathering a year's worth of data, we will be working with UMD's GIS lab to create a wind map of the North Shore.

Proctor School District

Proctor is setting an example in how to be a sustainable, energy-conscious school and their ideas are catching on. As a result of our work with Proctor Schools, the CSCD is doing similar projects in other parts of the state. We are currently working with Park Rapids School District to assist them in the installation of a 20 kW Jacob's wind turbine.

Challenges

During the early stages of the study, we had a few problems associated with measuring the wind. We've had several anemometers break (lose one or more of their cups) resulting in some lost data before we were able to replace them. Recently (July 2007) we purchased new anemometers from APRS World, LLC in Winona, MN. They have proven to be more reliable and built to withstand extreme elements.

We also have noticed several zero's in our data sets from various sites. We know the recorded zeros are suspect based on measurements at other sites and airports, but we have not figured out why they randomly appear in our data sets. The cause is probably a loose wire connection between the anemometer and data logger, or perhaps temporary battery failure in the data logger due to extreme cold or moisture. We are currently working to solve these problems, or at least minimize them going forward. Overall, they only affect a small percentage of our total data.

LITERATURE REVIEW

"Wind energy potential estimation and micrositing on Izmir Institute of Technology Campus, Turkey" – 2003/2004.

The study's purpose was to measure the wind over the campus of the Izmir Institute of Technology in Turkey. The wind was measured at heights of 10 and 30 meters over a 16 month period. To calculate wind statistics and energy calculations, WAsP and WindPRO software were used. The measured wind details were wind speed, wind direction, and air temperature. After all the data was collected, wind energy maps were created. The final stage of the study was selecting the most logical and appropriate turbines for the most suitable sites.
Source: https://wm3.d.umn.edu/horde/imp/message.php?index=272#

"Wind Resource Assessment Handbook: Fundamentals for Conducting a Successful Monitoring Program" – 1997. The National Renewable Energy Lab (NREL) issued a guide to measuring the wind from an on-site location. It includes step-by-step instructions on what to do and not to do when measuring the wind.

"Wind Assessment Study for the State Iowa" – 1999. The State of Iowa measured the wind at 12 sites at 10, 33 and 50 meters for 5 years. They used WindMap software to create their wind resource maps.
Source: http://www.energy.iastate.edu/renewable/wind/as-index.html

"The Oklahoma Wind Power Assessment Initiative" – 2001. Prepared by the Oklahoma Wind Power Initiative (OWPI). Prepared for The Oklahoma Department of Commerce. OWPI measured the wind at 76 Mesonet stations at 10 meters for 7 years. They extrapolated the data from 10 m to 50 m. They used WindMap and Neural Networks to make wind resource and wind power maps.
Source: http://www.ocgi.okstate.edu/owpi/#none

Warm Spring Indian Reservation, Oregon – 2003 – 2005. Warm Springs Indian Reservation of Oregon conducted a wind feasibility study from May 2003 – January 2005. Data was collected at four locations that spread throughout the reservation's land area. One of the locations, the Mutton Mountain site, was found to be the best site for potential development. The site had wind speeds measured from multiple towers locations, all of which had multiple anemometer heights. The towers ranged from 30 to 50 meters. Wind speeds were collected at 10, 30, and 50 meters and the prominent wind direction was also noted. A monthly production capacity model was then created using two turbine models. They did not make a map.
Source: www.eere.energy.gov/tribalenergy/pdfs/0610review_17mcclain.pdf

"Geographic Information Systems in Support of Wind Energy Activities at NREL" – 2001. The National Renewable Energy Lab (NREL) has developed a Wind Resource Assessment Model (WRAM). WRAM produces wind resource maps using ArcInfo GIS software and was designed for regional (areas greater than 50,000 km^2) wind resource

assessments. The model is designed to work in different geographic categories, such as inland areas and ocean and lake coastal areas. It takes into consideration terrain, wind power roses and vertical profiles of wind power.
Source:http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/gis_nrel.pdf