The General Wind Characteristics of the Greater La Crosse Region

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ABSTRACT

Recently there has been an increased awareness for alternative energy systems. This awareness, growing in many cases out of concern for the environment and a desire to decrease the dependency of foreign energy, has led some local politicians to promote legislation that would increase funding for the development of renewable energies. Wisconsin has recognized this dependency and has made strides to reduce this dependency through initiatives that promote clean energies. This promotion has increased incentive for businesses to pursue the goals of the state. Establishing a control group for wind energy production allows local developers, universities and politicians to make decisions that are more informed. The collection of the data for this research came from the NCDC automated airport weather stations. Analysis and presentation will use weibull parameters of the measured wind data. Weibull parameters are similar to the mean of the sample; weibull parameters, typically used with life data analysis, like weather forecasting, provide more flexibility than a normal or exponential distribution.

INTRODUCTION

Recently there has been an increased awareness for alternative energy systems. This awareness, growing in many cases out of concern for the environment and a desire to decrease the dependency of foreign energy, has led some local politicians to promote legislation that would increase funding for the development of renewable energies. In September 2003, Governor Jim Doyle assigned an energy task force to review the possibility of increasing energy efficiency and renewable sources within the state. This task force, led by various state representatives, businesses, environmentalists and public utilities companies concluded in 2004 that the state could reach the goal of producing 10% of its energy using renewable energy sources by 2015. As of 2004, the state is obtaining 2% of its electricity from renewable resources. The 10% goal requires renewable energy to increase by 2% yearly until 2010 with the remaining 4% obtained by 2015. The requirement encourages renewable energy production and allows the state to “set the standard” for renewable energy consumption. Since the recommendations by the task force, the number of wind energy projects has increased with multiple projects currently entering their construction phases.

One of the first steps in analyzing wind for energy production is measuring the wind characteristics of a particular site. Typically, selecting a site-specific is first, followed by a comparison of the historical regional wind data. Site-specific measurement is important because the geography of the land, man or natural made objects and the location of the proposed site all affect the characteristics of the wind. For example, the wind is stronger on top of a bluff, than it is below in the coulees.

According to Grant McNeilus of G.McNeilus Wind Energy Company of Dodge Center, Minnesota, the standard procedure is to look at historical wind data from local airports and compare the data with site-specific measurements. Collection of the data is typically from one local airport, but if two airports are available, the data will be more accurate; therefore providing greater substance and reliability.

Preliminary research into this project has led to the conclusion that site-specific measurement requires too many resources. The amount of resources involved in site-specific measurement lends itself more towards a business approach rather than for educational/informational purposes. Information gleaned from analysis of the wind statistics might prompt decisions to engage in further site-specific measurement research.

RESEARCH PURPOSE

Statement of the Topic

This report will provide a historical analysis of the wind characteristics of the greater La Crosse region by analyzing data obtained at two regional airports. This analysis will provide a control group for site-specific measurements.

Research Hypothesis

The purpose of comparing historical wind data to site-specific data is to establish a control group. Obtaining historical data will help prove/disprove site-specific measurements. Based on the analysis of historical data, the La Crosse region is an area of interest for potential wind energy production.

Justification of study

The awareness of foreign energy dependence has lead state governments to recognize their own "foreign" dependence of energy sources. This is evident by the importation of coal for energy production within Wisconsin's boarders. Wisconsin has recognized this dependency and has made strides to reduce this dependency through initiatives that promote clean energies. This promotion has increased incentive for businesses to pursue the goals of the state. Establishing a control group allows local developers, universities and politicians to make decisions that are more informed. Establishing a control group will provide scientific evidence for those who encourage decreasing the dependency of foreign energies; leaders must rely on scientific data that provides a valuable approach to their own initiatives. This research in establishing a control group is only the first step towards promoting "off-grid" goals.

RESEARCH DESIGN

Description of Data

The National Climatic Data Center (NCDC) is the world's largest active archive of weather data. NCDC produces numerous climate publications and responds to data requests from all over the world. To achieve this, the NCDC has placed a variety of sources that include but not limited to, automated airport weather stations, wind profilers, rocketsondes, solar radiation networks, and the NWS cooperative observers. These sources of information provide a historical perspective on the climate. "Through the use of over a hundred years of weather observations, reference data bases are generated. From this knowledge the clientele of NCDC can learn from the past to prepare for a better tomorrow."

The collection of the data for this research came from the NCDC automated airport weather stations. With the help of Wisconsin's state climatologist Ed Hopkins and by purchasing data from the NCDC's website, the collection of data is specific to wind characteristics. Because the NCDC collects a variety of data, the selection of data must be specific. The data obtained from the website came in the standard format called ASCII files. This format is a comma delimited, allowing more data to be stored in less space. Numerous software programs and devices record in an ASCII file.

The data collected for this research project consisted of variables such as, mean wind speed, wind direction, temperature, and pressure. The mean wind speed came in hourly and daily intervals with measurements in miles per hour and meters per second.

To increase the accuracy and reliability of the data, each data set obtained has over 20 years of compiled data. This large set of historical data allows research for site-specific data to be at least one year in length, which allows seasonal comparison of the data. A sample of twenty years or more allows one-year site-specific data comparison to be more accurate because a given year can be better or worse than the previous or the years to come. Hence, using historical data establishes a control group, for an experimental sample.

Descriptive Statistics and Discussion

Utilizing two software packages, presentation of the data from the NCDC will be in forms of different types of graphs and layouts. EMD, a Denmark-based company provided two packages, the "Basis" module and "Meteo" module. The basis module is necessary for any calculation used by EMD's Windpro software. The Meteo software has two primary functions, the import analysis and presentation of the measured wind data, and the calculation of the energy yield such as weibull parameters. Weibull parameters are similar to the mean of a sample, but are typically used with life data analysis because these parameters provide more flexibility than a normal or exponential distribution.

The data obtained from the Sparta/Ft. McCoy airport, begins in June of 1979 and ends September 2007. This data recorded by the U.S. Army Reserve, which created some errors in the data set. Out of the 54,407 hours, available 17,814 data or 32.74% were determined to contain errors. Filtering these hours out of the sample and were disregarded in the sample by Windpro all together. Furthermore, because the data is "time stamped," Windpro allows for the user to select outliers or adverse data that are caused by natural occurring extreme values or measurement equipment malfunctions. Assorting the data in a descending order allows data over 10 m/s to be deselected. Data at 10 m/s, or 22 mph, occur at extreme times and do not suggest a normal behavior of the wind. The reason for excluding wind speeds above 10 m/s and not 9 m/s is that only 89 values were above 10 m/s whereas values in the 9 m/s were present in the data sample suggesting “normal” behavior of the wind.

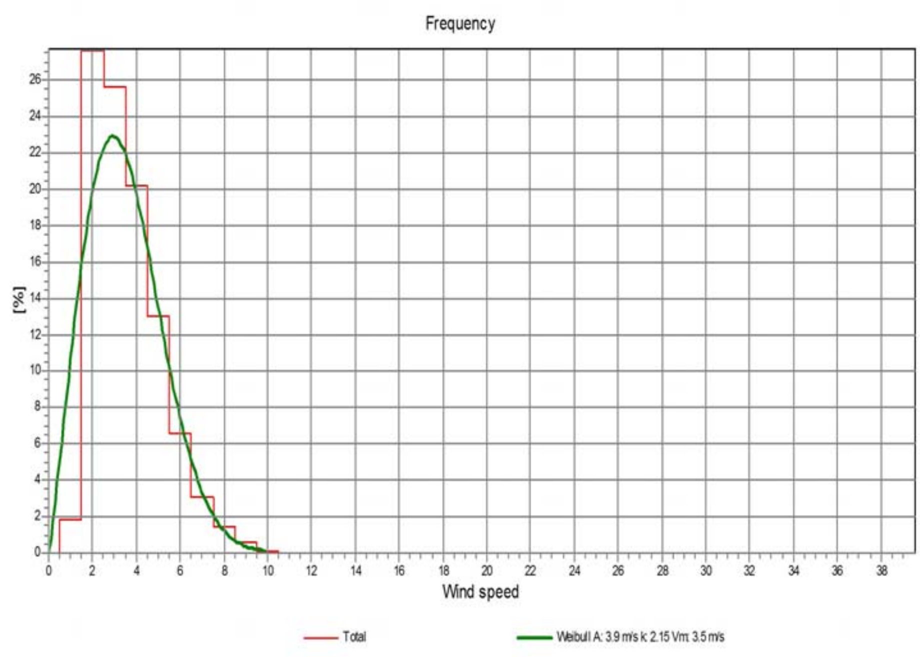


Figure 1

Figure 1 shows the weibull parameters (green curved line) of the Sparta data set. This parameter set shows that over the given period, the wind speed is typically 3.9 m/s or 7.9 mph at a height of 10 meters. Weibull parameters show the frequency of wind and suggest that the Sparta region receives 3.9 m/s wind speeds about 23% of the time but Sparta can expect wind speeds of 5 m/s 13% of the time and so forth. This graph is set a height of 10 meters, a typical measuring height for automated weather stations. Based on the power of the 1/7th law, increasing the height of measurement to actual hub height of a wind turbine will increase the accuracy of the data. The retardation of the winds is from natural and manufactured objects at surface levels.

The red line is a histogram of the wind speed. This line shows the frequency of each wind speed. For example, expected wind speeds will be between 5 m/s and 6 m/s 13% of the time and that 27% the wind is just over 2 m/s. This graph only shows the likeliness of wind speed and not the mean wind speed. In other words, the wind may typically arrive at 3.9 m/s but be above 3.9 m/s 70% of the time. This is important because a typical start up speed needed for turbines is about 4 m/s.

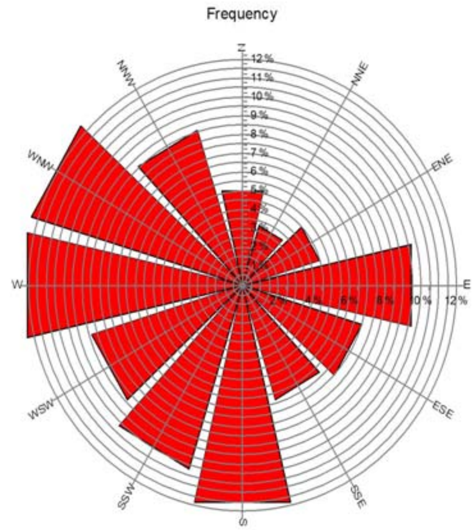


Figure 2

Figure 2 is a wind rose graph. This graph shows the distribution and frequency of the direction of wind. For instance, the wind in Sparta arrives 12% from the West, West-North-West, and South. The frequency of the wind and the direction it arrives is important to know with site-specific measurement because the location of the measuring device should be located in areas where these frequencies are best received.

The data from the La Crosse Airport contains minimal errors (280 out of 8543 or 3.8%) and is consistent from January 1st, 1984 until December 31st, 2007. The data, measured in daily mean intervals contains the wind speed (mph), direction (angular degrees), pressure, and temperature. Temperature and pressure are important information for analyzing the power capabilities from the wind speed. Windpro obtained the data from the NCDC's La Crosse National Weather station.

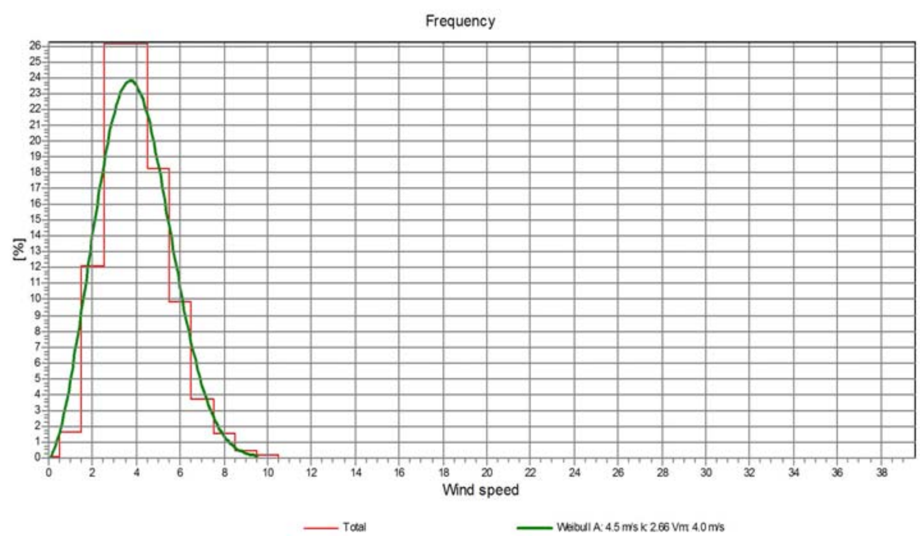


Figure 3

As stated earlier in the Sparta data, the Weibull parameter for the La Crosse data shows an increase in typical wind speed of 4.5 m/s or 10 mph. This data set also excluded wind speeds over 10 m/s to maintain consistency. Again, as the red line shows, expected wind speeds arrive above 3 m/s roughly 60% of the time.

What is different is the distribution of the wind direction. As figure 4 shows, the wind in La Crosse is predominantly from the south and north-northwest, where as in Sparta, the wind direction spreads across three different directions in Sparta. Two important geographic characteristics explain the differences. The location of the automated weather station in La Crosse is located on an island in the middle of the Mississippi river and the Mississippi river is located at the base of a valley between two dominant ridgelines (the bluffs). The Sparta airport's automated weather station is surrounded by woodlands, not near a major body of water or "sandwiched" between two elevated landmasses. This only stresses the importance of site-specific measurements.

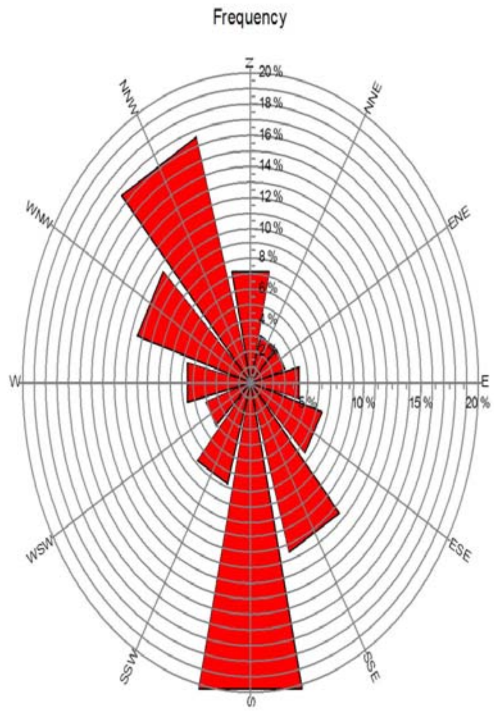


Figure 4

RESULTS AND ANALYSIS

Hypothesis Testing

Based on the analysis of historical data, the La Crosse region is an area of interest for potential wind energy production. The La Crosse data contains minimal errors and is consistent throughout the period. The weibull parameters for the data contains mean daily wind speeds of 4.5 m/s (10 mph) and arrives from the south or north-northwest at or above 3 m/s 60% of the time.

The Sparta data set contains more errors than the La Crosse data set. Through time series analysis, the Sparta data contains more errors than what was filtered out by Windpro. There is a period in the 1980's were the wind speed remains constant. Wind is not a constant, but a fluid that is in constant fluctuation and unfortunately, removal of this data did not occur. Furthermore, constant recording of the data from Sparta did not begin until the early part of the 21st century. The integrity of the data lacks for a plausible confirmation (or lack thereof) for wind energy potential.

Interpretation of Results

Influenced by the surface roughness of an area and by nearby obstacles, wind speeds change accordingly. The La Crosse/Sparta region is categorizes with a surface roughness of 1.5-2.0. Using metrological data for wind speed is sufficient for forecasting the weather and for aviation reports but not for wind energy planning. Site-specific measurements will accurately estimate the true wind energy potential. The data collected contains information that supports site-specific measurement. This cannot be stress enough.

Recording data in average daily wind speeds does not include the true fluctuations of the wind. For instance, the wind speed is not constant for one hour; it gusts at times and stops at others. Increasing the time stamp interval to 10-minute intervals will capture the true fluctuations of the wind. Ten-minute intervals increase the accuracy of the potential wind energy available. Furthermore, wind energy producers need to review the “peaks” and “valleys” of the wind speed because these fluctuations determine if a turbine is just starting and stopping or is constantly in motion.

Looking at appendix A, the Meteo analysis shows the Southerly winds arrive at 5-10 m/s 8% of the 20% distribution. The mean wind speed for these winds is 4.8 m/s. This shows that the wind speed is relatively fast enough for energy production, all though not frequent enough for maximum energy potential. The wind also arrives from the northwestern sector about 17% of the time with the winds arriving at 0-5 m/s 11% of the time.

Appendix B isolates the potential energy verses the known wind speed. This graph shows that the majority of the wind energy potential is between 6-9 m/s. At 7 m/s the energy potential is about 160 MWh/year. This is relatively low for large wind turbines. The directional analysis shows that utilization rate for each sector is between 30 and 40%. This utilization rate is also relatively low for large wind turbine operations.

The Sparta data in Appendix C shows the same type of information as appendix A but on a more diverse and less frequent distribution. The frequency wind rose graph only expands out to 10% of the time. This is because the diversity in the distribution. This diversity of the wind is also at a slower mean wind speed, and is dominated by wind speeds between 0-5 m/s. Appendix D shows the “energy verse wind speed” analysis. The utilization rate for the Sparta data is also between 32-40%. This rate too, is relatively low for energy production.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This report’s intention is to establish a control group for wind energy production. The analysis ran by the software Windpro is for site-specific analysis and does not consider the use of meteorological data. Looking at the analysis by Windpro suggests that the wind energy potential is relatively low. This contradicts the confirmed hypothesis. The contradiction is the result between energy production and wind characteristics. Wind turbines rarely operate at maximum capacity or use their full utilization rate. A typical wind turbine needs to operate at or around 75% capacity for energy production. However, if you look at the true research meaning in this report, historically speaking the daily mean wind speed meets and exceeds the needed velocity for energy production.

Recommendations

The general wind characteristics provide for potential energy production. Obtaining information recorded in 10-minute intervals would allow better analysis for site-specific measurements. These characteristics should be used for comparison purposes and should not be used for determining a large investment in wind producing technologies. Recording data on top of the region’s ridges would also benefit the area. The Viroqua airport would be an ideal area for data collection. There currently is a weather station located at the Viroqua airport but no recorded data is available for historical references.

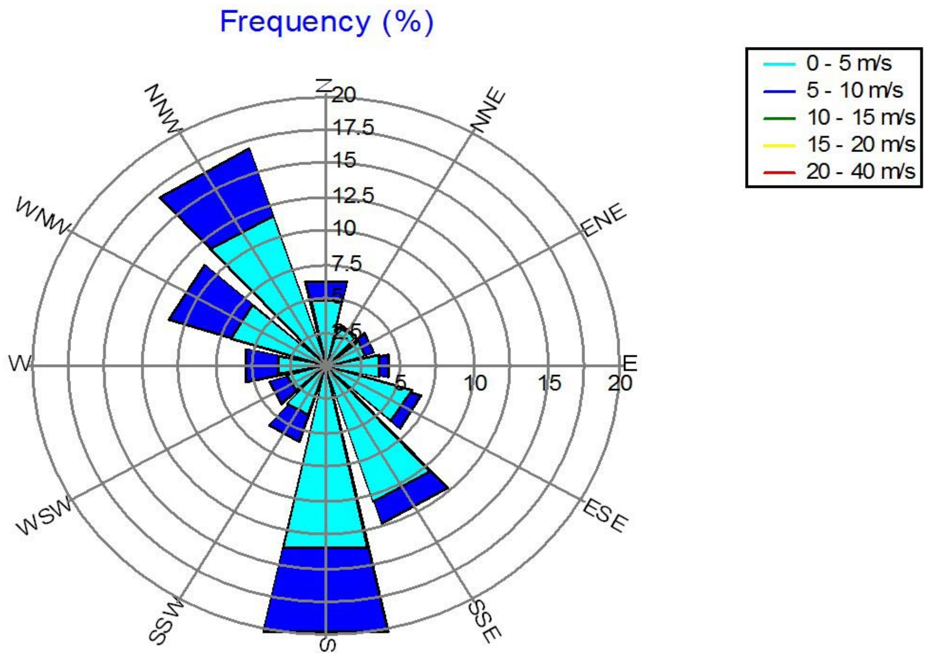
Limitations of the study

The data from Sparta contains numerous errors and reflects typical meteorological data. Recording data in averages does not reflect the true motion of the wind. Not incorporating wind speeds over 10 m/s also limits the study by placing a parameter within a life data set. This limitation, recording method and errors prevented the analysis to reflect accurately the constant fluctuation of the wind.

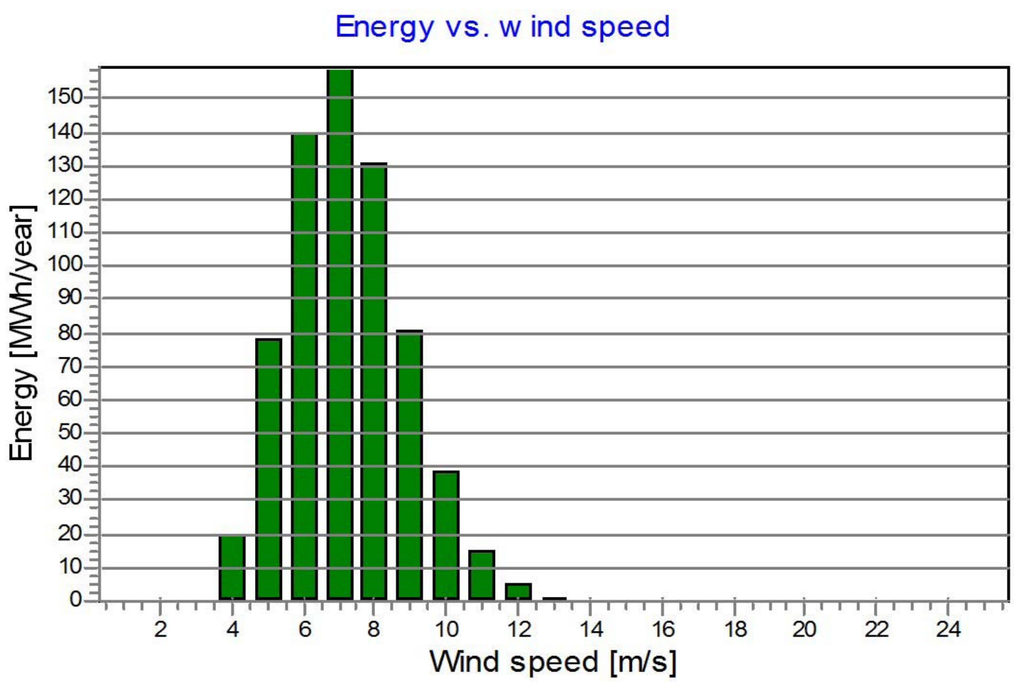
REFERENCES

Danish Wind Industry Association. 15 May 2008. May 2008 <http://www.windpower.org>.
McNeilus, Grant. Personal interview. Mar.-Apr. 2006.
National Oceanic and Atmospheric Administration. 29 May 2008. Feb.-Mar. 2008 <http://www.ncdc.noaa.gov/oa/ncdc.html>.
Richmond, Tim. "More Power From Wind, Cows Pushed." Wisconsin State Journal Jan. 2005.

APPENDIX A



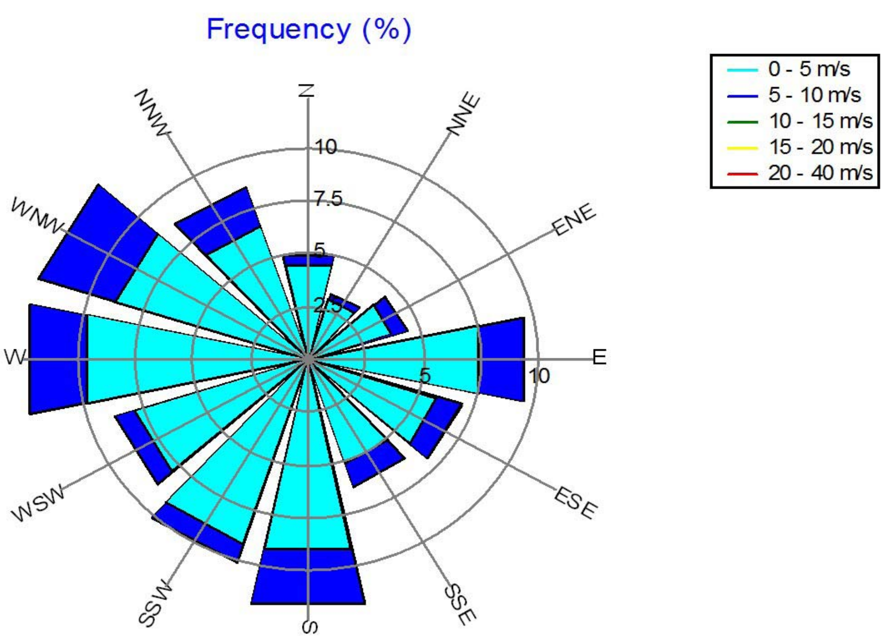
APPENDIX B



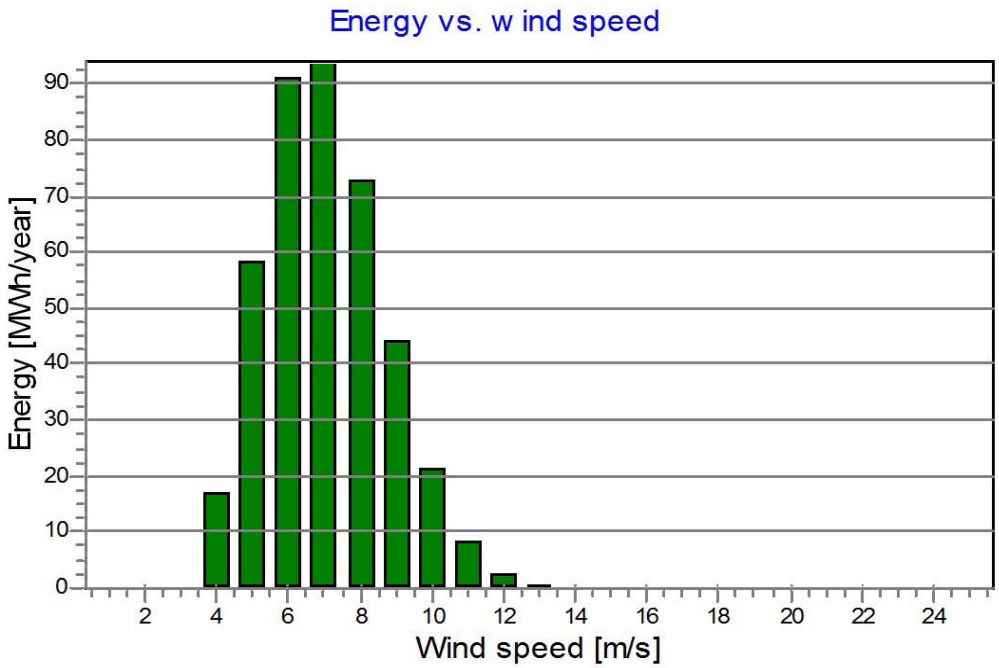
Directional Analysis La Crosse, WI

Sector	0 N	1 NNE	2 ENE	3 E	4 ESE	5 SSE	6 S	7 SSW	8 WSW	9 W	10 WNW	11 NNW	Total
Roughness based energy [MWh]	34	7.1	15.5	15.9	21.4	46.3	150	49	34.6	56	111.7	125.6	667
Resulting energy [MWh]	34	7.1	15.5	15.9	21.4	46.3	150	49	34.6	56	111.7	125.6	667
Specific energy [kWh/m2]													384
Specific energy [kWh/kW]													1,011
Directional Distribution [%]	5.1	1.1	2.3	2.4	3.2	6.9	22.5	7.4	5.2	8.4	16.7	18.8	100
Utilization [%]	38.8	30.1	37.3	35.4	34.1	35.4	41.2	41.7	41.7	42	41.8	40.9	40.1
Operational [Hours/year]	484	234	261	324	516	920	1,516	441	310	412	840	1,272	7,529
Full Load Equivalent [Hours/year]	51	11	23	24	32	70	227	74	52	85	169	190	1,011
A- parameter [m/s]	5.2	4.4	5.1	4.9	4.7	5	6	6.2	6.2	6.5	6.4	5.9	5.7
Mean wind speed [m/s]	4.6	4	4.6	4.4	4.1	4.5	5.4	5.5	5.5	5.8	5.7	5.2	5.1
k- parameter	2.43	3.17	3.07	3.15	2.81	3.49	3.67	3.31	3.28	3	2.89	2.87	2.94
Frequency [%]	6.4	3.1	3.5	4.3	6.9	12.2	20.1	5.9	4.1	5.5	11.2	16.9	100
Power density [W/m2]													109

APPENDIX C



APPENDIX D



Directional Analysis Sparta, WI

Sector	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
	N	**NNE**	**ENE**	**E**	**ESE**	**SSE**	**S**	**SSW**	**WSW**	**W**	**WNW**	**NNW**	**Total**
Roughness based energy [MWh]	13.3	7.8	15.5	46.7	23.3	25.9	58	23.8	21.4	54.4	77.9	42.5	410.5
Resulting energy [MWh]	13.3	7.8	15.5	46.7	23.3	25.9	58	23.8	21.4	54.4	77.9	42.5	410.5
Specific energy [kWh/m2]													237
Specific energy [kWh/kW]													622
Directional Distribution [%]	3.2	1.9	3.8	11.4	5.7	6.3	14.1	5.8	5.2	13.2	19	10.3	100
Utilization [%]	34	32.9	36.5	38.9	36.4	37.7	39.1	32.7	33.3	38.4	40.6	39.1	37.8
Operational [Hours/year]	331	212	292	626	454	412	768	661	575	801	800	559	6,489
Full Load Equivalent [Hours/year]	20	12	24	71	35	39	88	36	32	82	118	64	622
A- parameter [m/s]	4.4	4.4	4.7	5	4.6	5	5.2	4.3	4.3	5.1	5.7	5.3	4.9
Mean wind speed [m/s]	3.9	3.9	4.2	4.5	4.1	4.4	4.7	3.9	3.8	4.5	5	4.7	4.4
k- parameter	2.39	2.58	2.48	2.19	2.3	2.58	2.56	2.54	2.41	2.53	2.65	2.57	2.42
Frequency [%]	5.1	3.3	4.5	9.6	7	6.3	11.8	10.2	8.9	12.3	12.3	8.6	100
Power density [W/m2]													71