Wind Data Report

Peaks Island Wind Site

Peaks Island, Maine

Final Report

Prepared by

The University of Maine

August 28, 2011

Peaks Island, ME.	efficiency MAINE Leading the Way to a Brighter Future Program of the Maine Public Utilities Commission	ENGINEERING Orono, Maine

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Executive Summary

Wind monitoring equipment began operating at the Peaks site on August 23, 2010. The data contained in this report summarizes the wind data at the Peaks collected from August 23, 2010 through August 27, 2011. This report is a final report for the Peaks site. The report includes wind shear coefficient and estimated power density and power production for a Northern Power Northwind 100 wind turbine generator. The Northern Power Northwind 100 wind turbine generator is typical size for community scale generation. The results show site at the Peaks is not economically viable for a 37m tower. The results show that average wind speed at 30m is below the viable standard for commercial wind turbine operation of around 4.5 m/s.

Station Location

The monitoring tower is located at the Peaks facility. The site coordinates are 43.66083 latitude and -70.18655 longitude. Figure 1 shows the approximate location of the tower:

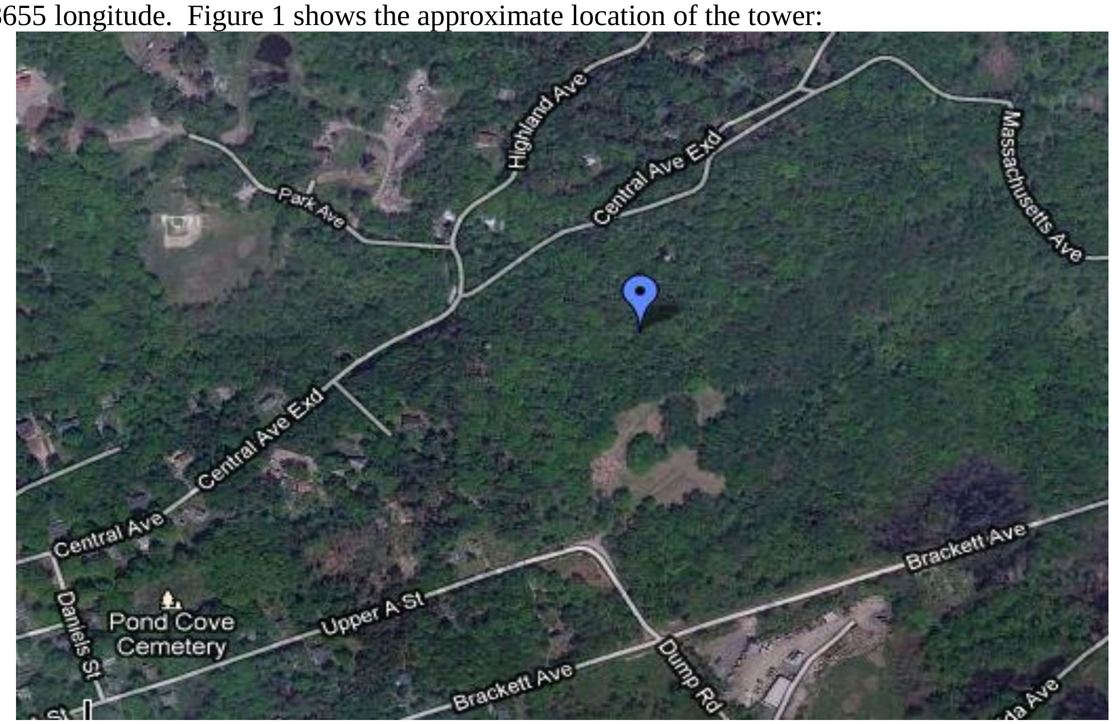


Figure 1 – Location of Tower

Instrumentation & Equipment

The 30m tower holds two separate NRG #40 anemometers, one at 30m and one at 20m. Wind direction is monitored only at 30m via an NRG #200 wind direction vane. Further, an NRG #110 temperature sensor with radiation shield is mounted a few feet above grade. The anemometers and wind vanes are mounted approximately 57" from the centerline of the tower. The data from the anemometers and wind vanes is provided to an NRG Symphonie data logger.

In summary, the tower consists of the following:

- NRG #110 temperature sensor with radiation shield
- Two NRG #40 anemometers with standard calibration
- NRG #200 wind direction vane
- Two booms to locate the monitoring equipment 57" from the tower centerline
- Simple lightning protection consisting of ground rod and ground conductor
- Guy wires at 120° and 80' from tower base with power driven anchors

Data Collection and Maintenance

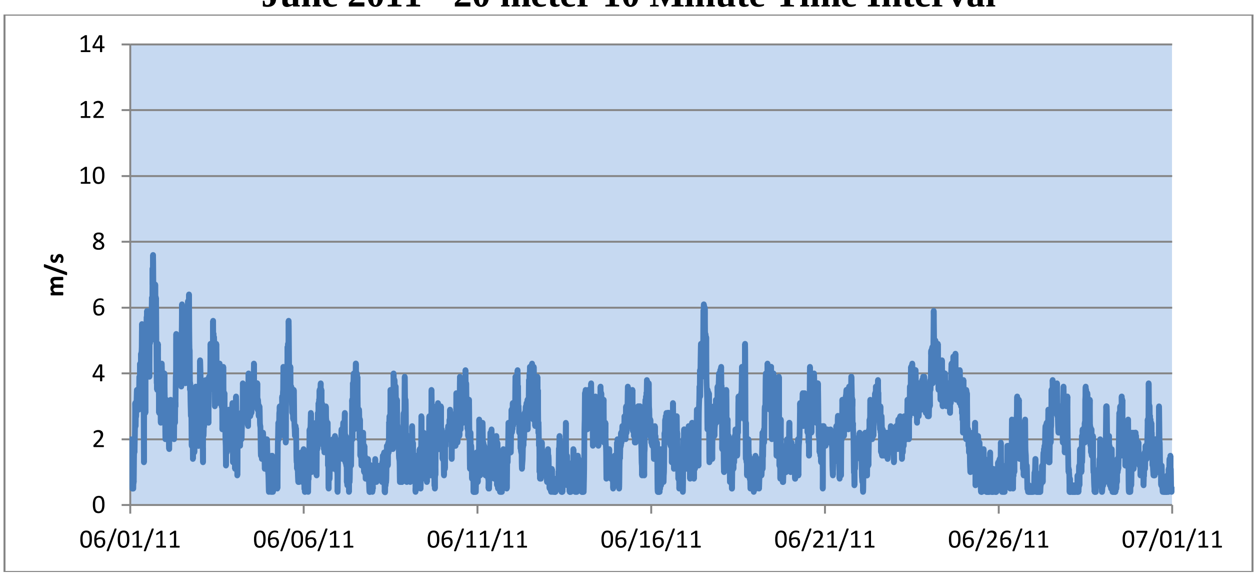
For the entire data collection period of 08/23/2010 to 08/27/2011, 308 data points were not properly recorded or transferred. This is less than 1% loss of data and does not impact the overall results.

Data Results

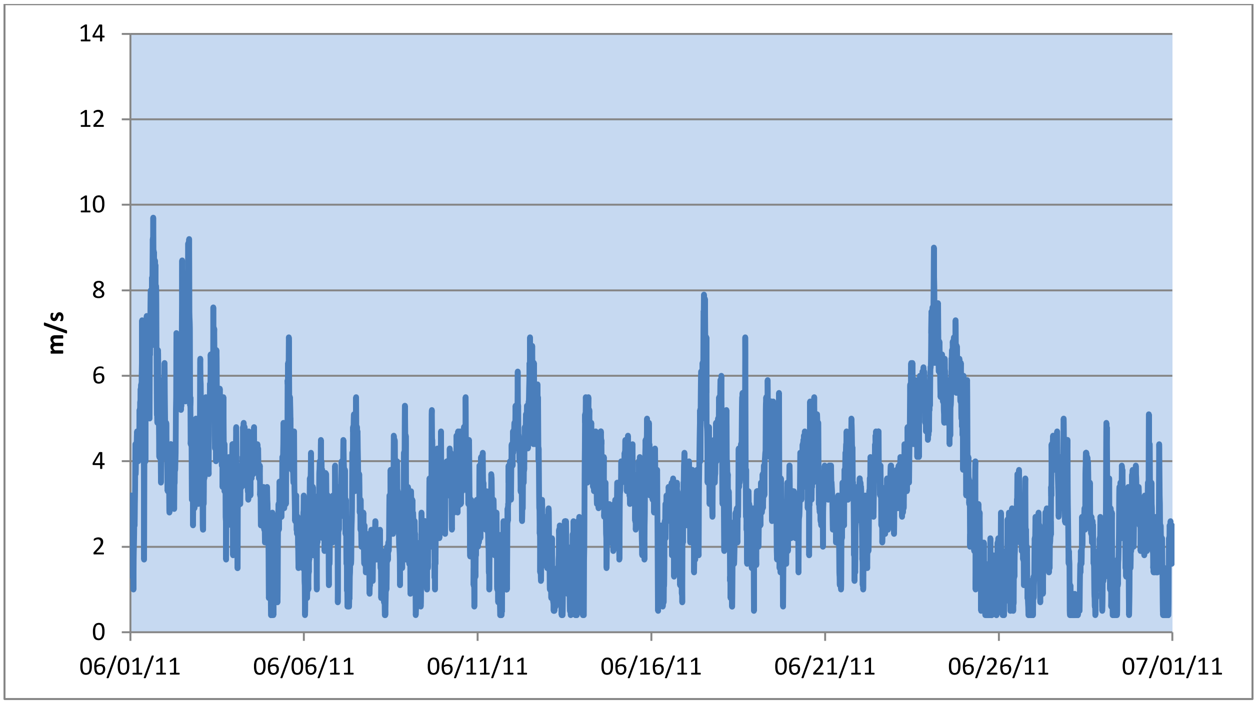
The average 30m wind speed for the time period identified in this report is 3.73 m/s. Standard commercial wind turbines have a nominal cut in speed of 4.5 to 5.3 m/s. The average wind speed at the site for this reports time period does not support the installation of a commercial scale turbine. However, new turbine designs that have lower cut in speeds are being developed and may be viable for this site. Estimated power production from August 23, 2010 to August 27, 2011 using the Northwind 100 power curve is 109,462kWh. Assuming a cost of ¢18/kWh results in an annual electricity savings of $19,703.13. The savings are likely to increase since it is anticipated that electricity rates will increase. However, the annual savings is not sufficient to justify the purchase of a wind turbine. The remainder of this section discusses the final quarter of data.

Time series data is useful to characterize variations in wind speed. The following figures identify the 10-minute time interval data for the site:

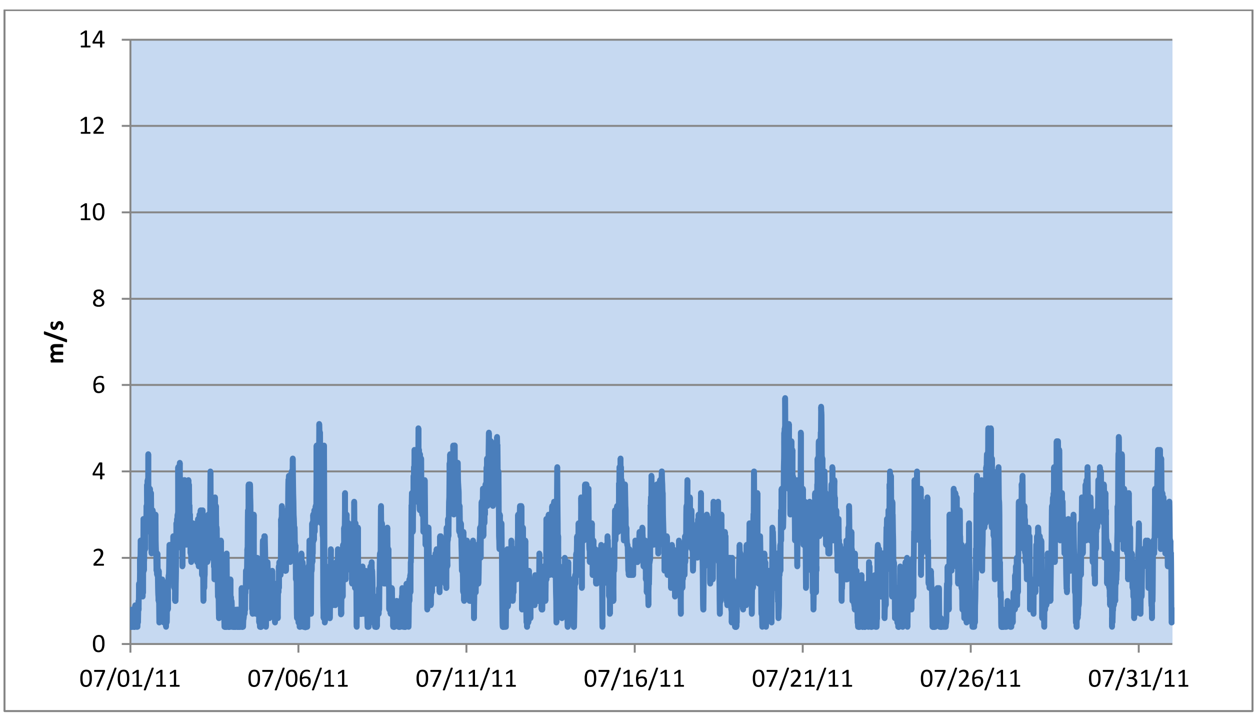
June 2011 - 20 meter 10 Minute Time Interval



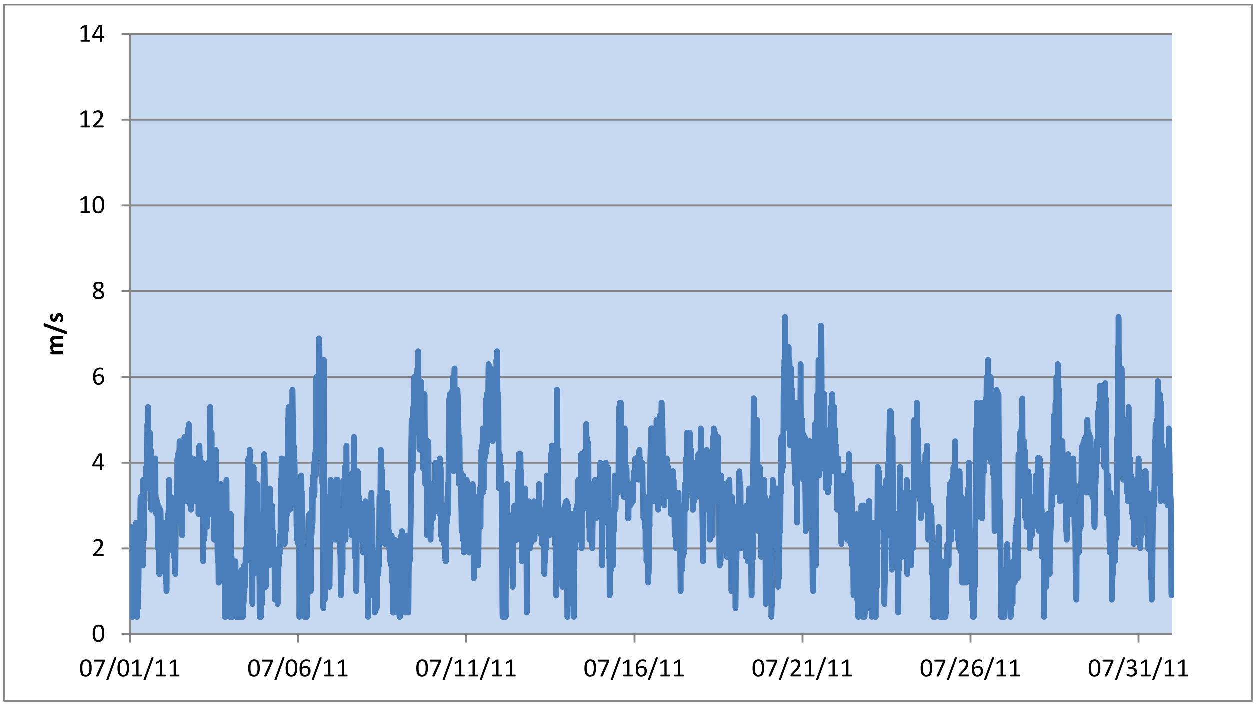
June 2011 - 30 meter 10 Minute Time Interval



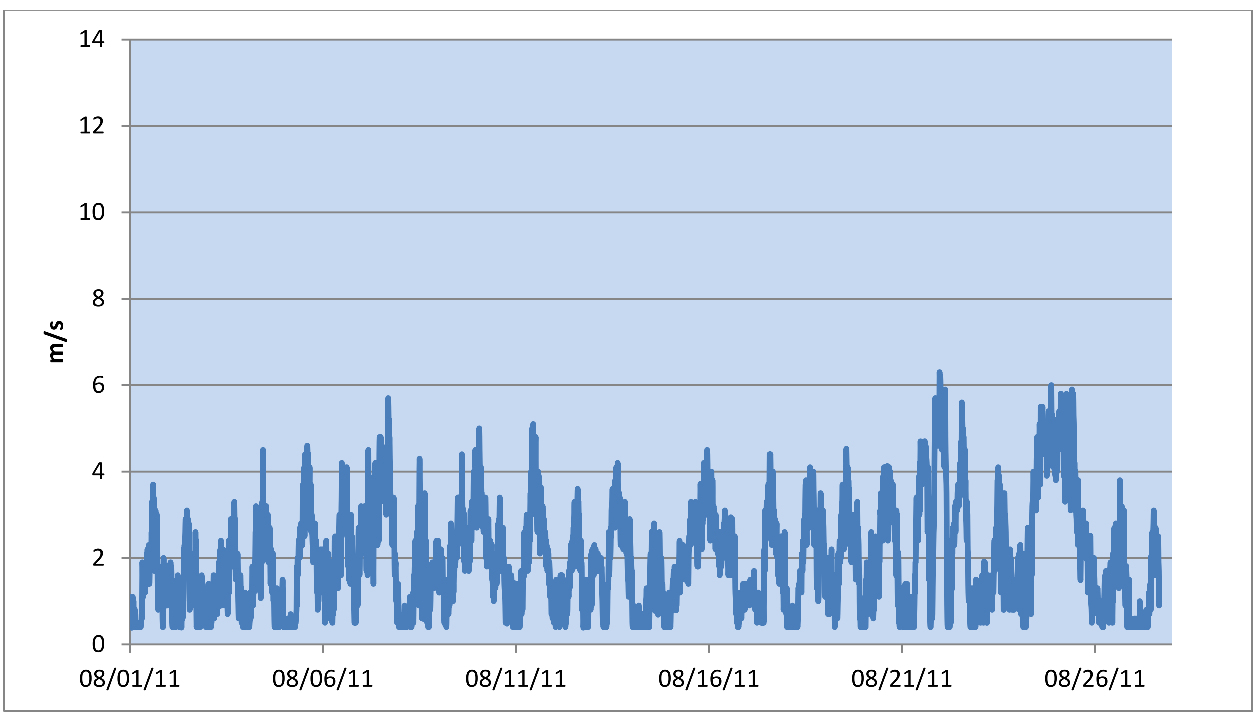
July 2011 - 20 meter 10 Minute Time Interval



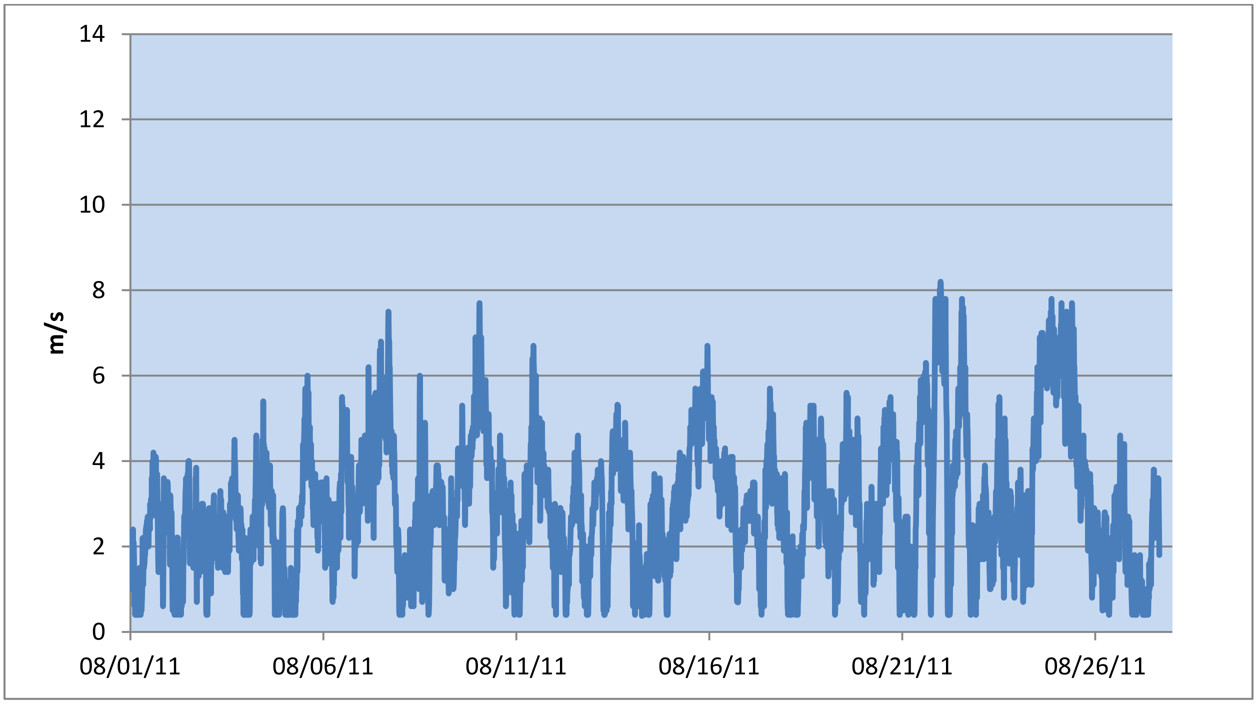
July 2011 - 30 meter 10 Minute Time Interval



August 2011 - 20 meter 10 Minute Time Interval

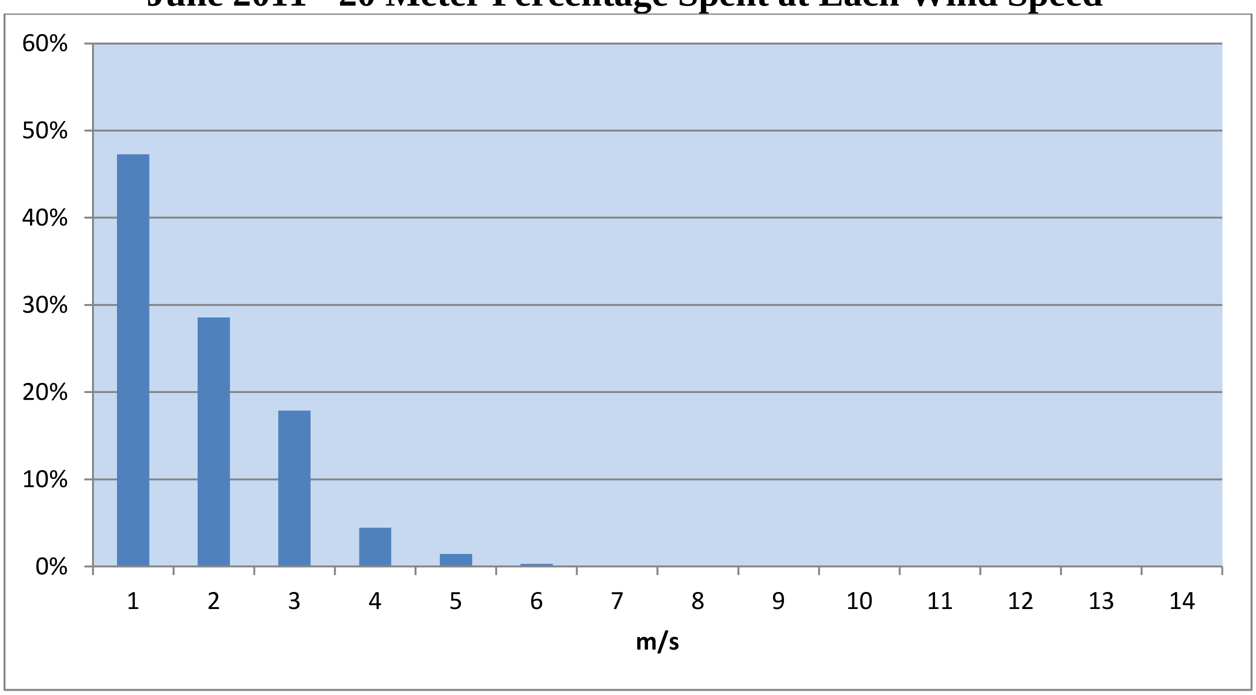


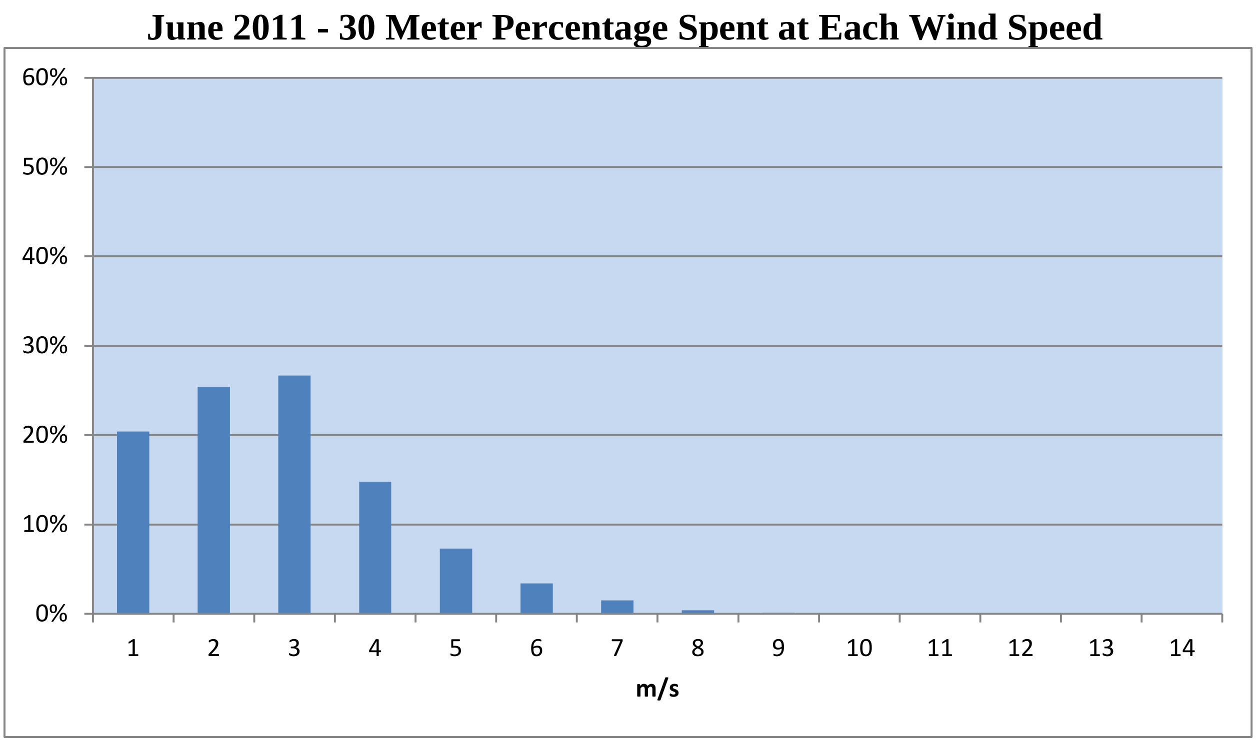
August 2011 - 30 meter 10 Minute Time Interval

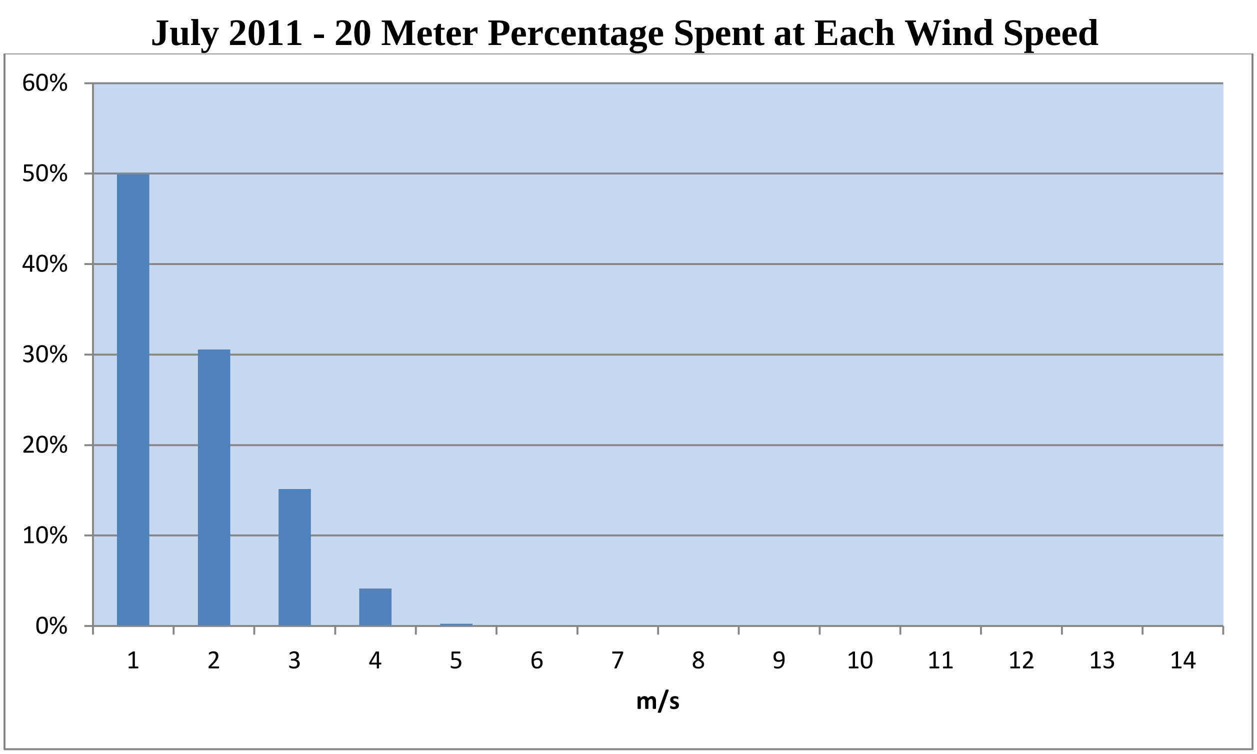


To estimate the anticipated output power for a particular site, forecasters develop equations based on probability. The analysis utilizes a Weibull Probability Density Function. To assist in the development of the probability density function, histograms depicting the percentage of time spent at a particular wind speed for each month are developed. The following figures are the histograms:

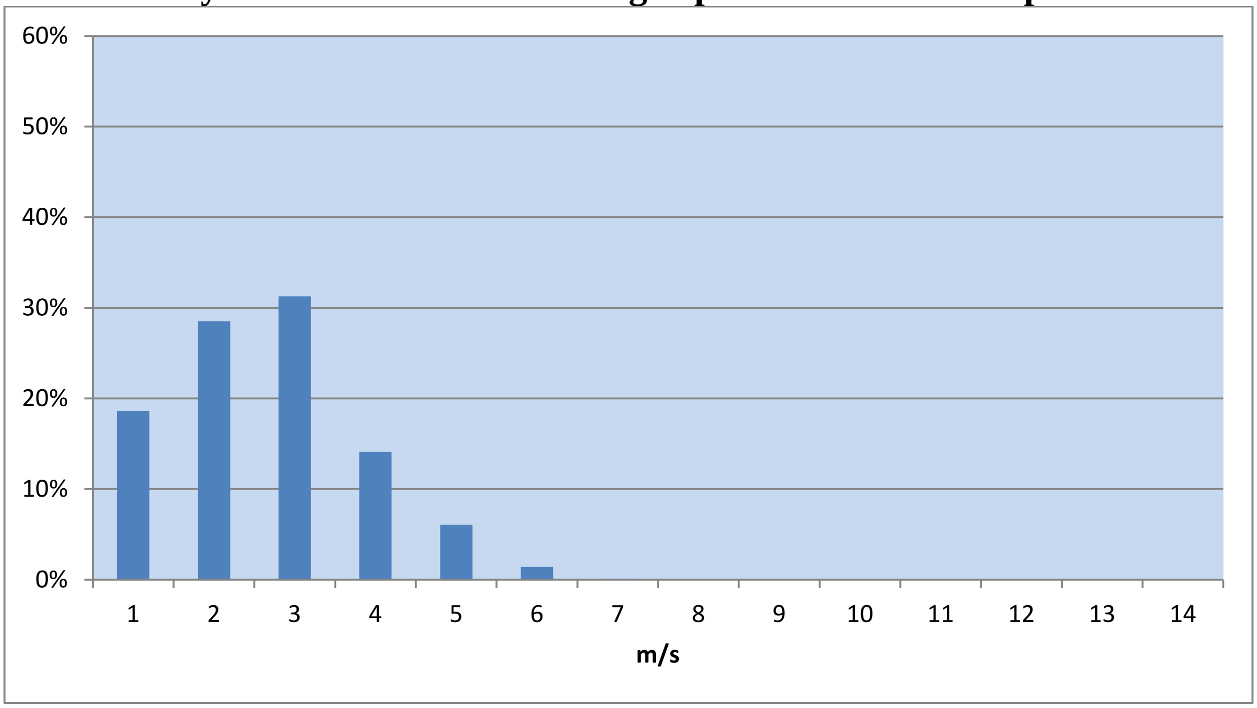
June 2011 - 20 Meter Percentage Spent at Each Wind Speed



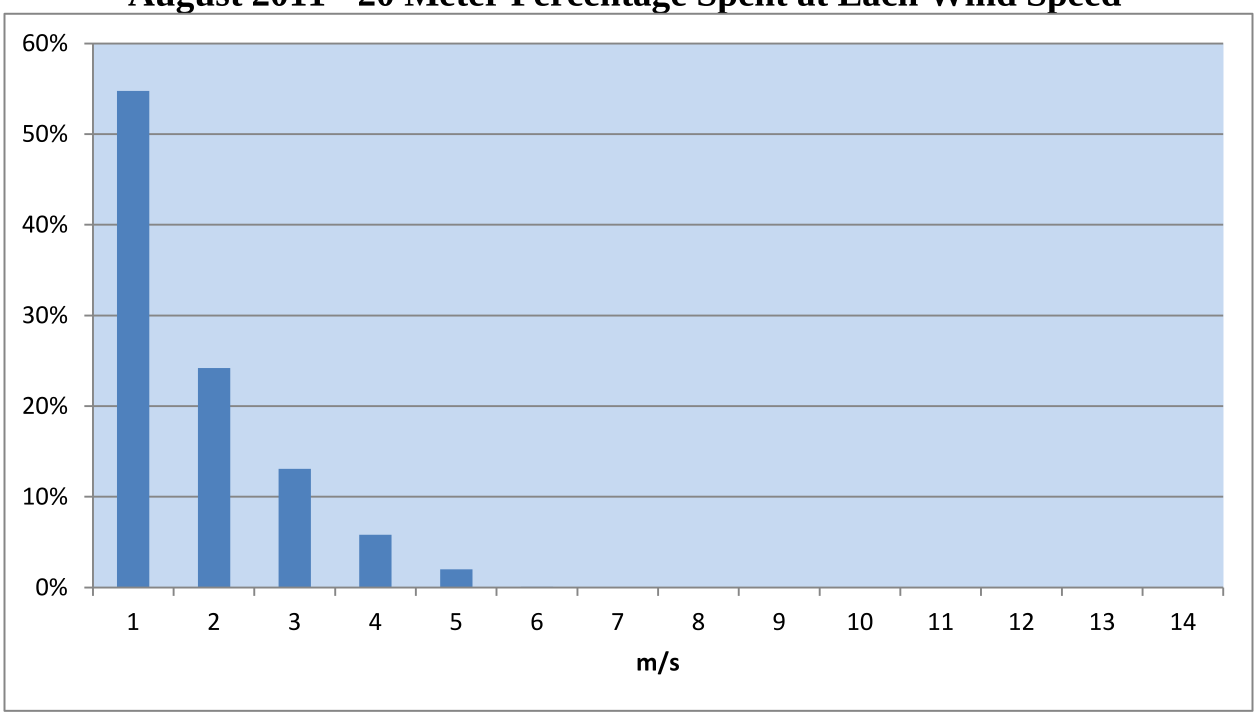

June 2011 - 30 Meter Percentage Spent at Each Wind Speed
60%
50%
40%
30%
20%
10%
0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14
m/s


July 2011 - 20 Meter Percentage Spent at Each Wind Speed
60%
50%
40%
30%
20%
10%
0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14
m/s

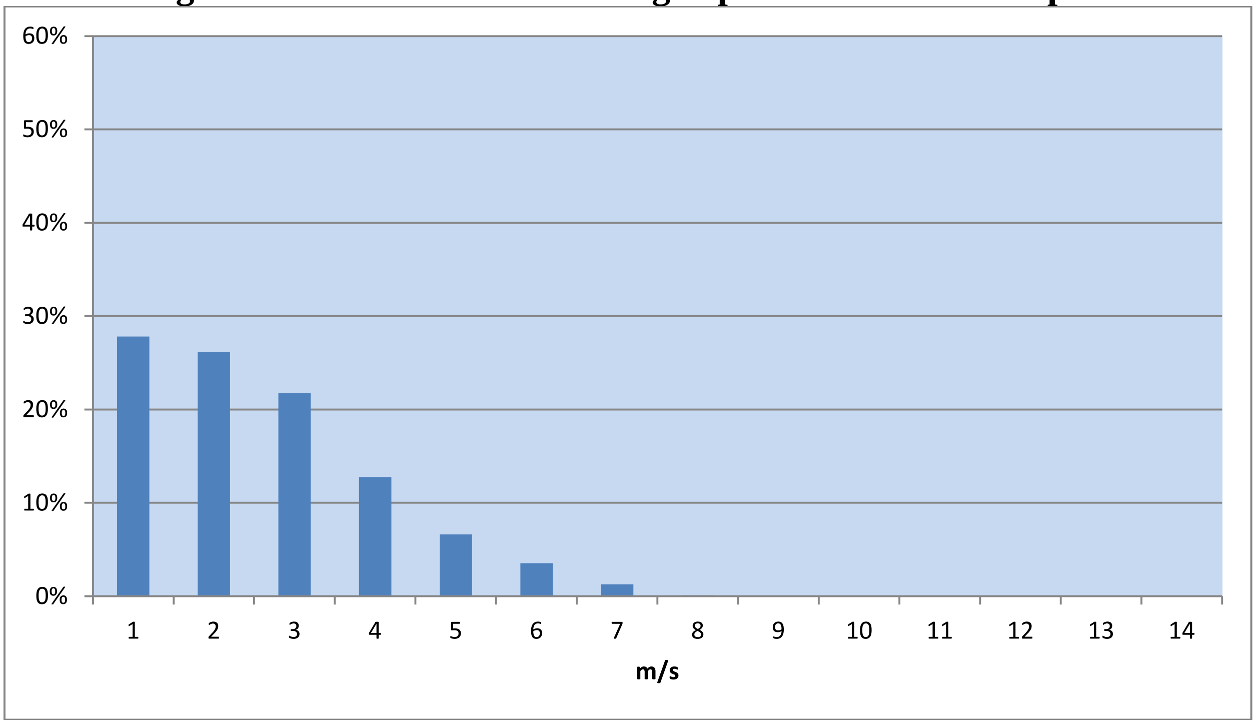
July 2011 - 30 Meter Percentage Spent at Each Wind Speed



August 2011 - 20 Meter Percentage Spent at Each Wind Speed

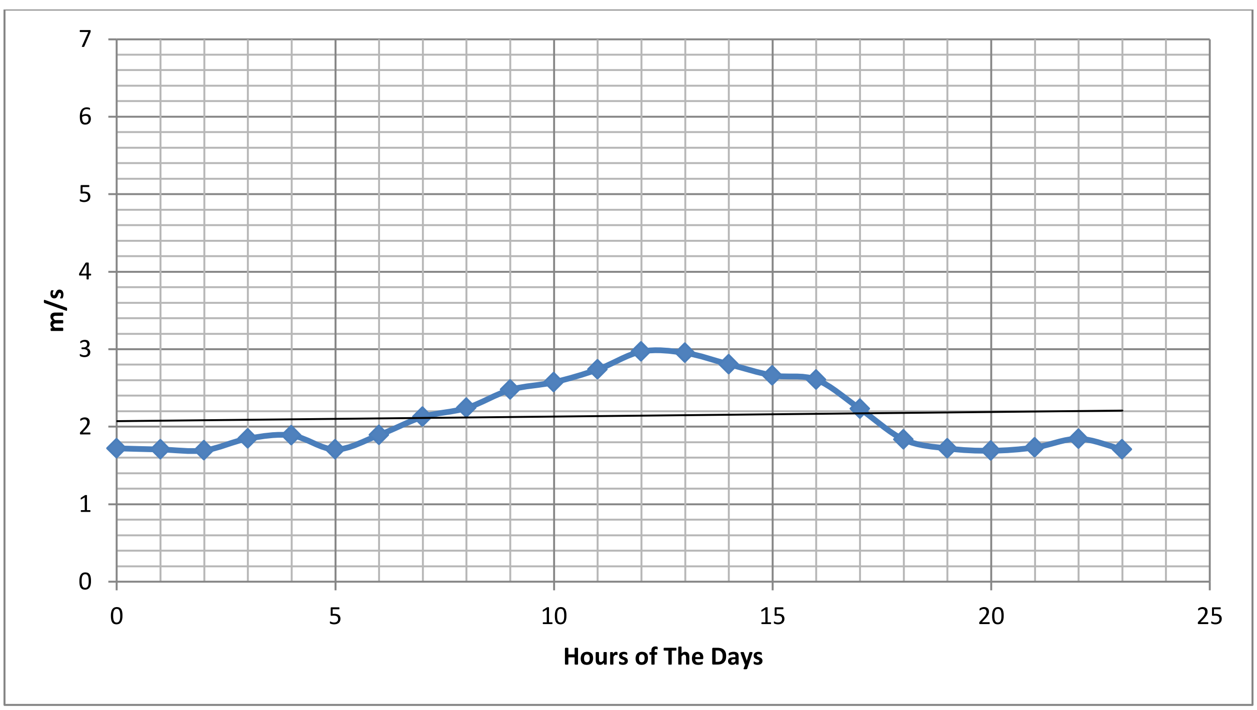


August 2011 - 30 Meter Percentage Spent at Each Wind Speed

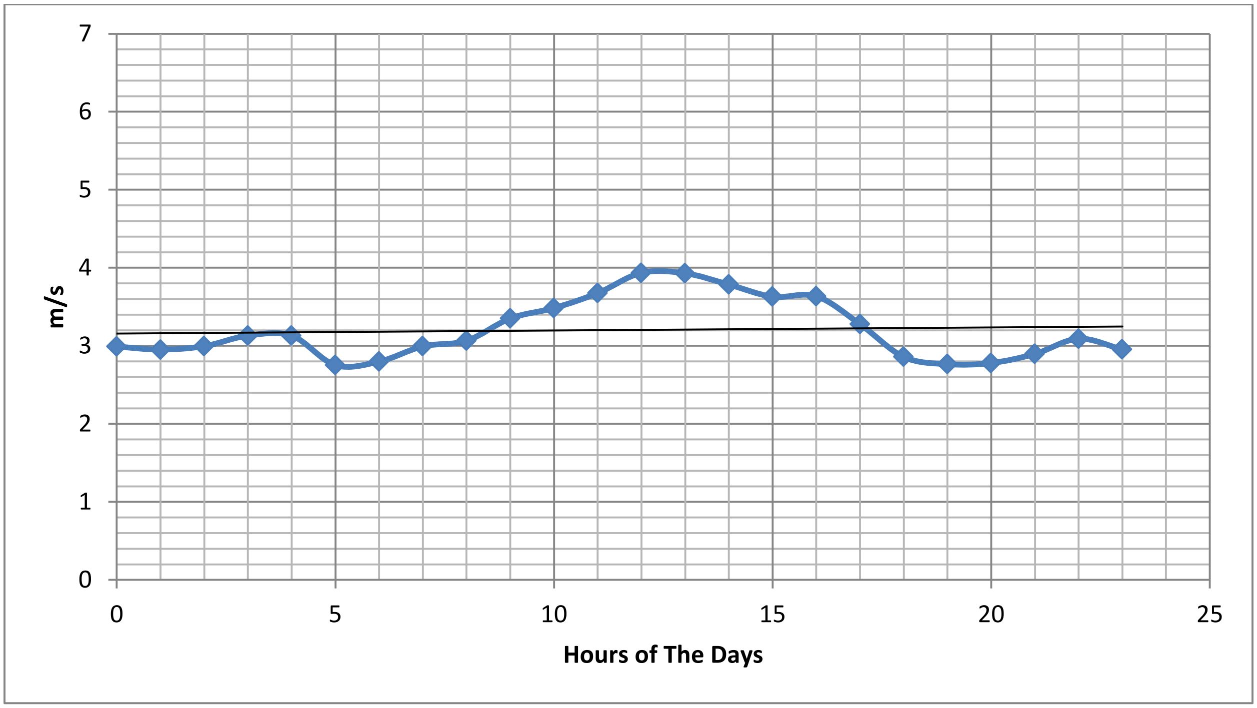


The following plots show the average wind speed each hour of the day. The data is useful to help energy forecasters match available energy from the wind with the demand on the electrical grid.

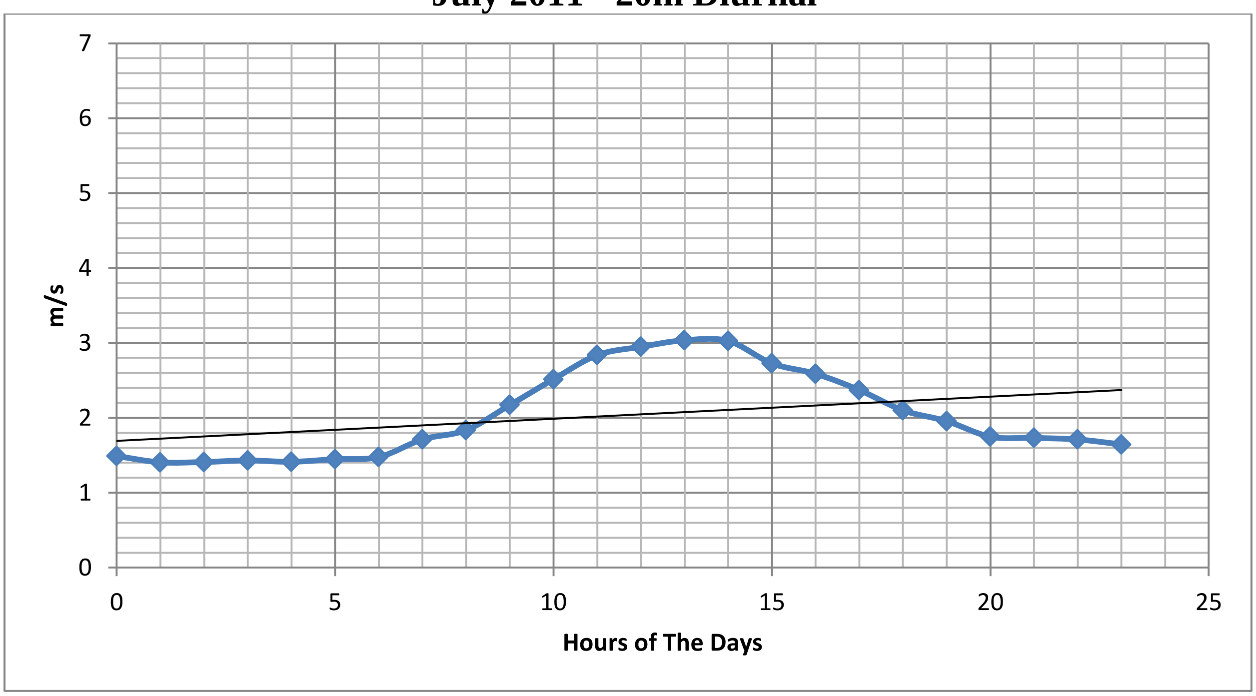
June 2011 - 20m Diurnal



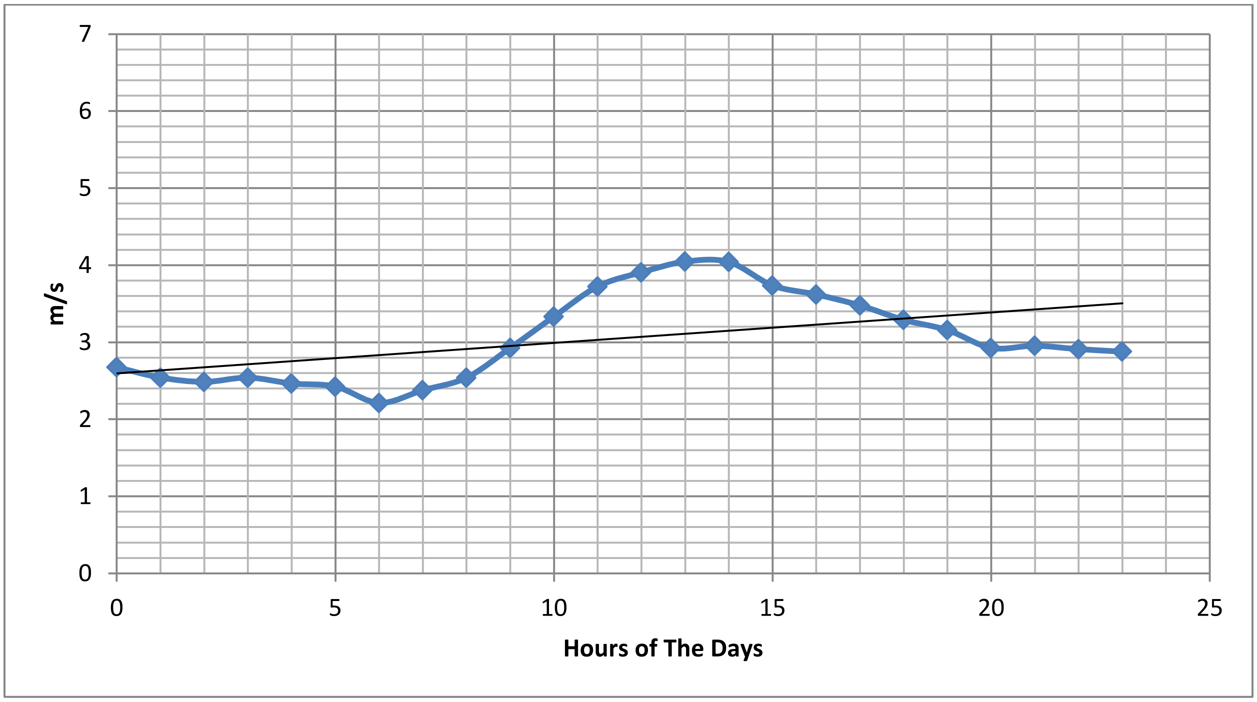
June 2011 - 30m Diurnal



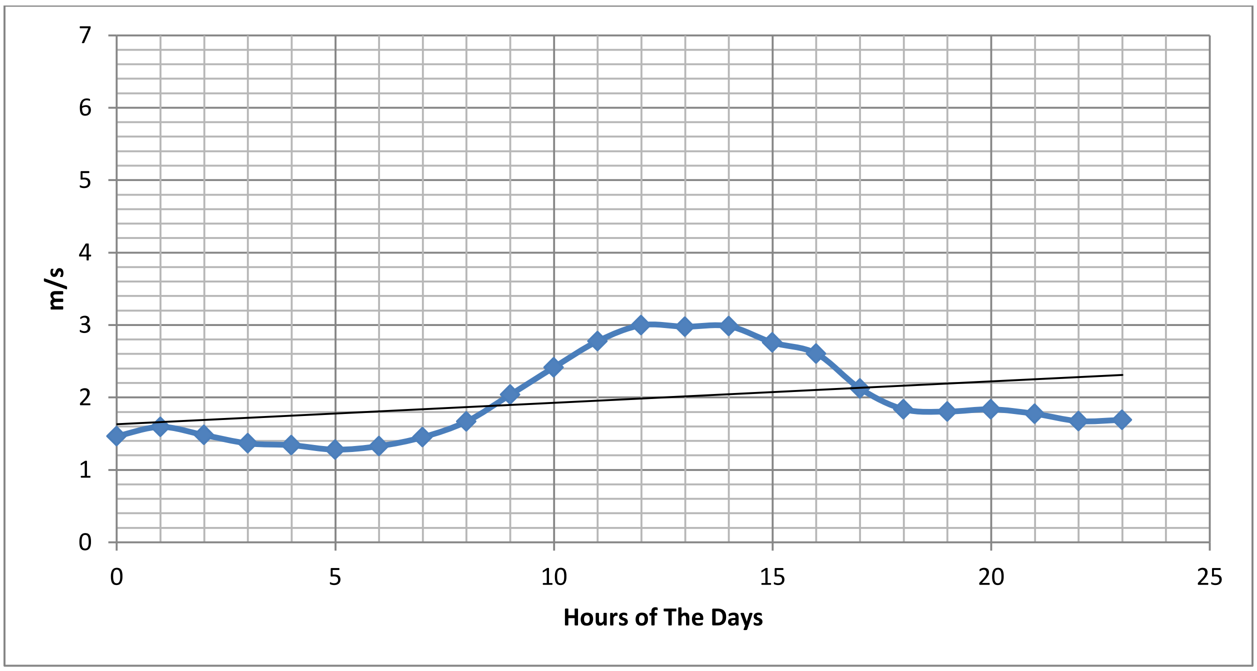
July 2011 - 20m Diurnal



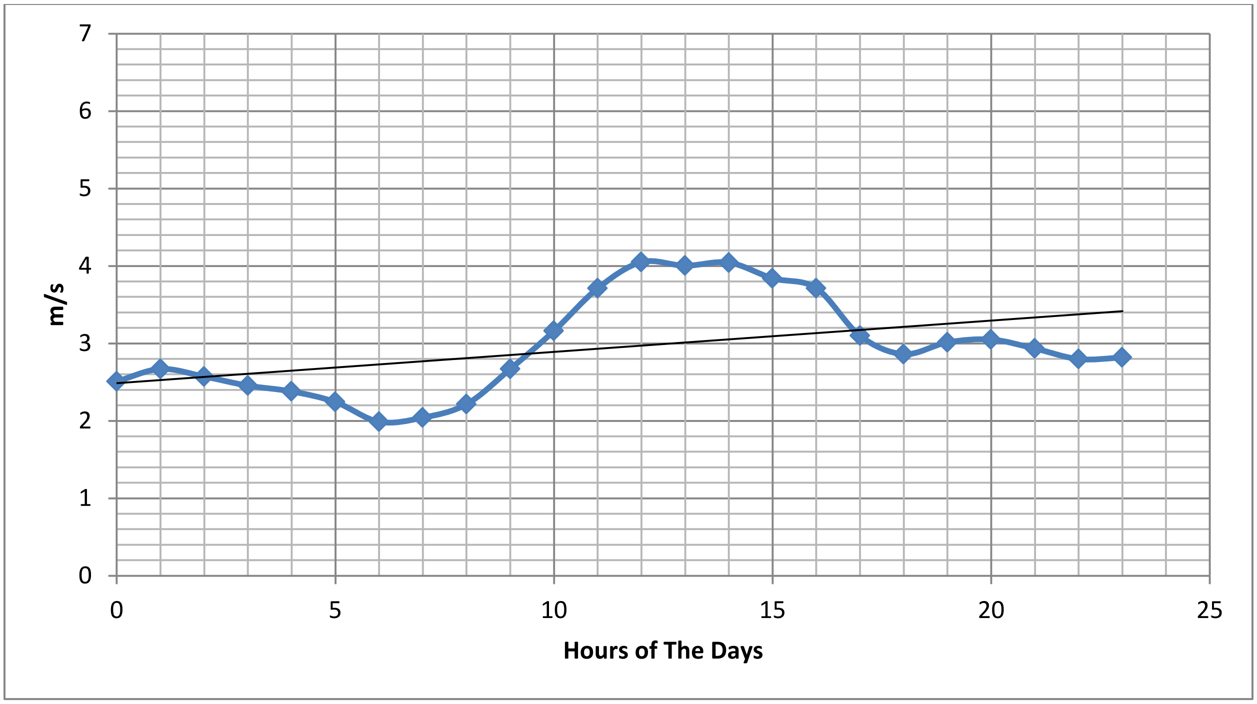
July 2011 - 30m Diurnal



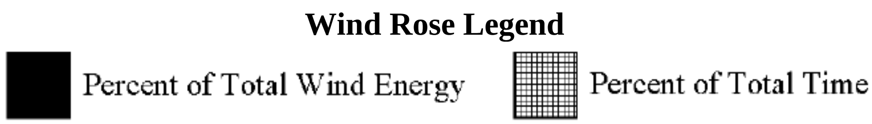
August 2011 - 20m Diurnal

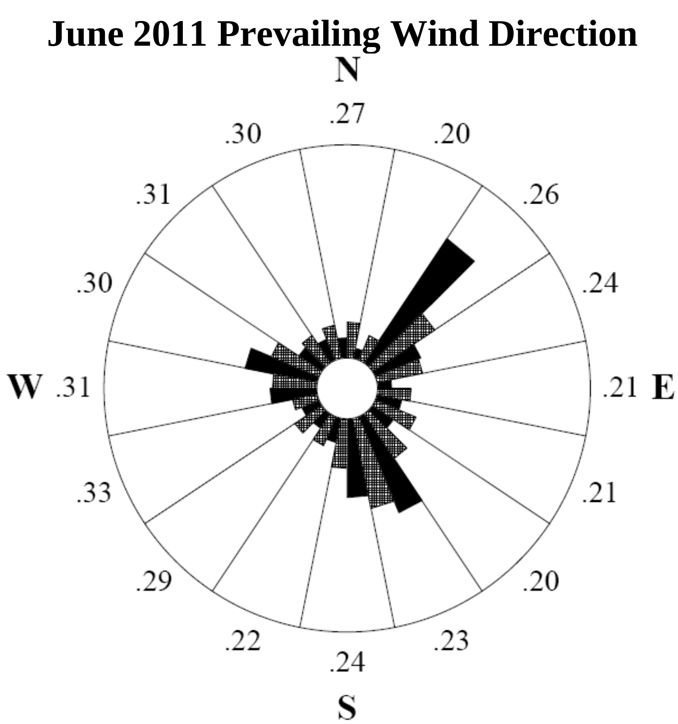


August 2011 - 30m Diurnal

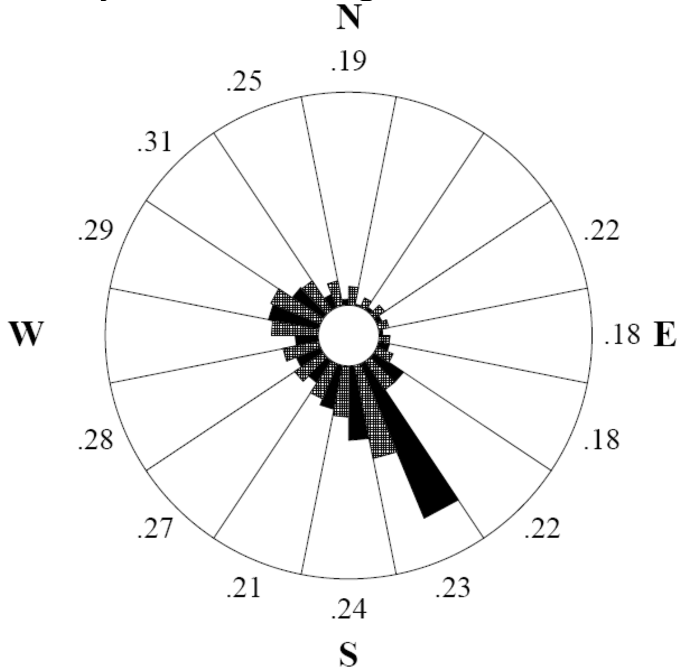


The normal direction of wind speed is useful when sitting a wind turbine. The following plots, termed wind rose, show the prevailing wind direction for each month. A legend identifying each of the plot style types is below.

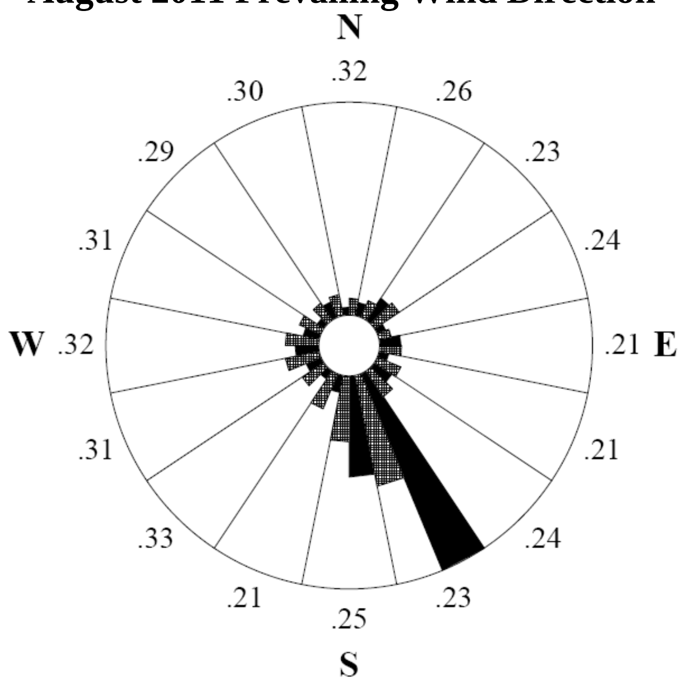




July 2011 Prevailing Wind Direction

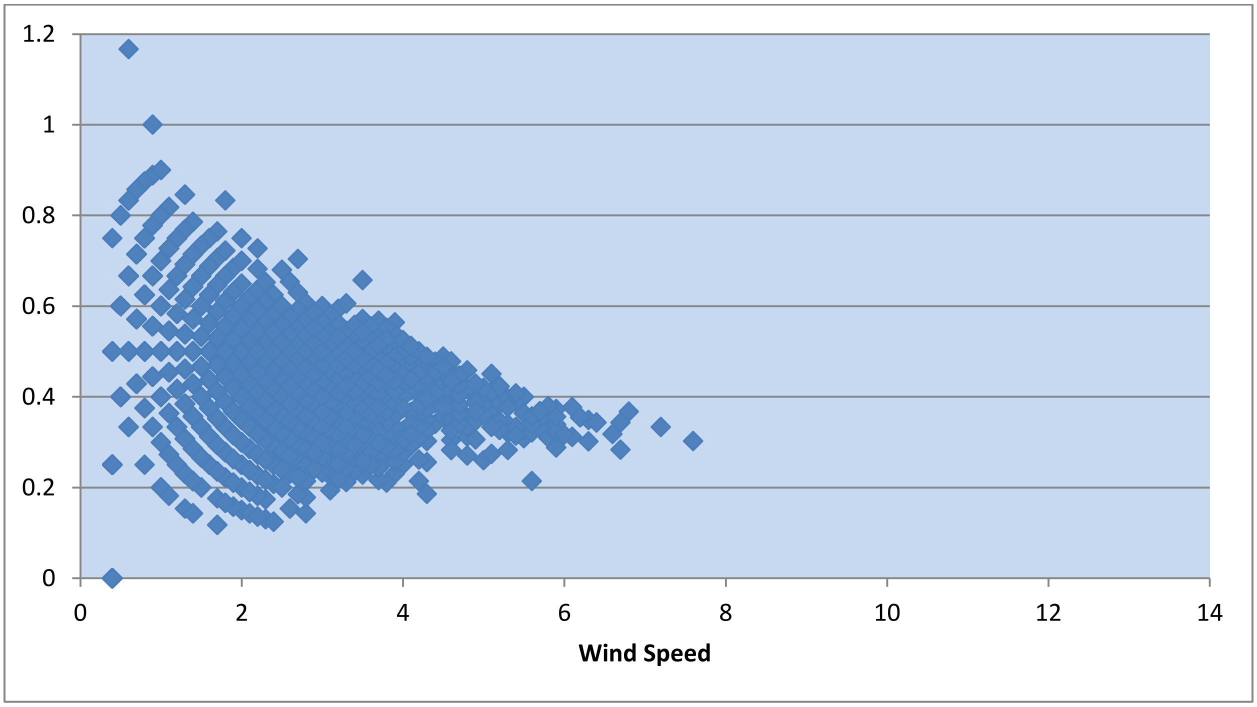


August 2011 Prevailing Wind Direction

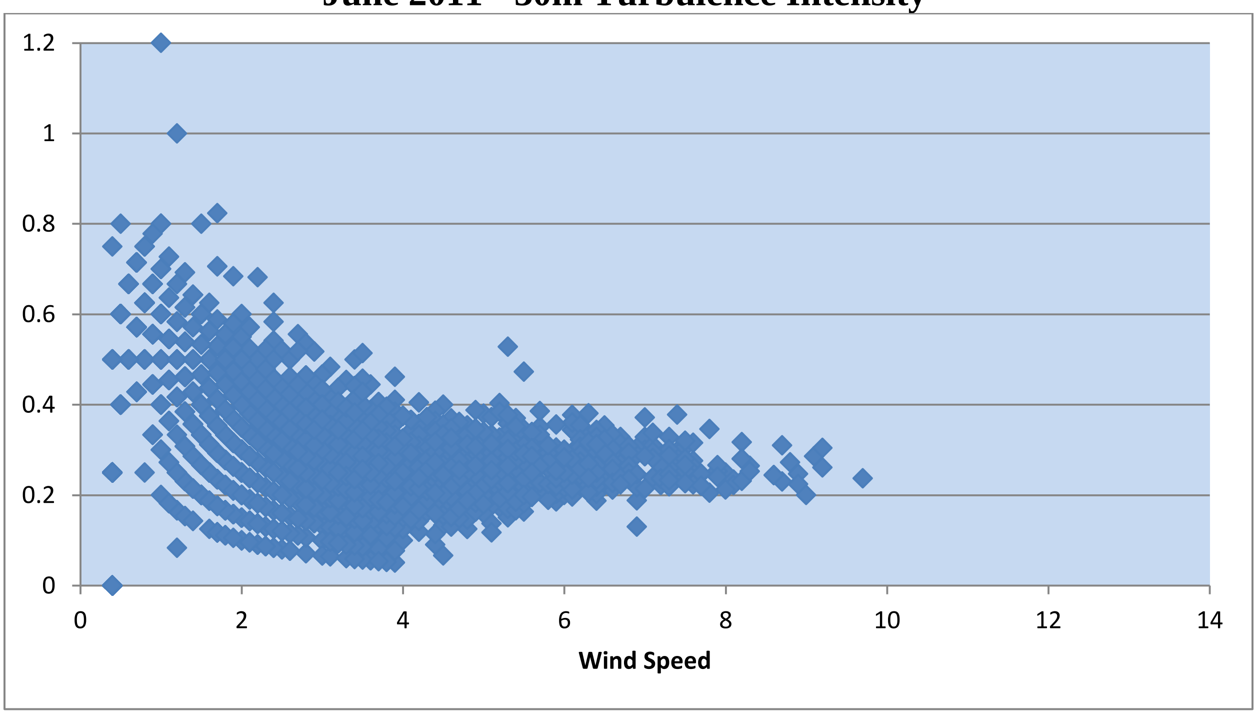


The final set of plots show the turbulence intensity. Turbulence intensity is calculated by dividing the standard deviation of the wind speed by the average wind speed and is plotted versus wind speed. It is used to determine the variation in wind speed that a turbine will see. Lower values of turbulence intensity translate to lower variations in mechanical loading.

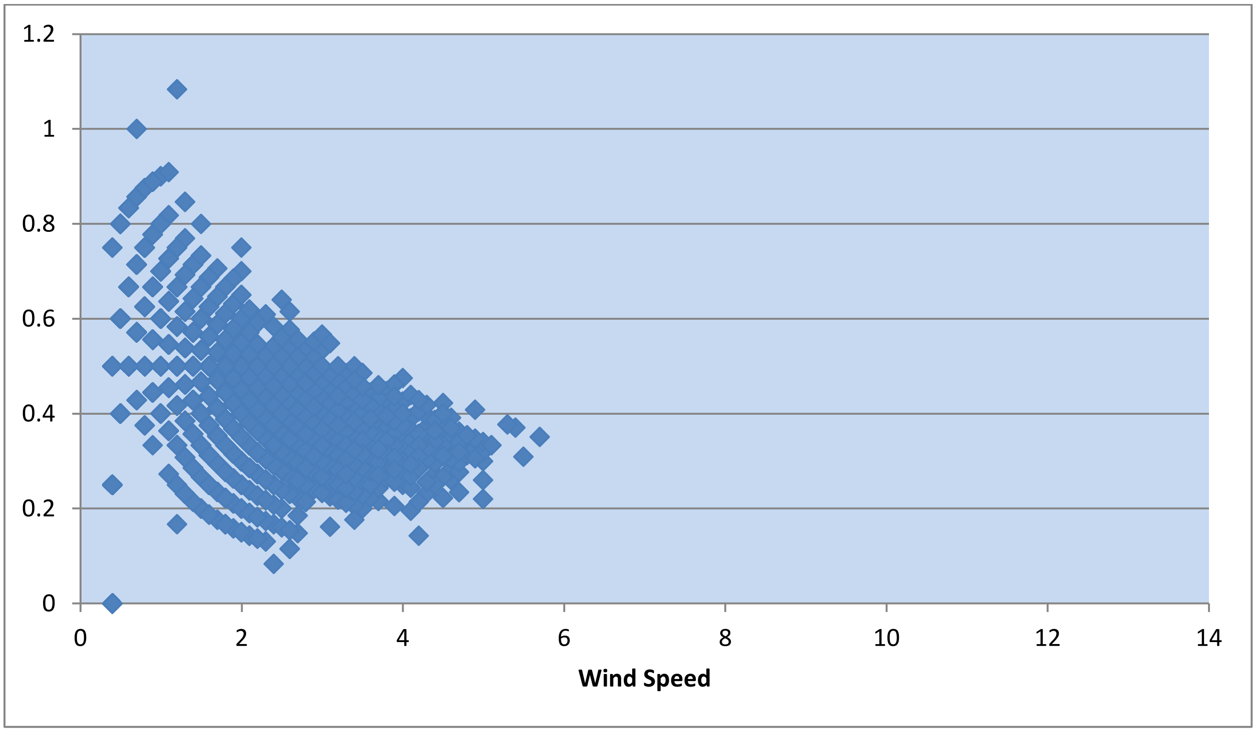
June 2011 - 20m Turbulence Intensity



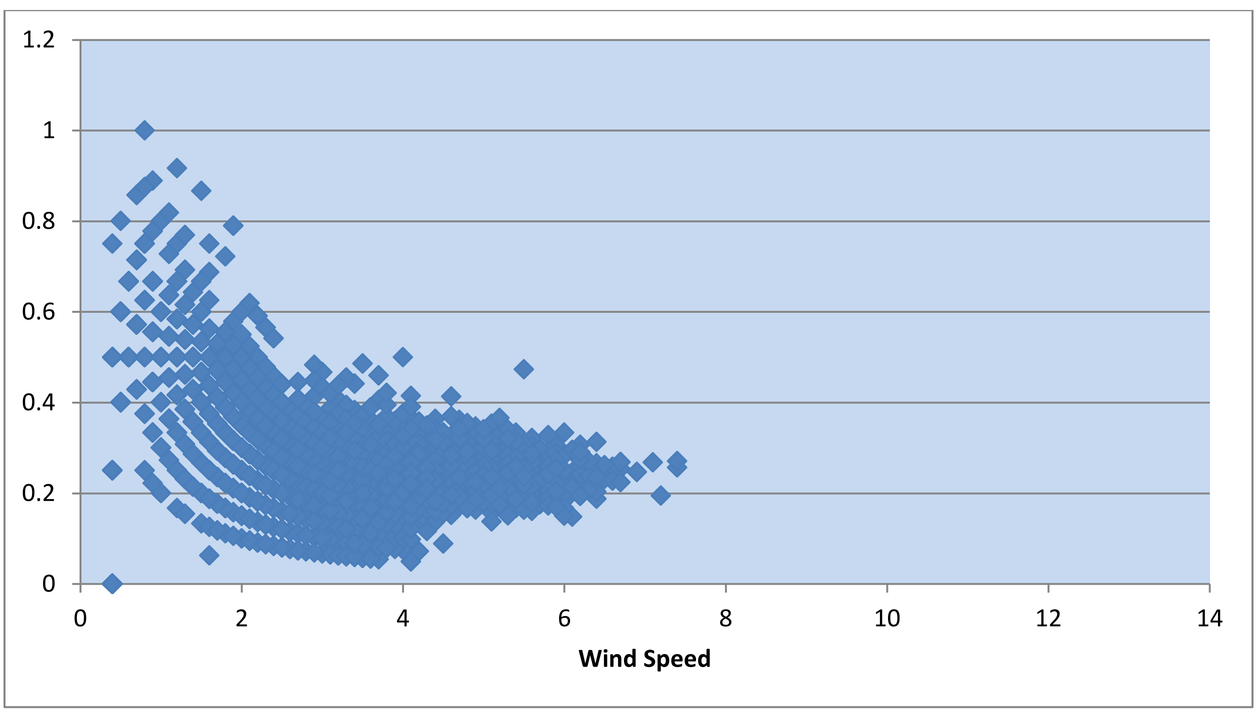
June 2011 - 30m Turbulence Intensity



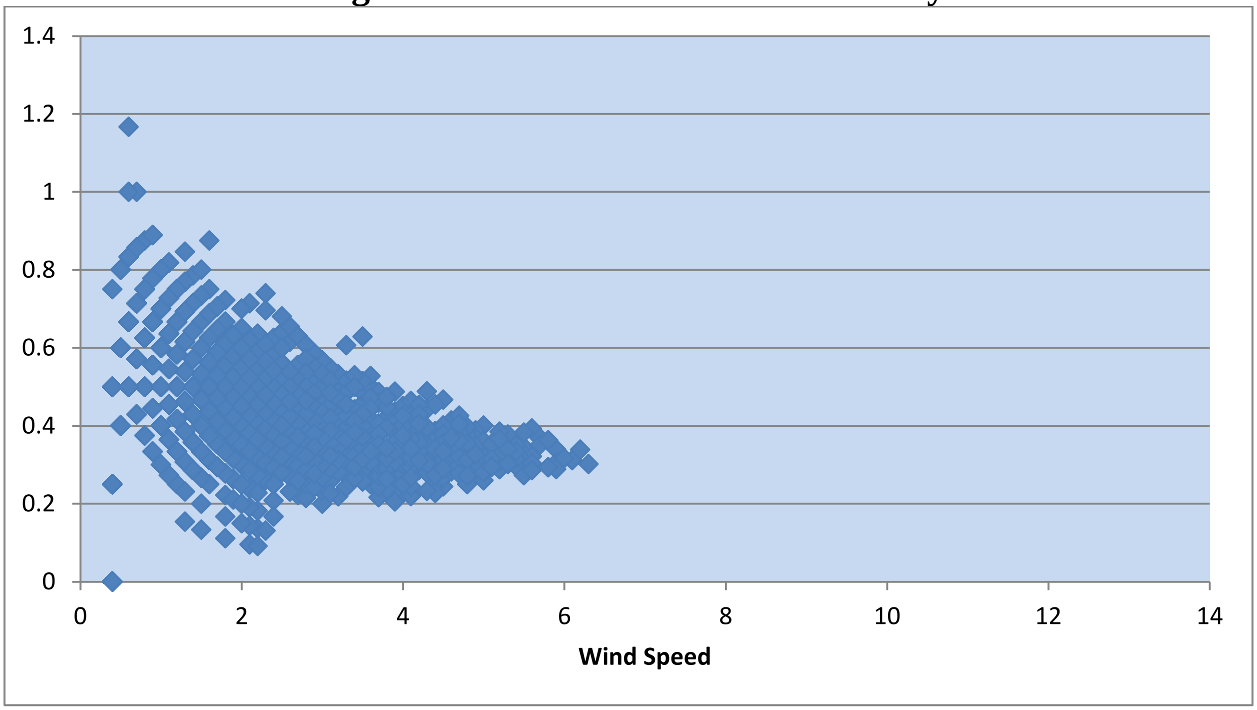
July 2011 - 20m Turbulence Intensity



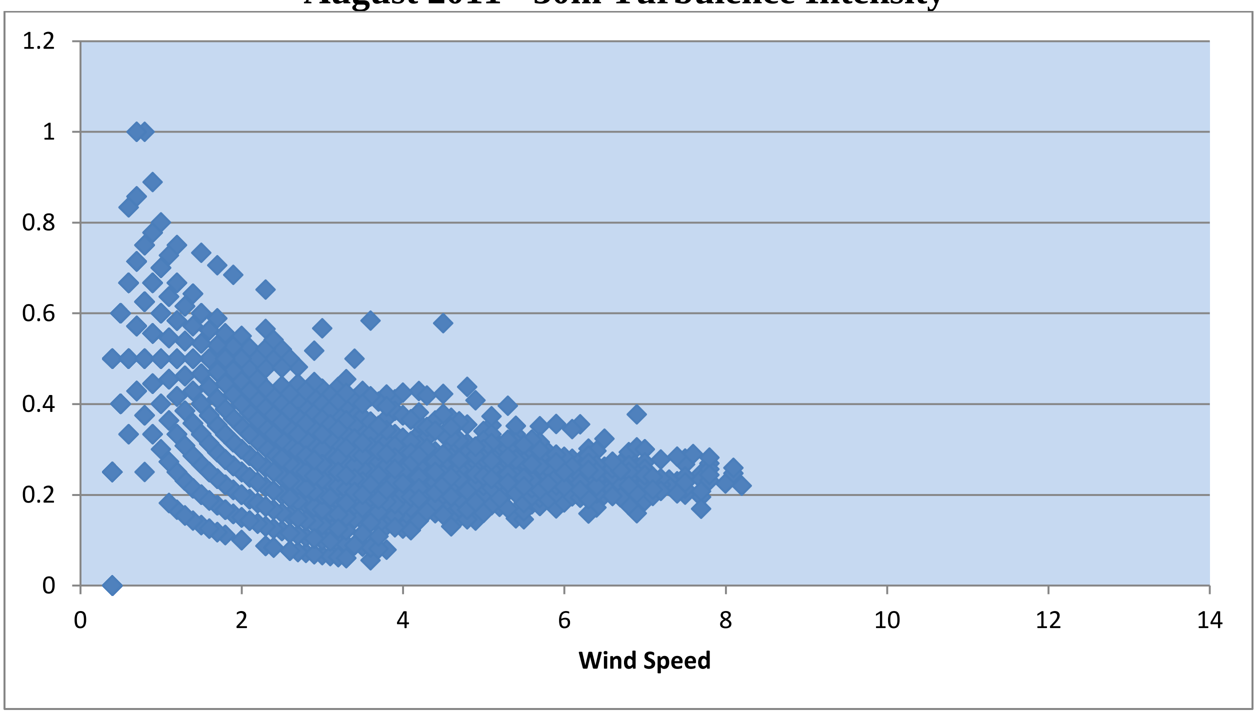
July 2011 - 30m Turbulence Intensity



August 2011 - 20m Turbulence Intensity



August 2011 - 30m Turbulence Intensity



Wind Shear

Wind shear is a measure of the rate of increase in wind speed as you increase the elevation. For wind developers, wind shear is important as it helps to determine the appropriate wind turbine hub height. The higher the value of shear, the faster the wind speed increases. This may result in lower hub heights to obtain required power production. Wind shear is determined using the wind anemometer at 30m and at 20m. Wind shear is a unit-less quantity. The calculation is as follows:

$$WS = \frac{\log\left(\frac{30m\ avg\ wind\ speed}{20m\ avg\ wind\ speed}\right)}{\log\left(\frac{30m}{20m}\right)}$$

Wind shear can be used to estimate the wind speed at a certain height using the following equation:

$$\text{Speed at height of interest} = speed\ at\ known\ height\left(\frac{height\ of\ \text{int}erest}{known\ height}\right)^{Wind\ Shear}$$

Note that wind shear calculation is not a definitive method for calculating exact wind speed at a certain height. It is only an estimate. The following values of wind shear were calculated for each month:

Month	Wind Shear
August, 2010	1.360
September, 2010	1.088
October, 2010	1.137
November, 2010	1.160
December, 2010	1.076
January, 2011	1.014
February, 2011	0.916
March, 2011	0.845
April, 2011	1.038
May, 2011	0.909
June, 2011	1.058
July, 2011	1.114
August, 2011	1.098

Summary of Data

The following data is a summary of the data collected August 23, 2010 to August 27, 2011.

Month	30m Mean [m/s]	30m Max [m/s]	30m Turbulence Intensity	20m Mean [m/s]	20m Max [m/s]	20m Turbulence Intensity	Prevailing Wind Direction
Aug. 10	3.52	13.30	0.25	2.16	12.50	0.43	215
Sept. 10	3.42	14.00	0.27	2.29	12.90	0.42	199
Oct. 10	3.71	28.10	0.30	2.44	22.40	0.46	218
Nov. 10	4.08	16.60	0.27	2.75	23.10	0.42	245
Dec. 10	4.70	28.10	0.27	3.22	23.90	0.43	259
Jan. 11	3.66	21.70	0.28	2.52	19.30	0.43	273
Feb. 11	4.09	20.50	0.28	2.91	20.10	0.39	239
Mar. 11	4.38	20.90	0.28	3.19	16.30	0.38	206
Apr. 11	4.09	25.10	0.29	2.86	22.70	0.42	193
May. 11	3.47	16.70	0.28	2.45	16.70	0.42	169
June. 11	3.20	19.00	0.29	2.14	14.80	0.44	171
July. 11	3.05	12.50	0.27	2.03	11.70	0.41	205
Aug. 11	2.95	14.40	0.29	1.97	12.50	0.43	181

Data Validation

The quality of data provided by the data logger is significant. The probability that all of the data is valid is low. As a result, it is necessary to check the data for errors or inconsistencies, to prevent invalid data from being included in the data analysis.

Expected Data Points

This refers to the number of data points that were expected to be recorded during a data collection period.

Actual Data Points

This refers to the number of data points actually recorded during the data collection period.

% Data Recovered

This calculation is used to determine the percentage of expected data points to actual data points recorded.

Min/Max Test

The Min/Max Test ensures that the data recorded is within the specified range of the instruments used at the site. The ranges used in the tests, were, 0 to 90m/s for wind speed, 0 to 4m/s for wind speed variation, 0 to 359.9°C for wind direction, and 60°C for temperature. If the data is not within the ranges of the related tests, the data is invalid and is flagged so. Data that is flagged invalid is removed before the analysis of the data is started.

Min/Max T Test

This test checks the variation of the data, using the wind speed and wind speed direction standard deviation. If the wind direction standard deviation is less than 0 degrees, or if the wind speed is less than 10 m/s and the wind direction standard deviation is greater than 100 degrees, or if the wind speed is greater than 10 m/s and the wind direction standard deviation is greater than 100 degrees, the data is in range. If the data does not pass this test the data is invalid and is removed before the data is analyzed.

Icing Test

The icing test is designed to find data that may be invalid due to conditions that cause the vane to be iced. It is determined by an average wind speed greater than 1m/s, a temperature less than 2°C, and a wind direction standard deviation less than 0.5m/s.

Hours Out of Range

The hours out of range are determined by the Min/Max and Min/Max T Test. This test flags data that falls outside of a specific range. The data that falls outside of the range determines the hours out of range.

Hours of Icing

The hours of icing are determined using the icing test. The test uses average wind speed, temperature, and wind direction standard deviation to determine what data to flag due to icing.

% Data Good

The percent of bad data is subtracted from the percent of the data recovered to determine the percent of good data.

June 2011 Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	%Data Recovered	Hours Out of Range	Hours of Icing	% Data Good
30m Wind Speed	4320	4320	100	0	0	100.00
30m Wind Speed SD	4320	4320	100	0	0	100.00
20m Wind Speed	4320	4320	100	0	0	100.00
20m Wind Speed SD	4320	4320	100	0	0	100.00
Wind Dir.	4320	4320	100	0	0	100.00
Temp.	4320	4320	100	0	0	100.00
Total	25920	25920	100	0	0	100.00

July 2011 Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	%Data Recovered	Hours Out of Range	Hours of Icing	% Data Good
30m Wind Speed	4464	4464	100	0	0	100.00
30m Wind Speed SD	4464	4464	100	0	0	100.00
20m Wind Speed	4464	4464	100	0	0	100.00
20m Wind Speed SD	4464	4464	100	0	0	100.00
Wind Dir.	4464	4464	100	0	0	100.00
Temp.	4464	4464	100	0	0	100.00
Total	26784	26784	100	0	0	100.00

August 2011 Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	%Data Recovered	Hours Out of Range	Hours of Icing	% Data Good
30m Wind Speed	3840	3840	100	0	0	100.00
30m Wind Speed SD	3840	3840	100	0	0	100.00
20m Wind Speed	3840	3840	100	0	0	100.00
20m Wind Speed SD	3840	3840	100	0	0	100.00
Wind Dir.	3840	3840	100	0	0	100.00
Temp.	3840	3840	100	0	0	100.00
Total	23040	23040	100	0	0	100.00

Total Data Collected From Aug 23, 2010 to Aug 27, 2011 Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	%Data Recovered	Hours Out of Range	Hours of Icing	% Data Good
Aug '10	7272	7272	100	0	0	100.00
Sept '10	25920	25920	100	0	0	100.00
Oct '10	26784	26784	100	0	0	100.00
Nov '10	25920	25920	100	0	0	99.98
Dec'10	26784	26784	100	0	1	99.98
Jan'11	26784	26784	100	0	47	98.95
Feb'11	24186	24186	100	0	0.17	100.00
Mar'11	25920	25920	100	0	0	100.00
Apr'11	25920	25920	100	0	1.17	99.97
May'11	26784	26784	100	0	0	100.00
June'11	25920	25920	100	0	0	100.00
July'11	26784	26784	100	0	0	100.00
Aug'11	23040	23040	100	0	0	100.00
Total	**294978**	**294978**	**100**	**0**	**49.39**	**99.91**

The following table shows the calculation of average wind speed for the site. In addition, an estimate annual energy production for a Northwind 100 wind turbine generator is provided based on the wind speed probability at the Peaks site.

37 m - Northwind 100 Energy Production

Wind Speed at 37m (m/s)	Fraction of Hours at Wind Speed	Wind Speed X fraction of hours	Northwind 100 Power (kW)	Hours at Wind Speed (h/year)	Energy (kWh/year)
0/1	0.102038886	0.1020	0	0	0
2	0.132224996	0.2644	0	0	0
3	0.216144651	0.6484	0	0	0
4	0.215482675	0.8619	3.7	1929.000908	7137
5	0.134059616	0.6703	19	1200.10168	22802
6	0.085243607	0.5115	29.4	763.1007717	22435
7	0.052731124	0.3691	41	472.0490241	19354
8	0.028048873	0.2244	54.3	251.0935089	13634
9	0.013996066	0.1260	66.8	125.2927826	8370
10	0.007187169	0.0719	77.7	64.339537	4999
11	0.004293388	0.0472	86.4	38.43440763	3321
12	0.002912695	0.0350	92.8	26.07444394	2420
13	0.00230746	0.0300	97.3	20.65637767	2010
14	0.001777879	0.0249	100	15.91556968	1592
15	0.000586322	0.0088	100.6	5.248751702	528
16	0.000586322	0.0094	99.8	5.248751702	524
17	0.000378272	0.0064	99.4	3.386291421	337
18	0	0.0000	98.6	0	0
19	0	0.0000	97.8	0	0
20	0	0.0000	97.3	0	0
21	0	0.0000	97.3	0	0
22	0	0.0000	98	0	0
23	0	0.0000	99.7	0	0
24	0	0.0000	0	0	0
25	0	0.0000	0	0	0
				Total Kw:	**109,462**
				Total $:	**19,703.13**
Note: The total money base on 18 cents/kWh					