

WIND DATA REPORT

Wellfleet, MA

November 20th 2006 to November 30th 2006

Prepared for

Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

Massachusetts Division of Energy Resources

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NOTICE AND ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

All the work presented in this Wind Data Report including installation and decommissioning of the meteorological tower and instrumentation, and the data analysis and reporting was performed by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst.

Wind monitoring at Wellfleet commenced in November, 2006. The first day of good data was November 20, 2006. Wind speed and direction are measured at three heights: 50 m, 38 m and 20 m.

This report covers data from November 20, 2006 through November 30, 2006. This is clearly a very short period of time, which restricts the amount of analysis that can be provided. Future quarterly reports will contain significantly more information. The wind vane at 50 m at the Wellfleet site is currently not functioning. Consequently, the mean wind speed and time series data presented below comes from the anemometer at 38 m. The mean wind speed at 38 m during the period covered by this report is 7.9 m/s (17.7 mph*).

Additional information about interpreting the data presented in this report can be found in the Fact Sheet, "Interpreting Your Wind Resource Data," produced by RERL and the Massachusetts Technology Collaborative (MTC). This document is found through the RERL website:

http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_6_Wind_resource_interpretation.pdf

* 1 m/s = 2.237 mph.

SECTION 1 - Station Location

The site is located at a parking lot very near the beach on Ocean View Drive in Wellfleet. The site elevation is 29 m above sea level. The circle in Figure 1 shows the exact location of the tower. The location of the tower base is at 41.934°N, 69.980°W (WGS84/NAD83).



Figure 1 - Wellfleet Site Location

Source: Google Earth

SECTION 2 - Instrumentation and Equipment

Wind monitoring equipment is mounted on a standard NRG 50 m tall 6-inch diameter tilt-up guyed tower. Wind vanes and anemometers are located at three heights on the tower: 50 m, 38 m, and 20 m. Redundant anemometers are positioned at 50 m and 38 m.

Additional equipment and models:

- NRG model Symphonie Cellogger
- 5 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s)

- 3 - #200P Wind direction vanes
- Lightning rod and grounding cable
- NRG 11S temperature Sensor

The data from the Symphonie logger is mailed to the University of Massachusetts, Amherst on a regular basis. The logger samples wind speed and direction once every two seconds. These are then combined into 10-minute averages, and along with the standard deviation for those 10-minute periods, are put into a binary file. These binary files are converted to ASCII text files using the NRG software BaseStation®. These text files are then imported into a database software program where they are subjected to QA tests prior to using the data.

SECTION 3- Data Collection and Maintenance

The following maintenance/equipment problems occurred during the report period, and the following corrective actions taken:

The tower was raised in November, 2006. Good data became available starting on November 20, 2006

The wind vane at 50 m is currently not functioning. All other sensors appear to be working normally, and data for these sensors has been collected. Consequently, the data presented in this report comes from the anemometer at 38 m. The logger was replaced on December 5, 2006 in the hopes of correcting this problem. Unfortunately, this was unsuccessful. This issue will hopefully be resolved soon.

SECTION 4- Significant Meteorological Events

There were no extreme meteorological events in the period covered by this report. The highest wind speeds in the period of this report are less than 12 m/s as shown by the time series graph.

SECTION 5 - Data Recovery and Validation

All raw wind data are subjected to a series of tests and filters to weed out data that are faulty or corrupted. Definitions of these quality assurance (QA) controls are given below under Test Definitions and Sensor Statistics. These control filters were designed to automate the quality control process and used many of the previous hand-worked data sets made at UMass to affect a suitable emulation. The gross percentage of data recovered

(ratio of the number of raw data points received to data points expected) and net percentage (ratio of raw data points which passed all QA control tests to data points expected) are shown below.

The values shown in the table are only for the sensors at 38 m and 20 m, since the vane at 50 m was not functioning.

Gross Data Recovered [%]	100
Net Data Recovered [%]	99.6

Test Definitions

All raw data were subjected to a series of validation tests, as described below. The sensors tested and the parameters specific to each sensor are given in the Sensor Performance Report that is included in APPENDIX A. Data that were flagged as invalid were not included in the statistics presented in this report.

MinMax Test: All sensors are expected to report data values within a range specified by the sensor and logger manufacturers. If a value falls outside this range, it is flagged as invalid. A data value from the sensor listed in Test Field 1 (TF1) is flagged if it is less than Factor 1 (F1) or greater than Factor 2. This test has been applied to the following sensors (as applicable): wind speed, wind speed standard deviation, wind direction, temperature, and solar insolation.

$$F1 > TF1 > F2$$

MinMaxT Test: This is a MinMax test for wind direction standard deviation with different ranges applied for high and low wind speeds. A wind direction standard deviation data value (TF1) is flagged either if it is less than Factor 1, if the wind speed (TF2) is less than Factor 4 and the wind direction standard deviation is greater than Factor 2, or if the wind speed is greater than or equal to Factor 4 and the wind direction standard deviation is greater than Factor 3.

$$\begin{aligned} & (TF1 < F1) \\ & \text{or } (TF2 < F4 \text{ and } TF1 > F2) \\ & \text{or } (TF2 \geq F4 \text{ and } TF1 > F3) \end{aligned}$$

Icing Test: An icing event occurs when ice collects on a sensor and degrades its performance. Icing events are characterized by the simultaneous measurements of near-zero standard deviation of wind direction, non-zero wind speed, and near- or below-freezing temperatures. Wind speed, wind speed standard deviation, wind direction, and wind direction standard deviation data values are flagged if the wind direction standard deviation (CF1) is less than or equal to Factor 1 (F1), the wind speed (TF1) is greater than Factor 2 (F2), and the temperature (CF2) is less than Factor 3 (F3). To exit an icing event, the wind direction standard deviation must be greater than Factor 4 (F4).

$$CF1 \leq F1 \text{ and } TF1 > F2 \text{ and } CF2 < F3$$

CompareSensors Test: Where primary and redundant sensors are used, it is possible to determine when one of the sensors is not performing properly. For anemometers, poor performance is characterized by low data values. Therefore, if one sensor of the pair reports values significantly below the other, the low values are flagged. At low wind speeds (Test Fields 1 and 2 less than or equal to Factor 3) wind speed data are flagged if the absolute difference between the two wind speeds is greater than Factor 1. At high wind speeds (Test Fields 1 or 2 greater than Factor 3) wind speed data are flagged if the absolute value of the ratio of the two wind speeds is greater than Factor 2.

$$\begin{aligned} & [TF1 \leq F3 \text{ and } TF2 \leq F3 \text{ and } \text{abs}(TF1 - TF2) > F1] \\ \text{or } & [(TF1 > F3 \text{ or } TF2 > F3) \text{ and } (\text{abs}(1 - TF1 / TF2) > F2 \text{ or } \text{abs}(1 - TF2 / TF1) > F2)] \end{aligned}$$

Sensor Statistics

Expected Data Points: the total number of sample intervals between the start and end dates (inclusive).

Actual Data Points: the total number of data points recorded between the start and end dates.

% Data Recovered: the ratio of actual and expected data points (this is the *gross data recovered percentage*).

Hours Out of Range: total number of hours for which data were flagged according to MinMax and MinMaxT tests. These tests flag data, which fall outside of an expected range.

Hours of Icing: total number of hours for which data were flagged according to Icing tests. This test uses the standard deviation of wind direction, air temperature, and wind speed to determine when sensor icing has occurred.

Hours of Fault: total number of hours for which data were flagged according to CompareSensors tests. These tests compare two sensors (e.g. primary and redundant anemometers installed at the same height) and flag data points where one sensor differs significantly from the other.

% Data Good: the filter results are subtracted from the gross data recovery percentage to yield the *net data recovered percentage*.

SECTION 6 - Data Summary

This report contains only two graphs, covering the period from November 20, 2006 until November 30, 2006. Future reports will contain other types of graphs as well.

- Time Series – 10-minute average wind speeds at a height of 38 m are plotted against time. The wind speed time series is shown in Figure 2.
- Turbulence Intensity - A plot of turbulence intensity as a function of wind speed at a height of 38 m. Turbulence Intensity is calculated as the standard deviation of the wind speed divided by the wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. The turbulence intensity graph flattens out after 3 m/s. The turbulence intensity plot is shown in Figure 3.

SECTION 7- Graphs

Wind Speed Time Series

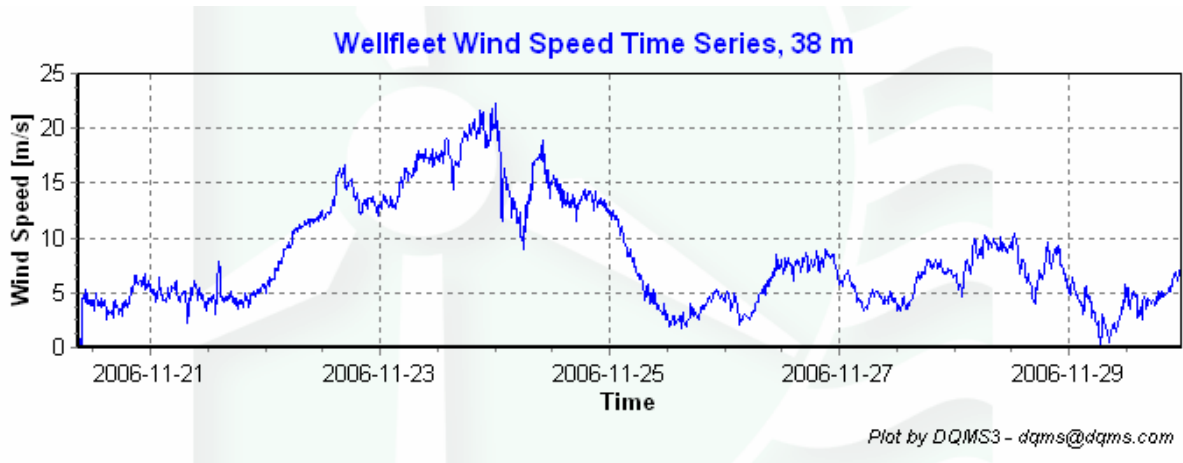


Figure 2 - Wind Speed Time Series, November 20, 2006 – November 30, 2006.

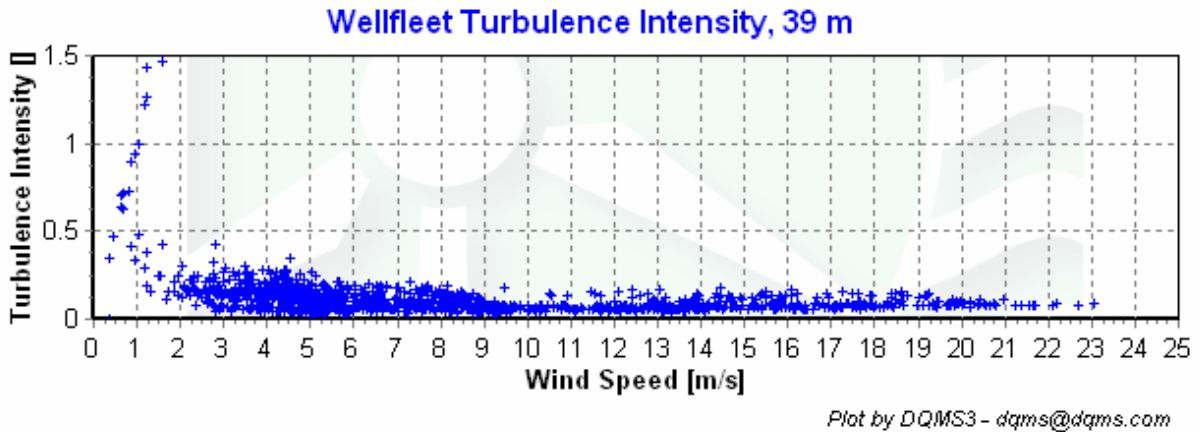


Figure 3 – Turbulence Intensity, November 20, 2006 – November 30, 2006.

APPENDIX A– Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	TestField3	CalcField1	CalcField2	TestType	Factor1	Factor2	Factor3	Factor4
1						TimeTest Insert	0	0	0	0
2	Etmp2aDEGC					MinMax	-30	60	0	0
3	Etmx2aDEGC					MinMax	-30	60	0	0
4	Etmn2aDEGC					MinMax	-30	60	0	0
5	EtmpSD2aDEGC					MinMax	-30	60	0	0
10	Anem50aMS					MinMax	0	90	0	0
11	Anem50bMS					MinMax	0	90	0	0
12	Anem38aMS					MinMax	0	90	0	0
13	Anem38bMS					MinMax	0	90	0	0
14	Anem20aMS					MinMax	0	90	0	0
15	Anem50yMS					MinMax	0	90	0	0
16	Anem38yMS					MinMax	0	90	0	0
20	AnemSD50aMS					MinMax	0	4	0	0
21	AnemSD50bMS					MinMax	0	4	0	0
22	AnemSD38aMS					MinMax	0	4	0	0
23	AnemSD38bMS					MinMax	0	4	0	0
24	AnemSD20aMS					MinMax	0	4	0	0
25	AnemSD50yMS					MinMax	0	4	0	0
26	AnemSD38yMS					MinMax	0	4	0	0
30	Vane50aDEG					MinMax	0	359.9	0	0
31	Vane38aDEG					MinMax	0	359.9	0	0
32	Vane20aDEG					MinMax	0	359.9	0	0
50	Turb50zNONE					MinMax	0	2	0	0
51	Turb38zNONE					MinMax	0	2	0	0

60	Wshr0zNONE					MinMax	-100	100	0	0
70	Pwr50zWMS					MinMax	0	5000	0	0
71	Pwr38zWMS					MinMax	0	5000	0	0
200	VaneSD50aDEG	Anem50yMS				MinMaxT	0	100	100	10
201	VaneSD38aDEG	Anem38yMS				MinMaxT	0	100	100	10
202	VaneSD20aDEG	Anem20aMS				MinMax	0	100	100	10
300	Anem50aMS	AnemSD50aMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
301	Anem50bMS	AnemSD50bMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
302	Anem38aMS	AnemSD38aMS	Vane38aDEG	VaneSD38aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
303	Anem38bMS	AnemSD38bMS	Vane38aDEG	VaneSD38aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
304	Anem20aMS	AnemSD20aMS	Vane20aDEG	VaneSD20aDEG	Etmp2aDEGC	Icing	0.5	1	2	10
400	Anem50aMS	Anem50bMS				CompareSensors	1	0.25	3	0
401	Anem38aMS	Anem38bMS				CompareSensors	1	0.25	3	0
500	Amax50aMS					MinMax	0	90	0	0
501	Amax50bMS					MinMax	0	90	0	0
502	Amax38aMS					MinMax	0	90	0	0
503	Amax38bMS					MinMax	0	90	0	0
504	Amax20aMS					MinMax	0	90	0	0
510	Amin50aMS					MinMax	0	90	0	0
511	Amin50bMS					MinMax	0	90	0	0
512	Amin38aMS					MinMax	0	90	0	0
513	Amin38bMS					MinMax	0	90	0	0
514	Amin20aMS					MinMax	0	90	0	0
520	Vmax50aDEG					MinMax	0	359.9	0	0
521	Vmax38aDEG					MinMax	0	359.9	0	0
522	Vmax20aDEG					MinMax	0	359.9	0	0
530	Vmin50aDEG					MinMax	0	359.9	0	0
531	Vmin38aDEG					MinMax	0	359.9	0	0
532	Vmin20aDEG					MinMax	0	359.9	0	0

Sensor Statistics

Sensors	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Etmp2aDEGC	2940	2940	100	9.833	0	0	97.993
EtmpSD2aDEGC	2940	2940	100	0	0	0	100
Anem50ams	2940	2940	100	0	471.5	0	3.776
AnemSD50ams	2940	2940	100	0	471.5	0	3.776
Anem50bms	2940	2940	100	0	471.5	0	3.776
AnemSD50bms	2940	2940	100	0	471.5	0	3.776
Vane50aDEG	2940	2940	100	0	471.5	0	3.776
VaneSD50aDEG	2940	2940	100	0	471.5	0	3.776
Anem38aMS	2940	2940	100	0	0	1	99.796

AnemSD38aMS	2940	2940	100	0	0	1	99.796
Anem38bMS	2940	2940	100	0	0	1.667	99.66
AnemSD38bMS	2940	2940	100	0	0	1.667	99.66
Vane38aDEG	2940	2940	100	0	0	0	100
VaneSD38aDEG	2940	2940	100	0	0	0	100
Anem20aMS	2940	2940	100	0	0	0	100
AnemSD20aMS	2940	2940	100	0	0	0	100
Vane20aDEG	2940	2940	100	0	0	0	100
VaneSD20aDEG	2940	2940	100	0	0	0	100
Total	52920	52920	100	9.833	2829	5.333	67.753