WIND DATA REPORT

Gardner NCCI

January 24, 2007 – January 24, 2008

Prepared for

Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

by

Nathan Mesick
James F. Manwell
Utama Abdulwahid
Anthony F. Ellis

September 23, 2008

Report template version 1.6

Renewable **E**nergy **R**esearch **L**aboratory
University of Massachusetts, Amherst
160 Governors Drive, Amherst, MA 01003
www.ceere.org/rerl • (413) 545-4359 • rerl@ecs.umass.edu

NOTICE AND ACKNOWLEDGEMENTS

This report was prepared by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst in the course of performing work sponsored by the Renewable Energy Trust (RET), as administered by the Massachusetts Technology Collaborative (MTC). The opinions expressed in this report do not necessarily reflect those of MTC or the Commonwealth of Massachusetts, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it.

TABLE OF CONTENTS

TABLE OF FIGURES

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.

This report covers wind data measured at a 50 meter meteorological tower installed at the North Central Corrections Institution, in Gardner, MA. The tower has four anemometers, two at each height of 50 meters and 38 meters, respectively, as well as two wind vanes, one at each height. The data is collected by a NRG Symphonie data logger.

This final report covers January 24, 2007 through January 24, 2008. The mean wind speed at 50 meters is 5.74 m/s (12.84 mph)* and the prevailing wind direction was Northwest. The gross data recovery percentage (the actual percentage of expected data received) was 100% and the net data recovery percentage (the percentage of the expected data which passed all of the quality assurance tests) was 95.507%.

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 station is located at Gardner North Central Correctional Institution, outside the prison on a grassy hill. The tower base is located at 42.581ºN, 71.939ºW. The red plus (+) denotes the approximate location of the tower.

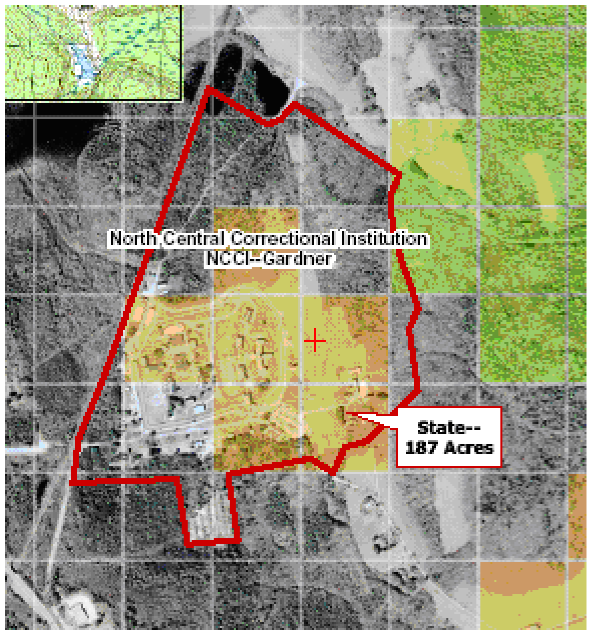

Figure 1 - Location of Tower

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a NRG systems 50 meter (164') meteorological tower. The sensors include:

- NRG Symphonie Data Logger.
- 4 – Maximum # 40 Anemometers, standard calibration (Slope – 0.765 m/s, Offset – 0.350 m/s). Two anemometers are located at 50m (164') and two at 38m (124'8").
- 2 – NRG 200P Wind Vanes. One vane is at each height, 50m and 38m (164' and 124'8", respectively).
- 1 – NRG 110S Temperature Sensor, at 2m.
- 6 – Sensor booms, four 59" in length, two 43" in length.

- Lightning rod and copper ground cable.
- Shielded sensor cables.

SECTION 3 - Data Summary

A summary of the wind speeds and wind directions measured during the reporting period is included in Table 1. Table 1 includes the mean wind speeds measured at each measurement height, the maximum instantaneous wind speed measured at each measurement height and the prevailing wind direction measured at each measurement height. These values are provided for each month of the reporting period and for the whole reporting period.

Table 1. Wind Speed and Direction Data Summary

Date	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction
Height Units	50 m [m/s]	50 m [m/s]	50 m [-]	38 m [m/s]	38 m [m/s]	38 m [-]
Feb 2007	7.52	18.45	NW	7.06	17.46	NW
Mar 2007	7.42	17.61	W	6.94	16.51	W
Apr 2007[1]	6.04	15.98	NW	5.72	15.02	NW
May 2007	5.62	12.79	N	5.19	11.91	W
June 2007	5.65	11.51	NNW	5.20	10.76	NW
July 2007	5.11	15.89	W	4.66	14.94	W
Aug 2007	4.92	13.89	W	4.50	12.76	W
Sept 2007	5.32	11.86	W	4.88	11.15	W
Oct 2007	5.56	14.64	WNW	5.07	13.71	W
Nov 2007	6.22	15.21	NW	5.81	14.30	NW
Dec 2007[2]	5.52	16.61	NW	5.13	15.59	NW
Jan 2008	6.47	17.52	W	6.02	16.91	W
Feb 2008[3]	6.19	16.35	NW	5.95	15.66	NW

[1] For the month of April 2007, the percent data good is 90.04, however, all anemometry and vanes are below 90%.
[2] For the month of December 2007, the percent data good is 72.859.

Mar 2008[4]	6.67	17.50	NW	6.21	16.91	NW
Apr 2008	5.50	17.54	SE	5.12	16.69	ESE
Jan 2007 - Jan 2008	**5.74**	**18.45**	**NW**	**5.32**	**17.46**	**NW**

Wind data statistics in the table are reported when more than 90% of the data during the reporting period are valid. In cases when larger amounts of data are missing, the percent of the available data that are used to determine the data statistics is noted.

No measurement of wind speed or direction can be perfectly accurate. Wind speed measurement errors occur due to anemometer manufacturing variability, anemometer calibration errors, the response of anemometers to turbulence and vertical air flow and due to air flows caused by the anemometer mounting system. Every effort is made to reduce the sources of these errors. Nevertheless, the values reported in this report have an expected uncertainty of about ± 2% or ± 0.2 m/s, whichever is greater. Wind direction measurement errors occur due to sensor measurement uncertainty, tower effects, boom alignment measurement errors and twisting of pipe sections during the raising of a pipe tower. Efforts are also made to reduce these errors, but the reported wind directions are estimated to have an uncertainty of +/- 5 degrees.

A summary of the turbulence intensity and mean wind shear measured at each measurement height during the reporting period is included in Table 2. These values are provided for each month of the reporting period and for the whole reporting period. Turbulence Intensity is calculated by dividing the standard deviation of the wind speed by the mean wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. Turbulence intensity varies with wind speed. The average turbulence intensity presented in Table 2 is the mean turbulence intensity when the wind speed at the highest measurement height is between 9.5 and 10.5 m/s.

Shear coefficients provide a measure of the change in wind speed with height. When data at multiple heights are available, shear coefficients, α, have been determined. They can be used in the following formula to estimate the average wind speed, $U(z)$, at height z, when the average wind speed, $U(z_r)$, at height z_r is known:

$$U(z)=U(z_r)\left(\frac{z}{z_r}\right)^{\alpha}$$

The change in wind speed with height is a very complicated relationship related to atmospheric conditions, wind speed, wind direction, time of day and time of year. This

[3] For the month of February 2008, the percent data good is 71.795.
[4] For the month of March 2008, the percent data good is 84.773.

formula will not always provide the correct answer at any given site. Nevertheless the calculated shear coefficient, based on measurements at two heights, can be used to characterize the degree of increase in wind speed with height at a site.

The mean wind shear coefficient that is provided here is calculated based on the mean wind speeds in Table 1, where z_{high} and z_{low} are the heights of the higher and lower mean wind speeds used in the calculation and $U(z_{low})$ and $U(z_{high})$ are the mean wind speeds at the two heights.

$$\alpha = \log\left(\frac{U(z_{high})}{U(z_{low})}\right) \Big/ \log\left(\frac{z_{high}}{z_{low}}\right)$$

Table 2. Shear and Turbulence Intensity Data Summary

Date Height Units	Turbulence Intensity at 10 m/s 50 m [-]	Turbulence Intensity at 10 m/s 38 m [-]	Mean Wind Shear Coefficient, α Between 50 m and 38 m [-]
January 2007	0.19	0.19	-
February 2007	0.19	0.20	0.23
March 2007	0.19	0.20	0.25
April 2007	0.20	0.20	0.19
May 2007	0.17	0.21	0.28
June 2007	0.16	0.22	0.31
July 2007	0.21	0.24	0.34
August 2007	0.19	0.23	0.32
September 2007	0.16	0.16	0.32
October 2007	0.14	0.19	0.34
November 2007	0.21	0.21	0.25
December 2007	0.19	0.21	0.26
January 2008	0.17	0.19	0.26
February 2008	0.18	0.20	0.14
March 2008	0.20	0.21	0.26
Jan 24, 2007 – Jan 24, 2008	**0.18**	**0.20**	**0.28**

SECTION 4- Long Term Estimate and Capacity Factor

Wind speed varies year by year and the mean obtained over the measurement period may be less or more compared to what is seen over a longer time period. Therefore, the use of the long term mean at the site is preferred when projecting the performance of a wind turbine. The long term mean at a site may be estimated by using the Measure-Correlate-Predict (MCP) method.

The MCP method correlates wind speed measurements at the target site to a reference site which collects data over the same period of time and has been collecting data for a much longer period. Based on this correlation, the reference wind speed data is used to predict long term mean at the site.

Long term data from Paxton between June 24th, 2003 and June 27th, 2008 is used as reference for Gardner NCCI. Correlation between the two sites is obtained from concurrent data between January 23rd, 2007 and April 25th, 2008. The long term mean at Gardner NCCI at 50 m is estimated to be 5.95 m/s with an uncertainty of 3.3% for the MCP process. This estimate may also be used to calculate the long term mean at different heights by using the mean wind shear at site and the equation described in the previous section. The long term mean wind speed at 70 m height is estimated at 6.54 m/s.

The capacity factor of a wind turbine at a given site depends on the hub height, wind speed distribution at the hub height, the wind turbine power curve and any assumptions about down time and losses due to wake effects from upwind wind turbines, etc. If the hub height wind speed is estimated from data at lower heights, then the capacity factor will also depend on the estimated wind shear and the wind speeds measured at lower heights. No simple estimate of capacity factor at a site could take all of these effects and choices into account. Nevertheless, an estimate of the capacity factor of a wind turbine at this site is provided here to help the reader understand the order of magnitude of the wind resource at this site.

The estimates assume a GE 1.5 sl turbine with a hub height of 80 m and the long term mean wind speed estimate at the highest measurement height and the mean wind shear at the site, in order to determine the mean hub height wind speed, in this case 6.79 m/s. The wind speed probability distribution is assumed to be given by a Rayleigh distribution. The average wind turbine power is then estimated from:

$$\overline{P_W} = \int_0^\infty P_W(U)\,p(U)\,dU$$

where $P_W(U)$ is the wind turbine power curve and $p(U)$ is the wind speed probability distribution. The capacity factor is then calculated from:

$$CF = \frac{\overline{P_W}}{P_{rated}}$$

where P_{rated} is the rated capacity of the turbine, i.e., 1500 kW. Based on this equation, the estimated capacity factor of a wind turbine at this site would be about 0.342.

SECTION 5- Graphs

This report contains several types of wind data graphs. Unless otherwise noted, each graph represents data from one calendar year (January 24, 2007 to January 24, 2008). The following graphs are included:

- Time Series – 10-minute average wind speeds are plotted against time. This graph includes all of the collected data.
- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed.
- Monthly Average – A plot of the monthly average wind speed over a 12-month period. This graph shows the trends in the wind speed over the whole period of data collection. The values are not shown for December 2007 and February 2008 because of large amounts of icing conditions.
- Diurnal – A plot of the average wind speed for each hour of the day.
- Turbulence Intensity – A plot of turbulence intensity as a function of wind speed. 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.
- Wind Rose – A plot, by compass direction showing the percentage of time that the wind comes from a given direction and the average wind speed in that direction.

Data for the wind speed histograms, monthly and diurnal average plots, and wind roses are included in APPENDIX B.

Wind Speed Time Series

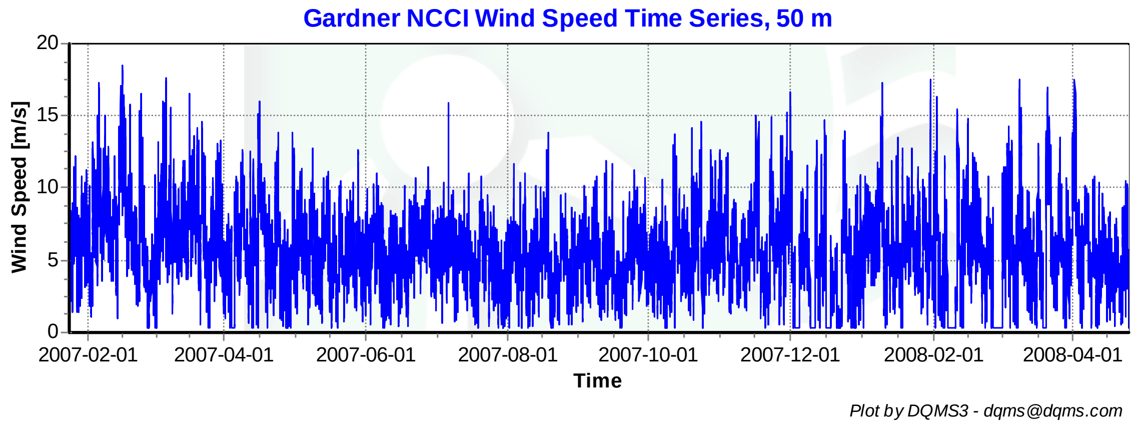

Figure 2 - Wind Speed Time Series, January 24, 2007 – April 25, 2008

Wind Speed Distributions

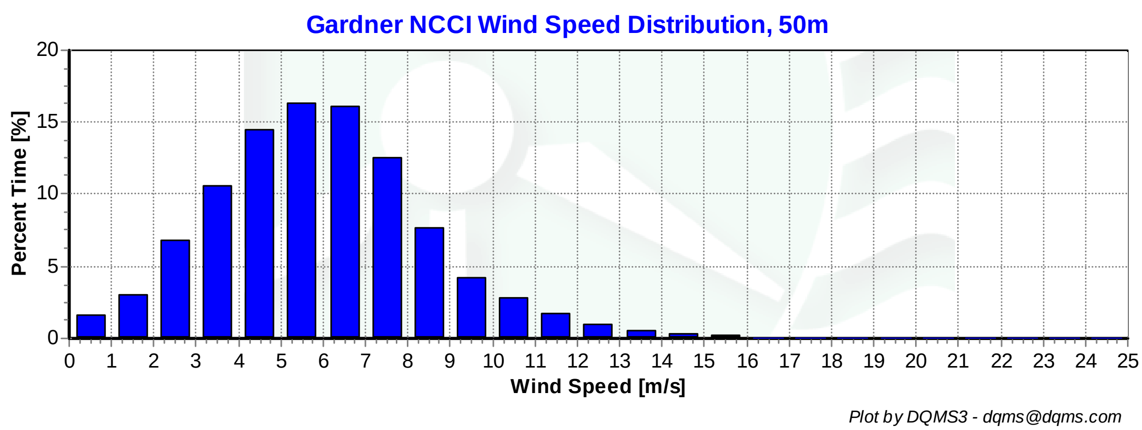

Figure 3 - Wind Speed Distribution, January 24, 2007 – January 24, 2008

Monthly Average Wind Speeds

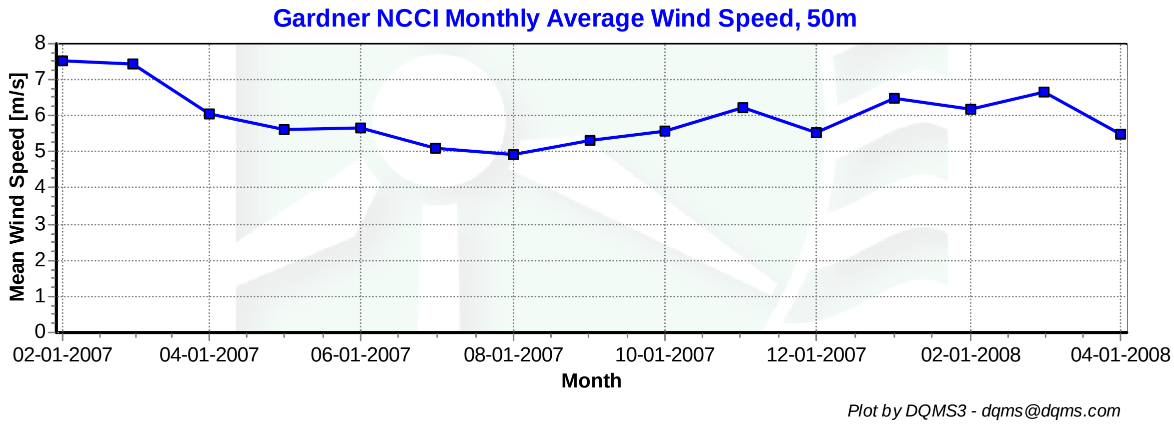

Figure 4 - Monthly Average Wind Speed, February, 2007 – April, 2008

Diurnal Average Wind Speeds

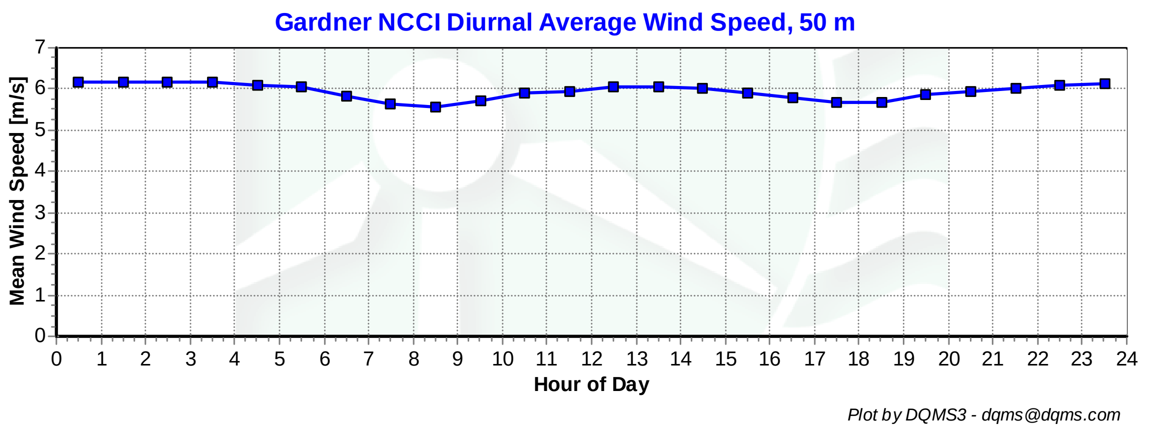

Figure 5 - Diurnal Average Wind Speed, January 24, 2007 – January 24, 2008

Turbulence Intensities

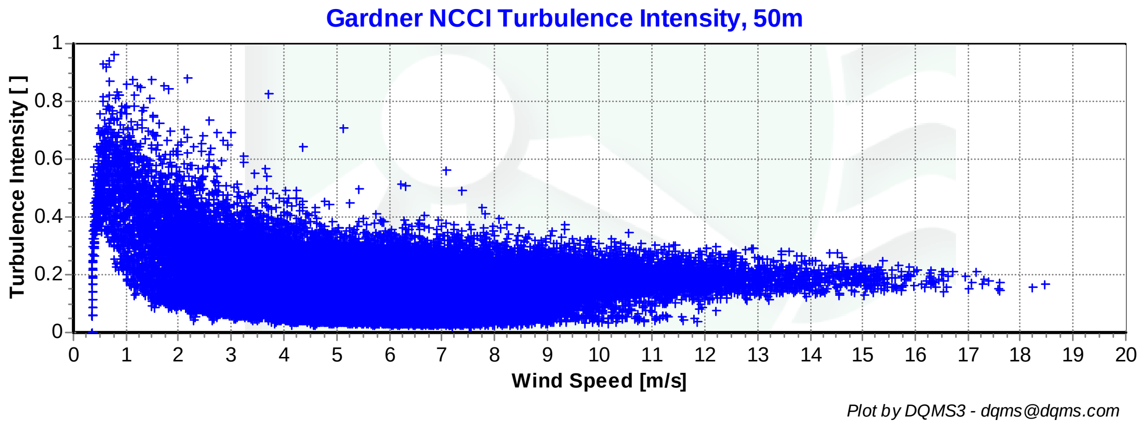

Figure 6 - Turbulence Intensity, January 24, 2007 – January 24, 2008

Wind Roses

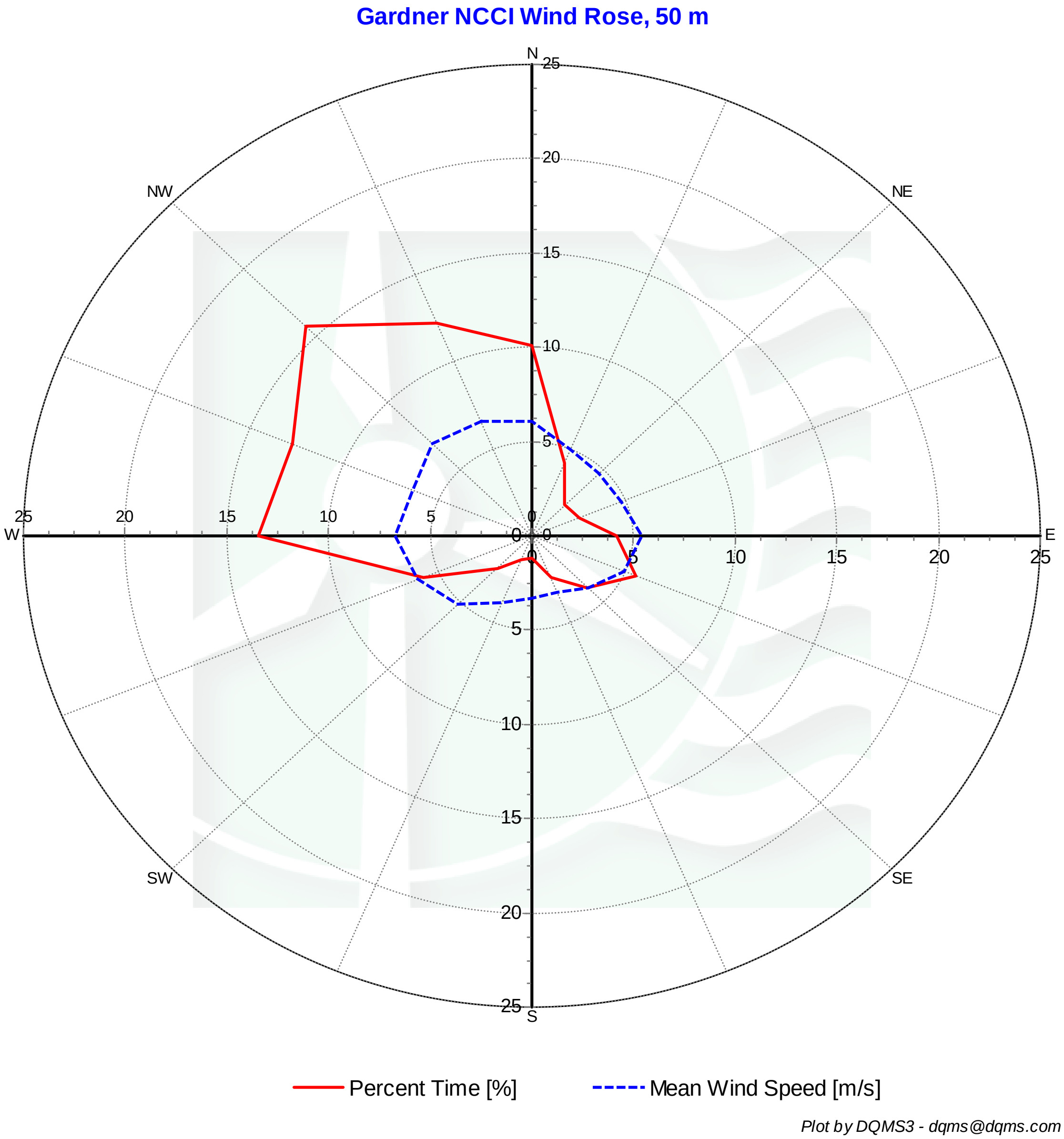

Figure 7 - Wind Rose, January 24, 2007 – January 24, 2008

SECTION 6 - Significant Meteorological Events

There were no extreme meteorological events during the period covered in this report. This can be seen by the lack of large wind speed values on the Wind Speed Time Series.

SECTION 7 - Data Collection and Maintenance

Several months did not meet the standard 90% good data, due to icing conditions. These values have been reported in Section 3, and the percentages given.

SECTION 8- 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.

Gross Data Recovered [%]	100.00
Net Data Recovered [%]	95.507

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 which is included in APPENDIX A. Data which 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.

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

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.

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

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 is greater than Factor 2.

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

Sensor Statistics

A summary of the results of the data collection and filtering are given in the Sensor Performance Report which is included in APPENDIX A. The following categories of information, tabulated for each sensor, are included in that report.

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*.

APPENDIX A - Sensor Performance Report

Test Definitions

TestOrder	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
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
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
50	Turb50zNONE					MinMax	0	2	0	0
51	Turb38zNONE					MinMax	0	2	0	0
60	Wshr0zNONE					MinMax	-100	100	0	0
70	Pwrd50zWMS					MinMax	0	5000	0	0
71	Pwrd38zWMS					MinMax	0	5000	0	0
200	VaneSD50aDEG	Anem50yMS				MinMaxT	0	100	100	10
201	VaneSD38aDEG	Anem38yMS				MinMaxT	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
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
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
520	Vmax50aDEG					MinMax	0	359.9	0	0
521	Vmax38aDEG					MinMax	0	359.9	0	0
530	Vmin50aDEG					MinMax	0	359.9	0	0
531	Vmin38aDEG					MinMax	0	359.9	0	0

Table 3 – Gardner NCCI Test Definitions

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Anem50aMS	52560	52560	100	1.167	473.5	1.833	94.561
AnemSD50aMS	52560	52560	100	1.167	473.5	1.833	94.561
Anem50bMS	52560	52560	100	1.167	468.167	19.833	94.416
AnemSD50bMS	52560	52560	100	1.167	468.167	19.833	94.416
Anem38aMS	52560	52560	100	0.5	427.833	5.5	95.048
AnemSD38aMS	52560	52560	100	0.5	427.833	5.5	95.048
Anem38bMS	52560	52560	100	0.667	422.167	26.667	94.869
AnemSD38bMS	52560	52560	100	0.667	422.167	26.667	94.869
Vane50aDEG	52560	52560	100	1.333	473.5	0	94.58
VaneSD50aDEG	52560	52560	100	1.333	473.5	0	94.58
Vane38aDEG	52560	52560	100	2.167	429	0	95.078
VaneSD38aDEG	52560	52560	100	2.167	429	0	95.078
Etmp2aDEGC	52560	52560	100	0	0	0	100
EtmpSD2aDEGC	52560	52560	100	0	0	0	100
Total	**735840**	**735840**	**100**	**14**	**5388.333**	**107.667**	**95.507**

Table 4 – Gardner NCCI Sensor Statistics

APPENDIX B - Plot Data

Wind Speed Distribution Data

Wind Speed [m/s]	Percent Time [%]
0.5	1.60
1.5	3.04
2.5	6.82
3.5	10.58
4.5	14.53
5.5	16.34
6.5	16.13
7.5	12.59
8.5	7.63
9.5	4.17
10.5	2.78
11.5	1.73
12.5	1.02
13.5	0.52
14.5	0.28
15.5	0.17
16.5	0.05
17.5	0.02
18.5	0.00
19.5	0.00
20.5	0.00
21.5	0.00
22.5	0.00
23.5	0.00
24.5	0.00

Table 5 – Gardner NCCI Wind Speed Distribution Data, 50m

Monthly Average Wind Speed Data

Month	Mean Wind Speed [m/s]
Feb-07	7.52
Mar-07	7.42
Apr-07	6.04
May-07	5.62
Jun-07	5.65
Jul-07	5.11
Aug-07	4.92
Sep-07	5.32
Oct-07	5.56
Nov-07	6.22
Dec-07	5.52
Jan-08	6.47
Feb-08	6.19
Mar-08	6.67
Apr-08	5.50

Table 6 – Gardner NCCI Monthly Average Wind Speed Data, 50m

Diurnal Average Wind Speed Data

Hour of Day	Mean Wind Speed [m/s]
0.5	6.16
1.5	6.17
2.5	6.18
3.5	6.18
4.5	6.10
5.5	6.05
6.5	5.84
7.5	5.62
8.5	5.57
9.5	5.72
10.5	5.90
11.5	5.94
12.5	6.07
13.5	6.04
14.5	6.03
15.5	5.92
16.5	5.78
17.5	5.69
18.5	5.67
19.5	5.87
20.5	5.94
21.5	6.02
22.5	6.10
23.5	6.15

Table 7 – Gardner NCCI Diurnal Average Wind Speed Data, 50m

Wind Rose Data

Wind Direction	Mean Wind Speed [m/s]	Percent of Time [%]
N	6.06	10.08
NNE	4.99	4.16
NE	4.64	2.30
ENE	4.77	2.51
E	5.45	4.17
ESE	4.88	5.55
SE	3.91	3.87
SSE	3.22	2.41
S	3.32	1.20
SSW	3.86	1.35
SW	5.18	2.40
WSW	6.06	5.80
W	6.70	13.46
WNW	6.34	12.77
NW	6.96	15.74
NNW	6.55	12.22

Table 8 – Gardner NCCI Wind Rose Data, 50m