WIND DATA REPORT

Lynn, MA

September 2005

Prepared for

Massachusetts Technology Collaborative
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by

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February 6, 2006

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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), pursuant to work order number 05-1. 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.

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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 equipment was first installed in Lynn MA late August 2004, with data collection starting from the 26th of that month through the present. Five anemometers, a temperature sensor, and a data logger are mounted on a 40 m monitoring tower.

Data collection percentages during the month of September 2005 were good: the raw data recovery rate was 96.616%, and after quality assurance the percentage of good data was 97.606%. The average wind speed during the month was 5.09 m/s at 39 m height (11.39 mph at 128 ft[1]). Turbulence intensity for that time period was an average of 0.15. The prevailing wind was from the North-West.

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] Conversion factors: *2.237 for m/s to mph, and *3.28 from m to ft.

SECTION 1 - Station Location

The monitoring tower is located on an elevated plateau about one mile south of the Lynn town center, near the ocean front; elevation is about 9 m above sea level. The wind monitoring equipment is mounted on a 40 m NRG tubular steel tower, anchored with guy lines at four directions. Site coordinates are 42° 27.095' North, 70° 57.464' West per the WGS84 standard (the World Geodetic System 1984, an international standard for absolute localization with earthly coordinates). See the figure below for a map of the tower location, denoted by the red crosshairs near the center.

Figure 1 – Site location of Lynn wind monitoring tower.

SECTION 2 - Instrumentation and Equipment

An unpainted, 40 m NRG tower holds five NRG anemometers on three booms: one at 10 m, two at 30 m, and two at 39 m. The photo below shows the deployment; each anemometer is 54" away from the tower, and 18" above its boom. Also on each boom is an NRG 200P Wind Vane.

Figure 2 – Lynn monitoring tower. Booms and anemometers are at 10, 30, and 39 m.

The installed equipment comprises:

- Symphonie data logger, serial #3090-4864

- NRG 110S Temperature Sensor
- Five #40 anemometers, standard calibration (slope 0.765 m/s, offset 0.350 m/s)
- Three #200P wind direction vanes
- Medium booms for vanes, 39” from tower mast
- Long side booms for anemometers, 54” from tower mast
- Lightning rod and grounding cable

SECTION 3 - Data Collection and Maintenance

During the period of September 2005, no maintenance events occurred. Data collection during this period was acceptable, with results summarized below.

Date	39m Mean 10 min [m/s]	39m Max [m/s]	30m Mean 10 min [m/s]	30m Max [m/s]	39m Turbulence Intensity [ ]	Prevailing Wind Direction [ ]
2005 September	5.09	20	4.75	19.8	0.15	315, North-West

No measurement of wind speed can be perfectly accurate. 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.

SECTION 4 - Significant Meteorological Events

The month of September 2005 was unremarkable meteorologically. There were no major wind events shown in the wind speed time series. For further information see:

http://www.erh.noaa.gov/box/MonthlyClimate2.shtml

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.

Gross Data Recovered [%]	97.616
Net Data Recovered [%]	97.606

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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.

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

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.

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

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 several types of wind data graphs. Unless otherwise noted, each graph represents data for 1 month. The following graphs are included:

- Time Series – 10-minute average wind speeds are plotted against time. See Fig. 3 below; for the month of September, speeds seldom exceeded 10 m/s.

- Monthly Average – A plot of the monthly average wind speed over the available data, here, a 13-month period in Fig. 4. This graph shows the trends in the wind speed over the year. As expected, the average increased during the winter season and declined during the summer season.

- 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. In Fig. 5 below, turbulence flattens out after 5 m/s around 0.15.

SECTION 7 - Graphs

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

Wind Speed Time Series

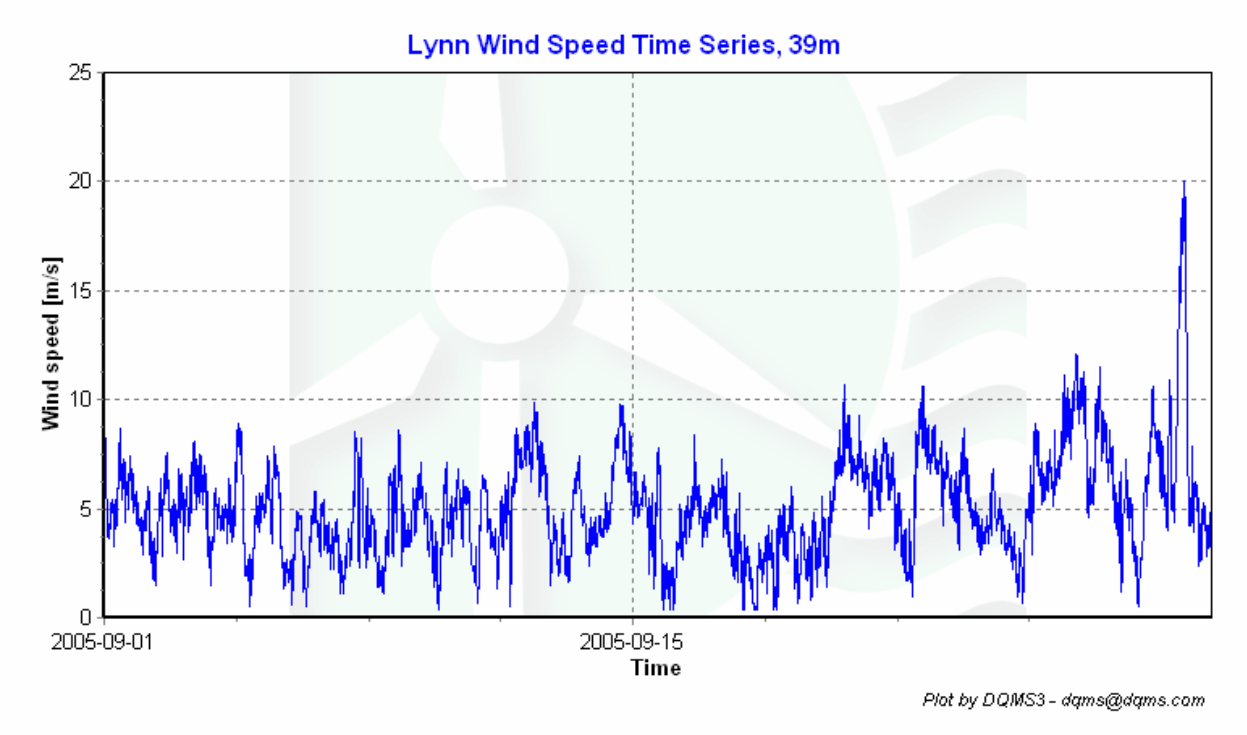

Figure 3 – Lynn wind speed time series, September 2005

Monthly Average Wind Speeds

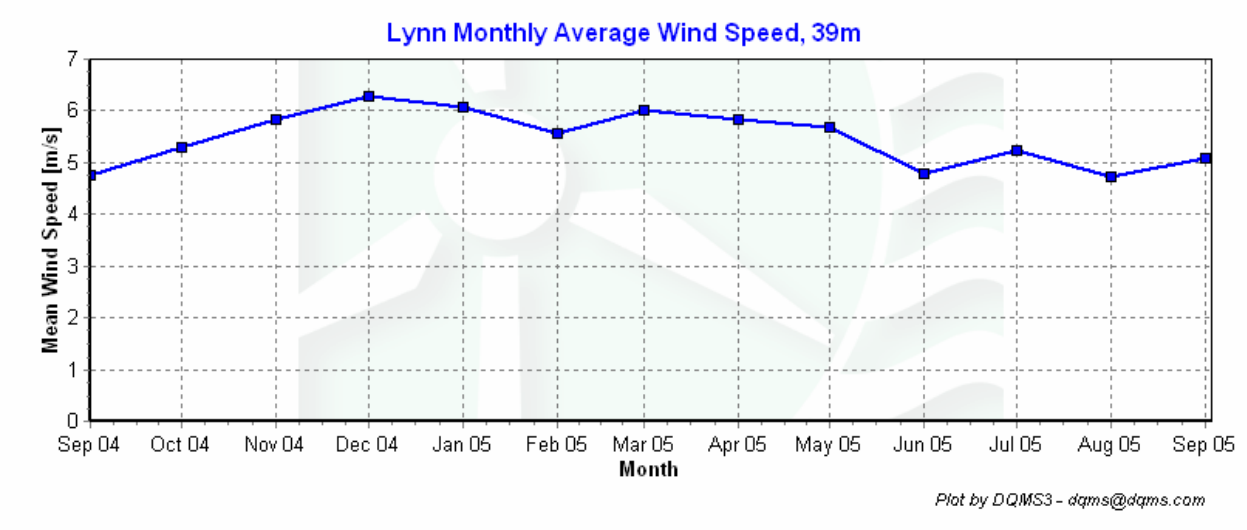

Figure 4 – Lynn monthly average wind speed at 39 m for September, 2004 – September, 2005

Turbulence Intensities

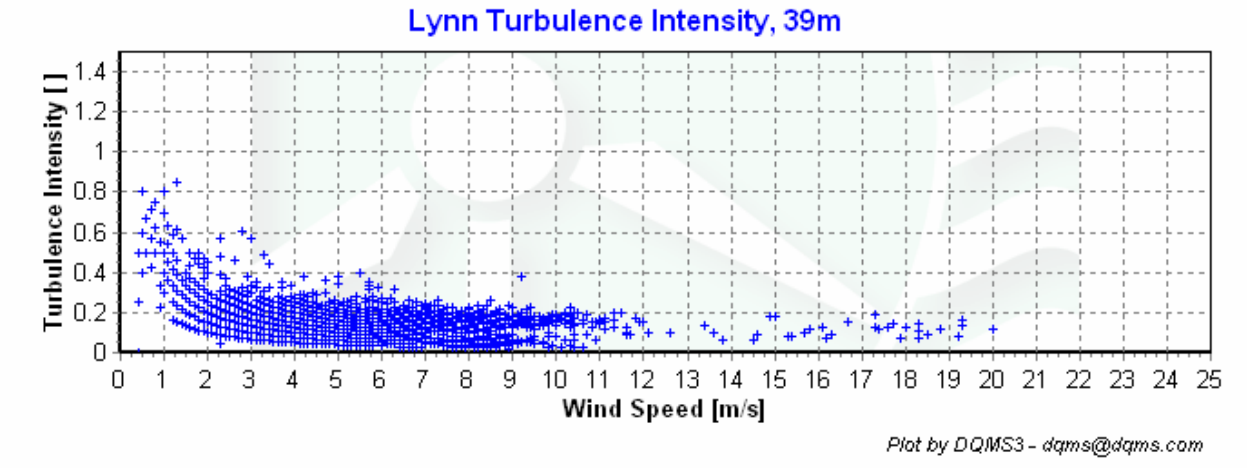

Figure 5 – Lynn turbulence intensity vs. wind speed, September, 2005

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	TestField3	CalcField1	CalcField2	TestType	Factor1	Factor2	Factor3	Factor4
1										
2	Etmp2DEGC					MinMax	-30	60		
3	EtmpSD2DEGC					MinMax	-30	60		
4	Etmpmax2DEGC					MinMax	-30	60		
5	Etmpmin2DEGC					MinMax	-30	60		
10	Anem39aMS					MinMax	0	90		
11	Anem39bMS					MinMax	0	90		
12	Anem30aMS					MinMax	0	90		
13	Anem30bMS					MinMax	0	90		
14	Anem10MS					MinMax	0	90		
20	AnemSD39aMS					MinMax	0	4	0	0
21	AnemSD39bMS					MinMax	0	4	0	0
22	AnemSD30aMS					MinMax	0	4	0	0
23	AnemSD30bMS					MinMax	0	4	0	0
24	AnemSD10MS					MinMax	0	4	0	0
30	Vane39DEG					MinMax	0	359.9		
31	Vane30DEG					MinMax	0	359.9		
32	Vane10DEG					MinMax	0	359.9		
50	Turb39zNONE					MinMax	0	2		
51	Turb30zNONE					MinMax	0	2		
52	Turb10zNONE					MinMax	0	2		
60	Wshr0zNONE					MinMax	-100	100		
200	VaneSD39DEG	Anem39yMS				MinMaxT	0	100	100	10
201	VaneSD30DEG	Anem30yMS				MinMaxT	0	100	100	10
202	VaneSD10DEG	Anem10MS				MinMaxT	0	100	100	10
301	Anem39aMS	AnemSD39aMS	Vane39DEG	VaneSD39DEG	Etmp2DEGC	Icing	0.5	1	2	2
302	Anem39bMS	AnemSD39bMS	Vane39DEG	VaneSD39DEG	Etmp2DEGC	Icing	0.5	1	2	2
303	Anem30aMS	AnemSD30aMS	Vane30DEG	VaneSD30DEG	Etmp2DEGC	Icing	0.5	1	2	2
304	Anem30bMS	AnemSD30bMS	Vane30DEG	VaneSD30DEG	Etmp2DEGC	Icing	0.5	1	2	2
305	Anem10MS	AnemSD10MS	Vane10DEG	VaneSD10DEG	Etmp2DEGC	Icing	0.5	1	2	2
400	Anem39aMS	Anem39bMS				CompareSensors	1	0.35	3	0
401	Anem30aMS	Anem30bMS				CompareSensors	1	0.35	3	0
500	Amax39aMS					MinMax	0	90		
501	Amin39aMS					MinMax	0	90		
502	Amax39bMS					MinMax	0	90		
503	Amin39bMS					MinMax	0	90		

504	Amax30aMS					MinMax	0	90		
505	Amin30aMS					MinMax	0	90		
506	Amax30bMS					MinMax	0	90		
507	Amin30bMS					MinMax	0	90		
508	Amax10MS					MinMax	0	90		
509	Amin10MS					MinMax	0	90		
510	Vmax39DEG					MinMax	0	359.9		
511	Vmin39DEG					MinMax	0	359.9		
512	Vmax30DEG					MinMax	0	359.9		
513	Vmin30DEG					MinMax	0	359.9		
514	Vmax10DEG					MinMax	0	359.9		
515	Vmin10DEG					MinMax	0	359.9		

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Etmp2DEGC	4321	4218	97.616	0	0	0	97.616
EtmpSD2DEGC	4321	4218	97.616	0	0	0	97.616
Anem39aMS	4321	4218	97.616	0	0	0	97.616
AnemSD39aMS	4321	4218	97.616	0	0	0	97.616
Anem39bMS	4321	4218	97.616	0	0	0.333	97.57
AnemSD39bMS	4321	4218	97.616	0	0	0.333	97.57
Anem30aMS	4321	4218	97.616	0	0	0	97.616
AnemSD30aMS	4321	4218	97.616	0	0	0	97.616
Anem30bMS	4321	4218	97.616	0	0	0	97.616
AnemSD30bMS	4321	4218	97.616	0	0	0	97.616
Anem10MS	4321	4218	97.616	0	0	0	97.616
AnemSD10MS	4321	4218	97.616	0	0	0	97.616
Vane39DEG	4321	4218	97.616	0.167	0	0	97.593
VaneSD39DEG	4321	4218	97.616	0.167	0	0	97.593
Vane30DEG	4321	4218	97.616	0	0	0	97.616
VaneSD30DEG	4321	4218	97.616	0	0	0	97.616
Vane10DEG	4321	4218	97.616	0.167	0	0	97.593
VaneSD10DEG	4321	4218	97.616	0.167	0	0	97.593
Total	77778	75924	97.616	0.667	0	0.667	97.606

APPENDIX B - Plot Data

Monthly Average Wind Speed Data

Date	Mean 10 min [m/s]
2004 September	4.75
October	5.28
November	5.83
December	6.29
2005 January	6.07
February	5.57
March	6.03
April	5.84
May	5.67
June	4.79
July	5.23
August	4.73
September	5.09
September 2004 – September 2005	**5.47**