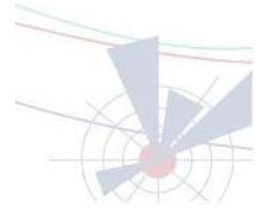


Northport Wind Turbine Project

Wind Resource Assessment and Turbine Selection



Executive Summary

Wind Resource Assessment

A wind resource study of the proposed site has been conducted for nearly one year. A 95 ft (29m) meteorological tower was erected in June 2009 and has been collecting wind data since installation.

Projections of windspeed and energy production at the site have been made using comparisons to nearby (medium term) meteorological sites projected to long term (32 year) performance using NCAR (National Center for Atmospheric Research) regional data.

The medium term (2006-2010) wind data is representative of long term data - within 1%. (2009 was near a 20 year low wind year, 2007 well above the mean and 2008 was slightly above normal.)

Various wind turbine power curves were used to calculate production using ten minute windspeed intervals from the medium term data and appropriate corrections made for turbulence, air density and line losses.

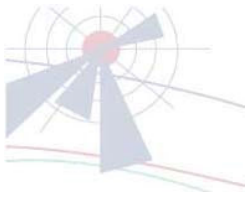
In addition, high resolution wind maps (AWS Wind Navigator) were used to validate the windspeed projections.

The attached technical summary indicates that the proposed turbine installation at 131 ft (40m) will produce 360,540 kw-hr per year.

The summary also includes statistical projections derived from the long term NCAR data and seasonal variations of energy production.

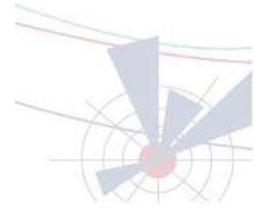
Wind Turbine Selection

The wind turbine selected is a re-manufactured Bonus 300/33. This is a Danish built machine with a rotor diameter of 33 meters (108 ft) on a 40 meter (131 ft) tower with a nameplate rating of 300kw. The turbine controller is modified to dump power over 150kw to a thermal sink to adhere to the 150kw nameplate limit set by Michigan's netmetering law. Thus the term Bonus B300/33/150kw.



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Technical Discussion

Section A – Basic Data

The proposed site is 1000 ft west of the Northport/Leelanau Township Wastewater Treatment Plant. It's on an exposed ridge about 100 ft above the treatment plant and is the highest land within 2000 ft. The ridge runs at 340 deg (SSE to NNW) from the site and there are 70-90 ft trees 500 ft away that cause a partial obstruction from 330 to 360 deg. It has good exposure to the south, southwest and west – the high wind energy direction for this region.

The surrounding area is considered complex terrain.

Test Equipment

New NRG #40 maximum (new) anemometers were placed at 95 and 76 ft elevations and a NRG #200P wind vane at 81 ft. The upper anemometer is on a 10 ft mast in clear air and the vane and lower anemometer are on booms oriented at 278 deg. The vane deadband is at 98 deg.

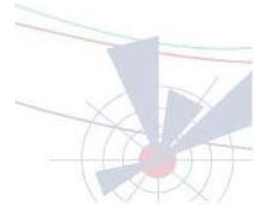
Data was logged on an APRS wind data logger at 10 sec intervals.

Section A Basic Data			
Location: 45.1248, -85.6267	0.6 miles SW of Northport, 26 miles N of Traverse City, MI		
Elevation: 725 ft ASL, 140 ft above Lake Michigan			
Test Period:	6/17/2009	to	5/30/2010
Test Equipment:	Sensors:	NRG #40 max	95 ft
		NRG #40 max	76 ft
		NRG #200p Vane	81 ft
	Logger:	APRS WindDataLogger	
Data Period:	347	Days	
Missing Data:	25.5	Days	
Data Recovery:	92.7%		
Data Hours:	7,717		
Data Intervals (10 min):	46,301		
	<u>mph</u>		
Average Measured Windspeed	10.00	@ 95 ft	
Average Measured Windspeed	9.32	@ 76 ft	
Wind Shear Exponent (alpha)	0.32	(95/76)	
Turbulence Intensity (over 8 mph)	0.17	Stdev / 10minAverage	



Northport Wind Turbine Project

Wind Resource Assessment and Turbine Selection



Section B - Medium Term Projections

Reference Sites

Two reference sites were used to develop long term predictions of wind data.

Grand Traverse Lighthouse (GTLM4) is located 6.5 miles NNW of the test site. The GTLM4 anemometer is an RM Young horizontal axis sensor on a mast in clear air at 65 ft above lake level (650 ft ASL). The site also logs temperature and barometric pressure. The site has clear exposure to Lake Michigan from 200 deg (SSW) through the north and then to about 100 deg (ESE). It is partially obstructed by trees and higher ground from 100 to 200 deg. The site has a continuous record of 10 min interval data from Oct 2006 to the present and has 100% data recovery. Time stamp is UTC.

Reference Site #2 is located about 26 miles SSW of the test site. The site is privately owned and the detailed data is confidential. The owners were kind enough to allow us to use the data for our study. The reference #2 met tower is 164 ft (50m) with anemometers at 50, 40 and 30m. The upper anemometer is an RM Young horizontal axis sensor, the others are NRG #40 maximum. Data logger is Second Wind Nomad. Temperature is recorded but not barometric pressure. The site has been in continuous operation since Sept 2006 and has 100% data recovery. It was certified by COWI (Europe) in 2008. Time stamp is UTC – 5:00 (EST).

Correlation with Reference Sites

Test Site Data Reduction

Test site data is logged in daily files with one line of data for each logging period. Data is processed through North Wind Measurement proprietary software to produce 10 min, hourly and daily data files of windspeed and wind direction. The software also calculates turbulence and turbulence intensity for each 10 min interval, wind shear exponent (alpha), and bins each by windspeed and wind direction.

GTML4 Data Reduction

Lighthouse met data is downloaded as .txt files from the NOAA website and converted to .csv files for later processing. Time stamp (UTC) is shifted to test site time stamp.

Reference Site #2 Data Reduction

This data is processed through Nomad2 Desktop software. The reports are exported to Excel and configured for later processing.

Test Site vs GTML4

The two sites have different exposure and obstruction patterns so there needs to be a sector-wise comparison. The sites are geographically close enough that hourly data can be used.

Hourly files from both sites are processed through North Wind Measurement software. This aligns each hourly period for eight wind direction sectors (45 deg). Linear regression equations and correlation coefficients are calculated for each sector.

Test Site vs Reference Site #2

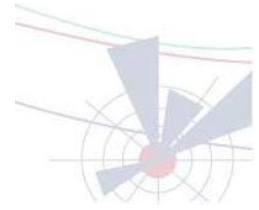
The two sites have similar exposure so sector-wise correlation is not necessary. However, they are 26 miles apart so daily intervals are required. A single linear equation relates the two sites.

Correlation Results



Northport Wind Turbine Project

Wind Resource Assessment and Turbine Selection



Test site vs GTML4

Good correlation was achieved in most sectors. The GTLM4 obstructed sector (100 – 200 deg) had the poorest correlation ($R^2 = 0.5-0.6$). The unobstructed sectors had $R^2 = 0.8$ to 0.9

Test Site vs Reference Site #2

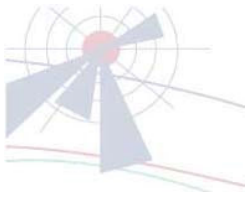
Very good correlation was achieved ($R^2 = 0.9$) for these sites.

Predicting Medium Term Performance at Northport

Both equation sets were used to calculate windspeed at Northport from 2006 to the present. The equations were applied to each 10min interval of reference data to calculate the medium term historical windspeed at Northport. GTLM4 data requires eight different linear equations – One equation for each 45 deg sector.

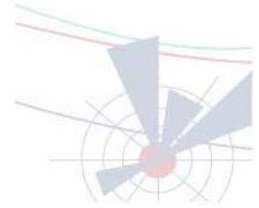
The results were similar: 10.71 mph using GTLM4 data and 10.84 mph using Ref #2 data. The average - 10.78 mph - was used as the 2006-to-present windspeed average at the upper (95 ft) anemometer at Northport.

Section B Medium Term Projections				
Medium Term Projections Using Nearby Reference Sites		Using GT Light Data	Using Ref #2 Data	
	Oct2006 - June2010 Calculated Windspeed at Northport at 95 ft	<u>10.71</u>	<u>10.84</u>	
	<u>Year</u>	<u>GTLM4</u>	<u>Ref #2</u>	<u>NCAR Ref</u>
	2007	12.18	**	15.79
	2008	12.16	**	15.23
	2009	<u>11.12</u>	<u>**</u>	<u>14.34</u>
	Average	<u>11.82</u>	<u>**</u>	<u>15.12</u>
Calculated Annual	<u>mph</u>	<u>Elevation (ft)</u>	<u>Alpha</u>	<u>Energy (V^3)</u>
Average Windspeed (2006-2010)	10.78	95	0.32	1.00
	11.87	131	0.30	1.34
	12.20	144	0.29	1.45
	12.65	164	0.28	1.62



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Section C – Long Term Projections

Comparing Medium Term Windspeed with Long Term Windspeed

NCAR (National Center for Atmospheric Research) provides long term wind data for regions around the world. 1977-2009 NCAR data for the Grand Traverse region was compared to the 2006-2009 medium term period and the results were within 1%. 2007 was a high wind year, 2008 was slightly above the mean, and 2009 was near the 20 year low windspeed. GTLM4 and Ref #2 were 0.79 and 0.80 of NCAR for 2007, 2008 and 2009. Therefore, the medium term data is representative of long term data patterns.

Section C Long Term Projections			
1977 to 2009 NCAR data projected to Northport at 131 ft			
	<u>NCAR (mph)</u>	<u>Northport mph (projected from NCAR)</u>	
32 Year Historical Mean	15.13	11.87	@ 131 ft (40m)
Standard Deviation (sigma)	0.75	0.59	
Mean - 1 Sigma		11.3	67 % of years, Average windspeed will be
Mean + 1 Sigma		12.5	between these two values
Mean - 2 Sigma		10.7	95 % of years, Average windspeed will be
Mean + 2 Sigma		13.0	between these two values

Section D – Projected Annual Energy Production

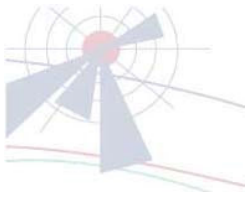
The medium term data was used to predict long term performance of various wind turbines. The medium term data has 183,000 ten minute intervals so the published power curves of Bonus 300/33 and Vestas V-27 were used to calculate energy (kw-hr) produced in each interval. Total production was then normalized to an annual output.

Michigan’s netmetering law restricts use of a turbine’s output to 150kw. Two strategies are available to accomplish this with a turbine with a higher rated output.

1. A variable pitch machine (Vestas V-27) can “feather” the blades to restrict the output to 150kw. This is easily accomplished through the controller.
2. A fixed pitch machine such as the Bonus 300 requires a resistive load dump strategy where excess energy is sent off as heat or mechanical energy. Again, this can be accomplished through the controller.

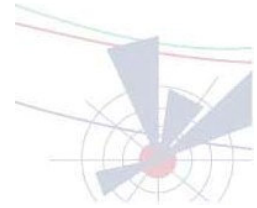
The net effect of either strategy is that the turbine outputs energy with its normal power curve up to 150kw. The 150kw break point is 8.4 m/s (19 mph) for the Bonus and 11.4 m/s (25.2 mph) for the Vestas. Since there are few wind occurrences over these values, only 15 to 20% of the potential output is lost.

Bonus 300/33 produced an average annual output of 480,300
Bonus 300/33/150kw produced an average annual output of 400,600
Vestas V-27/150kw produced an average annual output of 239,000



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Section D Projected Annual Energy Production			
		ENERGY PRODUCTION	
	<u>Bonus</u> 300/33	<u>Bonus</u> 300/33/150kw	Vestas V-27/150kw
Hub Height (ft)	131	131	131
Rated Output (kw)	300	150	150
Rotor Dia (m)	33	33	27
Cut in (m/s)	4	4	3.5
Cut out (m/s)	25	25	25
Gross Annual Output (kw-hr/year)	480,300	400,600	239,000
Corrected Annual Output (kw-hr/year)	432,270	360,540	215,100
Net Average Power (kw)	49.3	41.2	24.6
Net Capacity Factor	16.4%	27.4%	16.4%

Section E - Adjustments to Predicted Output

Three factors affect the predicted output:

1. Turbulence
2. Transmission losses
3. Air Density

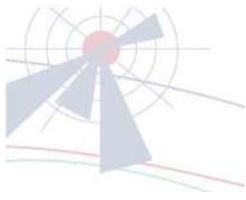
Commercial wind turbine power curves are calculated in 10 min intervals and corrected to STP (standard temperature and pressure) and turbulence intensity of 10%.

Turbulence Intensity: The measured average turbulence intensity at Northport for windspeeds over cut-in (8 mph) is 17%. Standard practice subtracts the difference between this and the tested value from energy production.

Transmission Losses: Losses from transformer to interconnection point are typically 4% or less.

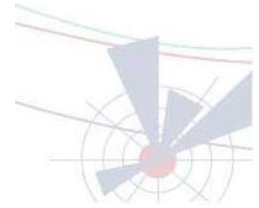
Air Density: Standard air density of 1.225 kg/m³ is used for turbine power curves. Northern Michigan enjoys the advantage of higher density air because of cold weather offset by lower air density because of higher elevation. The medium term (2006-2010) air density measured at GTLM4 was corrected to the elevation at the Northport site and resulted in an average air density value of 1.236 kg/m³ (1% over STP). Adding 1% is a conservative estimate because the high density air (cold) occurs during the high wind season, which will push the correction (and output) higher.

Section E Adjustments/Corrections	
Turbulence (17% vs 10% used for power curves)	-7%
Transmission Losses	-4%
Air Density Correction at Temperature and Altitude	<u>1%</u>
Total Correction	-10%



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Section F – Annual Energy Output Variation

The 30 year standard deviation of regional windspeed was used to calculate the expected annual variation in energy output (V^3).

Section F Annual Energy Output Variation	
One year in three, energy will exceed mean by	16%
One year in three, energy will be below mean by	-14%
One year in 20, energy will exceed mean by	33%
One year in 20, energy will be below mean by	-27%

Section G – Wind Map Reference Data

AWS TruePower’s “Wind Navigator” is a system of high resolution (200m) wind maps. The data can be accessed electronically through subscription. Data for the Northport site was retrieved at 95, 131, 145 and 164 ft.

Analysis of AWS data at 11 measured sites in this region shows that it consistently overestimates the long term wind resource at elevations under 50m (164 ft) by 0.5 to 1.0 mph. The AWS mapping system uses a wind shear exponent (alpha) that is 50 to 75% of the measured value at sites 100 to 164 ft (30-50m) in this region.

Therefore, their projections at these lower heights are always too high.

The calculations in section G subtract 1.0 mph from the AWS predicted values to compensate for this shortcoming.

Section G Wind Map Reference Data				
AWS Wind Navigator 200m topo resolution at test site	Height	AWS Predicted Annual Average	AWS Locally Adjusted (- 1.0 mph)	Measured Annual Average
	<u>ft</u>	<u>mph</u>	<u>mph</u>	<u>mph</u>
	95	12.2	11.2	10.8
	131	13.0	12.0	11.9
	145	13.3	12.3	12.2
	164	13.6	12.6	12.7

Section H – Turbulence

The Small Wind Industry Implementation Strategy Consortium (SWIIS) uses the IEC 61400 recommended limits for turbulence for installing a wind turbine. Turbulence (standard deviation over a 10min interval) vs windspeed defines a high and low limit.

- If the turbulence measured is under the low limit, the turbulence is acceptable.
- If the turbulence measured is above the high limit, the turbulence is too high, and the wind turbine should not be installed.



Northport Wind Turbine Project

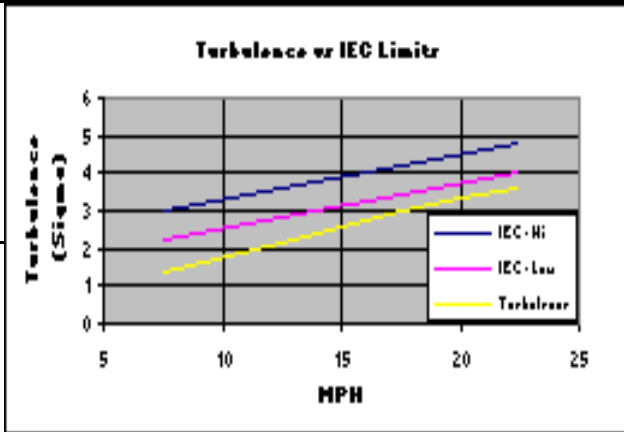
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- If the turbulence measured is between the low and high upper limits, there is a risk for the wind turbine, and more frequent inspections should be done.

The turbulence at the proposed site is below the low limit (acceptable)

Section H Turbulence



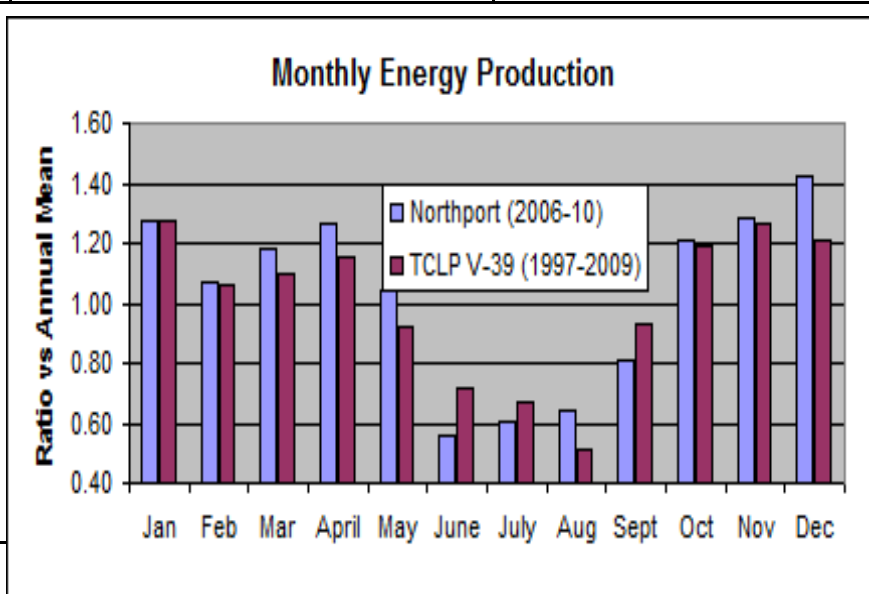
MPH	IEC - Hi	IEC - Low	Turbulence
7.5	3.03	2.24	1.35
12.5	3.63	2.84	2.13
17.5	4.23	3.44	2.98
22.5	4.83	4.04	3.60

Section I – Seasonal Variation

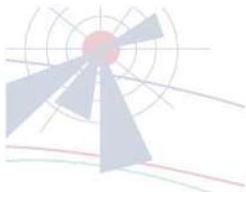
Four years of monthly windspeed data at the site (projected from GTLM4 and Ref#2) were used to calculate the monthly energy production at Northport. Twelve years of production from the Traverse City Light and Power Vestas V-39 is shown for reference. Results are shown as a ratio of the monthly average of 1.0.

For instance, energy production in June at Northport is 56% of the monthly average and December is 143% of the monthly average. Therefore, December production will be 2.5 times the June production.

Section I Seasonal Energy Variation

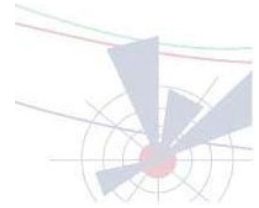


Month	Northport (2006-10)	TCLP V-39 (1997-2009)
Jan	1.27	1.28
Feb	1.07	1.06
Mar	1.18	1.10
April	1.27	1.16
May	1.04	0.92
June	0.56	0.71
July	0.61	0.67
Aug	0.64	0.51
Sept	0.81	0.93
Oct	1.21	1.19
Nov	1.29	1.27
Dec	1.43	1.21
Average	1.00	1.00



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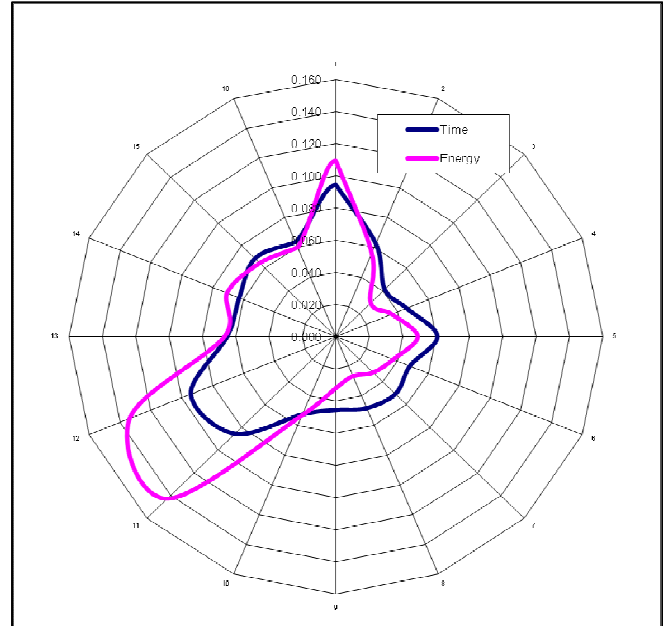
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Section J – Wind Energy and Wind Rose Polar Plots

The plot at right shows the frequency of wind by direction (wind rose) and the amount of energy in the wind by direction.

The plot is typical of Michigan with 60 - 70% of the wind energy coming from the SW quadrant and a secondary lobe from the north or northwest. There is some reduction in the northwest lobe because of trees on the NW ridge. (see below)

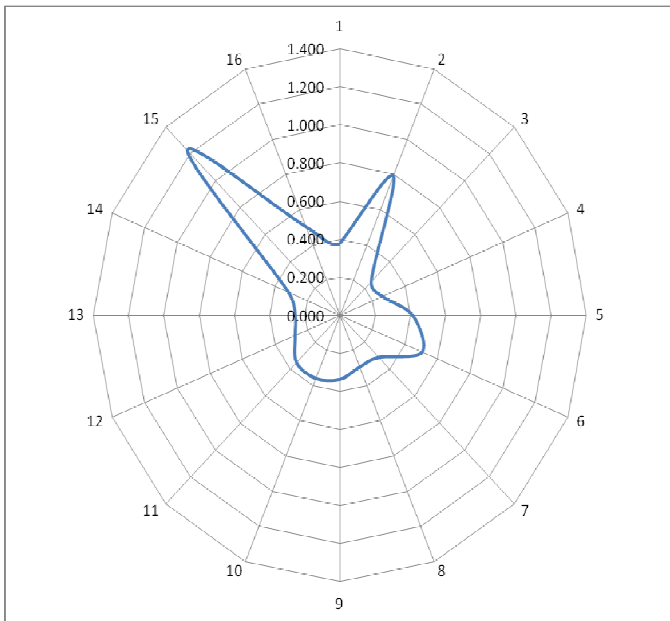


Section K – Wind Shear and Turbulence Polar Plots

Wind shear polar plots reveal the effect of various obstructions on the wind resource. Alpha represents the wind shear exponent in the equation:

$$V_1 = V_2 \times (H_1 / H_2)^{\text{alpha}}$$

Where V_1 = wind velocity at height H_1
 V_2 = wind velocity at height H_2



Alpha (wind shear) vs wind direction

Trees, buildings and the test tower itself will be evident from the plot. The plot to the left shows three distinct “lobes” indicating obstructions.

- Station 2 (22 degrees) represents a small grove of taller trees to the NNE
- Station 5-6 (100 degrees) is the tower shadowing the lower anemometer (98 deg)
- Station 15 (315 degrees) is the tree covered ridge to the NE of the test site

The region of maximum wind energy – station 10 to station 14 (210 to 290 degrees) has excellent exposure and represents the prevailing wind direction and region of maximum energy.

The calculation of alpha for predicting wind at higher elevations ignores the obstruction lobes because:

1. They are not in the prevailing energy direction
2. Their effect lessens with elevation