Wind Assessment for Sample

A three month study was performed in “center field” at Sample. A 90 ft meteorological tower was installed and logged windspeed and direction data for the test period.

Summary

The site as tested is not a good candidate for a wind turbine. Large trees on three sides (east, south and west) significantly reduce the potential wind resource.
A simulation of the site was performed assuming the trees were removed and, at hub heights over 120 ft, the site is viable.

Recommendations

1. Remove the trees to the south and west. The terrain loses elevation in these directions so you may have to go only 200-400 ft. into the trees. Trees to the east are not as important as very little wind energy comes from that direction.
2. Commit to a mid-sized wind turbine project – 150 to 500 kw. The economies of scale are significant. There are many attractively priced machines on the refurbished market in addition to grants, credits and subsidies. The payback period can be as short as 8 years.
3. Hire a reputable wind energy consultant for the project – someone who has completed similar projects. State block grants and 2% Tribal grants are available. (See recommended sources at the end of this report)

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Document Created Nov 22, 2009
Last Modified Nov 24, 2009
Submitted Nov 24, 2009
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4. If you commit to a project, re-test the site at the proposed hub height (120 to 150 ft) after trees are removed. The "treeless" simulation I performed is an approximation, but appears to be very accurate. (see "Sanity Check", page 7)

Test Period and Site

Met tower (90 ft) installed Aug 1, 2009, removed November 10, 2009
Site Location:
Site elevation: 940 ft
Exposure: N – Descending terrain to soccer field and parking lot
E – 80-100 ft trees 250 ft away
S – 80-100 ft trees 425 ft away
W – 80-100 ft trees 375 ft away

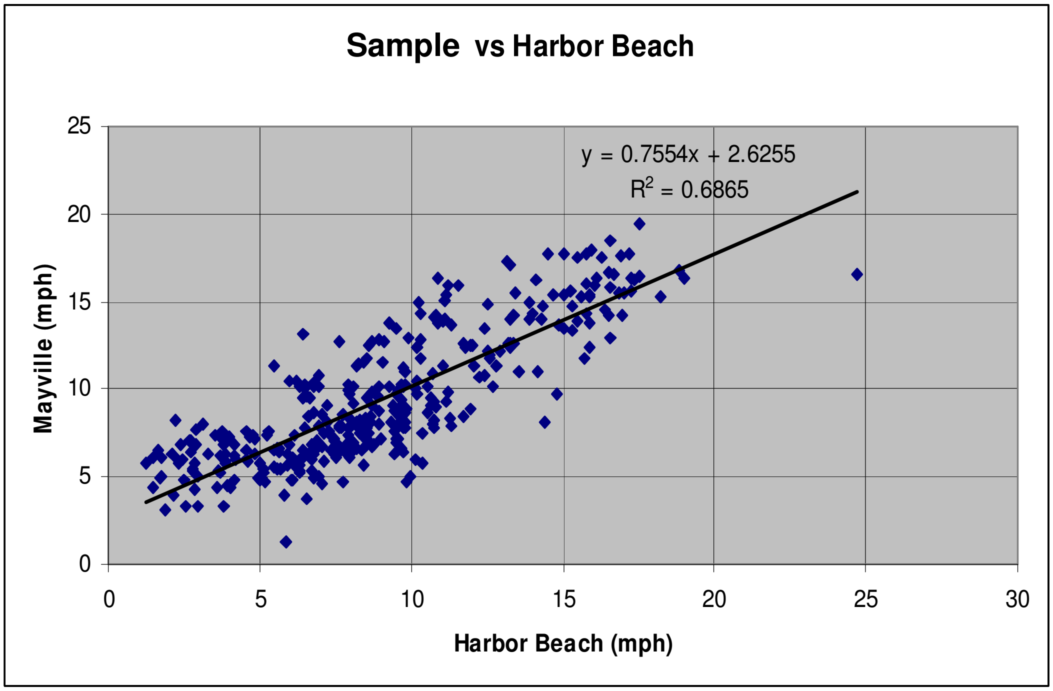
Short Term Wind Assessment Methodology

In order to assess a site in three months, there must be a long term reference site nearby. Harbor Beach (50 miles), Saginaw Bay Light (45 miles) and Port Sanilac (42 miles) are possible candidates. Harbor Beach was chosen because there are 6 years of data history vs. one year for the other sites.
Wind data at the test site is then compared in one hour and daily intervals to create transfer functions (equations) that relate the windspeed and wind direction at the two sites.
Once this relationship is calculated, the historical data at the reference site is used to calculate historical data at the test site.

Projected Average Annual Windspeeds

Data for the test period was synchronized with data from the Harbor Beach met station in one hour intervals. The data was divided into eight wind directions (sectors) and a linear regression line calculated for each sector. The equation for each sector is:

Sector (degrees)	Slope	Intercept	Equation
0 - North	0.404	2.78	Example – North wind at Harbor Beach:
45 - Northeast	0.278	3.29	
90 - East	0.178	4.68	Sample (mph) =
135 - Southeast	0.320	3.41	Harbor Beach (mph) x 0.404 + 2.78
180 - South	0.573	3.09	Etc.
225 - Southwest	0.755	2.63	
270 - West	0.554	3.04	
315 - Northwest	0.626	2.72	



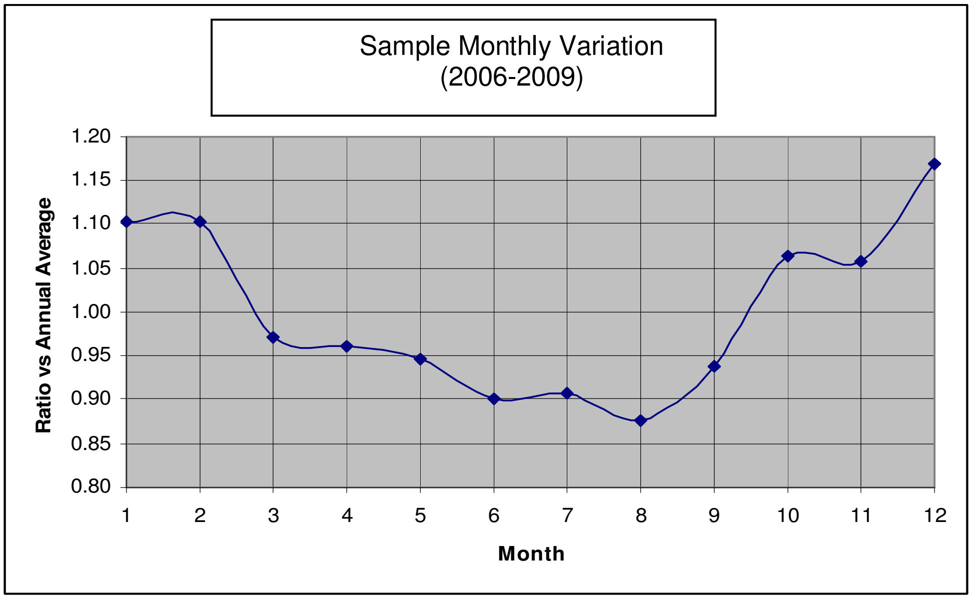
Typical Harbor Beach vs Sample windspeed transfer function. Wind sector is southwest (202 – 247 deg).
"y" is Sample windspeed. "x" is Harbor Beach windspeed. R-squared is the correlation coefficient – 1.0 is perfect correlation. 0.0 is no correlation. For windspeed correlation, R-squared values greater than 0.50 are considered good. (Ref: COWI report on Antrim / Petosky daily windspeed correlation)

Harbor Beach data from 2006 – 2008 was then used to calculate average windspeeds at Sample. Data was calculated in 6 minute increments reported at Harbor Beach:

Year	Months	Harbor Beach	Sample
2006	Jan - June	10.16	7.87
2006	July - Dec	10.48	8.25
2007	Jan - June	11.16	8.27
2007	July - Dec	10.62	8.49
2008	Jan - June	11.36	8.65
2008	July - Dec	10.72	8.48
Average	**2006 - 2008**	**10.75**	**8.33**

Wind Assessment for Sample

Seasonal Windspeed Variation

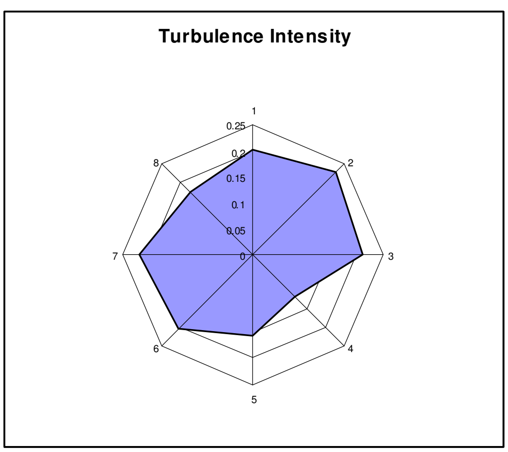


The projected windspeed variation for 2006-2008 is shown. 1.00 is the mean. Higher values indicate higher windspeed, lower values, lower windspeed. This is a typical inland variation curve. Coastal and high elevation curves are more pronounced, more aggressive, often showing +/-30% variations over the seasons.

The period 8-10 represents August-Oct when the test was conducted. The average ratio is 0.96 which means that the windspeed was 96% of the average annual windspeed during this period.
The measured windspeed during the test period was 7.96 mph. Dividing this by the ratio during this period produces an **average annual windspeed of 8.29 mph**.

This is in close agreement with the **8.33** predicted by the linear regression method.

Turbulence



Turbulence intensity (TI) measures the variation in windspeed. It's calculated by dividing the standard deviation of windspeed over a 10 minute period by the average windspeed over that same 10 minute period. Turbulence generally decreases with increased windspeed.
The effect of turbulence is to decrease the efficiency of a wind turbine because the machine must adjust to changes in speed and direction of the wind.

Wind Assessment for Sample

Turbulence (cont'd)

Turbulence measured at 90 ft was within expected range of 0.15 to 0.20. Higher turbulence was noted to the northeast (trees) and southwest (higher terrain).

Wind Shear

Wind shear is the change in windspeed with elevation. The equation is:

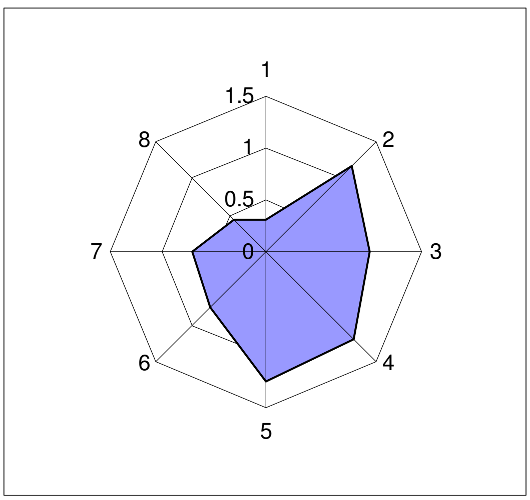
$$V_1/V_2 = (H_1/H_2)^{alpha}$$

Where: V_1 and V_2 are the windspeeds at two elevations
H_1 and H_2 are the two elevations
Alpha is the wind shear exponent (0.10 to 1.50)

H_1 and H_2 are the heights of the test anemometers – 90 and 76 ft.

A low value (0.10 to 0.25) indicates smooth (laminar) flow with a gradual increase in windspeed with increased elevation.

Higher values (over 0.40) indicate rapid changes in windspeed with elevation. This usually means that there are obstructions that must be overcome to achieve good performance from a wind turbine.
The polar plot below shows the measured wind shear exponent as a function of wind direction. The expected value of 0.25 to 0.35 is observed in the north and northwest sector. Values higher than this indicate significant obstructions.



The data shows significant obstruction from the trees to the northeast, east, southeast, south, southwest and west. The northwest and northern exposure exhibits typical values for turbulence and wind shear as the air flows over fairly unobstructed terrain over the soccer fields and parking lots to the north.

Wind Assessment for Sample

Removing the Trees

A simulation of the effect of removing the trees around the site was performed.

1. Scale “alpha” from the measured value to the expected value as we ascend from 90 ft to 200 ft – over the tree tops and calculate windspeed in each sector

2. Descend from 200 ft to 90 ft using typical values of alpha (0.25 to 0.35)

3. Calculate the average windspeed in each sector in the “treeless” site.

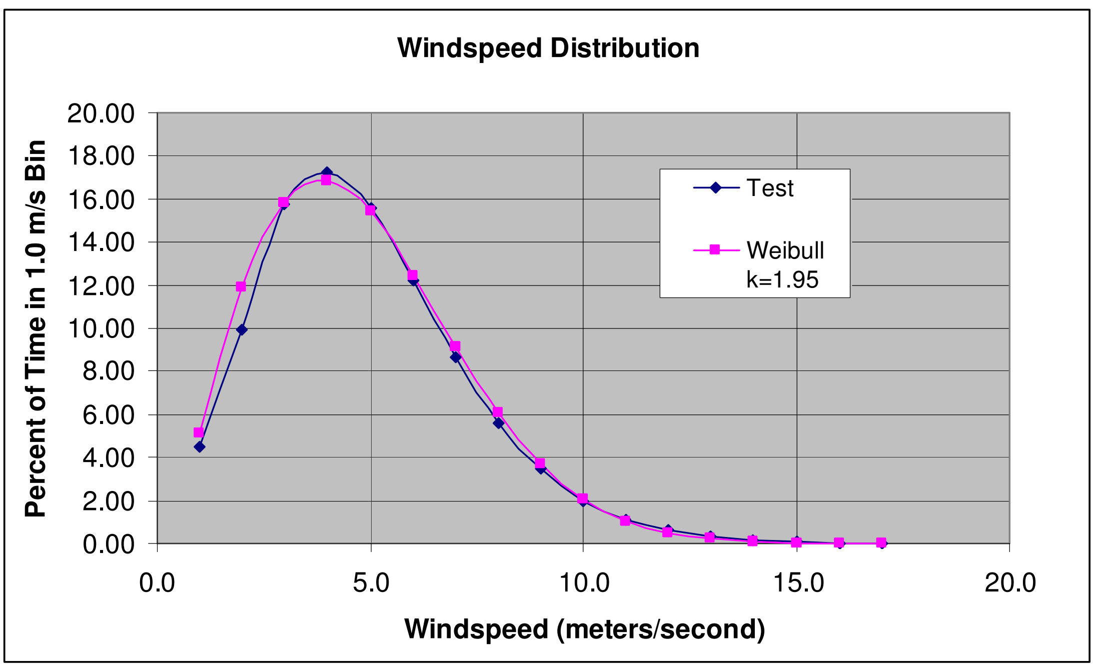
After this process, the average annual windspeed at 90 ft is 9.42 mph (vs 8.33 with trees).

Using this base windspeed, we can scale to various hub heights:

Hub Height (ft)	90	120	150	180	200
Average mph	9.42	10.33	11.05	11.61	11.91

Windspeed Distribution

The chart below shows the projected windspeed distribution for 2006-2008 at the test site. It demonstrates a typical “Rayleigh” windspeed distribution of about 2.0. Wind turbine manufacturers use this distribution to predict annual energy production. Therefore, we can confidently use the average predicted windspeed to predict annual energy production.



Wind Assessment for Sample

Annual Specific Yield

This is a simple way to estimate the energy yield at this site for a mid-sized wind turbine (100-500 kw). Simply take the swept area of the wind turbine's rotor (blades) and multiply by the specific yield. This will give a good estimate of the annual output in kw-hours.

Hub Height	Average Annual mph	Annual Yield (kw-hr/m2/year)
90	9.42	196
120	10.33	286
150	11.05	378
200	11.91	514

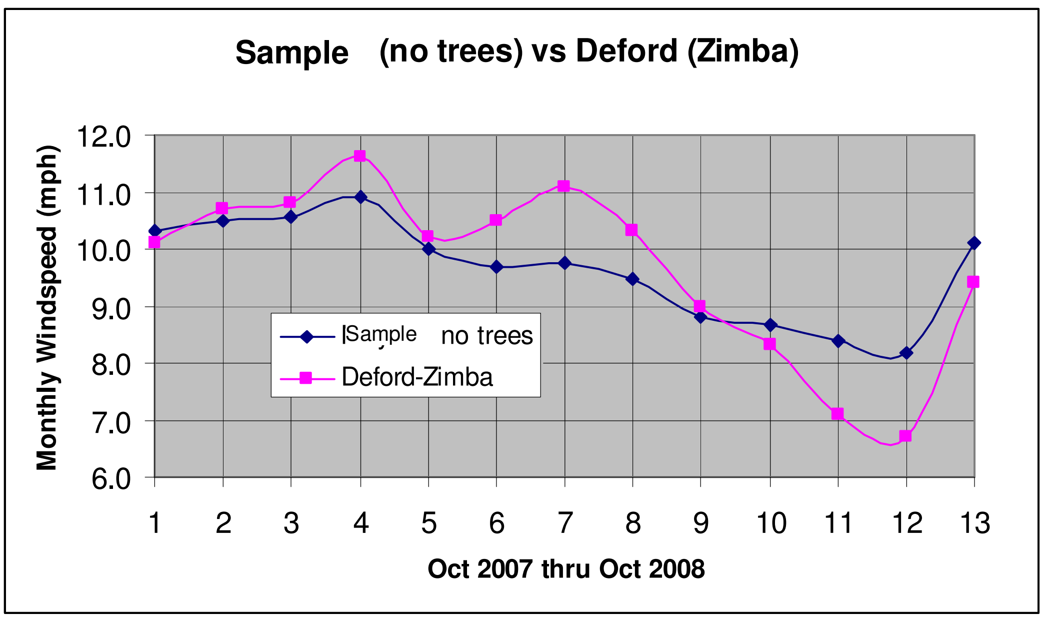
For example, a wind turbine with a swept area of 200 square meters at a hub height of 150 ft will produce:

200 x 378 = 75,600 kw-hrs per year
The value of this energy at $0.10 per kw-hr will be $7,560.

Sanity Check – A review of a similar recently tested site

MSU Extension anemometer loan program:
DeFord (15 miles from Sample). Zimba Dairy Farm, 7995 Mushroom Rd
100 ft on exposed location. Oct 2007 to Oct 2008. Elevation 775 ft
Average windspeed = 9.68 mph

Sample (no trees) at 100 ft, Oct 2007 to Oct 2008. Elevation 940 ft
Average windspeed = 9.64 mph



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Wind Assessment for Sample

Sample Wind Turbine Performance

The examples below demonstrate the range of options available in mid-sized wind turbines. Dealers will make many claims of production but nearly all modern machines fall into a narrow range of performance dictated by the swept area of the rotor.

A Northwind 100 has a rotor diameter of 21 meters.

AREA = 3.14 x 21 x 21 /4 = 346.4 square meters

At 120 ft, the annual output will be:

286 x 346.4 = 99,059 kw-hr

Electricity is worth about $0.10 per kw-hr so the annual dollar value is:

$0.10 x 99,059 = $9,906

Renewable energy credits (RECs) and production tax credits (PTCs) may increase this value by $0.03 to $0.06 per kw-hr. So the annual value could be up to $15,849.

The Northwind 100 is a very expensive machine – about $5,500 per kw or about $550,000 installed. Tax credits and grants (about 30%) will reduce the cost to about $385,000. But the simple payback period is still very long:

$385,000 / $9,906 = 38.9 years at $0.10 per kw-hr
$385,000 / $15,849 = 24.3 years at $0.16 per kw-hr
- past the useful life of the machine!

A Bonus 450 has a rotor diameter of 37 meters.

AREA = 3.14 x 37 x 37 / 4 = 1069 square meters

At 200 ft, the specific output is 514 and the annual output will be:

514 x 1069 = 549,384 kw-hr

Electricity is worth about $0.10 per kw-hr so the annual dollar value is:

$0.10 x 549,384 = $54,938 per year

A refurbished Bonus 450 on a 200 ft tower costs about $850,000 installed. Tax credits and grants (about 30%) will reduce the cost to about $595,000. The simple payback period is:

$595,000 / $54938 = 10.8 years

At the higher kw-hr rate ($0.16) the payback period is:

$595,000 / $87,901 = 6.8 years

In general, larger machines have shorter payback periods and higher hub heights have shorter payback periods.

Wind Assessment for Sample

Equipment and Calibration

Anemometers:

Inspeed Vortex reed switch type. Each unit was calibrated to an NRG #40 Max calibrated anemometer after test. Measured transfer functions:

Upper Unit MPH = 2.63 * Hz + 1.05
Lower Unit MPH = 2.66 * Hz + 1.02
Where: Hz = count (rotations) / interval (seconds)

Wind Vane: NRG #200, 10k ohm linear, direction (deadband) correction: +90 deg

Data Logger: APRS WindDataLogger, one minute logging interval, SD data storage card

Air Density Correction

There is usually a correction made for air density change due to elevation and temperature. Higher elevations have “lighter air” and colder air is more dense. Standard elevation is sea level and standard temperature is 20 C. In Michigan, at 900 ft elevation, these effects cancel each other. The air is less dense due to elevation but the colder weather offsets this loss in density. Throughout the state, the net variation is less than 1%.

Wind Assessment for Sample

Recommended Sources for Consulting

Bay Energy Services, LLC, Suttons Bay, MI. Steve Smiley was the project manager for the Traverse City Light & Power 600kw Vestas installed in 1995 and the two 900kw machines installed in Mackinac City in 2007. Steve has over 30 years experience in the wind industry in the US and Europe. Smiley27@earthlink.net

Wolverine Power Systems, Wind Turbine Division. Wolverine is best known for their stationary power systems (generators). They branched into wind systems several years ago and have several knowledgeable engineers on staff.
Contact: Lisa Spaugh, (lisa.spaugh@wolverinepower.com), 616-879-0040

www.windustry.org. This is a Minnesota based non-profit that promotes community wind systems. Their website has great information on how to launch a community wind project.

Recommended Reading

"Wind Energy Basics", second edition by Paul Gipe.