Preliminary Assessment

For

Wind Based Power Generation

In

Escanaba

5/10/08

Wind Energy Basics

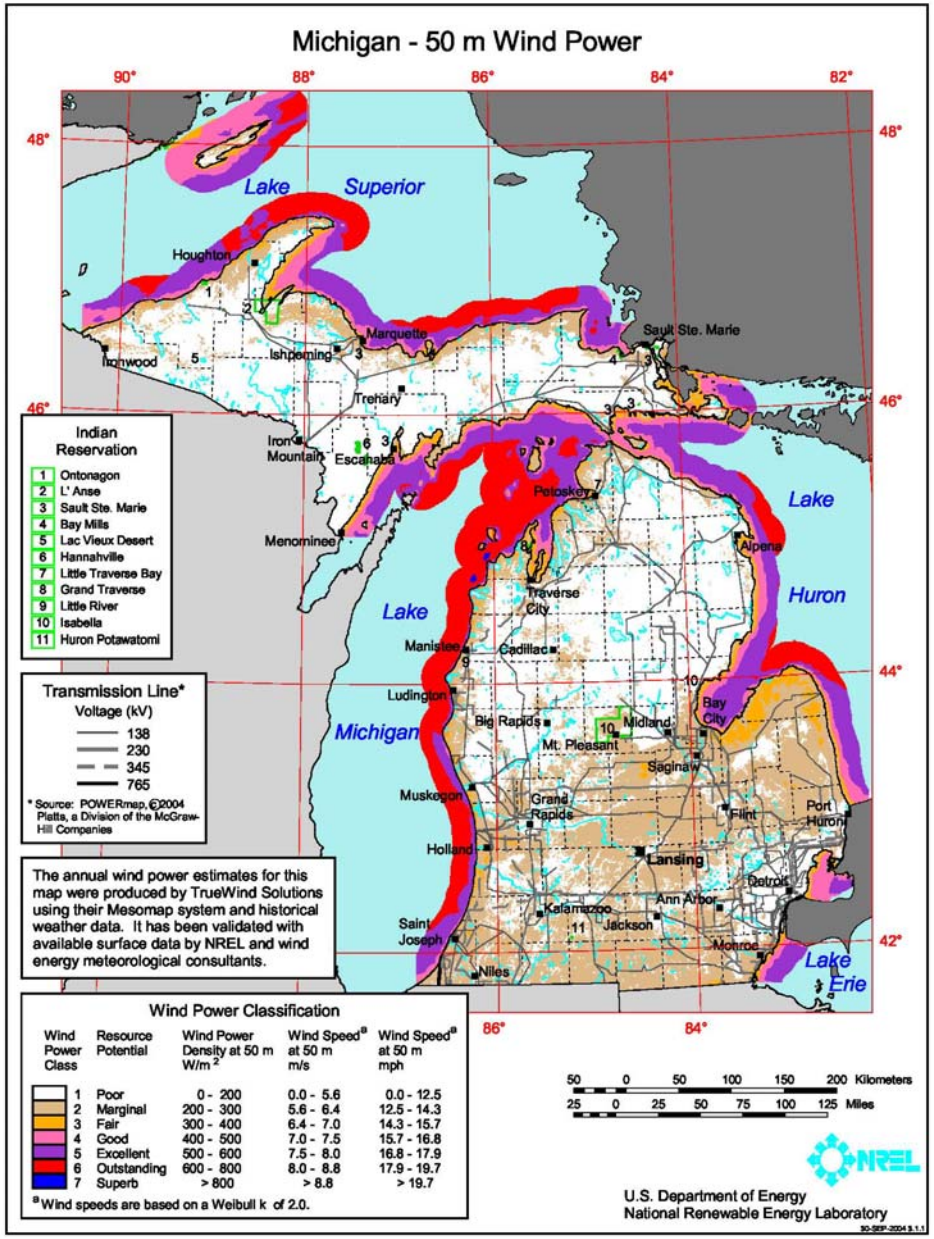
- **Wind is a byproduct of solar energy**

- **Wind results from:**
  - **Uneven heating and cooling of the earth**
  - **Creates atmospheric pressure gradients**
  - **Gradients force air movement from areas of high pressure to low pressure**

- **Wind turbine power generation depends on:**
  - **Cross sectional area of turbine swept blades (i.e., square of blade length)**
  - **Cube of wind velocity**
  - **Power = ½ $\rho A^2 V^3$ where**
    - **ρ = Air density**
    - **A = Blade area**
    - **V = Wind velocity**

- **Wind velocity increases with height above ground**
  Wind velocity at higher elevations, V_2 at H_2, is estimated by:

  - **$V_2 = V_s (H_2 / H_s)^{\alpha}$**
  - **V_s = sensor wind velocity and H_s = height of sensor above the ground**
  - **α varies with terrain, elevation, etc. α = 1/7 for this study.**



http://www.hrt.msu.edu/energy/Notebook/pdf/Sec5/MI_50m_Wind_Power_by_NREL1.pdf

Wind Power Potential Classification System [1]

Wind Power Class	Resource Potential	Average Wind Speed at 10 Meters, mph
1	Poor	0 – 9.8
2	Marginal	9.8 – 11.5
3	Fair	11.5 – 12.5
4	Good	12.5 – 13.4
5	Excellent	13.4 – 14.3
6	Outstanding	14.3 – 15.7
7	Superb	> 15.7

(1) U.S. Dept of Energy, National Renewable Energy Laboratory

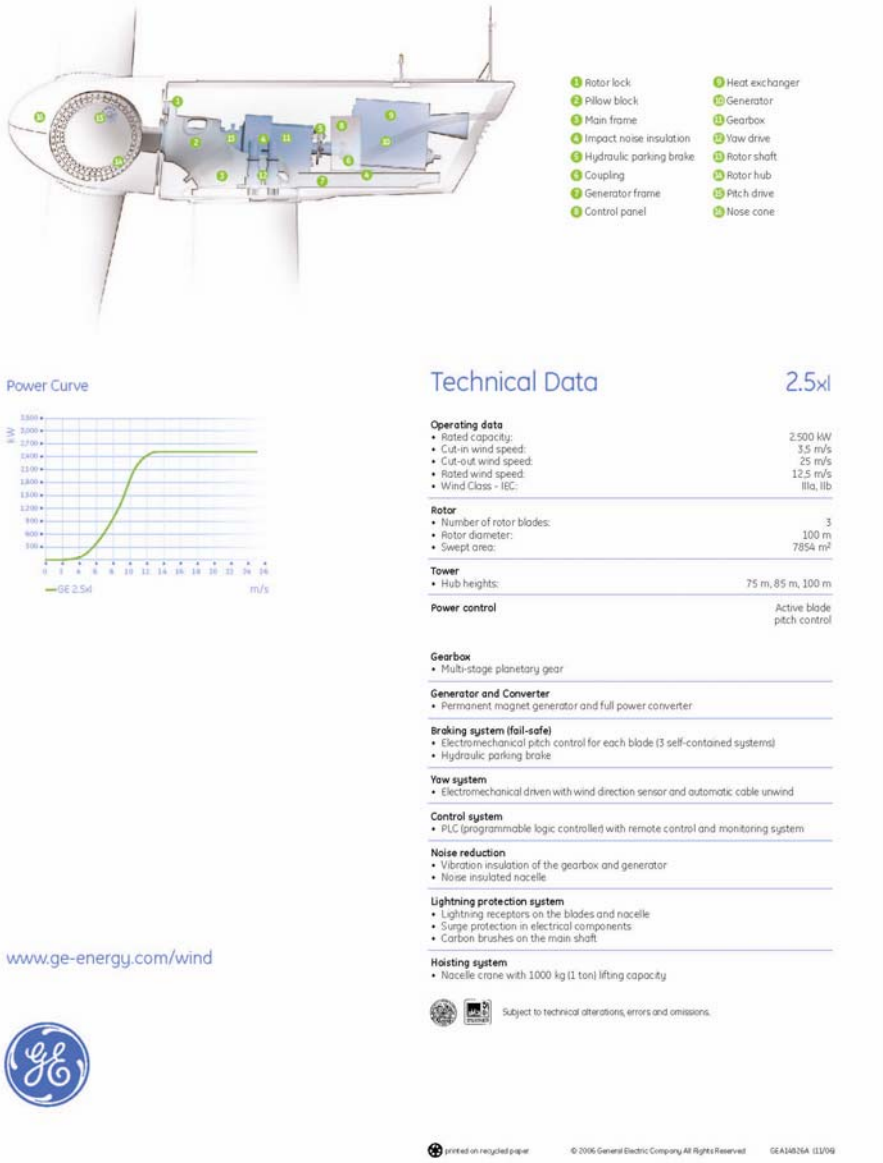
Commercial Wind Turbine Performance Specifications

Supplier	Generation Capacity, MW	Rotor Blade Radius, m	Tower Hub Heights, m	Cut-in [1] Wind Speed, mph	Rated [2] Wind Speed, mph	Cut-out [3] Wind Speed, mph
GE	1.5	38.5	61.4/64.7/80	7.8	31.3	55.9
	2.5	50	75/85/100	7.8	28.0	55.9
	3.6	52	75/85/100	7.8	31.3	60.4
Vestas	1.65	41	50/70/80	7.8	29.1	53.7
	2.0	40	67/80	8.9	33.6	55.9
	3.0	45	80/105	8.9	33.6	55.9
Zephyros (gearless)	2.0	35.3	65/85	6.7	29.1	55.9
EWT – Direct wind (gearless)	0.9	27.0	40/50/75	6.7	29.1	55.9
Mackinaw City Turbines (NEG Micon)	0.9	25.9	70	8.9	35.8	55.9

(1) Wind speed when power generation starts.
(2) Wind speed when rated generation capacity reached (e.g., 2.5 MW for a GE 2.5 MW Wind Turbine).
(3) Wind speed when turbine blades feathers and generation stops to prevent damage to the wind turbine.

Note: Wind conversion factor: 1 meter/second = 1 m/s = 2.24 mph

http://www.ge-energy.com/prod_serv/products/wind_turbines/en/downloads/ge_25mw_brochure.pdf



1 Rotor lock
2 Pillow block
3 Main frame
4 Impact noise insulation
5 Hydraulic parking brake
6 Coupling
7 Generator frame
8 Control panel
9 Heat exchanger
10 Generator
11 Gearbox
12 Yaw drive
13 Rotor shaft
14 Rotor hub
15 Pitch drive
16 Nose cone

Power Curve

kW

GE 2.5xl

m/s

www.ge-energy.com/wind

Technical Data 2.5xl

Operating data
- Rated capacity: 2.500 kW
- Cut-in wind speed: 3.5 m/s
- Cut-out wind speed: 25 m/s
- Rated wind speed: 12.5 m/s
- Wind Class - IEC: IIIa, IIb

Rotor
- Number of rotor blades: 3
- Rotor diameter: 100 m
- Swept area: 7854 m²

Tower
- Hub heights: 75 m, 85 m, 100 m

Power control Active blade pitch control

Gearbox
- Multi-stage planetary gear

Generator and Converter
- Permanent magnet generator and full power converter

Braking system (fail-safe)
- Electromechanical pitch control for each blade (3 self-contained systems)
- Hydraulic parking brake

Yaw system
- Electromechanical driven with wind direction sensor and automatic cable unwind

Control system
- PLC (programmable logic controller) with remote control and monitoring system

Noise reduction
- Vibration insulation of the gearbox and generator
- Noise insulated nacelle

Lightning protection system
- Lightning receptors on the blades and nacelle
- Surge protection in electrical components
- Carbon brushes on the main shaft

Hoisting system
- Nacelle crane with 1000 kg (1 ton) lifting capacity

Subject to technical alterations, errors and omissions.

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GEA14826A (11/06)

Commercial Scale Wind Turbine Sizes (1)

Turbine Capacity, MW	Rotor Blade Length, ft.	Tower Hub Height, ft.	Maximum Blade Tip Height Above Ground, ft.	Maximum Blade Tip Height Relative to Harbor Tower (2)
0.9	88	131 to 246	219 to 334	1.3X to 2.0X
1.5	126	201 to 262	327 to 388	2.0X to 2.4X
2.5	164	246 to 328	410 to 492	2.5X to 3.0X
3.6	171	246 to 328	417 to 499	2.5X to 3.0X

(1) EWT Directwind & GE Wind Turbine size specifications

(2) Harbor Tower apartment building height 164 feet

(3) May be subject to FAA tower height limits in proximity to the Delta County Airport

Montfort Wind Power Facility - Eden, WI

Summary of Escanaba 2007 Wind Data

Wind Sensor	**Delta County Airport AWOS, near the ILL tower**
Wind Sensor Height	**10 meters**
Wind Data File	**National Climatic Data Center (NCDC) Quality Controlled Local Climatological Data Hourly Average Observations for 2007; edited to remove blanks and obviously spurious data points. 8760 for full set, edited set is 8567 data points. (1)**
Annual Average Wind Speed, mph	**8.3 (Wind Power Class = 1, Poor Resource Potential)**
Minimum Hourly Average Wind Speed, mph	**0.0**
Maximum Hourly Average Wind Speed, mph	**34.0**

(1) Data files also edited for corresponding Hourly City Load and Fairport, MI NOAA (FPTM4) wind sensor data.

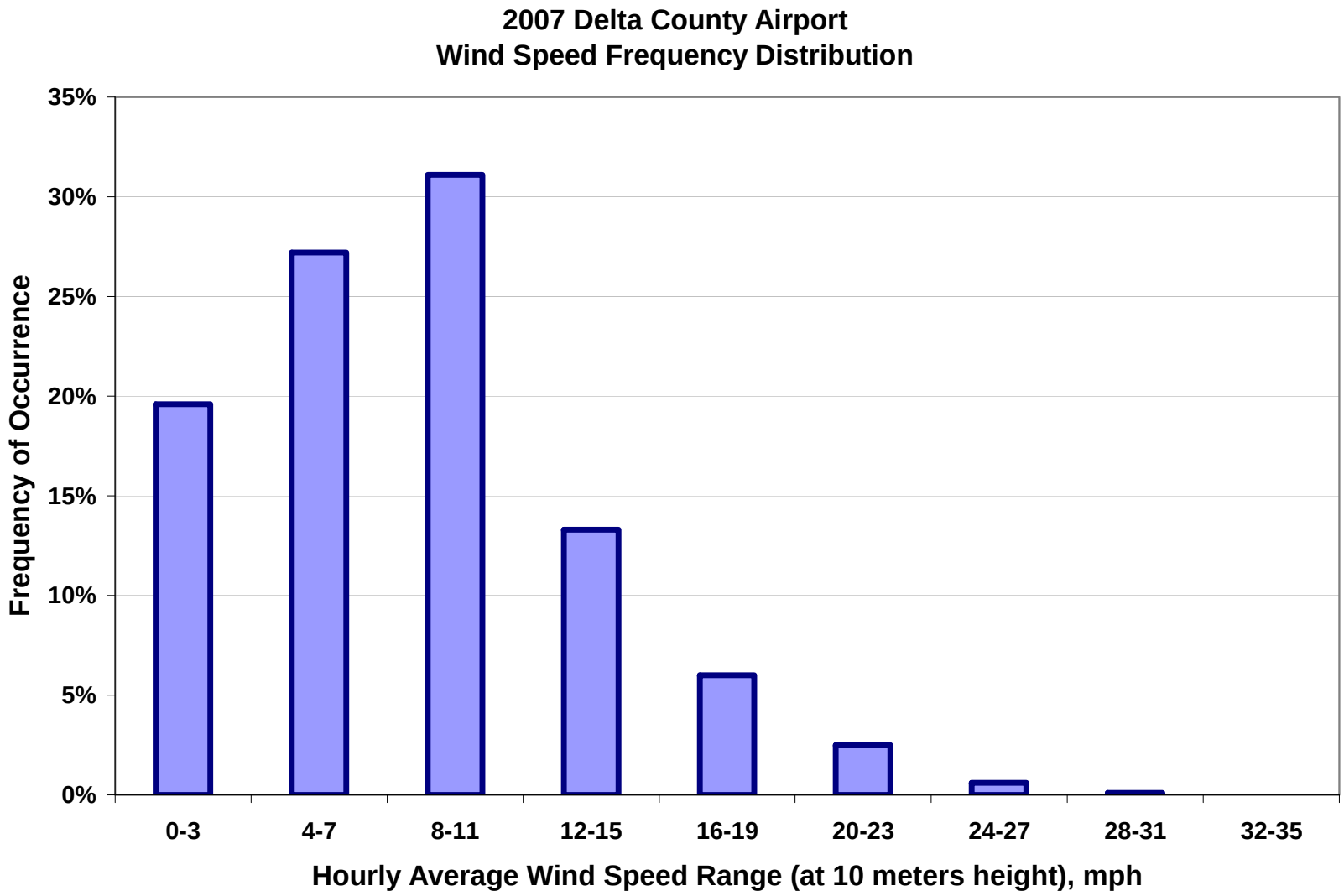
2007 Hourly Data File Developed for Analysis

Local Time	Esc City Load, MW	ESC WSP Hr Avg at 10 Meters, mph	FPTM4 WSP Hr Avg at 10 meters, mph	Calc ESC WSP at 85 Meters, mph	GE 2.5MW Wind Turbine Power, MW	Calc ESC WSP at 75 Meters, mph	EWT 0.9MW Wind Turbine Power, MW
1/1/07 0:00	13.35	3	6.22	4.07	0.00	4.00	0.000
1/1/07 1:00	12.99	9	6.06	12.22	0.547	12.00	0.213
1/1/07 2:00	12.73	8	6.93	10.86	0.379	10.67	0.159
1/1/07 3:00	11.74	8	6.25	10.86	0.379	10.67	0.159
1/1/07 4:00	12.21	13	6.43	17.65	1.219	17.34	0.427
1/1/07 5:00	12.64	15	9.27	20.36	1.555	20.00	0.535
1/1/07 6:00	14.14	14	8.40	19.01	1.387	18.67	0.481
1/1/07 7:00	14.57	9	7.17	12.22	0.547	12.00	0.213
1/1/07 8:00	14.70	11	7.08	14.93	0.883	14.67	0.320
1/1/07 9:00	14.90	10	8.61	13.58	0.715	13.34	0.267
1/1/07 10:00	15.02	11	8.11	14.93	0.883	14.67	0.320
1/1/07 11:00	14.21	13	6.31	17.65	1.219	17.34	0.427
1/1/07 12:00	15.38	17	5.77	23.08	1.891	22.67	0.642
1/1/07 13:00	14.85	11	5.51	14.93	0.883	14.67	0.320
1/1/07 14:00	14.24	13	4.95	17.65	1.219	17.34	0.427
1/1/07 15:00	14.09	9	5.72	12.22	0.547	12.00	0.213
1/1/07 16:00	14.17	10	6.56	13.58	0.715	13.34	0.267
1/1/07 17:00	15.29	9	5.43	12.22	0.547	12.00	0.213
1/1/07 18:00	16.71	7	6.43	9.50	0.211	9.33	0.106
1/1/07 19:00	16.63	9	5.35	12.22	0.547	12.00	0.213
1/1/07 20:00	16.19	6	6.16	8.15	0.043	8.00	0.052

Note: This is part of first page of 8567 data points edited from 8760 set, used for the calculations.

2007 Hourly Data File Summary

	Esc City Load, MW	ESC WSP Hr Avg at 10 Meters, mph	FPTM4 WSP Hr Avg at 10 meters, mph	Calc ESC WSP at 85 Meters, mph	GE 2.5MW Wind Turbine Power, MW	Calc ESC WSP at 75 Meters, mph	EWT 0.9MW Wind Turbine Power, MW
TOTAL	151,545	70,782	49,728	96,094	4,961	94,391	1830
Average	17.69	8.26	5.81	11.22	0.58	11.02	0.21
Max	29.89	34.00	33.28	46.16	2.50	45.34	0.90
Min	6.93	0.00	0.00	0.00	0.00	0.00	0.00
St Dev	3.77	5.26	3.46	7.15	0.66	7.02	0.22
GE 2.5 MW Wind Turbine Capacity Factor = 0.58 / 2.5 =					23.2%		
EWT 0.9 MW Wind Turbine Capacity Factor = 0.21 / 0.9 =							23.3%


2007 Delta County Airport
Wind Speed Frequency Distribution
35%
30%
25%
20%
15%
10%
5%
0%
Frequency of Occurrence
0-3
4-7
8-11
12-15
16-19
20-23
24-27
28-31
32-35
Hourly Average Wind Speed Range (at 10 meters height), mph

Potential Siting Location Impact on Wind Speed

- Large lake shores and ocean coasts provide higher wind speeds because of differential heating from the sun between the land and water.
- Ridges and valleys can enhance the wind speed.

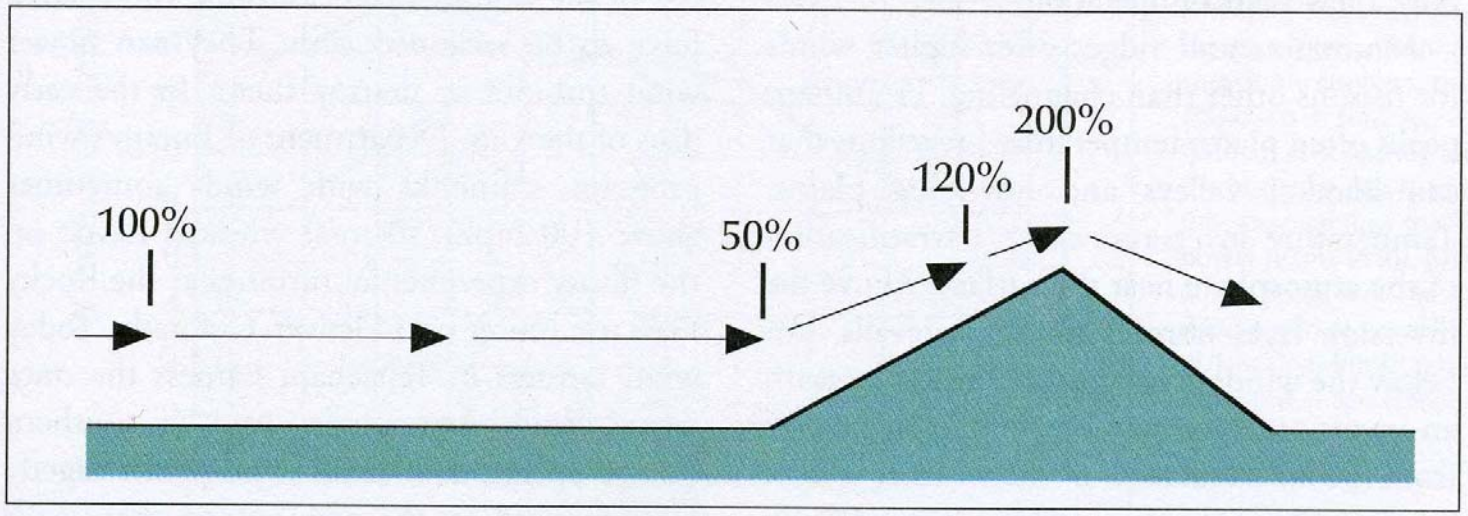
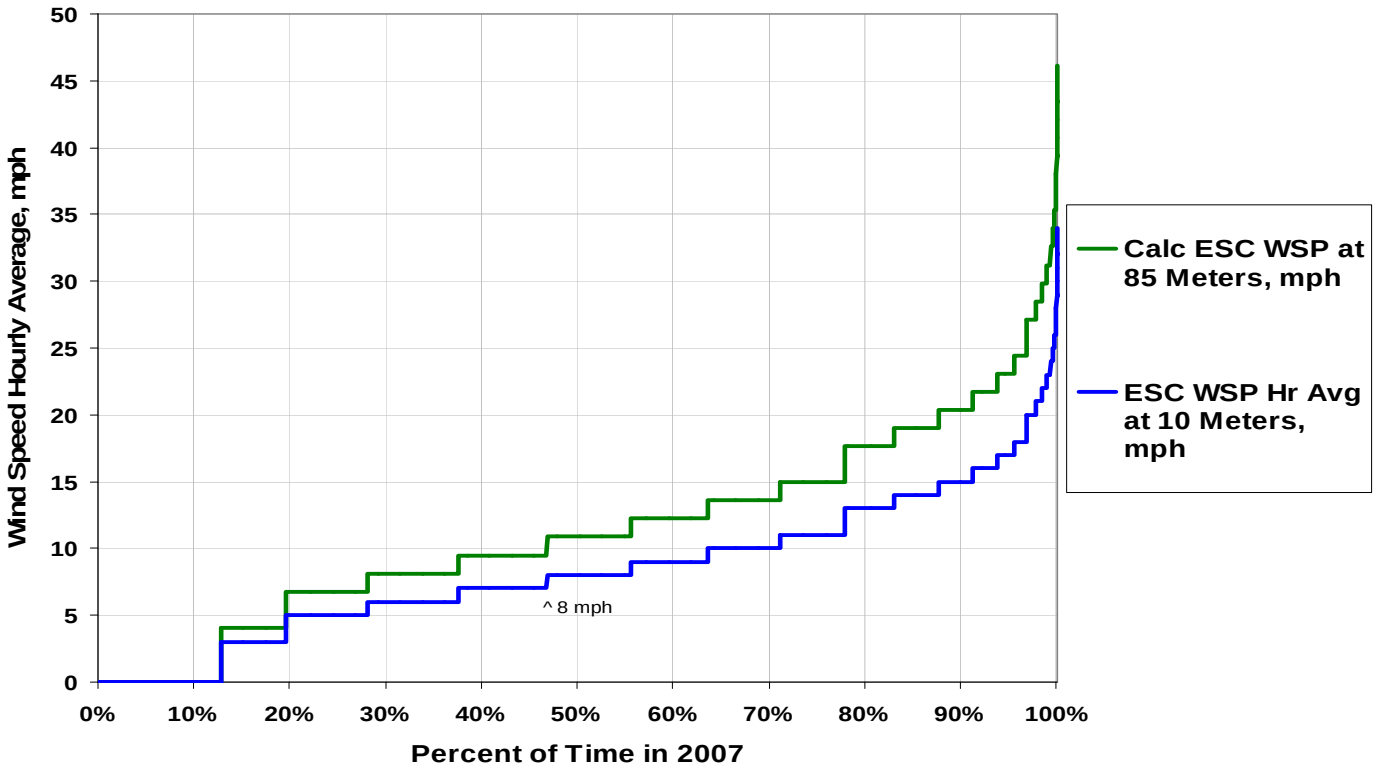


Figure 3-2. Increase in wind speed over a ridge. Wind speed increases near the summit of a long ridge lying across the wind's path. Though there can be some acceleration of the flow on the flanks, wind speeds typically are lower at the foot of the ridge. (Battelle PNL)

- Gladstone/WPPI/Private developer wind survey study is to include monitoring at Gladstone Ski Hill (ridge) and lake shore locations.

2007 Escanaba Wind NCDC Data at 10 Meters and Estimated 85 Meters

- Approximately 46% of the time in 2007, the Delta County Airport wind speed at 10 meters height was less than 8 mph.
- Approximately 28% of the time in 2007, the estimated wind speed at 85 meters height was less than 7.8 mph, the Cut-in wind speed for power generation to start for a GE 2.5MW turbine.
- Less than 5% of the time in 2007, the estimated wind speed at 85 meters exceeded 28 mph to reach the rated capacity of a GE 2.5 MW turbine.



2007 Calculated Power Production Based on Escanaba Wind NCDC Data
GE 2.5 MW Wind Turbine at 85 meters

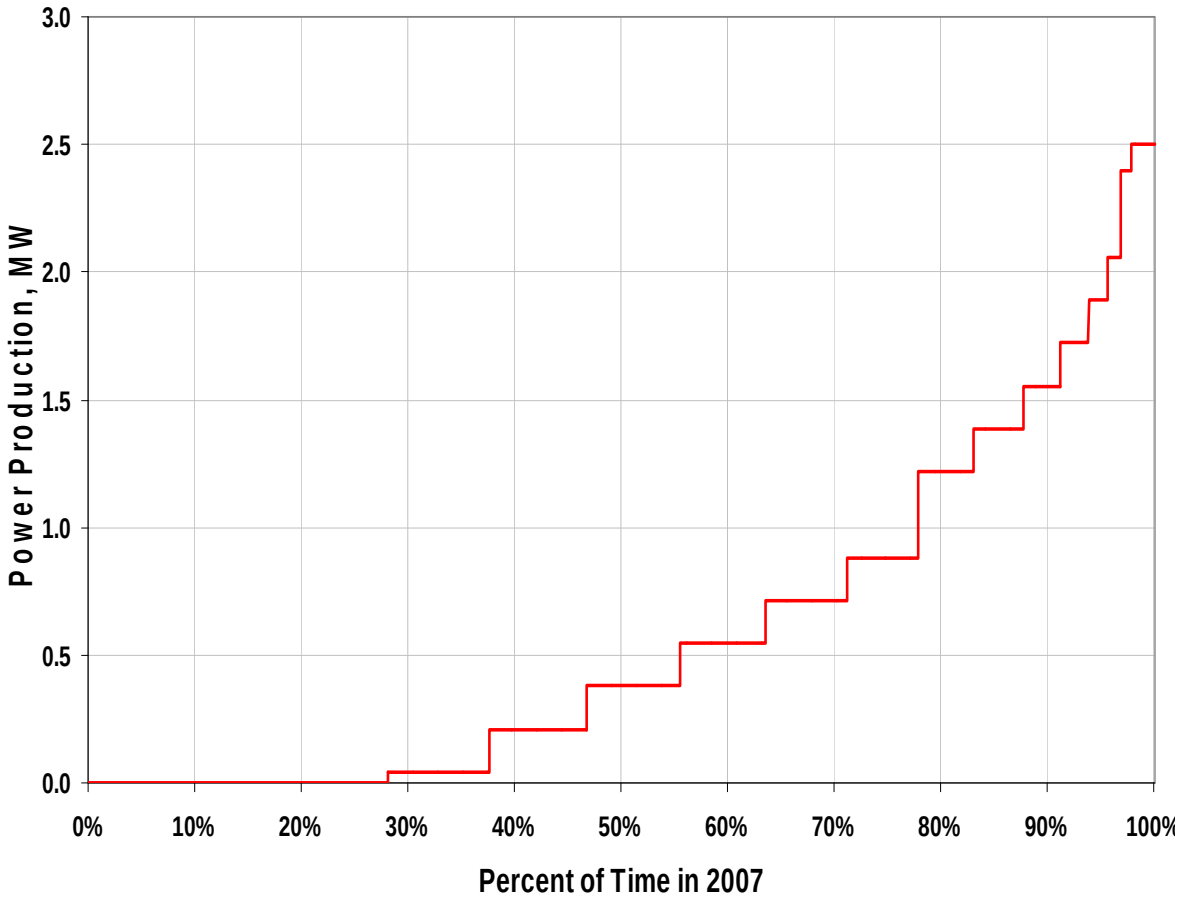
In 2007, the wind turbine would produce:

NO POWER ~ 28% of the time

Less than 0.38 MW ~ 48% of the time

Less than 0.88 MW ~ 72% of the time

Less than 1.57 MW ~ 90% of the time



Cost of Wind Turbine Construction [1]

- **In 2008, the total installed cost of a commercial wind turbine is estimated at $2,075/kw capacity.**
- **At a 23% capacity factor the installed cost per kw of generation is $9,022.**
- **Therefore the estimated installed cost for a 2.5 MW GE wind turbine is 2.5MW x (1000kw/MW) x ($2,075/kw) = $5,187,500**

Wind Energy Production Tax Credits

- **The Federal production tax credit (PTC) provides a 1.5 cent/kwh tax credit for electricity generated with wind turbines over the first 10 years of operation.**
- **The Federal production tax credit is due to expire December 31, 2008, but is expected to be extended when new energy legislation is passed.**
- **To be eligible for the production tax credit, the producer must have a federal tax liability. Therefore municipalities or non-profit organizations are not qualified to receive the production tax credits.**

[1] Renewable Energy Systems Americas, February 27, 2008, presentation to the Wisconsin Public Policy Initiative

U.S. Department of Energy
Energy Efficiency and Renewable Energy
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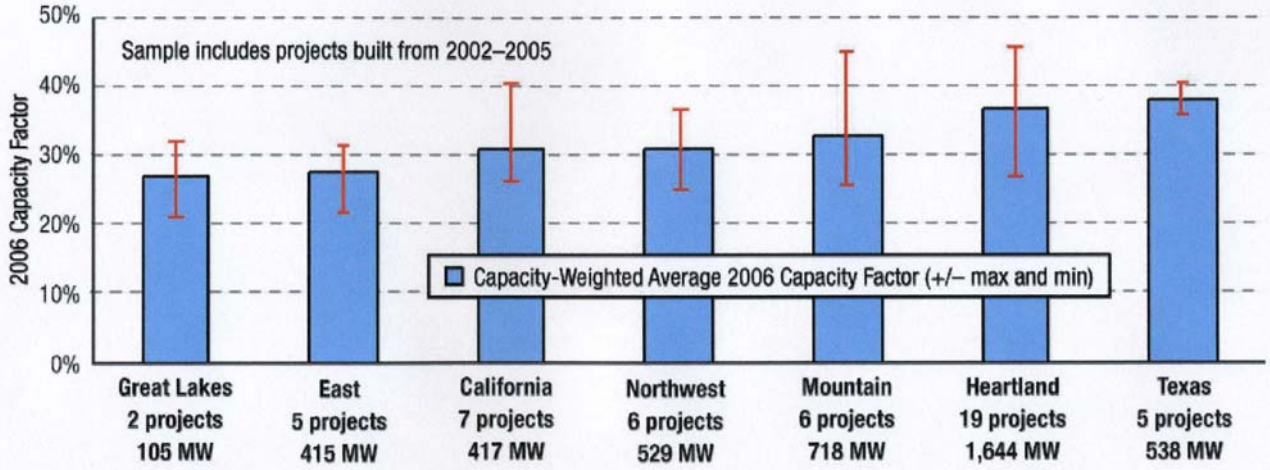
Regional Performance Differences Are Apparent



Source: Berkeley Lab database.

Capacity factors average more than 35% in Texas and the Heartland, and less than 30% in the East and Great Lakes

Note: Figure only includes projects that came online from 2002-05; note that sample size is problematic for several regions, including the Great Lakes

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Annual Report on U.S. Wind Power Installation, Cost and Performance Trends: 2006- May 30, 2007 Report Summary

Wind Generation Costs are Primarily Determined by:

- Installed capital costs where lower cost is better
- Capacity Factor where higher average wind speed yields the more desirable higher capacity factor.
- Operating and Maintenance costs; Smaller scale projects (i.e., less than 5MW) experience higher O&M costs.

Cost of Wind Generation in 2008[1]

Turbine Cost	$ 1,675 / kw
Balance of construction cost	$ 400 / kw
Total installed cost	$ 2,075 / kw
Total cost of generation [2] (including Production Tax Credit)	$55 / MWhr to $90 / MWhr

1 Renewable Energy Systems Americas, February 27, 2008 presentation to the Wisconsin Public Policy Initiative
2 Range primarily determined by the Capacity Factor

Preliminary Assessment Findings for Wind Based Power Generation in Escanaba

1. **Published wind maps and 2007 Delta County Airport wind data indicates Escanaba is a poor wind resource potential area.**

2. Using 2007 Delta County airport wind data, a commercial scale 2.5MW GE wind turbine was estimated to have:

- **Produced NO POWER 28% of the time**
- **Average 0.58 MW of power generation**
- **Utilized only 23% of the wind turbine generation capacity**

3. With present wind turbine technology, a commercial wind turbine in Escanaba could not be used to replace an existing electric generation source. (i.e., the two 12.5MW coal fired units or the 15MW CT unit).

4. Municipalities like Escanaba are not eligible for the wind generation production tax credits.

Recommendations

1. **Follow the planned Gladstone/WPPI/Private Developer wind resource assessment. The planned higher elevation wind speed monitoring is critical to make a sound investment decision and predict generation costs.**

2. **Monitor wind turbine technology developments for wind turbines with lower Cut-in wind speeds.**

3. **Establish a net metering policy for city residents and businesses. Net metering is an accounting mechanism where electric customers, who generate a portion of their electric needs from solar or wind sources, are billed only for their net energy usage. The energy supplied by the utility less the energy generated by the customer and delivered to the utility is the amount of billed electricity.**

4. **Establish Zoning Codes for residential and business owners of solar and wind generation capacity.**