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Wind Resource Assessment for PORT HEIDEN, ALASKA Site # 2548

Date last modified: 11/04/2005
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Latitude: (NAD27)	56˚ 55' 52" N 56˚ 55.867'
Longitude: (NAD27)	158˚ 37' 11.6" W 158˚ 37.193'

Elevation:	68 ft
Tower Type:	100-foot guyed lattice tower
Monitor Start: Monitor End:	8/06/2004 In operation

INTRODUCTION

On September 23, 2003, one anemometer and one wind vane were mounted on a 10-kW Bergey wind turbine tower at a height of 85 feet. The 100-foot tower is a 3-legged guyed lattice tower located next to the city building. A temperature sensor was mounted at a height of 14 feet. This system recorded data intermittently until the logger failed. On August 6, 2004, a new NRG Symphonie data logger was installed. On October 7, 2004, an additional anemometer and wind vane were installed at a height of 85 feet and at a 90 degree offset from the first set of equipment to reduce the effects of the tower on readings from certain directions. For consistency in the data sample, this report focuses on data collected by the Symphonie logger, beginning August 6, 2004.

The purpose of this monitoring effort, jointly funded by the Bristol Bay Native Corporation, the Sustainable Energy Council of the Alaska Peninsula (SECAP), and AEA, is to evaluate the feasibility of utilizing utility-scale wind energy in the community. This report summarizes the wind resource data collected and the long-term energy production potential of the site.

SITE DESCRIPTION

Port Heiden is located about 400 miles southwest of Anchorage on the north side of the Alaska Peninsula. It lies at the mouth of the Meshik River near the Aniakchak National Preserve and Monument. The climate is maritime with cool summers and relatively warm winters. Figure 1 shows the location of the wind monitoring tower relative to the surrounding terrain.

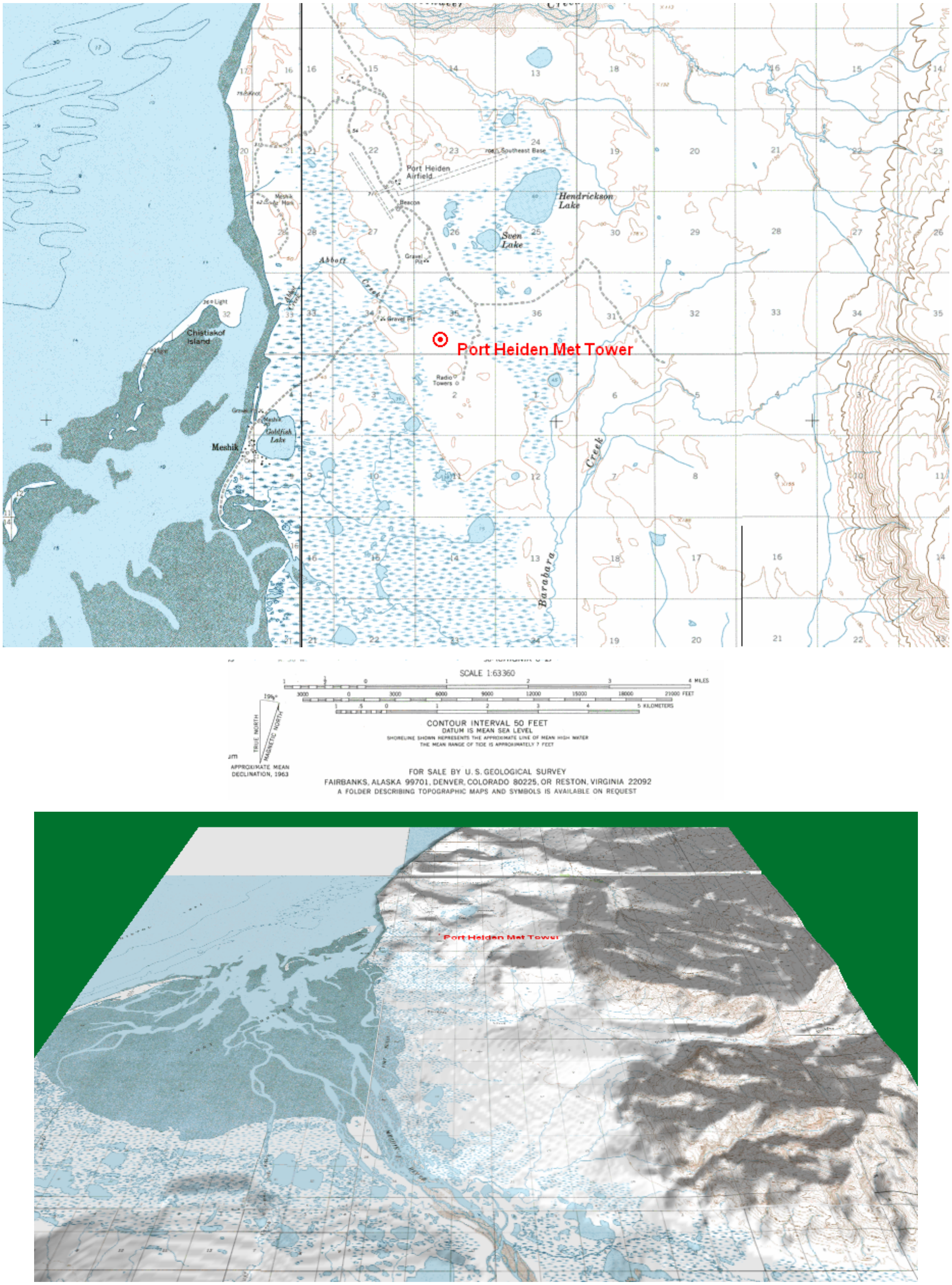
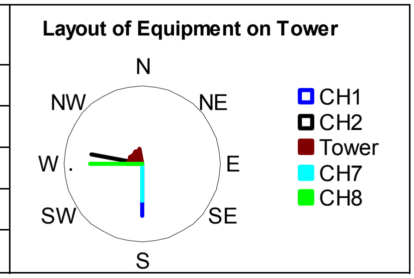


Figure 1. Topographic Map of Wind Tower Site and Surrounding Area

Table 1 lists the types of sensors that were mounted on the tower, the channel of the data logger that each sensor was wired into, and where each sensor was mounted on the tower.

Table 1. Summary of Sensors Installed on the Met Tower

Ch #	Sensor Type	Height	Offset	Boom Orientation
1	#40 Anemometer	85 ft	NRG Standard	180˚ True
2	#40 Anemometer	85 ft	NRG Standard	280˚ True
7	#200P Wind Vane	85 ft	180˚ True	180˚ True
8	#200P Wind Vane	80 ft	90˚ True	270˚ True
9	#110S Temperature	4 m	NRG Standard	-



In order to install the sensors, the wind tower was tilted down, as shown in the photos below.

Figure 2. Installation of Sensors on Wind Tower in Port Heiden

DATA PROCESSING PROCEDURES AND DEFINITIONS

The following information summarizes the data processing procedures that were performed on the raw measured data in order to create an annual dataset of "typical" wind speeds, which could then be used to calculate potential power production from wind turbines. There are various methods and reasons for adjusting the raw data, so the purpose of these notes is to document what was done in this situation. The raw data set is available on the Alaska Energy Authority website (www.akenergyauthority.org) so one could perform their own data processing procedures.

Units – Since most wind turbine manufacturer data is provided in metric units, those units are used here.

1 meter/second = 2.24 mph = 1.95 knots
1 meter = 3.28 feet
1 ˚C = 5/9 (˚F – 32)

Max/Min Test – All of the 10-minute data values were evaluated to ensure that none of them fell outside of the normal range for which the equipment is rated.

Tower Shadow – The tower itself can affect readings from the anemometer at times when the anemometer is located downwind of the tower. To minimize this effect, one data set is compiled from the 2 anemometers depending on the direction of the wind at any given time.

Icing – Anomalies in the data can suggest when the sensors were not recording accurately due to icing events. Since wind vanes tend to freeze before the anemometers, icing events are typically identified whenever the 10-minute standard deviation of the wind vane is zero (the wind vane is not moving) and the temperature is at or below freezing. Some additional time before and after the icing event are filtered out to account for the slow build up and shedding of ice.

Filling Gaps – Whenever measured met tower data is available, it is used. Two different methods are used to fill in the remaining portion of the year. First, nearby airport data is used if available. A linear correlation equation is defined between the airport and met tower site, which is used to adjust the hourly airport data recorded at the time of the gap. If neither met tower nor airport data is available for a given timestep, the software program Windographer (www.mistaya.ca) is used. Windographer uses statistical methods based on patterns in the data surrounding the gap, and is good for filling short gaps in data.

Long-term Estimates – The year of data collected at the met tower site can be adjusted to account for inter-annual fluctuations in the wind resource. To do this, a nearby weather station with a consistent historical record of wind data and with a strong correlation to the met tower location is needed.

Turbulence Intensity – Turbulence intensity is the most basic measure of the turbulence of the wind. Turbulence intensity is calculated at each 10-minute timestep by dividing the standard deviation of the wind speed during that timestep by the average wind speed over that timestep. It is calculated only when the mean wind speed is at least 4 m/s. Typically, a turbulence intensity of 0.10 or less is desired for minimal wear on wind turbine components.

Wind Shear – Typically, wind speeds increase with height above ground level. This vertical variation in wind speed is called wind shear and is influenced by surface roughness, surrounding terrain, and atmospheric stability. If the met tower is equipped with anemometers at different heights the wind shear exponent, α, can be calculated according to the power law formula:

$\left(\frac{H_1}{H_2}\right)^{\alpha} = \left(\frac{v_1}{v_2}\right)$ where H_1 and H_2 are the measurement heights and v_1 and v_2 are the measured wind speeds.

Wind shear is calculated only with wind speed data above 4 m/s. Values can range from 0.05 to 0.25. Since wind speeds were not measured at different heights at this location, a typical value of 0.14 is assumed.

Scaling to Hub Height – If the wind turbine hub height is different from the height at which the wind resource is measured, the wind resource can be adjusted using the power law formula described above and using the wind shear data calculated at the site.

Air Density Adjustment – The power that can be extracted from the wind is directly related to the density of the air. Air density, ρ, is a function of temperature and pressure and is calculated for each 10-minute timestep according to the following equation (units for air density are kg/m^3):

$\rho = \frac{P}{R \times T}$, where P is pressure (kPa), R is the gas constant for air (287.1 J/kgK), and T is temperature in Kelvin.

Since air pressure is not measured at the met tower site, the site elevation is used to calculate an annual average air pressure value according to the following equation:

P = 1.225 – (1.194 x 10^{-4}) x elevation

Since wind turbine power curves are based on a standard air density of 1.225 kg/m3, the wind speeds measured at the met tower site are adjusted to create standard wind speed values that can be compared to the standard power curves. The adjustment is made according to the following formula:

$$V_{s\tan dard} = V_{measured} \times \left(\frac{\rho_{measured}}{\rho_{s\tan dard}} \right)^{\frac{1}{3}}$$

Wind Power Density – Wind power density provides a more accurate representation of a site's wind energy potential than the annual average wind speed because it includes how wind speeds are distributed around the average as well as the local air density. The units of wind power density are watts per square meter and represent the power produced per square meter of area that the blades sweep as they rotate around the rotor.

Wind Power Class – A seven level classification system based on wind power density is used to simplify the comparison of potential wind sites. Areas of Class 4 and higher are considered suitable for utility-scale wind power development.

Weibull Distribution – The Weibull distribution is commonly used to approximate the wind speed frequency distribution in many areas when measured data is not available. In this case, the Weibull distribution is used to compare with our measured data. The Weibull is defined as follows:

$$P(v) = \frac{k}{c} \left(\frac{v}{c} \right)^{k-1} \exp \left(\frac{-v}{c} \right)^{k}$$

Where P(v) is the probability of wind speed v occurring, c is the scale factor which is related to the average wind speed, and k is the shape factor which describes the distribution of the wind speeds. Typical k values range from 1.5 to 3.0, with lower k values resulting in higher average wind power densities.

LONG-TERM REFERENCE STATION

Wind data from the Port Heiden Airport weather station, located about 2 miles north of the met tower site, serves as a long-term reference for the wind resource in the area. This data is measured at a height of 7 meters above ground level and at an elevation of 29 meters. Since the airport is close to the met tower site and the surrounding terrain is relatively flat, the patterns in wind resource data between the sites are expected to be similar.

Nearly 30 years of wind speeds are shown in Table 2 and Figure 3. The average wind speed over the 30-year period is 5.7 m/s at a height of 7 meters above ground level. The annual wind speed rarely deviates more than 8% above or below this average.

Table 2. Average Wind Speeds at 7-m Height at Port Heiden Airport (m/s)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG	% of 30-yr Average
1976	5.4	5.86	5.83	4.7	5.44	4.45	4.34	3.94	4.66	5.5	5.22	5.55	5.1	89%
1977	7.11	6.49	6.61	5.74	4.44	4.78	5.43	5.2	5.55	6.33	6.36	6.14	5.8	102%
1978	5.46	6.52	5.62	5.58	4.65	5.06	5.17	5.57	5.99	5.9	7.8	8.9	5.7	99%
1979	7.55	5.79	5.92	6.13	5.93	4.91	3.95	5.43	5.66	6.06	7.14	7.33	6.0	105%
1980	6.66	5.41	6.92	5.28	6.05	6.64	5.18	4.76	5.47	4.81	4.64	6.61	5.7	100%
1981	5.36	6.93	5.42	4.14	5.39	4.19	5.08	6.52	5.21	6.52	6.61	6.68	5.6	98%
1982	6.09	6.26	6.5	6.07	5.39	5.8	6.8	5.07	5.89	5.88	5.23	5.41	5.9	102%
1983	5.38	4.85	4.9	5.1	5.54	4.2	4.51	4.56	5.83	6.09	5.52	6.92	5.3	92%
1984	5.98	6.29	4.38	5.44	4.55	4.41	4.26	4.41	5.34	5.28	6.54	6.22	5.3	93%
1985	7.43	6.35	6.63	5.53	6.17	4.67	4.46	5.88	5.65	7.66	7.45	6.84	6.2	108%
1986	5.41	6.43	4.78	5.56	6.03	6.41	4.44	5.42	5.95	4.57	6.19	6.33	5.6	98%
1987	6.46	6.23	5.88	5.91	5.36	5.51	4.58	5.33	5.58	6.13	5.26	6.11	5.7	100%
1988	5.89	7	5.78	5.6	4.85	4.82	4.62	5.12	5.78	5.59	5.61	7.24	5.7	99%
1989	7.86	9.07	5.35	5.97	5.9	4.95	4.62	5.33	6.33	7.95	5.77	6.38	6.2	108%
1990	7.39	7.04	4.7	4.62	6.53	5.41	5.24	5.55	6.36	5.48	6.36	6.96	6.1	106%
1991	4.88	7.42	6.43	4.99	7.06	6.44	4.85	5.25	6.27	5.43	4.83	6.68	5.8	101%
1992	5.21	4.88	5.99	4.56	3.73	5.78	4.67	6.12	4.99	5.59	5.3	7.02	5.3	93%
1993	6.6	7.77	6.06	5.25	5.84	4.79	4.92	6.06	6.03	4.51	6.19	6.15	5.8	102%
1994	5.3	5.51	6.88	4.96	4.73	4.88	4.37	4.82	5.79	5.76	8.15	7.04	5.6	98%
1995	5.3	6.7	5.57	4.83	5.79	4.38	5.97	5.03	5.62	6.39	4.47	6.08	5.6	97%
1996	5.03	8.57	6.14	6.08	5.1	6.6	4.37	4.68	6.82	4.99	7.04	6.25	5.9	104%
1997	6.16	4.66	4.92	4.48	5.01	4.65	3.73	5.32	6.05	4.71	5.49	5.88	5.0	87%
1998	4.96	3.72	7.65	7.11	6.49	5.38	4.58	6.57	6.14	6.09	5.64	7.8	6.0	105%
1999	6.3	6.89	5.71	6.49	5.23	4.94	4.87	5.17	5.3	4.96	5.77	6.62	5.7	99%
2000	6.34	9.01	7.01	5.24	5.14	6.06	4.93	5.6	5.82	5.66	6.69	8.58	6.2	108%
2001	6.13	7.12	6.05	6.14	5.99	5.05	5.64	5.1	5.6	6.44	6.35	6.34	6.0	105%
2002	6.9	7.0	6.5	6.3	5.8	4.4	5.3	4.6	6.6	6.6	5.6	6.4	6.0	105%
2003	6.3	5.6	6.0	5.7	5.6	5.5	4.6	4.9	4.7	5.7	7.2	6.5	5.7	99%
2004	5.5	5.7	6.1	5.9	5.2	5.2	4.5	5.1	5.8	6.7	6.7	7.0	5.8	101%
AVG	6.12	6.42	5.94	5.42	5.45	5.16	4.81	5.24	5.69	5.81	6.01	6.62	5.7	100%

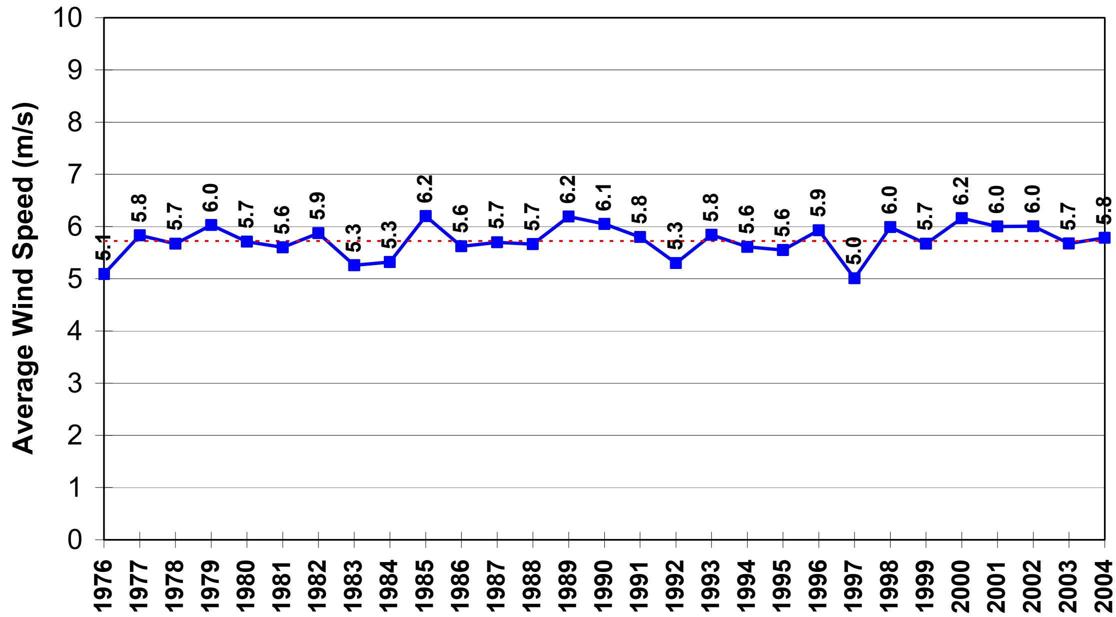


Figure 3. Annual Average Wind Speeds at 7-m Height at Port Heiden Airport Weather Station

Hourly wind speed measurements from the Port Heiden Airport weather station that are concurrent with recordings from the wind monitoring tower site were purchased from the National Climatic Data Center. Data between these sites was compared and a correlation coefficient of 0.90 was calculated (a value of 1 is perfect). This suggests that, although the actual wind speed values at the two sites are different, the pattern of wind speed fluctuations is similar between the sites. Based on this correlation a long-term estimate of the wind speed at the wind tower site was developed.

WIND DATA RESULTS FOR WIND TOWER SITE
Table 3 summarizes the amount of data that was successfully retrieved from the anemometers at the wind tower site.

Table 3. Data Recovery Rates for Met Tower Data

Month	Data Recovery
January	48%
February	91%
March	100%
April	100%
May	100%
June	100%
July	89%
August	47%
September	95%
October	99%
November	98%
December	100%
Annual Avg	**89%**

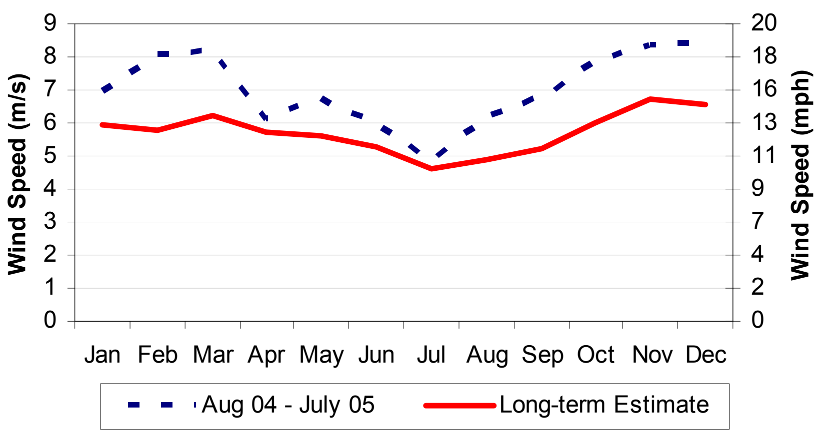
Table 4 and Table 5 summarize the wind resource data measured at the wind tower site as well as the estimated long-term data for this site.

Table 4. Measured Wind Speeds at 26-m Height at Wind Tower Location, Aug 2004 - July 2005 (m/s)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	7.1	7.9	8.7	6.1	6.4	5.1	4.6	6.3	7.1	7.4	8.5	8.1	7.0
1	7.8	8.1	8.4	6.0	5.9	5.3	4.8	6.4	6.8	7.7	8.4	8.4	7.0
2	7.9	8.2	7.9	6.0	6.3	5.1	4.8	6.2	6.8	8.4	9.1	8.3	7.1
3	7.8	7.9	8.1	5.7	5.9	5.4	4.6	5.7	6.8	8.3	9.3	8.1	7.0
4	7.9	8.5	8.4	5.3	5.9	5.1	4.2	5.9	6.6	8.0	9.3	8.0	6.9
5	7.7	8.8	8.4	5.3	6.3	5.3	4.3	6.1	6.9	8.2	9.3	8.2	7.1
6	6.9	8.9	8.2	5.3	6.4	5.2	4.5	5.3	7.1	8.2	9.6	8.3	7.0
7	7.0	8.7	8.0	5.2	6.3	5.0	4.1	5.2	6.9	8.2	9.5	8.8	6.9
8	6.9	8.4	8.3	5.2	6.3	5.4	4.3	5.9	6.7	8.2	9.1	9.0	7.0
9	7.4	8.1	8.4	5.7	6.8	6.1	4.6	6.6	6.7	8.2	9.0	9.2	7.2
10	8.6	8.4	8.7	6.3	7.3	6.7	4.8	6.2	7.2	8.6	8.1	9.5	7.5
11	8.6	8.5	9.3	6.5	7.8	7.1	5.2	6.4	7.2	9.1	8.2	9.7	7.8
12	8.3	8.6	9.3	6.6	8.0	7.6	5.8	6.6	7.1	9.3	8.5	9.2	7.9
13	7.5	8.4	9.2	7.1	8.3	7.9	6.1	6.5	7.4	9.6	8.2	9.0	7.9
14	6.9	8.5	9.2	7.7	8.5	8.3	6.0	7.2	7.4	9.6	8.5	9.3	8.1
15	6.8	8.1	9.5	7.8	8.6	8.1	6.4	7.4	7.4	8.8	8.1	9.1	8.0
16	6.9	8.5	9.0	7.9	8.5	7.7	6.3	7.2	7.5	8.3	8.0	8.6	7.9
17	6.8	8.6	8.8	7.8	8.3	7.2	6.0	7.1	7.6	7.9	7.9	8.3	7.7
18	6.5	8.8	8.3	7.5	7.7	6.8	6.1	7.1	7.3	7.1	8.2	9.0	7.5
19	6.5	9.1	7.9	7.0	7.6	6.6	5.8	7.2	7.1	7.2	8.3	9.1	7.5
20	5.5	8.8	7.8	6.7	7.1	6.3	5.2	6.9	7.0	7.4	8.3	8.8	7.1
21	6.4	8.3	7.7	6.4	6.5	5.6	5.0	6.2	7.3	7.7	8.7	8.9	7.1
22	6.9	8.4	8.2	6.2	6.2	5.2	4.6	6.0	7.0	7.9	9.1	8.6	7.0
23	6.8	8.2	8.5	6.3	6.2	5.4	4.6	6.2	7.1	7.6	9.1	8.4	7.0
Avg	7.2	8.4	8.5	6.4	7.0	6.2	5.1	6.4	7.1	8.2	8.7	8.7	7.3

Table 5. Estimated Long-term Wind Speeds at 26-m Height at Wind Tower Location (m/s)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	7.7	6.7	7.1	6.0	5.6	5.7	5.0	5.6	5.4	6.7	8.1	7.6	6.4
1	7.5	6.8	7.0	6.2	5.6	5.4	5.0	5.5	5.6	6.5	8.0	7.5	6.4
2	7.2	6.2	6.9	5.7	5.6	5.2	4.8	5.2	5.5	6.6	8.4	7.5	6.2
3	7.1	7.1	7.2	5.8	5.8	5.0	4.8	5.1	5.0	6.6	8.5	7.9	6.3
4	6.8	6.9	6.8	5.6	5.7	5.0	4.6	4.9	5.5	6.6	8.5	7.6	6.2
5	6.8	6.8	7.0	5.7	5.4	5.1	4.5	4.9	5.5	6.8	8.3	7.6	6.2
6	6.8	6.6	7.0	5.4	5.7	5.0	4.5	4.9	5.7	7.0	8.4	7.6	6.2
7	7.1	6.4	7.0	5.2	5.6	5.5	4.7	4.7	5.7	6.9	8.3	7.7	6.2
8	6.5	6.1	6.9	6.0	6.0	6.1	5.2	5.4	5.6	7.4	7.9	8.2	6.4
9	6.8	7.0	7.2	6.2	6.8	6.3	5.3	5.9	5.9	7.8	8.1	8.4	6.8
10	6.4	6.4	7.5	7.0	7.3	6.9	5.7	6.2	6.9	8.1	8.0	8.9	7.1
11	7.1	7.1	8.0	7.5	7.6	7.4	5.9	6.4	7.4	8.4	8.4	8.6	7.5
12	7.7	7.6	8.8	8.3	8.3	7.5	6.2	6.6	7.8	8.6	8.7	8.6	7.9
13	8.3	8.2	8.6	9.0	8.7	7.9	6.7	6.7	7.9	8.8	8.9	8.7	8.2
14	7.9	8.7	9.1	9.3	8.9	8.2	6.9	6.9	7.8	9.0	8.7	8.6	8.3
15	8.5	8.7	9.4	9.1	9.1	8.3	7.0	7.1	8.2	8.9	8.9	8.8	8.5
16	7.9	7.7	9.1	9.0	8.7	8.1	7.0	7.6	8.0	8.3	8.7	8.2	8.2
17	7.5	7.6	8.6	9.1	8.6	7.9	6.7	7.3	7.8	8.0	8.6	7.9	8.0
18	7.5	6.9	8.2	8.9	8.3	7.8	6.6	7.2	7.5	7.2	8.3	8.3	7.7
19	7.5	6.9	7.8	8.1	8.1	7.2	6.3	6.9	6.6	7.1	8.0	8.4	7.4
20	7.3	6.8	7.0	7.1	6.9	6.4	5.9	6.3	6.0	6.4	8.1	8.1	6.9
21	7.3	7.1	7.3	6.6	6.5	5.8	5.5	5.9	5.7	6.7	8.1	8.1	6.7
22	7.5	6.7	7.0	6.5	5.9	5.5	4.9	5.6	5.6	6.7	8.4	8.4	6.5
23	7.5	6.7	6.9	6.3	5.5	5.6	5.0	5.6	5.5	6.9	7.8	7.9	6.4
Avg	7.3	7.1	7.6	7.1	6.9	6.4	5.6	6.0	6.4	7.4	8.3	8.1	7.0



Month	Aug 04 - July 05		Long-term Estimate	
	m/s	mph	m/s	mph
Jan	6.9	15.5	6.0	13.3
Feb	8.1	18.1	5.8	12.9
Mar	8.2	18.2	6.2	13.9
Apr	6.1	13.7	5.7	12.9
May	6.7	15.1	5.6	12.6
Jun	6.0	13.4	5.3	11.8
Jul	4.9	10.9	4.6	10.3
Aug	6.1	13.8	4.9	11.0
Sep	6.8	15.2	5.2	11.7
Oct	7.9	17.6	6.0	13.5
Nov	8.3	18.6	6.7	15.1
Dec	8.4	18.7	6.6	14.7
Avg	**7.0**	**15.7**	**5.7**	**12.8**

Figure 4. Monthly Average Wind Speeds at Wind Tower Site (26m Height)

As shown, the highest wind month is typically November and the lowest wind month is typically July. As shown below, the diurnal variation is more pronounced during the summer months than the winter months, with winds typically lowest in the morning and increasing in the afternoon.

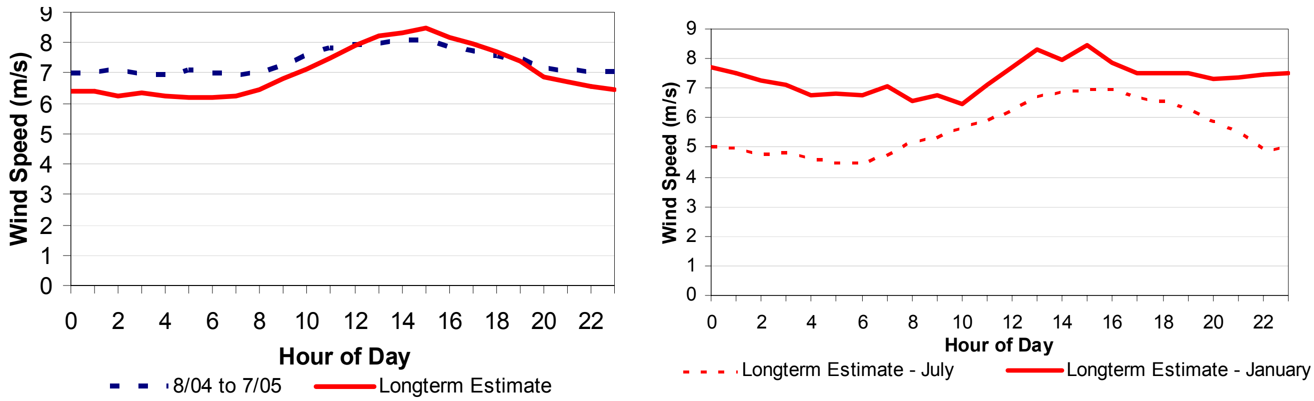
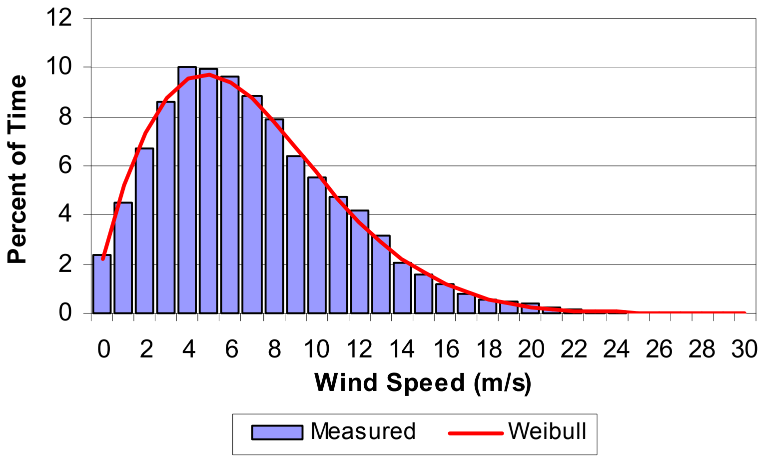


Figure 5. Hourly Average Wind Speeds at Wind Tower Site (26m Height)

A common method of displaying a year of wind data is a wind frequency distribution, which shows the percent of the year that each wind speed occurs. Figure 6 shows the measured wind frequency distribution as well as the best matched Weibull distribution (c = 8.3, k= 1.8).



Bin m/s	Measured Hours	Bin m/s	Measured Hours
0	209	15	136
1	392	16	102
2	589	17	69
3	752	18	47
4	881	19	39
5	872	20	32
6	846	21	22
7	777	22	12
8	690	23	6
9	559	24	5
10	483	25	3
11	414	26	1
12	370	27	1
13	276	28	0
14	177	29	0
		Total:	8,760

Figure 6. Wind Speed Frequency Distribution of Wind Tower Data

The cut-in wind speed of many wind turbines is 4 m/s and the cut-out wind speed is around 25 m/s. The frequency distribution shows that a large percentage of the wind in Port Heiden falls within this operational zone.

Table 6 shows the annual wind rose at the wind tower site versus the wind rose at the Port Heiden airport. The predominant wind energy direction at both the wind tower and the airport is SE, with summer winds coming from the SW.

Table 6. Annual Wind Rose for Wind Tower Site and Airport Site

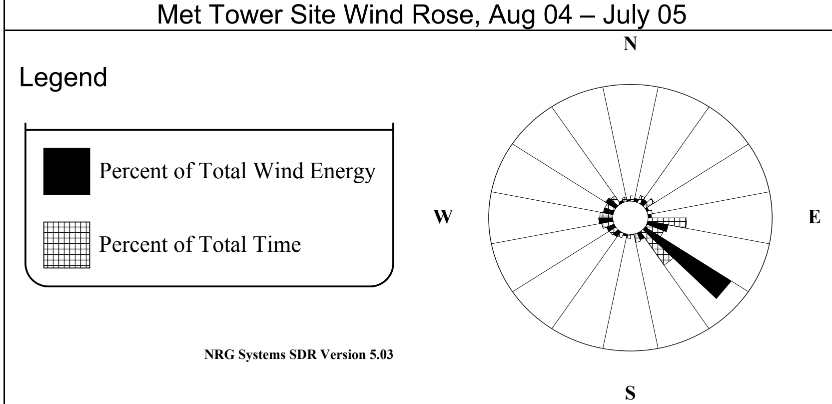
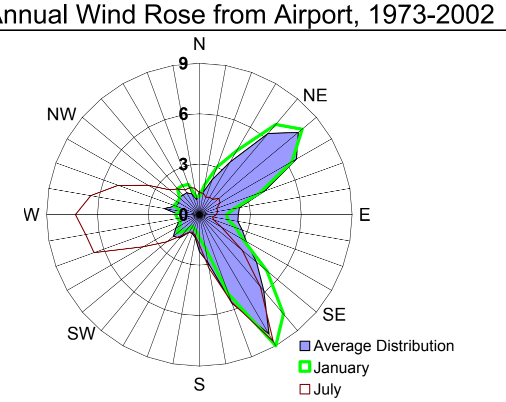
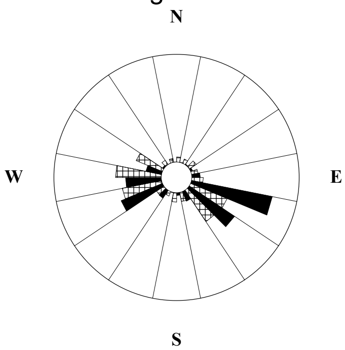
Met Tower Site Wind Rose, Aug 04 – July 05	Annual Wind Rose from Airport, 1973-2002
	

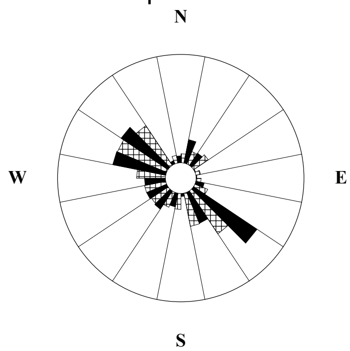
Table 7 breaks the annual wind rose at the wind tower site into monthly wind roses.

Table 7. Monthly Wind Roses for Wind Tower Site

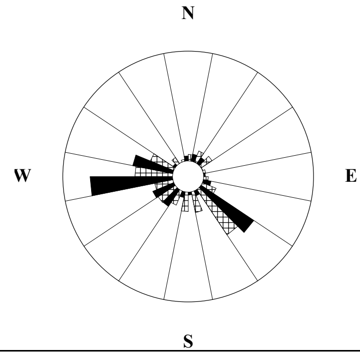
Aug 2004



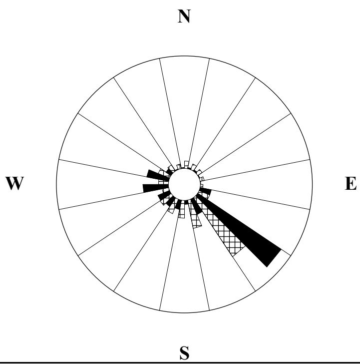
Sept 2004



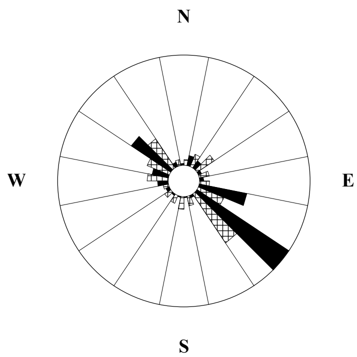
Oct 2004



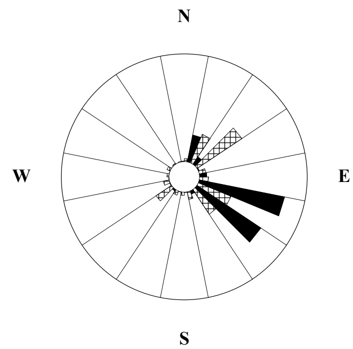
Nov 2004



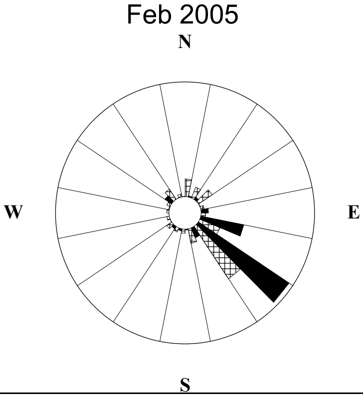
Dec 2004



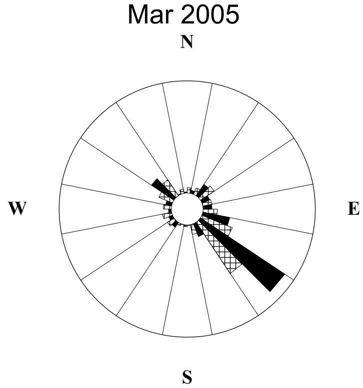
Jan 2005



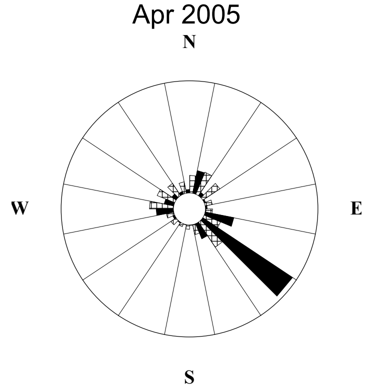
Feb 2005



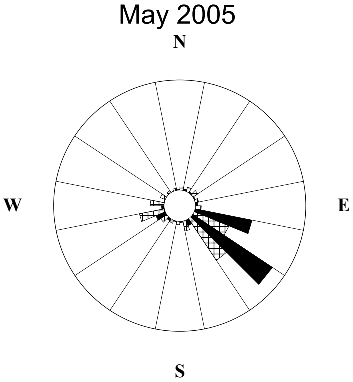
Mar 2005



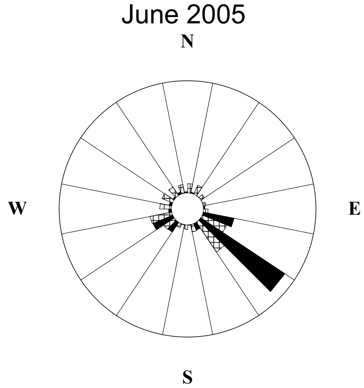
Apr 2005



May 2005



June 2005



July 2005

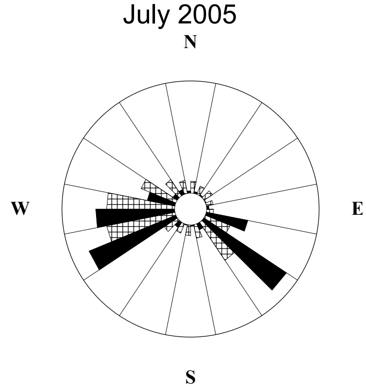
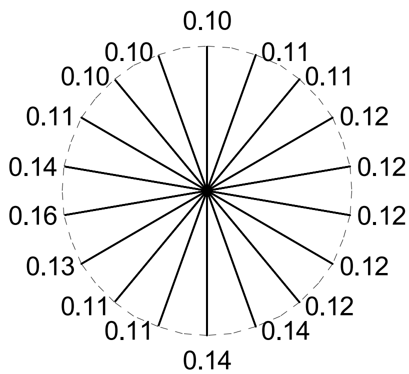


Table 8 summarizes the monthly turbulence intensity at the wind tower site. The turbulence intensity of 0.10 to 0.16 is considered moderate and unlikely to contribute to excessive wear of wind turbines.

Table 8. Monthly Turbulence Intensity at Wind Tower Site

Month	Turbulence Intensity
Jan	0.11
Feb	0.10
Mar	0.12
Apr	0.12
May	0.12
Jun	0.12
Jul	0.12
Aug	0.12
Sep	0.11
Oct	0.11
Nov	0.10
Dec	0.11
Annual Avg	**0.11**

Figure 7. Turbulence Intensity by Direction, Aug 2004 - July 2005



The air temperature can affect wind power production in two primary ways: 1) colder temperatures lead to higher air densities and therefore more power production, and 2) some wind turbines shut down in very cold situations (usually below -25˚C). Since the temperature sensor at the wind tower was not functioning properly, the following information comes from data recorded at the Port Heiden airport weather station. Between January 2001 and August 2005, the temperature dropped below -25˚C for about 1 hour and was below -20˚C for about 13 hours.

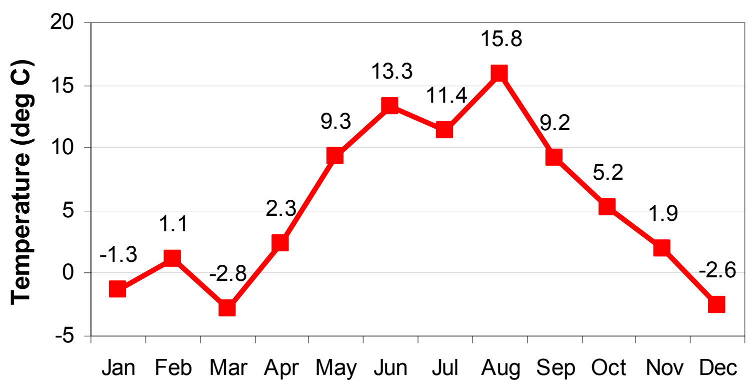


Figure 8. Monthly Average Temperatures in Port Heiden

POTENTIAL POWER PRODUCTION FROM WIND TURBINES

Table 9 lists a number of parameters used to characterize the power production potential of a particular site.

Table 9. Summary of Power Production Potential of Met Tower Site

Average Wind Power Density (30m)	490 W/m^2
Wind Power Class	5-6
Rating	Excellent

Various wind turbines, listed in Table 12, were used to calculate the energy production at the met tower site based on the long-term wind resource data set. Although different wind turbines are offered with different tower heights, to be consistent it is assumed that any wind turbine rated at 100 kW or less would be mounted on a 30-meter tall tower, while anything larger would be mounted on a 50-meter tower. The wind resource was adjusted to these heights based on the standard wind shear of 0.14. The wind resource was also adjusted for local air density. Table 10 summarizes the estimated energy production from various wind turbines at the met tower site.

Table 10. Gross Annual Energy Production from Different Wind Turbines at Met Tower Site (kWh)

Month	Proven 2.5kW	Proven 6kW	Bergey 10 kW	FL30	Entegrity	FL100	NW100	FL250	V27	V47
Jan	847	2,147	2,339	10,645	17,819	34,809	28,515	79,642	72,500	240,127
Feb	693	1,763	1,910	8,762	14,596	28,484	23,343	65,447	59,454	197,511
Mar	836	2,152	2,417	10,828	17,544	34,512	28,354	79,193	72,654	246,969
Apr	644	1,657	1,745	8,225	13,038	25,590	20,840	59,714	54,583	187,440
May	682	1,774	1,935	8,919	13,804	27,378	22,366	64,177	58,658	203,360
Jun	572	1,487	1,597	7,320	11,263	22,506	18,416	53,020	48,383	165,982
Jul	456	1,222	1,272	6,202	8,752	17,492	14,174	42,975	39,125	142,568
Aug	556	1,461	1,542	7,264	11,063	21,878	17,898	51,833	47,546	166,276
Sep	566	1,486	1,600	7,442	11,084	22,192	18,072	52,914	48,340	170,126
Oct	733	1,886	1,985	9,423	14,946	29,289	23,825	68,265	62,539	214,067
Nov	881	2,248	2,367	11,277	18,612	35,918	29,362	84,447	76,267	257,599
Dec	912	2,323	2,534	11,605	19,303	37,705	30,887	86,460	78,743	261,782
Annual	8,378	21,607	23,243	107,911	171,825	337,751	276,053	788,086	718,792	2,453,808
Annual kWh/m^2	853	878	573	782	956	950	949	1,108	1,204	1,339

Table 10 also lists the annual energy production per square meter of swept area (kWh/m^2). This allows one to directly compare the efficiency of one wind turbine against another, as shown in Figure 1.

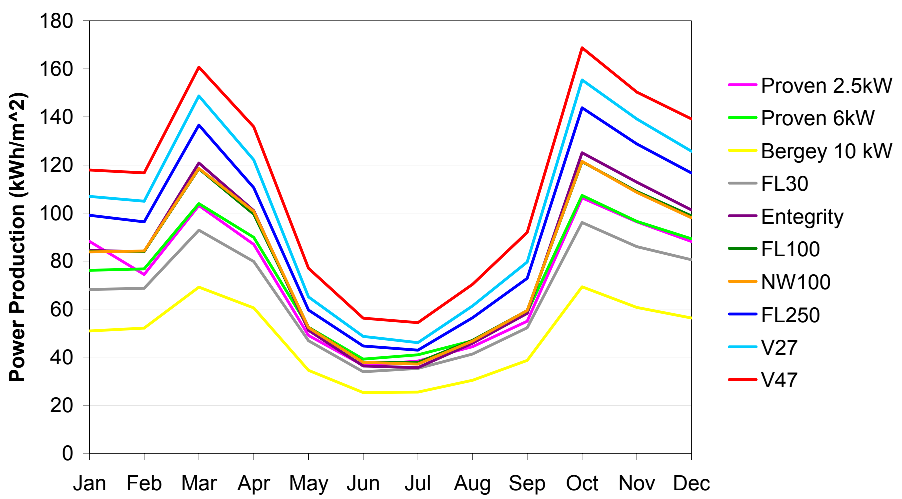


Figure 9. Comparison of Power Production per Square Meter of Swept Area from Various Wind Turbines

Table 11 summarizes the gross capacity factor of the wind turbines per month. Gross capacity factor is the amount of energy produced based on the given wind resource divided by the maximum amount of energy that could be produced if the wind turbine were to operate at rated power during that entire period. The gross capacity factor could be further reduced by up to 10% to account for transformer/line losses, turbine downtime, soiling of the blades, icing of the blades, yaw losses, and extreme weather conditions.

Table 11. Gross Capacity Factor of Different Wind Turbines at Met Tower Site

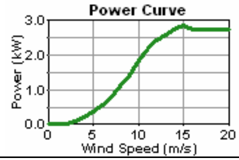
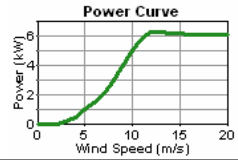
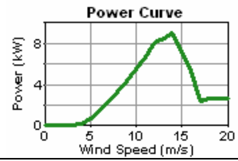
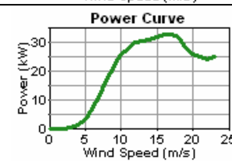
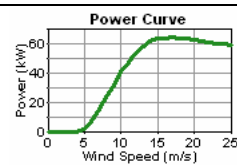
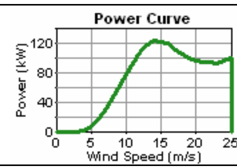
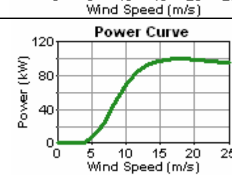
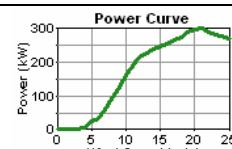
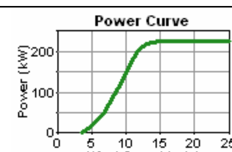
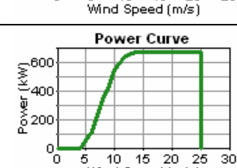
Month	Proven 2.5kW	Proven 6kW	Bergey 10 kW	FL30	Entegrity	FL100	NW100	FL250	V27	V47
Jan	46%	48%	31%	48%	36%	47%	38%	43%	43%	49%
Feb	41%	44%	28%	43%	33%	42%	35%	39%	39%	45%
Mar	45%	48%	32%	49%	36%	46%	38%	43%	43%	50%
Apr	36%	38%	24%	38%	27%	36%	29%	33%	34%	39%
May	37%	40%	26%	40%	28%	37%	30%	35%	35%	41%
Jun	32%	34%	22%	34%	24%	31%	26%	29%	30%	35%
Jul	25%	27%	17%	28%	18%	24%	19%	23%	23%	29%
Aug	30%	33%	21%	33%	23%	29%	24%	28%	28%	34%
Sep	31%	34%	22%	34%	23%	31%	25%	29%	30%	36%
Oct	39%	42%	27%	42%	30%	39%	32%	37%	37%	44%
Nov	49%	52%	33%	52%	39%	50%	41%	47%	47%	54%
Dec	49%	52%	34%	52%	39%	51%	42%	46%	47%	53%
Annual	38%	41%	27%	41%	30%	39%	32%	36%	36%	42%

CONCLUSION

This report provides a summary of wind resource data collected from August 2004 through July 2005 in Port Heiden, Alaska. The data was compared to long-term trends in the area. Based on correlations with the long-term weather station at the Port Heiden airport, estimates were made to create a long-term dataset for the Port Heiden wind tower site. This information was used to make predictions as to the potential energy production from wind turbines at that site.

It is estimated that the long-term annual average wind speed at the wind tower site is 7.0 m/s at a height of 26 meters above ground level. Taking the local air density into account, the average wind power density for the site is 490 w/m^2. This information means that Port Heiden has a Class 5 to 6 wind resource, which is excellent for wind power development.

Table 12. Wind Turbine Models Used in Power Production Analysis

Proven 2.5 kW http://www.provenenergy.com			Tower Height: 30 meters Swept Area: 9.6 m^2 Turbine Weight: 190 kg
Proven 6 kW http://www.provenenergy.com			Tower Height: 30 meters Swept Area: 23.8 m^2 Turbine Weight: 500 kg
Bergey 10 kW www.bergey.com			Tower Height: 30 meters Swept Area: 38.5 m^2 Weight: not available
Fuhrlander FL30 30 kW www.lorax-energy.com			Tower Height: 30 meters Swept Area: 133 m^2 Weight (nacelle & rotor): 410 kg
Entegrity 66 kW www.entegritywind.com			Tower Height: 30 meters Swept Area: 177 m^2 Weight (drivetrain & rotor): 2,420 kg
Fuhrlander FL100 100 kW www.lorax-energy.com			Tower Height: 30 meters Swept Area: 348 m^2 Weight (nacelle & rotor): 2,380 kg
Northern Power NW100/19 100 kW www.northernpower.com			Tower Height: 30 meters Swept Area: 284 m^2 Weight (nacelle & rotor): 7,086 kg
Fuhrlander FL250 250 kW www.lorax-energy.com			Tower Height: 50 meters Swept Area: 684 m^2 Weight (nacelle & rotor): 4,050 kg
Vestas V27 225 kW (refurbished, various suppliers)			Tower Height: 50 meters Swept Area: 573 m^2 Weight: not available
Vestas V47 660 kW www.vestas.com			Tower Height: 50 meters Swept Area: 1,735 m^2 Weight: not available