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Wind Resource Assessment for BETHEL, ALASKA

Date last modified: 2/21/2006

Compiled by: Mia Devine

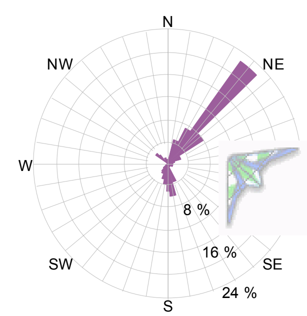
SITE SUMMARY

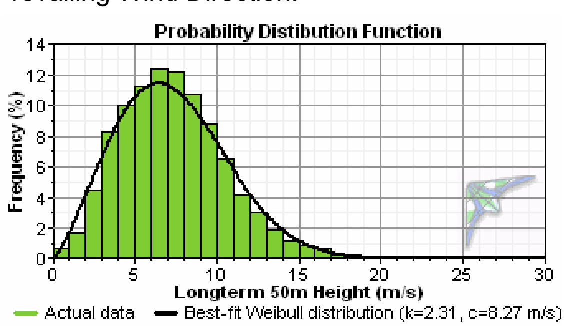
Site #:	5334
Latitude (NAD27):	60˚ 47' 8" N
	N 60.7856
Longitude (NAD27):	161˚ 53' 6" W
	W 161.885
Magnetic Declination:	14˚ 59' East
Tower Type:	50-meter NRG Tall Tower
Sensor Heights:	30m, 40m, 50m
Elevation:	42.3 meters (128 ft)
Monitor Start:	12/9/2004 18:00
Monitor End:	2/12/2006 11:00

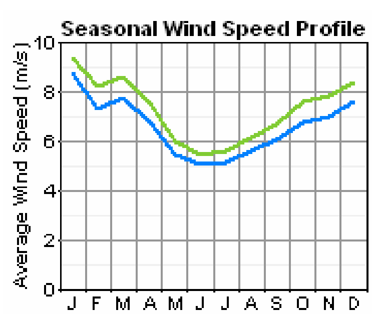
In December 2004, a 50-meter meteorological tower was installed on high ground west of the Bethel airport. The purpose of this monitoring effort is to evaluate the feasibility of utilizing utility-scale wind energy in the community. The measured wind speed and direction data at the site was compared to long-term trends in the area and estimates were calculated for the potential energy production from various types of wind turbines.

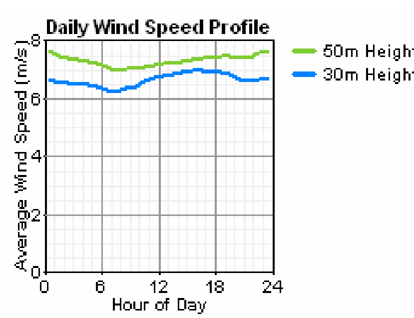
WIND RESOURCE SUMMARY

Annual Average Wind Speed (50m height):	7.3 m/s (16.3 mph)
Annual Average Wind Speed (30m height):	6.7 m/s (15.0 mph)
Average Wind Power Density (50m height):	440 W/m^2
Average Wind Power Density (30m height):	345 W/m^2
Wind Power Class (range = 1 to 7):	Class 4
Rating (Poor, Marginal, Fair, Good, Excellent, Outstanding):	Good
Prevailing Wind Direction:	Northeast









INTRODUCTION

Previous wind monitoring efforts have been conducted in the Bethel area with less than favorable results. The equipment used in those studies was mounted on 20-meter towers and were located adjacent to the buildings that would be served by a wind turbine. The Alaska Energy Authority (AEA) felt that the close proximity to buildings and the low elevation of the sites resulted in a wind resource that was not representative of the area and that winds suitable for a utility-scale wind project could be found a short distance outside of town. In December 2004, AEA, V3Energy, and local residents installed a 50-meter meteorological tower (leased from Chugach Electric) on private land west of town. This location is more likely to be representative of Bethel's best wind resource area and was recommended by wind siting meteorologist John Wade. The purpose of this monitoring effort 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

Bethel is located near the mouth of the Kuskokwim River, about 40 miles inland from the Bering Sea and 400 air miles west of Anchorage. Figure 1 shows the location of the met tower relative to the surrounding terrain. The met tower is located on a ridge at slightly higher elevation than the town site.

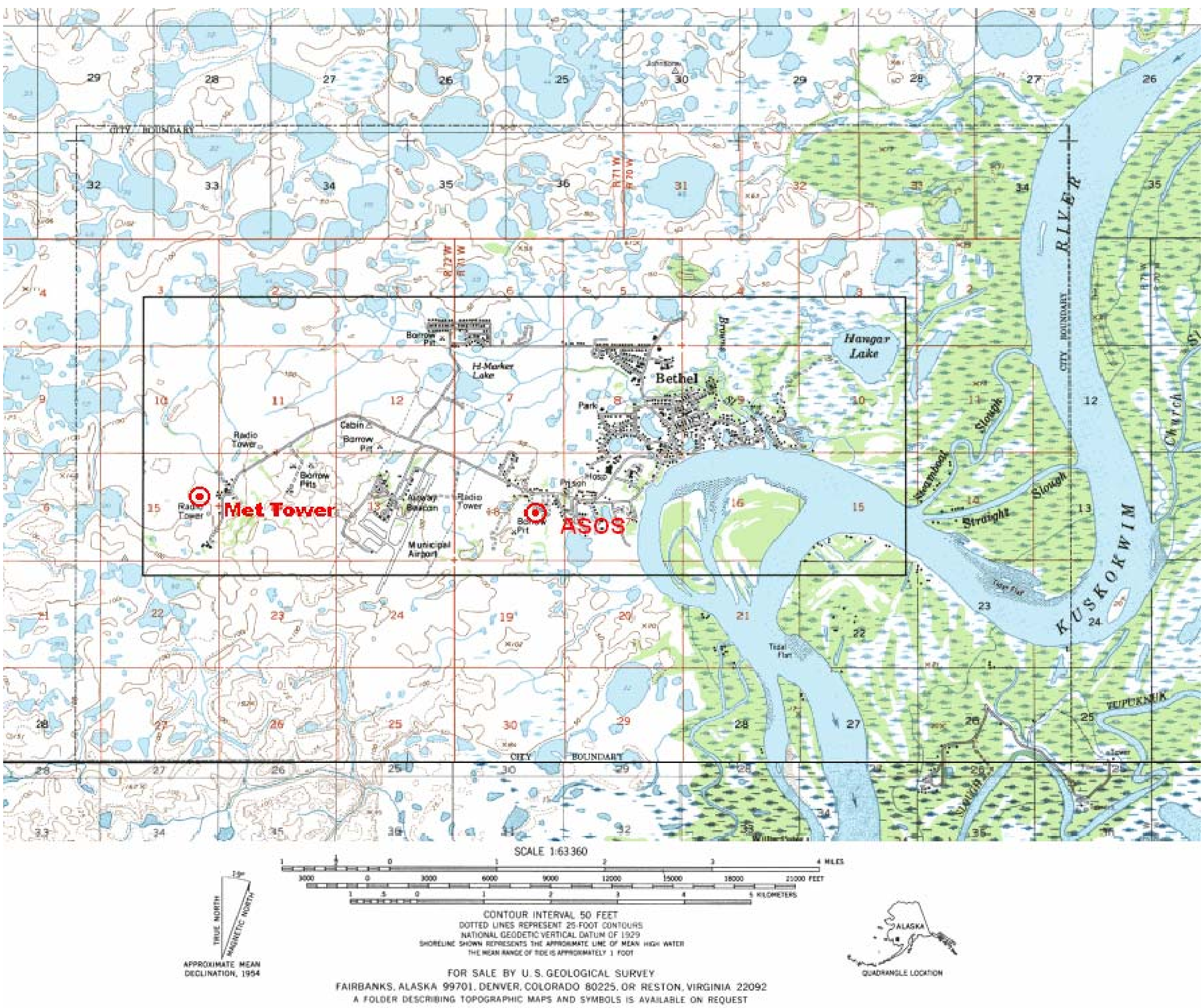


Figure 1. Topographic Map of Met Tower Site and Surrounding Area

The photos below illustrate the surrounding ground cover and any major obstructions, which could affect how the wind flows over the terrain from a particular direction. As shown, the landscape surrounding the met tower site is free of obstructions and relatively flat.

NW North NE East

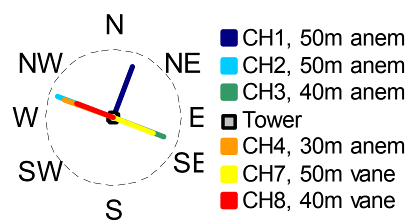
SE South SW West

Figure 2. Views Taken from Met Tower Base

Table 1 lists the types of sensors that were used, 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	50 m	NRG Standard	20˚ True
2	#40 Anemometer	50 m	NRG Standard	290˚ True
3	#40 Anemometer	40 m	NRG Standard	110˚ True
4	#40 Anemometer	30 m	NRG Standard	280˚ True
7	#200P Wind Vane	50 m	290˚ True	110˚ True
8	#200P Wind Vane	40 m	110˚ True	290˚ True
9	#110S Temperature	4 m	NRG Standard	-



Aerial view of equipment on tower

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. The processed data set is also available.

Units – Since most wind turbine specifications are provided in metric units, those units are used in this report.

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

Tower Shadow – The tower itself can affect readings from the anemometer at times when the anemometer is located downwind of the tower. To avoid this effect, two anemometers were placed at the top level so that neither would be in the wake of the tower at the same time. 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 removed to account for the slow build up and shedding of ice on the sensors.

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, if nearby airport data is available, a linear correlation equation is defined between the airport and met tower site, and airport data is adjusted to fill 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. If a suitable station is not available, there is a higher level of uncertainty in the wind speed that is measured being representative of a typical year.

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. The met tower is equipped with anemometers at different heights so that 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 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, with a typical value of 0.14.

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:

$$P = 1.225 - (1.194 \times 10^{-4}) \times \text{elevation}$$

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. Units of wind power density are watts per square meter and represent the power produced per square meter of area that the blades sweep.

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.

Classes of Wind Power Density

Class	10 m		30m		50m		Rating
	WPD (W/m^2)	Speed (m/s)	WPD (W/m^2)	Speed (m/s)	WPD (W/m^2)	Speed (m/s)	
1	<100	<4.4	<160	<5.1	<200	<5.6	Poor
2	100 - 150	4.4 - 5.1	160 - 240	5.1 - 5.8	200 - 300	5.6 - 6.4	Marginal
3	150 - 200	5.1 - 5.6	240 - 320	5.8 - 6.5	300 - 400	6.4 - 7.0	Fair
4	200 - 250	5.6 - 6.0	320 - 400	6.5 - 7.0	400 - 500	7.0 - 7.5	Good
5	250 - 300	6.0 - 6.4	400 - 480	7.0 - 7.4	500 - 600	7.5 - 8.0	Excellent
6	300 - 400	6.4 - 7.0	480 - 640	7.4 - 8.2	600 - 800	8.0 - 8.8	Outstanding
7	>400	>7.0	>640	>8.2	>800	>8.8	

Weibull Distribution – The Weibull distribution is commonly used to approximate the wind speed frequency distribution. 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 Bethel airport weather station, located 2.5 miles east of the met tower site, serves as a long-term reference for the wind resource in the area. Data is measured at a height of 10 meters above ground level and an elevation of 37.5 meters.

The National Weather Service upgraded the meteorological monitoring equipment at the Bethel airport to an Automated Surface Observing System (ASOS) on November 1, 1998. This new equipment, although more accurate, represents a discontinuity in the long-term wind speed record. Therefore, this report is based on measurements beginning January 1, 1999.

Figure 3. ASOS Equipment in Bethel

Hourly wind speed measurements from the Bethel airport weather station that are concurrent with recordings from the met tower site were purchased from the National Climatic Data Center. The correlation coefficient between these sites is 0.87 (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. Any historical patterns in the airport station data can also be applied to the met tower site with a high degree of certainty.

As shown in Table 2 and Figure 4, the area has a strong seasonal pattern, with greater wind speeds in the winter months than the summer months. The long-term annual average wind speed at the Bethel airport site is 5.2 m/s, which is fairly consistent, fluctuating up to 3% from year to year.

Table 2. Monthly Average Wind Speeds at Bethel Airport, 10-meter height (m/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave	% of Long-Term Ave
1999	7.0	4.5	5.8	5.6	4.7	4.0	4.9	4.3	4.7	4.4	5.5	5.7	5.1	99%
2000	6.6	5.0	5.3	5.0	4.3	4.0	4.4	5.2	4.6	4.7	6.2	6.4	5.2	100%
2001	5.4	5.8	6.2	5.9	5.2	4.7	4.5	4.6	4.3	5.0	5.0	5.2	5.2	100%
2002	6.5	6.1	5.2	6.5	4.8	4.2	4.0	4.3	5.3	5.6	5.3	4.7	5.2	101%
2003	6.3	5.5	7.0	5.5	4.5	4.5	4.9	4.1	4.4	4.8	5.3	4.9	5.2	100%
2004	6.3	6.2	5.2	4.6	4.7	4.3	3.8	4.2	4.2	5.6	6.2	5.8	5.1	98%
2005	7.4	5.2	5.7	5.0	4.6	4.1	4.3	4.8	5.9	4.5	6.3	6.0	5.3	103%
Ave	6.5	5.5	5.8	5.5	4.7	4.3	4.4	4.5	4.8	5.0	5.7	5.5	5.2	100%

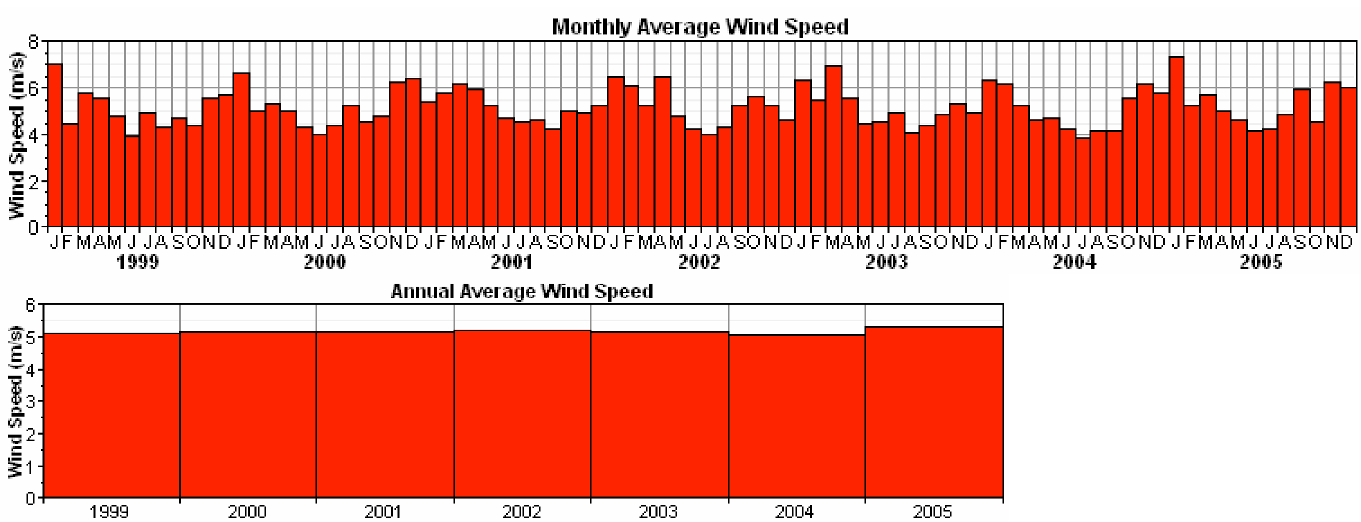


Figure 4. Monthly and Annual Average Wind Speeds at Bethel Airport, 10-meter height

According to the ASOS data, the average wind speed in the year 2005 was 3% greater than the long-term average. Therefore, the wind speed data recorded at the met tower site during the year 2005 was adjusted downwards by 3% to more accurately reflect what would be expected over the long term. Both measured and long-term data sets at the airport and met tower sites are shown in Figure 5.

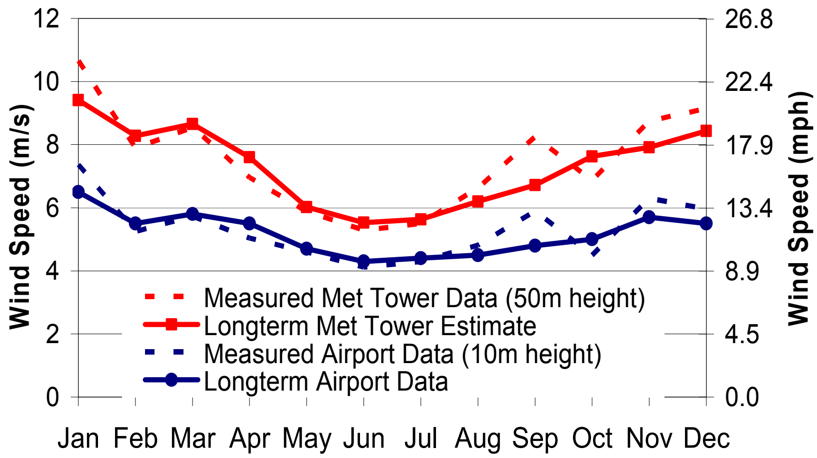


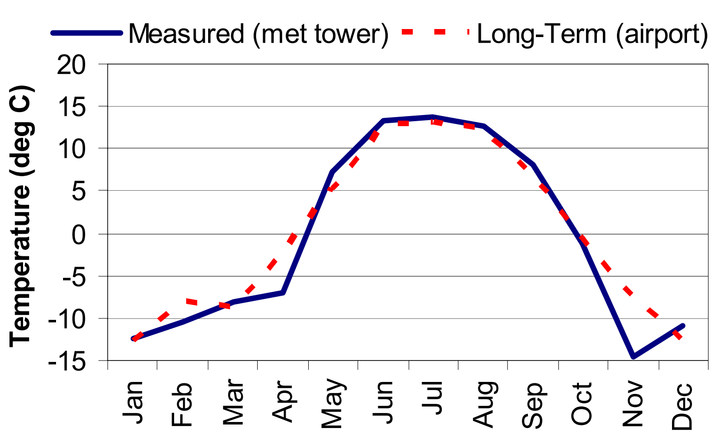
Figure 5. Measured Versus Long-Term Wind Speeds in Bethel

Extreme wind speeds recorded at the Bethel ASOS are summarized in Table 3. The fastest mile is defined as the speed of one mile of wind that passes the weather station and can be considered as the maximum sustained wind speed. The fastest mile recorded over a 41-year period was 27.7 m/s in February 1951. The peak gust over a 16-year period was 34.4 m/s in October 1992.

Table 3. Extreme Wind Speeds in Bethel, 10m height (source: Western Regional Climate Center)

	Airport Fastest Mile (1957-1998)			Airport Peak Gust (1982-1998)		
Month	**m/s**	**mph**	**Year**	**m/s**	**mph**	**Year**
Jan	24.1	54	1979	27.3	61	1993
Feb	27.7	62	1951	26.4	59	1988
Mar	21.9	49	1977	25.0	56	1991
Apr	19.7	44	1979	22.8	51	1995
May	18.3	41	1960	23.7	53	1985
Jun	19.2	43	1978	26.4	59	1980
Jul	17.9	40	1974	20.6	46	1982
Aug	20.6	46	1978	25.0	56	1994
Sep	24.6	55	1960	30.8	69	1982
Oct	23.2	52	1992	34.4	77	1992
Nov	26.8	60	1958	29.5	66	1990
Dec	25.9	58	1977	29.9	67	1982

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 around –25°C). The monthly average temperatures for Bethel are shown below. Typically, the temperature drops below -25°C during 2% of the year, or 185 hours per year.



Month	Measured (˚C)	Long-Term (˚C)
Jan	-12.4	-12.7
Feb	-10.4	-8.0
Mar	-8.2	-8.8
Apr	-7.0	-2.2
May	7.3	5.3
Jun	13.3	12.6
Jul	13.8	13.1
Aug	12.7	12.3
Sep	8.1	7.0
Oct	-1.2	-0.5
Nov	-14.6	-7.5
Dec	-10.8	-12.6
Ave	-0.8	-0.2

WIND DATA RESULTS FOR BETHEL MET TOWER SITE

Table 4 summarizes the amount of data that was successfully retrieved from the data logger at the met tower site. There was significant data loss during the winter months due to icing of the sensors, particularly in November, December and February. The airport ASOS data was used to fill these gaps where possible. The remaining gaps were filled with Windographer.

Table 4. Data Recovery Rate for Met Tower Anemometers

Month	Data Recovery Rate	Data Loss Due to Icing
January 2005	100%	11%
February 2005	100%	34%
March 2005	100%	8%
April 2005	100%	6%
May 2005	100%	2%
June 2005	100%	0%
July 2005	100%	0%
August 2005	100%	0%
September 2005	100%	0%
October 2005	100%	16%
November 2005	100%	31%
December 2005	100%	54%
Annual Average	100%	13%

Wind Speed Measurements

The wind resource was measured at various heights on the tower. Results from the 50-meter and 30-meter heights are summarized below. More details of the 50-meter level are shown in Table 6.

Table 5. Measured and Long-Term Average Monthly Wind Speeds at Met Tower Site

Wind Speeds (m/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
50m Height, Measured	10.7	7.9	8.5	7.0	5.9	5.3	5.5	6.6	8.3	6.9	8.8	9.1	7.5
50m Height, Long-term	9.4	8.3	8.7	7.6	6.0	5.5	5.6	6.2	6.7	7.6	7.9	8.4	7.3
30m Height, Measured	10.0	7.0	7.7	6.2	5.4	4.9	5.1	6.1	7.5	6.1	7.8	8.3	6.9
30m Height, Long-term	8.8	7.4	7.8	6.8	5.5	5.1	5.2	5.7	6.1	6.8	7.0	7.6	6.7

The seasonal wind speed profile shows that the highest wind month is January and the lowest wind month is June. The daily wind speed profile shows that wind speeds are typically greater in the afternoon and evening hours and calmer in the morning.

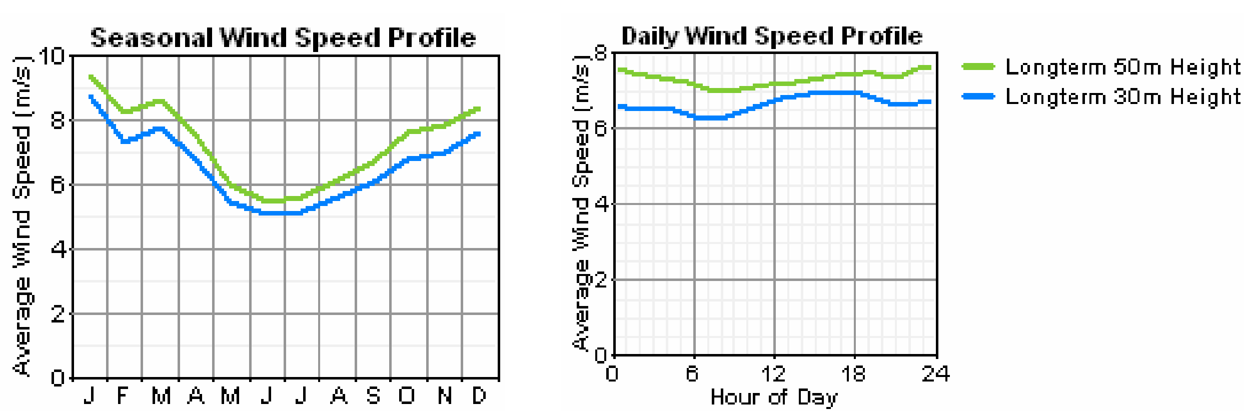


Figure 6. Seasonal and Diurnal Wind Speed Profile for Met Tower Site, Long-term Estimate

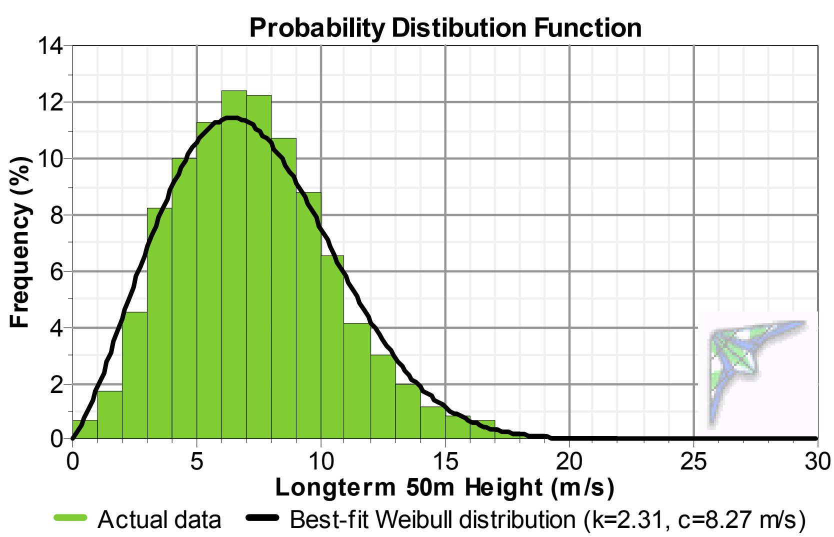
Table 6. Estimated Long-Term Wind Speeds at Met Tower Site, 50m Height (m/s)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
0	9.6	8.5	8.8	8.1	6.4	6.0	6.8	6.4	6.8	7.8	8.1	8.4	7.6
1	9.4	8.5	8.7	8.0	6.3	6.0	6.4	6.2	6.5	7.8	7.9	8.3	7.5
2	9.5	8.4	8.6	8.0	6.0	5.9	5.9	6.0	6.4	7.8	7.7	8.8	7.4
3	9.5	8.2	8.4	8.0	6.0	5.8	5.8	5.9	6.5	7.8	7.8	8.7	7.4
4	9.5	8.5	8.7	7.9	6.0	5.6	5.6	5.8	6.5	7.5	7.8	8.5	7.3
5	9.3	8.4	8.8	8.1	5.9	5.4	5.3	6.0	6.5	7.4	7.7	8.3	7.3
6	9.1	8.2	8.7	7.9	5.7	5.0	5.2	5.8	6.4	7.4	7.9	8.3	7.1
7	9.3	8.0	8.7	7.9	5.2	4.7	4.8	5.6	6.3	7.6	7.9	8.3	7.0
8	9.3	8.2	8.6	7.5	5.0	4.7	4.8	5.6	6.3	7.9	7.9	8.5	7.0
9	9.2	8.5	8.7	7.1	5.1	4.8	5.1	5.8	6.3	7.7	8.1	8.4	7.1
10	9.3	8.1	8.9	6.7	5.6	5.0	5.0	6.1	6.7	7.4	8.3	8.2	7.1
11	9.4	8.1	8.8	6.5	5.8	5.2	5.1	6.4	6.9	7.4	8.3	8.1	7.2
12	9.3	8.2	8.8	6.7	5.9	5.3	5.3	6.4	6.9	7.6	8.1	8.2	7.2
13	9.3	8.4	8.6	7.0	6.0	5.3	5.2	6.6	7.2	7.4	7.8	8.2	7.3
14	9.3	8.4	8.4	7.1	6.1	5.3	5.3	6.7	7.3	7.5	7.7	8.7	7.3
15	9.6	8.3	8.7	7.3	6.1	5.4	5.7	6.7	7.0	7.6	7.7	8.3	7.4
16	9.6	8.2	8.7	7.3	6.4	5.6	6.0	6.6	7.0	7.3	7.8	8.3	7.4
17	9.7	8.3	8.6	7.6	6.7	5.7	5.8	6.6	6.9	7.3	7.8	8.3	7.4
18	9.5	8.3	8.3	7.7	6.5	6.0	6.0	6.6	6.8	7.5	8.0	8.7	7.5
19	9.5	8.4	8.5	7.9	6.2	6.0	6.1	6.3	6.7	7.6	8.1	8.7	7.5
20	9.3	8.1	8.8	8.0	6.3	6.0	5.7	5.9	6.7	7.7	7.9	8.4	7.4
21	9.3	8.0	8.8	8.2	6.6	5.9	5.7	6.1	6.7	7.9	7.9	8.3	7.4
22	9.6	8.1	8.8	8.1	6.6	6.0	6.0	6.4	6.8	8.2	7.9	8.7	7.6
23	9.4	8.2	8.6	8.2	6.4	6.2	6.4	6.3	7.0	8.0	8.1	8.6	7.6
Avg	9.4	8.3	8.7	7.6	6.0	5.5	5.6	6.2	6.7	7.6	7.9	8.4	7.3

The estimated long-term average wind speed is 7.3 m/s at a height of 50 meters above ground level.

Wind Frequency Distribution

A common method of displaying a year of wind data is a wind frequency distribution, which shows the percent of time that each wind speed occurs. Figure 7 shows the measured wind frequency distribution as well as the best matched Weibull distribution.



Bin m/s	Hrs/yr
0	60
1	151
2	396
3	722
4	880
5	989
6	1,086
7	1,073
8	942
9	772
10	572
11	365
12	262
13	170
14	103

Bin m/s	Hrs/yr
15	78
16	58
17	27
18	15
19	9
20	8
21	8
22	4
23	3
24	3
25	2
26	2
27	1
28	1
29	0
Total:	8,760

Figure 7. Wind Speed Frequency Distribution of Met Tower Data, 50-meter height

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

Wind Direction

Wind power roses show the percent of total power that is available in the wind by direction. The annual wind power rose for the met tower site is compared to the airport site in Figure 8. The met tower site is based on one year of data, while the airport site is based on seven years of data. The correlation coefficient between the sites is 0.97. The predominant wind direction at both locations is northeast.

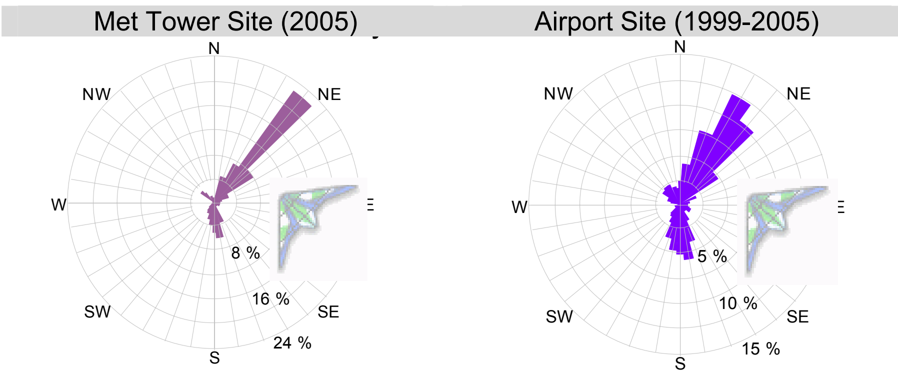


Figure 8. Annual Wind Power Roses for Met Tower Site and Airport Site

Monthly wind power roses for the met tower site are shown below. The strong winter winds come from the northeast, while the lighter summer winds tend to come from the south.

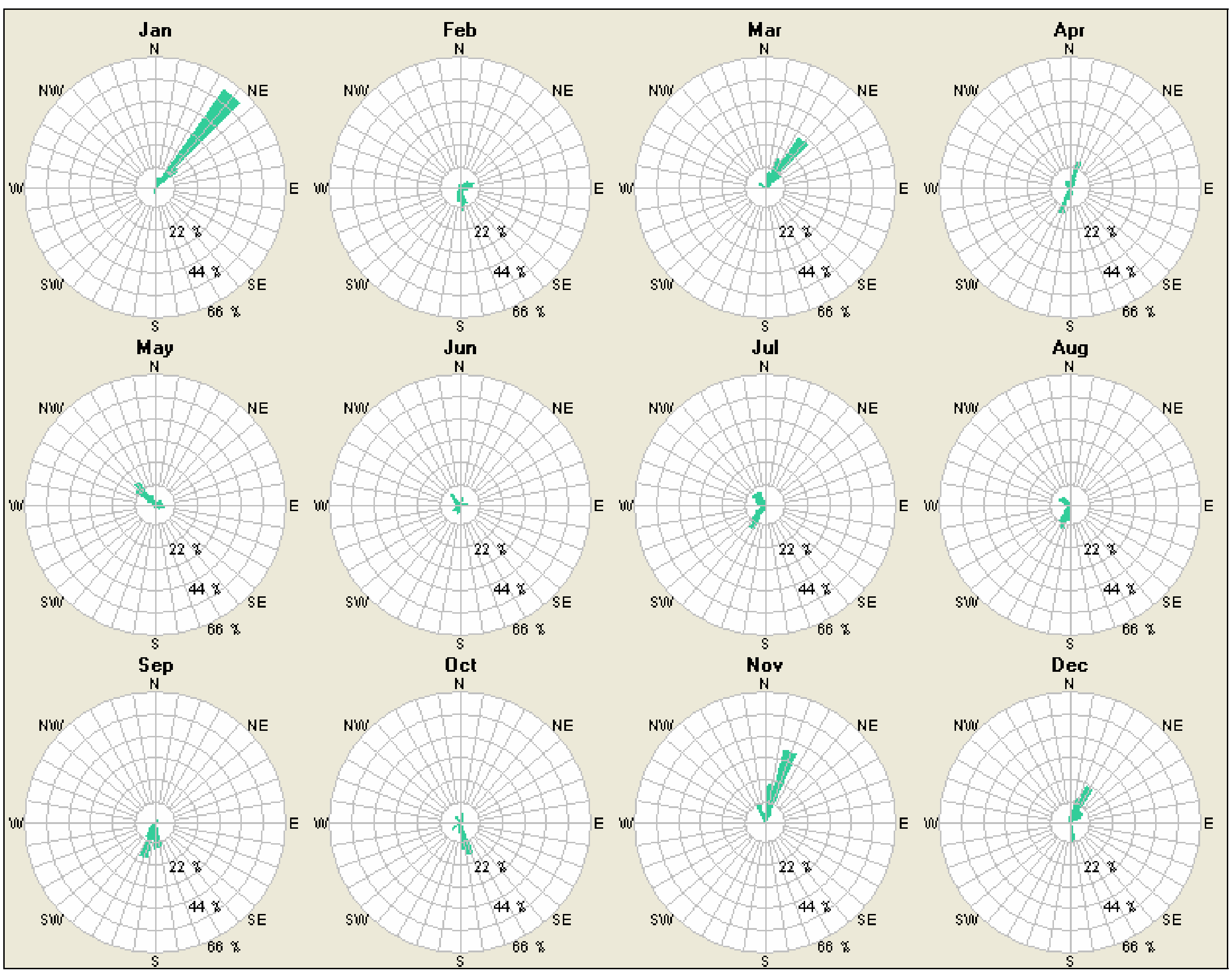
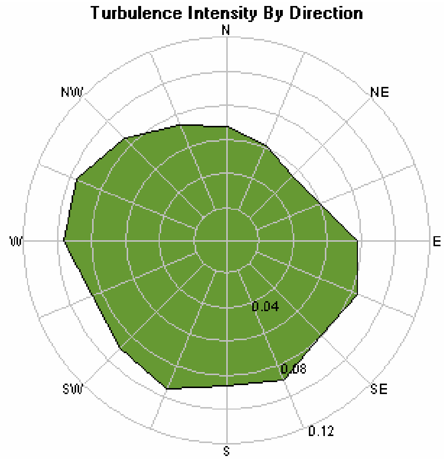


Figure 9. Monthly Wind Power Roses for Met Tower Site

Turbulence Intensity

Various turbulence intensity characteristics are shown in Figure 10. The turbulence intensity from all directions and for all months is low and unlikely to contribute to excessive wear of wind turbines.

Month	Turbulence Intensity
Jan	0.06
Feb	0.06
Mar	0.06
Apr	0.07
May	0.12
Jun	0.14
Jul	0.13
Aug	0.11
Sep	0.10
Oct	0.08
Nov	0.06
Dec	0.06
Ave	0.09



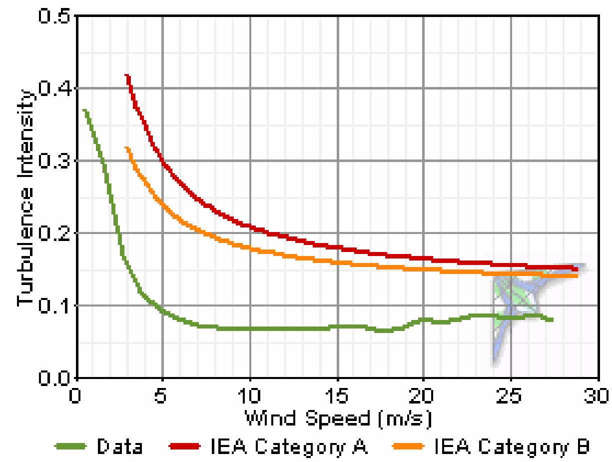


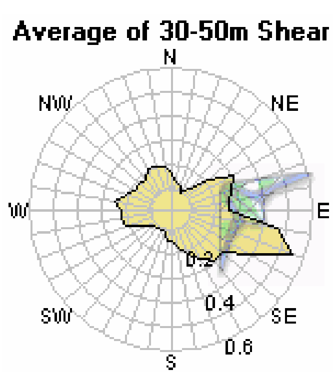
Figure 10. Turbulence Intensity Characteristics of Met Tower Site

Figure 10 plots the average turbulence intensity versus wind speed for the met tower site as well as for Category A and B turbulence sites as defined by the International Electrotechnical Commission Standard 61400-1, 2nd Edition. Category A represents a higher turbulence model than Category B. In this case, the met tower data is less turbulent than both categories across the whole range of wind speeds.

Wind Shear

Wind shear was calculated between the 50-meter anemometer and the 30-meter anemometer, and results are summarized in Figure 11.

Month	30m to 50m Wind Shear
Jan	0.11
Feb	0.26
Mar	0.23
Apr	0.23
May	0.18
Jun	0.17
Jul	0.16
Aug	0.19
Sep	0.18
Oct	0.23
Nov	0.18
Dec	0.23
Ave	0.19



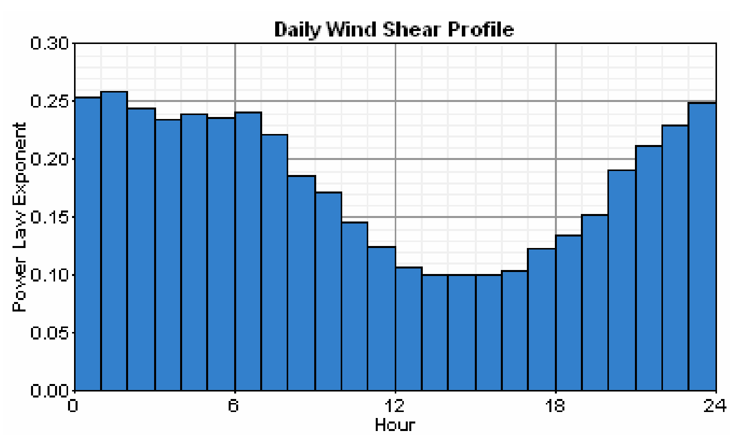


Figure 11. Wind Shear Characteristics of Met Tower Site

The average wind shear for the site is 0.19. As shown, the wind shear varies by month, direction of the wind, and time of day. These wind shear values can be used to adjust the wind resource data to heights other than those that were measured and reported here, as described previously in the Data Processing Procedures and Definitions section.

POTENTIAL POWER PRODUCTION FROM WIND TURBINES

Various wind turbines, listed in Table 7, were used to calculate the potential 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 measured wind shear at the site. The wind resource was also adjusted to standard air density.

Results are shown in Table 7. Among the results is the gross capacity factor, which is defined as the actual amount of energy produced divided by the maximum amount of energy that could be produced if the wind turbine were to operate at rated power for the entire year. Inefficiencies such as transformer/line losses, turbine downtime, soiling of the blades, yaw losses, array losses, and extreme weather conditions can further reduce turbine output. The gross capacity factor is multiplied by 0.90 to account for these factors, resulting in the net capacity factor listed.

CONCLUSION

This report provides a summary of wind resource data collected from December 2004 through January 2006 in Bethel, Alaska. The data was compared to long-term trends in the area and, based on correlations with the Bethel airport weather station, estimates were made to create a long-term dataset for the Bethel met tower site. This information was used to make predictions as to the potential energy production from wind turbines at the site.

It is estimated that the long-term annual average wind speed at the site is 7.3 m/s at a height of 50 meters above ground level and 6.7 m/s at a height of 30 meters. Taking the local air density and wind speed distribution into account, the average wind power density for the site is 440 W/m^2. This information means that Bethel has a Class 4 wind resource, which is “good” for wind power development. The net capacity factor for large scale wind turbines would range from 21 – 36%.

Table 7. Power Production Analysis of Various Wind Turbine Models

Wind Turbine Options			N/A						
Manufacturer Information	Bergey 10 kW	Fuhrlander FL30 30 kW	Vestas V15* 65 kW	Entegrity 15/50 65 kW	Fuhrlander FL100 100 kW	Northern Power NW100 100 kW	Fuhrlander FL250 250 kW	Vestas V27* 225 kW	Vestas V47* 660 kW
Tower Height	30 meters	30 meters	30 meters	30 meters	50 meters	50 meters	50 meters	50 meters	50 meters
Swept Area	38.5 m^2	133 m^2	177 m^2	177 m^2	348 m^2	284 m^2	684 m^2	573 m^2	1,735 m^2
Weight (nacelle & rotor)	N/A	410 kg	N/A	2,420 kg	2,380 kg	7,086 kg	4,050 kg	N/A	N/A
Gross Energy Production (kWh/year)									
Jan	3,174	13,867	22,934	22,978	45,137	37,265	101,646	94,070	319,353
Feb	1,805	8,744	12,517	13,235	25,896	21,194	69,692	63,947	223,083
Mar	2,304	10,772	16,181	16,683	32,836	26,855	84,428	77,643	271,135
Apr	1,602	7,650	11,013	11,431	22,706	18,494	60,982	56,017	197,646
May	987	5,073	5,023	6,193	12,825	10,168	35,887	32,365	126,207
Jun	788	3,955	3,680	4,688	10,120	7,979	28,215	25,405	95,828
July	874	4,312	4,212	5,242	11,326	9,022	30,498	27,321	100,304
Aug	1,162	5,696	6,413	7,521	15,469	12,446	40,718	37,137	138,078
Sep	1,449	6,835	8,797	9,733	19,645	15,997	48,995	44,984	162,470
Oct	1,599	8,054	11,202	11,894	23,420	18,851	63,102	57,128	204,948
Nov	2,062	9,598	14,290	14,907	29,406	24,101	72,506	66,665	232,602
Dec	2,360	10,973	15,471	16,441	32,459	26,772	81,604	75,463	269,962
Annual	20,165	95,530	131,732	140,947	281,243	229,146	718,271	658,145	2,341,615
Annual Average Capacity Factor									
Gross CF	23%	36%	23%	24%	32%	26%	33%	33%	41%
Net CF	21%	33%	21%	22%	29%	24%	30%	30%	36%

Notes: The sizes of Vestas turbines listed are no longer available new. Remanufactured turbines are available from various suppliers.
Energy estimates are based on the wind resource measured at the met tower site, adjusted for long-term trends and local air density.