

**Wind Resource Assessment for  
 FALSE PASS, ALASKA  
 Site # 2399**

Date last modified: 7/20/2005  
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Latitude: (NAD27)	54° 52' 26.6" N
Longitude: (NAD27)	163° 24' 38.8" W

Elevation:	13 m
Tower Type:	30-meter NRG Tall Tower
Monitor Start:	05/07/2005
Monitor End:	In operation

**INTRODUCTION**

In August 2004 the Alaska Energy Authority, V3Energy, Aleutian/Pribilof Islands Association, and the City of False Pass installed a 30-meter tall meteorological tower in False Pass. The purpose of this monitoring effort is to evaluate the feasibility of utilizing 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**

False Pass is located on the eastern shore of Unimak Island about 650 miles southwest of Anchorage. Figure 1 shows the location of the met tower relative to the surrounding terrain.

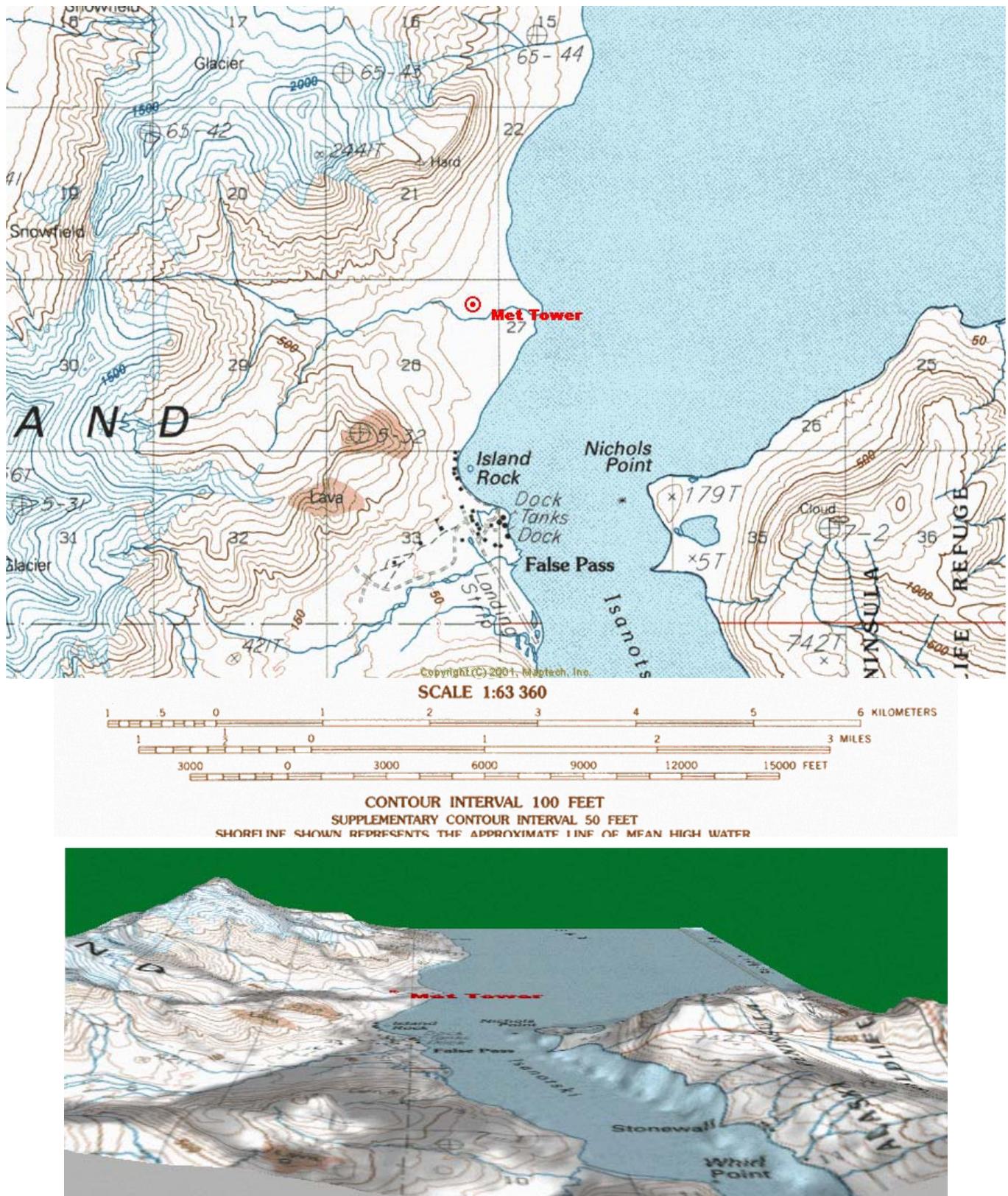


Figure 1. Topographic Map of Met Tower Site and Surrounding Area

Table 1 lists the channel of the data logger each sensor is wired into and where they are mounted on the tower. The temperature sensor is not functioning properly. In August 2005 a bear chewed through the cables to the data logger.

**Table 1. Summary of Sensors Installed on the Met Tower**

Ch #	Sensor Type	Height	Offset	Boom Orientation
1	#40 Anemometer	30 m	NRG Standard	250° True
2	#40 Anemometer	30 m	NRG Standard	95° True
3	#40 Anemometer	20 m	NRG Standard	230° True
7	#200P Wind Vane	30 m	50° True	230° True
9	#110S Temperature	4 m	NRG Standard	-

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



View NW from tower base



Facing North from South anchor

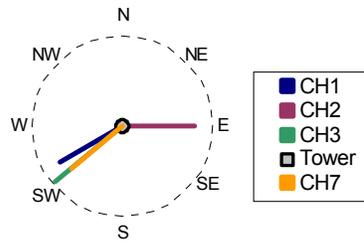


View NE from tower base



View West from tower base

**Arial view of equipment on tower**



Layout of sensor booms



View East from West anchor



View SW from tower base



View South from North anchor



View SE from tower base

## 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](http://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 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 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](http://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,  $\alpha$ , can be calculated according to the power law formula:

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

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,  $\rho$ , 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  $\text{kg/m}^3$ ):

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

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  $1.225 \text{ kg/m}^3$ , 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:

$$V_{s \text{ tandard}} = V_{m \text{ easured}} \times \left( \frac{\rho_{m \text{ easured}}}{\rho_{s \text{ tandard}}} \right)^{\frac{1}{3}}$$

**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:

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

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 Cold Bay Airport weather station (shown in Figure 2), located about 2.5 miles east 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 10 m above ground level and at an elevation of 37.5 m.

[Not Yet Available]

#### Figure 2. ASOS Equipment in Cold Bay

Over 30 years of wind speeds are shown in Table 2 and Figure 3. The average wind speed over the 30-year period is 5.5 m/s. The annual wind speed rarely deviates more than 10% above or below this average. The largest deviations occurred in 1978, 1979, and 1980 when the respective wind speed was 11%, 17%, and 13% greater than the long-term average. The average dropped 9% below the long-term average in 1976.

#### Table 2. Monthly Wind Speeds at 10-m Height at Cold Bay Airport 1973-2005 (m/s)

[Not Yet Available]

[Not Yet Available]

#### Figure 3. Annual Average Wind Speeds at 10-m Height at Cold Bay Airport Weather Station

The extreme wind speeds at the Cold Bay Airport are summarized in Table 3 (source: Western Regional Climate Center). The period of record for the fastest mile is 41 years and for the peak gust is 16 years. The fastest mile can be considered the maximum sustained wind speed. It is defined as the speed of one mile of wind that passes the weather station.

#### Table 3. Peak Wind Speeds at Cold Bay Airport (10m height)

[Not Yet Available]

Hourly wind speed measurements from the Cold Bay Airport weather station that are concurrent with recordings from the met tower site were purchased from the National Climatic Data Center. Data between these sites was compared and a correlation coefficient of 0.87 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 met tower site was developed.

It should be noted that the National Weather Service upgraded the meteorological monitoring equipment at the Cold Bay airport to an Automated Surface Observing System (ASOS) on November 1, 1998. Since this time, the annual average wind speed is 5.0 m/s and the average wind speed has fluctuated up to 3% from year to year. This new equipment, although more accurate, represents a discontinuity in the long-term wind speed record. Therefore, long-term adjustments to the met tower data are based on ASOS measurements beginning 11/1/1998.

**WIND DATA RESULTS FOR MET TOWER SITE**

Table 4 summarizes the amount of data that was successfully retrieved from the anemometers at the met tower site.

**Table 4. Data Recovery Rates for Met Tower Data**

[Not Yet Available]

Table 5 and Table 6 summarize the wind resource data measured at the met tower site as well as the estimated long-term data for this site. Figure 4 and Figure 5 show this same data graphically. As shown, the highest wind month is typically January and the lowest wind month is typically July. Also, 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.

**Table 5. Measured Wind Speeds at 30-m Height at Met Tower Location (m/s)**

[Not Yet Available]

**Table 6. Estimated Long-term Wind Speeds at 30-m Height at Met Tower Location (m/s)**

[Not Yet Available]

[Not Yet Available]

**Figure 4. Monthly Average Wind Speeds at Met Tower Site (30m Height)**

[Not Yet Available]

**Figure 5. Hourly Average Wind Speeds at Met Tower Site (30m 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 ( $c = 9.4, k = 2.2$ ).

[Not Yet Available]

**Figure 6. Wind Speed Frequency Distribution of Met 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 False Pass is within this operational zone.

Table 7 shows the annual wind rose at the met tower site and the Cold Bay Airport and Table 8 shows the monthly wind roses for the data measured at the met tower. The predominant wind energy direction at both locations is NE, with lighter summer winds coming from the SW.

**Table 7. Annual Wind Rose for Met Tower Site and Airport Site**

Legend	Annual Wind Rose	Annual Wind Rose from Airport
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; align-items: center; margin-bottom: 5px;"> <div style="width: 15px; height: 15px; background-color: black; margin-right: 5px;"></div> <span>Percent of Total Wind Energy</span> </div> <div style="display: flex; align-items: center;"> <div style="width: 15px; height: 15px; border: 1px solid black; background-image: linear-gradient(to right, black 1px, transparent 1px), linear-gradient(to bottom, black 1px, transparent 1px); background-size: 4px 4px; margin-right: 5px;"></div> <span>Percent of Total Time</span> </div> </div> <p style="font-size: small; margin-top: 10px;">NRG Systems SDR Version 5.03</p>		

**Table 8. Monthly Wind Roses for Met Tower Site**

Dec 2004	Jan 2005	Feb 2005
Mar 2005	Apr 2005	May 2005
June 2005	July 2005	Aug 2005
Sept 2005	Oct 2005	Nov 2005

Table 9 summarizes the monthly turbulence intensity and wind shear at the met tower site. The turbulence intensity is less than 0.10 and is considered low and unlikely to contribute to excessive wear of wind turbines. Wind shear was calculated between the 30-meter anemometer and the 20-meter anemometer.

**Table 9. Monthly Turbulence Intensity and Wind Shear at Met Tower Site**

[Not Yet Available]

[Not Yet Available]

**Figure 7. Turbulence Intensity and Wind Shear by Direction**

## POTENTIAL POWER PRODUCTION FROM WIND TURBINES

Table 10 lists a number of parameters used to characterize the power production potential of a particular site.

**Table 10. Summary of Power Production Potential of Met Tower Site**

Average Wind Power Density (30m)	
Wind Power Class	
Rating	

Various wind turbines, listed in Table 13, 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 measured wind shear at the site. Table 11 summarizes the estimated energy production from various wind turbines at the met tower site.

**Table 11. Gross Annual Energy Production from Different Wind Turbines at Met Tower Site (kWh)**

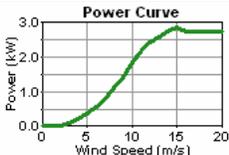
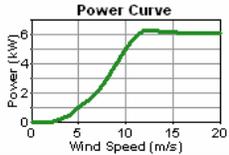
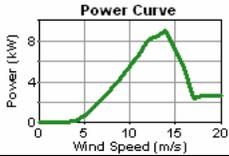
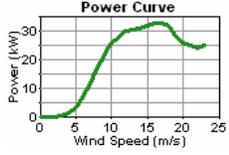
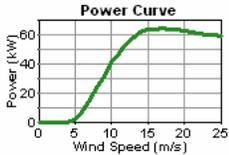
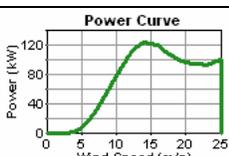
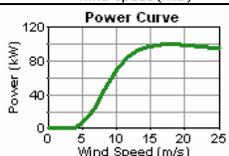
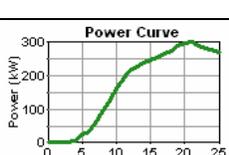
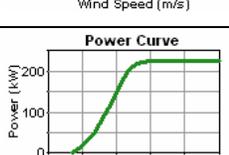
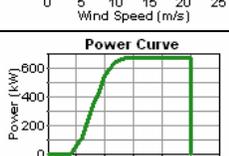
[Not Yet Available]

Table 12 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, and yaw losses.

**Table 12. Gross Capacity Factor of Different Wind Turbines at Met Tower Site**

[Not Yet Available]

**Table 13. Wind Turbine Models Used in Power Production Analysis**

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