

OREGON ANEMOMETER LOAN PROGRAM

# *Wind Resource Evaluation: ODAK Tall Tower Site*



Prepared By:  
**Energy Resources Research laboratory**  
**Oregon State University**

**November 26, 2007**

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# *Wind Resource Evaluation: ODAK 50m Tower Site*

Prepared by:

**Philip L. Barbour  
Stel N. Walker, Ph.D.  
Energy Resources Research Laboratory  
Department of Mechanical Engineering  
Oregon State University  
Corvallis, OR 97331**

Sponsor:

**Energy Trust of Oregon, Inc.  
733 SW Oak Street, Suite 200  
Portland Oregon, 97205**





## 1.0 *SITE DESCRIPTION*

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<b>Site Name:</b>	ODAK 50m
<b>Latitude:</b>	45-37.323 (NAD 84)
<b>Longitude:</b>	118-31.241
<b>Elevation:</b>	3320 ft.
County:	Wallowa
Tower Height:	50 meter
Types of Sensors:	NRG Maximum #40 wind speed NRG 200 series2 wind vane
Instrumentation:	170 ft. – Wind Speed (2), Wind Direction 120 ft. – Wind Speed, Wind Direction 90 ft. – Wind Speed
Types of Data:	10 min. average wind speed (mph) 10 min. mean wind direction (deg) 10 min temperature (Deg F) Standard Deviation, maximum and minimum over 10 min. period also available for each data type.
Data Available from:	August 23, 2005
Data Available to:	September 30, 2007

**Site Location:** Wallowa is a small town in the Wallowa Valley located in north-east Oregon. The tower site was located approximately three miles north of the town on a bluff overlooking the valley. The location of the tower site is marked on the map included in Appendix A. Access to the site is by an unimproved road running through and to the east of the landowner's property.

**Site Description:** The anemometer site is situated on a bluff about 400 feet above the valley floor on the north-east side. The site has good exposure in the immediate vicinity except to the south-east where there are several hills of slightly higher elevation. The area is open with few trees or structures that might influence the wind flow at the site. Most of the valley is used as farmland while the surrounding hills consist of grass and scattered trees. In a broader sense, the Wallowa Valley is dwarfed by the Wallowa Mountain to the south-west. A gap in the mountains exists directly west of the anemometer site. A 20 meter tower was installed about one mile south of this location as part of the Oregon Anemometer Loan program. The 20 meter site was in place from August 2003 to September 2004.

**Project Description:** Unknown. The ERRL had no input into selection of the site location and no site visit has been conducted.

## 2.0 WIND DATA PROCESSING

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NRG equipment was used at this site including Maximum #40 anemometers and a Symphony data logger. Data have been provided by a third party via CD and email in the form of raw NRG Symphony files. Documentation about the site including sensor levels and location was also provided by this third party. NRG Symphony software was used to read these files and produce monthly files of ten minute averages. These files were then converted to hourly averages and converted to an internal ERRL format to accommodate data checking and to perform analysis using existing programs. In this process each level/site combination is assigned a two digit site code. These codes are listed in Table 1.

**Table 1: Site codes and information for the ODAK 50m site location.**

Site ID	Site Name	Latitude dd-mm	Longitude dd-mm	Elev. (ft)	Sensor Ht (ft)	Period of Record
K1	ODAK	45-37.323	117-31.241	3320	170	Aug. 23 2007 - Sept. 30 2007
K2	ODAK	45-37.323	117-31.241	3320	120	Aug. 23 2007 - Sept. 30 2007
K3	ODAK	45-37.323	117-31.241	3320	90	Aug. 23 2007 - Sept. 30 2007

In addition to the filter available for use with the NRG Symphony software, data files were also scanned manually to identify any additional periods in which ice might be present and to identify any additional problems. At low wind sites it is often difficult to distinguish between icing periods and periods of natural calm. As a result there are a number of periods left in the records in which icing might be present.

The monthly mean and data recovery rates are shown in Figure 1 and in Table 1 and illustrate several problems with the site. First, there is a large gap in the data starting near the end of December 2005 and lasting until March 2006. All data is missing for this period. After March 23, 2006 data records resumed for the top level (K1) and lower level (K3) but no further data was available from the mid-level sensor (K2). Because of the gap and to avoid introducing any seasonal bias, data from April 2006 through March 2007 was analyzed. Also as a result of the missing mid-level data, only the upper and lower level data were included.

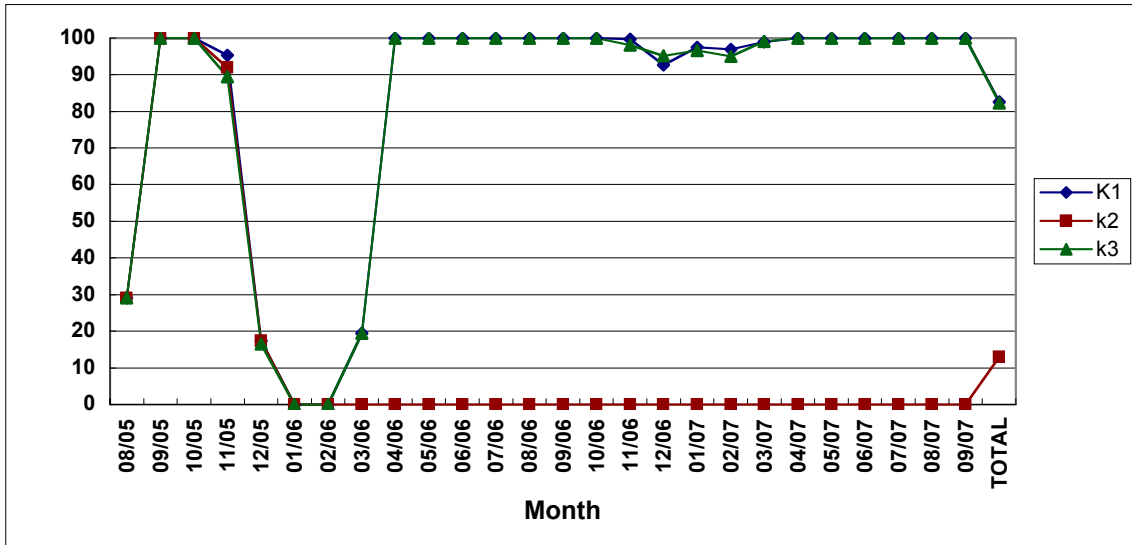


Figure 1: Data recovery for the 3 levels of the ODAK tower site.

**Table 2. Monthly mean wind speeds and data recovery rates for the entire period.**

Month	K1 (170')		K2 (120')		K3 (90')	
	Mean (mph)	Rec. (%)	Mean (mph)	Rec. (%)	Mean (mph)	Rec. (%)
AUG-05	7.3	29.2	7.3	29.2	6.7	29.2
SEP	5.6	100.0	5.7	100.0	5.2	100.0
OCT	3.8	100.0	3.8	100.0	3.4	100.0
NOV	5.5	95.3	5.5	91.9	5.1	89.4
DEC	5.2	17.5	5.0	17.5	4.6	16.5
JAN-06	0.0	0.0	0.0	0.0	0.0	0.0
FEB	0.0	0.0	0.0	0.0	0.0	0.0
MAR	5.4	19.5	0.0	0.0	5.3	19.5
APR	6.1	100.0	0.0	0.0	5.7	100.0
MAY	6.9	100.0	0.0	0.0	6.5	100.0
JUN	5.9	100.0	0.0	0.0	5.5	100.0
JUL	6.5	100.0	0.0	0.0	6.2	100.0
AUG	6.2	100.0	0.0	0.0	5.9	100.0
SEP	5.2	100.0	0.0	0.0	4.8	100.0
OCT	5.3	100.0	0.0	0.0	4.8	100.0
NOV	6.9	99.7	0.0	0.0	6.3	98.1
DEC	4.4	92.6	0.0	0.0	4.1	95.2
JAN-07	4.9	97.4	0.0	0.0	4.7	96.6
FEB	5.3	96.9	0.0	0.0	4.8	95.1
MAR	6.2	98.9	0.0	0.0	5.8	99.2
APR	7.1	100.0	0.0	0.0	6.7	100.0
MAY	6.9	100.0	0.0	0.0	6.4	100.0
JUN	7.5	100.0	0.0	0.0	7.1	100.0
JUL	6.8	100.0	0.0	0.0	6.4	100.0
AUG	6.3	100.0	0.0	0.0	6.0	100.0
SEP	6.1	100.0	0.0	0.0	5.9	100.0
ANN	6.0	82.6	5.2	13.0	5.6	82.3

### 3.0 WIND CHARACTERISTICS

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In the following sections, several characteristics of the winds at the ODAK 50 m site are examined and discussed. The goals are to evaluate the characteristics that can help explain the physical processes at work at the site and to highlight the properties that are important to assessing the wind energy potential. These evaluations are done using hourly averaged means that have been constructed using the 10 minute means recorded at the site. This is done so that existing analysis programs can be used and is not expected to have any appreciable influence on the interpretation of data. Plots of various quantities are included in this section and more complete tables can be found in Appendix B.

This analysis is also confined to a single annual period. This is done so that the results are not biased by the addition of data from only a single season or a portion of a year. *The period analyzed here is for April 1, 2006 to March 31, 2007.*

#### Monthly Means:

Table 3: Monthly Mean Wind Speed Values and data recovery rates for the annual study period.

Month	K1 (170')		K2 (120')		K3 (90')	
	Mean (mph)	Rec. (%)	Mean (mph)	Rec. (%)	Mean (mph)	Rec. (%)
APR	6.1	100.0	0.0	0.0	5.7	100.0
MAY	6.9	100.0	0.0	0.0	6.5	100.0
JUN	5.9	100.0	0.0	0.0	5.5	100.0
JUL	6.5	100.0	0.0	0.0	6.2	100.0
AUG	6.2	100.0	0.0	0.0	5.9	100.0
SEP	5.2	100.0	0.0	0.0	4.8	100.0
OCT	5.3	100.0	0.0	0.0	4.8	100.0
NOV	6.9	99.7	0.0	0.0	6.3	98.1
DEC	4.4	92.6	0.0	0.0	4.1	95.2
JAN-07	4.9	97.4	0.0	0.0	4.7	96.6
FEB	5.3	96.9	0.0	0.0	4.8	95.1
MAR	6.2	98.9	0.0	0.0	5.8	99.2
ANN	5.8	98.8	0.0	0.0	5.4	98.7

**Diurnal Means:**

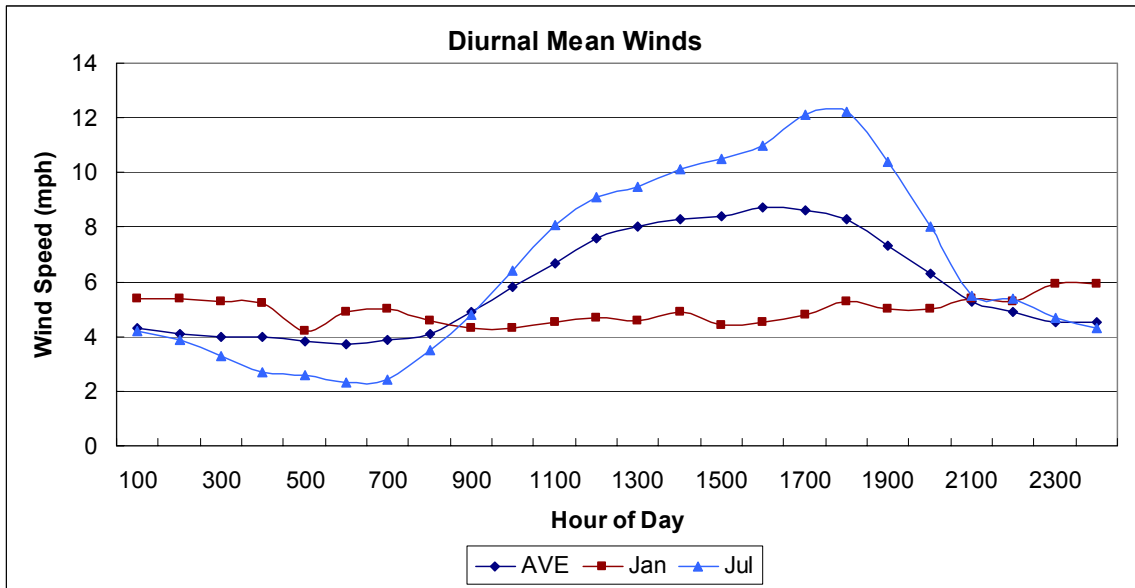


Figure 2: Diurnal mean wind speed values for the 170 ft. level of the ODAK tower Site.

**Frequency Distribution:**

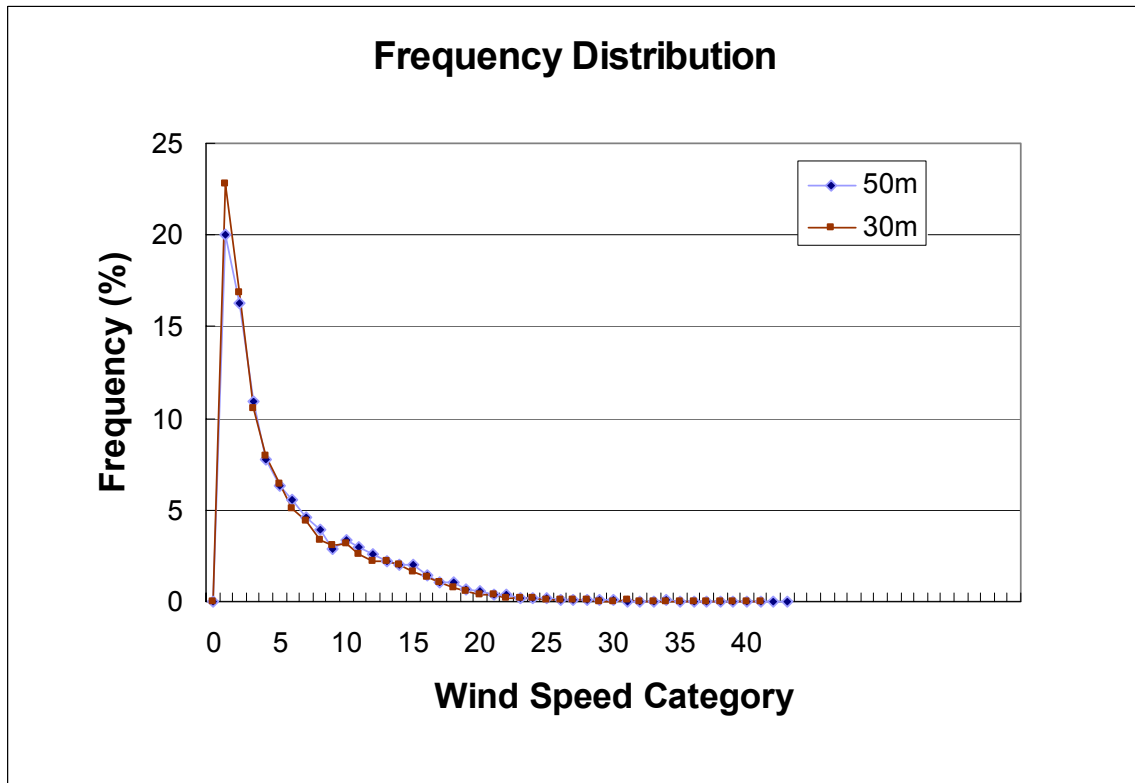
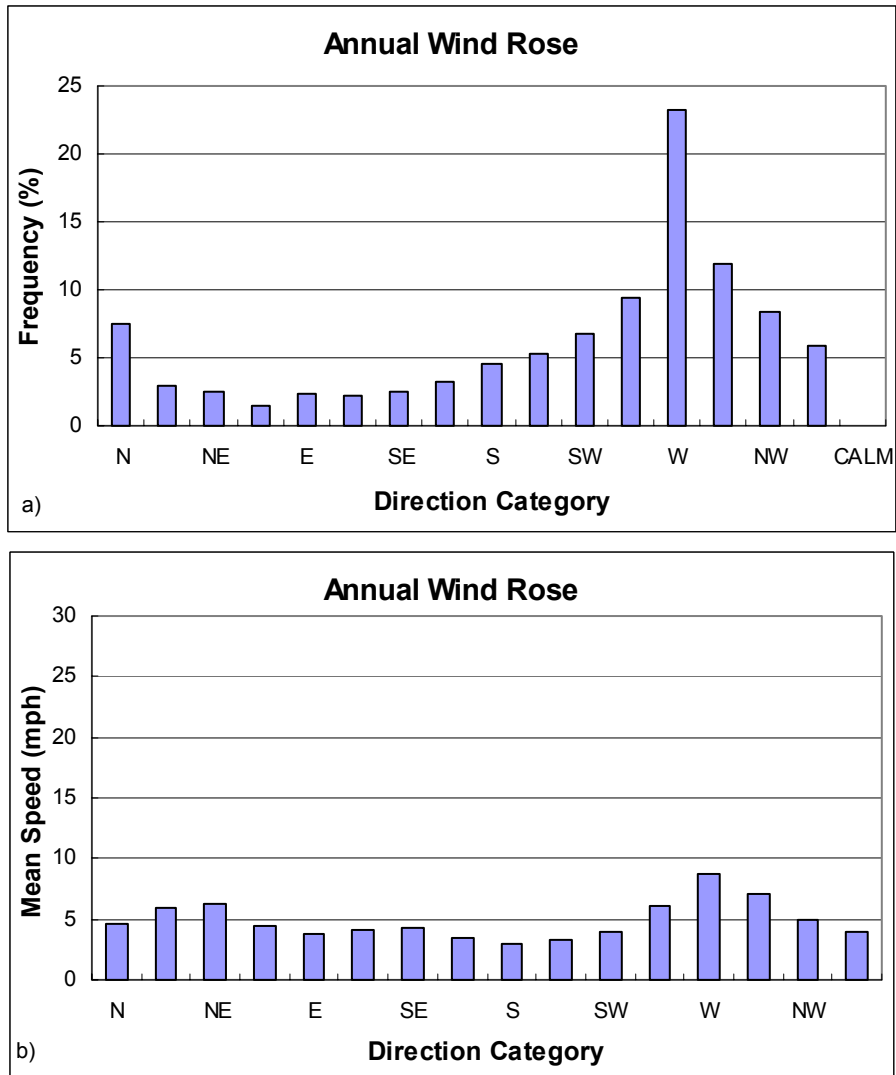
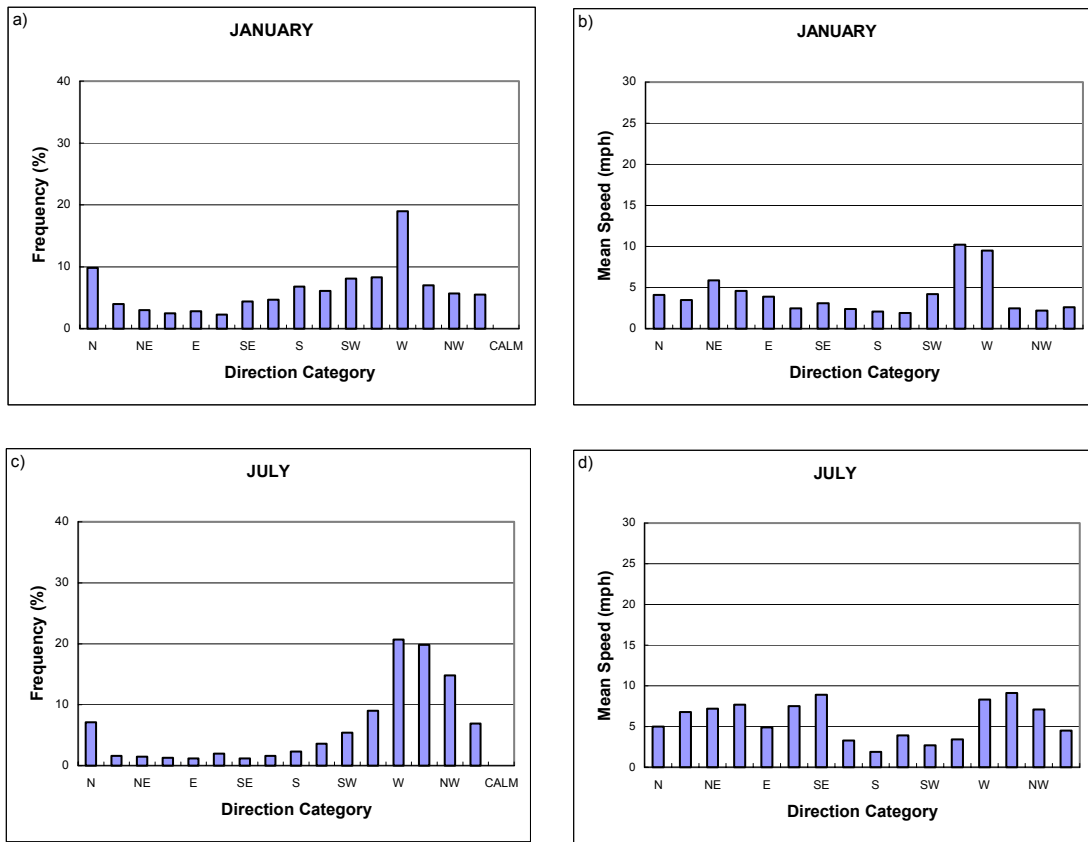


Figure 3: Wind speed frequency distribution for the 170 ft. and 90 ft. levels of the ODAK tower Site.

**Wind Rose:**



**Figure 4a-b: Frequency (%) and average wind speed (mph) for each of 16 wind direction categories from the 170 ft. level of the ODAK tower Site.**



**Figure 5a-d: Frequency (%) and average wind speed (mph) for each of 16 wind direction categories for the months of January and July from the 170 ft. level of the ODAK tower Site.**

#### 4.0 CLIMATOLOGICAL ANALYSIS

Measurements taken over a single one-year period can provide a good estimation of the winds and wind energy potential of a site. However, this is a fairly limited period and is only meaningful if we can place the period into a larger climatological context. The difficulty with this is usually finding appropriate long-term sites to base this on. For the current site, the nearest site with a long-term record is the National Weather Service site at Pendleton (KPDT). The location and site information for these sites is shown in Table 3. These long-term normals are taken using data from a 30 year period (1970-2000). All data were obtained from the National Climate Data Center.

The wind speed departures show that the winds at Pendleton were about 9.2 % above normal for the overall analysis period used here. Perhaps more importantly, there were several individual months in which the winds were significantly above normal. For example, November at Pendleton had winds 36 % above normal. This was a high wind month at the ODAK site as well (in relative terms). However, based on the low winds at the ODAK site and the distance from Pendleton it is probably of most use here to make the qualitative assessment that the winds appeared to be above normal for this period.

**Table 4: Monthly mean and departures for winds at the Pendleton National Weather Service site.**

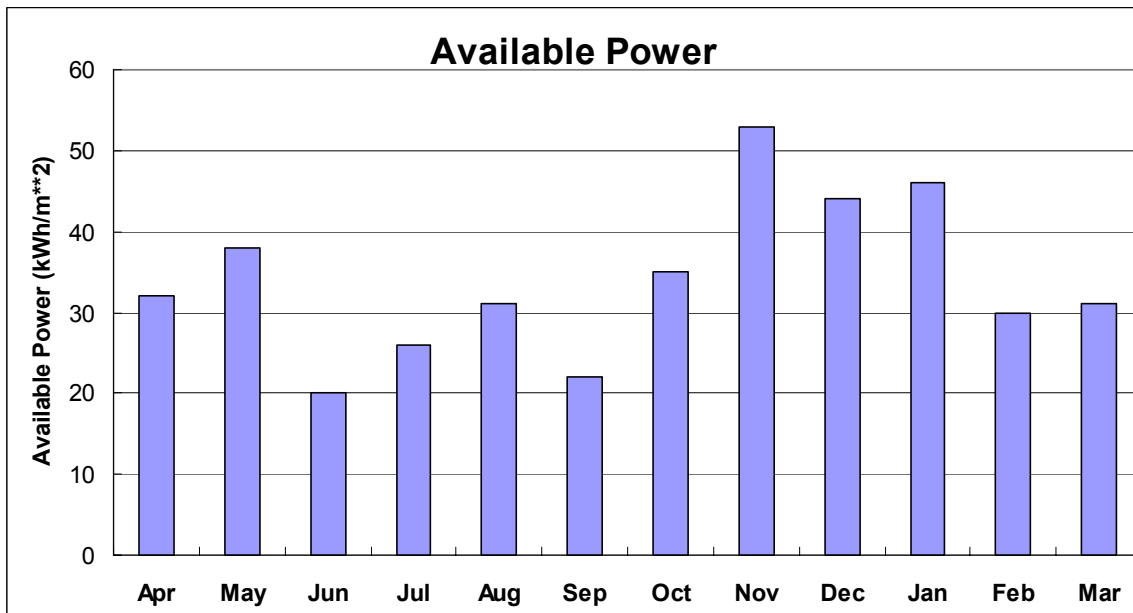
<b>Pendleton (KPDT) NWS</b>			
<b>Latitude: 45.68N</b>		<b>Elevation: 1481'</b>	
<b>Longitude 118.833W</b>			
<b>Month</b>	<b>Normal (mph) 1971-2000</b>	<b>Mean (mph) 2006-2007</b>	<b>Departure (%)</b>
<b>Apr</b>	8.6	8.8	2.3
<b>May</b>	8.7	9.8	12.6
<b>Jun</b>	8.5	8.1	-4.7
<b>Jul</b>	8.4	9.5	13.1
<b>Aug</b>	8.1	9.3	14.8
<b>Sep</b>	7.7	8.5	10.4
<b>Oct</b>	7.4	8.1	9.5
<b>Nov</b>	7.5	10.2	36.0
<b>Dec</b>	6.8	6.5	-4.4
<b>Jan</b>	6.9	7.5	8.7
<b>Feb</b>	7.1	7.2	1.4
<b>Mar</b>	8.2	8.7	6.1
<b>ANN</b>	7.8	8.5	9.2

## 5.0 SITE POWER CHARACTERISTICS

In order to evaluate the wind power potential at this site a number of quantities were computed using the collected wind data. As with the wind characteristics, hourly wind data was used to complete this work. The power density calculation requires air density. This is estimated assuming a standard atmosphere and the site elevation. The computed quantities include the monthly mean and recovery rate of the hourly values, the maximum one hour average, the available power, the frequency that the wind was observed within a wind speed range (12 mph to 60 mph) and the shear coefficient (alpha). These quantities are shown in Table 5 and reveal a number of things about the potential for generating energy at the site.

**Table 5: Observed and computed power quantities for the ODAK tower Site. Values shown are for the 170 ft. and 90 ft. levels. The last three columns are for the 170 ft. level.**

Month	50 m		30 m		Shear Factor	Max 1-Hr	Time in Range (12-60)	Available Energy
	Mean	Recovery	Mean	Recovery				
	(mph)	Rate (%)	(mph)	Rate (%)		(mph)	mph (%)	KWh/m**2
Apr	6.1	100.0	5.7	100.0	0.107	24.6	14.6	32
May	6.9	100.0	6.5	100.0	0.089	30.0	19.1	38
Jun	5.9	100.0	5.5	100.0	0.107	18.8	9.7	20
Jul	6.5	100.0	6.2	100.0	0.093	20.6	17.2	26
Aug	6.2	100.0	5.9	100.0	0.094	24.9	15.7	31
Sep	5.2	100.0	4.8	100.0	0.124	24.1	11.1	22
Oct	5.3	100.0	4.8	100.0	0.135	33.9	13.6	35
Nov	6.9	99.7	6.3	98.1	0.149	37.4	17.4	53
Dec	4.4	92.6	4.1	95.2	0.115	40.3	8.3	44
Jan	4.9	97.4	4.7	96.6	0.071	43.4	11.4	46
Feb	5.3	96.9	4.8	95.1	0.151	29.3	13.2	30
Mar	6.3	98.9	5.8	99.2	0.120	20.6	17.7	31
<b>ANN</b>	<b>5.8</b>	<b>98.8</b>	<b>5.4</b>	<b>98.7</b>	<b>0.115</b>	<b>43.4</b>	<b>14.1</b>	<b>412</b>



**Figure 6: Monthly available power for 170 ft. level of the ODAK tower site.**

An analysis program was run to evaluate the energy that could be produced by two separate wind turbine types. To do this, an analysis program was run that adjusts the site Weibul distribution using the shear coefficient (alpha) calculated from the hourly values (from 90 ft. to 170 ft.). Density variations are approximated using the site elevation and a standard atmosphere. Two wind turbine types are shown for reference, a moderate sized Vestas 660 kW and a larger GE 1.5 MW. Table 6 compares the gross capacity factors for each month for the two wind turbines. Net capacity factor estimates would account for array losses, availability losses electric line and transmission losses, yaw, turbulence, control, blade soiling, icing and high wind cycling. While these losses would be dependent upon the design of the wind farm, a general estimate is that these losses could be in the range of eleven to fifteen percent.

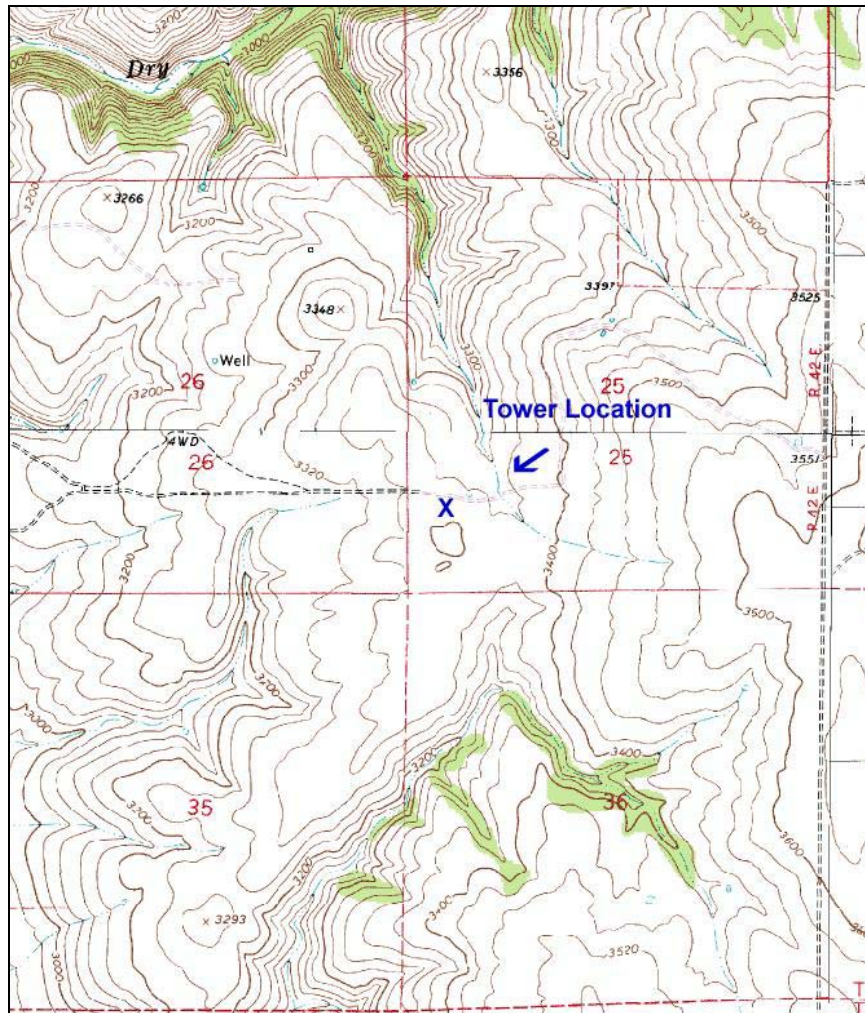
**Table 6: Gross monthly and annual capacity factors for four wind turbine types.**

<b>Turbine</b>	<b>AER 1500-77</b>	<b>Furlander 1500-77</b>	<b>Nordic N1000</b>	<b>GE Wind 70.5</b>
<b>Size (kW)</b>	<b>1500</b>	<b>1500</b>	<b>1000</b>	<b>1500</b>
<b>Hub Ht. (ft.)</b>	<b>213</b>	<b>213</b>	<b>197</b>	<b>210</b>
<b>Apr</b>	<b>0.053</b>	<b>0.053</b>	<b>0.034</b>	<b>0.044</b>
<b>May</b>	<b>0.059</b>	<b>0.060</b>	<b>0.038</b>	<b>0.049</b>
<b>Jun</b>	<b>0.029</b>	<b>0.030</b>	<b>0.015</b>	<b>0.023</b>
<b>Jul</b>	<b>0.046</b>	<b>0.047</b>	<b>0.026</b>	<b>0.037</b>
<b>Aug</b>	<b>0.049</b>	<b>0.049</b>	<b>0.030</b>	<b>0.040</b>
<b>Sep</b>	<b>0.036</b>	<b>0.036</b>	<b>0.022</b>	<b>0.029</b>
<b>Oct</b>	<b>0.051</b>	<b>0.050</b>	<b>0.034</b>	<b>0.043</b>
<b>Nov</b>	<b>0.082</b>	<b>0.080</b>	<b>0.055</b>	<b>0.069</b>
<b>Dec</b>	<b>0.054</b>	<b>0.052</b>	<b>0.040</b>	<b>0.047</b>
<b>Jan</b>	<b>0.059</b>	<b>0.058</b>	<b>0.042</b>	<b>0.041</b>
<b>Feb</b>	<b>0.053</b>	<b>0.052</b>	<b>0.035</b>	<b>0.044</b>
<b>Mar</b>	<b>0.050</b>	<b>0.051</b>	<b>0.032</b>	<b>0.041</b>
<b>ANN</b>	<b>0.052</b>	<b>0.052</b>	<b>0.034</b>	<b>0.043</b>

## Summary,

- 1) *Wind data for the mid-level sensor were missing from the records for the analysis period used here (April 2006 to March 2007). Only the Top level (170 ft). and lower level (90 ft.) are analyzed.*
- 2) The measured shear coefficient between the 90 ft. and 170 ft. levels was 0.115 on an annual basis
- 3) Winds at the site were observed to be fairly consistent through the different seasons. The regions appears to suffer from strong inversions in the winter resulting in long periods of light winds.
- 4) Computed gross capacity factors for four sample wind turbine types were found in a range between 3.4 % and 5.2 %. Estimates of the net capacity factors would be even lower
- 5) No adequate long-term wind site is available for comparison but the wind data from the National Weather Service site in Pendleton indicated that the wind observed over the analysis period (April 2006 to March 2007) could be as much as 9.2 % above the expected long-term mean.

Appendix A: Topographic map of the area in which the ODAK site is located.



Appendix B: Miscellaneous analysis Tables.

STATION - ODAK (k1 - 170 ft.)  
 WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY  
 DATA PERIOD OF RECORD - 4/2006 - 3/2007  
 NORMALIZATION PERIOD - ONE YEAR  
 AVERAGE WIND SPEED FOR PERIOD: 5.8 MPH  
 NORMALIZED AVAILABLE ENERGY: 412.8 KWH/M\*\*2/YEAR  
 TOTAL HOURS OBSERVED: 8655

NORMALIZED				NORMALIZED	
SPD	HOURS/ AVAIL. ENERGY	REL FREQ	CUMHRS	CUMREL FREQ	AVAIL. ENERGY KWH/M**2/YEAR
0	0	0.00	8655	100.00	0.0
1	1736	20.06	8655	100.00	0.1
2	1406	16.24	6919	79.94	0.6
3	948	10.95	5513	63.70	1.3
4	671	7.75	4565	52.74	2.2
5	547	6.32	3894	44.99	3.4
6	478	5.52	3347	38.67	5.2
7	395	4.56	2869	33.15	6.8
8	343	3.96	2474	28.58	8.8
9	246	2.84	2131	24.62	9.0
10	287	3.32	1885	21.78	14.4
11	256	2.96	1598	18.46	17.1
12	225	2.60	1342	15.51	19.5
13	191	2.21	1117	12.91	21.1
14	171	1.98	926	10.70	23.6
15	177	2.05	755	8.72	30.0
16	123	1.42	578	6.68	25.3
17	95	1.10	455	5.26	23.4
18	94	1.09	360	4.16	27.5
19	59	0.68	266	3.07	20.3
20	46	0.53	207	2.39	18.5
21	31	0.36	161	1.86	14.4
22	32	0.37	130	1.50	17.1
23	20	0.23	98	1.13	12.2
24	17	0.20	78	0.90	11.8
25	14	0.16	61	0.70	11.0
26	11	0.13	47	0.54	9.7
27	4	0.05	36	0.42	4.0
28	8	0.09	32	0.37	8.8
29	4	0.05	24	0.28	4.9
30	4	0.05	20	0.23	5.4
31	1	0.01	16	0.18	1.5
32	1	0.01	15	0.17	1.6
33	3	0.03	14	0.16	5.4
34	4	0.05	11	0.13	7.9
35	1	0.01	7	0.08	2.2
36	2	0.02	6	0.07	4.7
37	2	0.02	4	0.05	5.1
38	0	0.00	2	0.02	0.0
39	0	0.00	2	0.02	0.0
40	1	0.01	2	0.02	3.2
41	0	0.00	1	0.01	0.0
42	0	0.00	1	0.01	0.0
43	1	0.01	1	0.01	4.0

STATION - ODAK (K1 - 170 ft.)

MONTHLY WIND SPEEDS (MPH)

DATA PERIOD OF RECORD - 4/2006 - 3/2007

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
2006	0.0	0.0	0.0	6.1	6.9	5.9	6.5	6.2	5.2	5.3	6.9	4.4	6543	5.94	5.31
# OBS	0	0	0	720	744	720	744	744	720	744	718	689			
2007	4.9	5.3	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2112	5.52	5.59
# OBS	725	651	736	0	0	0	0	0	0	0	0	0			
AVG	4.9	5.3	6.2	6.1	6.9	5.9	6.5	6.2	5.2	5.3	6.9	4.4	8655	5.84	5.38
SD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

STATION - odak (k3 - 90 ft.)

MONTHLY WIND SPEEDS (MPH)

DATA PERIOD OF RECORD - 4/2006 - 3/2007

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
2006	0.0	0.0	0.0	5.7	6.5	5.5	6.2	5.9	4.8	4.8	6.3	4.1	6550	5.53	5.04
# OBS	0	0	0	720	744	720	744	744	720	744	706	708			
2007	4.7	4.8	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2096	5.12	5.25
# OBS	719	639	738	0	0	0	0	0	0	0	0	0			
AVG	4.7	4.8	5.8	5.7	6.5	5.5	6.2	5.9	4.8	4.8	6.3	4.1	8646	5.43	5.09
SD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

STATION - ODAK (KI- 170 ft.)  
 DIURNAL WIND SPEEDS (MPH)  
 DATA PERIOD OF RECORD - 4/2006 - 3/2007

	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	AVG SPD
MON	5.4	5.4	5.3	5.2	4.2	4.9	5.0	4.6	4.3	4.3	4.5	4.7	4.6	4.9	4.4	4.5	4.8	5.3	5.0	5.0	5.4	5.3	5.9	5.9	4.9
JAN	4.7	4.5	4.4	4.1	4.4	4.3	4.0	3.9	4.6	4.9	5.3	6.3	6.5	6.8	7.1	7.6	7.1	6.3	6.1	5.3	4.8	4.5	4.9	5.3	5.3
FEB	5.3	5.4	5.1	4.8	4.6	4.1	3.8	4.4	5.7	6.6	7.2	7.5	8.3	9.3	9.3	8.7	7.2	6.9	6.2	6.0	6.2	5.8	5.1	5.7	6.2
MAR	4.6	4.1	3.8	3.2	3.2	2.3	3.2	3.9	5.0	6.4	8.0	9.5	9.6	9.4	9.0	8.7	9.3	8.6	7.7	7.0	5.5	5.6	4.7	4.5	6.1
APR	4.1	3.2	3.4	3.1	3.3	2.9	3.5	5.0	6.2	7.6	9.2	9.9	9.7	9.6	9.8	11.5	12.0	11.9	9.8	8.7	6.9	5.4	4.3	3.9	6.9
MAY	4.5	3.9	3.2	3.6	3.3	3.5	3.6	4.1	5.0	5.7	6.6	7.2	8.3	7.9	8.6	8.7	9.0	10.2	8.4	7.6	5.1	4.8	4.4	4.0	5.9
JUN	4.2	3.9	3.3	2.7	2.6	2.3	2.4	3.5	4.8	6.4	8.1	9.1	9.5	10.1	10.5	11.0	12.1	12.2	10.4	8.0	5.5	5.4	4.7	4.3	6.5
JUL	3.4	2.9	2.3	2.8	2.8	2.6	2.9	3.3	4.5	6.3	7.5	8.9	9.8	10.7	10.7	11.3	12.0	11.4	10.2	6.7	4.7	3.6	3.6	3.9	6.2
AUG	2.3	2.5	2.9	2.9	3.1	3.5	3.6	4.0	4.7	5.7	6.5	7.1	8.2	8.5	9.1	9.7	9.2	7.6	6.4	4.1	3.8	3.3	2.7	2.3	5.2
SEP	3.5	3.2	3.2	3.5	3.4	3.2	2.8	3.1	3.5	4.6	5.8	7.6	8.7	9.2	9.3	9.1	8.4	6.7	5.4	5.3	5.0	4.3	4.0	3.8	5.3
OCT	5.5	6.2	7.2	7.7	7.3	7.2	7.6	6.6	6.2	6.5	6.6	8.0	7.8	7.6	8.3	8.5	7.2	7.6	7.3	6.6	6.0	5.7	5.2	5.4	6.9
NOV	4.1	4.2	3.9	4.6	4.0	4.2	4.5	3.2	3.8	4.3	4.4	5.2	5.1	4.9	4.7	4.3	4.3	4.4	4.1	4.6	4.9	4.7	4.7	4.5	4.4
DEC																									
AVG	4.3	4.1	4.0	4.0	3.8	3.7	3.9	4.1	4.9	5.8	6.7	7.6	8.0	8.3	8.4	8.7	8.6	8.3	7.3	6.3	5.3	4.9	4.5	4.5	5.8
SPD																									

STATION - ODAK (K1 - 170 ft.)  
WIND ROSE FOR ALL DATA - 8655 OBSERVATIONS  
DATA PERIOD OF RECORD - 4/2006 - 3/2007

DIR	SPEED CATEGORIES (MPH)																TOTAL %	MEAN SPEED (MPH)	
	0	10	13	16	19	22	25	28	31	34	37	40	43	46	49	52			>=
	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	55		
N	7.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	4.6
NNE	2.3	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	6.0
NE	1.9	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	6.2
ENE	1.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	4.4
E	2.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	3.8
ESE	2.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	4.1
SE	2.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.3
SSE	3.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.4
S	4.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	3.0
SSW	4.9	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	3.3
SW	6.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	4.0
WSW	7.5	0.6	0.4	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	6.1
W	13.6	3.4	2.9	1.8	0.9	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.2	8.8
WNW	8.3	1.8	1.1	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9	7.1
NW	7.3	0.6	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	5.0
NNW	5.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	3.9
CALM																		0.0	
TOTAL	79.8	8.4	5.8	3.3	1.4	0.7	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	5.8

NOTE: MEAN SPEED OF THE TOTAL IN A WIND ROSE MAY DIFFER FROM THE SPEED FREQUENCY DISTRIBUTION FOR A GIVEN PERIOD DUE TO DATA SELECTION. SPEED FREQUENCY DISTRIBUTIONS REQUIRE ONLY A WIND SPEED OBSERVATION BE PRESENT. WIND ROSES, ON THE OTHER HAND, REQUIRE BOTH SPEED AND DIRECTION BE PRESENT FOR EACH OBSERVATION.

STATION - ODAK (KI- 170 ft.)  
 ENERGY ROSE (TOTALS ARE NORMALIZED AVAILABLE ENERGY (KWH/M\*\*2)  
 DATA PERIOD OF RECORD - 4/2006 - 3/2007

MON	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	OBS.
JAN	0.7	0.2	0.6	0.3	0.2	0.0	0.1	0.1	0.1	0.0	3.9	12.6	26.4	0.3	0.1	0.1	45.6	724
FEB	0.3	0.1	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.4	3.4	3.2	20.5	1.0	0.4	0.3	30.2	650
MAR	0.9	0.1	0.8	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.2	4.0	17.6	5.3	1.4	0.3	31.2	736
APR	0.3	2.1	2.6	0.8	0.2	0.9	0.5	0.2	0.2	0.6	2.9	2.2	13.3	3.2	1.4	0.7	32.2	720
MAY	0.8	3.1	0.9	0.1	0.2	0.4	0.9	0.8	1.4	0.1	0.3	2.0	15.8	9.4	1.9	0.5	38.6	744
JUN	0.9	0.8	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	1.1	11.2	4.1	1.1	0.2	20.2	719
JUL	1.2	0.5	0.3	0.4	0.1	0.7	0.5	0.1	0.0	0.6	0.1	0.4	9.5	10.0	5.1	0.7	30.4	744
AUG	1.5	1.6	1.2	0.1	0.5	0.6	0.1	0.1	0.3	0.1	0.1	1.3	10.2	9.9	2.7	1.0	31.2	743
SEP	0.5	0.7	0.7	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.5	13.5	3.3	0.8	0.3	22.1	719
OCT	0.2	0.0	1.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.2	2.4	28.2	1.8	0.2	0.1	34.7	744
NOV	0.7	0.2	0.0	0.0	0.1	0.1	0.2	0.8	3.0	3.5	6.9	17.9	16.0	2.7	1.0	0.4	53.5	716
DEC	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.1	2.5	1.3	2.1	16.2	19.1	1.0	0.1	0.2	44.0	687
TOT	8.9	9.5	8.6	2.2	1.7	3.1	2.8	2.3	7.8	7.1	20.4	64.8	201.2	52.1	16.2	4.9	413.7	8646

NOTE: AVAILABLE ENERGY IN AN ENERGY ROSE MAY DIFFER FROM THE SPEED FREQUENCY DISTRIBUTION FOR A GIVEN PERIOD DUE TO DATA SELECTION. SPEED FREQUENCY DISTRIBUTIONS REQUIRE ONLY A WIND SPEED OBSERVATION BE PRESENT. ENERGY ROSES, ON THE OTHER HAND, REQUIRE BOTH SPEED AND DIRECTION BE PRESENT FOR EACH OBSERVATION.

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