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Appendix B

to

Comprehensive Renewable Energy Feasibility Study for Sealaska Corporation

Final Meteorological Report for Yakutat

WIND DATA REPORT
FOR THE
YAKUTAT
JULY 2004 – July 2005

Prepared on

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For

Bob Lynette
212 Jamestown Beach Lane
Sequim WA 98382

By
John Wade
Wind Consultant LLC
2575 NE 32nd Ave
Portland OR 97212

INTRODUCTION

This report summarizes new data taken from late July 2004 through July 15, 2005, at three locations in Yakutat. The report contains a description of the site, instruments installed, data collection and equipment performance. The report will also discuss site climatology based on analysis of a nearby long-term reference location in Yakutat. The purpose of this climatology is to put the validation period into context as to the degree of normality of the climatic conditions during the study period.

DESCRIPTION OF THE AREA

Yakutat is surrounded on three sides by water: to the north by Yakutat Bay, to the west by the Pacific Ocean and to the northeast by Russell Fiord (see Figure 1). To the north and northeast, are the peaks of the St. Elias Range, which rise to heights of between 14,000 and 20,000 feet. This higher terrain means that southeasterly flow circulating around the Aleutian Low is a barrier that first slows the onshore winds and then lifts them dropping abundant precipitation in the Yakutat area. The annual precipitation, of around 150 inches, is one of the greatest in the state (see Table 1). Figure 2 shows a three dimensional view of the area and from this view it is clear that the only direction the winds can come from are the east though SSW all other directions are blocked by higher terrain.

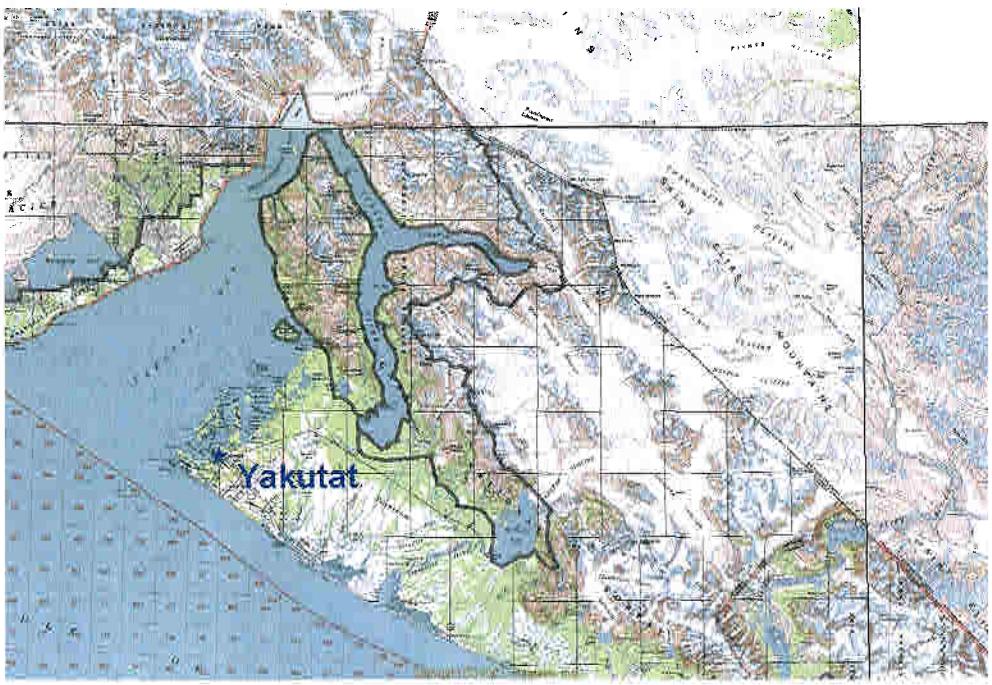

Figure 1 The Yakutat area.

Table 1 Meteorological Statistics for the Yakutat Airport.

Yakutat	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature	F	25.1	28	31	36.3	43.3	49.4	53.6	53.2	48.2	40.9	31.3	27.1	39
Precipitation	(inches)	12.2	10.7	10.7	9.9	9.7	7.3	8.2	11.5	18.6	23	14.5	14.9	151
Snowfall	inches	37.1	36.8	37	16.6	1.4	0.05	0	0	0.05	5.5	22	37.6	194
Speed	mph	7.3	7.6	7.1	7.2	7.6	7.1	6.7	6.5	7	7.9	7.4	8	7.3

The warmest month is July, with an average temperature of 53.6 degrees Fahrenheit and the highest temperature recorded in any month was 86 degrees in August. The coldest month is January, with average temperatures of 25.1 degrees F. The coldest temperature recorded (-24 degrees Fahrenheit) occurred in the month of December.

The winds are generally easterly from September to April, and east-southeast from May to August. During the spring, fall, and winter, frequent low-pressure systems, originating near the Aleutian Islands, pass through the gulf south of Yakutat. These storms are often accompanied by high winds, clouds, and heavy precipitation. The highest wind speed recorded in Yakutat occurred in January and was 81 miles per hour. The winds from the upper air site provide data on winds unaffected by local round level obstructions (see Figure 3 and 4). Closer to the surface the winds are more east-northeast to east-southeast and aloft are more east to southeast. There is no evidence of strong westerly or northwesterly winds.

The annual air density for this area assuming a 60 meter hub height turbine, an average elevation of 10 meters and an annual temperature of 3.3 degrees Centigrade is 1.26 kg/m^3.

Figure 2 A three dimensional view of the Yakutat area.

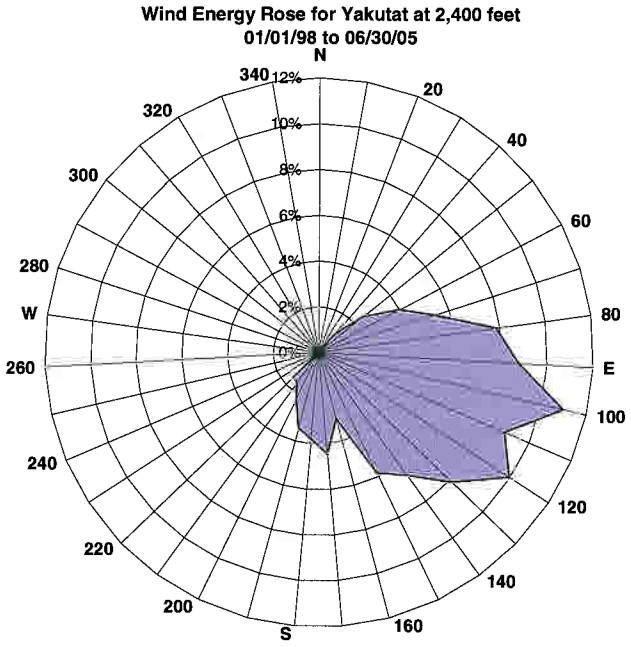

Figure 3 The energy producing wind directions at around 2,400 feet.

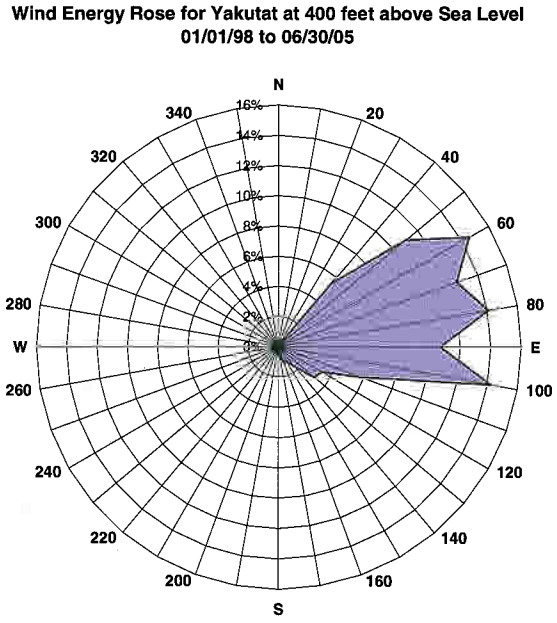

Figure 4 The energy producing wind directions at around 400 feet.

DESCRIPTION OF THE DATA AND METEOROLOGICAL EQUIPMENT

There are three meteorological towers all instrumented at 20 and 30 meters. Sensors used for measuring wind speed are Maximum 40 cup anemometers with protective terminal boots. Wind direction is measured with a 200P-wind direction sensor. The tower is grounded with a lightening spike, 35 meters of copper grounding wire, and ground rod. All sensors are connected to the logger with shielded 20-gauge cable.

The Maximum cup anemometer on each revolution generates two sine wave cycles that are linearly proportional to the wind speed. Anemometer voltage varies between 0.5 and 6 volts VAC. The transfer constant to convert the Maximum 40P output to wind speed is a multiplier of 1.711 with a 0.78 mph offset.

Each site is equipped with a NRG Symphonie Data Logger with an internal cellular phone interface with a local internet provider. A 5-watt photovoltaic panel powers the sensors and loggers. A terminal reader is supplied to program the logger on-site and view data. Having a separate display increases the logger's low temperature-operating threshold and provides security so that only authorized personnel can view the output. The data logger is backed up with non-volatile "flash" memory cards.

Table 2. Site Description for Yakutat Sites.

Site Name: A Ocean Cape Site 002 **Latitude**: 59° 32.502' N **Longitude:** 139° 51.738' W **Map Datum:** WGS 84 **Elevation**: 40 feet. **Terrain:** Small escarpment on coastal headland. **Roughness**: Spruce and Red Cedar. **Prevailing Wind Direction:** SE – SW **Magnetic Declination**: 25 degrees East **Tower Height**: 30 meters **Sensor Levels**: 30 and 20 meters **Logger**: 4410
Site Name: B YakMet Beach 001 **Latitude**: 59° 32.881' N **Longitude:** 139° 48.525' W **Elevation**: 6 feet. **Terrain:** Gradually sloping beach **Roughness**: Spruce and Cedar **Prevailing Wind Direction:** East -Southeast **Magnetic Declination**: 25 degrees East **Tower Height**: 30 meters **Sensor Levels**: 30 and 20 meters **Logger:** 4409
Site Name: C YakCoast Guard 003 **Latitude**: 59° 32.881' N **Longitude:** 139° 48.525' W **Elevation**: 20 feet. **Terrain:** Gradually sloping beach **Roughness**: Spruce and Cedar **Prevailing Wind Direction:** Southeast -Southwest **Magnetic Declination**: 25 degrees East **Tower Height**: 30 meters **Sensor Levels**: 30 and 20 meters **Logger:** 4408

DATA COLLECTION

Data is sent by email to this consultant office in Portland, Oregon, which uses NRG data collection software and stores binary and ASCI data files for further analysis. The averaging interval of the data logger is 10-minutes, but the data analysis uses hourly data. The raw data remains in 10-minute intervals.

DATA RECOVERY

Data recovery was over 99% for two of the sites and 92% for the Ocean Cape site which had some data logger problems in October 2004.

CLIMATOLOGY

A climatological analysis is an important part of the wind resource validation study. Typically, a wind resource assessment is conducted for a period of only one to two years prior to installing wind turbines. A general rule is that a year of data is sufficient to estimate the mean annual wind speed to within ±10% at the 90% confidence level. This means that the annual energy output may be off by 20 to 25%. To increase the confidence in the relatively short record of data at the candidate site, data at a nearby long-term reference site can be analyzed.

The approach in the climatological analysis is to select a nearby reference station with a long-term record that would provide information on annual and seasonal variation in the wind resource. For this report the Yakutat upper air data was used because it was thought to provide a climatology unaffected by population and development growth in the area or changes in measurement equipment. Data near the surface (400 foot) was used to determine a correction for seasonality and interannual variation. Table 3 shows that while there were some significant departures from normal during the year, on average the winds during the measurement period were normal.

Table 3 Upper Air Data at 400 feet.

	400 foot data												
year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1998	2.7	4.1	2.6	4.5	4.8	3.2	3.6	4.6	3.7	3.2	2.1	3.9	3.8
1999	2.5	3.3	3.5	4.8	4.0	3.5	3.6	4.5	5.7	5.5	3.7	6.8	4.3
2000	3.4	2.9	3.9	3.8	3.8	3.6	3.0	3.8	4.5	3.6	4.8	4.8	3.8
2001	5.4	3.0	4.6	3.7	4.3	2.9	3.7	2.5	4.3	3.6	4.2	3.0	3.7
2002	4.7	3.7	5.1	3.2	3.3	3.9	3.7	3.7	3.6	4.8	5.6	2.6	4.0
2003	3.4	3.7	4.2	3.0	3.3	3.3	3.1	3.4	3.4	3.9	3.0	3.5	3.4
2004	3.9	4.7	4.3	4.3	2.9	3.1	2.9	2.8	4.1	4.3	3.9	5.2	3.8
2005	3.5	4.9	4.8	3.4	3.1	2.7	2.9						3.8
Mean	3.7	3.8	4.1	3.8	3.7	3.3	3.3	3.6	4.2	4.1	3.9	4.3	3.8
Period of Measurement													
2004							2.9	2.8	4.1	4.3	3.9	5.2	
2005	3.5	4.9	4.8	3.4	3.1	2.7	2.9						
Mean for Measurement Period	3.5	4.9	4.8	3.4	3.1	2.7	2.898	2.8	4.1	4.3	3.9	5.2	3.8
Departure from Normal	-6%	30%	16%	-11%	-15%	-18%	-12%	-22%	-2%	4%	0%	23%	0%

DATA ANALYSIS

Tables 4-6 and Figures 5-7 summarize the important statistics measured to date. In addition to measured average speed, wind direction, temperature and extreme wind speed other statistics derived measurements such as shear, turbulence, and 60 and 80 meter wind speeds. Several statistics stand out – one is that despite the low average wind speed, the extreme wind speeds are very high. All three locations have similar mean annual wind speeds at 30 meters to the long-term airport site, despite the airport anemometer being only 10 meters above ground.

The vertical wind variation is large at all but the Beach site, which is right near the bay. Based on the roughness near the met towers the shear at all three sites should be closer to 0.26. Using a shear value of 0.26 to extrapolate to 60 meters the annual Gross Capacity Factor should be close to 12%.

The turbulence intensity is high at all three sites. The wind roses show that there is no wind flow from the north down the bay and no onshore flow from the west. Based on the data collected, the best location for a turbine would be south of the airport or slightly off shore with good exposure to the southeast. A location south of the airport would have some conflicts with aviation as the FAA may require turbines to be 40 machine heights (about a two mile exclusion zone) from either approach end of the runway. The runways are oriented SE-NW and SW-NE. The feasibility of an offshore project would depend on the cost of underwater cables and the depth of the water.

Table 4 Statistics for Met A Ocean Cape site.

mon	30m V	Max Gust	Red 30m V	20m V	Temp	Shear	60m V m/s	80m V m/s	Count	Recovery Rate
Jul-04	6.05	38.5	6.60	6.32	57.6	0.058	2.99	3.22	216	100%
Aug-04	5.73	41.9	6.28	5.81	59.6	0.157	2.99	4.98	744	100%
Sep-04	9.23	60.6	9.72	9.17	50.9	0.100	4.69	6.02	717	100%
Oct-04	9.24	58.9	9.72	8.38	48.4	0.415	5.36	5.86	215	29%
Nov-04	9.09	62.5	9.63	8.43	37.6	0.419	5.22	6.41	657	91%
Dec-04	10.32	58.9	10.76	9.55	34.9	0.360	5.77	5.03	738	99%
Jan-05	7.42	59.8	7.97	6.75	32.3	0.455	4.46	5.11	731	98%
Feb-05	9.31	54.6	9.77	8.43	32.9	0.431	5.44	6.14	671	100%
Mar-05	8.56	52.1	9.03	7.95	38.4	0.332	4.86	5.40	742	100%
Apr-05	7.17	52.1	7.76	6.91	43.2	0.304	4.02	4.47	720	100%
May-05	6.57	45.2	6.91	5.82	51.7	0.599	4.27	5.26	744	100%
Jun-05	6.96	27.3	7.32	6.97	56.5	0.165	3.43	3.61	720	100%
Jul-05	6.86	28.2	7.07	6.61	58.9	0.286	3.51	3.75	277	100%
Average	**7.88**	**62.5**	**8.35**	**7.47**	**46.4**	**0.31**	**4.38**	**5.02**	**7892**	**92%**
Expected Annual Wind Speed m/s	**3.52**						**4.22**	**4.55**		
Expected Annual Gross Capacity Factor at 60 meters							**13%**			

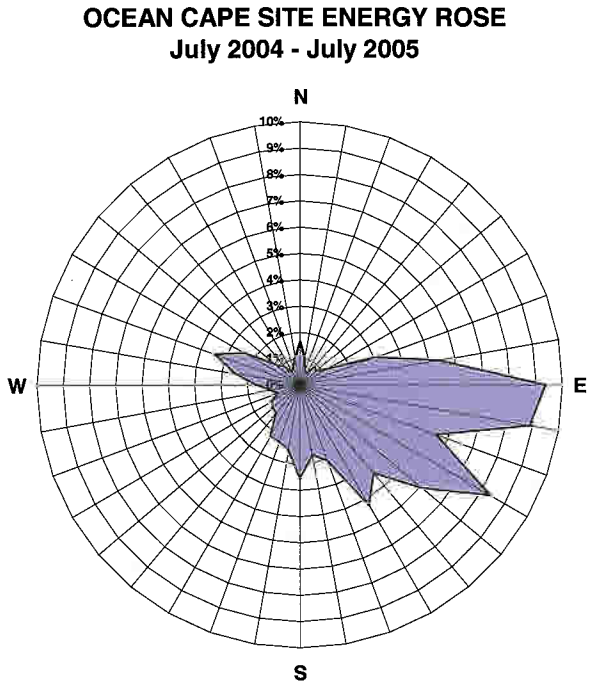

Figure 5 Energy Rose for Ocean Cape Site 1.

Table 5 Statistics for Met B Beach site.

Month	30m V	Max Gust	TI	Red 30m V	20m V	Shear	60m V m/s	80m V m/s	Count	Data Recovery Rate
Jul-04	6.3	35.9	0.139	6.51	6.35	0.004	2.9	2.9	175	100%
Aug-04	4.5	41.0	0.156	4.89	4.66	0.047	2.1	2.1	744	100%
Sep-04	7.4	51.3	0.161	7.45	7.34	0.060	3.5	3.6	718	100%
Oct-04	7.9	55.5	0.145	7.82	7.81	0.062	3.7	3.8	737	99%
Nov-04	8.9	51.3	0.156	8.64	8.50	0.106	4.3	4.5	720	100%
Dec-04	8.6	45.2	0.165	8.42	8.22	0.128	4.2	4.4	744	100%
Jan-05	6.2	44.4	0.140	6.04	6.00	0.137	3.1	3.2	744	100%
Feb-05	8.4	52.9	0.146	8.50	8.47	0.073	4.0	4.1	672	100%
Mar-05	8.8	42.7	0.151	8.61	8.60	0.098	4.2	4.4	739	99%
Apr-05	6.8	44.4	0.136	6.51	6.39	0.146	3.5	3.7	718	100%
May-05	5.6	41.9	0.173	5.40	5.55	-0.085	2.6	2.7	744	100%
Jun-05	5.6	25.6	0.186	5.30	5.51	-0.089	2.6	2.7	720	100%
Jul-05	5.4	26.4	0.175	5.07	5.23	-0.078	2.6	2.6	279	100%
Mean	6.9	55.5	0.16	6.86	6.82	0.05	3.33	3.45	8454	99.8%
Expected Annual Wind Speed m/s	3.10						3.71	4.00		
Expected Annual Gross Capacity Factor at 60 meters							12%			

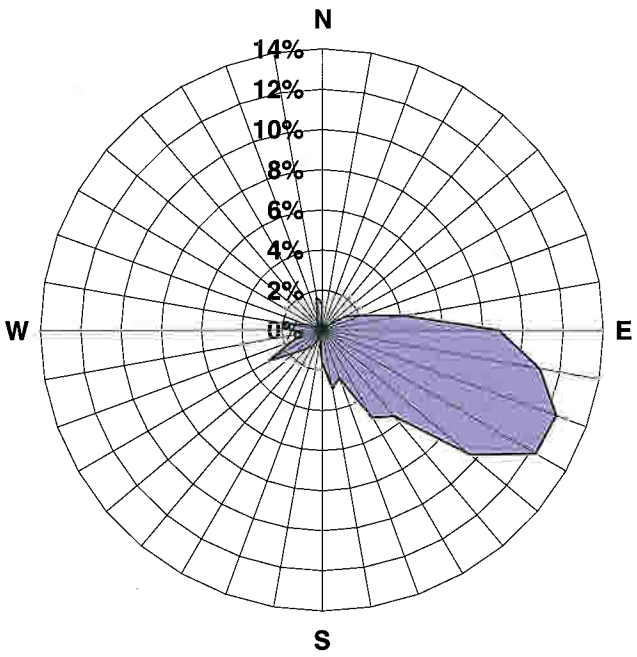

Figure 6 Energy Rose for Beach Site 2.

Table 6 Statistics for Met C Coast Guard Site.

mon	30m V	Max Gust	TI	Red 30m V	20m V	Temp	Shear	60m V m/s	80m V m/s	Count	Recovery Rate
Jul-04	6.1	38.5	0.200	5.8	5.7	57.1	0.169	3.2	3.5	198	100%
Aug-04	5.2	40.1	0.140	4.8	4.4	58.7	0.426	3.3	3.9	742	100%
Sep-04	8.6	60.6	0.151	8.1	7.2	49.4	0.472	5.2	6.1	719	100%
Oct-04	7.7	58.9	0.184	7.2	6.1	42.2	0.572	5.1	6.1	742	100%
Nov-04	8.9	65.7	0.154	8.4	7.3	36.7	0.615	5.7	6.8	718	100%
Dec-04	9.7	53.8	0.122	9.1	8.2	33.4	0.564	5.9	6.9	713	96%
Jan-05	7.1	54.6	0.147	6.3	5.4	28.9	0.655	5.0	6.2	725	97%
Feb-05	9.0	59.8	0.167	8.3	7.3	31.7	0.592	5.8	6.8	658	98%
Mar-05	8.4	50.4	0.195	8.1	7.1	37.6	0.472	5.1	5.9	734	99%
Apr-05	6.3	50.4	0.188	5.9	5.3	41.9	0.481	4.0	4.8	720	100%
May-05	5.6	17.0	0.071	5.2	4.8	48.0	0.648	4.0	5.4	744	100%
Jun-05	7.0	25.6	0.105	6.1	5.7	54.4	0.735	5.0	6.6	720	100%
Jul-05	6.4	27.3	0.102	5.6	5.0	57.5	0.830	4.9	6.6	325	100%
Mean	7.7	65.7	0.165	7.2	6.4	41.8	0.502	4.8	5.7	2837	99.1%
Expected Annual Wind Speed m/s	3.44							4.12	4.45		
Expected Annual Gross Capacity Factor at 60 meters								12%			

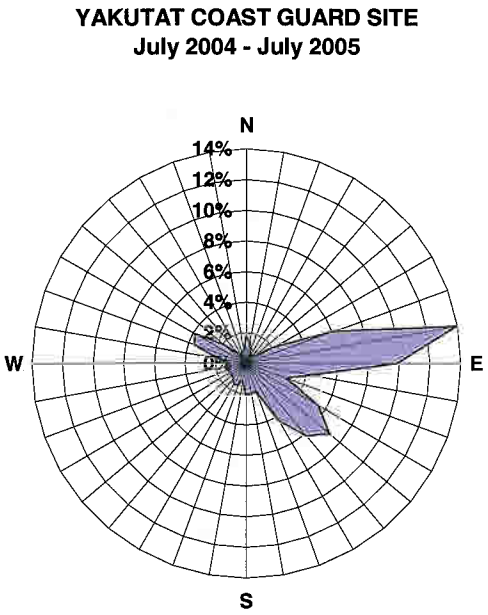

Figure 7 Energy Rose for Coast Guard Site 3.

Diurnal Variation

The diurnal variation of wind speed shows very little amplitude even in the summer months when thermal effects in the lower 48 states create large diurnal variations (see Figure 8). In the summer the peak is later in the day than in the spring or fall. Winter characteristically is a season of little diurnal variation and it is true at Yakutat.

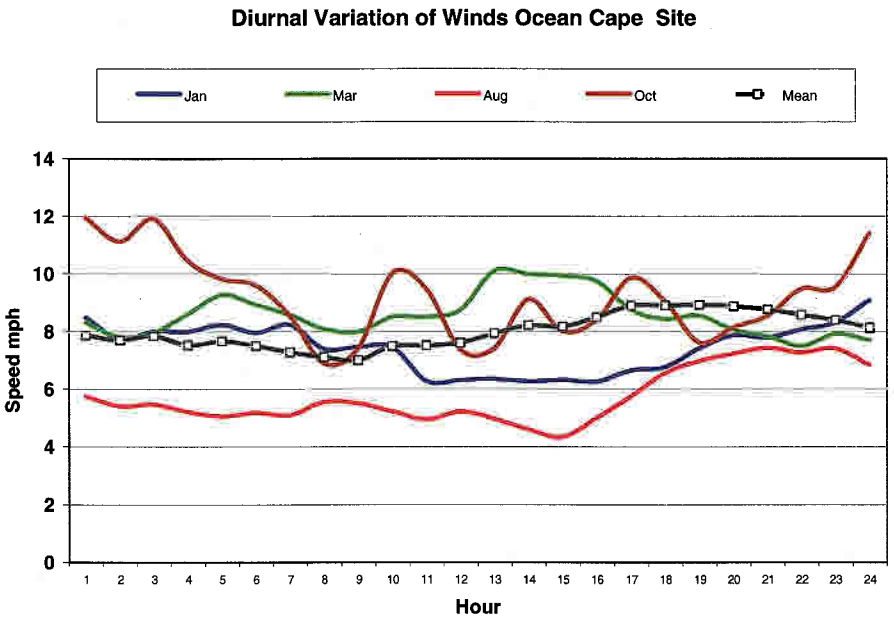

Figure 8 Hourly Wind Speed Variations

Conclusions

Based on the data collected so far, a modern wind turbine like a GE 1500 kW machine would achieve a gross Capacity Factor (CF) of about 12% at all three sites at a hub height of 60 meters. Since this machine has a very aggressive power curve, one could expect worse results from other available machines in the 600 kW size range.