Appendix I: Wind Energy Resource Reports

I-A. Buckland

September 2010 Buckland Wind Resource Report, V3 Energy
Buckland site wind report, New Roots Energy

I-B. Deering

September **2010 Deering Wind Resource Report, V3 Energy**

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August 2010 Ambler Windographer summary report, WHPacific

Appendix I-A: Buckland

September 2010 Buckland Wind Resource Report, V3 Energy

Buckland site wind report, New Roots Energy

Buckland Wind Resource Report

By: Douglas Vaught, P.E., V3 Energy LLC, Eagle River, Alaska
Date: September 17, 2010

Buckland met tower; D. Vaught photo

Contents

Summary

The wind resource measured at the new Buckland site is good with at mid-wind power Class 3. The met tower site experiences low turbulence conditions but is subject to storm winds that raise the probability of extreme wind events higher than one might otherwise expect from a Class 3 site. Met tower site selection (new site) in Buckland was based on results of a previous met tower study at a site immediately south of the village which showed very quiet Class 1 to 2 winds. The new site is more exposed and at a much higher elevation than the village but distant from the village compared to the previous site.

Met tower data synopsis

Data dates	June 11, 2008 to March 13, 2010 (21 months)
Wind Power Class	Mid Class 3 (fair)
Power density mean, 30 meters	302 W/m^2
Wind sped mean, 30 meters	5.58 m/s
Max. 10-minute wind speed average	39.6 m/s
Maximum wind gust	44.3 m/s (January 2009)
Weibull distribution parameters	K = 1.53, c = 6.22 m/s
Wind shear power law exponent	0.0717
Roughness class	0.00
Turbulence intensity, mean	0.082
IEC 61400-1, 3rd ed. classification	Class II-C

Community profile

Current Population:	432 (2009 DCCED Certified Population)
Incorporation Type:	2nd Class City
Borough Located In:	Northwest Arctic Borough
Taxes:	Sales: 6% (City), Property: None, Special: None
National Flood Insurance Program Participant:	Yes
Coastal Management District:	Northwest Arctic Borough

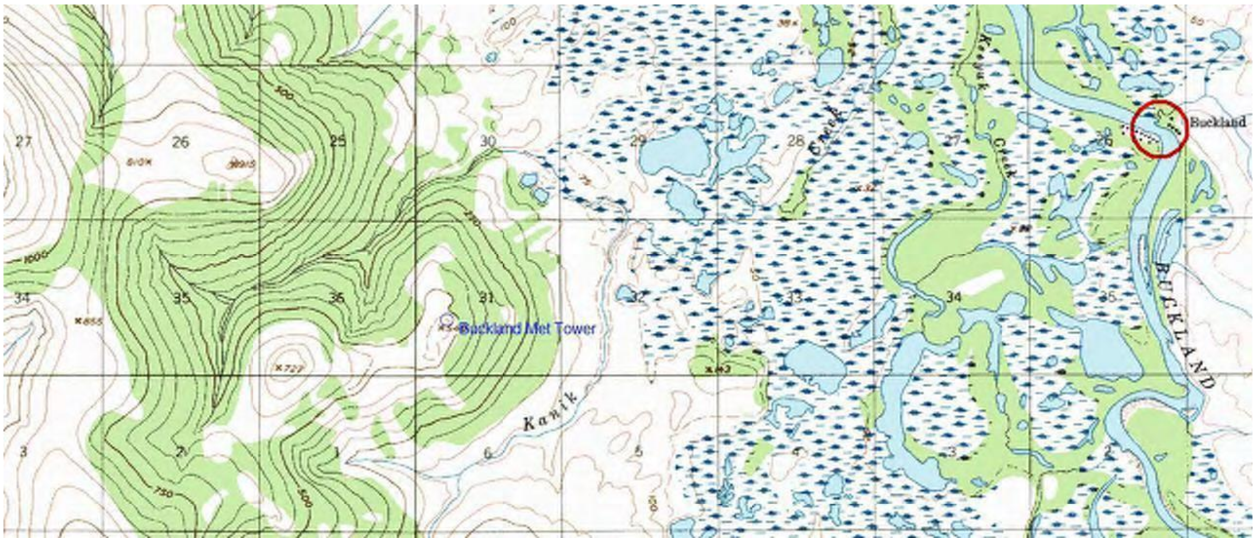
Test Site Location

The met tower was located 7 km (4.5 miles) from the western edge of the village on a plateau of the first significant hill of a north-south trending boundary range of high hills separating the river drainage where Buckland is located from Seward Peninsula to the west. The site is at 143 meters elevation but a higher hill a few kilometers west is 430 meters high. Conveniently, the site is located immediately above a rock quarry constructed to upgrade the village airport and hence an excellent road exists across the marshy bottomland separating the met tower site from the village.

Site information

Site number	5063
Latitude/longitude	N 63° 57.724’, W 161° 17.111’
Site elevation	143 meters
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 30-meter tall tower, 152 mm (6 inch) diameter
Anchor type	DB88 duckbill

Topographic map image



Google Earth image

Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.765	0.35	110° T
2	NRG #40 anemometer	30 m (B)	0.765	0.35	305° T
3	NRG #40 anemometer	20 m	0.765	0.35	110° T
7	NRG #200P wind vane	30 m	0.351	220	040° T
9	NRG #110S Temp C	2 m	0.136	-86.383	N

Photographs

Installation crew; D. Vaught photo

Old met tower site in Buckland; D. Vaught photo

Transporting tower parts to site; D. Vaught photo

Raising the met tower; D. Vaught photo

Data Recovery

The quality of data from the (new) Buckland met tower was acceptable to describe the essentials of the wind resource, but unfortunately the temperature sensor never worked properly and data from it was deleted. Temperature data from the airport AWOS was substituted for this report. Also, the 30 meter B anemometer often exhibited odd behavior which necessitated deleted a higher percentage of its data than from the other sensors. For the remaining sensors, the relatively minor data loss was due to apparent winter icing events. Although the met tower site is at an elevation potentially susceptible to rime icing conditions, rime ice does not appear to a factor in the data loss which likely is attributable to freezing rain and sleet conditions.

Data recovery summary table

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)
Speed 30 m A	m/s	30 m	92,250	89,623	97.2
Speed 30 m B	m/s	30 m	92,250	83,390	90.4
Speed 20 m	m/s	20 m	92,250	89,919	97.5
Direction 30 m	°	30 m	92,250	87,247	94.6
Temperature	°C		92,250	0	0.0

Anemometer data recovery

			30 m A		30 m B		20 m	
Year	Month	Possible Records	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)
2008	Jun	2,970	2,805	94.4	2,805	94.4	2,805	94.4
2008	Jul	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2008	Aug	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2008	Sep	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2008	Oct	4,464	4,265	95.5	4,315	96.7	4,315	96.7
2008	Nov	4,320	3,463	80.2	3,548	82.1	3,590	83.1
2008	Dec	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Jan	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Feb	4,032	4,032	100.0	3,472	86.1	4,032	100.0
2009	Mar	4,464	4,464	100.0	3,626	81.2	4,464	100.0
2009	Apr	4,320	4,320	100.0	3,948	91.4	4,320	100.0
2009	May	4,464	4,271	95.7	3,848	86.2	4,464	100.0
2009	Jun	4,320	4,320	100.0	4,227	97.9	4,320	100.0
2009	Jul	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Aug	4,464	4,464	100.0	4,230	94.8	4,464	100.0
2009	Sep	4,320	4,320	100.0	4,199	97.2	4,320	100.0
2009	Oct	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Nov	4,320	3,706	85.8	3,644	84.4	3,706	85.8
2009	Dec	4,464	4,418	99.0	3,781	84.7	4,464	100.0
2010	Jan	4,464	4,464	100.0	3,673	82.3	4,464	100.0
2010	Feb	4,032	3,479	86.3	2,604	64.6	3,359	83.3
2010	Mar	1,728	1,728	100.0	366	21.2	1,728	100.0
All data		92,250	89,623	97.2	83,390	90.4	89,919	97.5

Wind Speed

Wind data collected from the met tower, from the perspective of mean wind speed and mean wind power density, indicates a good wind resource for wind power development. Although not considered in the power density calculations because the temperature sensor was inoperative for the duration of the test period, the cold arctic winter temperatures in Buckland would increase wind power density above that reported below. Although not strictly necessary for this analysis, missing anemometer data was synthesized to illustrate a more complete wind profile, especially for the 30 meter B (channel 2) sensor. The synthetic data results in some curve smoothing, but does not significantly change the analysis.

Anemometer data summary

	Original Data			Synthesized data		
Variable	Speed 30 m A	Speed 30 m B	Speed 20 m	Speed 30 m A	Speed 30 m B	Speed 20 m
Measurement height (m)	30	30	20	30	30	20
Mean wind speed (m/s)	5.65	5.27	5.51	5.64	5.64	5.50
Max 10-min avg wind speed (m/s)	39.2	39.6	38.0			
Max gust wind speed (m/s)	43.6	44.3	43.9			
Weibull k	1.53	1.67	1.54	1.53	1.55	1.54
Weibull c (m/s)	6.22	5.85	6.06	6.20	6.19	6.04
Mean power density (W/m²)	302	210	278	300	293	275
Mean energy content (kWh/m²/yr)	2,646	1,842	2,432	2,629	2,567	2,409
Energy pattern factor	2.78	2.41	2.76	2.78	2.72	2.76
1-hr autocorrelation coefficient	0.895	0.867	0.893	0.894	0.892	0.893
Diurnal pattern strength	0.070	0.073	0.075	0.068	0.07	0.076
Hour of peak wind speed	17	17	16	17	17	16

Time Series

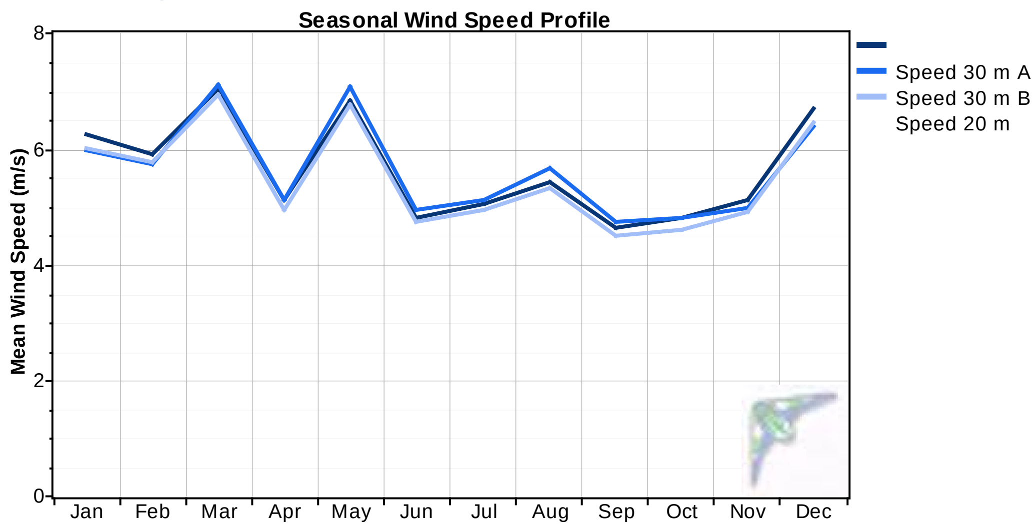
As is the typical rule in Alaska, the Buckland met tower site experiences higher winds in the winter compared to summer. The higher winds of March and May compared to April are likely a measurement artifact that would smooth out with a multi-year data view.

30m A anemometer data summary

		Original 30 m A Data					Synth Data Added	
Year	Month	Mean (m/s)	Max 10-min avg (m/s)	Max gust (m/s)	Weibull k (-)	Weibull c (m/s)	Mean (m/s)	Ratio: synth to original mean spd (-)
2008	Jun	4.98	15.1	16.8	1.79	5.58	4.88	98.1%
2008	Jul	5.62	15.5	18.7	2.02	6.33	5.62	100.0%
2008	Aug	4.88	17.9	21.8	1.74	5.47	4.88	100.0%
2008	Sep	4.72	16.1	17.9	1.77	5.29	4.72	100.0%

2008	Oct	4.73	15.3	18.3	1.70	5.29	4.63	97.9%
2008	Nov	5.49	16.0	19.1	2.19	6.17	5.36	97.7%
2008	Dec	6.53	22.2	26.0	1.93	7.33	6.53	100.0%
2009	Jan	6.45	39.2	43.6	1.19	6.85	6.45	100.0%
2009	Feb	7.93	30.6	35.2	1.35	8.64	7.93	100.0%
2009	Mar	7.27	27.2	30.9	1.64	8.12	7.27	100.0%
2009	Apr	5.11	21.0	28.7	1.29	5.52	5.11	100.0%
2009	May	6.71	19.7	24.0	1.93	7.57	6.83	101.8%
2009	Jun	4.75	17.3	21.4	1.75	5.34	4.75	100.0%
2009	Jul	4.49	18.7	22.1	1.80	5.07	4.49	100.0%
2009	Aug	5.94	26.7	31.3	1.71	6.68	5.94	100.0%
2009	Sep	4.54	20.9	25.2	1.58	5.05	4.54	100.0%
2009	Oct	4.95	14.3	17.6	1.68	5.52	4.95	100.0%
2009	Nov	4.90	17.4	21.4	1.61	5.48	4.85	99.0%
2009	Dec	6.94	22.3	24.4	1.58	7.68	6.89	99.3%
2010	Jan	6.06	21.1	22.6	1.61	6.75	6.06	100.0%
2010	Feb	3.70	16.9	20.6	1.38	4.05	3.86	104.2%
2010	Mar	6.46	22.0	27.1	1.19	6.83	6.46	100.0%
MMM Annual		5.65	39.2	43.6	1.53	6.22	5.64	99.8%

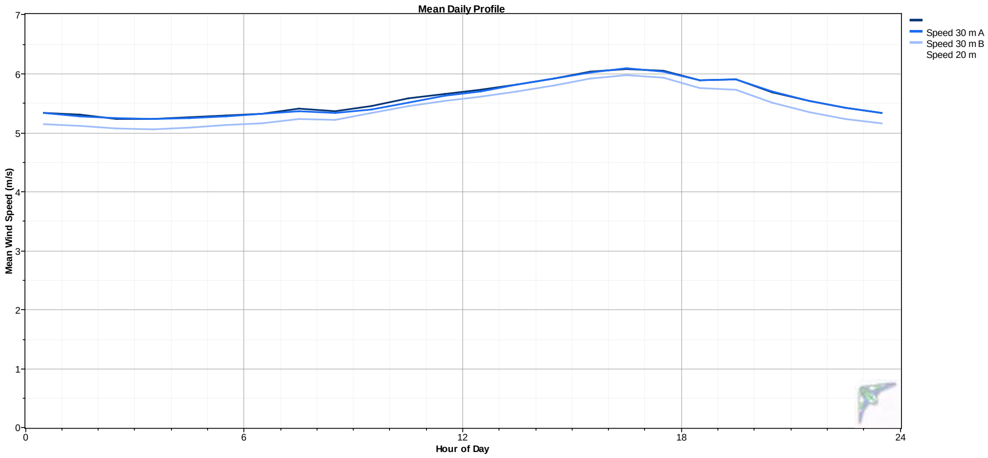
Time series graph (synth. data)



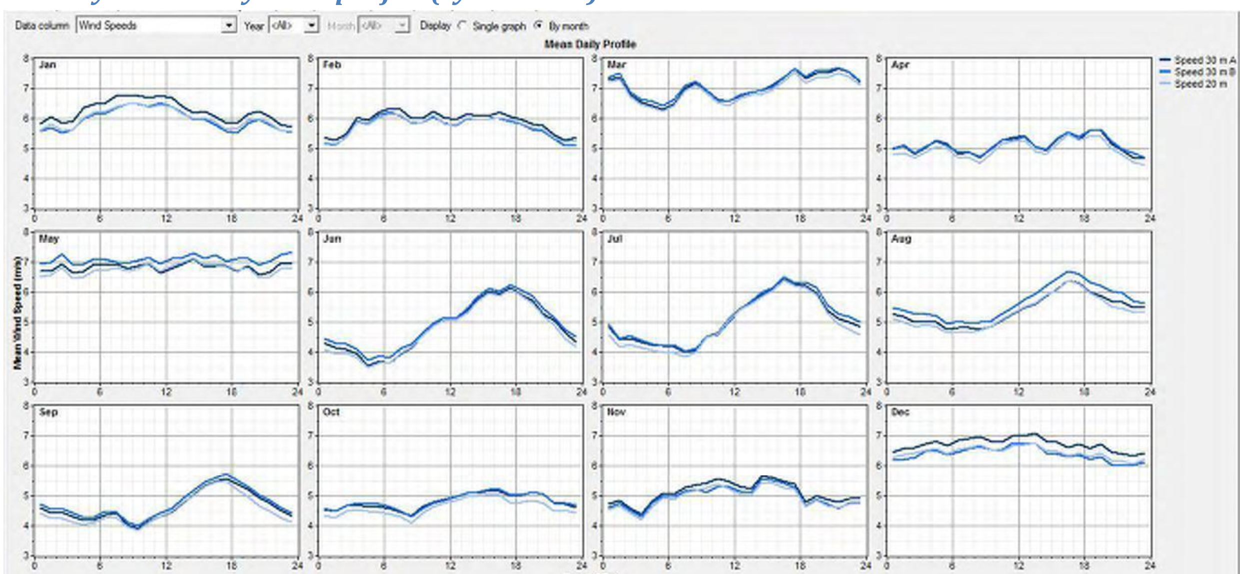
Daily Wind Profile

The average daily wind profile in Buckland indicates somewhat significant diurnal variability of wind speeds throughout the day, with lowest wind speeds in the very early morning hours and highest wind speeds during late afternoon. This coincides nicely of course with typical electrical energy usage patterns.

Annual-basis daily wind profile (synth. data)



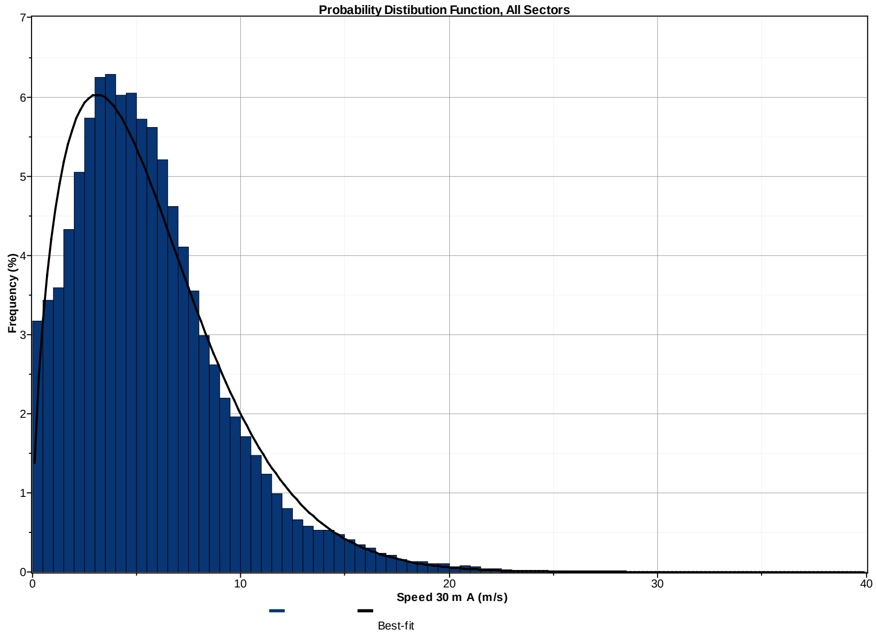
Monthly-basis daily wind profile (synth. data)



Probability Distribution Function

The probability distribution function (PDF), or histogram, of the 30 meter A wind speeds indicates wind speed "bins" oriented toward the lower speeds compared to a normal wind power shape curve of k=2.0, otherwise known as the Raleigh distribution. Note in the cumulative frequency table below that 37.8 percent of the winds are less the 4 m/s, the cut-in wind speed of most wind turbines.

PDF of 30 m A anemometer



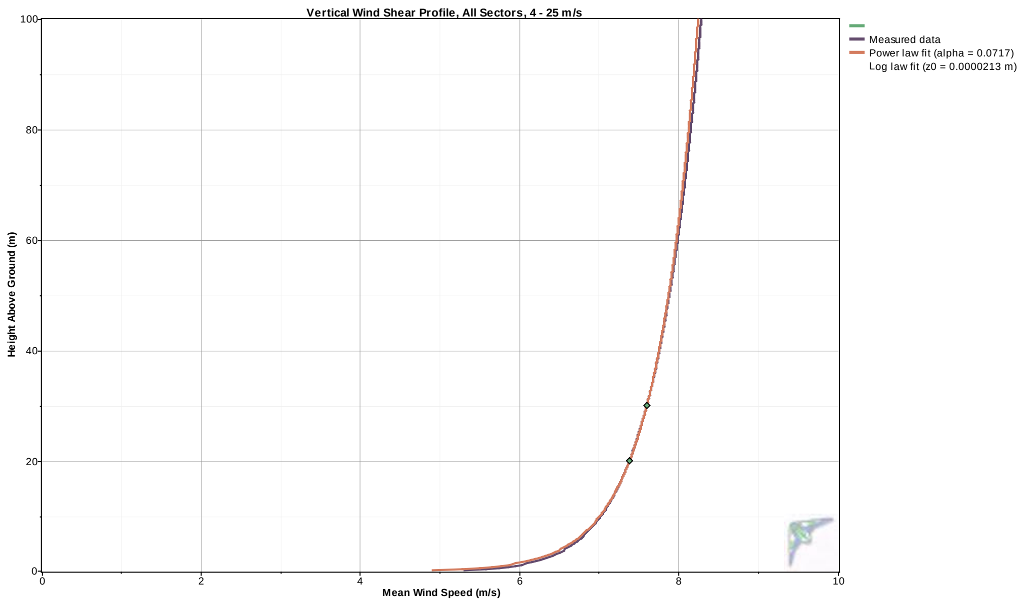
Cumulative frequency table

Bin (m/s) Lower	Bin (m/s) Upper	Occurrences	Freq. (%)	Cum. Freq. (%)	Bin (m/s) Lower	Bin (m/s) Upper	Occurrences	Freq. (%)	Cum. Freq. (%)
0	1	5,911	6.60	6.60	21	22	100	0.11	99.8
1	2	7,092	7.91	14.5	22	23	54	0.06	99.8
2	3	9,654	10.77	25.3	23	24	33	0.04	99.8
3	4	11,219	12.52	37.8	24	25	20	0.02	99.9
4	5	10,815	12.07	49.9	25	26	28	0.03	99.9
5	6	10,152	11.33	61.2	26	27	23	0.03	99.9
6	7	8,801	9.82	71.0	27	28	21	0.02	99.9
7	8	6,848	7.64	78.7	28	29	11	0.01	100.0
8	9	5,013	5.59	84.2	29	30	5	0.01	100.0
9	10	3,725	4.16	88.4	30	31	5	0.01	100.0
10	11	2,855	3.19	91.6	31	32	6	0.01	100.0
11	12	1,983	2.21	93.8	32	33	2	0.00	100.0
12	13	1,306	1.46	95.3	33	34	3	0.00	100.0
13	14	992	1.11	96.4	34	35	5	0.01	100.0
14	15	894	1.00	97.4	35	36	3	0.00	100.0
15	16	665	0.74	98.1	36	37	2	0.00	100.0
16	17	478	0.53	98.6	37	38	1	0.00	100.0
17	18	330	0.37	99.0	38	39	1	0.00	100.0
18	19	238	0.27	99.3	39	40	1	0.00	100.0
19	20	194	0.22	99.5	All		89,623	100.0	100.0
20	21	134	0.15	99.6					

Wind Shear and Roughness

A wind shear power law exponent of 0.0717 indicates very low wind shear at the test site; hence wind turbine construction at a low hub height may be a desirable option. Related to wind shear, a calculated surface roughness of 9.08 EE-6 meters (the height above ground level where wind velocity would be zero) indicates extremely smooth terrain (roughness description: smooth) surrounding the met tower.

Vertical wind shear profile, 4 m/s < wind < 25 m/s



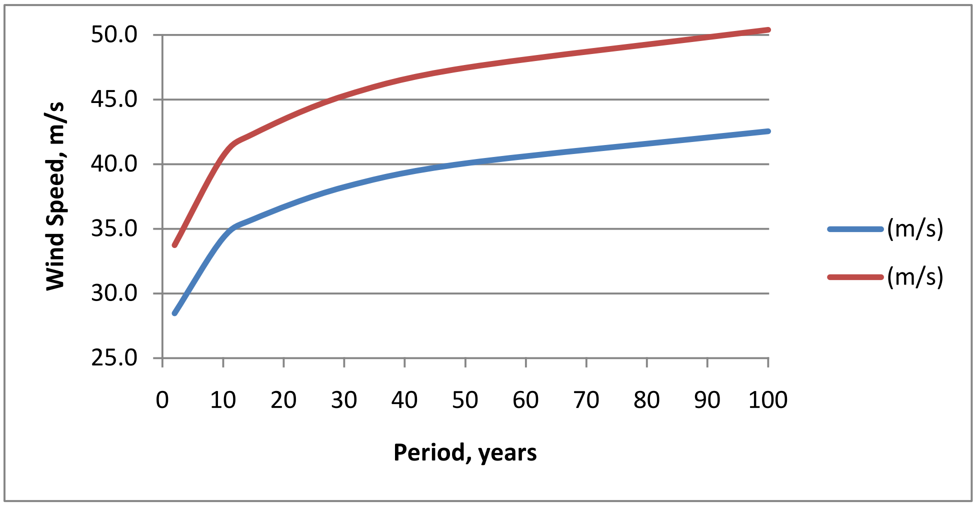
Extreme Winds

The relatively short duration of Buckland met tower data should be considered minimal for calculation of extreme wind probability, but nevertheless it can be estimated with a reasonable level of accuracy. Analysis indicates that Buckland experiences sufficiently robust storm and other high wind events to exceed IEC 61400-1, 3rd edition (2005), Class III criteria and hence classifies as an IEC Class II wind site.

Extreme wind speed probability table

	V_{ref}	Gust	IEC 61400-1, 3rd ed.	
Period (years)	(m/s)	(m/s)	Class	V_{ref}, m/s
2	28.5	33.7	I	50.0
10	34.3	40.6	II	42.5
15	35.7	42.3	III	37.5
30	38.2	45.3	S	designer-specified
50	40.0	47.5		
100	42.5	50.4		
average gust factor:	1.18			

Extreme wind probability graph



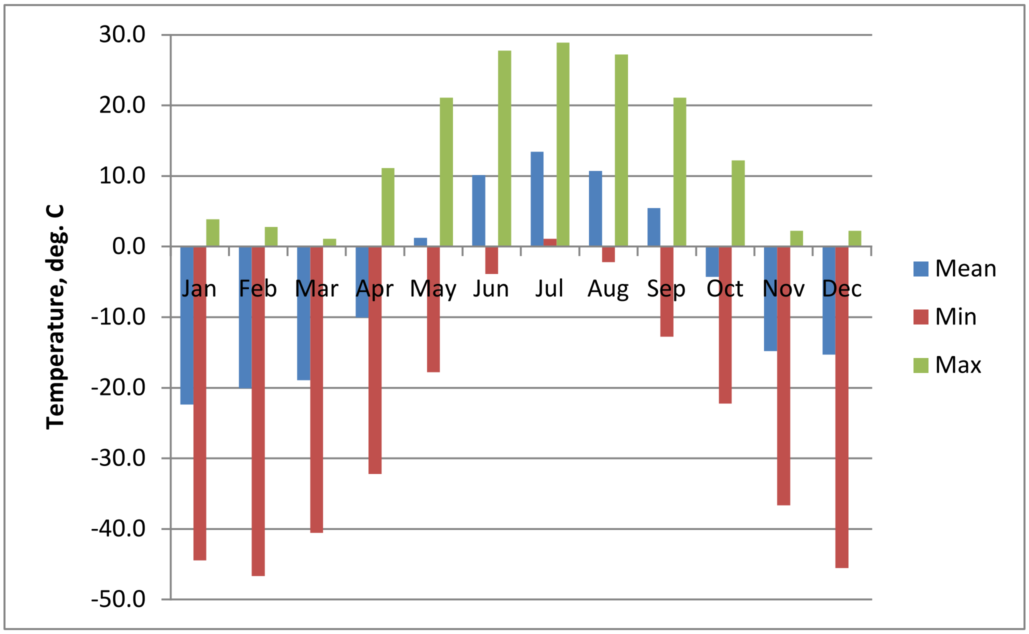
Temperature and Density

The temperature sensor on the met tower, for reasons not understood, did not work properly during the test period. Hence, temperature data from the Buckland airport AWOS are referenced below. This data represents a six year time period – July 2004 to July 2010. Air density was not directly measured, but calculated using standard pressure at eight meters (elevation of the airport) and the ideal gas law. Note that Buckland experiences a typical continental arctic climate with extremely cold winters and cool summers. On many occasions, temperatures colder than -40° C, the minimum operating temperature of arctic-rated wind turbines, were recorded. Of course, it is possible that the airport and village environs, due to inversion effects, experience colder temperatures than the higher elevation met tower site.

Temperature and density table

	Temperature			Air Density		
	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m^3)	Max (kg/m^3)	Min (kg/m^3)
Jan	-22.4	-44.4	3.9	1.407	1.543	1.273
Feb	-20.1	-46.7	2.8	1.394	1.558	1.278
Mar	-18.9	-40.6	1.1	1.388	1.517	1.286
Apr	-10.0	-32.2	11.1	1.341	1.464	1.241
May	1.2	-17.8	21.1	1.286	1.381	1.199
Jun	10.1	-3.9	27.8	1.245	1.310	1.172
Jul	13.4	1.1	28.9	1.231	1.286	1.168
Aug	10.7	-2.2	27.2	1.243	1.302	1.174
Sep	5.5	-12.8	21.1	1.266	1.355	1.199
Oct	-4.3	-22.2	12.2	1.312	1.406	1.236
Nov	-14.8	-36.7	2.2	1.365	1.492	1.281
Dec	-15.3	-45.6	2.2	1.368	1.550	1.281
Annual	-4.1	-46.7	28.9	1.311	1.558	1.168

Temperature graph



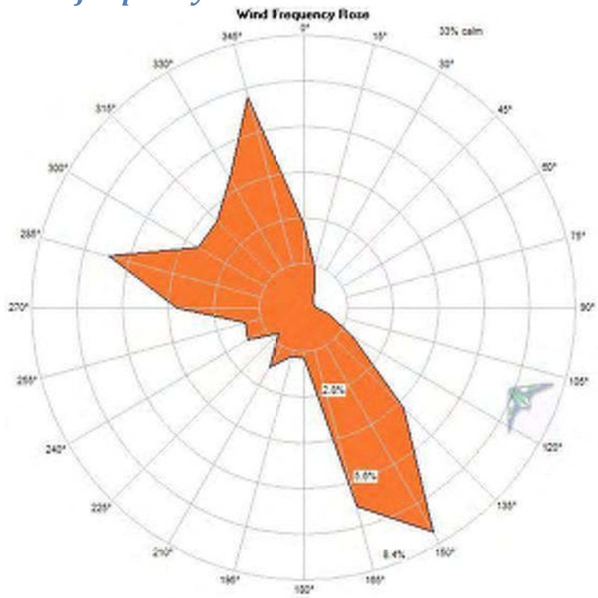
Temperature table, Fahrenheit and Celsius

	Temp (°F)			Temp (°C)		
	Mean	Min	Max	Mean	Min	Max
Jan	-8.3	-48	39	-22.4	-44.4	3.9
Feb	-4.1	-52	37	-20.1	-46.7	2.8
Mar	-2.1	-41	34	-18.9	-40.6	1.1
Apr	13.9	-26	52	-10.0	-32.2	11.1
May	34.2	0	70	1.2	-17.8	21.1
Jun	50.2	25	82	10.1	-3.9	27.8
Jul	56.2	34	84	13.4	1.1	28.9
Aug	51.3	28	81	10.7	-2.2	27.2
Sep	41.8	9	70	5.5	-12.8	21.1
Oct	24.3	-8	54	-4.3	-22.2	12.2
Nov	5.4	-34	36	-14.8	-36.7	2.2
Dec	4.5	-50	36	-15.3	-45.6	2.2
Annual	24.5	-52	84	-4.1	-46.7	28.9

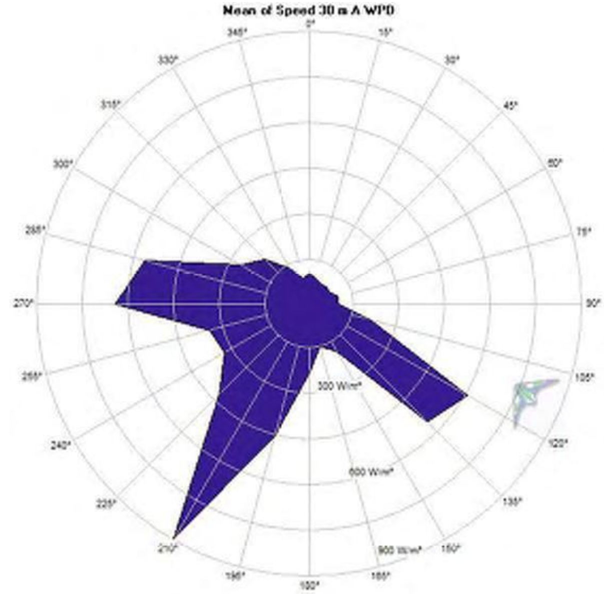
Wind Direction

The wind frequency rose for the Buckland test site indicates predominately southeast and west-northwest to north-northwest winds. Interestingly, though, although a minor frequency component, southwest winds, when present, are exceptionally strong. Integrating the two roses, one can see with the wind energy rose that predominate power winds are southwest and west-northwest with a lesser extent of southwest winds.

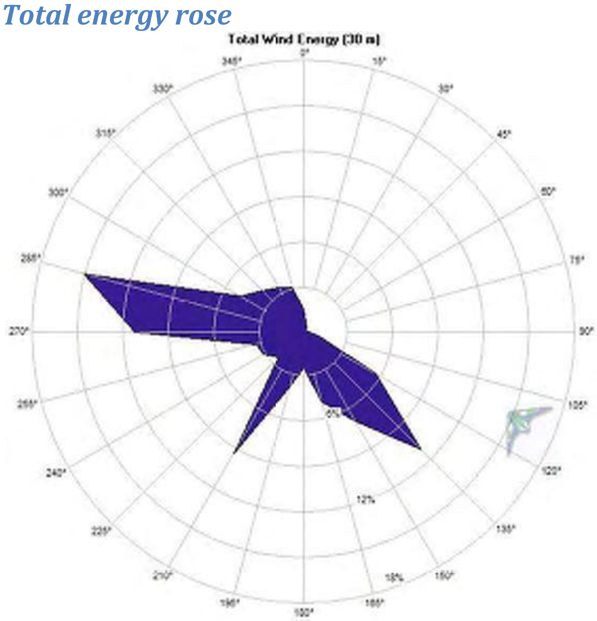
Wind frequency rose



Mean value rose



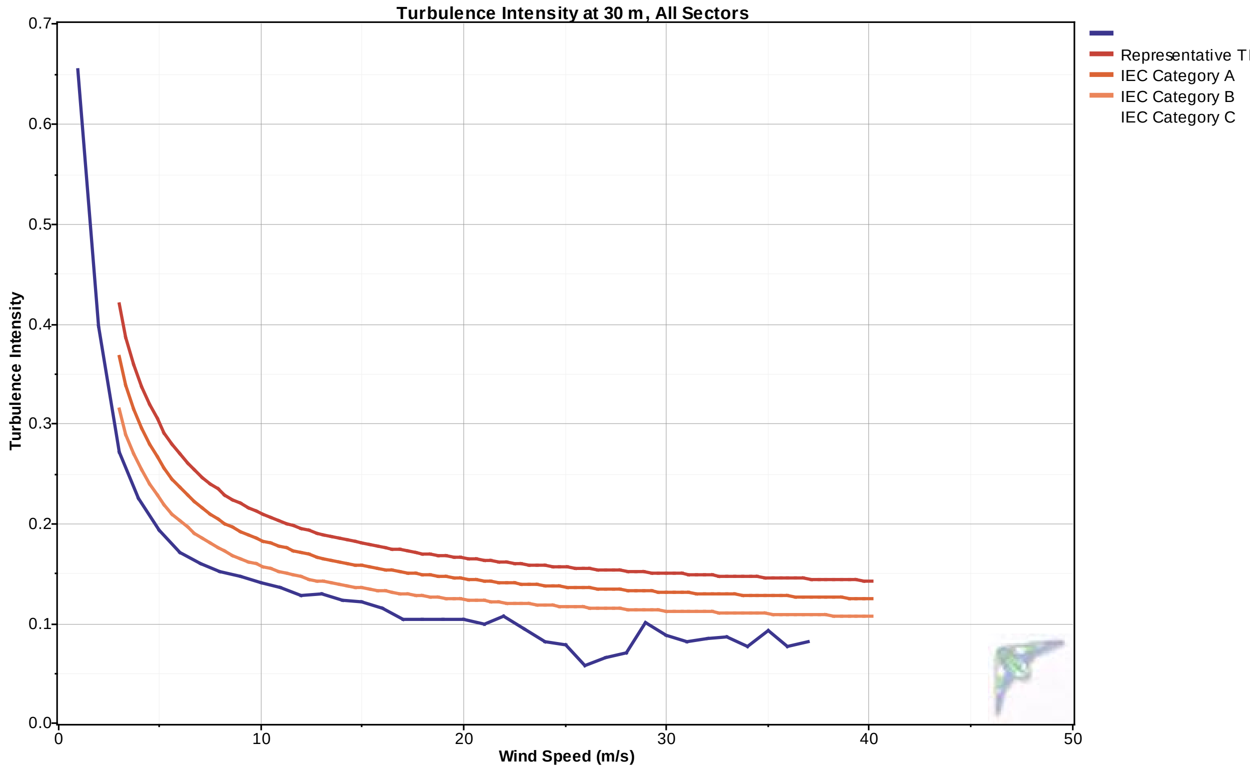
Total energy rose



Turbulence

Turbulence intensity at the Buckland test site is well within acceptable standards for wind power development with an International Electrotechnical Commission (IEC) 61400-1, 3rd edition (2005), classification of turbulence category C, which is the lowest defined. Mean turbulence intensity at 15 m/s is 0.082.

Turbulence intensity, all wind sectors



Turbulence table

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records In Bin	Mean TI	Standard Deviation of TI	Representative TI	Peak TI
1	0.5	1.5	6,284	0.436	0.170	0.653	1.286
2	1.5	2.5	8,398	0.238	0.125	0.397	1.063
3	2.5	3.5	10,723	0.162	0.086	0.271	0.840
4	3.5	4.5	11,024	0.135	0.070	0.225	0.821
5	4.5	5.5	10,542	0.119	0.059	0.194	0.851
6	5.5	6.5	9,696	0.107	0.050	0.170	0.500
7	6.5	7.5	7,803	0.102	0.045	0.159	0.412
8	7.5	8.5	5,846	0.099	0.041	0.152	0.407
9	8.5	9.5	4,316	0.096	0.040	0.147	0.441
10	9.5	10.5	3,287	0.093	0.037	0.140	0.379
11	10.5	11.5	2,430	0.090	0.035	0.135	0.342
12	11.5	12.5	1,595	0.087	0.032	0.127	0.244
13	12.5	13.5	1,108	0.088	0.033	0.130	0.228
14	13.5	14.5	940	0.084	0.030	0.122	0.353
15	14.5	15.5	789	0.082	0.030	0.121	0.260
16	15.5	16.5	568	0.078	0.029	0.115	0.261
17	16.5	17.5	398	0.073	0.024	0.103	0.171

18	17.5	18.5	265	0.072	0.024	0.103	0.178
19	18.5	19.5	213	0.071	0.025	0.104	0.229
20	19.5	20.5	159	0.070	0.027	0.104	0.181
21	20.5	21.5	132	0.066	0.025	0.098	0.145
22	21.5	22.5	75	0.071	0.028	0.107	0.207
23	22.5	23.5	36	0.069	0.020	0.095	0.124
24	23.5	24.5	26	0.059	0.018	0.081	0.115
25	24.5	25.5	24	0.056	0.018	0.078	0.102
26	25.5	26.5	27	0.049	0.007	0.058	0.066
27	26.5	27.5	25	0.052	0.011	0.065	0.071
28	27.5	28.5	15	0.058	0.010	0.070	0.074
29	28.5	29.5	7	0.080	0.016	0.100	0.109
30	29.5	30.5	4	0.073	0.012	0.087	0.083
31	30.5	31.5	4	0.072	0.007	0.081	0.081
32	31.5	32.5	4	0.073	0.008	0.084	0.085
33	32.5	33.5	4	0.077	0.007	0.087	0.087
34	33.5	34.5	3	0.071	0.004	0.076	0.076
35	34.5	35.5	3	0.082	0.009	0.093	0.090
36	35.5	36.5	4	0.065	0.008	0.076	0.075
37	36.5	37.5	2	0.069	0.009	0.081	0.075
38	37.5	38.5	0				
39	38.5	39.5	2	0.060	0.001	0.062	0.061
40	39.5	40.5	0				

Airport AWOS Data

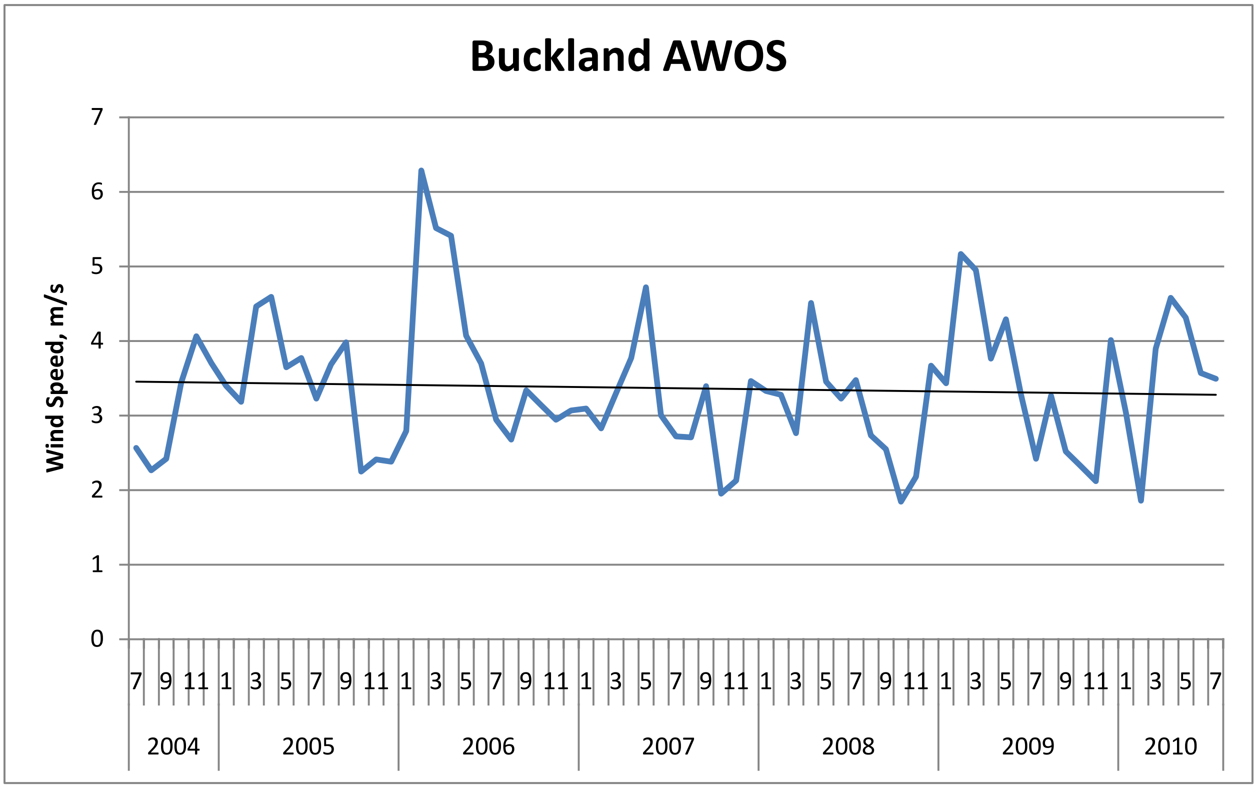
Analysis of Buckland airport AWOS wind speed data from July 2004 (date AWOS was installed) to July 2010 indicates that in general, the wind resource at the met tower site is significantly better than at the airport and presumably similar elevations in its vicinity. A trend of the AWOS data (see graph) indicates slightly decreasing average wind speeds from 2004 to 2010, but the time period is too short to be statistically significant enough to scale the met tower data against.

Airport/met tower data comparison

	AWOS, 10 m sensor (m/s)	AWOS data scaled to 30 m (m/s)	Met tower 30 m A (m/s)
Jan	3.20	3.73	6.25
Feb	3.65	4.26	5.89
Mar	4.02	4.69	7.04
Apr	4.39	5.12	5.11
May	4.10	4.78	6.83
Jun	3.42	3.99	4.81

Jul	3.02	3.52	5.05
Aug	2.99	3.49	5.41
Sep	3.05	3.56	4.63
Oct	2.41	2.81	4.79
Nov	2.58	3.01	5.11
Dec	3.43	4.00	6.71
Annual	3.34	3.90	5.64

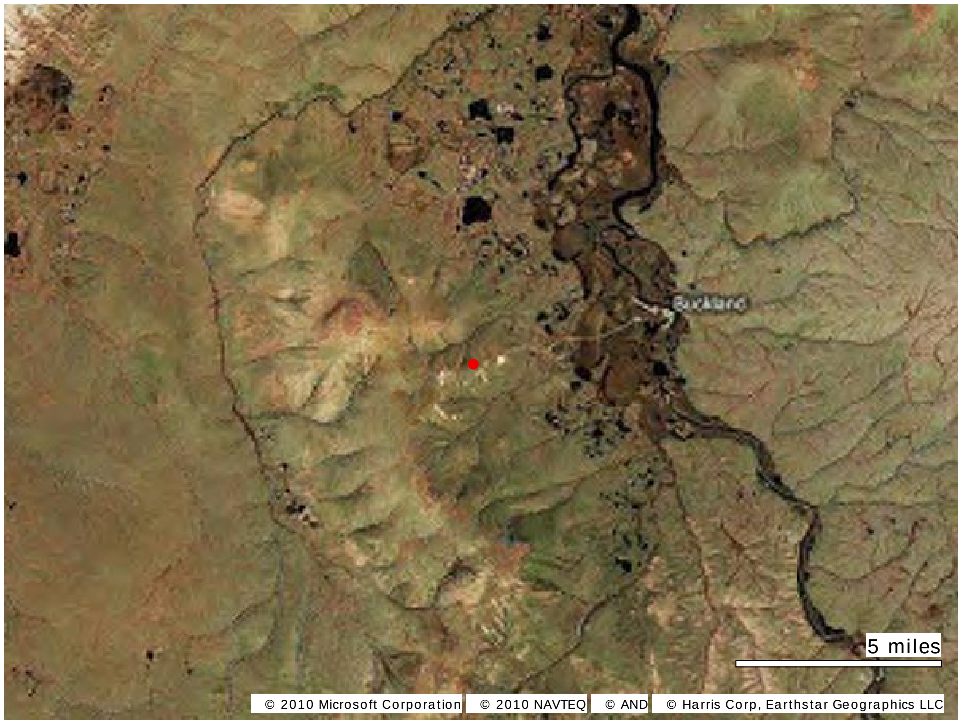
Buckland Airport AWOS wind speed graph



Wind Report by New Roots Energy

info@newrootsenergy.com | PMB 634, 11124 NE Halsey, Portland OR 97220

Turbine Production:



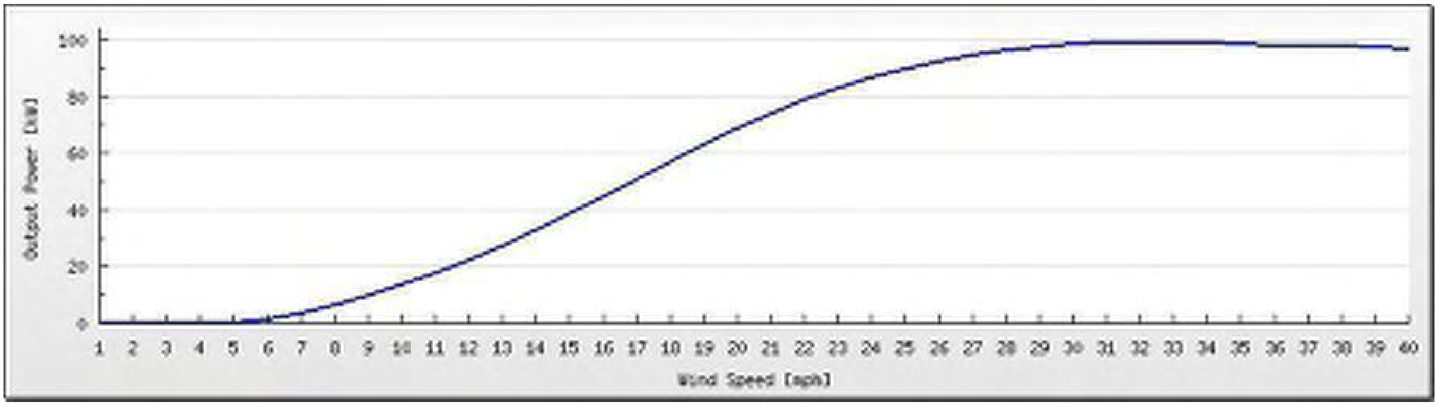
Turbine Selection	NW 100
Nameplate Capacity [kW]	100.0
Rotor Diameter [m]	21.0

Site Location:
65.961667° latitude
-161.288889° longitude

Average Wind Speed [mph]	11.88
Tower Height [ft]	120.0
Altitude [ft]	470.0
Weibull K	2.0
Wind Shear	0.12
Turbulence Factor [%]	0.0

Average Output Power [kW]	18.8
Daily Energy Output [kWh]	451.5
Monthly Energy Output [kWh]	13,733.7
Annual Energy Output [kWh]	164,804.9
Hub Average Wind Speed [mph]	11.9
Air Density Coefficient	1.0
Turbulence Coefficient	1.0
Operating Time [%]	70.9

Power Curve & Wind Distribution:



Wind Speed [m/s]	Wind Speed [mph]	Power [kW]	Wind Probability [%]	Net Power @ Voltage [kW]
1.0	2.2	0.0	5.46	0.00
2.0	4.5	0.0	10.04	0.00
3.0	6.7	0.0	13.09	0.00
4.0	8.9	3.6	14.34	0.52
5.0	11.2	10.3	13.92	1.43
6.0	13.4	18.6	12.26	2.29
7.0	15.7	28.9	9.93	2.86
8.0	17.9	40.2	7.45	3.00
9.0	20.1	53.3	5.20	2.77
10.0	22.4	65.6	3.39	2.22
11.0	24.6	76.3	2.07	1.58
12.0	26.8	84.8	1.18	1.00
13.0	29.1	91.1	0.63	0.58
14.0	31.3	95.5	0.32	0.31
15.0	33.6	98.1	0.15	0.15
16.0	35.8	98.9	0.07	0.07
17.0	38.0	98.7	0.03	0.03
18.0	40.3	97.9	0.01	0.01
19.0	42.5	97.5	0.00	0.00
20.0	44.7	96.8	0.00	0.00
			99.53	18.81

The Wind Report model is intended for providing budgetary estimates only. Actual turbine production at a particular location is dependent on a variety of factors that are outside the immediate control of New Roots Energy or are outside the scope of this model.

New Roots Energy has made every effort to insure the accuracy of the Wind Report turbine production and financial modeling tools. We recommend that the user verify the accuracy of the tools through independent analysis, considering the end client's specific circumstances. New Roots Energy will not be held responsible for errors or omissions in this model.

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Appendix I-B: Deering

September **2010 Deering Wind Resource Report, V3 Energy**

Deering Wind Resource Report

By: Douglas Vaught, P.E., V3 Energy LLC, Eagle River, Alaska
Date: September 17, 2010 (revision1)

Village of Deering; D. Vaught photo

Contents

Summary

The wind resource measured in Deering is good at high wind power Class 3. The met tower site experiences low turbulence conditions but is subject to storm winds that raise the probability of extreme wind events higher than might otherwise be expected for a Class 3 site. Met tower placement was based on observations of wind patterns in Deering, the relatively high elevation of the site, and proximity to existing roads. The site is thought to have the best developable wind regime near Deering. Other locations near Deering, such as the summit plateau of the high, broad hill east of the village, are likely windier but development costs there would be very high.

Met tower data synopsis

Data dates	August 9, 2008 to August 6, 2010 (24 months)
Wind Power Class	High Class 3 (fair)
Power density mean, 30 m	316 W/m^2
Wind speed mean, 30 m	6.00 m/s
Max. 10-min wind speed average	25.9 m/s
Maximum wind gust	30.9 m/s (January 2009)
Weibull distribution parameters	k = 1.78, c = 6.72 m/s
Wind shear power law exponent	0.0951
Roughness class	0.0 (smooth)
Turbulence intensity, mean	0.075 (at 15 m/s)
IEC 61400-1, 3rd ed. classification	Class III-C

Community profile

Current Population:	118 (2009 DCCED Certified Population)
Incorporation Type:	2nd Class City
Borough Located In:	Northwest Arctic Borough
Taxes:	Sales: None, Property: None, Special: None
National Flood Insurance Program Participant:	Yes
Coastal Management District:	Northwest Arctic Borough

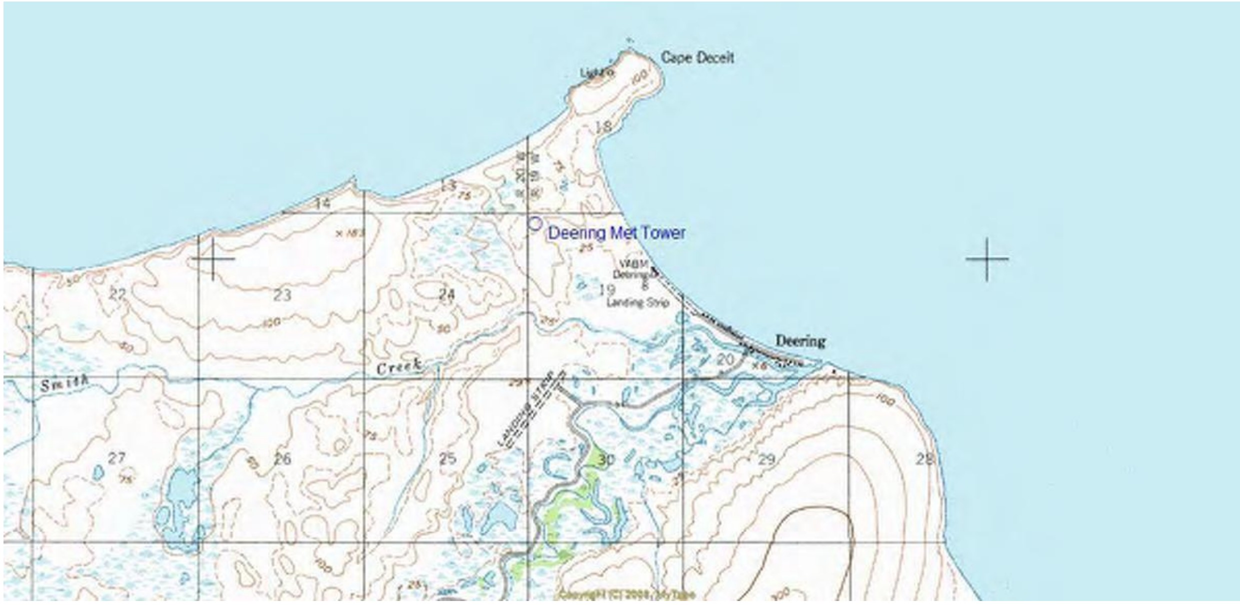
Test Site Location

The met tower is located 1.5 km (0.9 miles ft) from the western edge of the village. The site is south of Cape Deceit on a broad sloping hill overlooking Kotzebue Sound with good exposure to winds from all directions.

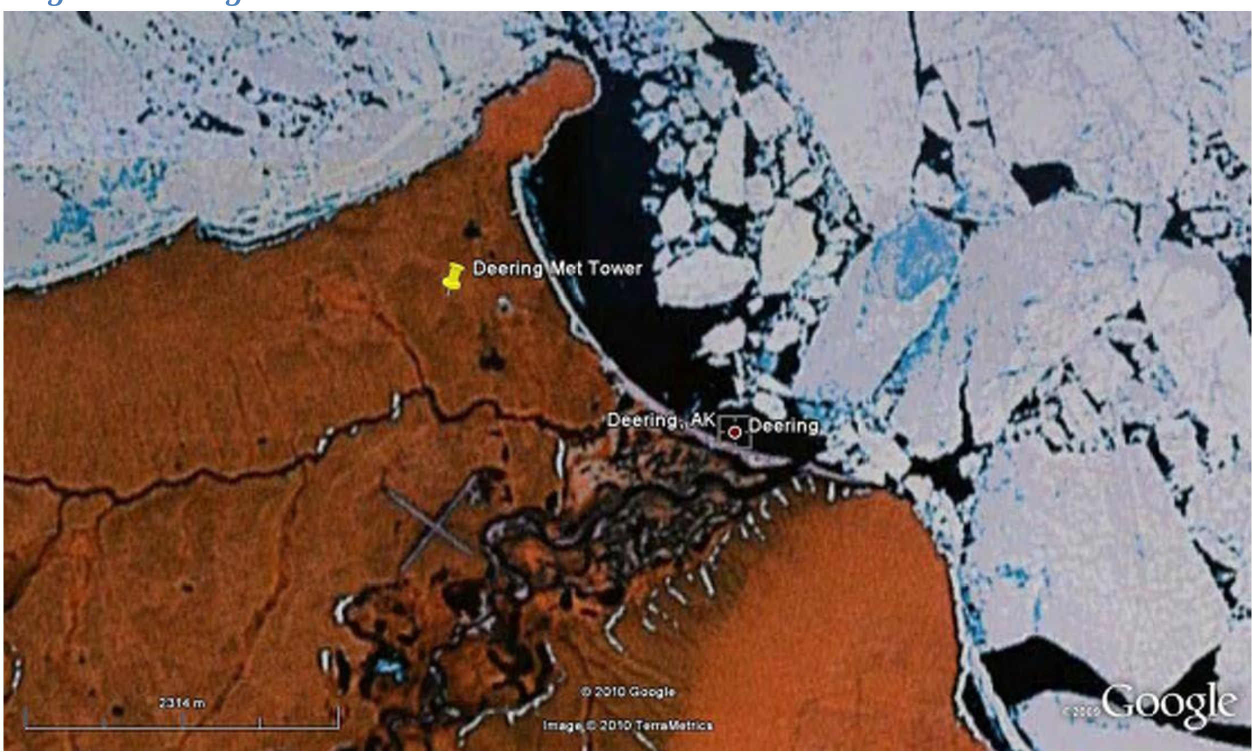
Site information

Site number	7312
Latitude/longitude	N 66° 5.1’, W 162° 45.8’ (WGS 84)
Site elevation	15 meters
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 30-meter tall tower, 152 mm diameter
Anchor type	Buried plate (configured with plywood and screw-in anchor)

Topographic map image



Google Earth image



Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	29 m (A)	0.765	0.35	WNW
2	NRG #40 anemometer	29 m (B)	0.765	0.35	ENE
3	NRG #40 anemometer	20 m	0.765	0.35	NNW
7	NRG #200P wind vane	29 m	0.351	000	359° T
9	NRG #110S Temp C	3 m	0.136	-86.383	N

Photographs

Deering crew; D. Vaught photo

Installing plate anchors; D. Vaught photo

Deering met tower; D. Vaught photo

Deering crew; D. Vaught photo

Data Recovery

The quality of data from the Deering met tower was acceptable to describe the essentials of the wind resource, but unfortunately there were a number of problems including inoperability of the temperature sensor for the first three months after tower installation (after which the sensor was replaced but data has been suspect) and complete failure of the wind vane that resulted in no recorded wind data. Fortunately, the nearby Deering airport has been equipped with an Automated Surface

Observing System (ASOS) weather station since 1984 and hence wind direction from it is a suitable substitute for the met tower site. Other data problems with the met tower include two long episodes of missing data: 6/30/09 to 8/31/09 and 11/14/09 to 2/3/10. Reportedly, one episode was due to a lost or misplaced data card and the other to failure of the datalogger.

Apparent icing events, characterized by relatively long periods of zero sensor output, non-variant sensor standard deviation, and temperatures near or below freezing, were removed from the data set for quality control purposes. It is apparent from the data that icing events (likely freezing rain/sleet but also possibly hoarfrost conditions) certainly occur frequently during the winter months, but the site is not of sufficient elevation for the highly problematic rime icing conditions.

Data recovery summary table

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)
Speed 29 m A	m/s	29 m	104,717	79,341	75.8
Speed 29 m B	m/s	29 m	104,717	79,229	75.7
Speed 20 m	m/s	20 m	104,717	76,768	73.3
Direction 24 m	°	24 m	104,717	0	0.0
Temperature	°C		104,717	67,853	64.8

Anemometer data recovery

			29 m A		29 m B		20 m	
Year	Month	Possible Records	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)
2008	Aug	3,227	3,227	100.0	3,227	100.0	3,227	100.0
2008	Sep	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2008	Oct	4,464	4,443	99.5	4,439	99.4	4,455	99.8
2008	Nov	4,320	2,365	54.8	2,348	54.4	2,368	54.8
2008	Dec	4,464	4,290	96.1	4,276	95.8	4,331	97.0
2009	Jan	4,464	3,539	79.3	3,511	78.7	3,192	71.5
2009	Feb	4,032	3,615	89.7	3,614	89.6	2,325	57.7
2009	Mar	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Apr	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2009	May	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Jun	4,320	3,906	90.4	3,906	90.4	3,906	90.4
2009	Jul	4,464	0	0.0	0	0.0	0	0.0
2009	Aug	4,464	54	1.2	54	1.2	54	1.2
2009	Sep	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2009	Oct	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Nov	4,320	1,578	36.5	1,578	36.5	1,578	36.5
2009	Dec	4,464	0	0.0	0	0.0	0	0.0
2010	Jan	4,464	0	0.0	0	0.0	0	0.0

2010	Feb	4,032	3,106	77.0	3,245	80.5	2,114	52.4
2010	Mar	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2010	Apr	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2010	May	4,464	4,464	100.0	4,277	95.8	4,464	100.0
2010	Jun	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2010	Jul	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2010	Aug	834	834	100.0	834	100.0	834	100.0
All data		104,717	79,341	75.8	79,229	75.7	76,768	73.3

Wind Speed

Wind data collected from the met tower, from the perspective of mean wind speed and mean wind power density, indicates a good wind resource for wind power development. The cold arctic temperatures of Deering contributed to the high power density. It is problematic, however, analyzing wind data with significant concentrated data loss, such as occurred in Deering during the two data loss episodes. Fortunately, however, with met tower data collection encompassing a two year time period, missing months of data in 2009 and 2010 were duplicated by data collected in 2008 and 2009. Nevertheless, to correct the anemometer data loss problem, synthetic data was inserted in the data gaps to create a more complete wind speed profile. To be sure, long segments of synthetic data introduce uncertainty to the data set, but missing data does as well. With synthetic data inserted to fill in the data gaps, the mean wind annual wind speed and power density decrease slightly from the original data.

Anemometer data summary

	Original Data			Synthesized data		
Variable	Speed 29 m A	Speed 29 m B	Speed 20 m	Speed 29 m A	Speed 29 m B	Speed 20 m
Measurement height (m)	29	29	20	29	29	20
Mean wind speed (m/s)	6.00	6.06	5.96	5.94	6.00	5.82
Max 10-min avg wind speed (m/s)	25.9	25.2	24.4			
Max gust wind speed (m/s)	30.9	29.8	29.8			
Weibull k	1.71	1.74	1.77	1.67	1.69	1.72
Weibull c (m/s)	6.62	6.72	6.55	6.64	6.72	6.52
Mean power density (W/m²)	312	322	301	309	316	285
Mean energy content (kWh/m²/yr)	2,737	2,820	2,635	2,703	2,768	2,493
Energy pattern factor	2.244	2.236	2.183	2.311	2.299	2.268
1-hr autocorrelation coefficient	0.913	0.914	0.915	0.908	0.909	0.91
Diurnal pattern strength	0.013	0.018	0.014	0.025	0.028	0.028
Hour of peak wind speed	15	15	13	13	13	12

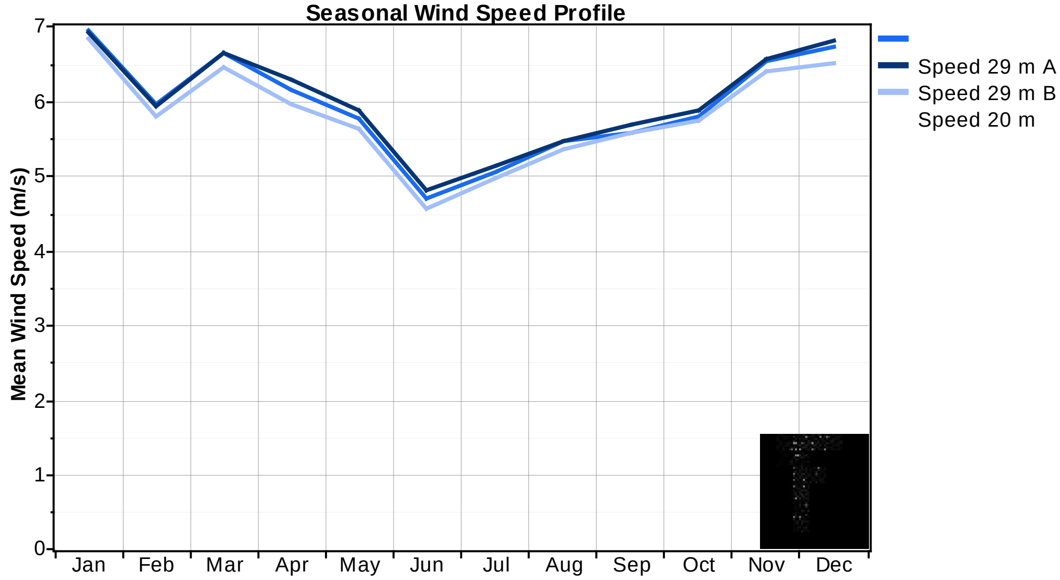
Time Series

Time series calculations indicate moderately wind speed averages during the autumn, winter and spring months, but winds die down during summer. Fortunately, however, seasonal wind speeds correlate to a typical village electric load profile of high winter loads and light summer loads.

29m B anemometer data summary

		Original 29m B Data					Synth Data Added	
Year	Month	Mean (m/s)	Max 10-min avg (m/s)	Max gust (m/s)	Weibull k (-)	Weibull c (m/s)	Mean (m/s)	Ratio: synth to original mean speed (-)
2008	Aug	5.52	15.3	17.6	2.198	6.24	5.52	100.0%
2008	Sep	5.94	13.3	15.3	2.15	6.693	5.94	100.0%
2008	Oct	5.59	15.4	18.7	1.958	6.305	5.57	99.6%
2008	Nov	6.38	13.4	16.1	2.484	7.174	6.01	94.2%
2008	Dec	7.05	20.5	24	1.945	7.913	6.92	98.1%
2009	Jan	7.14	25.1	29.8	1.536	7.963	6.69	93.8%
2009	Feb	7.55	22	25.6	1.586	8.375	6.98	92.3%
2009	Mar	6.76	24.7	27.9	1.609	7.538	6.76	100.0%
2009	Apr	5.50	25.2	29.8	1.593	6.128	5.50	100.0%
2009	May	6.30	19.6	24.8	2.175	7.118	6.30	100.0%
2009	Jun	4.91	15.9	19.5	2.042	5.543	4.91	100.1%
2009	Jul						4.96	
2009	Aug	12.07	16.2	19.9	6.252	12.969	5.68	47.1%
2009	Sep	5.42	14.1	17.2	1.947	6.116	5.42	100.0%
2009	Oct	6.21	16.5	19.5	1.72	6.943	6.21	100.0%
2009	Nov	7.38	20.5	23.7	1.533	8.166	7.10	96.3%
2009	Dec						6.67	
2010	Jan						7.14	
2010	Feb	4.37	12.9	14.1	1.942	4.892	4.89	112.1%
2010	Mar	6.52	15.6	19.5	1.695	7.236	6.52	100.0%
2010	Apr	7.05	20.2	22.6	1.66	7.828	7.05	100.0%
2010	May	5.32	15.6	18.7	1.753	5.936	5.47	102.8%
2010	Jun	4.72	17.8	20.6	1.994	5.329	4.72	100.0%
2010	Jul	5.29	16.4	19.1	1.809	5.95	5.29	100.0%
2010	Aug	4.12	10.1	13.3	2.095	4.648	4.12	100.0%
MMM Annual		6.06	25.2	29.8	1.738	6.716	6.00	98.9%

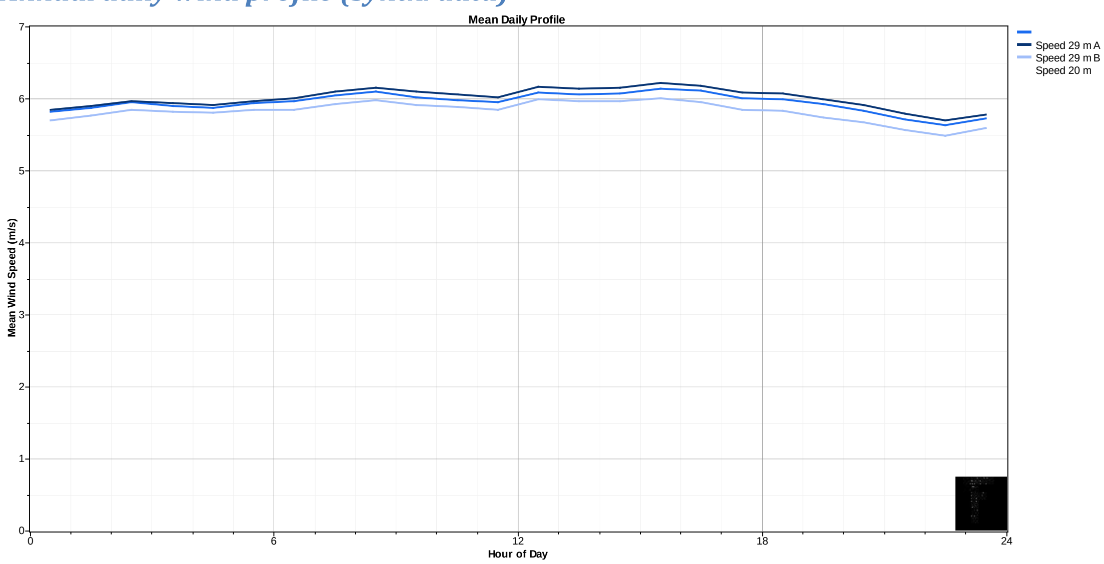
Time series graph (synth. data)



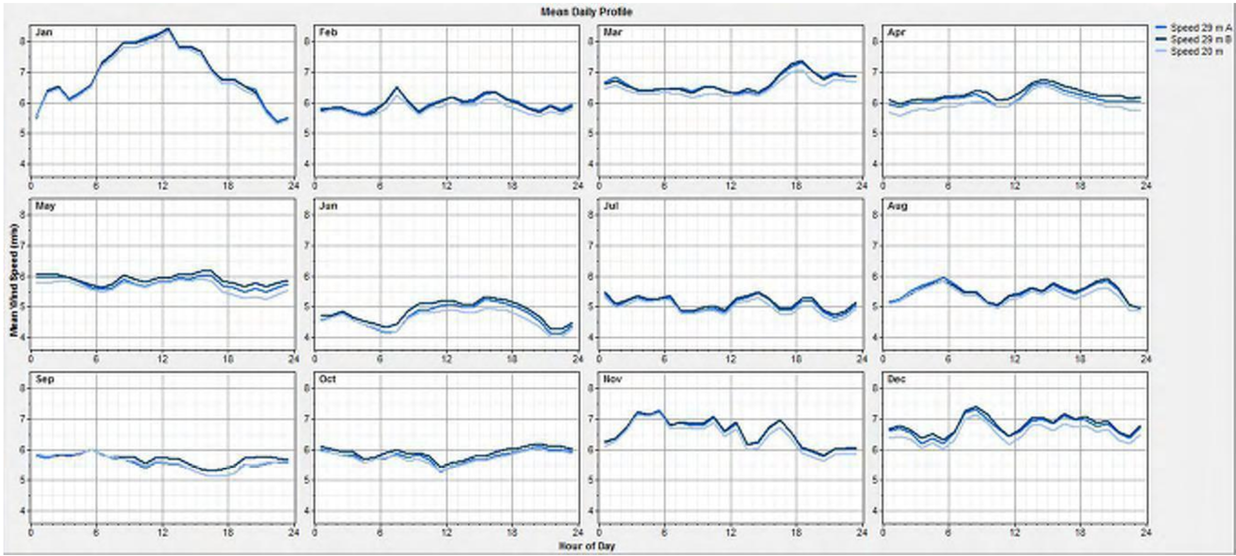
Daily Wind Profile

The average annual daily wind profile in Deering indicates a minor variation of wind speeds throughout the day, with lowest wind speeds during the late night and early morning hours and highest winds during mid to late afternoon. This perspective changes somewhat when considering monthly views of daily profiles as much more variation is observed.

Annual daily wind profile (synth. data)



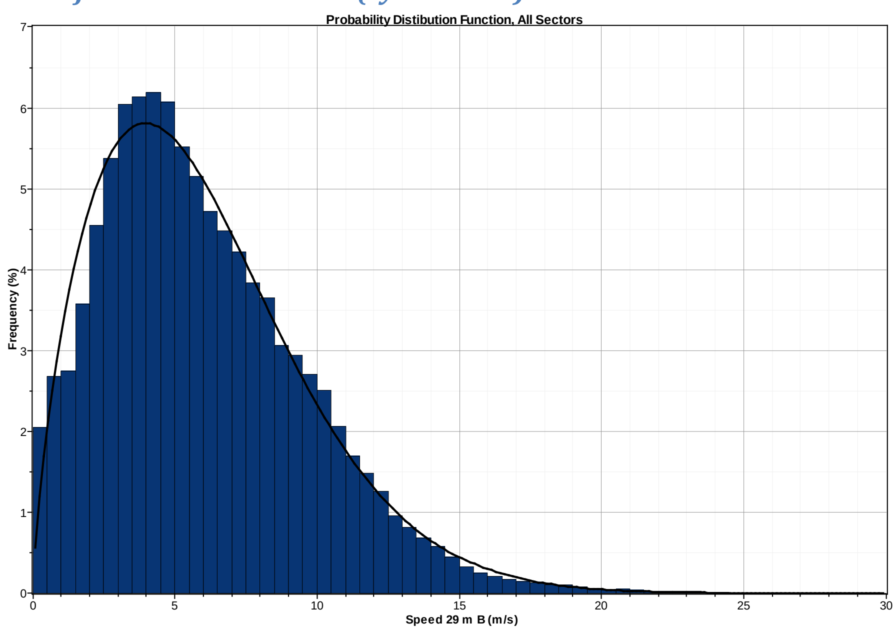
Monthly daily wind profiles (synth. data)



Probability Distribution Function

The probability distribution function (PDF), or histogram, of wind speed indicates wind speed "bins" oriented somewhat toward the lower speeds compared to a normal wind power shape curve of k=2.0, otherwise known as the Raleigh distribution. Note in the cumulate frequency table below that 33 percent of the winds are less than 4 m/s, the cut-in wind speed of most wind turbines.

PDF of 29m B anemometer (synth. data)



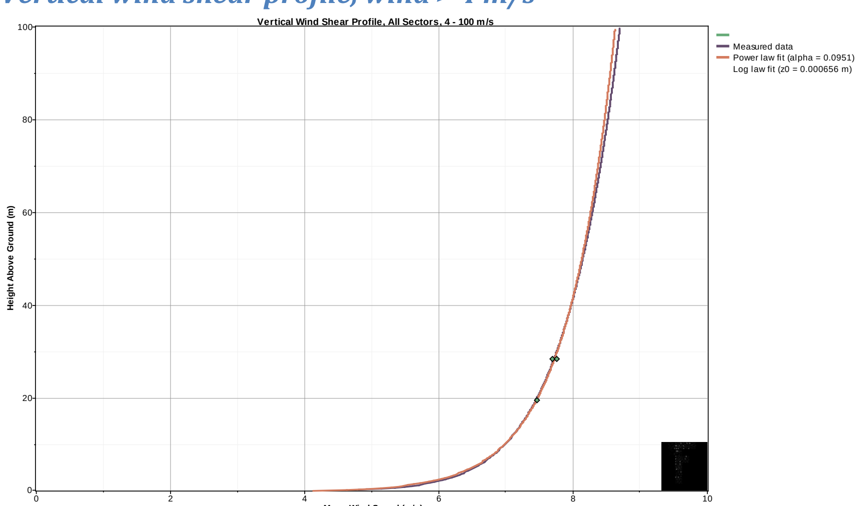
Cumulative frequency table

Bin (m/s) Lower	Bin (m/s) Upper	Occurrences	Freq. (%)	Cum. Freq. (%)	Bin (m/s) Lower	Bin (m/s) Upper	Occurrences	Freq. (%)	Cum. Freq. (%)
0	1	4,952	4.73	4.7	15	16	606	0.58	98.7
1	2	6,616	6.32	11.0	16	17	402	0.38	99.1
2	3	10,382	9.91	21.0	17	18	290	0.28	99.4
3	4	12,747	12.17	33.1	18	19	219	0.21	99.6
4	5	12,827	12.25	45.4	19	20	140	0.13	99.7
5	6	11,167	10.66	56.0	20	21	97	0.09	99.8
6	7	9,635	9.20	65.2	21	22	70	0.07	99.9
7	8	8,429	8.05	73.3	22	23	58	0.06	99.9
8	9	7,030	6.71	80.0	23	24	37	0.04	100.0
9	10	5,918	5.65	85.7	24	25	19	0.02	100.0
10	11	4,773	4.56	90.2	25	26	5	0.01	100.0
11	12	3,331	3.18	93.4	26	27	4	0.00	100.0
12	13	2,317	2.21	95.6	27	28	1	0.00	100.0
13	14	1,572	1.50	97.1	28	29	0	0.00	100.0
14	15	1,073	1.03	98.1	29	30	0	0	100.0
					All		104,717	100.00	

Wind Shear and Roughness

A wind shear power law exponent of 0.0951 indicates very low wind shear at the site; hence wind turbine construction at a low hub height may be a desirable option. Related to wind shear, a calculated surface roughness of 0.00002 meters (the height above ground level where wind velocity would be zero) indicates very smooth terrain (roughness description: smooth) surrounding the met tower.

Vertical wind shear profile, wind > 4 m/s



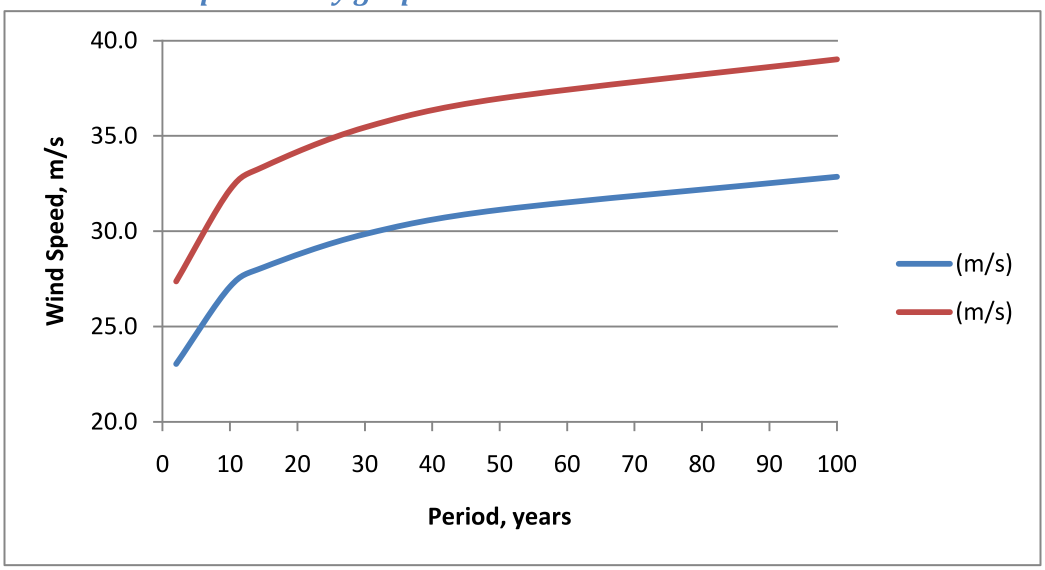
Extreme Winds

The relatively short duration of Deering met tower should be considered minimal for calculation of extreme wind probability, but nevertheless it can be estimated with a reasonable level of accuracy. During the test period, Deering experienced only moderate storm wind events and hence classifies as an IEC 61400-1, 3rd edition (2005), Class III wind site, the lowest defined.

Extreme wind speed probability table

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. Class	V_{ref}, m/s
2	23.0	27.4	I	50.0
10	27.1	32.2	II	42.5
15	28.1	33.4	III	37.5
30	29.9	35.5	S	designer-specified
50	31.1	37.0		
100	32.9	39.0		
average gust factor:	1.19			

Extreme winds probability graph



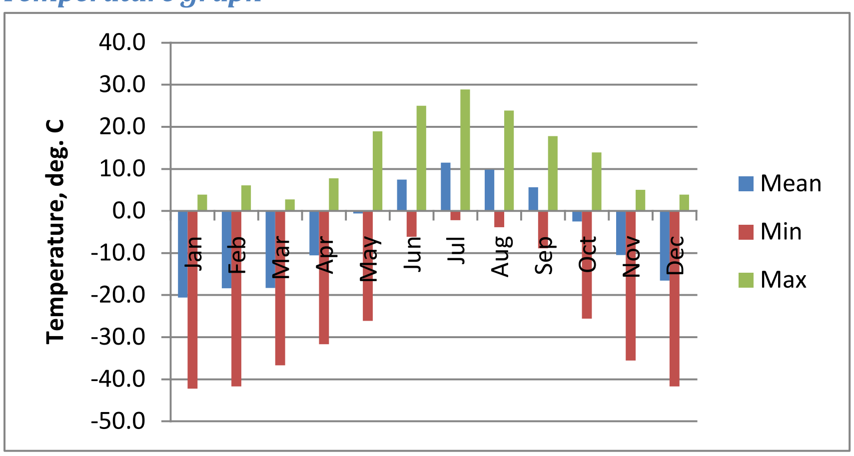
Temperature and Density

In addition to the data loss noted in the Data Recovery section of this report, by examination the met tower temperature data appears faulty. Hence, instead of reporting met tower temperature data, temperature data from the airport ASOS are referenced below. This data represents a restively long time period: 1984 to the present but note that data from years 1986 to 1997 are missing. Density was not directly measured, but calculated using standard pressure at 15 meters elevation and the ideal gas law. Note that in general Deering is a cool maritime climate characterized by severely cold winters.

Temperature and density table

	Temperature			Air Density		
	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Max (kg/m³)	Min (kg/m³)
Jan	-20.6	-42.2	3.9	1.395	1.526	1.272
Feb	-18.3	-41.7	6.1	1.383	1.523	1.262
Mar	-18.3	-36.7	2.8	1.383	1.490	1.277
Apr	-10.5	-31.7	7.8	1.342	1.460	1.255
May	-0.6	-26.1	18.9	1.293	1.427	1.207
Jun	7.5	-6.1	25.0	1.256	1.320	1.182
Jul	11.5	-2.2	28.9	1.238	1.301	1.167
Aug	9.8	-3.9	23.9	1.246	1.309	1.186
Sep	5.6	-8.9	17.8	1.264	1.334	1.211
Oct	-2.5	-25.6	13.9	1.302	1.423	1.228
Nov	-10.4	-35.6	5.0	1.342	1.483	1.267
Dec	-16.5	-41.7	3.9	1.374	1.523	1.272
Annual	-4.4	-42.2	28.9	1.318	1.526	1.167

Temperature graph



Temperature table, Fahrenheit and Celsius

	Mean (°C)	Min (°C)	Max (°C)	Mean (°F)	Min (°F)	Max (°F)
Jan	-20.6	-42.2	3.9	-5.0	-44.0	39.0
Feb	-18.3	-41.7	6.1	-1.0	-43.0	43.0
Mar	-18.3	-36.7	2.8	-0.9	-34.0	37.0
Apr	-10.5	-31.7	7.8	13.1	-25.0	46.0
May	-0.6	-26.1	18.9	31.0	-15.0	66.0
Jun	7.5	-6.1	25.0	45.5	21.0	77.0
Jul	11.5	-2.2	28.9	52.7	28.0	84.0
Aug	9.8	-3.9	23.9	49.6	25.0	75.0

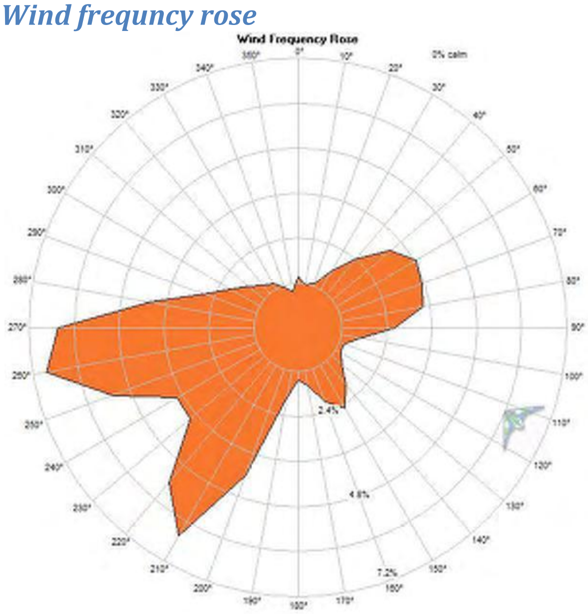
Sep	5.6	-8.9	17.8	42.1	16.0	64.0
Oct	-2.5	-25.6	13.9	27.5	-14.0	57.0
Nov	-10.4	-35.6	5.0	13.2	-32.0	41.0
Dec	-16.5	-41.7	3.9	2.2	-43.0	39.0
Annual	-4.4	-42.2	28.9	24.2	-44.0	84.0

Wind Direction

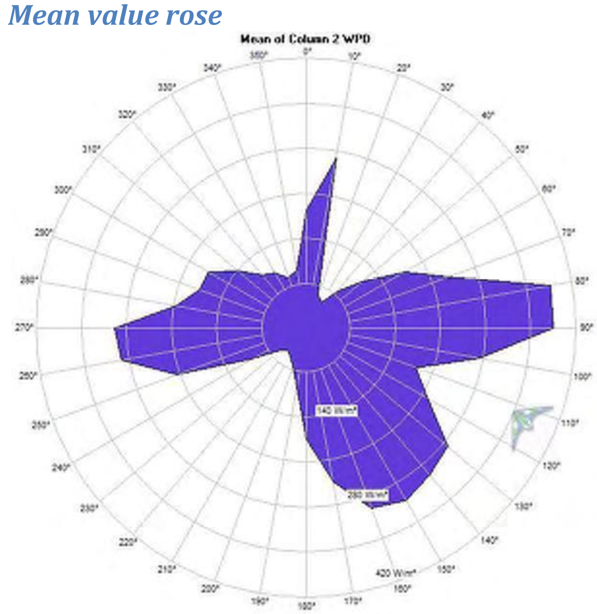
The met tower wind vane was inoperative during the entire measurement period, with no data return. However, nearby airport ASOS data (1984 to present) is usable for wind direction analysis and presented below.

The wind frequency rose for Deering indicates predominately southwesterly to westerly winds with a lesser component of east-northeasterly winds and some southeasterly winds. The mean value rose indicates that when the easterly and southeasterly winds do occur, they tend to be very powerful. Combining the frequency and mean value rose into the total energy rose results in the observation that the power-producing winds are chiefly westerly. Not critically important, but note that the resolution of the ASOS wind direction data is ten degrees, not one degree as with met tower wind vane sensors.

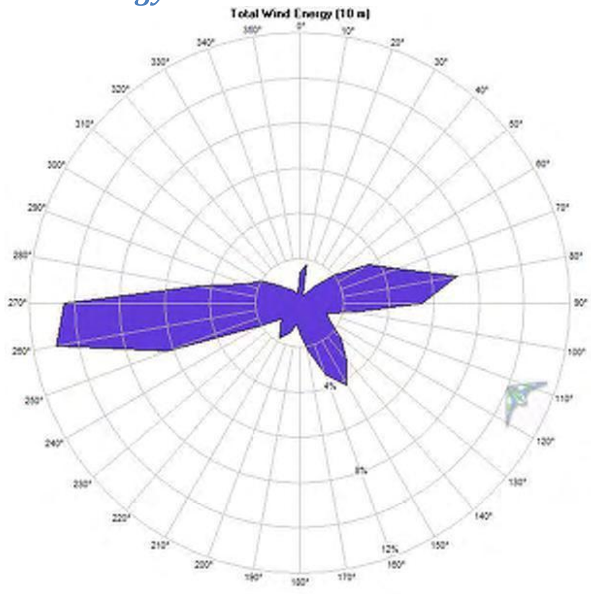
Wind frequncy rose



Mean value rose



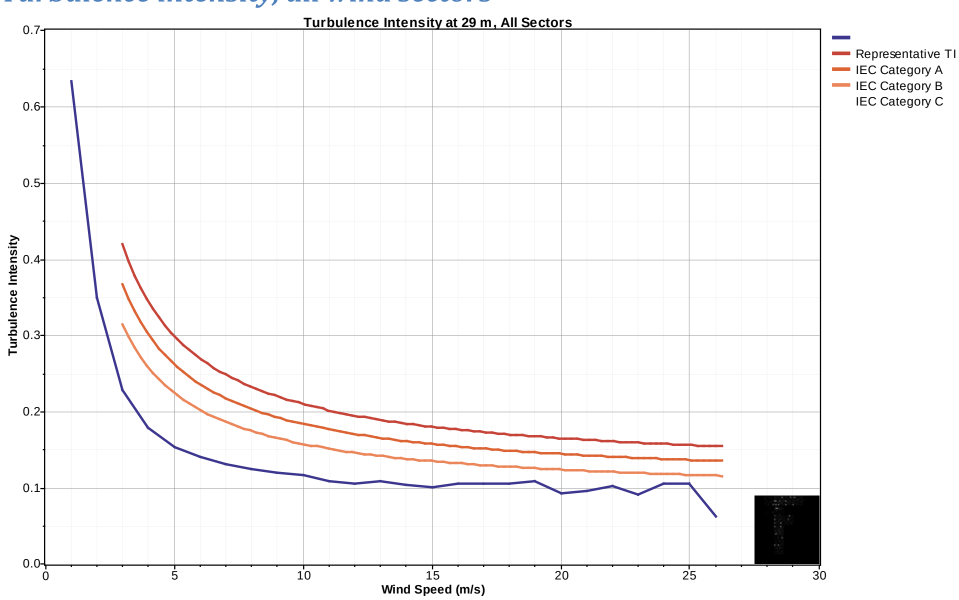
Total energy rose



Turbulence

Turbulence intensity at the Deering test site is well within acceptable standards for wind power development with an International Electrotechnical Commission (IEC) 61400-1, 3rd edition (2005) classification of turbulence category C, which is the lowest defined. Mean turbulence intensity at 15 m/s is 0.075.

Turbulence intensity, all wind sectors



Turbulence table

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Upper (m/s)	Records In Bin	Mean TI	Standard Deviation of TI	Representative TI	Peak TI
1	0.5	1.5	3,858	0.416	0.170	0.634	1.333
2	1.5	2.5	6,218	0.208	0.110	0.349	0.941
3	2.5	3.5	8,963	0.138	0.070	0.228	0.769
4	3.5	4.5	10,044	0.109	0.054	0.178	0.683
5	4.5	5.5	9,206	0.095	0.045	0.153	0.660
6	5.5	6.5	7,891	0.089	0.040	0.140	0.532
7	6.5	7.5	7,298	0.084	0.036	0.131	0.354
8	7.5	8.5	5,994	0.082	0.034	0.125	0.519
9	8.5	9.5	4,751	0.080	0.031	0.119	0.326
10	9.5	10.5	4,028	0.079	0.029	0.116	0.308
11	10.5	11.5	2,995	0.077	0.024	0.108	0.255
12	11.5	12.5	2,103	0.076	0.023	0.105	0.218
13	12.5	13.5	1,359	0.077	0.025	0.109	0.235
14	13.5	14.5	885	0.075	0.022	0.103	0.200
15	14.5	15.5	539	0.075	0.020	0.101	0.158
16	15.5	16.5	317	0.077	0.021	0.105	0.178
17	16.5	17.5	228	0.078	0.021	0.105	0.164
18	17.5	18.5	151	0.078	0.021	0.105	0.152
19	18.5	19.5	99	0.078	0.024	0.109	0.195
20	19.5	20.5	64	0.071	0.018	0.093	0.128
21	20.5	21.5	38	0.070	0.019	0.095	0.125
22	21.5	22.5	43	0.076	0.020	0.102	0.129
23	22.5	23.5	15	0.071	0.015	0.090	0.099
24	23.5	24.5	17	0.075	0.023	0.105	0.119
25	24.5	25.5	8	0.080	0.020	0.106	0.102
26	25.5	26.5	1	0.062	0.000	0.062	0.062

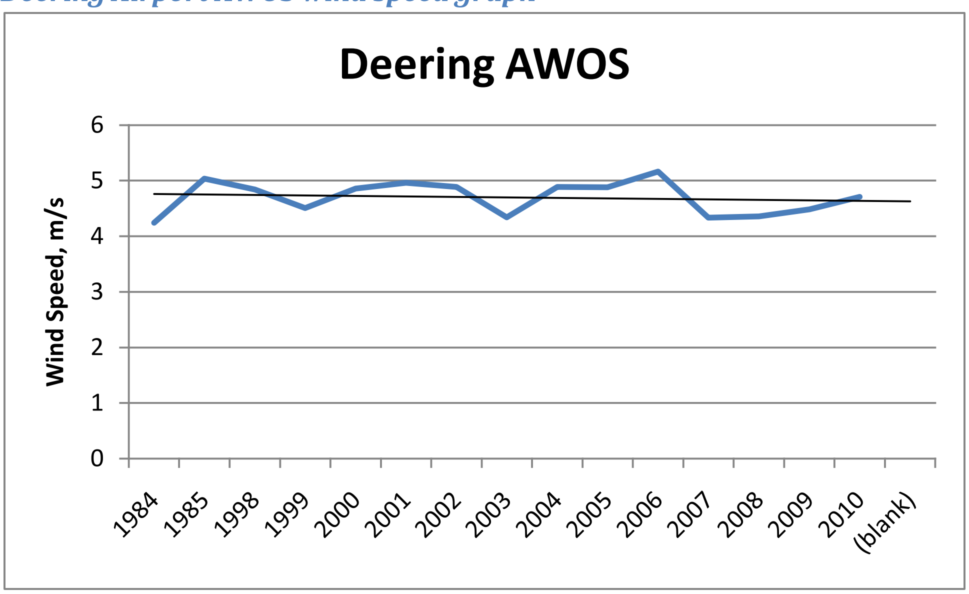
Airport ASOS Data

Analysis of airport ASOS wind speed data since 1984 confirms the met tower data results. Airport data is collected at an elevation of 10 meters. Shown below, the data was scaled to 29 meters with a power law algorithm using an α (power law exponent) value of 0.095 (measured by the met tower) and 0.14 (typical of tundra terrain). In both cases, average wind speeds measured by the met tower exceed airport wind speeds. This likely is due to the more exposed location of the met tower on higher terrain. In 2005, Alaska Energy Authority analyzed the Deering airport data and predicted a Class 3 wind resource from it. Deering met tower data confirms that classification but adjusted to the high end of the Class 3 range.

Airport/met tower data comparison

	Deering Airport			Met Tower, 29 m B	
	AWOS, 10 m sensor (m/s)	Data adj. to 29 m, α=0.095 (m/s)	Data adj. to 29 m, α=0.14 (m/s)	Collected Data (m/s)	Synth. Data (m/s)
Jan	5.16	5.71	5.99	7.14	6.91
Feb	5.90	6.52	6.84	6.05	5.93
Mar	5.19	5.75	6.03	6.64	6.64
Apr	5.10	5.64	5.92	6.27	6.27
May	4.34	4.80	5.03	5.82	5.88
Jun	3.95	4.37	4.59	4.81	4.82
Jul	4.18	4.63	4.86	5.29	5.12
Aug	4.46	4.93	5.18	5.32	5.47
Sep	4.54	5.02	5.27	5.68	5.68
Oct	4.44	4.91	5.15	5.90	5.89
Nov	4.55	5.03	5.28	6.78	6.56
Dec	5.20	5.76	6.04	7.05	6.80
Annual	4.71	5.21	5.47	6.06	6.00

Deering Airport AWOS wind speed graph



Appendix I-C: Noorvik

September 2010 Noorvik Wind Resource Report, V3 Energy

Noorvik site wind report, New Roots Energy

Noorvik Wind Resource Report

By: Douglas Vaught, P.E., V3 Energy LLC, Eagle River, Alaska
Date: September 17, 2010

Village of Noorvik aerial view; D. Vaught photo

Contents

Summary

The wind resource measured at the new Noorvik wind power site, located on the old runway, is difficult to characterize as data recovery from the met tower proved to be sporadic with just six and a half months of data. If projected to a full year, however, a Class 2 (marginal) wind resource is predicted. Unfortunately, the Noorvik airport is not equipped with a NOAA weather observing system (an AWOS or ASOS); hence it is not possible to correlate the met tower recovered data with airport data to predict annual wind energy statistics. Because the winter met tower data appeared promising for met tower development, it is may be advisable to re-erect a met tower at the project site location and obtain a full year data set. If viable, the old runway is ideal for wind power development due to proximity to the power plant and other infrastructure.

Met tower data synopsis

Data dates	August 2, 2008 to May 6, 2009 (6.5 months recovered)
Wind Power Class	Class 2 (marginal), projected from 6.5 months data
Power density mean, 30 meters	170 W/m^2, 6.5 months data
Wind sped mean, 30 meters	4.50 m/s, 6.5 months data
Max. 10-minute wind speed average	24.0 m/s
Maximum wind gust	29.1 m/s (February 2009)
Weibull distribution parameters	K = 1.41, c = 4.83 m/s, 6.5 months data
Wind shear power law exponent	0.237
Roughness class	3.16 (forest)
Turbulence intensity, mean	0.106
IEC 61400-1, 3rd ed. classification	Not calculated, insufficient data

Community profile

Current Population:	628 (2009 DCCED Certified Population)
Incorporation Type:	2nd Class City
Borough Located In:	Northwest Arctic Borough
Taxes:	Sales: 4% (City), Property: None, Special: 4% Utility Tax (City); 4% Landfill Tax (City)
National Flood Insurance Program Participant:	Yes

Coastal Management District: Northwest Arctic Borough

Test Site Location

The met tower was located at the intersection of the main runway and the cross-wind runway of Noorvik's old airport. This site was chosen due to its proximity to the Noorvik powerplant and other infrastructure and its ready construction and wintertime access.

Site information

Site number	0002
Latitude/longitude	N 66° 49.829', W 161° 1.848'
Site elevation	15 meters
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 30-meter tall tower, 102 mm (4 inch) diameter
Anchor type	DB88 duckbill

Google Earth image

Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.765	0.35	SW
2	NRG #40 anemometer	30 m (B)	0.765	0.35	NE
3	NRG #40 anemometer	20 m	0.765	0.35	SW
7	NRG #200P wind vane	30 m	0.351		NW
9	NRG #110S Temp C	2 m	0.136	-86.383	N

Data Recovery

Unfortunately, data recovery in Noorvik proved to be poor with a datalogger failure on November 20, 2008 that was not corrected until February 6, 2009, after which data was collected (although not temperature) until May 6, 2009. Reportedly, the met tower was removed in October, 2009. Status of data possibly collected from May through October 2009 is not known. Of the data that was collected – approximately 6.5 months worth overall – few icing events were recorded and sensors appeared to function normally. One very significant confusion, however, was that the replacement datalogger in February 2009 did not have the correct site number programmed into it and subsequent data was difficult to manage. Additionally, upon replacement of the datalogger in February, 2009, the temperature sensor now longer functioned and wind direction data no longer matched well with that collected August through November 2009. Reasons for these discrepancies are not known.

Data recovery summary table

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)
Speed 30 m A	m/s	30 m	39,889	28,582	71.7
Speed 30 m B	m/s	30 m	39,889	28,582	71.7
Speed 20 m	m/s	20 m	39,889	28,582	71.7
Direction 30 m	°	30 m	39,889	28,490	71.4
Temperature	°C		39,889	15,769	39.5

Anemometer data recovery

			30 m A		30 m B		20 m	
Year	Month	Possible Records	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)
2008	Aug	4,237	4,237	100.0	4,237	100.0	4,237	100.0
2008	Sep	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2008	Oct	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2008	Nov	4,320	2,748	63.6	2,748	63.6	2,748	63.6
2008	Dec	4,464	0	0.0	0	0.0	0	0.0
2009	Jan	4,464	0	0.0	0	0.0	0	0.0
2009	Feb	4,032	3,225	80.0	3,225	80.0	3,225	80.0
2009	Mar	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Apr	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2009	May	804	804	100.0	804	100.0	804	100.0
All data		39,889	28,582	71.7	28,582	71.7	28,582	71.7

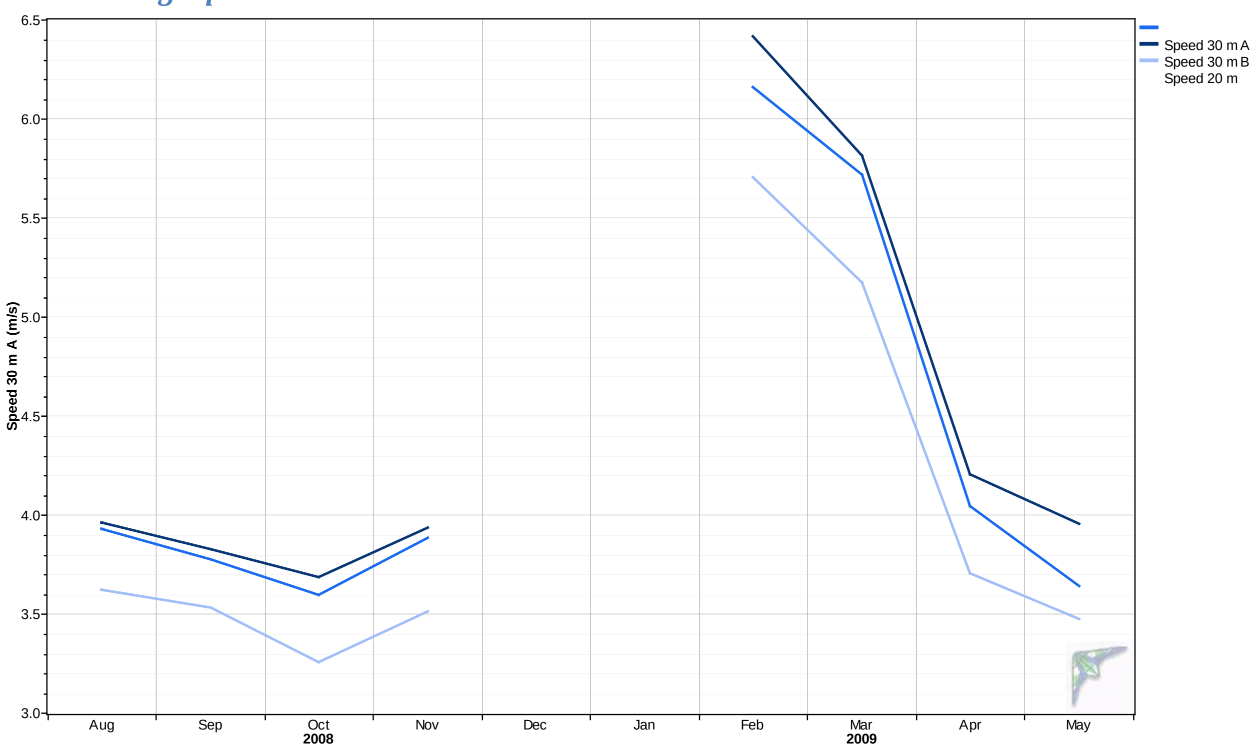
Wind Speed

Wind data collected from the met tower was not sufficient to adequately characterize the site or predict the annual wind resource. Of data that was collected, late winter winds in Noorvik were stronger than late summer/autumn winds.

Anemometer data summary

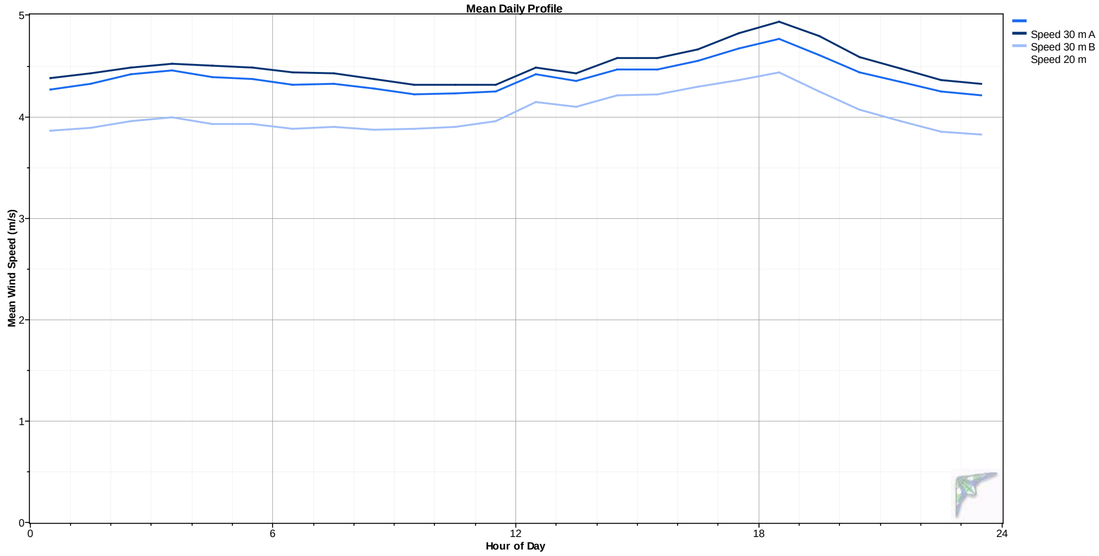
Variable	Speed 30 m A	Speed 30 m B	Speed 20 m
Measurement height (m)	30	30	20
Mean wind speed (m/s)	4.39	4.50	4.03
Max 10-min avg wind speed (m/s)	23.8	24	22.2
Max gust wind speed (m/s)	29.4	29.1	28.3
Weibull k	1.41	1.44	1.43
Weibull c (m/s)	4.83	4.96	4.44
Mean power density (W/m²)	165	170	125
Mean energy content (kWh/m²/yr)	1,441	1,488	1,093
Energy pattern factor	3.14	3.01	3.08
1-hr autocorrelation coefficient	0.925	0.918	0.922
Diurnal pattern strength	0.027	0.032	0.049
Hour of peak wind speed	19	19	17

Time series graph



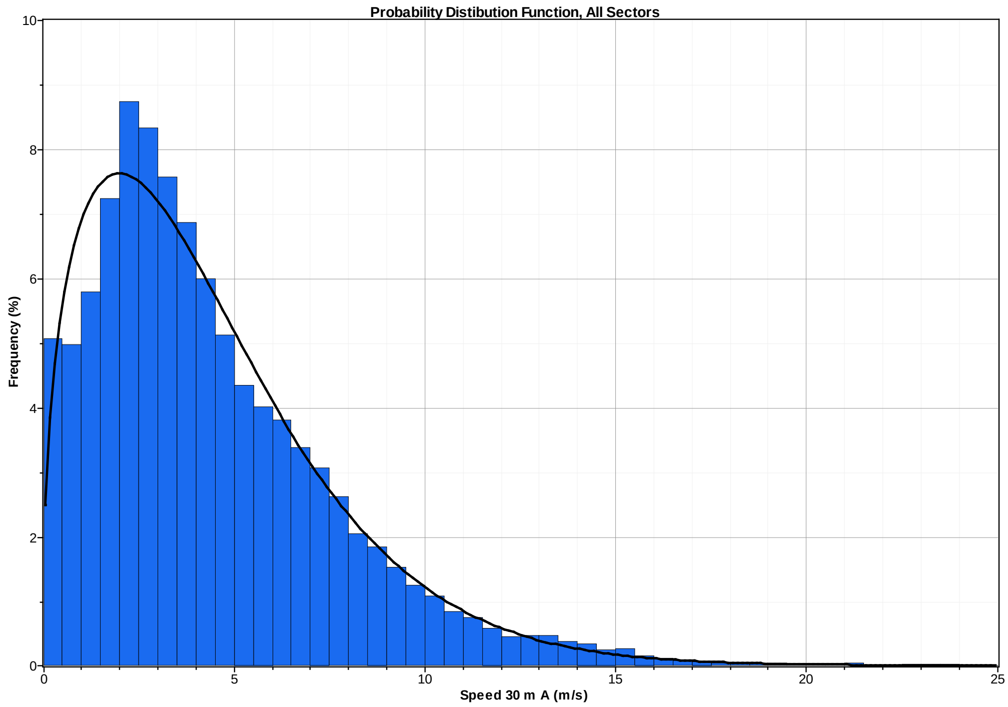
Daily Wind Profile

The average daily wind profile in Noorvik indicates lowest wind speeds during the mid-morning hours and highest wind speeds during early evening.



Probability Distribution Function

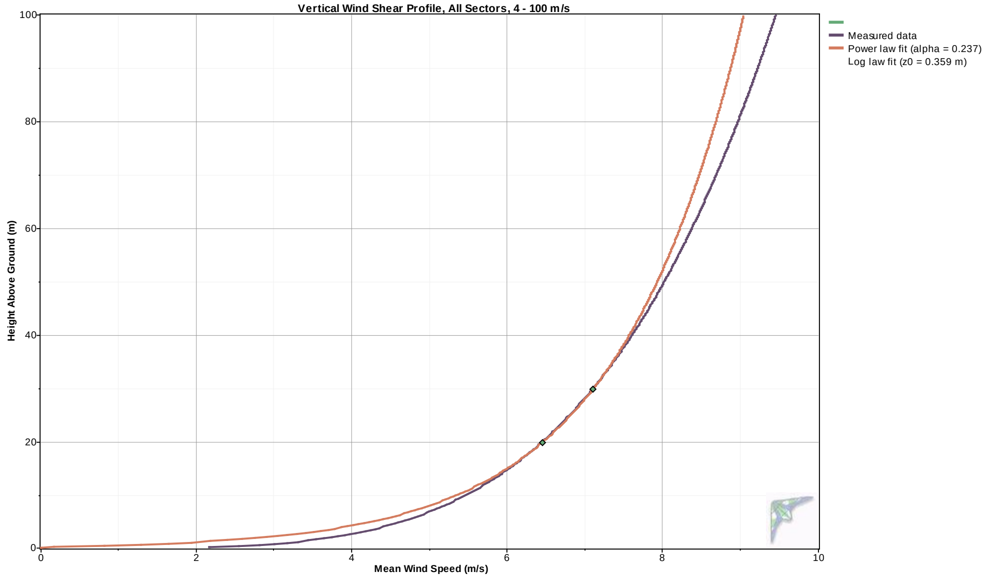
The probability distribution function (PDF), or histogram, of the 30 meter A wind speeds indicates wind speed "bins" oriented toward the lower speeds compared to a normal wind power shape curve of k=2.0, otherwise known as the Raleigh distribution.



Wind Shear and Roughness

A wind shear power law exponent of 0.237 indicates fairly wind shear at the test site; hence wind turbine construction at a high hub height would be a desirable option. Related to wind shear, a calculated surface roughness of 0.403 meters (the height above ground level where wind velocity would be zero) indicates very rough terrain (roughness description: forest) surrounding the met tower. Undoubtedly this is related to the heavy willow brush in the vicinity of Noorvik's old runway.

Vertical wind shear profile, wind > 4 m/s



Extreme Winds

Insufficient data was collected to predict extreme wind probability for the site. It is likely though, considering the low average and maximum winds recorded during the 6.5 months of data recovery, that the site classifies as International Electrotechnical Commission (IEC) 61400-1, 3rd edition (2005), Class III, the lowest defined and most common.

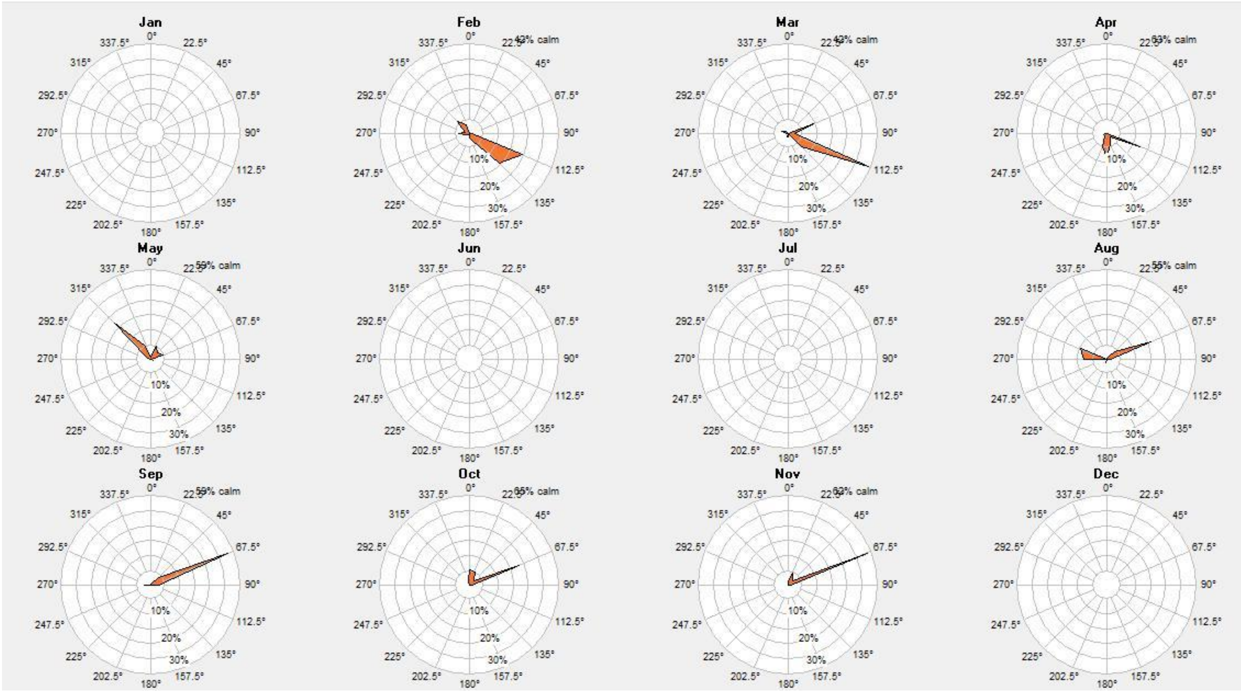
Temperature and Density

Only 3.5 months of temperature data were collected from the met tower as the temperature sensor following datalogger replacement in February 2009 was inoperative. Without airport weather station data, it is not possible at this point to precisely characterize temperature and air density in Noorvik, although given Noorvik's proximity to Selawik and Kotzebue, either location could be considered a reasonably good substitute this data.

Wind Direction

Measured wind direction information from the met tower is suspiciously inconsistent from the first data collection period, August to November 2008, and the second period, February to May 2009. For that reason and given the fact that this met tower study is not comprehensive enough to adequately characterize the wind power potential of the site, summary wind direction is not presented here, although below are monthly wind frequency roses measured during the study.

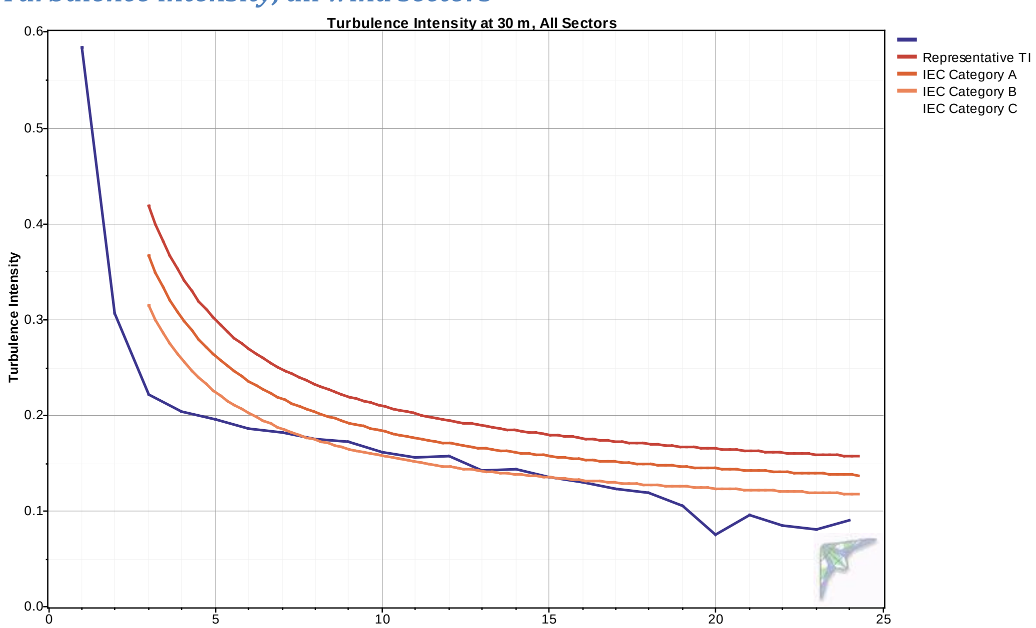
Monthly wind frequency roses



Turbulence

Turbulence intensity at the Noorvik test site, for the time period measured, is within acceptable standards for wind power development with an IEC 61400-1, 3rd edition (2005), classification of turbulence category C, which is the lowest defined. Mean turbulence intensity at 15 m/s is 0.106.

Turbulence intensity, all wind sectors



Wind Report by New Roots Energy
info@newrootsenergy.com | PMB 634, 11124 NE Halsey, Portland OR 97220

Turbine Production:

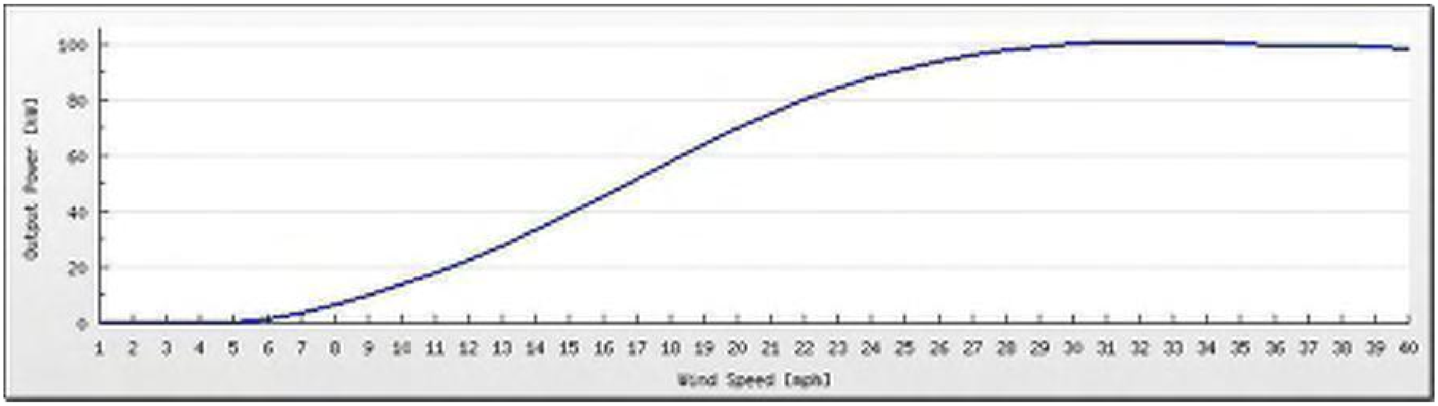
Turbine Selection	NW 100
Nameplate Capacity [kW]	100.0
Rotor Diameter [m]	21.0

Site Location:
66.830556° latitude
-160.867806° longitude

Average Wind Speed [mph]	10.33
Tower Height [ft]	120.0
Altitude [ft]	50.0
Weibull K	2.0
Wind Shear	0.12
Turbulence Factor [%]	0.0

Average Output Power [kW]	13.4
Daily Energy Output [kWh]	321.9
Monthly Energy Output [kWh]	9,792.3
Annual Energy Output [kWh]	117,508.1
Hub Average Wind Speed [mph]	10.3
Air Density Coefficient	1.0
Turbulence Coefficient	1.0
Operating Time [%]	63.5

Power Curve & Wind Distribution:



Wind Speed [m/s]	Wind Speed [mph]	Power [kW]	Wind Probability [%]	Net Power @ Voltage [kW]
1.0	2.2	0.0	7.16	0.00
2.0	4.5	0.0	12.81	0.00
3.0	6.7	0.0	15.95	0.00
4.0	8.9	3.7	16.40	0.60
5.0	11.2	10.5	14.68	1.54
6.0	13.4	18.9	11.70	2.22
7.0	15.7	29.3	8.43	2.47
8.0	17.9	40.8	5.52	2.25
9.0	20.1	54.1	3.30	1.79
10.0	22.4	66.6	1.81	1.20
11.0	24.6	77.4	0.91	0.71
12.0	26.8	86.1	0.42	0.36
13.0	29.1	92.5	0.18	0.17
14.0	31.3	96.9	0.07	0.07
15.0	33.6	99.6	0.03	0.03
16.0	35.8	100.4	0.01	0.01
17.0	38.0	100.2	0.00	0.00
18.0	40.3	99.4	0.00	0.00
19.0	42.5	99.0	0.00	0.00
20.0	44.7	98.2	0.00	0.00
			99.38	13.41

The Wind Report model is intended for providing budgetary estimates only. Actual turbine production at a particular location is dependent on a variety of factors that are outside the immediate control of New Roots Energy or are outside the scope of this model.

New Roots Energy has made every effort to insure the accuracy of the Wind Report turbine production and financial modeling tools. We recommend that the user verify the accuracy of the tools through independent analysis, considering the end client's specific circumstances. New Roots Energy will not be held responsible for errors or omissions in this model.

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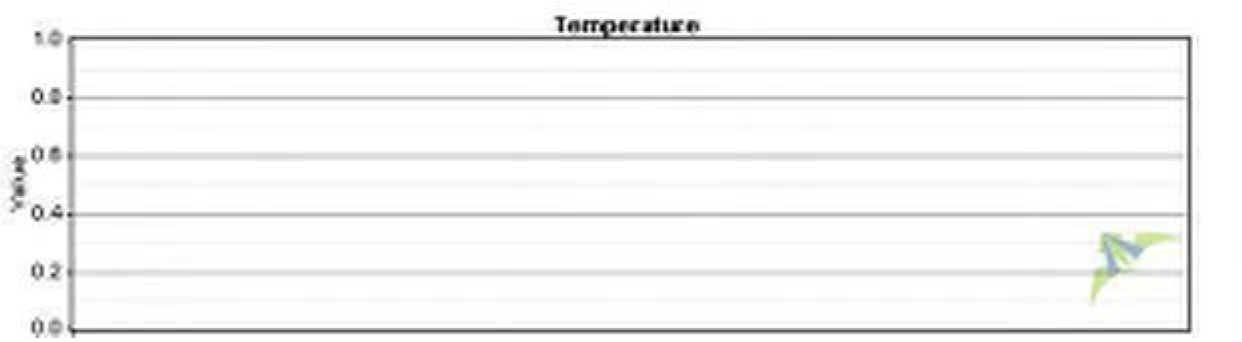
Appendix I-D: Ambler

August 2010 Ambler Windographer summary report, WHPacific

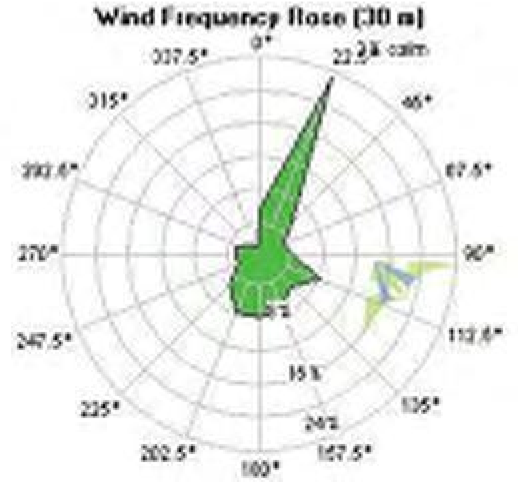
Data Set Properties

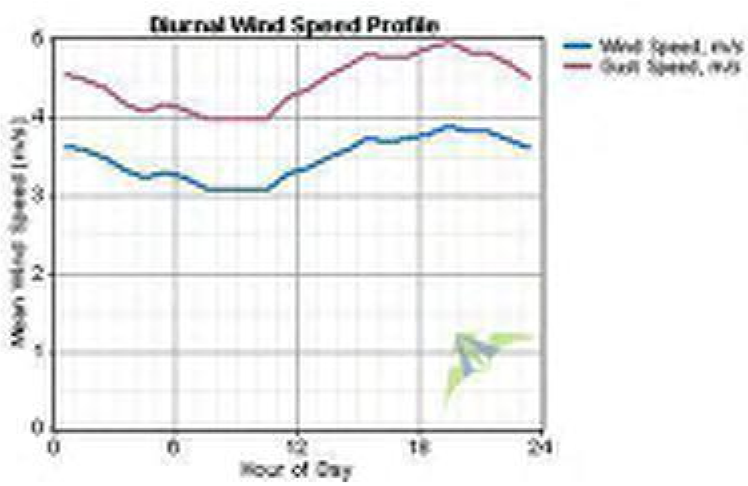
Report Created: 8/19/2010 14:48 using Windographer 2.0.4
Filter Settings: <Unflagged data>

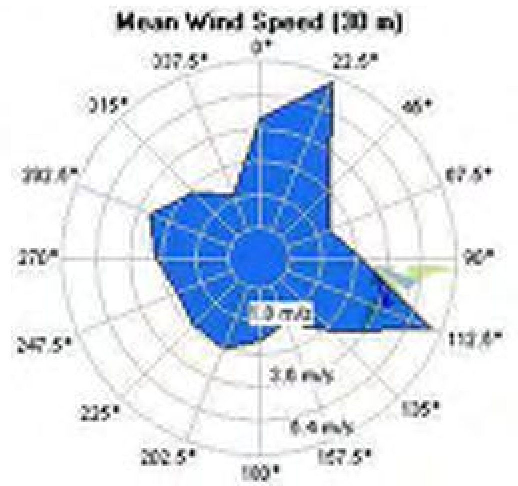
Variable	Value
Latitude	N 67° 5' 12.500"
Longitude	E 157° 51' 38.300"
Elevation	110 ft
Start date	10/30/2009 14:31
End date	7/26/2010 11:09
Duration	8.8 months
Length of time step	2 minutes
Calm threshold	0 m/s
Mean temperature	14.8 °C
Mean pressure	100.9 kPa
Mean air density	1.219 kg/m³
Power density at 50m	n/a
Wind power class	n/a
Power law exponent	n/a
Surface roughness	n/a
Roughness class	n/a
Roughness description	n/a

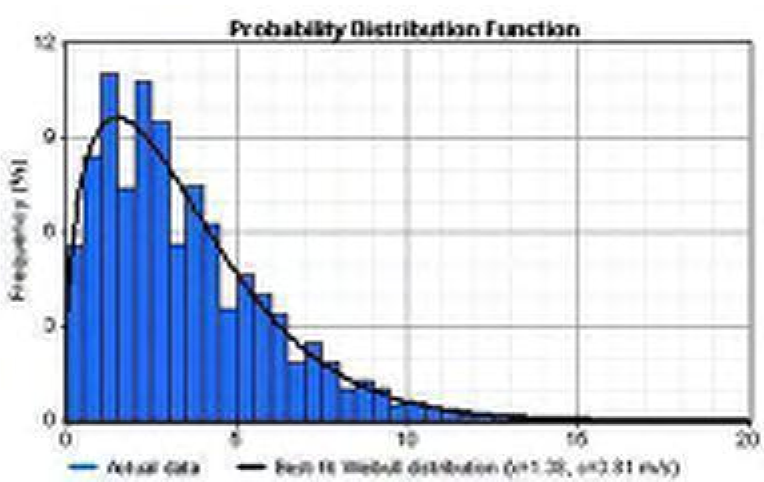


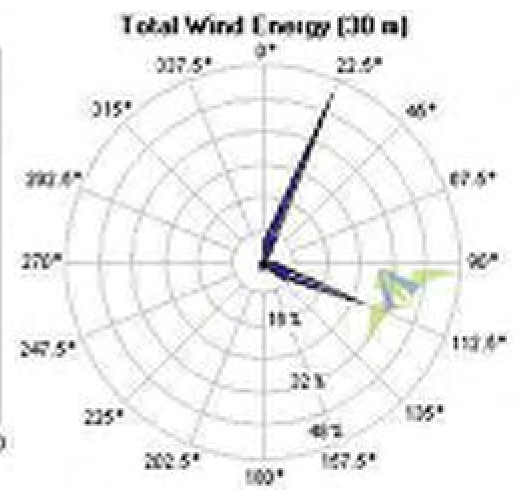
Wind Speed and Direction











Data Column Properties

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
Solar Radiation, W/m²()			193,579	153,854	79.48	125	1	1,057	191
Wind Speed, m/s	m/s	30 m	193,579	153,854	79.48	3.48	0.00	18.18	2.52
Gust Speed, m/s	m/s	30 m	193,579	153,854	79.48	4.45	0.00	21.89	3.20
Wind Direction, ø()	°	30 m	193,579	153,854	79.48	49.9	0.0	355.2	96.0
Air Density	kg/m³		193,579	193,579	100.00	1.219	1.221	1.221	0.002
Wind Speed, m/s WPD	W/m²		193,579	153,854	79.48	77	0	3,668	170
Gust Speed, m/s WPD	W/m²		193,579	153,854	79.48	161	0	6,403	374