Buckland Wind Resource Report

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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

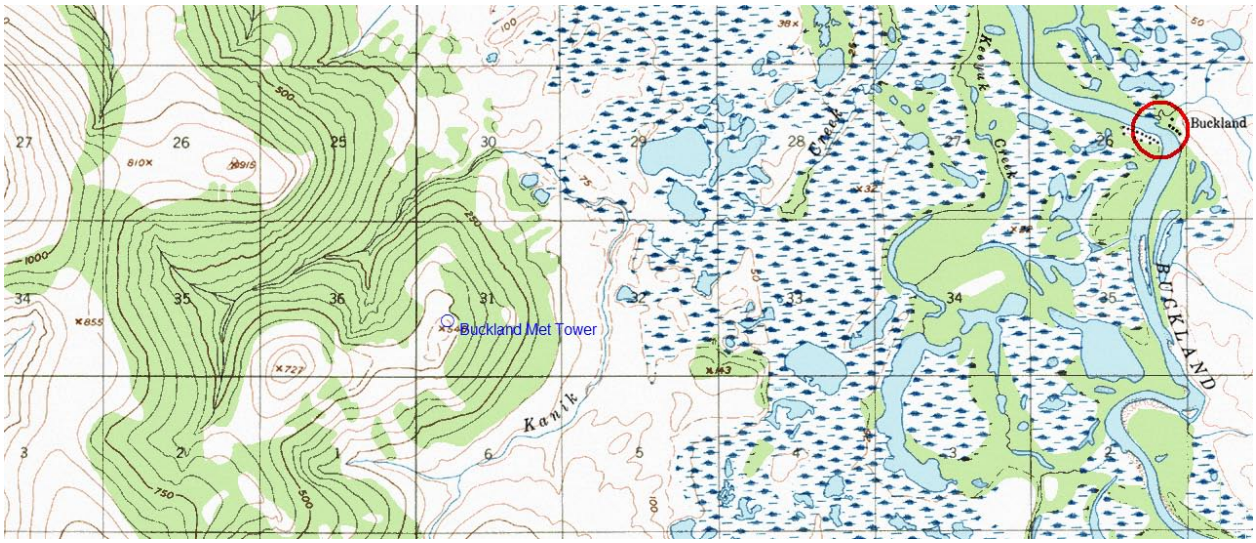
Test Site Location

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

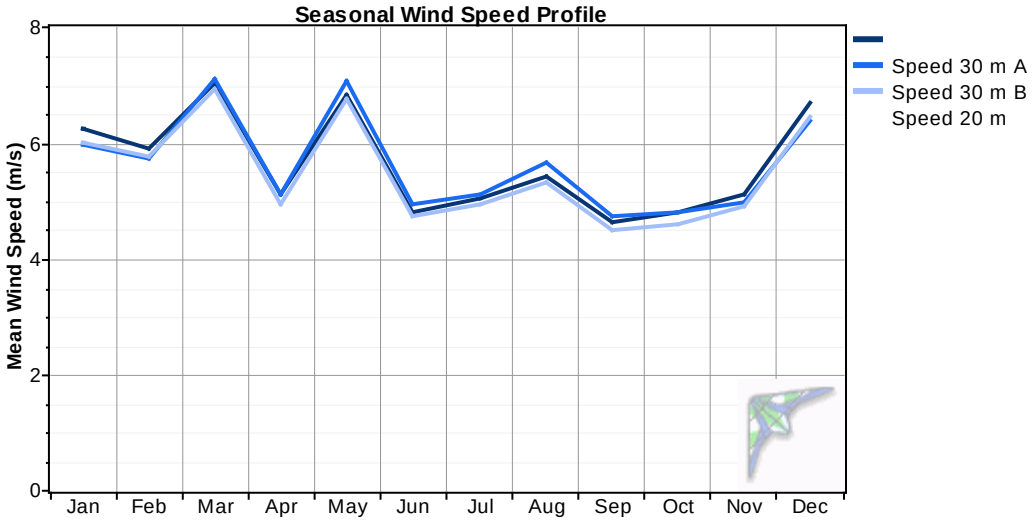
As is the typical rule in Alaska, the Buckland met tower site experiences higher winds in the winter compared to summer. The higher winds of March and May compared to April are likely a measurement artifact that would smooth out with a multi-year data view.

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%

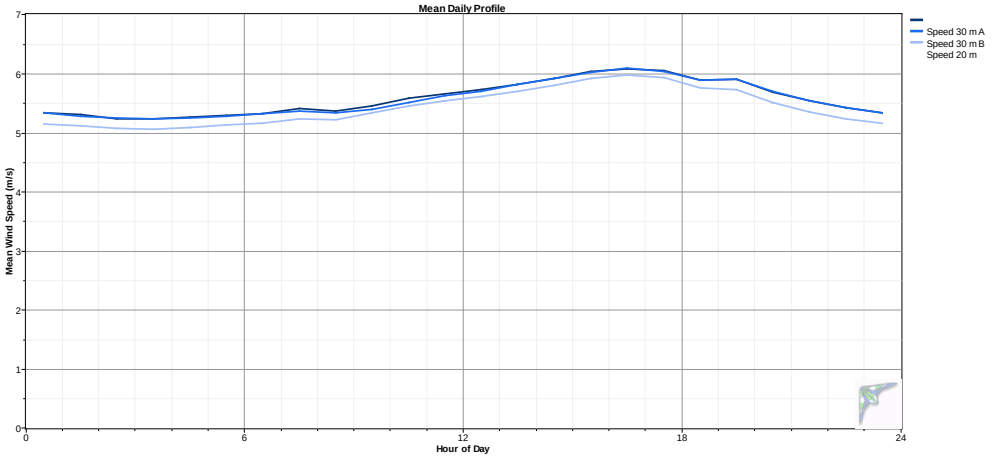
Time series graph (synth. data)



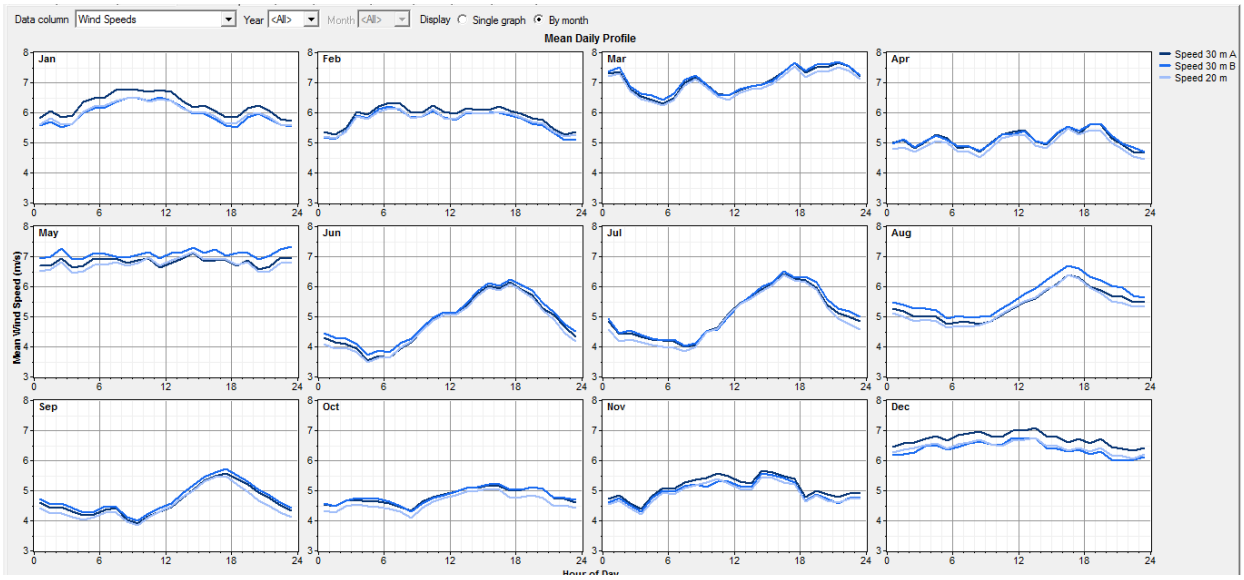
Daily Wind Profile

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)



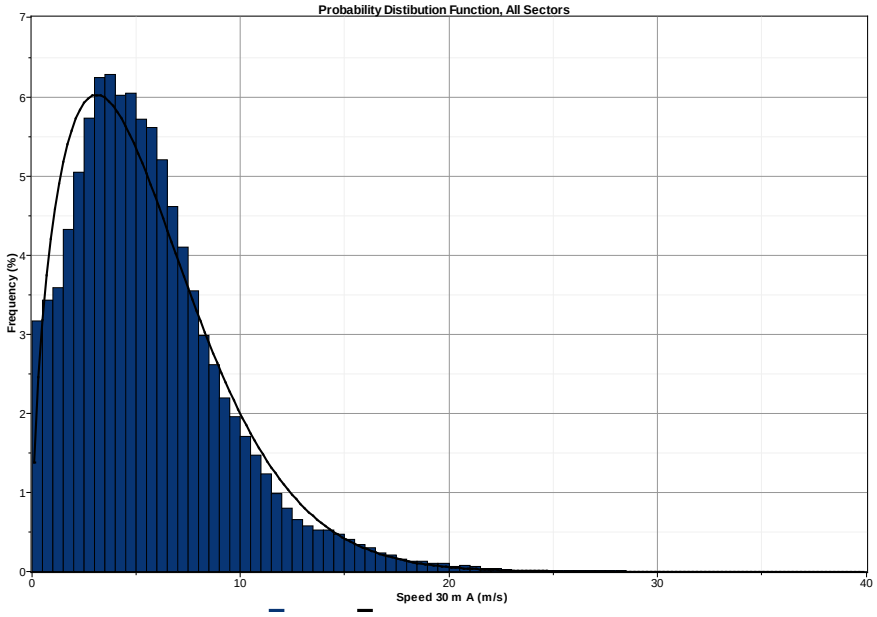
Monthly-basis daily wind profile (synth. data)



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



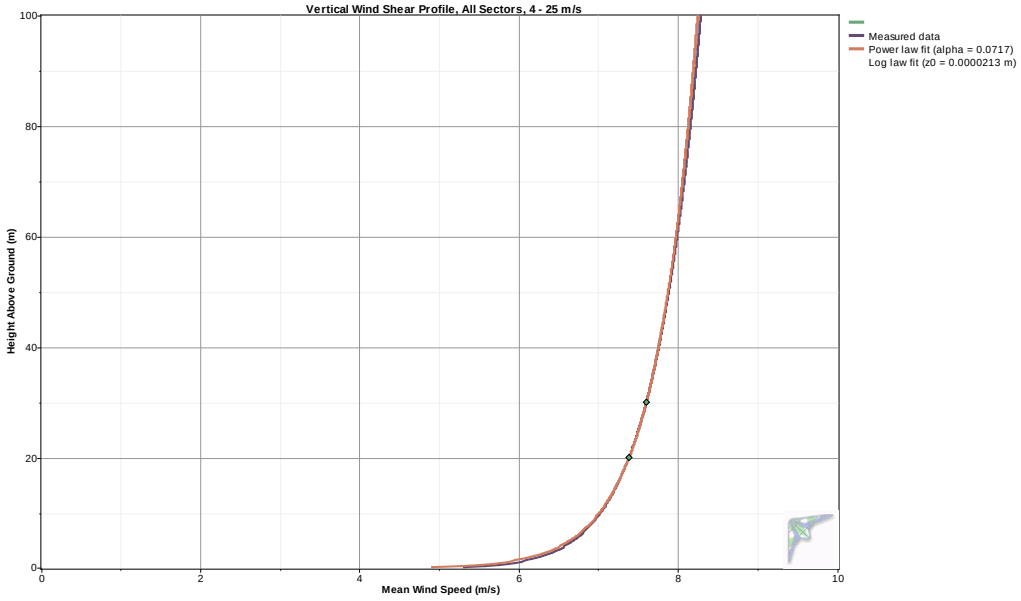
Cumulative frequency table

Bin (m/s)			Freq.	Cum. Freq.	Bin (m/s)			Freq.	Cum. Freq.
Lower	Upper	Occurrences	(%)	(%)	Lower	Upper	Occurrences	(%)	(%)
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



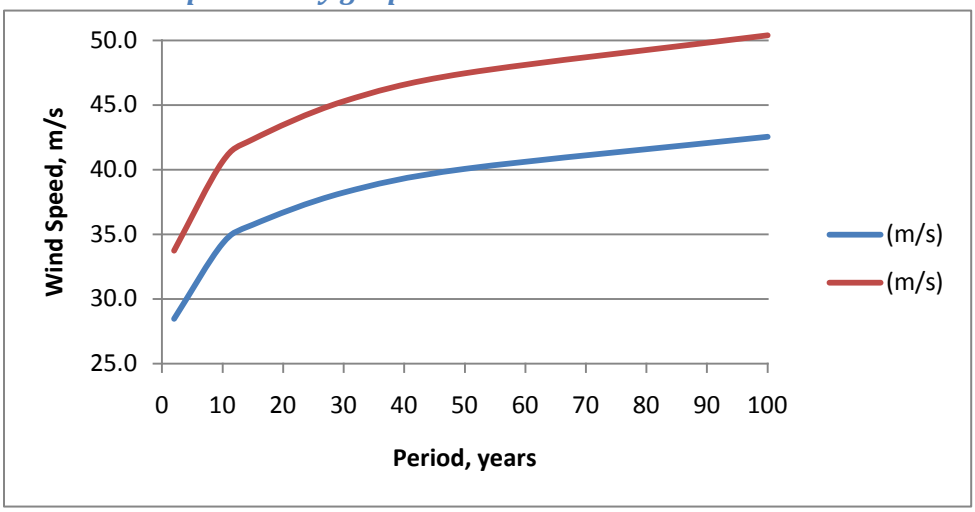
Extreme Winds

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

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. 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



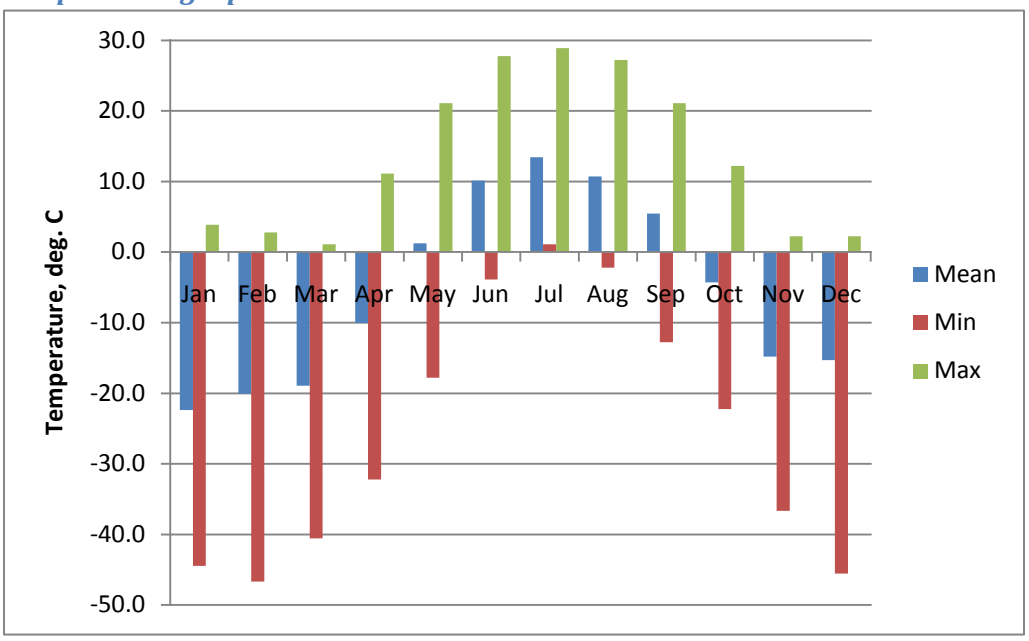
Temperature and Density

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



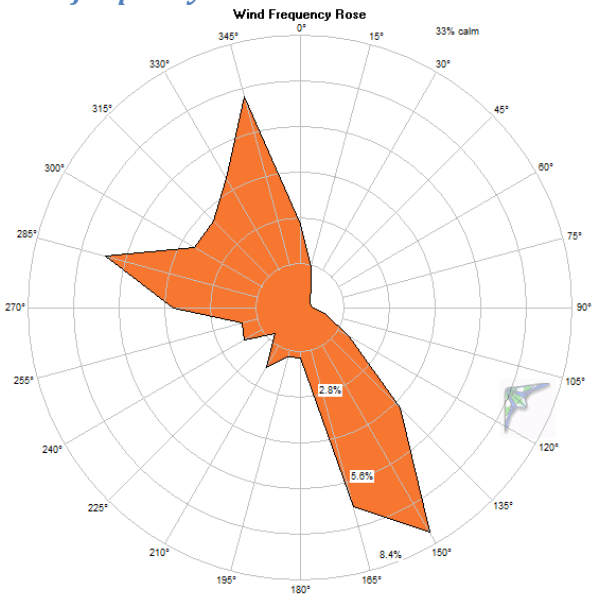
Temperature table, Fahrenheit and Celsius

	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

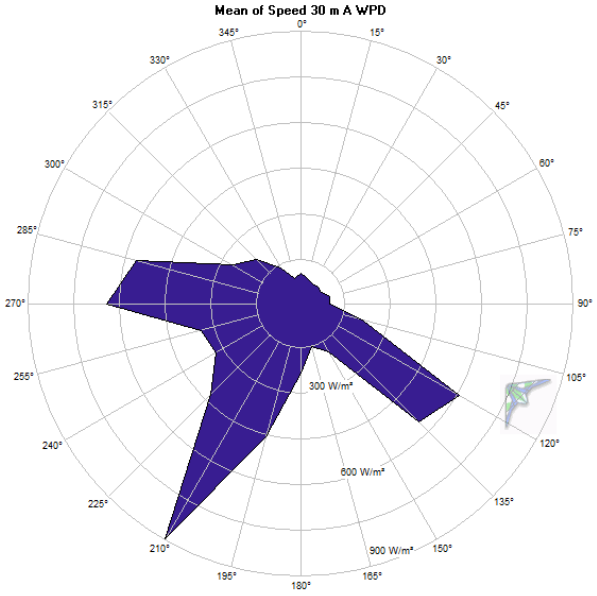
Wind Direction

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.

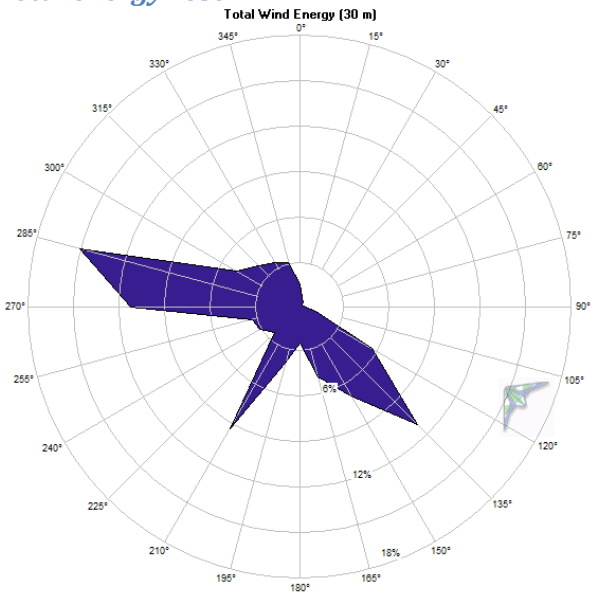
Wind frequency rose



Mean value rose



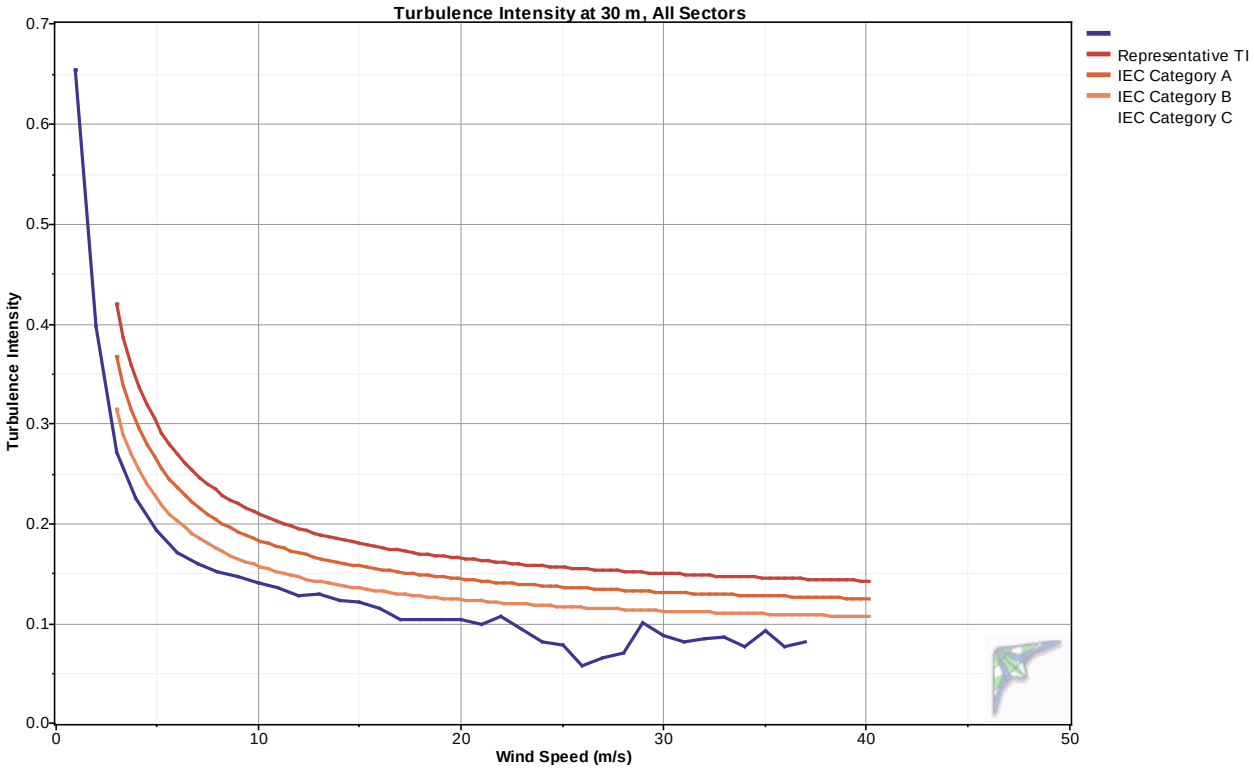
Total energy rose



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