Eek Wind Power Report

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Summary Information

The wind resource in Eek is estimated based on wind studies completed in the nearby communities of Quinhagak, Bethel, and Kongiganak. The wind resource in Quinhagak was measured from October 2005 to May 2007 with a 30 meter met tower located near the site of the recently-constructed wind turbines. The mean wind speed in Quinhagak (at 30 meters) was measured at 6.3 m/s with calculated wind power density of 338 W/m^2. Quinhagak classified as IEC Class III-c.

Other data sources, including a March 2006 AEA Report (M. Devine) for Chefornak, indicate mean annual mean wind speed in Bethel as 6.9 m/s and Kongiganak as 7.3 m/s. The Bethel and Kongiganak data indicated similar Weibull k, turbulence and wind shear values as Quinhagak. Given that a met tower study has not been conducted in Eek, but the referenced communities of Quinhagak, Bethel and Kongiganak bracket Eek in three directions and share similar topographic features, the referenced data sources are thought highly representative of Eek's expected wind resource. Of the three referenced communities, the wind data in Quinhagak was selected to represent Eek as it exhibited the lowest average wind speed and hence is most conservative. The actual wind resource in Eek may be stronger; closer to that of Kongiganak. If true, energy production from the proposed wind turbine would be higher than estimated in this report.

Wind Turbine Performance

It is perhaps counterintuitive that wind power density and wind class do not correlate linearly with turbine power output. This is due to a number of factors, including theoretical limitations of a lift-producing aerodynamic device (the turbine rotor) and practical limitations of generator weight and rated output. For these reasons and others, a wind turbine in a low power class wind regime may still produce sufficient energy to warrant installation of turbines. A simplistic consideration of possible turbine output in Eek is to model power output of a particular turbine with mean of monthly means data collected to date and extrapolating to the turbine hub height.

Turbine performance was analyzed with the HOMER software using the Northern Power Northwind 100 B model (100 kW rated output, 21 meter rotor diameter), the (remanufactured) Vestas V17 (90 kW rated output, 17 meter rotor diameter) and the Bergey Excel-S (10 kW, 7 meter rotor diameter). Note that the NW100/21 is available with a 37 meter tower (a 30 meter tower may be available by special order), the Vestas with a 26 meter tower, and the Bergey is available with a wind range of tower options, including tubular, lattice and tilt-up options. For this study, 30, 37 and 43 meter standard guyed lattice towers were considered.

Eek Turbine Performance Estimates

Turbine	Hub height (m)	Wind speed (m/s)	100% availability Capacity factor (%)	100% availability Production MWh/yr	90% availability Capacity factor (%)	90% availability Production MWh/yr	80% availability Capacity factor (%)	80% availability Production MWh/yr
NW100/21	37	6.49	28.7	259.2	25.8	233.3	23.0	207.4
Vestas V17	26	6.18	23.8	187.4	21.4	168.7	19.0	149.9
Excel-S	30	6.30	27.5	24.1	24.8	21.7	22.0	19.3
	37	6.49	29.3	25.6	26.4	23.0	23.4	20.5
	43	6.63	30.6	26.8	27.5	24.1	24.5	21.4

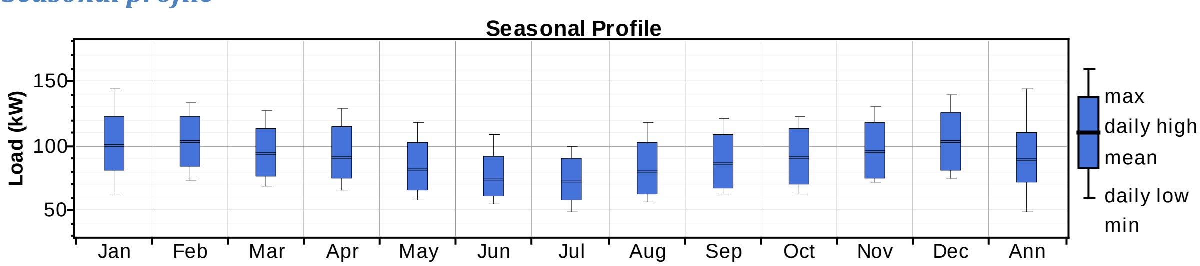
Wind Farm

AVEC has proposed installation of one or more wind turbines to create a wind-diesel hybrid power system for the village of Eek. HOMER software was used to create an Eek village simulation model.

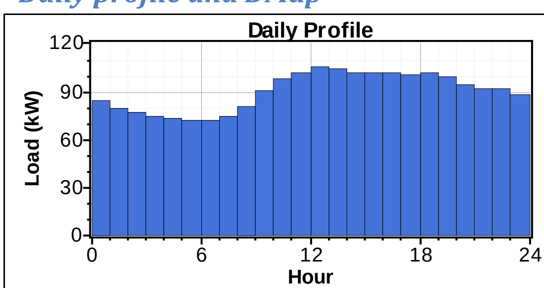
Village Load

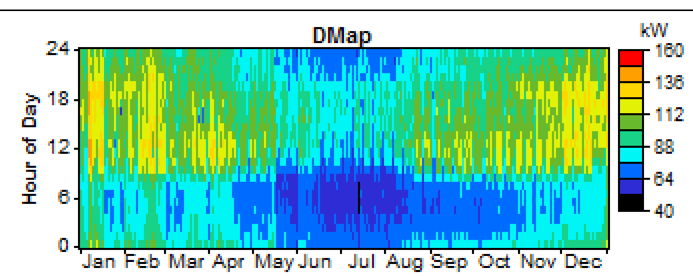
An Eek hourly load profile was synthesized using the Alaska village load calculator Excel spreadsheet developed by Alaska Energy Authority several years ago. The results were adjusted slightly to match actual village average and peak loads of Eek documented by AVEC in their 2008 annual power generation report. The result is a virtual Eek village with a 90 kW average load, 144 kW peak load and average daily power usage of 2,156 kWh/day. Seasonal, daily and DMap profiles of the Eek virtual load are shown below.

Seasonal profile

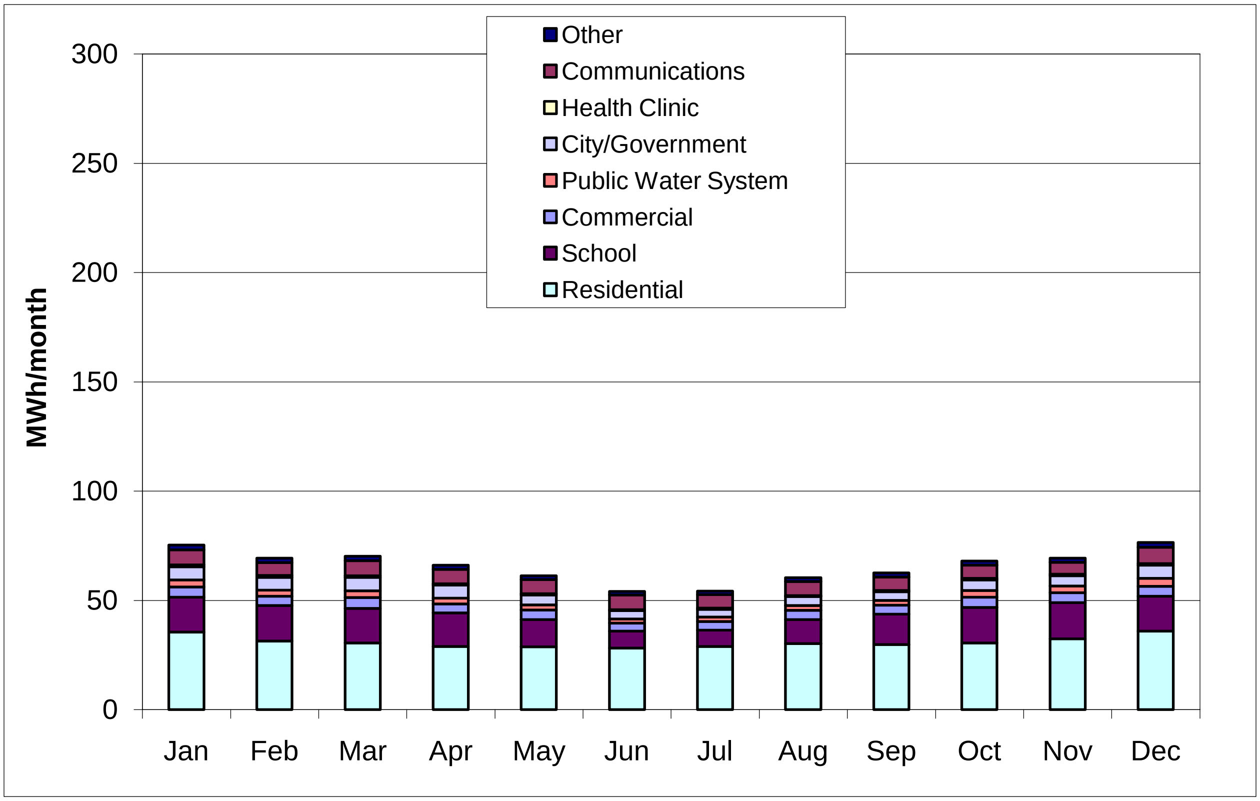


Daily profile and DMap





Alaska village calculator load details, Eek



Eek Wind Farm Performance

HOMER software was used to estimate wind turbine production, wind penetration and fuel displacement for wind power input from operation of one Northern Power NW100/21 and three to six Bergey Excel-S turbines in an Eek wind regime based on nearby Quinhagak met tower data. HOMER modeling may in some cases yield lower production estimates than Alaska Energy Authority (AEA) methods which consider only performance of the turbine displacing fuel usage from diesel generators supplying essentially an infinite load. HOMER considers the dynamics of the actual village load and the reality that turbines will on occasion generate more power than can be absorbed by the village electric load. During these times, excess energy must be diverted to a secondary use, such as a thermal heating load, or turbine operation must be curtailed. For HOMER modeling, it was assumed that a diesel generator would remain on-line at all times with a minimum load of 25 kW. Control constraints for the model are system operating reserves of 10% of current load plus 50% of wind power input.

Wind turbine production estimates, 100% turbine availability

Turbine	No. of Turbines	Hub ht. (m)	System Wind Penetration (%)	Wind Production (MWh/yr)	Fuel Displaced (gal)	System Excess Energy (MWh/yr)	System Excess Energy (%)	Heating Fuel Equiv. (gal)
NW100/21	1	37	32.9	259.2	15,103	30.1	3.7	1,204
Vestas V17	1	26	23.8	187.4	12,547	11.7	1.5	468
Excel-S	3	**37**	9.8	77.0	5,496	0.0	0.0	0
	4	**37**	13.0	102.6	7,304	0.3	0.1	12
	5	**37**	16.3	128.3	9,018	2.0	0.3	80
	6	**37**	19.6	154.0	10,592	5.6	0.7	224

Notes:

1. Quinhagak wind resource, Eek virtual village load
2. HOMER modeling assumes 100% turbine availability
3. Displaced fuel for electrical generation only
4. Excess electricity to secondary thermal heating load
5. Heating fuel equivalent for system excess energy dump; 25 kWh/gal conversion
6. HOMER model operation reserves: 10% current load, 50% wind power output
7. Diesel generator efficiency data from 2008 AVEC annual generation report
8. Minimum **25** kW diesel generator loading; all excess energy to secondary load

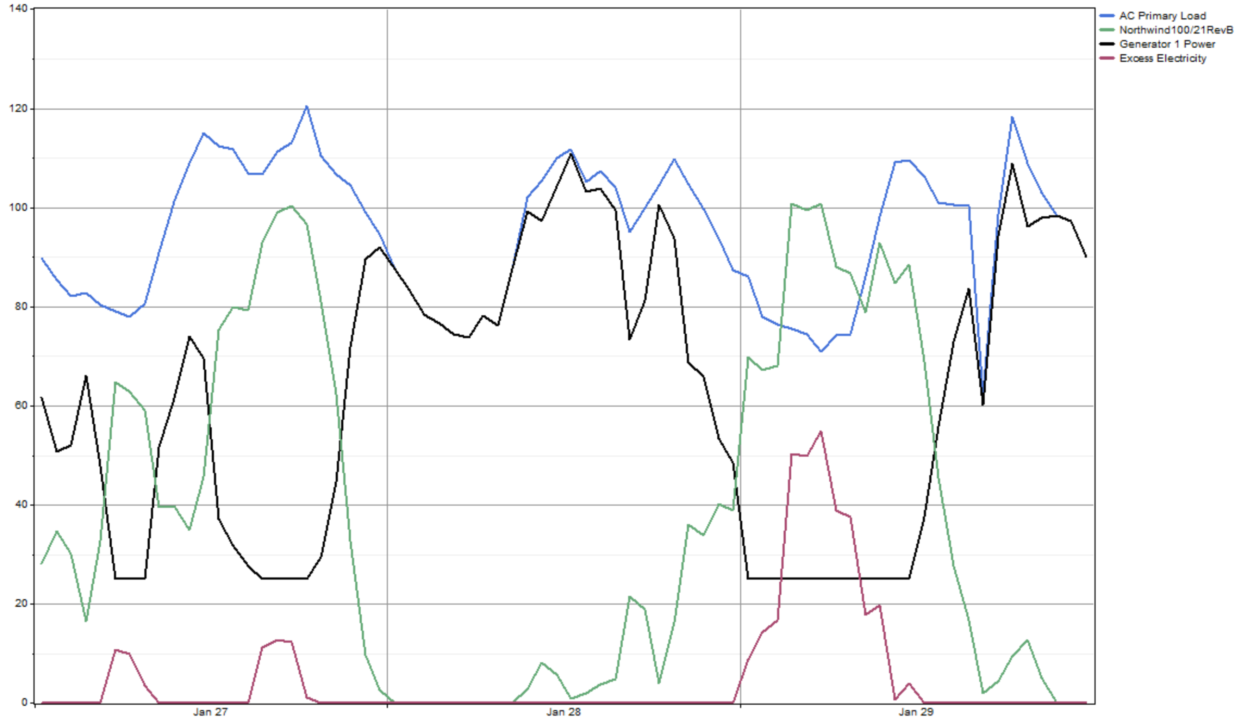
Wind turbine production estimates, 80% turbine availability

Turbine	No. of Turbines	Hub ht. (m)	System Wind Penetration (%)	Wind Production (MWh/yr)	Fuel Displaced (gal)	System Excess Energy (MWh/yr)	System Excess Energy (%)	Heating Fuel Equiv. (gal)
NW100/21	1	37	26.3	207.4	12,083	24.1	3.0	963
Vestas V17	1	26	19.0	149.9	10,038	9.4	1.2	374
Excel-S	3	**37**	7.8	61.6	4,397	0.0	0.0	0
	4	**37**	10.4	82.1	5,844	0.2	0.1	10
	5	**37**	13.0	102.6	7,214	1.6	0.2	64
	6	**37**	15.7	123.2	8,473	4.5	0.6	179

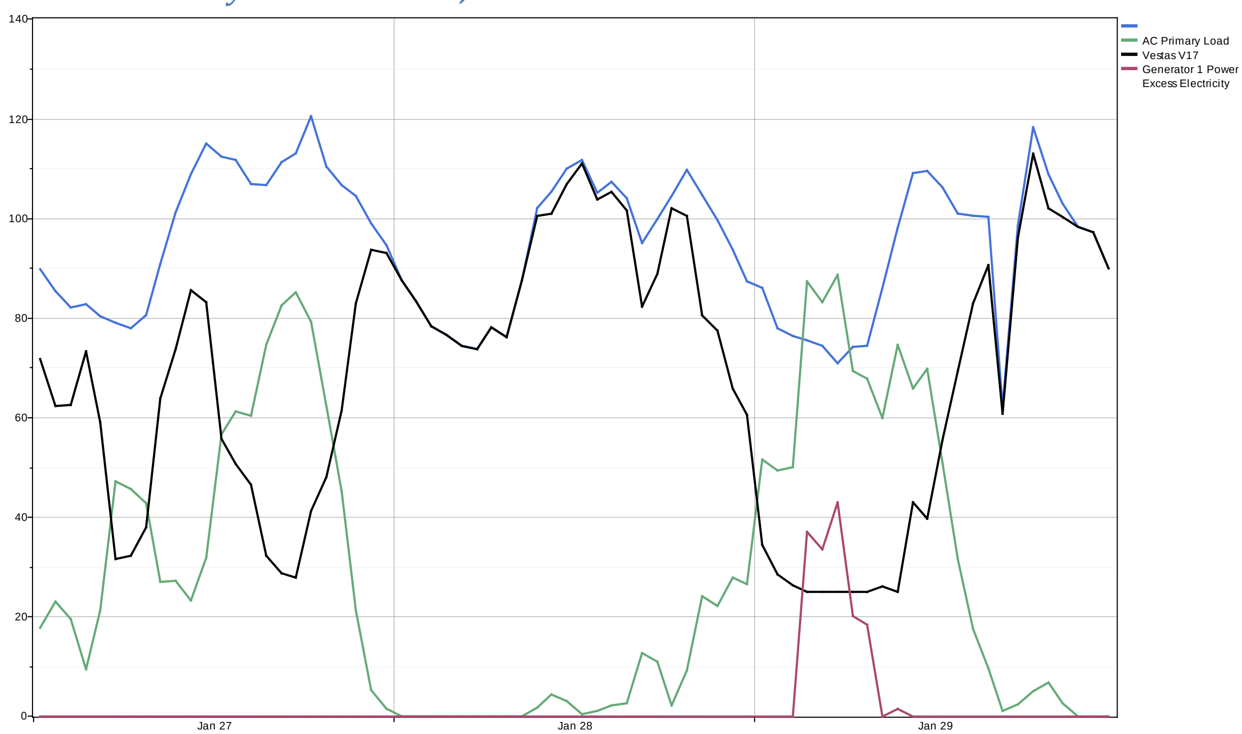
Notes:

1. Quinhagak wind resource, Eek virtual village load
2. Turbine availability adjusted to 80%
3. Displaced fuel for electrical generation only
4. Excess electricity to secondary thermal heating load
5. Heating fuel equivalent for system excess energy dump; 25 kWh/gal conversion
6. HOMER model operation reserves: 10% current load, 50% wind power output
7. Diesel generator efficiency data from 2008 AVEC annual generation report
8. Minimum **25** kW diesel generator loading; all excess energy to secondary load

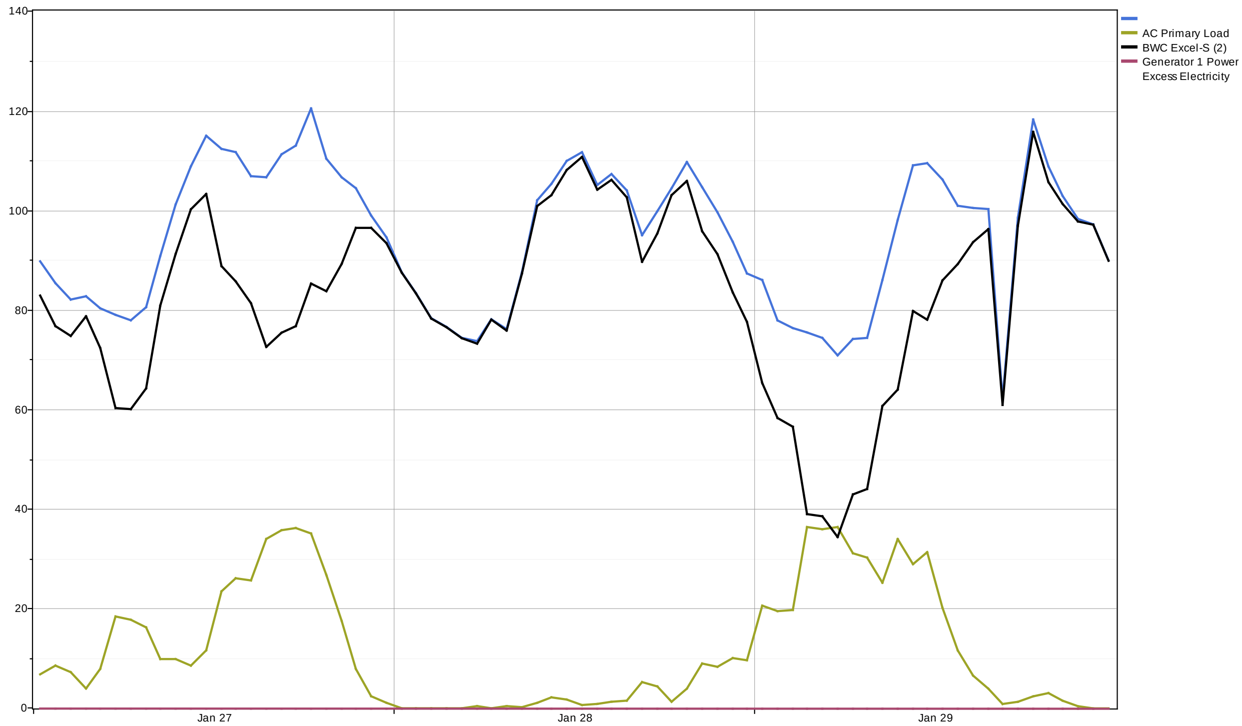
HOMER modeled system interaction, one NW100 turbine



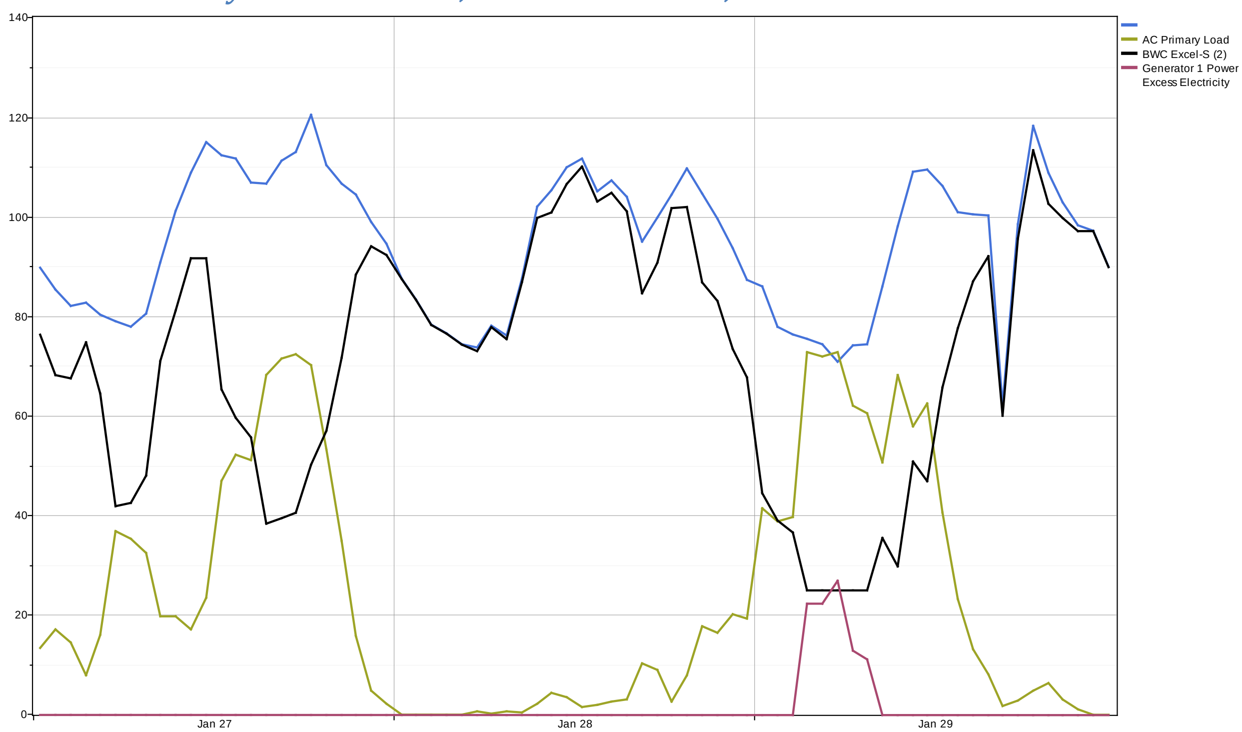
HOMER modeled system interaction, one V17 turbine



HOMER modeled system interaction, three Excel-S turbines, 37 m hub ht.



HOMER modeled system interaction, six Excel-S turbines, 37 m hub ht.



Quinhagak Met Tower Wind Data

Meteorological Tower Data Synopsis

Wind power class (measured to date)	Class 4 – Good
Average wind speed (30 meters)	6.31 m/s
Maximum wind gust (2 seconds)	43.6 m/s (1/30/07)
Mean wind power density (50 meters)	436 W/m^2
Mean wind power density (30 meters)	340 W/m^2
Mean energy content (30 meters)	2,978 $kWh/m^2/yr$
Roughness Class	2.35 (few trees)
Power law exponent	0.197 (moderate wind shear)
Turbulence intensity	0.0915 (low)
Frequency of calms (4 m/s threshold)	27 percent
Data start date	October 23, 2005
Most recent data date	May 24, 2007

Met Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.765	0.35	NE
2	NRG #40 anemometer	30 m (B)	0.765	0.35	SW
3	NRG #40 anemometer	20 m	0.765	0.35	SW
7	NRG #200P wind vane	25 m	0.351	220	NE
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Site Information

Site number	0022
Site Description	Adjacent to proposed new powerplant, near tank farm
Latitude/longitude	N 059° 44.646'; W 161° 55.030'
Site elevation	3 meters
Datalogger type	NRG Symphonie
Tower type	NRG 30-meter tall tower, 152 mm (6-in) diameter

Data Quality Control Summary

Data was filtered to remove presumed icing events that yield false zero wind speed data. Data that met the following criteria were filtered: wind speed < 1 m/s, wind speed standard deviation = 0, and temperature < 3 °C. Other obvious icing data was removed even if it did not meet the above criteria. An offset failure in the temperature sensor occurred on July 7, 2006 resulting logged temperature data reading approximately 30° C lower than normal. An offset correction of +32.8° was added to all subsequent temperature data. It is not known if this offset correction is completely accurate for the ten months it covers, but a near accurate temperature record of the site was deemed more desirable than deleting most of the temperature record.

Data quality table

		30 m A anem.		30 m B anem.		20 m anem.	
		Records	Recovery Rate	Records	Recovery Rate	Records	Recovery Rate
2005	Oct	1,235	90.5	1,235	90.5	1,235	90.5
2005	Nov	3,428	79.4	3,851	89.1	3,851	89.1
2005	Dec	4,148	92.9	3,986	89.3	4,464	100
2006	Jan	4,464	100	4,464	100	4,464	100
2006	Feb	4,032	100	4,032	100	4,032	100
2006	Mar	4,464	100	4,464	100	4,464	100
2006	Apr	4,320	100	4,320	100	4,320	100
2006	May	4,464	100	4,464	100	4,464	100
2006	Jun	4,320	100	4,320	100	4,320	100
2006	Jul	4,464	100	4,464	100	4,464	100
2006	Aug	4,464	100	4,464	100	4,464	100
2006	Sep	4,320	100	4,320	100	4,320	100
2006	Oct	4,464	100	4,464	100	4,464	100
2006	Nov	4,320	100	4,320	100	4,320	100
2006	Dec	4,464	100	4,464	100	4,464	100
2007	Jan	4,464	100	4,464	100	4,464	100
2007	Feb	4,032	100	4,032	100	4,032	100
2007	Mar	4,464	100	4,464	100	4,464	100
2007	Apr	4,201	97.2	4,320	100	4,204	97.3
2007	May	3,366	100	3,366	100	3,366	100
All data		81,898	98.3	82,278	98.7	82,640	99.1

		25 m vane		Temperature	
		Records	Recovery Rate	Records	Recovery Rate
2005	Oct	1,235	90.5	1,235	100
2005	Nov	3,397	78.6	4,320	100
2005	Dec	3,204	71.8	4,464	100
2006	Jan	4,193	93.9	4,464	100
2006	Feb	3,703	91.8	4,032	100
2006	Mar	4,464	100	4,464	100
2006	Apr	3,929	90.9	4,320	100
2006	May	4,464	100	4,464	100
2006	Jun	4,320	100	4,320	100
2006	Jul	4,464	100	4,464	100
2006	Aug	4,464	100	4,464	100
2006	Sep	4,320	100	4,320	100

2006	Oct	4,464	100	4,464	100
2006	Nov	4,320	100	4,320	100
2006	Dec	4,464	100	4,464	100
2007	Jan	4,239	95	4,464	100
2007	Feb	4,032	100	4,032	100
2007	Mar	4,464	100	4,464	100
2007	Apr	4,320	100	4,320	100
2007	May	3,366	100	3,366	100
All data		79,826	95.8	83,225	100

Note: shaded temperature data notes months where +32.8° offset correction was inserted for sensor offset error

Measured Wind Speeds

The Channel 1 (30-meter [A]) anemometer wind speed average for the reporting period is 6.31 m/s. The Channel 2 (30-meter [B]) anemometer wind speed average is 6.30 m/s and the Channel 3 (20-meter) anemometer wind speed average for the reporting period is 5.80 m/s.

Typically, the highest wind speeds occur during the winter months of October through March with the lowest winds during the summer months of May through September. The unusually low winds measured in January 2006 were due to a persistent high pressure system over Alaska that month that yielded calm winds and extremely cold weather Statewide. January 2006 was then followed by an extremely windy February 2006. As one can see, the winds during winter 2005/06 were quite different from winter 2006/07.

The daily wind speed profile indicates that the lowest winds of the day occur in the morning at about 3 a.m. to 9 a.m. and the highest winds of the day occur in the afternoon and early evening hours of about 1 p.m. to 8 p.m. This correlates reasonably well with the times of day where load demand is highest.

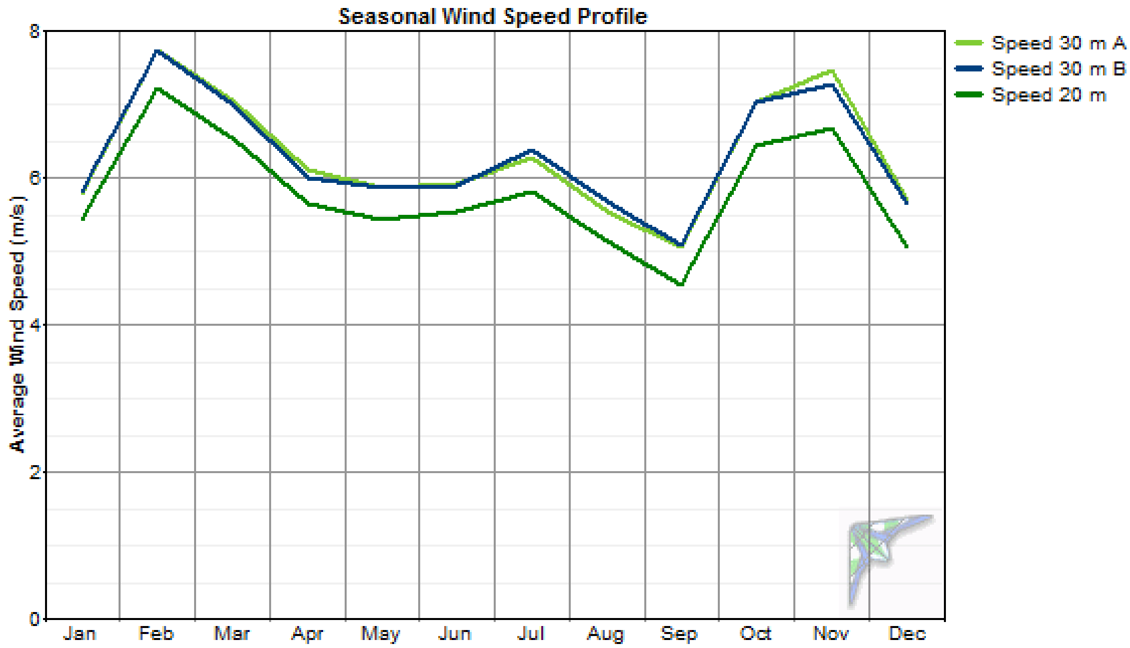
Anemometer data summary

	30 m A anemometer					30 m B anem.		20 m anemometer	
Month	Mean (m/s)	Max (m/s)	SD (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)	Mean (m/s)	Max (m/s)
Jan	5.79	43.6	4.33	1.38	6.34	5.82	43.9	5.46	41.6
Feb	7.74	33.2	4.65	1.74	8.71	7.75	33.6	7.23	32.1
Mar	7.07	29.4	3.59	2.05	7.96	7.03	29.8	6.55	29.1
Apr	6.13	22.6	2.96	2.19	6.93	6.00	22.9	5.66	22.6
May	5.88	20.2	2.68	2.32	6.63	5.88	19.9	5.45	19.9
Jun	5.92	19.5	2.79	2.25	6.69	5.90	19.5	5.56	19.5
Jul	6.28	20.6	2.81	2.36	7.08	6.39	21.8	5.83	20.2
Aug	5.56	16.4	2.85	2.05	6.28	5.70	16.8	5.16	16.4
Sep	5.08	24.4	2.98	1.80	5.72	5.10	24.8	4.56	24.0

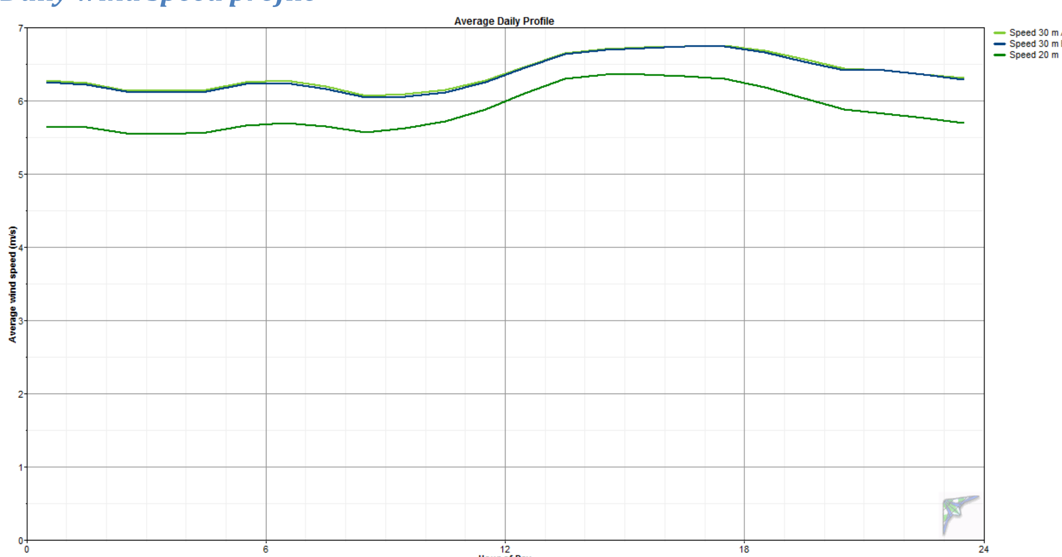
Oct	7.03	26.3	3.74	1.95	7.92	7.04	26.0	6.45	25.2
Nov	7.47	27.5	3.59	2.18	8.42	7.29	27.9	6.69	26.8
Dec	5.73	21.8	2.72	2.20	6.45	5.65	22.1	5.06	21.4
Annual	6.31	43.6	3.31	2.04	7.09	6.30	43.9	5.80	41.6

Note: Max speed data are 2 second gust readings

Wind profile



Daily wind speed profile

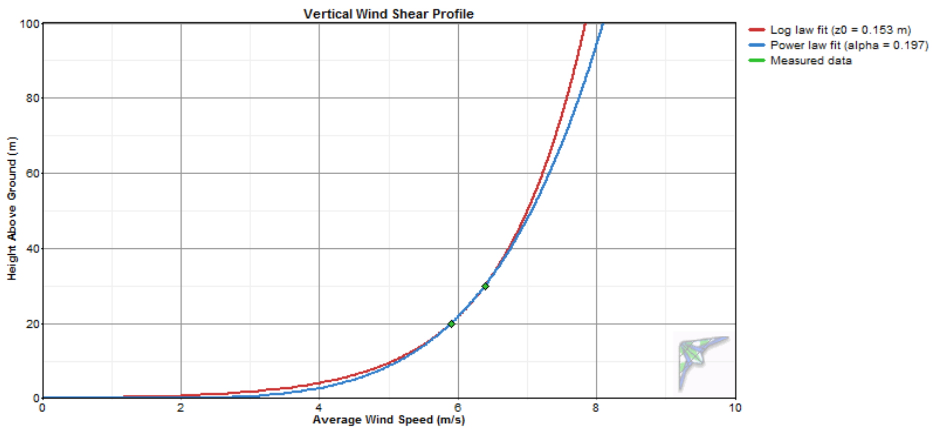


Wind Shear

The power law exponent was calculated at 0.197, indicating moderate wind shear at the Quinhagak met tower test site. The shear data is shown in greater detail in the accompanying seasonal, daily and directional plots of the power law exponent, or wind shear.

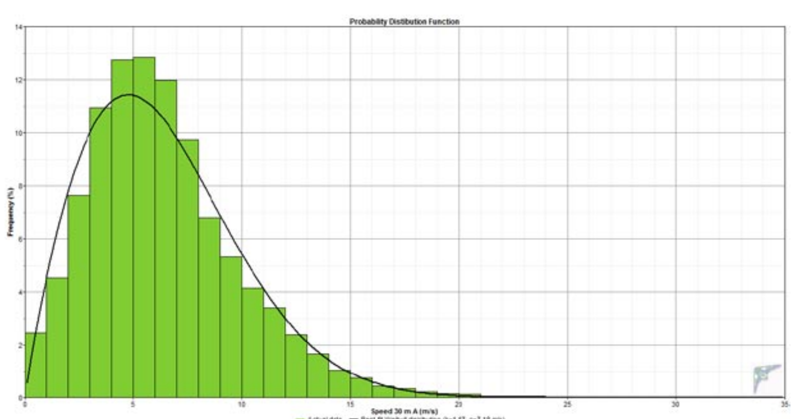
The practical application of this data is that one can expect appreciably higher power production with increased turbine tower height. A tower height/power production cost tradeoff study is recommended. Note that some of the observed shear may be due to the presence of tanks and other structures north of the met tower test site and would not be indicative of general wind shear conditions in the Quinhagak area.

Wind shear profile



Probability Distribution Function

The graphed probability distribution function provides a visual indication of measured wind speeds in one meter per second "bins." Note that most wind turbines do not begin to generate power until the wind speed at hub height reached 4 m/s; using this criteria, 27% of Quinhagak's winds are calm (less than 4 m/s). The black line in the graph is a best fit Weibull approximation of the wind speed distribution. At the 30 meter level, the Weibull parameters are k = 1.87 (indicates a relatively narrow distribution of wind speeds) and c = 7.18 m/s (scale factor for the Weibull distribution).

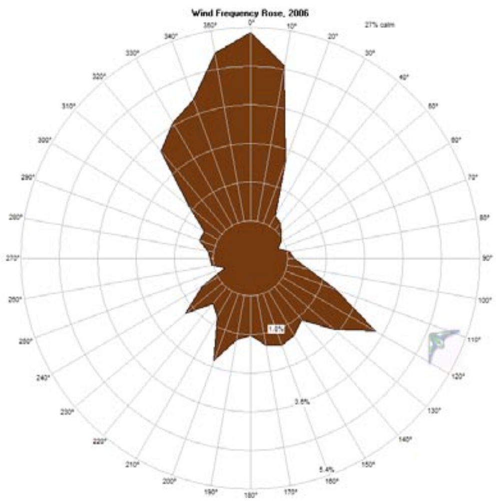


Wind Roses

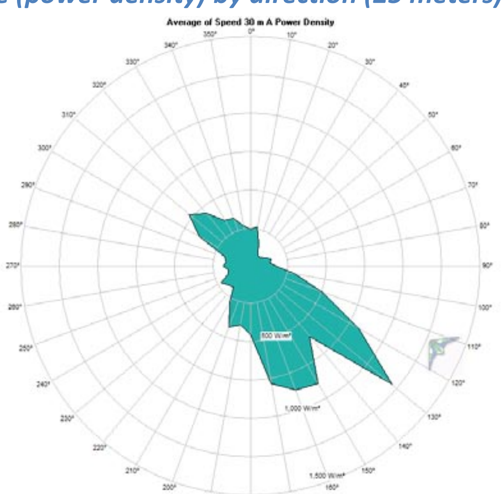
Quinhagak winds are directional in frequency (percent of time) from the north and to a lesser extent from the southwest, south and southeast (wind frequency rose). Interestingly though, the power of the winds (mean value by direction) indicate that the southeast winds, when they occur, are much stronger than the northerly winds. Combining the frequency rose and the mean value rose yields the third wind rose – the total value (power density) rose. This wind rose indicates frequency of power density by direction and is most important of the three for siting of turbines.

To minimize wake turbulence, wind turbines should be located with due consideration of clear zones from nearby obstructions and especially other turbines. If one were to consider just the frequency rose, turbines might be placed on more of an east-west alignment. But with consideration of the total value (power density) rose, turbines should be located on a northeast to southwest alignment with plenty of clearance from obstructions located to the northwest and southeast of the turbines.

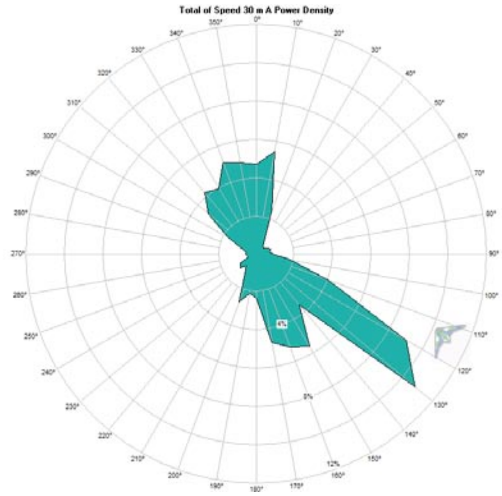
Wind frequency rose (25 meters)



Mean Value (power density) by direction (25 meters)



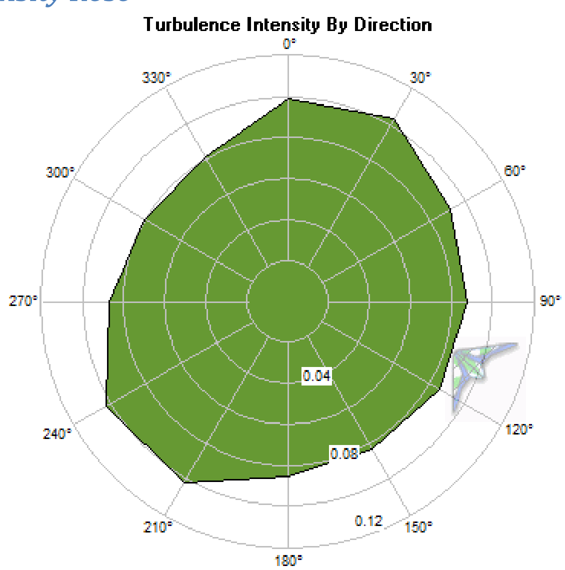
Total value (power density) rose (25 meters)



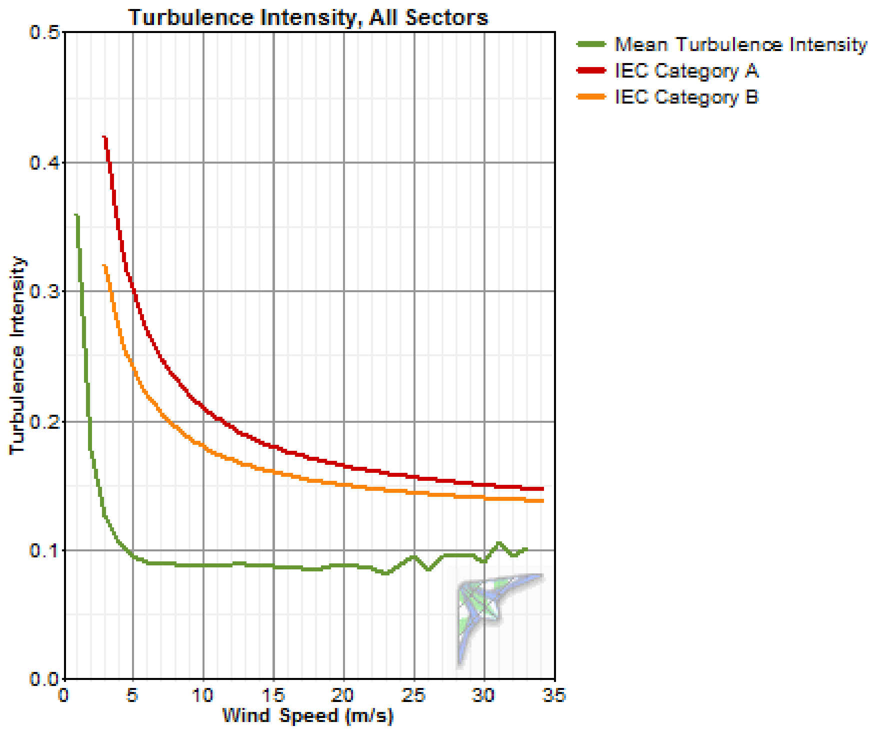
Turbulence Intensity

The turbulence intensity (TI) is acceptable for the north-northeast and southeast wind directions, with mean turbulence intensity of 0.0915, indicating relatively smooth air for wind turbine operations. This turbulence intensity is calculated with a threshold wind speed of 4 m/s (only wind speeds exceeding 4 m/s are considered). The relatively high turbulence intensity to the northeast and southwest are of little consequence as essentially no power producing winds are from these directions.

Turbulence Intensity Rose



Turbulence Intensity by Wind Speed



Turbulence Intensity Table

Turbulence Intensity Table, 30 m A anemometer, 25 m vane, 10/22/05 to 5/24/07

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Upper (m/s)	Records In Bin	SD of Wind Speed (m/s)	Mean Turbulence Intensity	Standard Deviation of Turbulence Intensity	Characteristic Turbulence Intensity
1	0.5	1.5	2517	0.338	0.359	0.160	0.519
2	1.5	2.5	4939	0.347	0.178	0.094	0.272
3	2.5	3.5	7687	0.375	0.127	0.058	0.185
4	3.5	4.5	9988	0.418	0.106	0.046	0.151
5	4.5	5.5	10511	0.474	0.096	0.038	0.134
6	5.5	6.5	10494	0.544	0.092	0.033	0.125
7	6.5	7.5	8962	0.621	0.090	0.032	0.121
8	7.5	8.5	6743	0.706	0.089	0.030	0.119
9	8.5	9.5	4828	0.787	0.088	0.027	0.115
10	9.5	10.5	3851	0.868	0.087	0.025	0.112
11	10.5	11.5	3067	0.959	0.088	0.024	0.112
12	11.5	12.5	2396	1.060	0.089	0.023	0.112
13	12.5	13.5	1601	1.159	0.090	0.022	0.112
14	13.5	14.5	1057	1.228	0.088	0.022	0.110
15	14.5	15.5	759	1.308	0.088	0.021	0.109

16	15.5	16.5	445	1.369	0.086	0.020	0.106
17	16.5	17.5	314	1.456	0.086	0.021	0.107
18	17.5	18.5	247	1.516	0.085	0.020	0.104
19	18.5	19.5	136	1.644	0.087	0.019	0.106
20	19.5	20.5	123	1.784	0.090	0.019	0.109
21	20.5	21.5	82	1.830	0.088	0.016	0.104
22	21.5	22.5	43	1.886	0.086	0.015	0.100
23	22.5	23.5	45	1.889	0.082	0.015	0.097
24	23.5	24.5	32	2.153	0.090	0.012	0.102
25	24.5	25.5	18	2.400	0.096	0.014	0.110
26	25.5	26.5	7	2.171	0.084	0.010	0.094
27	26.5	27.5	3	2.567	0.096	0.013	0.108
28	27.5	28.5	4	2.675	0.096	0.020	0.116
29	28.5	29.5	4	2.775	0.096	0.011	0.107
30	29.5	30.5	3	2.733	0.091	0.007	0.098
31	30.5	31.5	3	3.300	0.107	0.014	0.121
32	31.5	32.5	2	3.050	0.095	0.006	0.101
33	32.5	33.5	5	3.340	0.102	0.010	0.112

Air Temperature and Density

Over the reporting period, Quinhagak had an annual average temperature of -3.9 degrees C. The minimum recorded temperature during the test period was -49.1° C (see below; possibly incorrect) and the maximum temperature 23.8° C.

Note that on July 7, 2006 the temperature sensor experienced an unusual fault in that although it continued to record what appeared to be normal variations of temperature, the offset suddenly changed by approximately 30° C. This offset change (-32.8° C exactly) was added to subsequent temperature data in order to produce a best likely temperature record of Quinhagak, but because the nature of the fault is unknown, the corrective measure may be faulty to some extent. Hence, it is unlikely that the extreme low temperature data readings of -40° C and lower during the winter months of 2006/07 are completely accurate, although 2006/07 was a very cold winter in general. Despite the likelihood of error with the post 7/7/06 temperature data, it is more accurate for power density and turbine performance estimates to insert a corrective offset than to delete the faulty temperature data altogether.

Consequent to the rather cool average temperature in Quinhagak, air density is rather high, boosting the nominal performance of wind turbines. The average air density in Quinhagak is 1.326 kg/m^3, approximately eight percent higher than standard sea level atmospheric air density of 1.225 kg/m^3. This density variance from standard *is* accounted for in turbine performance predictions in this report. Note that the density estimates, because they are based on calculations using temperature data and not direct measurement, are likely a few percent lower than actual.

Temperature and density table

	Temperature				Air Density			
	Mean (m/s)	Min (m/s)	Max (m/s)	SD (m/s)	Mean (kg/m^3)	Min (kg/m^3)	Max (kg/m^3)	SD (kg/m^3)
Jan	-18.6	-49.1	4.6	13.1	1.389	1.270	1.574	0.0730
Feb	-9.2	-38.6	6.5	11.0	1.339	1.261	1.504	0.0579
Mar	-18.9	-45.5	9.1	14.4	1.392	1.250	1.549	0.0787
Apr	-6.7	-21.0	6.1	5.6	1.324	1.263	1.399	0.0278
May	0.9	-16.7	23.8	7.4	1.288	1.188	1.375	0.0344
Jun	11.4	2.9	21.3	3.3	1.240	1.198	1.278	0.0144
Jul	7.3	-7.3	22.7	5.1	1.258	1.192	1.327	0.0227
Aug	6.9	-9.0	23.4	7.0	1.260	1.189	1.335	0.0314
Sep	5.0	-13.2	19.7	7.3	1.269	1.205	1.357	0.0336
Oct	0.1	-14.6	13.7	5.4	1.290	1.224	1.364	0.0274
Nov	-12.5	-35.4	4.0	8.4	1.355	1.273	1.484	0.0441
Dec	-12.3	-45.1	7.1	11.7	1.355	1.259	1.547	0.0624
Year	-3.9	-49.1	23.8	13.6	1.326	1.188	1.574	0.0701

Note: low temperature and max air density data likely faulty; see explanation in text

Temperature boxplot