Savoonga, Alaska Wind Resource Report

Report prepared by: Douglas Vaught, V3 Energy LLC, Eagle River, AK
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Photo by Doug Vaught, V3 Energy LLC

Savoonga Meteorological Tower Data Synopsis

Wind power class	Class 6 – Outstanding
30 meter average wind speed	7.16 m/s
Maximum wind speed	40.9 m/s, 2/13/06
Mean wind power density (50 meters)	772 W/m^2 (estimated)
Mean wind power density (30 meters)	656 W/m^2 (measured)
Roughness Class	0.34 (rough sea)
Power law exponent	0.100 (low wind shear)

Data start date	September 22, 2004
Data end date	August 8, 2006

Community Profile

Location:
Savoonga is located on the northern coast of St. Lawrence Island in the Bering Sea, 164 miles west of Nome. It lies 39 miles southeast of Gambell at approximately 63.694170° North Latitude and 170.478890° West Longitude (Sec. 08, T021S, R061W, Kateel River Meridian). Savoonga is located in the Cape Nome Recording District and encompasses 6.1 sq. miles of land.

History:
St. Lawrence Island has been inhabited intermittently for the past 2,000 years by Yup'ik Eskimos. The island once had numerous villages with a total population of about 4,000 in the 19th century. A tragic famine occurred on the island in 1878-80, severely reducing the population. In 1900 a herd of reindeer was moved to the island, and by 1917 the herd had grown to over 10,000 animals. A reindeer camp was established in 1916 at the present village site where grazing lands were better and the herd tended to remain. Good hunting and trapping in the area attracted more residents. A post office was established in 1934 and the City was incorporated in 1969. When the Alaska Native Claims Settlement Act (ANCSA) was passed in 1971, Gambell and Savoonga decided not to participate, and instead opted for title to the 1.136 million acres of land in the former St. Lawrence Island Reserve. The island is jointly owned by Savoonga and Gambell.

Culture:
It is a traditional St. Lawrence Yup'ik village with a subsistence lifestyle centered on walrus and whale hunting. Savoonga is hailed as the "Walrus Capital of the World." Whale, seal, walrus and reindeer comprise 80% of islander's diets. Due to the island's isolation, most residents are bilingual -- Siberian Yup'ik is still the first language. Islanders today have successfully mixed the past with the present. The sale, importation and possession of alcohol are banned in the village.

Economy:
The economy of Savoonga is largely based upon subsistence hunting of walrus, seal, fish and bowhead and gray whale, with some cash income. Eight residents hold commercial fishing permits, and Norton Sound Seafood Products operates in Savoonga. Reindeer harvests occur, but the herd is not managed. Fox are trapped as a secondary source of income. Islanders are known for their quality ivory carvings. Some tourism occurs by bird-watchers.

Facilities:
Utilities are operated by Savoonga Joint Utilities, a non-profit arm of the City and run by a Utility Board. Well water is treated and stored in a 100,000-gallon tank at the washeteria. A new circulating water and sewer utilidor system, including household plumbing, came on-line in January 1999. Forty-five residents are served; the remaining 32 homes currently haul water and honey buckets. In 2004 the washeteria was closed as revenues were not sufficient to cover operating expenditures. Twenty new HUD housing units on the west side are plumbed, but need to be connected to the system. The clinic and school have independent wells and septic systems. A new landfill was recently completed.

Transportation:
Savoonga's isolated location with no seaport and iced-in conditions during the winter means a dependence on air transport. The State-owned 4,402' long by 100' wide gravel airstrip is undergoing major improvements. Regular air service is available from Nome and Unalakleet. There is no dock so supplies must be lightered from Nome and off-loaded on the beach. Locals want a small boat harbor and dry dock.

Climate:
Savoonga has a subarctic maritime climate with some continental influences during the winter. Summer temperatures average 40 to 51; winters average -7 to 11. Temperature extremes from -34 to 67 have been recorded. Average precipitation is 10 inches annually with 58 inches of snowfall. Freeze-up on the Bering Sea occurs in mid-November with break-up in late May.

(Above information from State of Alaska Department of Commerce, Community, and Economic Development website, http://www.dced.state.ak.us/)

Meteorological Tower Site Information

Site number	0029
Site Description	Savoonga - AVEC
Latitude/longitude	N 063° 41.459'; W 170° 29.557'
Site elevation	20 meters
Datalogger type	NRG Symphonie
Tower type	NRG 30-meter tall tower, 152 mm (6-in) diameter

Met Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m	0.765	0.35	west
2	NRG #40 anemometer	20 m	0.765	0.35	north
7	NRG #200P wind vane	30 m	0.351	250	east
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Data Quality Control Summary

Data was filtered to remove presumed icing events that may 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. In addition, the data was manually filtered for winter data anomalies (obvious ice data that did not meet the above criteria) and for sensor failures.

Note that initially data recovery during summer months was nearly 100% but winter data recovery was less, as slow as 76 percent in December 2004. However, in January 2006 for the channel 1 anemometer and in March 2006 for the wind vane, these sensors failed (or began erratic readings) and resulting faulty data were removed.

To construct a complete data set and make use of the 20 meter, channel 2 anemometer data which was good for the entire measurement period, a data gap fill routine of the Windographer® software was employed. Windographer® filled these gaps with synthetic data that have statistical properties similar to the measured data. All subsequent analyses contained in this wind resource report are based on the gap-filled data set.

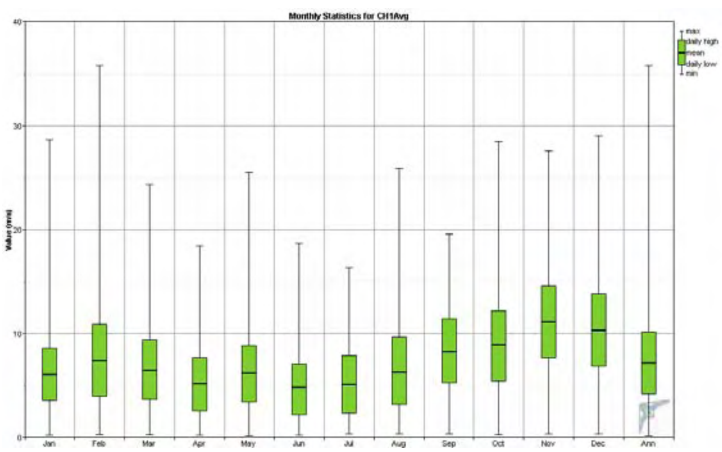
		Ch1 anemometer		Ch2 anemometer		Ch7 wind vane		Ch9 temperature	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2004	Sep	1,195	100.0	1,195	100.0	1,195	100.0	1,195	100.0
2004	Oct	4,432	99.3	4,426	99.1	4,426	99.1	4,464	100.0
2004	Nov	4,294	99.4	4,267	98.8	4,267	98.8	4,320	100.0
2004	Dec	3,405	76.3	3,391	76.0	3,400	76.2	4,464	100.0
2005	Jan	4,402	98.6	4,414	98.9	4,395	98.5	4,464	100.0
2005	Feb	3,989	98.9	3,989	98.9	3,986	98.9	4,032	100.0
2005	Mar	4,426	99.1	4,425	99.1	4,423	99.1	4,464	100.0
2005	Apr	4,251	98.4	4,245	98.3	4,245	98.3	4,320	100.0
2005	May	4,332	97.0	4,330	97.0	4,343	97.3	4,464	100.0
2005	Jun	4,223	97.8	4,207	97.4	4,207	97.4	4,320	100.0
2005	Jul	4,463	100.0	4,463	100.0	4,463	100.0	4,464	100.0
2005	Aug	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2005	Sep	4,320	100.0	4,320	100.0	4,320	100.0	4,320	100.0
2005	Oct	4,455	99.8	4,450	99.7	4,450	99.7	4,464	100.0
2005	Nov	3,569	82.6	4,279	99.1	4,215	97.6	4,320	100.0
2005	Dec	3,584	80.3	4,396	98.5	4,345	97.3	4,464	100.0
2006	Jan	852	19.1	4,088	91.6	3,566	79.9	4,464	100.0
2006	Feb	2,404	59.6	3,877	96.2	2,324	57.6	4,032	100.0
2006	Mar	0	0.0	4,213	94.4	0	0.0	4,464	100.0
2006	Apr	0	0.0	4,162	96.3	0	0.0	4,320	100.0
2006	May	0	0.0	4,277	95.8	0	0.0	4,464	100.0
2006	Jun	0	0.0	4,072	94.3	0	0.0	4,320	100.0
2006	Jul	0	0.0	4,464	100.0	0	0.0	4,464	100.0
2006	Aug	0	0.0	1,080	100.0	0	0.0	1,080	100.0
All data		67,067	68.0	95,494	96.8	71,036	72.0	98,611	100.0

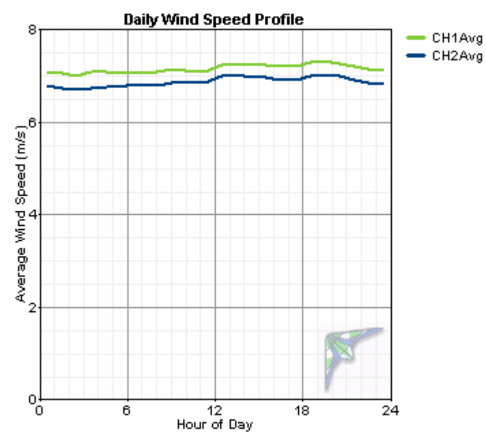
Measured Wind Speeds

The Channel 1 (30-meter) anemometer wind speed average for the reporting period is 7.16 m/s and the Channel 2 (20-meter) anemometer wind speed average is 6.88 m/s. The daily wind profile indicates very little variation, although wind speeds tend to be slightly lower from 10 pm to 4 am and slightly higher from 1 pm to 8 pm.

	30 m anemometer					20 m anemometer	
Month	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)
Jan	6.07	28.7	4.84	1.34	6.63	5.88	27.7
Feb	7.35	35.8	5.36	1.38	8.03	7.12	34.6

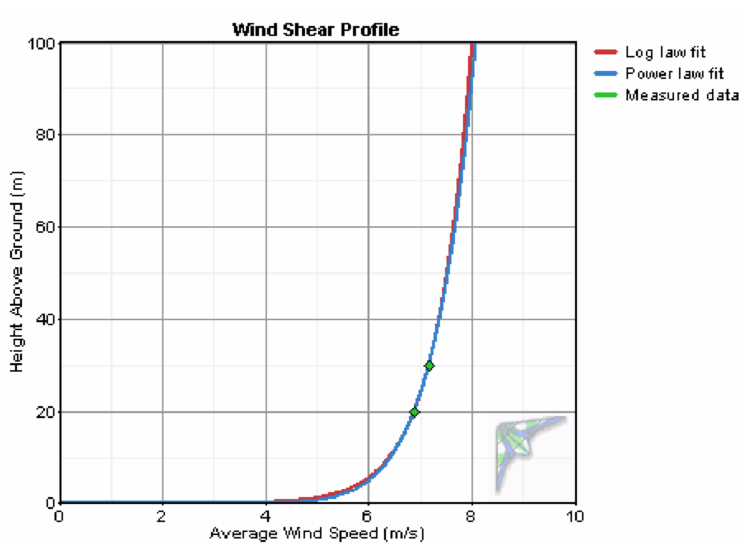
Mar	6.48	24.4	4.18	1.57	7.22	6.23	23.2
Apr	5.18	18.4	3.40	1.60	5.80	5.05	17.6
May	6.17	25.5	4.51	1.41	6.79	5.94	24.5
Jun	4.81	18.7	3.40	1.48	5.34	4.66	18.0
Jul	5.10	16.4	3.01	1.73	5.72	4.88	15.7
Aug	6.24	25.9	4.51	1.40	6.85	5.91	25.4
Sep	8.25	19.6	3.59	2.46	9.30	7.96	19.1
Oct	8.93	28.5	4.90	1.89	10.06	8.51	27.2
Nov	11.13	27.6	5.63	2.03	12.51	10.72	26.7
Dec	10.32	29.0	5.28	2.03	11.63	9.75	27.9
All data	**7.16**	35.8	4.92	1.48	7.93	**6.88**	34.6

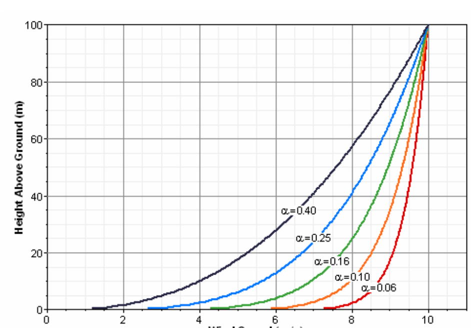




Wind Shear Profile

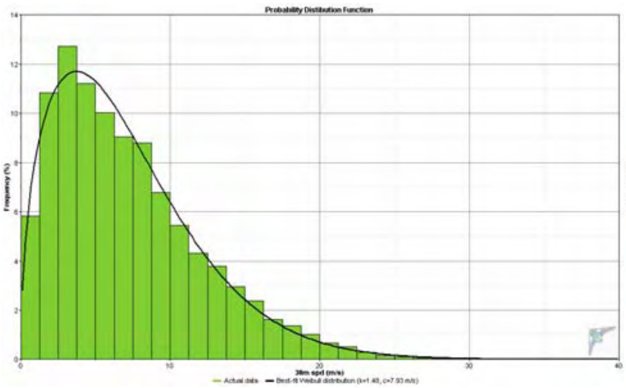
The power law exponent was calculated at 0.100, indicating low wind shear at the Savoonga met tower test site. The practical application of this data is that a low turbine tower height is possible as there will be little appreciable gain in wind speed/power recovery with additional tower height. However, a tower height/energy production cost tradeoff study is recommended.

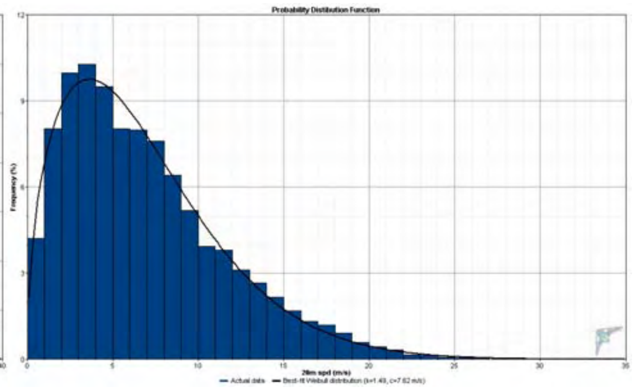




Probability Distribution Function

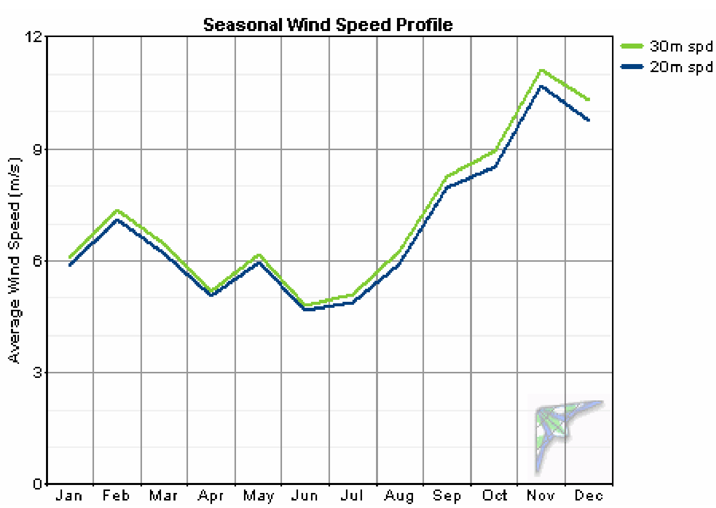
The probability distribution function provides a visual indication of measured wind speeds in one meter per second "bins". Note that most wind turbines do not begin to generate power until the wind speed at hub height reaches 4 m/s; using this criteria, 32% of Savoonga's winds are calm (less than 4 m/s). The black line in the graphs is a best fit Weibull characterization of the breadth of the wind speed distribution. At the 30 meter level, Weibull parameters are k = 1.48 (indicates a broad distribution of wind speed bins) and c = 7.93 m/s (scale factor for the Weibull distribution). At 20 meters, the Weibull k = 1.49 and c = 7.62 m/s.

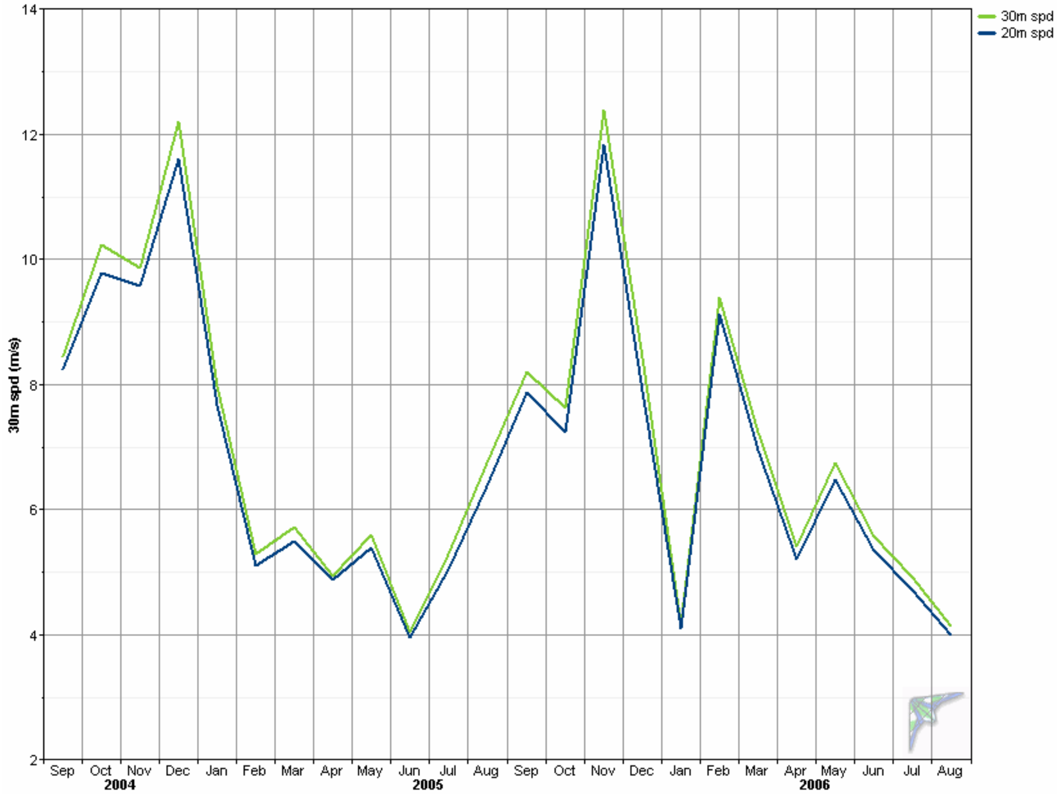


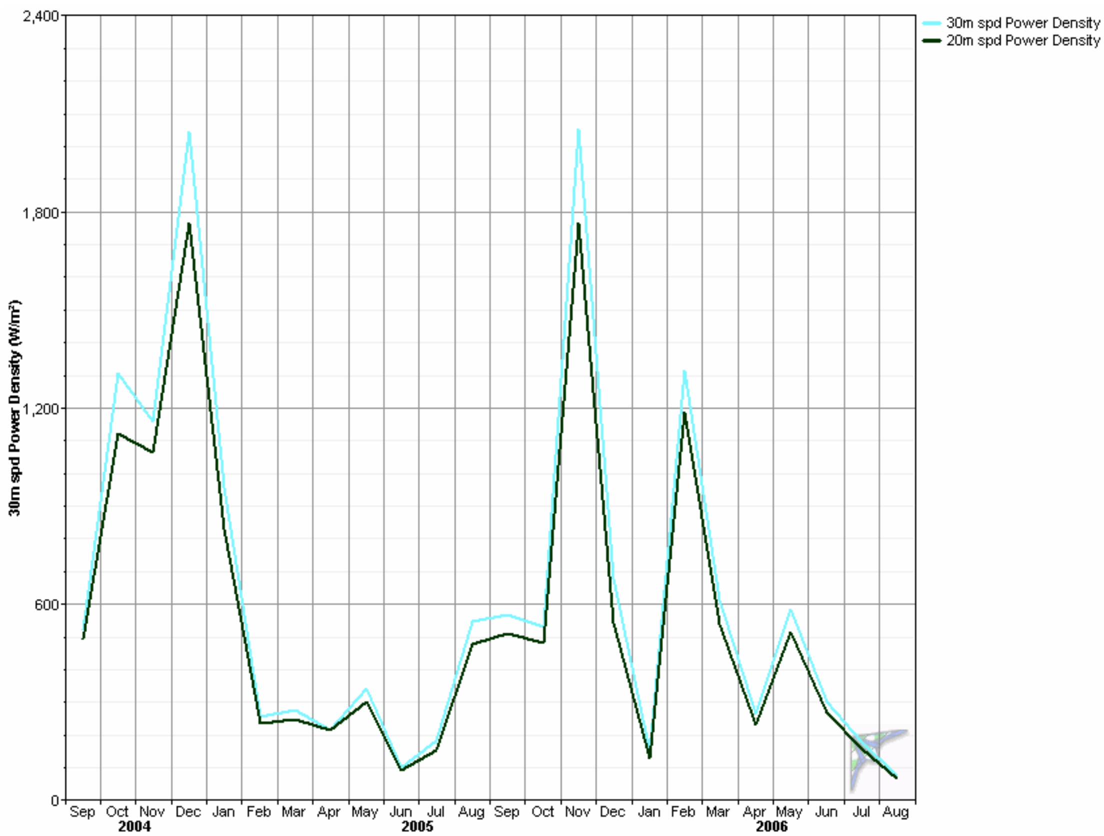


Time Series of Wind Speed Monthly Averages

The average wind speed at 30 meters for the measurement period is 7.16 m/s. Typically, the highest winds occur during the winter months of October through February/March with the lowest winds during the spring-summer-autumn months of April 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. This wind speed is not particularly high compared to the nearby village of Gambell where the 30 meter average wind speed was recorded at 9.13 m/s over the same measurement period.



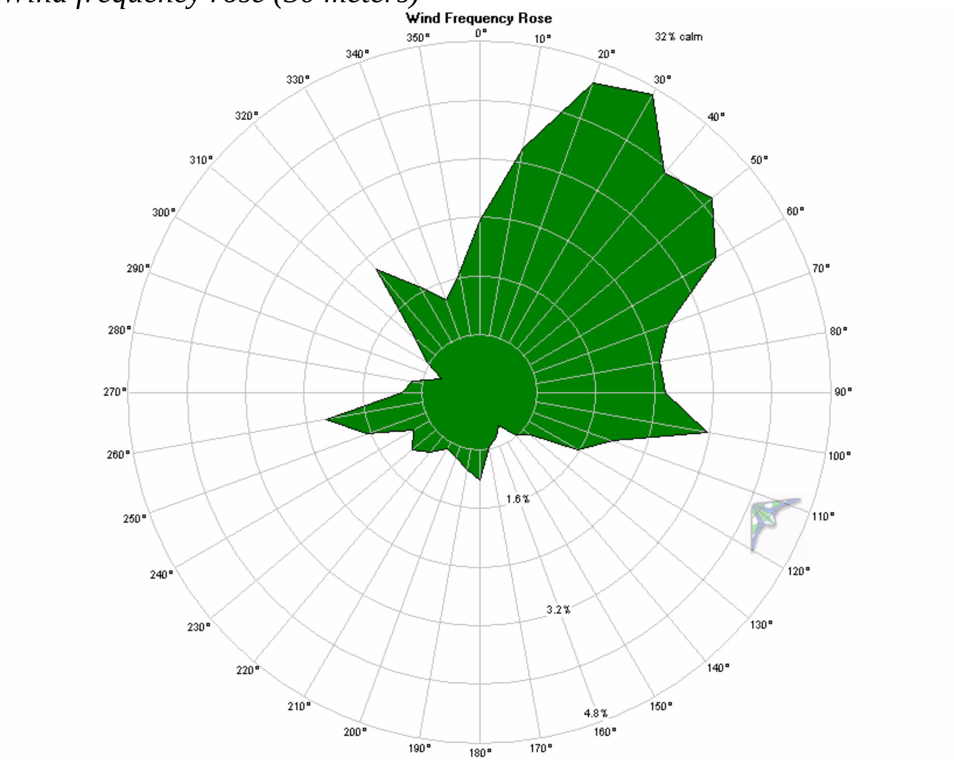

30m spd
20m spd
30m spd (m/s)
14
12
10
8
6
4
2
Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
2004
2005
2006


30m spd Power Density
20m spd Power Density
30m spd Power Density (W/m²)
2,400
1,800
1,200
600
0
Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
2004
2005
2006

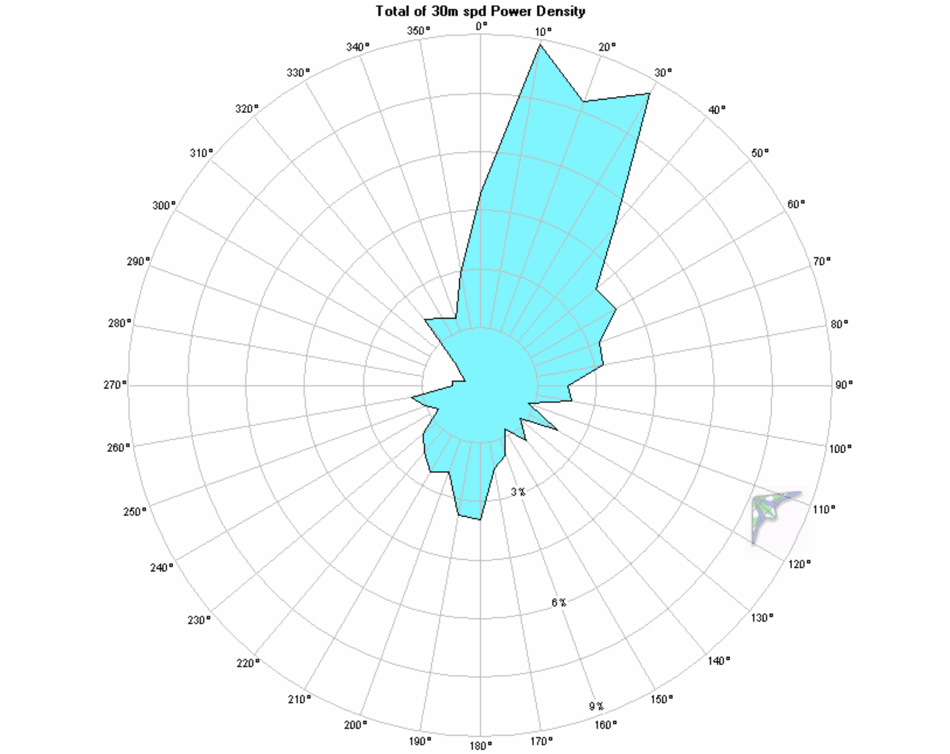
Frequency and Power Density Wind Roses

Savoonga winds are highly directional; the wind frequency rose indicates mostly north-northeasterly and to lesser extent south-southwesterly winds. This observation is reinforced with reference to the power density rose below. Power producing winds are mostly NNE with some SSW power producing winds. The practical application of this information is that the project site west of the village is excellent in that northerly to northeasterly winds travel an extremely long fetch of open water or pack ice before traversing the site; SSW winds traverse open, treeless tundra before traversing the site. If more than one turbine were to be placed in Savoonga, they should be oriented WNW to ESE (perpendicular to the prevailing NNE/SSW winds) with a 2 to 2½ rotor diameter hub-to-hub placement.

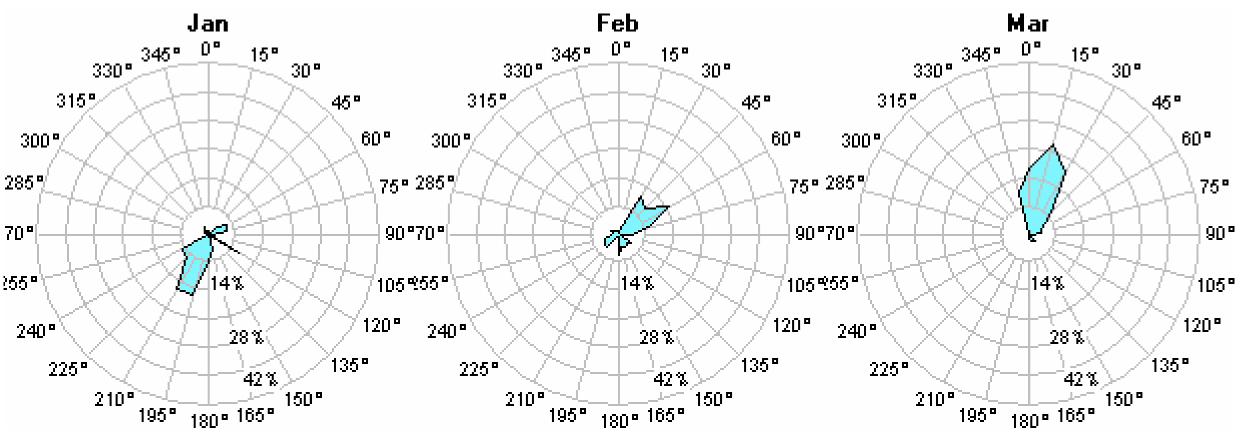
Wind frequency rose (30 meters)

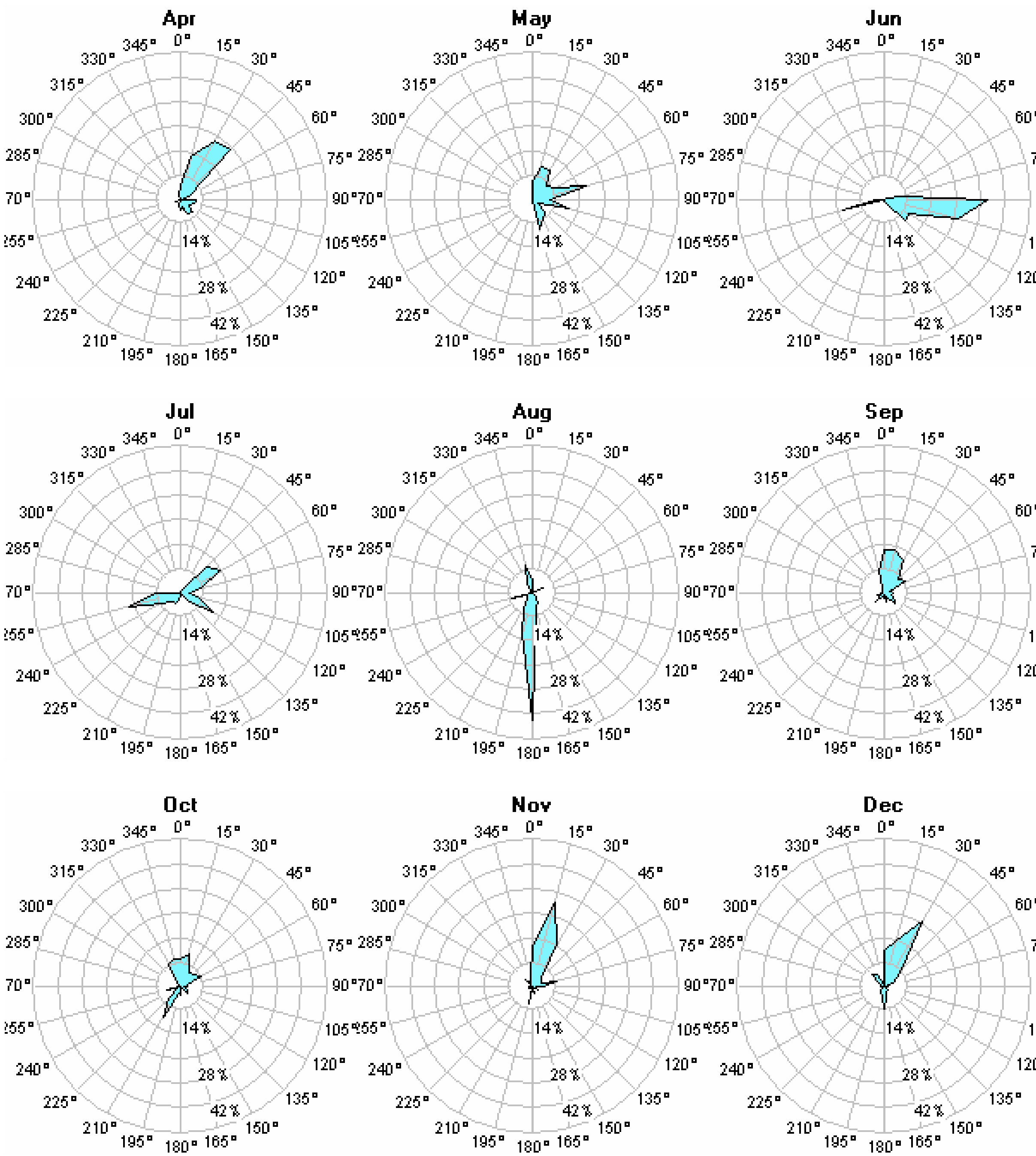


Wind power density rose (30 meters)



Monthly wind power density roses (30 meters); scale is common

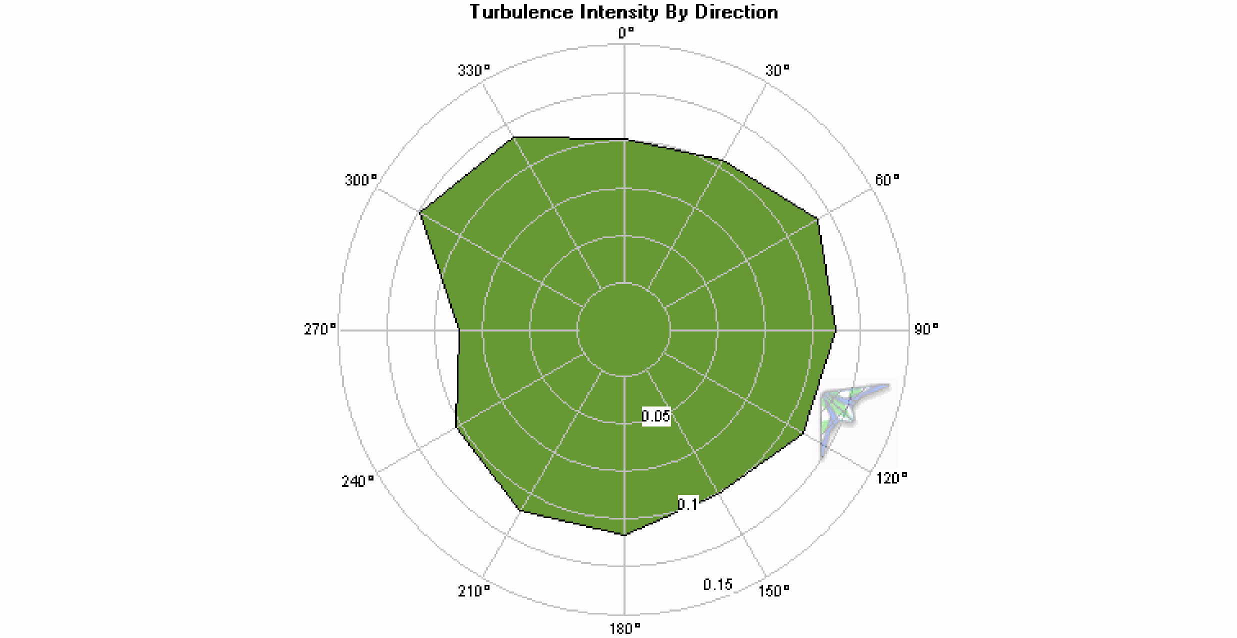




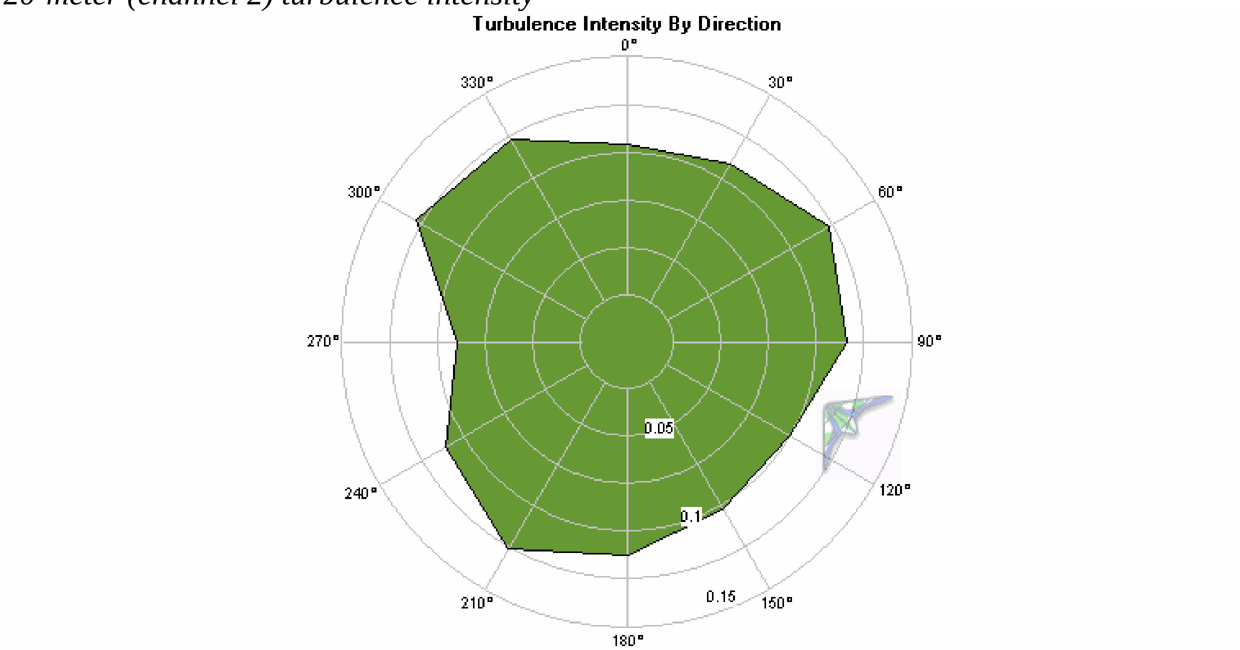
Turbulence Intensity

The Savoonga turbulence intensity (TI) is acceptable for all wind directions, with a mean turbulence intensity of 0.108 (30 meters) and 0.113 (20 meters), indicating relatively smooth air. These TIs are calculated with a threshold wind speed of 4 m/s (only wind speeds exceeding 4 m/s are considered in the TI calculation). The spike of relatively high turbulence to the west and southeast in both graphs is due to the infrequent and low speed winds from these sectors. The important TIs for the Savoonga test site are for winds from the NNE and to as lesser extent, SSE. As indicated below, turbulence at the Savoonga project test site is well below International Energy Agency (IEA) standards at all measured wind speeds and from all four quadrants of the wind rose.

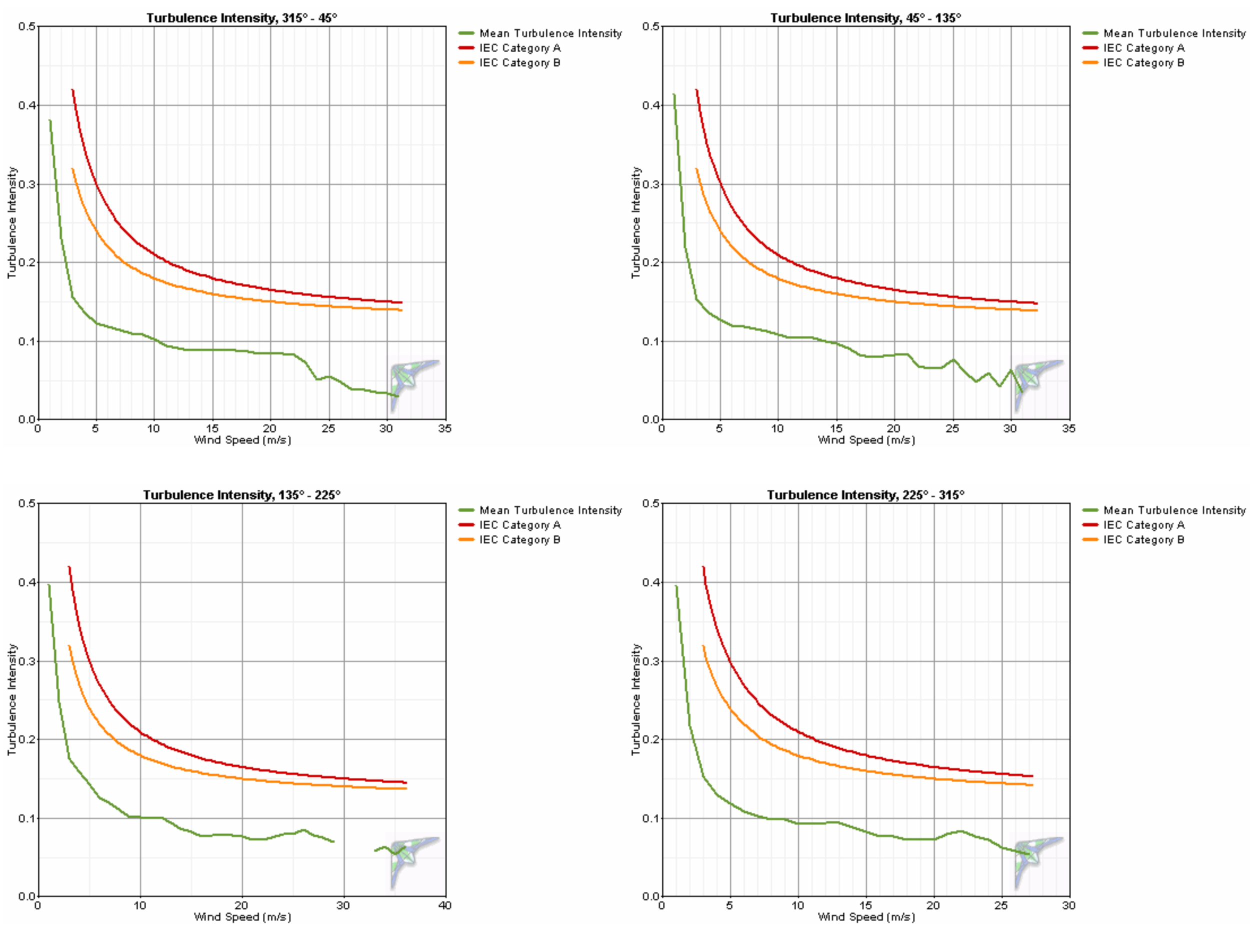
30-meter (channel 1) turbulence intensity



20-meter (channel 2) turbulence intensity



International Energy Agency turbulence category comparisons



Air Temperature and Density

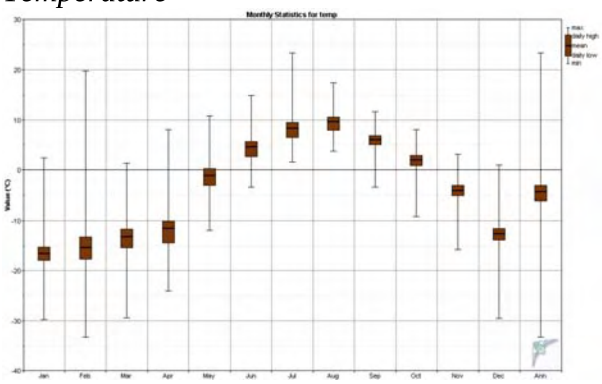
Over the reporting period, Savoonga had an average temperature of -4.4° C. The minimum recorded temperature during the measurement period was -33.2° C and the maximum temperature was 23.3° C, indicating a wide variability of an ambient temperature operating environment important to wind turbine operations.

Consequent to Savoonga's very cool temperatures, the average air density of 1.310 kg/m^3 is seven percent higher than the standard air density of 1.225 kg/m^3 (at 20° C), indicating that Savoonga, due to its cold annual temperature average and low elevation, has denser air than the standard air density used to calculate turbine power curves. This density variance from standard *is* accounted for in turbine performance predictions in this report.

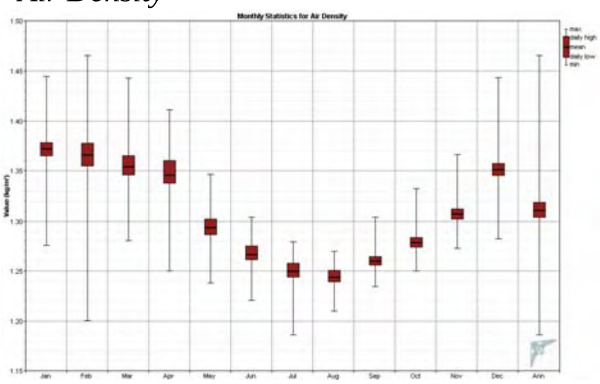
	Temperature				Density
Month	Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Mean (kg/m³)
Jan	-16.6	-29.8	2.4	6.87	1.371
Feb	-15.4	-33.2	19.8	8.60	1.366

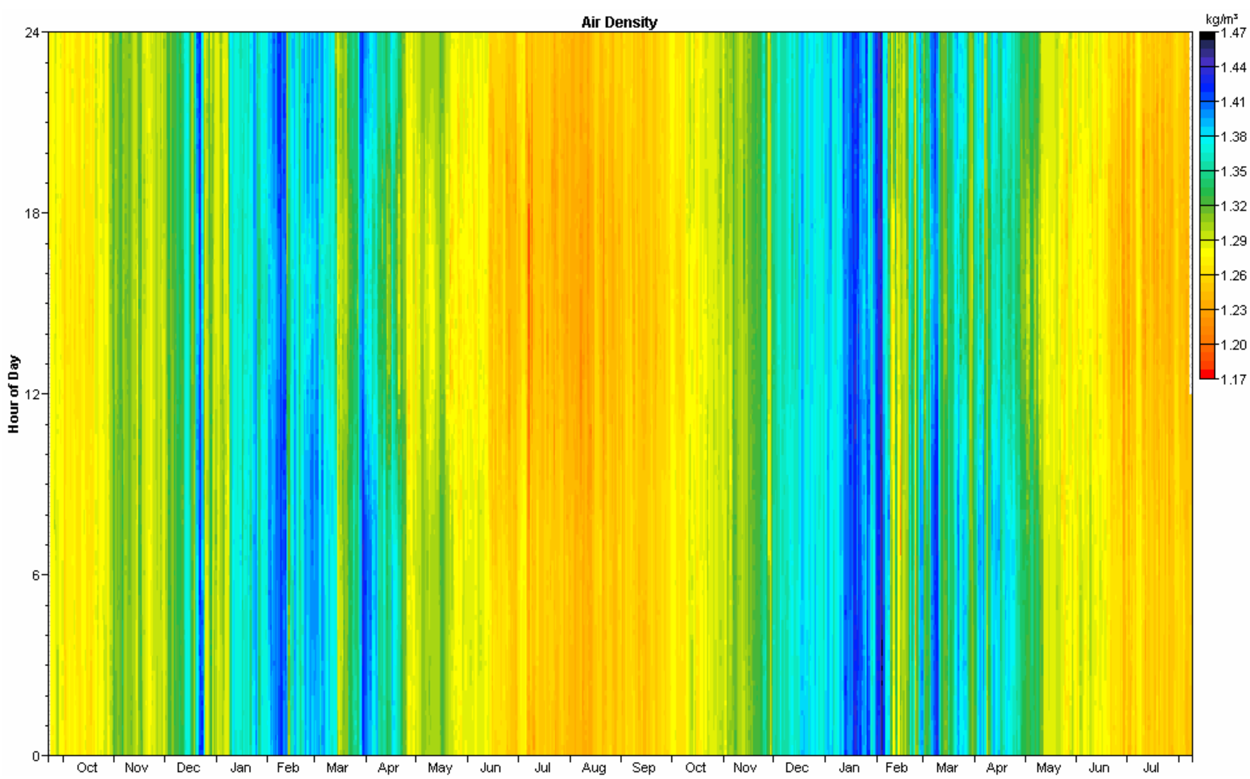
Mar	-13.2	-29.4	1.4	6.63	1.354
Apr	-11.6	-24.0	8.1	6.35	1.345
May	-1.2	-12.0	10.8	3.83	1.293
Jun	4.6	-3.5	14.9	3.46	1.266
Jul	8.2	1.6	23.3	2.69	1.250
Aug	9.6	3.7	17.4	2.08	1.244
Sep	6.0	-3.5	11.6	2.78	1.260
Oct	1.9	-9.2	8.1	2.87	1.279
Nov	-4.1	-15.8	3.1	3.31	1.307
Dec	-12.7	-29.5	1.0	6.05	1.351
All data	**-4.4**	-33.2	23.3	10.53	**1.310**

Temperature



Air Density

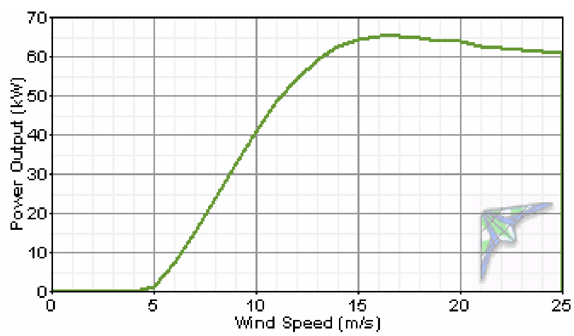




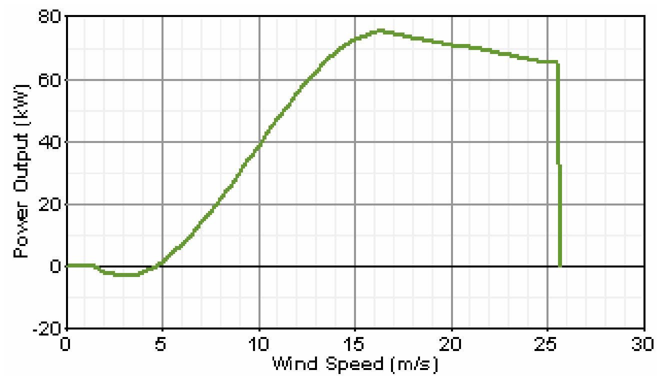
Wind Turbine Performance Predictions

The turbine performance predictions noted below are based on 90% turbine availability with an expected 10% downtime for maintenance, repairs and/or other outages. Note that these performance estimates were predicted with use of Windographer® wind analysis software; power curves provided by manufacturers are not independently verified and are assumed to be accurate. The power curves are presented for a standard air density of 1.225 kg/m^3 at 20°C, however the predictions of power production are density compensated by multiplying the standard density power output by the ratio of the measured air density to standard air density. A special note for Savoonga is that the 10-minute average winds occasionally 25 m/s, which is the shut-off wind speed threshold for most turbines. Although the power output predictions predict zero power output for winds exceeding 25 m/s, in practice turbines operate with a hysteresis loop where wind speeds must be well below 25 m/s for a set length of time before the turbine will re-engage and begin producing power again. That dynamic will be addressed in a later revision to this report.

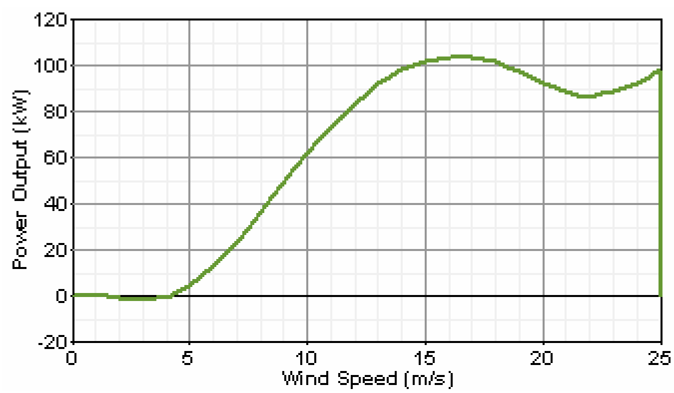
Entegrity eW-15: 65 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Entegrity Energy Systems)



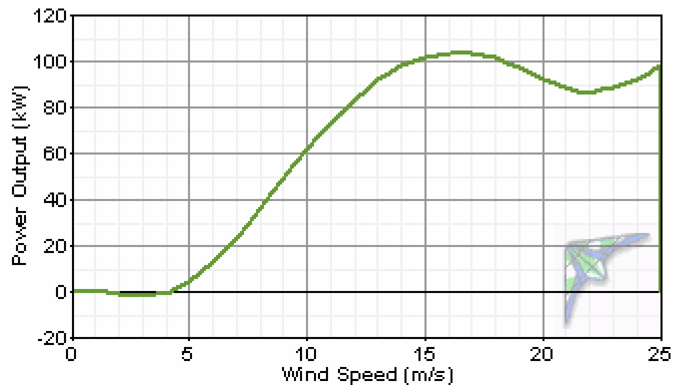
Vestas V15: 75 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Powercorp Alaska LLC)



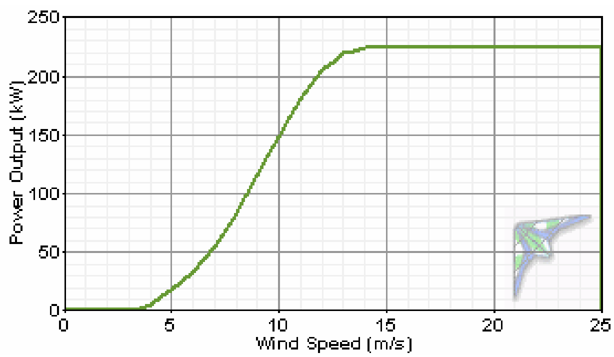
Northwind 100/19: 100 kW rated power output, 19 meter rotor, stall-controlled (power curve provided by Northern Power Systems)



Northwind 100/20: 100 kW rated power output, 20 meter rotor (19 meter rotor blades with 0.6 meter blade root extensions added), stall-controlled (power curve provided by Northern Power Systems)



Vestas V27: 225 kW rated power output, 27 meter rotor, pitch-controlled (power curve provided by Alaska Energy Authority)



Turbine Power Output Comparison

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Power Output (kW)	Annual Energy Output (kWh/yr)	Average Capacity Factor (%)
Entegrity eW-15 60 Hz	25	7.03	32.6	10.54	21.3	168,266	32.8
Entegrity eW-15 60 Hz	31	7.16	32.1	11.23	21.9	172,548	33.7
NW 100/19	25	7.03	32.9	7.41	30.1	236,981	30.1
NW 100/20	25	7.03	32.8	10.02	33.1	260,712	33.1
Vestas V15	25	7.03	37.8	7.50	21.1	166,004	28.1
Vestas V15	31	7.16	37.2	7.91	21.7	170,960	28.9
Vestas V27	32	7.18	17.0	8.72	78.1	615,357	34.7
Vestas V27	42	7.40	16.5	9.67	81.2	640,234	36.1

Capacity Factor <20%
Capacity Factor >20%, <30%
Capacity Factor >30%, <40%
Capacity Factor >40%, <50%
Capacity Factor >50%

Note: Annual energy output assumes a turbine availability of 90% (100% turbine output x 0.90); other indices are not adjusted

Annual Fuel Cost Avoided for Energy Generated by Wind Turbine vs. Diesel Generator

Turbine	Annual Energy Output (kW-hr/yr)	Fuel Quantity Avoided (gallons)	Fuel Price (USD/gallon)							Turbine Hub Height (m)
			$1.75	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	
Entegrity eW-15										
	168,266	12,464	$21,812	$24,928	$28,044	$31,160	$34,276	$37,392	$40,508	25
	172,548	12,781	$22,367	$25,563	$28,758	$31,953	$35,149	$38,344	$41,539	31
NPS NW100/19										
	236,981	17,554	$30,720	$35,108	$39,497	$43,885	$48,274	$52,662	$57,051	25
NPS NW100/20										
	260,712	19,312	$33,796	$38,624	$43,452	$48,280	$53,108	$57,936	$62,764	25
Vestas V15										
	166,004	12,297	$21,519	$24,593	$27,667	$30,742	$33,816	$36,890	$39,964	25
	170,960	12,664	$22,162	$25,327	$28,493	$31,659	$34,825	$37,991	$41,157	31
Vestas V27										
	615,357	45,582	$79,769	$91,164	$102,560	$113,955	$125,351	$136,746	$148,142	32
	640,234	47,425	$82,993	$94,849	$106,706	$118,562	$130,418	$142,274	$154,130	42

Note: Savoonga electrical energy production efficiency is 13.5 kW-hr/gal

Note: Assumes 90% turbine availability with no diversion of power to a thermal or other dump load

Vestas V27 Wind Turbine Monthly Performance at 32 Meter Hub Height

Month	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Power Output (kW)	Average Energy Output (kWh)	Average Capacity Factor (%)
Jan	6.08	24.3	5.1	56.7	42,184	25.2
Feb	7.37	19.6	11.4	81.5	54,767	36.2
Mar	6.52	17.8	4.5	71.3	53,066	31.7
Apr	5.20	21.4	1.9	44.6	32,133	19.8
May	6.20	21.9	5.1	62.9	46,791	28.0
Jun	4.83	27.9	1.0	39.7	28,568	17.6
Jul	5.11	22.4	0.2	40.2	29,897	17.9
Aug	6.24	21.3	5.5	60.7	45,144	27.0
Sep	8.25	5.2	3.3	102.0	73,690	45.5
Oct	8.92	7.1	12.6	106.0	79,156	47.3
Nov	11.17	7.0	29.7	143.0	103,203	63.7
Dec	10.34	5.1	21.6	130.0	96,561	57.7
Overall	7.18	17.0	8.7	78.1	683,730	34.7

Note: Energy output assumes 100% turbine availability

Temperature Conversion Chart °C to °F

°C	°F	°C	°F	°C	°F
-40	-40.0	-10	14.0	20	68.0
-39	-38.2	-9	15.8	21	69.8
-38	-36.4	-8	17.6	22	71.6
-37	-34.6	-7	19.4	23	73.4
-36	-32.8	-6	21.2	24	75.2
-35	-31.0	-5	23.0	25	77.0
-34	29.2	-4	24.8	26	78.8
-33	-27.4	-3	26.6	27	80.6
-32	-25.6	-2	28.4	28	82.4
-31	-23.8	-1	30.2	29	84.2
-30	-22.0	0	32.0	30	86.0
-29	-20.2	1	33.8	31	87.8
-28	-18.4	2	35.6	32	89.6
-27	-16.6	3	37.4	33	91.4
-26	-14.8	4	39.2	34	93.2
-25	-13.0	5	41.0	35	95.0
-24	-11.2	6	42.8	36	96.8
-23	-9.4	7	44.6	37	98.6
-22	-7.6	8	46.4	38	100.4
-21	-5.8	9	48.2	39	102.2
-20	-4.0	10	50.0	40	104.0
-19	-2.2	11	51.8	41	105.8
-18	-0.4	12	53.6	42	107.6
-17	1.4	13	55.4	43	109.4
-16	3.2	14	57.2	44	111.2
-15	5.0	15	59.0	45	113.0
-14	6.8	16	60.8	46	114.8
-13	8.6	17	62.6	47	116.6
-12	10.4	18	64.4	48	118.4
-11	12.2	19	66.2	49	120.2

Wind Speed Conversion Chart, m/s to mph

m/s	mph	m/s	mph	m/s	mph	m/s	mph	m/s	mph
0.5	1.1	10.5	23.5	20.5	45.9	30.5	68.2	40.5	90.6
1.0	2.2	11.0	24.6	21.0	47.0	31.0	69.3	41.0	91.7
1.5	3.4	11.5	25.7	21.5	48.1	31.5	70.5	41.5	92.8
2.0	4.5	12.0	26.8	22.0	49.2	32.0	71.6	42.0	93.9
2.5	5.6	12.5	28.0	22.5	50.3	32.5	72.7	42.5	95.1
3.0	6.7	13.0	29.1	23.0	51.4	33.0	73.8	43.0	96.2
3.5	7.8	13.5	30.2	23.5	52.6	33.5	74.9	43.5	97.3
4.0	8.9	14.0	31.3	24.0	53.7	34.0	76.1	44.0	98.4
4.5	10.1	14.5	32.4	24.5	54.8	34.5	77.2	44.5	99.5
5.0	11.2	15.0	33.6	25.0	55.9	35.0	78.3	45.0	100.7
5.5	12.3	15.5	34.7	25.5	57.0	35.5	79.4	45.5	101.8
6.0	13.4	16.0	35.8	26.0	58.2	36.0	80.5	46.0	102.9
6.5	14.5	16.5	36.9	26.5	59.3	36.5	81.6	46.5	104.0
7.0	15.7	17.0	38.0	27.0	60.4	37.0	82.8	47.0	105.1
7.5	16.8	17.5	39.1	27.5	61.5	37.5	83.9	47.5	106.3
8.0	17.9	18.0	40.3	28.0	62.6	38.0	85.0	48.0	107.4
8.5	19.0	18.5	41.4	28.5	63.8	38.5	86.1	48.5	108.5
9.0	20.1	19.0	42.5	29.0	64.9	39.0	87.2	49.0	109.6
9.5	21.3	19.5	43.6	29.5	66.0	39.5	88.4	49.5	110.7
10.0	22.4	20.0	44.7	30.0	67.1	40.0	89.5	50.0	111.8

Distance Conversion m to ft

m	ft	m	ft
5	16	35	115
10	33	40	131
15	49	45	148
20	66	50	164
25	82	55	180
30	98	60	197

Selected definitions (courtesy of Windographer® software by Mistaya Engineering Inc.)

Wind Power Class

The wind power class is a number indicating the average energy content of the wind resource. Wind power classes are based on the average wind power density at 50 meters above ground, according to the following table. Source: Wind Energy Resource Atlas of the United States (http://rredc.nrel.gov/wind/pubs/atlas/tables/A-8T.html)

Wind Power Class	Description	Power Density at 50m (W/m^2)
1	Poor	0-200
2	Marginal	200-300
3	Fair	300-400
4	Good	400-500
5	Excellent	500-600
6	Outstanding	600-800
7	Superb	800-2000

Windographer classifies any wind resource with an average wind power density above 2000 W/m^2 as class 8.

Probability Distribution Function

The probability distribution function f(x) gives the probability that a variable will take on the value x. It is often expressed using a frequency histogram, which gives the frequency with which the variable falls within certain ranges or bins.

Wind Turbine Power Regulation

All wind turbines employ some method of limiting power output at high wind speeds to avoid damage to mechanical or electrical subsystems. Most wind turbines employ either stall control or pitch control to regulate power output.

A stall-controlled turbine typically has blades that are fixed in place, and are designed to experience aerodynamic stall at very high wind speeds. Aerodynamic stall dramatically reduces the torque produced by the blades, and therefore the power produced by the turbine.

On a pitch-controlled turbine, a controller adjusts the angle (pitch) of the blades to best match the wind speed. At very high wind speeds the controller increasingly feathers the blades out of the wind to limit the power output.