Gambell, Alaska Wind Resource Report

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Photo © Doug Vaught

General Site Information

Site number	0030
Site Description	Gambell, Alaska
Latitude/longitude	N 063° 46.748'; W 171° 42.828'
Site elevation	6 meters
Datalogger type	NRG Symphonie
Tower type	NRG 30-meter tall tower, 152 mm (6 in) diameter

Location:

Gambell is located on the northwest cape of St. Lawrence Island, 200 miles southwest of Nome, in the Bering Sea. The City is 36 miles from the Chukotka Peninsula, Siberia. It lies at approximately 63.779720° North Latitude and -171.74111° West Longitude. (Sec. 03, T020S, R067W, Kateel River Meridian.) Gambell is located in the Cape Nome Recording District. The area encompasses 10.9 sq. miles of land and 19.5 sq. miles of water.

History:

St. Lawrence Island has been inhabited intermittently for the past 2,000 years by Yup'ik Eskimos. In the 18th and 19th centuries, over 4,000 people inhabited the island in 35 villages. Sivuqaq is the Yup'ik name for the village and for the Island. The City was renamed for Mr. and Mrs. Vene C. Gambell. A tragic famine between 1878 and 1880 decimated the population. In 1900, reindeer were introduced to the island for local use, and in 1903, President Roosevelt established a reindeer reservation. During the 1930s, some residents moved to Savoonga to establish a permanent settlement there. The City was incorporated in 1963. 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:

The isolation of Gambell has helped to maintain their traditional St. Lawrence Yup'ik culture, their language, and their subsistence lifestyle based upon marine mammals. Residents are almost completely bilingual. Walrus-hide boats are still used to hunt. The sale, importation or possession of alcohol is banned in the village.

Economy:

The economy in Gambell is largely based upon subsistence harvests from the sea -- seal, walrus, fish and bowhead and gray whales. Fox are trapped as a secondary source of cash income. Some reindeer roam free on the island, but most harvesting occurs out of Savoonga. Ivory carving is a popular source of income. The abundant number of seabird colonies provides an opportunity for limited tourism by bird-watchers.

Facilities:

Water is derived from wells and Troutman Lake, is treated and stored in three storage tanks. One hundred sixteen homes are now connected to the piped water and sewer system. The schools and washeteria have individual water wells and septic tank systems. Thirty-seven homes in the original town site still haul water and honey buckets. A Master Plan is underway. A new water source is needed to ensure no shortages will occur. The landfill is not permitted; the City wants to develop a new site.

Transportation:

Gambell's isolated location on an island with no seaport results in heavy dependence upon air transport. The State-owned airport is currently under major improvements; it provides a 4,500 ft long by 96 ft wide asphalt runway. Regular flights from Nome and charters from Unalakleet are available. Lighterage services bring freight from Kotzebue and Shishmaref.

Climate:

Gambell has a maritime climate with continental influences in the winter. Winds and fog are common, and precipitation occurs 300 days per year. Average annual precipitation is 15 inches, including 80 inches of snowfall. The Bering Sea freezes during mid-November, with break-up at the end of May. Average summer temperatures are 34 to 48 F; average winter temperatures are -2 to 10 F. Extremes from -30 to 65 F have been recorded.

(Above information from State of Alaska DCED website)

Data Synopsis

Wind power class (at 50 meters)	Class 7 – Superb
30 meter average wind speed	9.13 m/s
Maximum wind speed	35.2 m/s, 10/18/04
Mean wind power density (50 meters)	961 W/m^2
Mean wind power density (30 meters)	919 W/m^2
Roughness Class	0.00 (smooth)
Power law exponent	0.0248 (extremely low wind shear)
Data start date	September 18, 2004
Data end date	August 7, 2006

Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m	0.765	0.35	north
2	NRG #40 anemometer	22 m	0.765	0.35	east
7	NRG #200P wind vane	30 m	0.351	125	305° T
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Quality Control

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. In addition, the data was manually filtered for winter data anomalies (obvious ice data that did not meet the above criteria). Note that data recovery during summer months was nearly 100% but winter data recovery was less, as slow as 77 percent in January 2005. One interesting data anomaly was temperature data in December 2005 through February 2006. For an approximately seven week period of time, the temperature sensor gave erroneously high readings and then began reading correctly again.

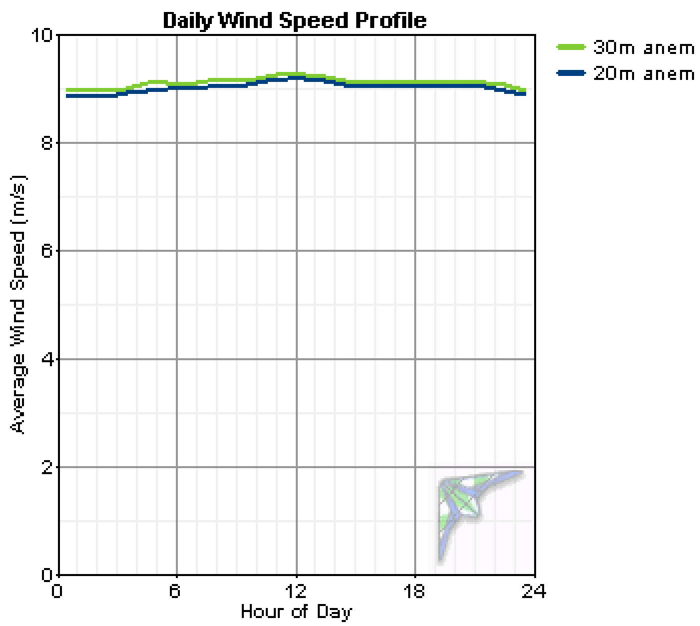
		Ch 1 anemometer		Ch 2 anemometer		Ch 7 vane		Ch 9 temperature	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2004	Sep	1,740	96.9	1,742	97.0	1,744	97.1	1,765	98.3
2004	Oct	4,445	99.6	4,445	99.6	4,445	99.6	4,464	100.0
2004	Nov	4,307	99.7	4,307	99.7	4,307	99.7	4,320	100.0
2004	Dec	3,566	79.9	3,565	79.9	3,614	81.0	4,464	100.0
2005	Jan	3,449	77.3	3,504	78.5	4,245	95.1	4,464	100.0

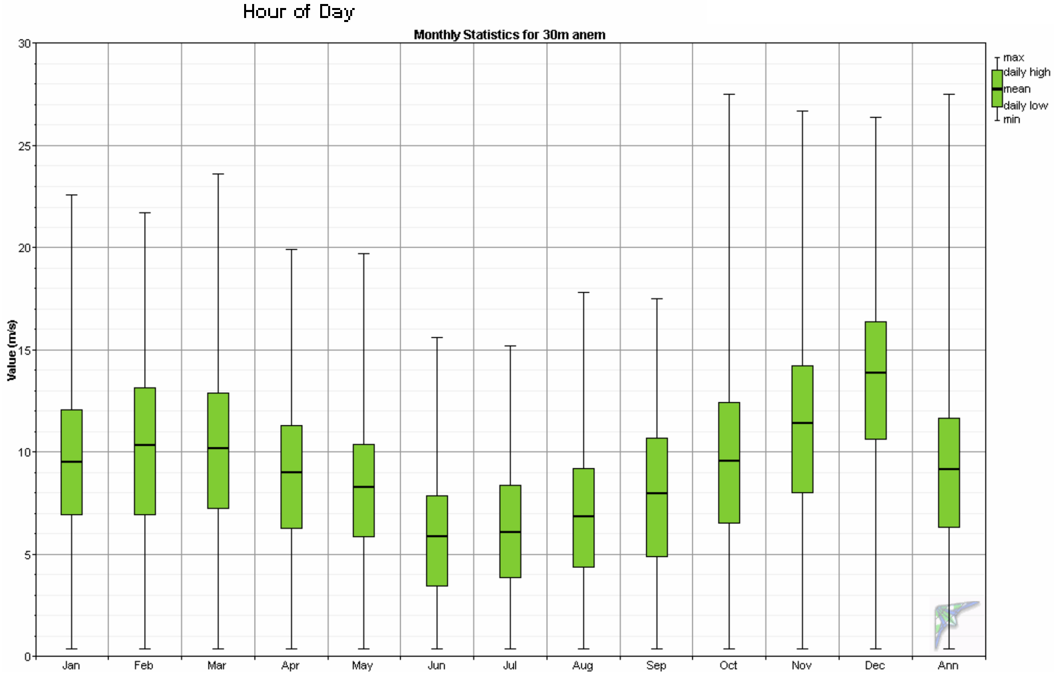
2005	Feb	4,032	100.0	4,032	100.0	4,032	100.0	4,032	100.0
2005	Mar	4,459	99.9	4,304	96.4	4,304	96.4	4,464	100.0
2005	Apr	4,270	98.8	4,273	98.9	4,270	98.8	4,320	100.0
2005	May	4,448	99.6	4,453	99.8	4,448	99.6	4,464	100.0
2005	Jun	4,273	98.9	4,277	99.0	4,273	98.9	4,320	100.0
2005	Jul	4,464	100.0	4,464	100.0	4,464	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	4,420	99.0	4,434	99.3	4,420	99.0	4,464	100.0
2005	Nov	4,293	99.4	4,294	99.4	4,293	99.4	4,320	100.0
2005	Dec	4,461	99.9	4,462	100.0	4,461	99.9	2,926	65.5
2006	Jan	4,464	100.0	4,464	100.0	4,464	100.0	0	0.0
2006	Feb	3,993	99.0	3,992	99.0	3,992	99.0	2,902	72.0
2006	Mar	4,451	99.7	4,448	99.6	4,448	99.6	4,464	100.0
2006	Apr	4,311	99.8	4,311	99.8	4,311	99.8	4,320	100.0
2006	May	4,432	99.3	4,412	98.8	4,411	98.8	4,464	100.0
2006	Jun	4,303	99.6	4,309	99.7	4,303	99.6	4,320	100.0
2006	Jul	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2006	Aug	948	100.0	948	100.0	948	100.0	948	100.0
All data		96,777	97.7	96,688	97.6	97,445	98.3	91,917	92.8

Monthly Wind Speed Averages

The Channel 1 (30-meter) anemometer wind speed average for the reporting period is 9.13 m/s and the Channel 2 (20-meter) anemometer wind speed average is 9.04 m/s. The daily wind profile indicates very little variation, although wind speeds tend to be slightly lower from 11 pm to 3 am and slightly higher from 10 am to 2 pm.

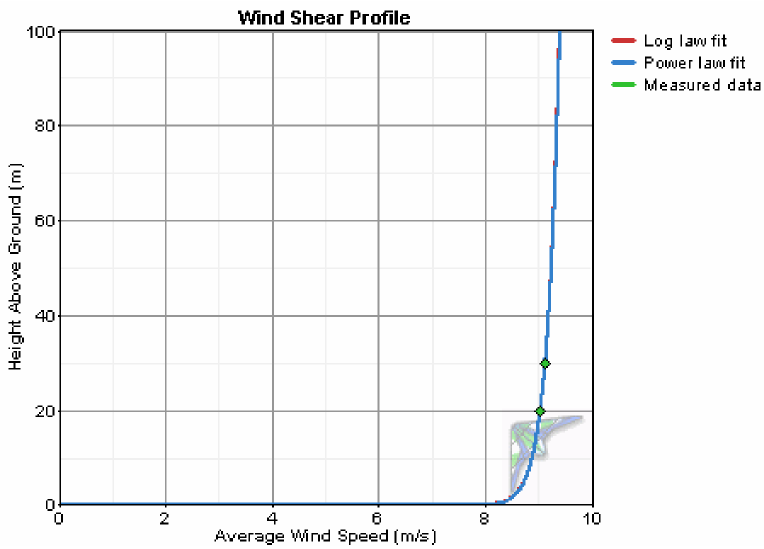
	Ch 1 (30 meters)					Ch 2 (20 meters)	
Month	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)
Jan	9.52	22.6	4.20	2.37	10.68	9.40	22.1
Feb	10.32	21.7	4.13	2.68	11.59	10.03	21.3
Mar	10.18	23.6	4.02	2.77	11.44	10.08	22.7
Apr	9.00	19.9	3.47	2.79	10.06	8.88	19.5
May	8.27	19.7	3.90	2.23	9.31	8.26	19.6
Jun	5.88	15.6	3.05	1.97	6.60	5.83	15.1
Jul	6.08	15.2	2.81	2.25	6.82	5.91	15.3
Aug	6.83	17.8	3.32	2.13	7.69	6.89	17.6
Sep	7.96	17.5	3.71	2.25	8.96	7.97	17.2
Oct	9.58	27.5	4.90	2.02	10.77	9.56	25.8
Nov	11.39	26.7	5.18	2.29	12.79	11.36	25.4
Dec	13.86	26.4	5.29	2.88	15.50	13.67	26.3
All data	**9.13**	27.5	4.64	2.04	10.28	**9.04**	26.3

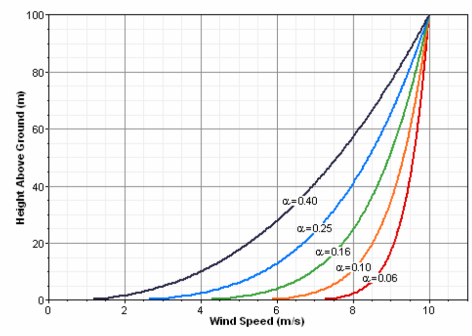




Wind Shear Profile

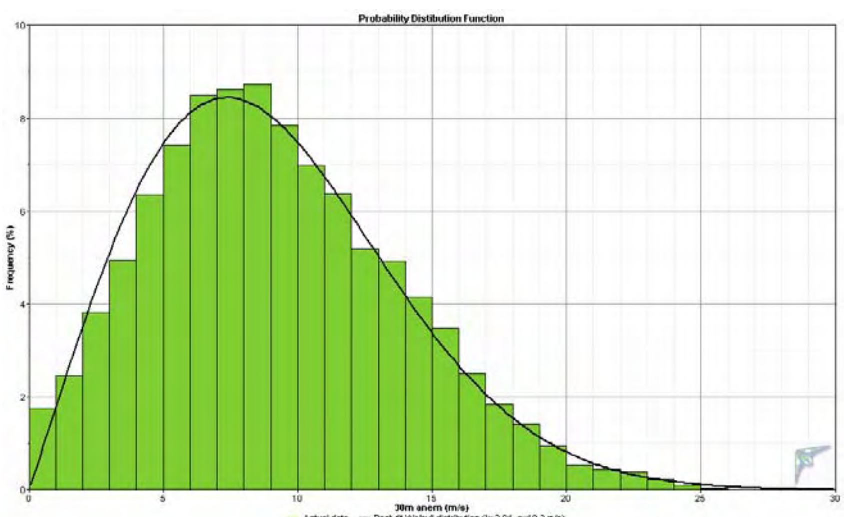
The power law exponent was calculated at 0.0248 indicating extremely low wind shear at the Gambell test site. The practical application of this data is that a low turbine tower height is possible as there will be very little appreciable gain in wind speed/power recovery with additional tower height.





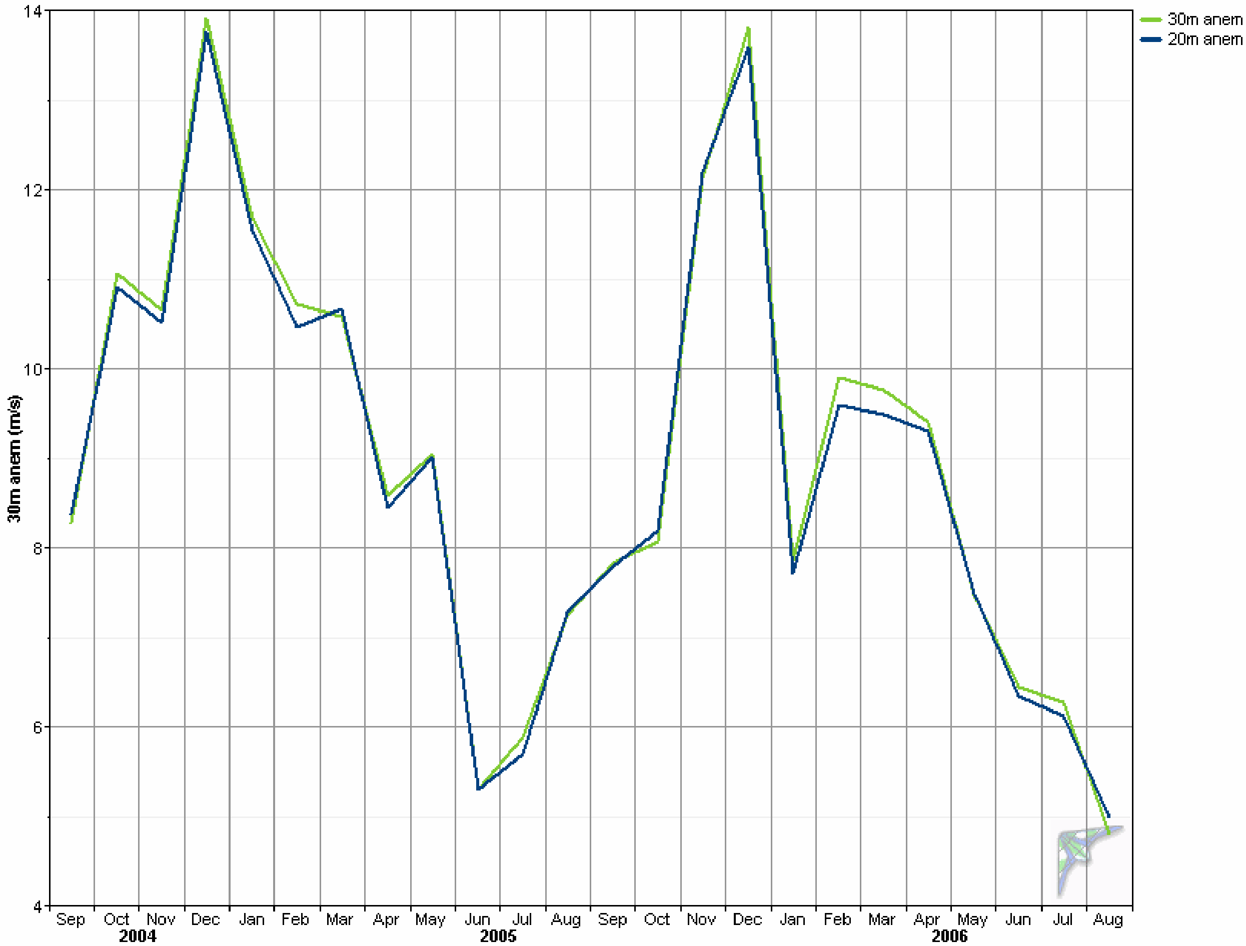
Probability Distribution Function

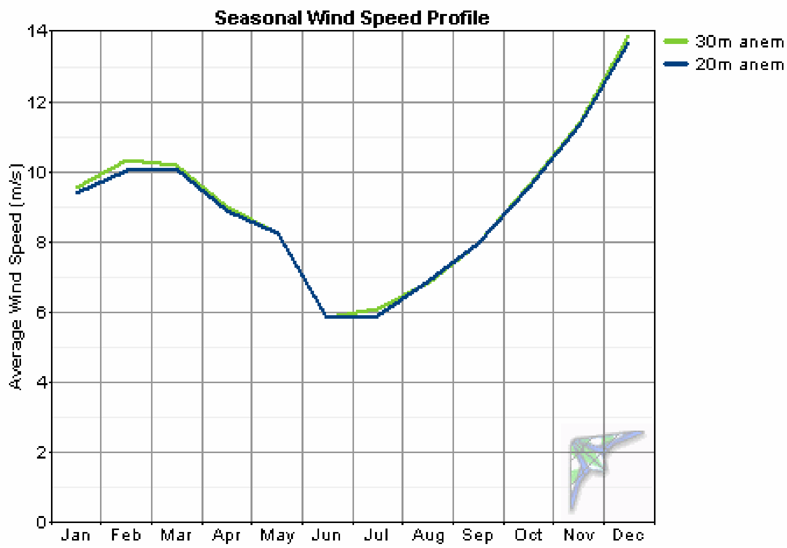
The probability distribution function provides a visual indication of measured wind speeds in one meter per second “bins”. Note that most wind turbines do not begin to generate power until the wind speed at hub height reaches 4 m/s; using this criteria, 13% of Gambell’s winds are calm winds (less than 4 m/s). The black line in the graph is a best fit Weibull distribution. Weibull parameters are k = 2.04, c = 10.3 m/s.



Time Series of Wind Speed Monthly Averages

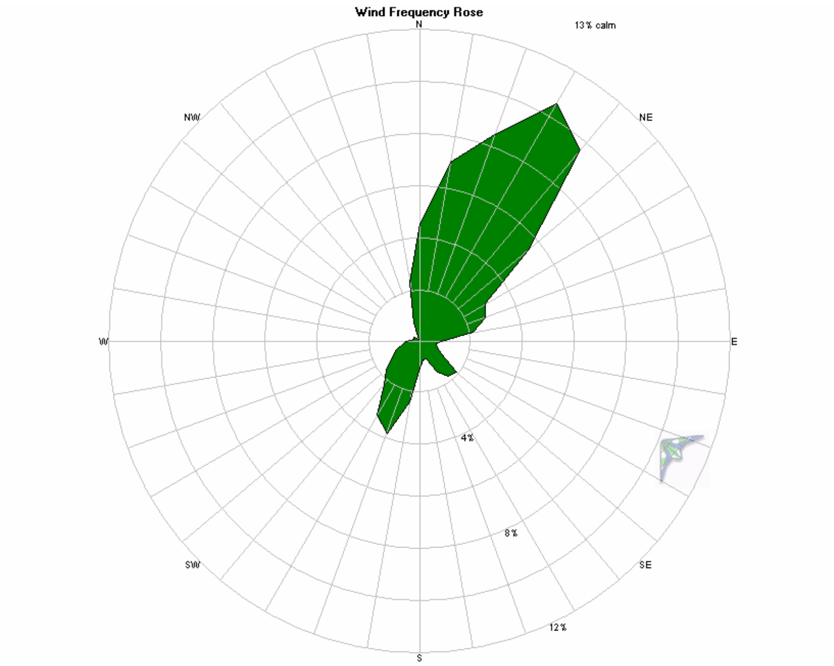
The average wind speed at 30 meters for the measurement period is 9.13 m/s. Typically, the highest winds occur during the winter months of October through April with the lowest winds during the spring-summer-autumn months of May through September. The unusually low winds measured in January 2006 were due to a persistent high pressure system over Alaska that month that yielded calm winds and extremely cold weather Statewide.





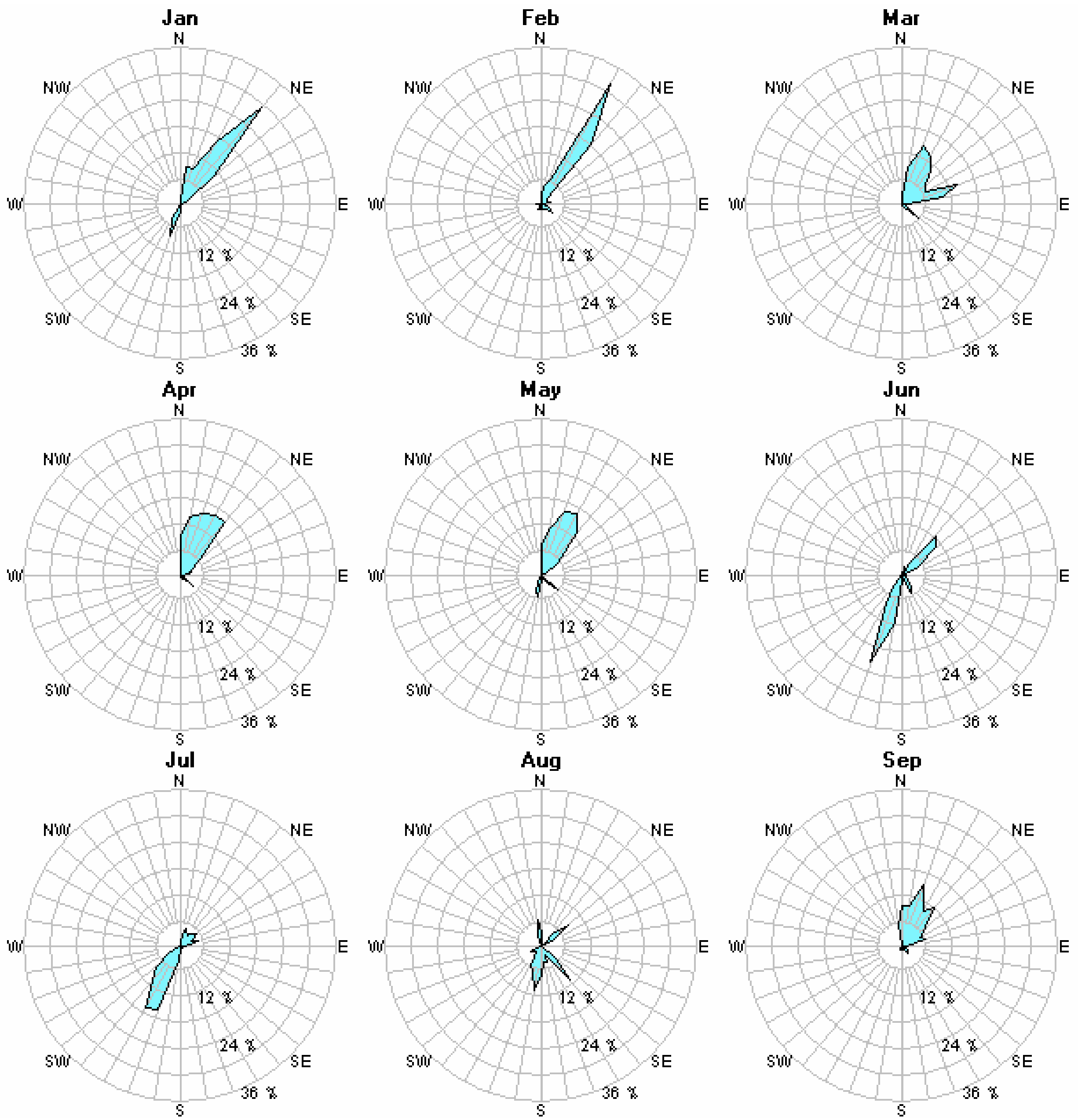
Wind Roses

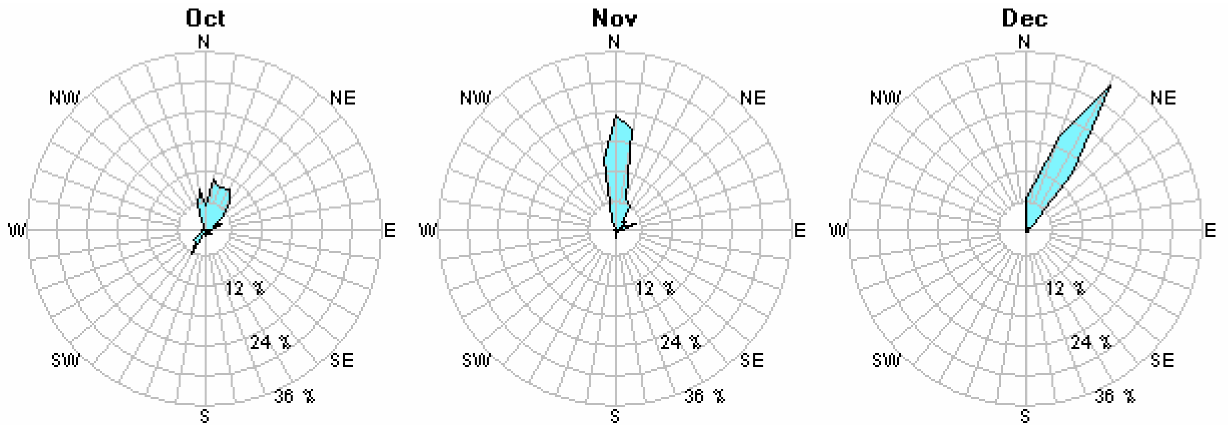
Gambell winds are highly directional; the wind frequency rose indicates mostly north-northeasterly and some minor south-southwesterly winds. This observation is reinforced with reference to the power density rose below. Power producing winds are almost entirely north-northeasterly. The practical application of this information is that the project site on shore north of the village is ideal in that northerly to northeasterly winds travel an extremely long fetch of open water or pack ice before traversing the site. If more than one turbine were to be placed in Gambell, they should be oriented WNW to ESE (perpendicular to the prevailing NNE winds) with a minimum 2.5 rotor diameter placement hub-to-hub.



Wind Power Density Rose (30 meters)

Wind Power Density Rose by Month (30 meters – common scale)

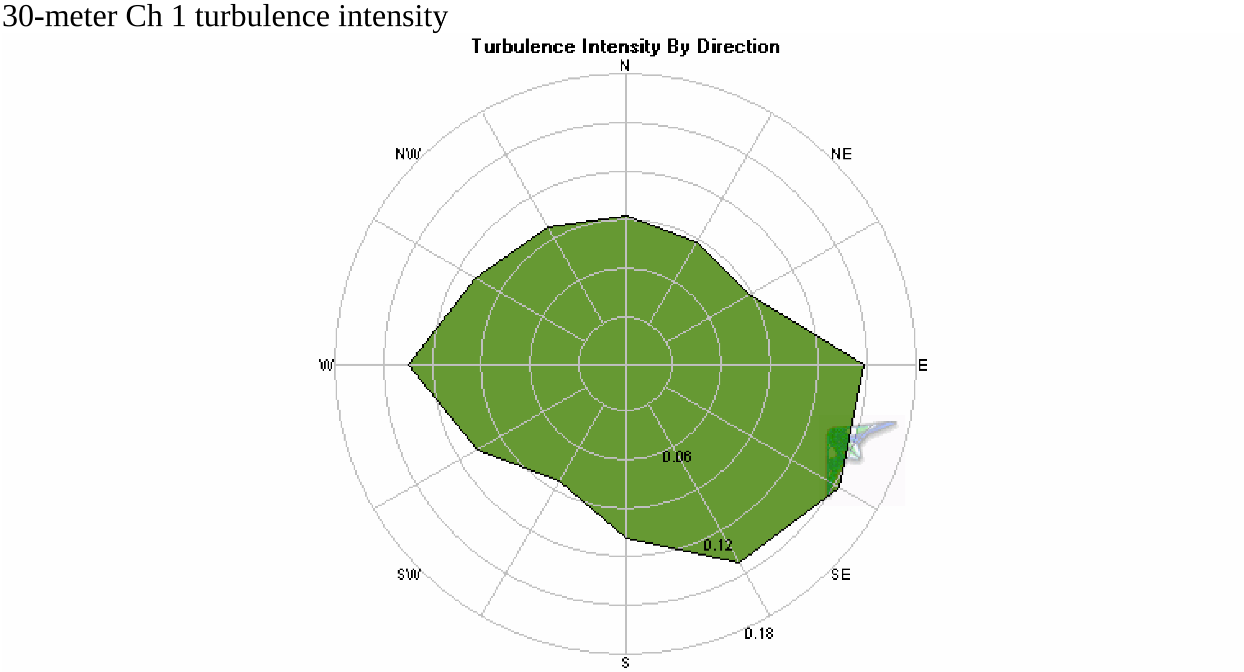




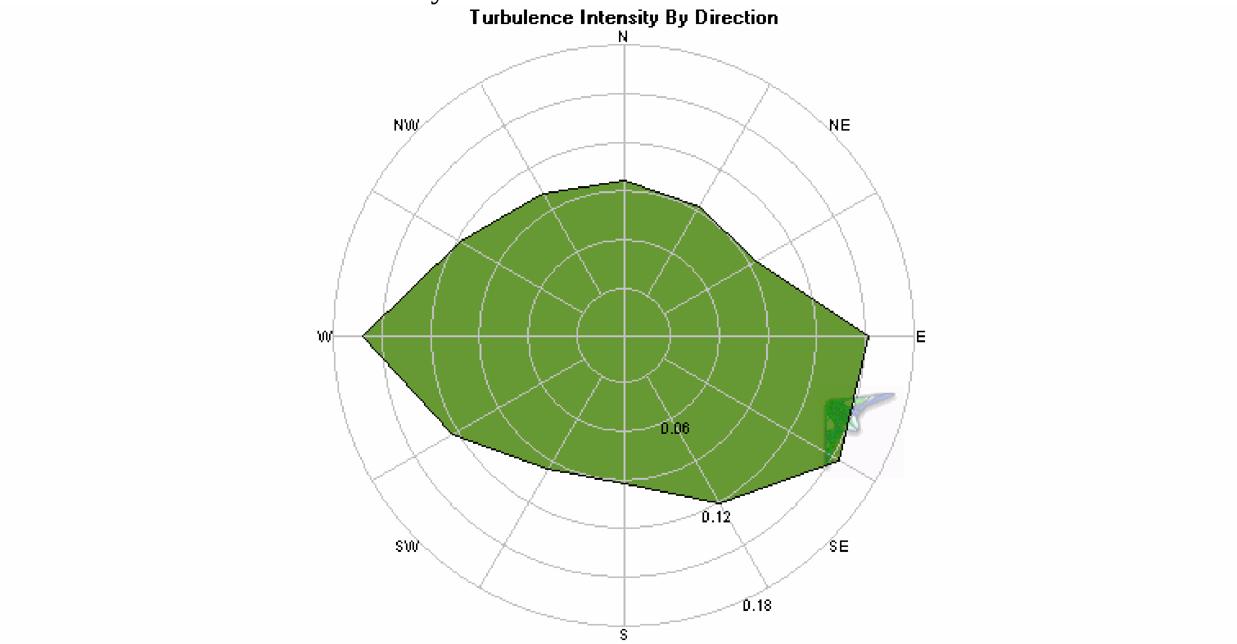
Turbulence Intensity

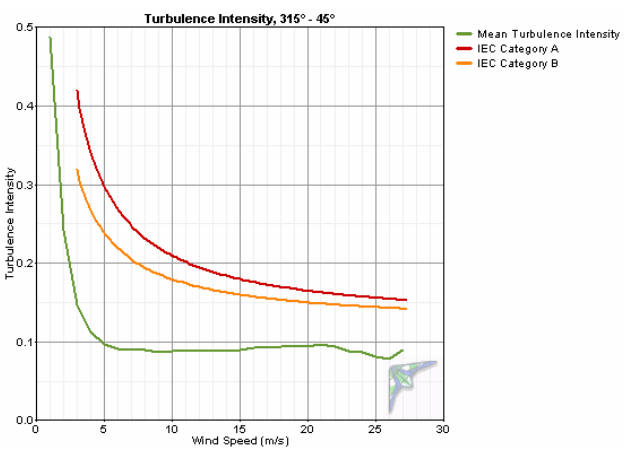
The turbulence intensity (TI) is acceptable for all wind direction, with a mean turbulence intensity of 0.100 (Channel 1) and 0.104 (Channel 2), indicating relatively smooth air. These TIs are calculated with a threshold wind speed of 4 m/s. The spike of relatively high turbulence to the west and southeast in both graphs is due to the infrequent winds from these sectors. The important TI is for winds from the north-northeast. As indicated below, turbulence at the Kokhanok 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.

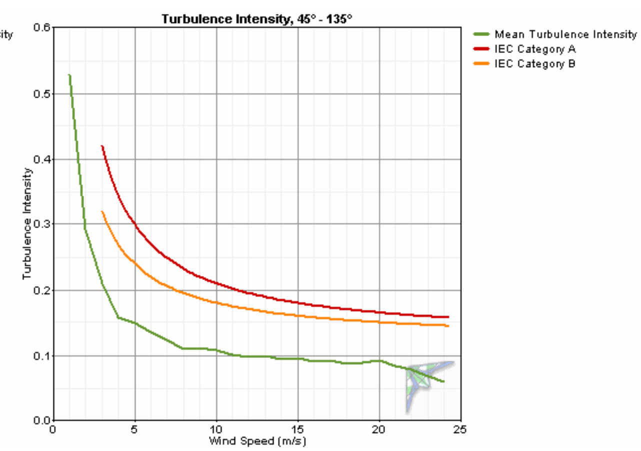
30-meter Ch 1 turbulence intensity

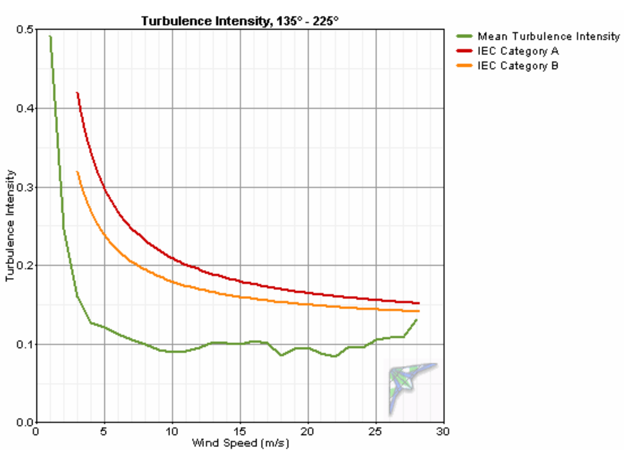


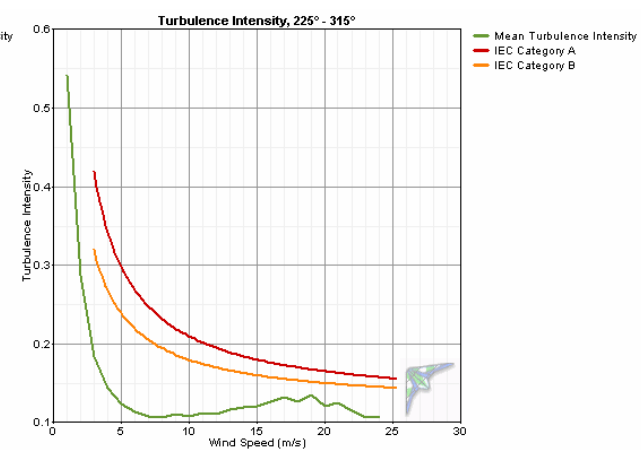
20-meter Ch 2 turbulence intensity





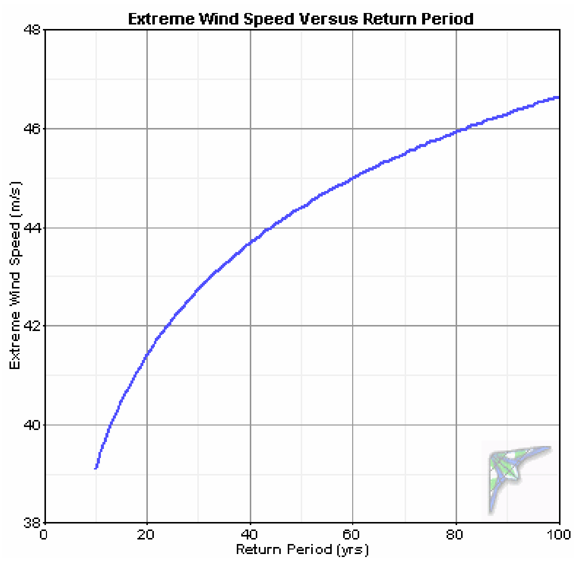


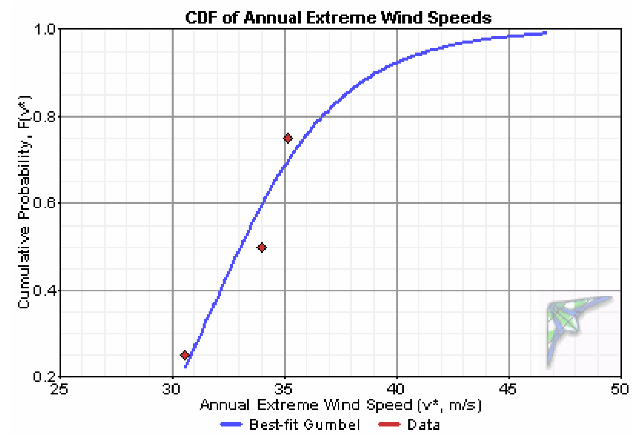




Extreme Wind Analysis

By probability, Gambell winds are expected to exceed 42.2 m/s at least once every 25 years and 44.4 m/s every 50 years. Note, however, that these graphs were generated with only three data points and should be used with considerable caution for design purposes – maximum expected winds may indeed by higher.



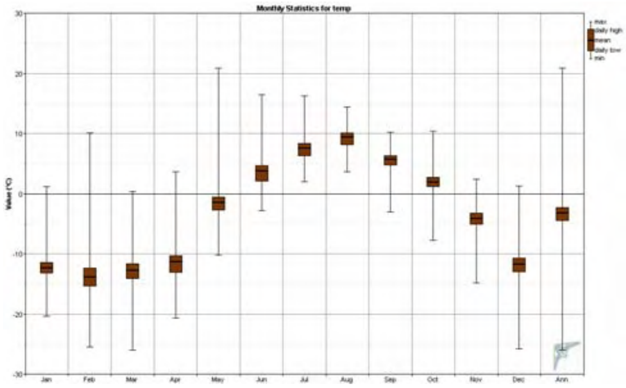


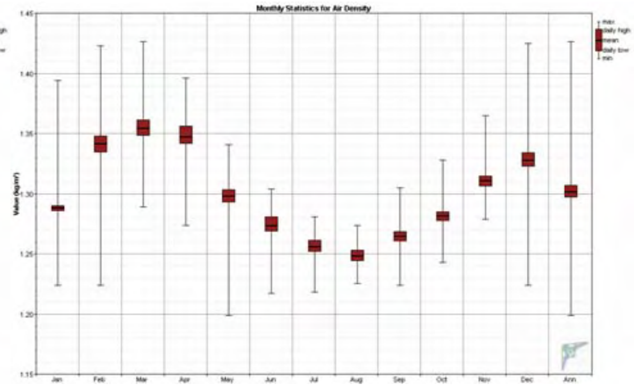
Air Temperature and Density

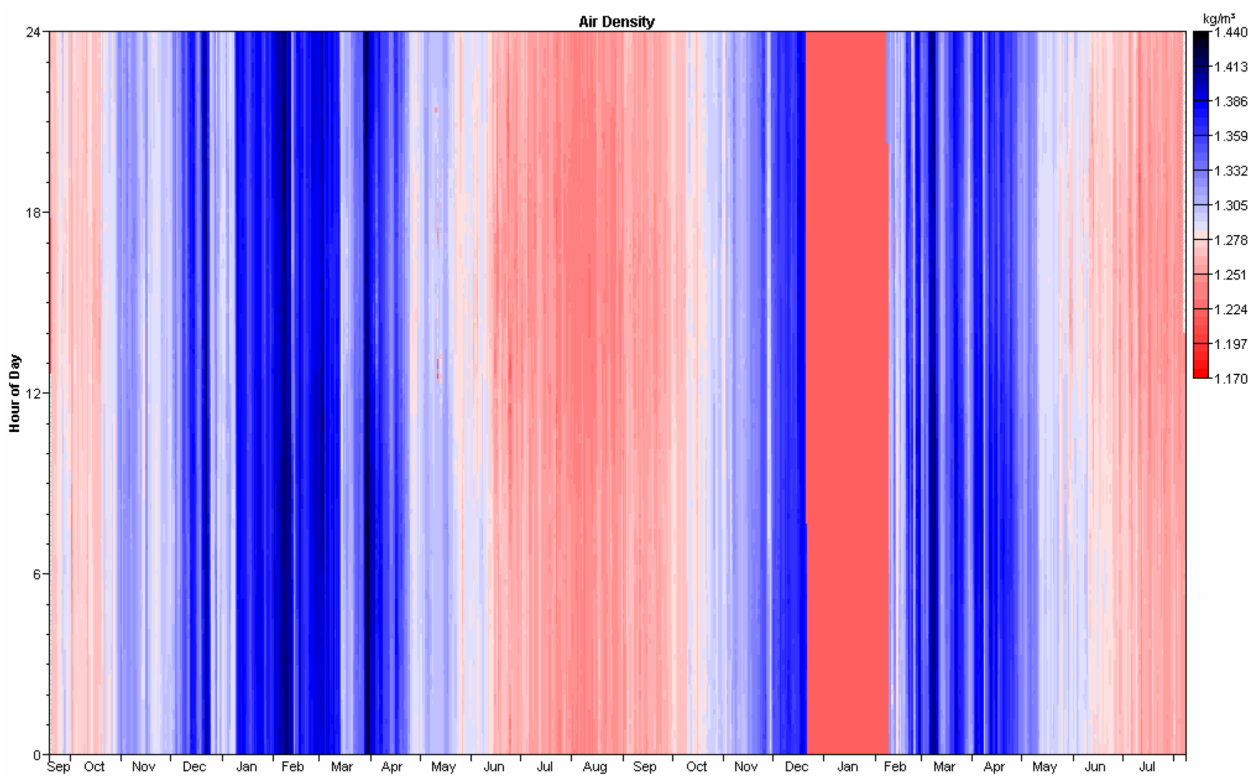
Over the reporting period, Gambell had an average temperature of -3.2° C. The minimum recorded temperature during the measurement period was -26.0° C and the maximum temperature was 20.9° C, indicating a wide variability of an ambient temperature operating environment important to wind turbine operations. Consequent to Gambell's cool temperatures, the average air density of 1.302 kg/m^3 is over six percent higher than the standard air density of 1.225 kg/m^3 (at 20° C), indicating that Gambell, 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	-12.4	-20.3	1.2	6.62	1.288
Feb	-13.9	-25.4	10.2	7.31	1.342
Mar	-12.7	-26.0	0.4	6.33	1.355
Apr	-11.3	-20.6	3.7	5.70	1.347
May	-1.4	-10.2	20.9	3.15	1.298
Jun	3.8	-2.8	16.5	2.91	1.274
Jul	7.6	2.1	16.3	1.91	1.256
Aug	9.4	3.7	14.5	1.54	1.248
Sep	5.7	-3.0	10.3	2.47	1.264
Oct	2.0	-7.7	10.5	2.91	1.282

Nov	-4.1	-14.8	2.5	3.36	1.311
Dec	-11.7	-25.7	1.3	5.64	1.328
All data	**-3.2**	-26.0	20.9	9.33	**1.302**



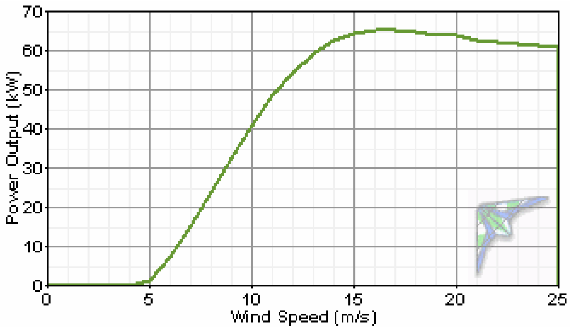




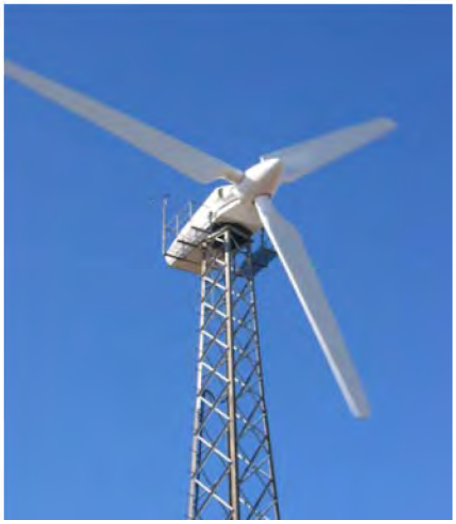
Turbine Performance Predictions

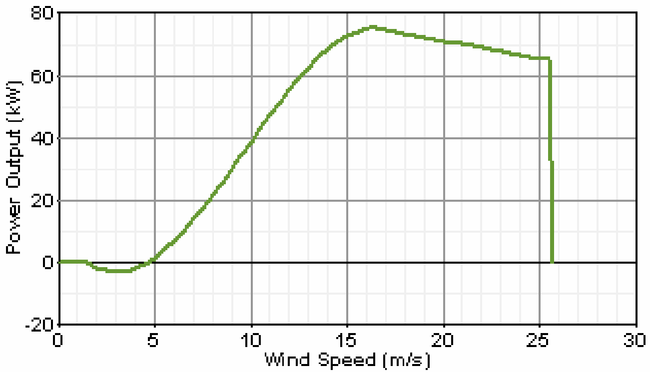
The turbine performance predictions noted below are based on 90% turbine availability with 10% downtime for maintenance and repairs and/or other outages. The manufacturer-provided power curve is presumed to be accurate. The power curves are presented for a standard air density of 1.225 kg/m^3, however 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 Gambell is that the 10-minute average winds often exceed 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: 50 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Entegrity Energy Systems)

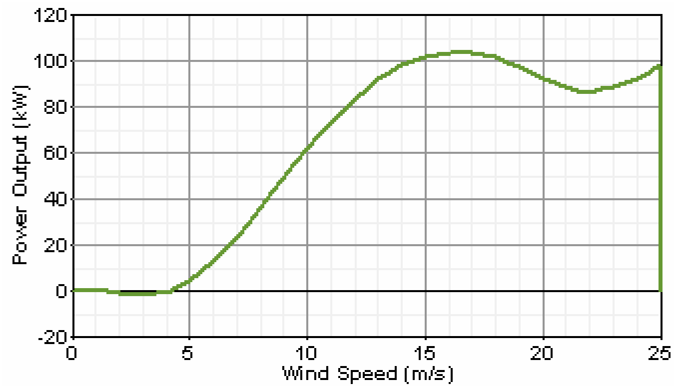


Vestas V15: 75 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Powercorp Alaska LLC)

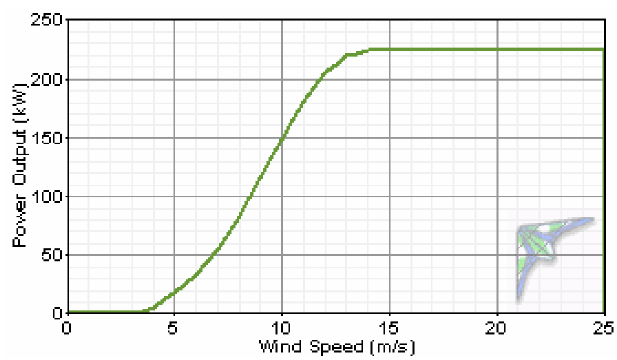




Northwind 100/19: 100 kW rated power output, 19 meter rotor, stall-controlled (power curve provided by Northern Power Systems)



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



Turbine Power Output Comparison

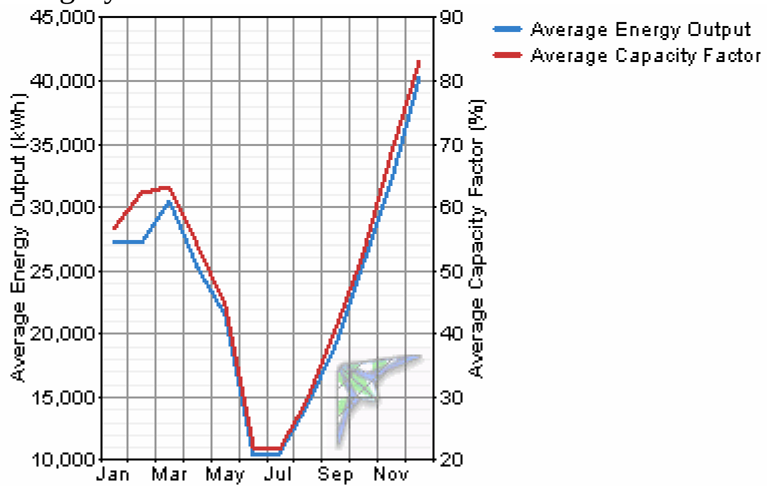
	Manufacturer	Entegrity Wind Systems			Vestas			Northern Power Systems		
	Model	eW-15			E15			NW100/19		
	Rated Power	65 kW			75 kW			100 kW		
	Maximum Power Output	65 kW			75 kW			102 kW		
Hub Height (m)	Mean Wind Speed (m/s)	Capacity Factor (%)	Avg Pwr Output (kW)	Annual Energy (kW-hr/yr)	Capacity Factor (%)	Avg Pwr Output (kW)	Annual Energy (kW-hr/yr)	Capacity Factor (%)	Avg Pwr Output (kW)	Annual Energy (kW-hr/yr)
25	9.08	50.5	32.8	258,750	44.5	33.4	262,980	46.5	46.5	366,480
31	9.09	50.5	32.8	258,840	44.5	33.4	263,250			
32								46.6	46.6	367,290
42										

		Vestas V27 225 kW 225 kW		
Hub Height (m)	Mean Wind Speed (m/s)	Capacity Factor (%)	Avg Pwr Output (kW)	Annual Energy (kW-hr/yr)
32	9.10	50.9	114.0	902,430
42	9.16	51.3	115.0	910,440

Legend:
- Capacity Factor <20%
- Capacity Factor >20%, <30%
- Capacity Factor >30%, <40%
- Capacity Factor >40%, <50%
- Capacity Factor >50%

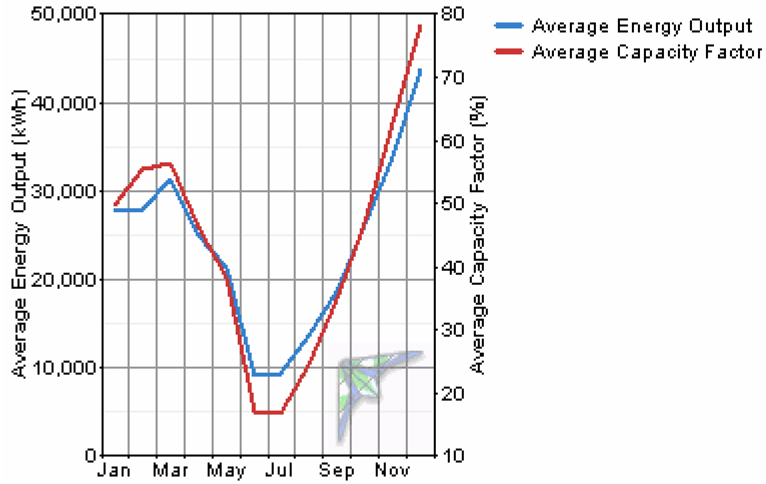
Note: Annual energy production assumes a turbine availability of 90 percent.

Entegrity eW-15 at 25 meters



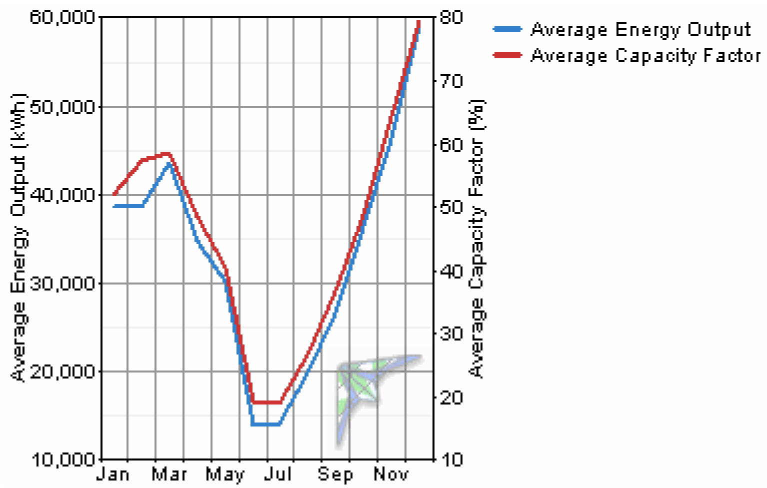
Time at zero power: 13.5%, time at rated power: 17.5%

Vestas V15 at 25 meters



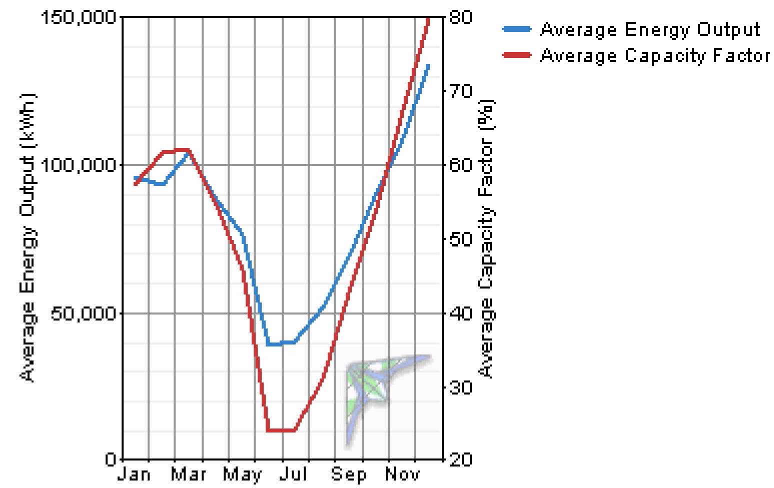
Time at zero power: 17.0%, time at rated power: 12.4%

NPS NW-100/19 at 25 meters



Time at zero power: 13.7%, time at rated power: 13.0%

Vestas V27 at 32 meters



Time at zero power: 6.3%, time at rated power: 13.0%

Annual Fuel Cost Avoided for Electrical Energy Generation by Diesel Genset

			Fuel Price (dollars delivered)							
Turbine	Annual Energy Output (kW-hr/yr)	Fuel Quantity Avoided (gallons)	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	$3.50	Hub Height (m)
Entegrity eW-15										
	287,500	21,296	$42,593	$47,917	$53,241	$58,565	$63,889	$69,213	$74,537	25
	287,600	21,304	$42,607	$47,933	$53,259	$58,585	$63,911	$69,237	$74,563	31
Vestas E15										
	292,200	21,644	$43,289	$48,700	$54,111	$59,522	$64,933	$70,344	$75,756	25
	292,500	21,667	$43,333	$48,750	$54,167	$59,583	$65,000	$70,417	$75,833	31
NPS NW100/19										
	407,200	30,163	$60,326	$67,867	$75,407	$82,948	$90,489	$98,030	$105,570	25
	408,100	30,230	$60,459	$68,017	$75,574	$83,131	$90,689	$98,246	$105,804	32
Vestas V27										
	1,002,700	74,274	$148,548	$167,117	$185,685	$204,254	$222,822	$241,391	$259,959	32
	1,011,600	74,933	$149,867	$168,600	$187,333	$206,067	$224,800	$243,533	$262,267	42

Note: Gambell 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

Temperature Conversion Chart °C to °F

°C	°F	°C	°F	°C	°F
-40	-40	-10	14	20	68
-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	-5	23	25	77
-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	32	30	86
-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	5	41	35	95
-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	10	50	40	104
-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	15	59	45	113
-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.