Kodiak, Alaska Site 1 Wind Resource Report

Report written by: Douglas Vaught, V3 Energy LLC, Eagle River, AK
Date of report: November 3, 2006

Photo by Doug Vaught, V3 Energy LLC

Meteorological Tower Data Synopsis

Wind power class (measured to date)	Class 7 – Superb
Channel 1 average wind speed	7.76 m/s (at 30 meters)
Maximum wind speed	47.7 m/s, 3/9/06, 7:30 am (30 m level)

Mean wind power density (50 meters)	833 W/m^2 (predicted by calculation)
Roughness Class	0.63 (description: snow surface)
Power law exponent	0.117 (low wind shear)
Time exceeding 25 m/s wind speed	75.7 hours (0.9% of the time)
Data start date	November 2, 2005
Most recent data date	October 31, 2006

Community Profile

Location:

Kodiak is located near the north eastern tip of Kodiak Island in the Gulf of Alaska. Kodiak Island is known as "the emerald isle" and is the largest island in Alaska. Kodiak National Wildlife Refuge encompasses a large portion of Kodiak Island and nearby Afognak Island. Kodiak is 400 kilometers (250 miles) southwest of Anchorage, has a population of about 6000 people, and has jet and commuter turboprop aircraft service to Anchorage. The climate of the Kodiak has a strong marine influence. Severely cold temperatures are relatively infrequent for its northerly latitude and there is considerable rain and snowfall with frequent cloud cover and fog. Severe storms with high winds are common from December through February.

History:

Kodiak Island has been inhabited for the past 8,000 years. The first non-Native contacts were in 1763, by the Russian Stephen Glotov, and in 1792 by Alexander Baranov, a Russian fur trapper. Sea otter pelts were the primary incentive for Russian exploration and a settlement was established at Chiniak Bay, the site of present-day Kodiak. At that time, there were over 6,500 Sugpiaqs (Koniags) in the area and the Island was called "Kikhtak." It later was known as "Kadiak," the Inuit word for island.

Kodiak became the first capital of Russian Alaska and Russian colonization had a devastating effect on the local Native population. By the time Alaska became a U.S. Territory in 1867, the Koniag region Eskimos had almost disappeared as a viable culture. Alutiiq (Russian-Aleut) is the present-day Native language. Sea otter fur harvesting was the major commercial enterprise, and eventually led to the near extinction of the species. However, in 1882 a fish cannery opened at the Karluk spit. This sparked the development of commercial fishing in the area. The "Town of Kodiak" was incorporated in 1940.

During the Aleutian Campaign of World War II, the Navy and the Army built bases on the Island. Fort Abercrombie was constructed in 1939, and later became the first secret radar installation in Alaska. Development continued and the 1960s brought growth in commercial fisheries and fish processing. The 1964 earthquake and subsequent tidal wave virtually leveled downtown Kodiak. The fishing fleet, processing plant, canneries, and 158 homes were destroyed - $30 million in damage. The infrastructure was rebuilt, and by 1968, Kodiak had become the largest fishing port in the U.S. in terms of dollar value. The Magnusson Act in 1976 extended the U.S. jurisdiction of marine resources to 200 miles offshore, which reduced competition from the foreign fleet, and over time, allowed Kodiak to develop a ground fish processing industry.

Culture:

The local culture centers on commercial and subsistence fishing activities. The Coast Guard comprises a significant portion of the community and there is a large seasonal population. Kodiak is primarily non-Native; the majority of the Native population is Alutiiq. Filipinos are a large subculture in Kodiak due to their work in the canneries. A Russian Orthodox Church seminary is located in Kodiak, one of two existing Russian Orthodox seminaries in the U.S. The Shoonaq' Tribe of Kodiak was federally recognized in January 2001. A branch of the University of Alaska Anchorage, Kodiak College is located in the City of Kodiak.

Economy:
The Kodiak economy is based on fishing, seafood processing, retail services and government. Adaptability and diversification in a variety of fisheries has enabled the Kodiak economy to develop and stabilize. Six hundred sixty-five area residents hold commercial fishing permits and numerous fish processing companies operate here year-round. The largest processors include Trident, Ocean Beauty, North Pacific, and Western Processors. The hospital and City also rank among the top employers. The largest Coast Guard station in the United States is located just south of the city. The Kodiak Launch Complex, a $38 million low-Earth orbit launch facility on 27 acres, was completed about ten years ago at Cape Narrow near Chiniak. This complex is the only commercial launch range in the U.S. that is not co-located with a federal facility. The KLC launched its first payload in November 1998.

Facilities:
Pillar Creek and Monashka Creek Reservoirs provide water, which is stored and distributed by pipe throughout the area. Piped sewage is processed in a treatment plant. All homes are fully plumbed. The piped system has been expanded to Miller Point and Spruce Cape, to replace individual wells and septic tanks in those areas. Refuse collection services are provided by the Borough. The landfill is located 6 miles north of the City at Monashka Bay. Kodiak Electric Association, a cooperative utility, operates and purchases power from the Four Dam Pool-owned Terror Lake Hydroelectric Facility. It also operates a Coast Guard-owned plant, and owns three additional diesel-powered plants at Swampy Acres, Kodiak and Port Lions.

Transportation:
Kodiak is accessible by air and sea. Three scheduled airlines serve Kodiak with several daily flights and a number of air taxi services provide flights to other communities on the Island. City-owned seaplane bases at Trident Basin and Lilly Lake serve floatplane traffic. The Alaska Marine Highway System operates a ferry service to and from Seward and Homer. The Port of Kodiak includes two boat harbors with 600 boat slips and three commercial piers: the ferry dock, city dock and container terminal. Boat launch ramps and vessel haul-outs are also available. A $20 million breakwater on Near Island provides another 60 acres of mooring space at St. Herman Harbor. The replacement of the 32-year-old float system at the St. Paul Inner Harbor downtown was completed in 2000. Approximately 140 miles of state roads connect island communities on the east side of the island.

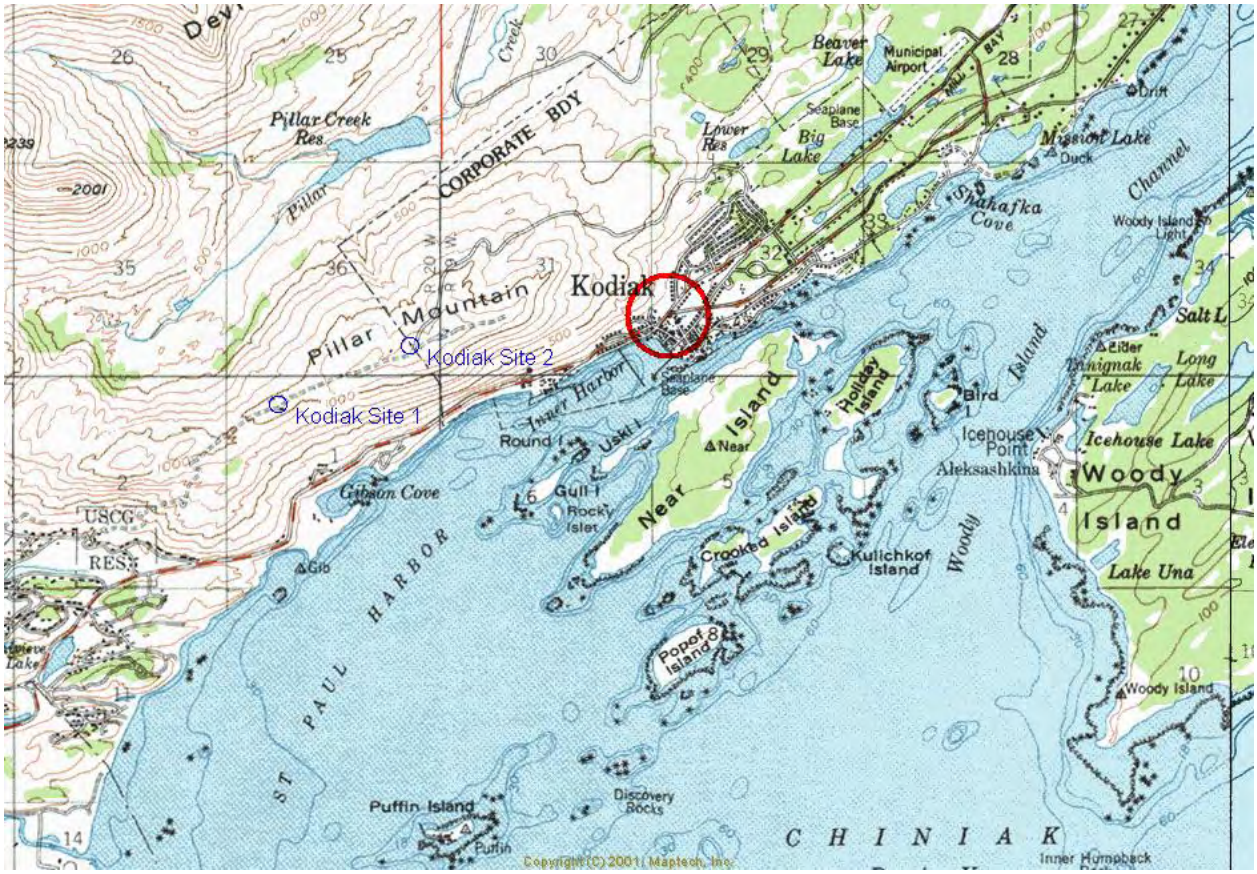
Climate:
The climate of the Kodiak Islands has a strong marine influence. There is little freezing weather, moderate precipitation, occasional high winds, and frequent cloud cover and fog. Severe storms are common from December through February. Annual rainfall is 67 inches and snowfall

averages 78 inches. January temperatures range from 14 to 46 F; July temperatures vary from 39 to 76 F.

(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	7309
Site Description	Kodiak, Alaska, Pillar Mountain ridgeline
Latitude/longitude	N 057° 47.008'; W 152° 27.464'
Site elevation	300 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 (A)	NRG #40 anemometer	30 m	0.765	0.35	east
2 (B)	NRG #40 anemometer	30 m	0.765	0.35	south
3	NRG #40 anemometer	20 m	0.765	0.35	southeast
7	NRG #200P wind vane	30 m	0.351	165	NNW

9	NRG #110S Temp C	2 m	0.138	-86.383	N/A

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 < 2° C. Note that data recovery during May through October was nearly 100%, but during the months of November through April some data was filtered, with March being the most ice prone as far as data loss is concerned. In some cases, calm conditions with temperatures colder than 2° C would result in inadvertent filtering of data, but these situations are uncommon and not significant.

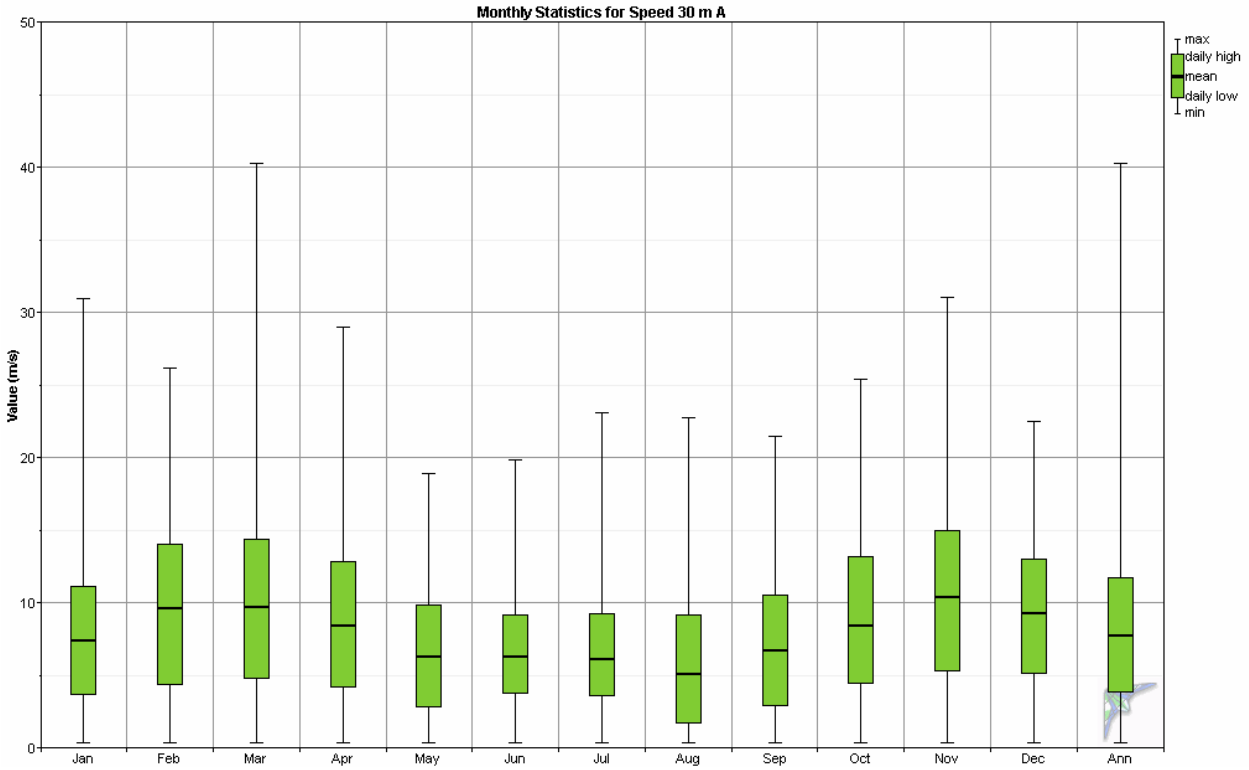
		Ch 1 anemometer		Ch 2 anemometer		Ch 3 anemometer	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2005	Nov	3,991	97.6	3,989	97.5	3,995	97.7
2005	Dec	4,412	98.8	4,412	98.8	4,414	98.9
2006	Jan	4,394	98.4	4,390	98.3	4,365	97.8
2006	Feb	3,946	97.9	3,946	97.9	3,947	97.9
2006	Mar	4,282	95.9	4,270	95.7	4,349	97.4
2006	Apr	4,137	95.8	4,160	96.3	4,175	96.6
2006	May	4,459	99.9	4,445	99.6	4,461	99.9
2006	Jun	4,320	100.0	4,320	100.0	4,320	100.0
2006	Jul	4,464	100.0	4,464	100.0	4,464	100.0
2006	Aug	2,934	100.0	2,934	100.0	2,934	100.0
2006	Sep	4,320	100.0	4,320	100.0	4,320	100.0
2006	Oct	4,410	100.0	4,410	100.0	4,410	100.0
All data		41,339	98.4	41,330	98.4	41,424	98.6

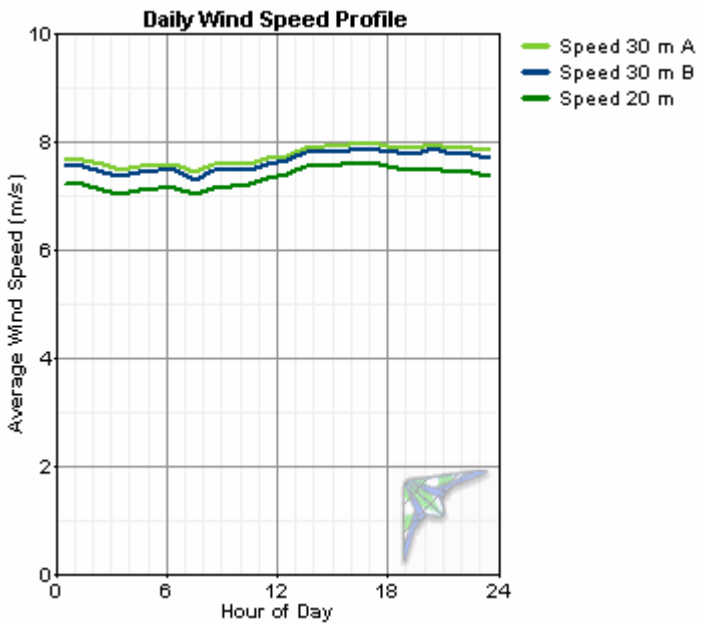
		Ch 7 vane		Ch 9 temperature	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2005	Nov	3,989	97.5	4,091	100.0
2005	Dec	4,412	98.8	4,464	100.0
2006	Jan	4,343	97.3	4,464	100.0
2006	Feb	3,946	97.9	4,032	100.0
2006	Mar	4,244	95.1	4,464	100.0
2006	Apr	4,133	95.7	4,320	100.0
2006	May	4,445	99.6	4,464	100.0
2006	Jun	4,320	100.0	4,320	100.0
2006	Jul	4,464	100.0	4,464	100.0
2006	Aug	2,934	100.0	2,934	100.0
2006	Sep	4,320	100.0	4,320	100.0
2006	Oct	4,410	100.0	4,410	100.0
All data		41,230	98.1	42,017	100.0

Measured Wind Speeds

The Channel 1 (30-meter) anemometer wind speed average for the reporting period is 7.76 m/s, the Channel 2 (30-meter) anemometer wind speed average is 7.66 m/s, and the Channel 3 (20-meter) anemometer wind speed average is 7.35 m/s. The daily wind profile indicates that the lowest wind speeds of the day occur in the morning hours of 3 to 8 a.m. and the highest wind speeds of the day occur during the afternoon and evening hours of 2 to 6 p.m.

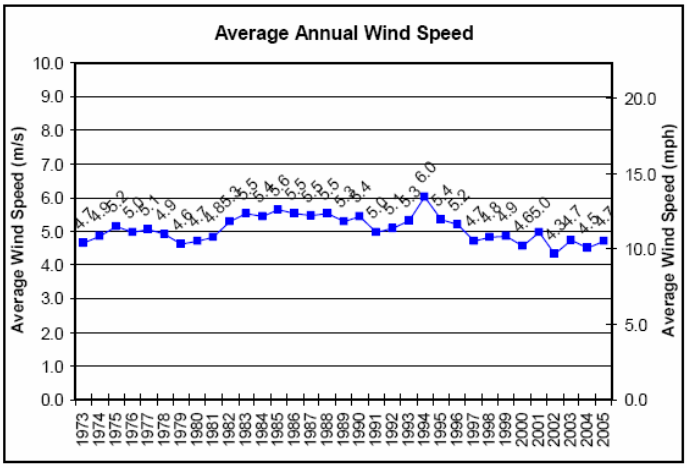
		Ch 1 (30 meters)					Ch 2 (30 m)		Ch 3 (20 m)	
Year	Month	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)	Mean (m/s)	Max (m/s)
2005	Nov	10.37	31.1	6.17	1.69	11.58	10.23	31.1	9.67	31.3
2005	Dec	9.29	22.5	4.66	1.98	10.37	9.27	22.8	8.76	21.4
2006	Jan	7.40	31.0	4.58	1.64	8.25	7.31	31.2	6.79	29.9
2006	Feb	9.59	26.2	5.87	1.59	10.63	9.56	25.6	9.08	26.2
2006	Mar	9.74	40.3	7.90	1.29	10.56	9.57	40.7	9.16	40.4
2006	Apr	8.42	29.0	6.43	1.30	9.12	8.28	29.0	7.96	29.2
2006	May	6.29	18.9	3.95	1.62	7.02	6.18	19.2	5.99	18.4
2006	Jun	6.31	19.9	3.97	1.57	7.00	6.10	20.3	6.16	18.8
2006	Jul	6.08	23.1	4.90	1.16	6.41	6.12	22.9	5.74	22.6
2006	Aug	4.62	19.5	3.73	1.23	4.95	4.59	19.5	4.37	18.1
2006	Sep	6.68	21.50	4.23	1.55	7.40	6.42	21.8	6.47	20.3
2006	Oct	8.46	25.40	4.77	1.81	9.48	8.37	25.3	8.11	24.6
All data		**7.76**	40.3	5.47	1.42	8.52	**7.66**	40.7	**7.35**	40.4





Long-term Data Comparison

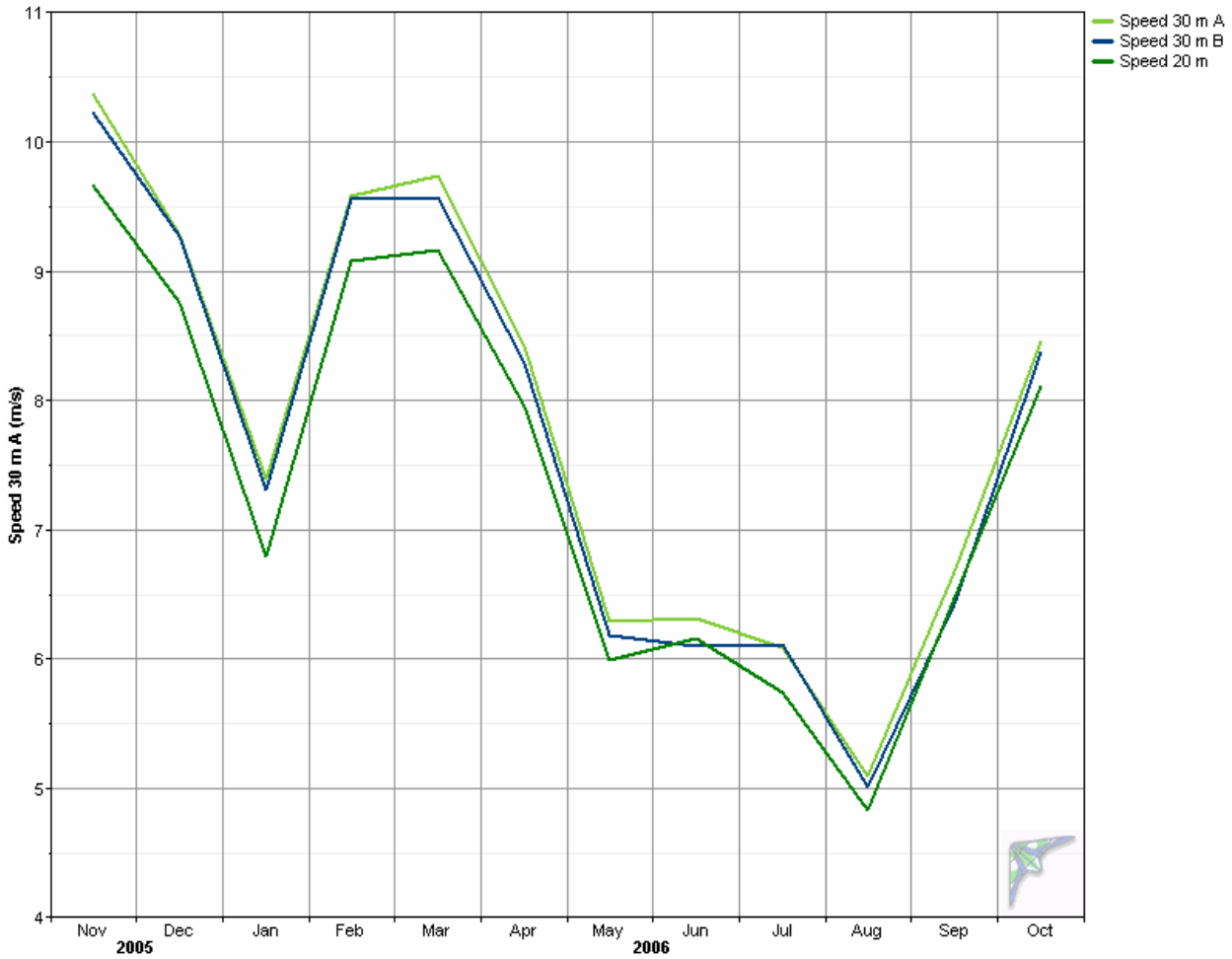
The graph below of average annual wind speed for the nearby Kodiak airport indicates that 2005 experienced possibly low average annual wind speeds when compared to data over the past thirty-two years, although in comparison to the last eight years, the 2005 data is about average. The discrepancy between earlier data and the past eight years can be attributed to an AWOS equipment upgrade. Adjusted wind data collected during the measurement period against long-term data measurement may be included in a later revision of this report, although for Site 1 this effort is of marginal interest considering the exceptionally strong wind resource at the site.



Time Series of Wind Speed Monthly Averages

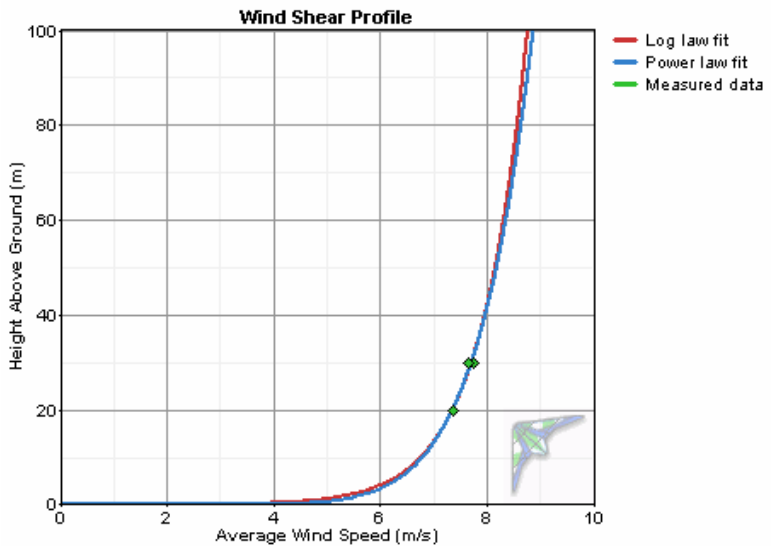
The average wind speed at 30 meters for the measurement period is 7.76 m/s. As expected, the highest winds occurred during the fall through spring months with relatively light winds during

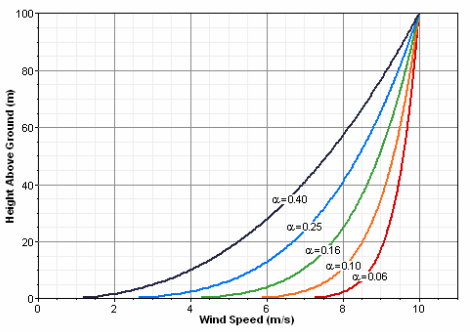
the late summer months of May through August. The unusually low winds measured in January 2006 were due to a persistent high pressure system over Alaska that month that resulted in relatively calm winds and extremely cold temperatures Statewide.

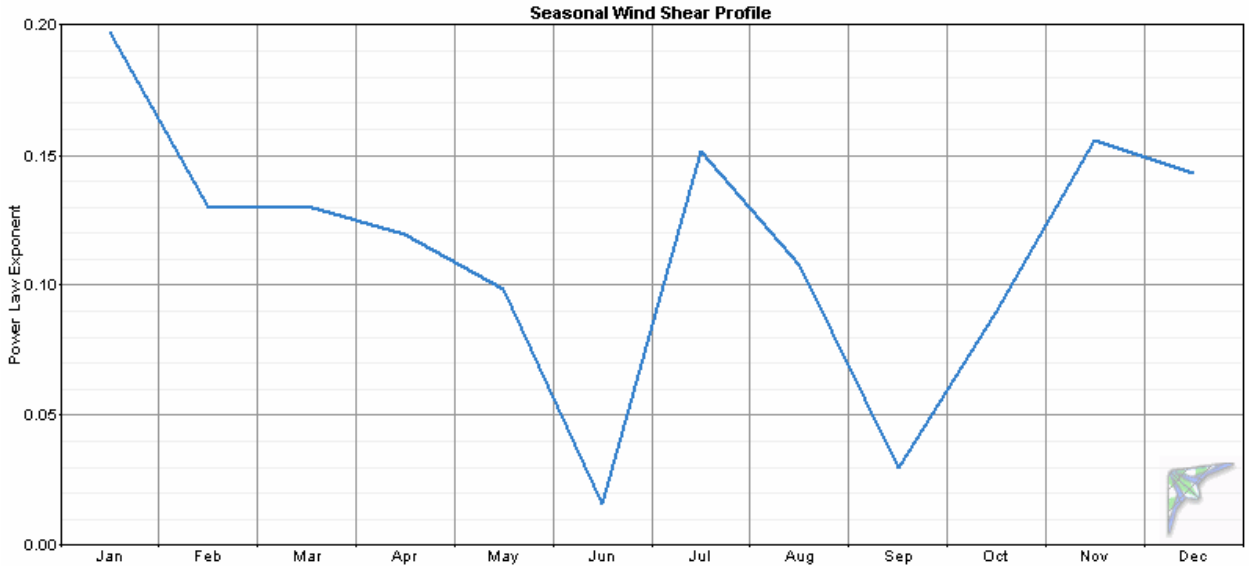


Wind Shear Profile

The average power law exponent was calculated at 0.117, indicating low wind shear at Site 1. The practical application of this information is that a lower turbine tower height is possible as there is relatively low marginal gain in average wind speed with height. However, a tower height/power recovery/construction cost tradeoff study is advisable.

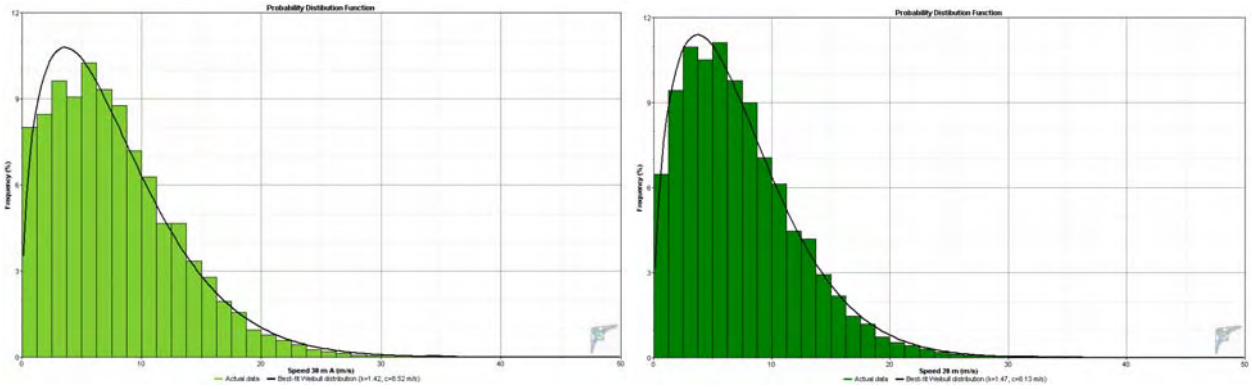






Probability Distribution Function

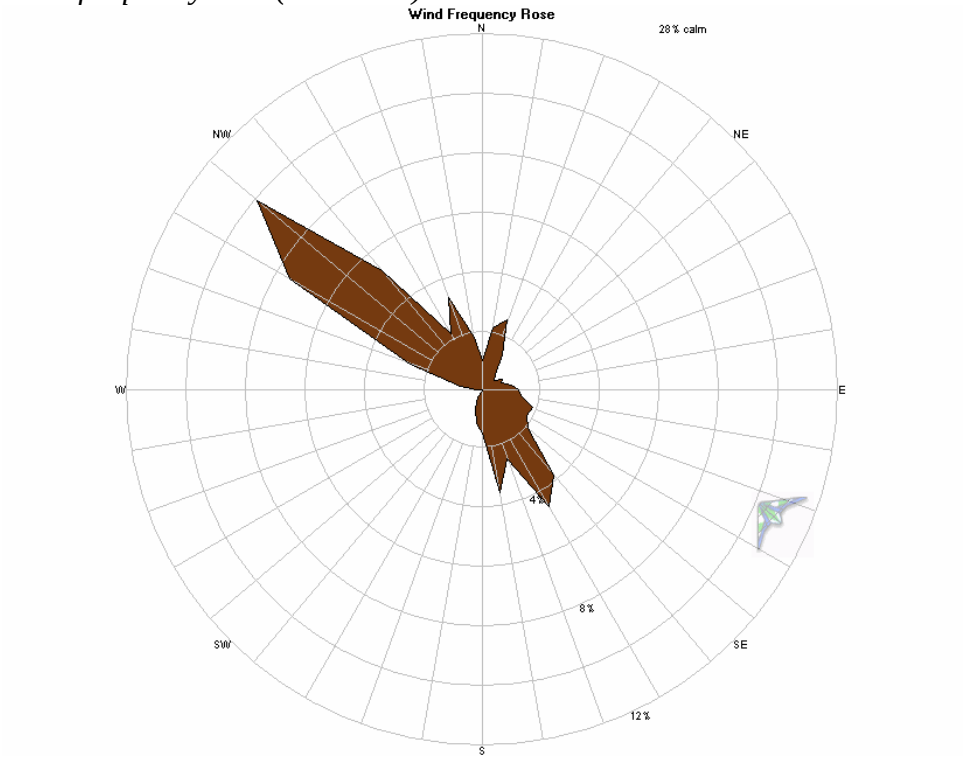
The probability distribution function provides a visual indication of measured wind speeds in one meter per second "bins". Note that most wind turbines do not begin to generate power until the wind speed at hub height reaches 4 m/s, also known as the "cut-in" wind speed. The black line in the graph is a best fit Weibull distribution. At the 30 meter level, Weibull parameters are k = 1.42 (indicates a relatively broad distribution of wind speeds) and c = 8.52 m/s (scale factor for the Weibull distribution). At 20 meters, k = 1.47 and c = 8.13 m/s.



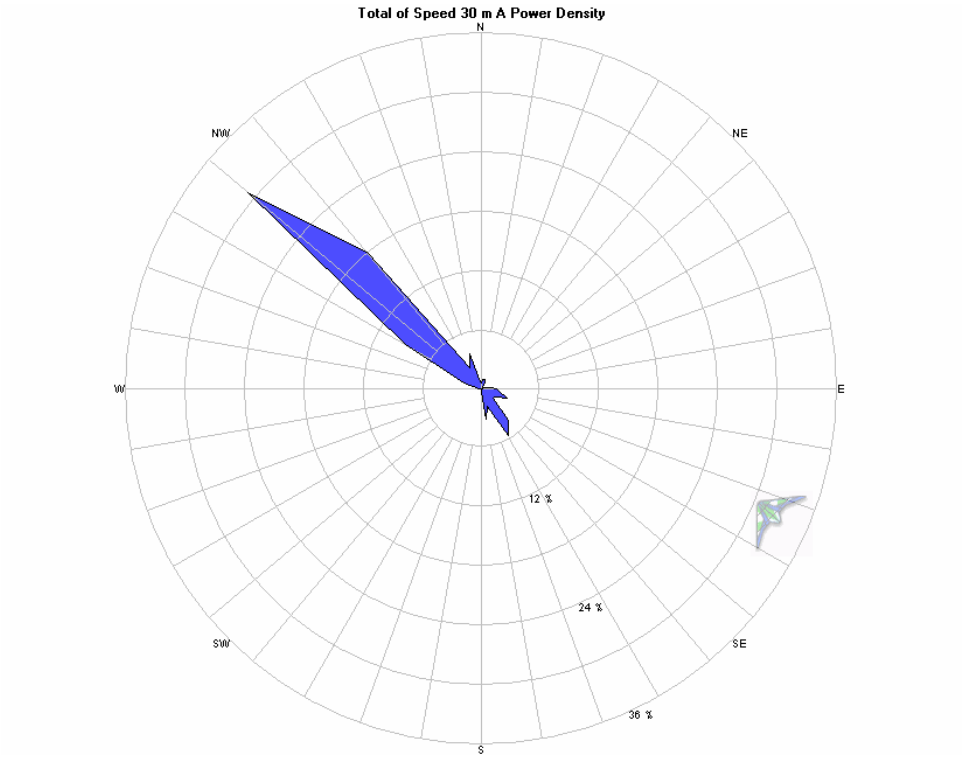
Frequency and Power Density Wind Roses

Kodiak Site 1 winds are strongly directional; the wind frequency rose indicates predominately northwest winds with a lesser component of south-southeast winds. This data observation is even stronger when one considers the power density rose (second wind rose). As one can see, the power producing winds are almost entirely concentrated in one ten-degree sector centered on northwest. The practical application of this information is that several turbines can potentially be spaced closely together perpendicular to the prevailing NW and SSE winds.

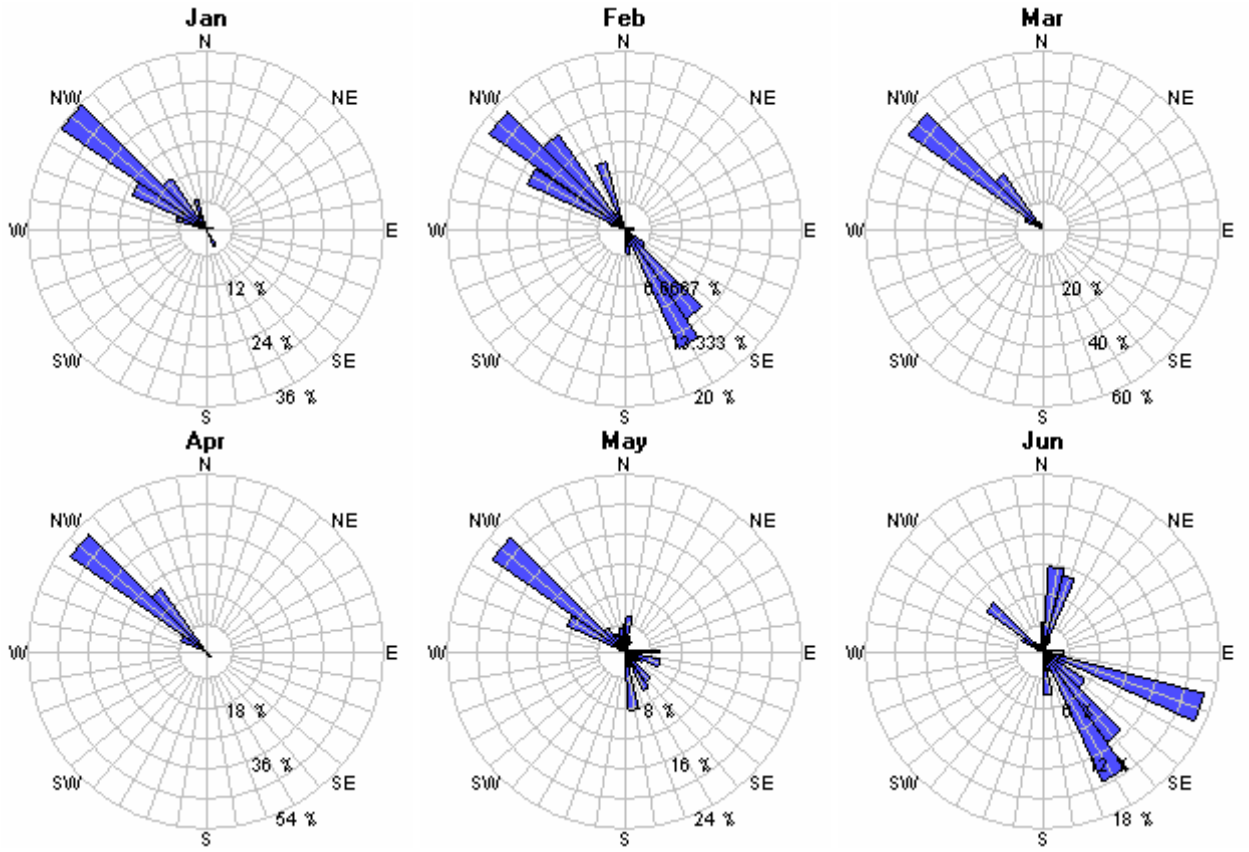
Wind frequency rose (30 meters)

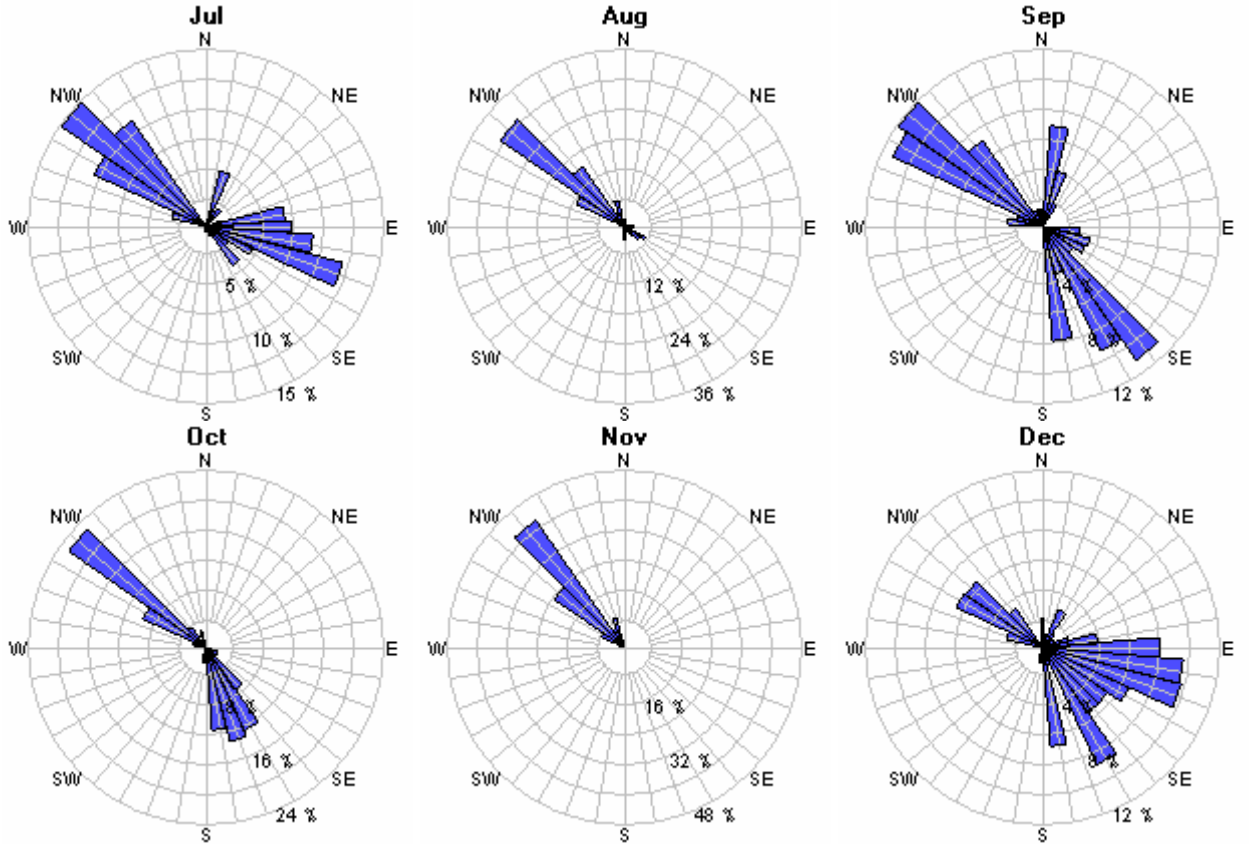


Power density rose (30 meters)



Wind Power Density Rose by Month (30 meters); note that scale is not common

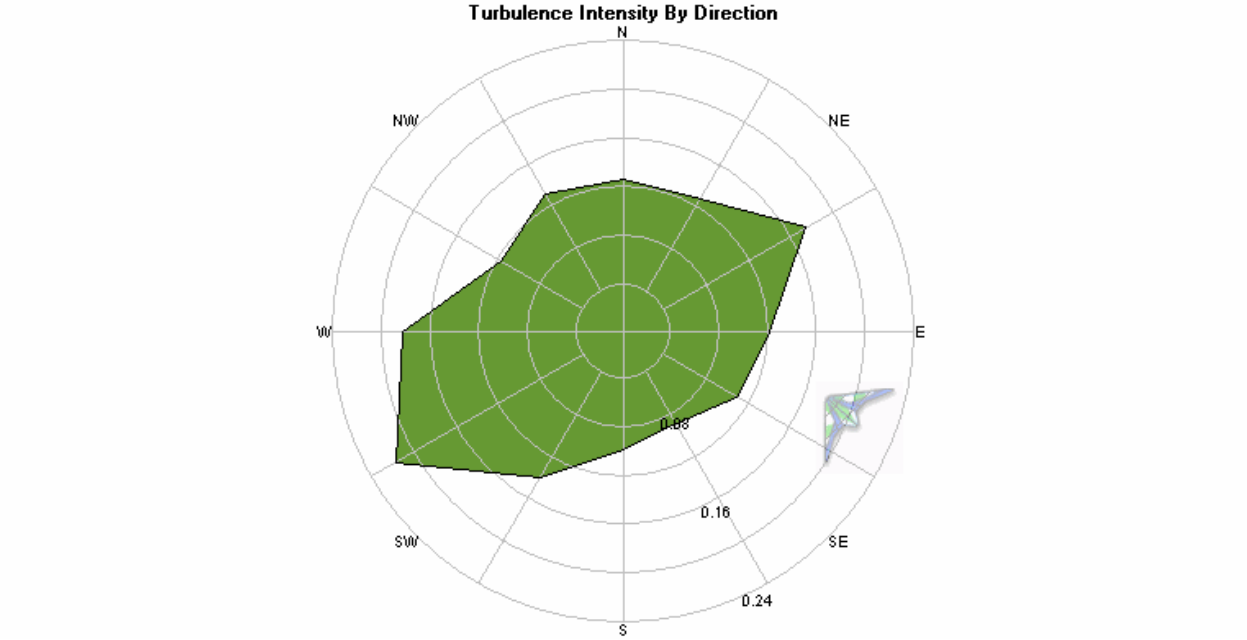




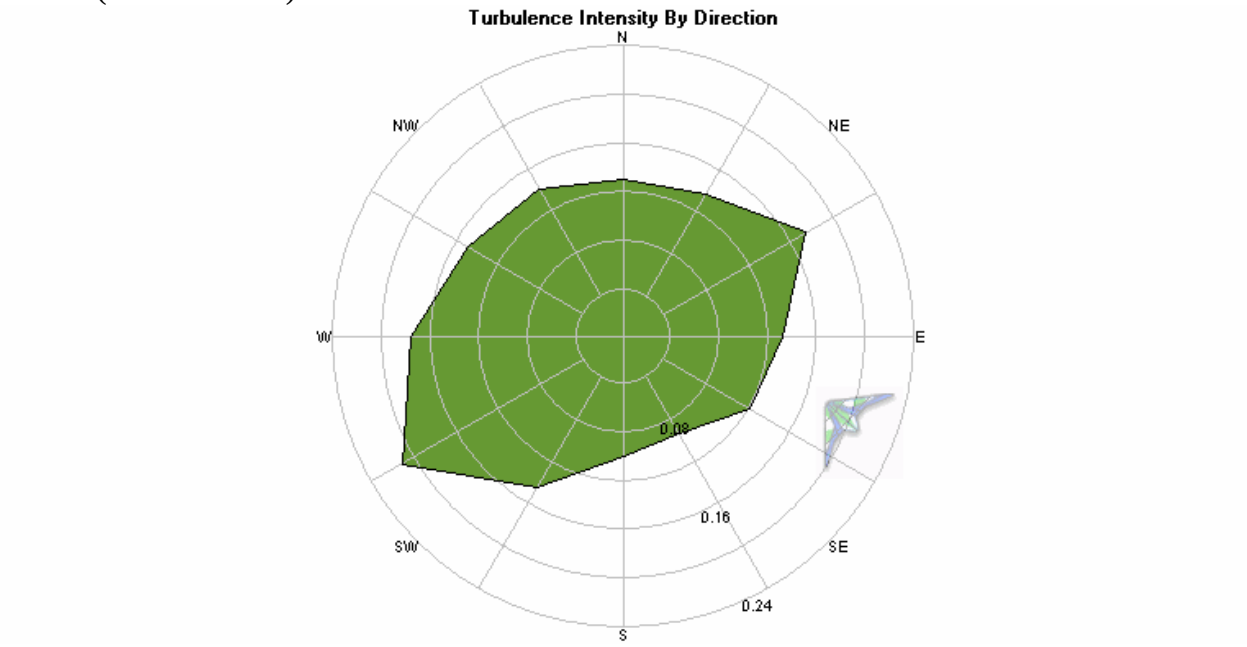
Turbulence Intensity

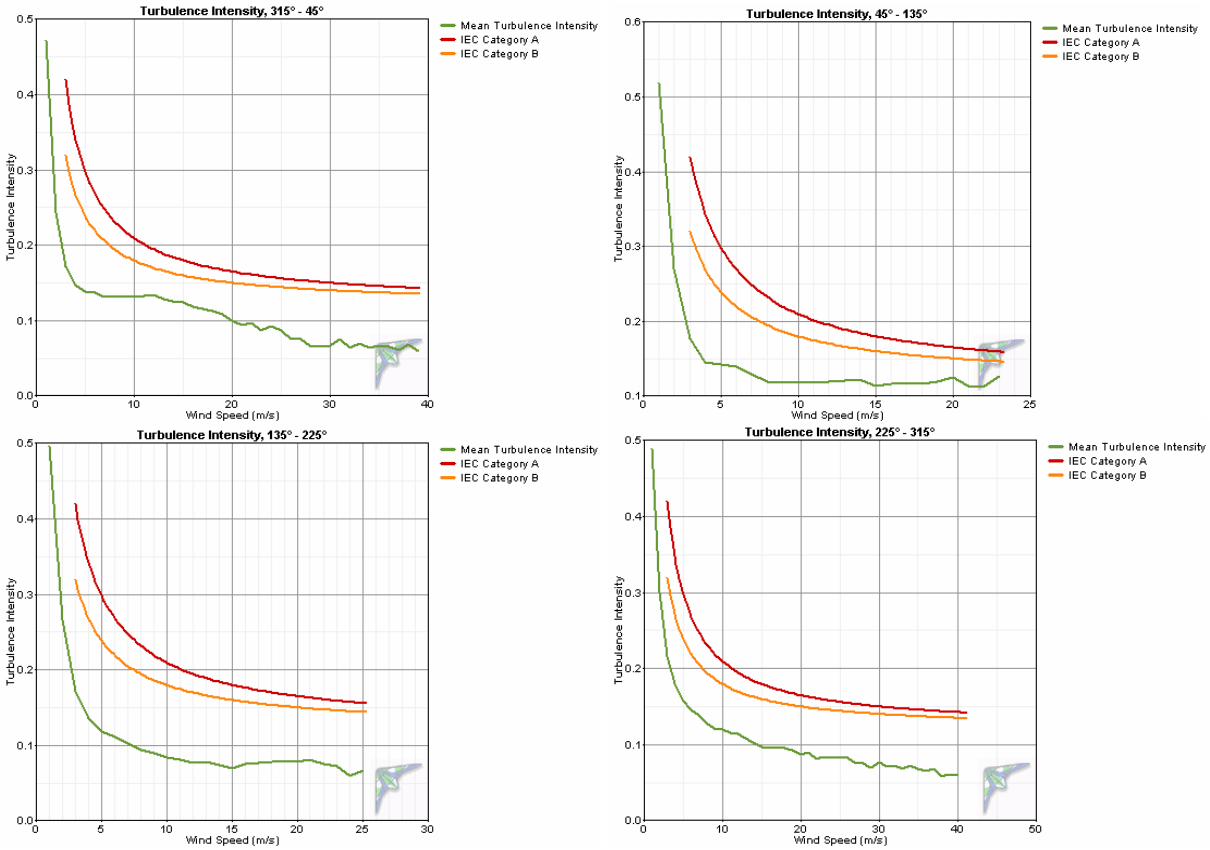
The Kodiak Site 1 turbulence intensity remains quite acceptable with a mean of 0.118. The higher turbulence in the southwest quadrant is inconsequential as the wind almost never blows from this direction. As indicated below, turbulence is well below International Energy Agency (IEA) Category A and B standards for all wind directions and at all measured wind speeds.

30-meter Ch 1 Turbulence Intensity
(Mean = 0.118)



20-meter Ch 3 Turbulence Intensity
(Mean = 0.131)



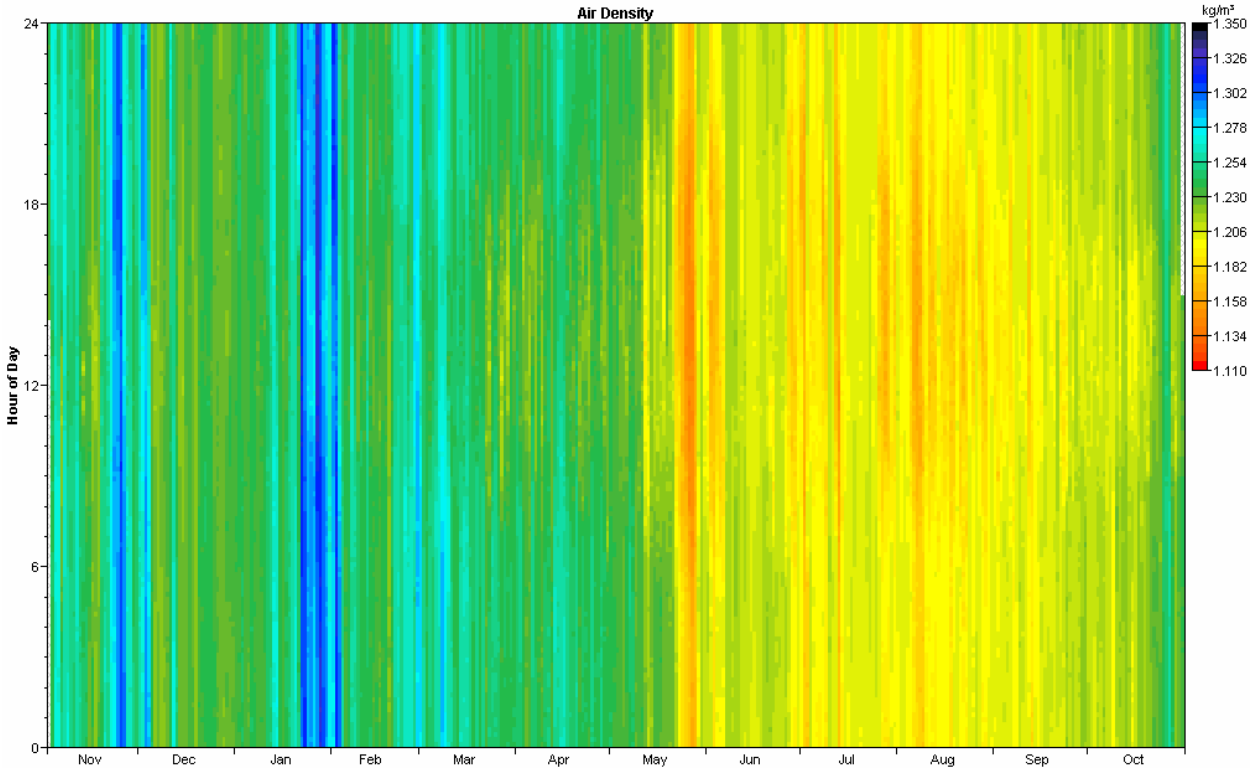


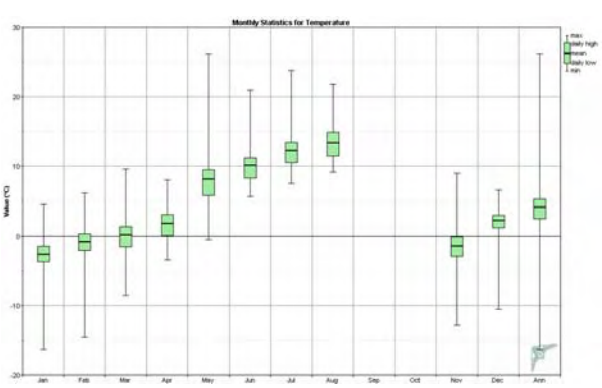
Air Temperature and Density

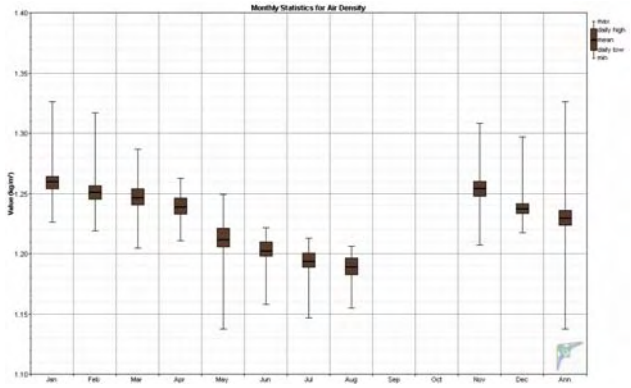
Over the reporting period, Kodiak Site 1 had an average temperature of 5.1° C. The minimum recorded temperature during the measurement period was -16.3° C and the maximum temperature was 26.2° C, indicating a cool temperate operating environment for wind turbine operations. Consequent to Kodiak's cool temperatures, but counterbalanced by Site 1's elevation of 300 meters, the average air density of 1.225 kg/m^3 is exactly equal to the standard air density of 1.225 kg/m^3 (at 15° C). Any density variance from standard is accounted for in the turbine performance predictions.

		Temperature				Air Density		
Year	Month	Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
2005	Nov	-1.4	-12.8	9.0	4.43	1.254	1.207	1.308
2005	Dec	2.3	-10.5	6.6	3.61	1.237	1.218	1.297
2006	Jan	-2.6	-16.3	4.6	5.63	1.260	1.226	1.326
2006	Feb	-0.8	-14.5	6.2	4.18	1.251	1.219	1.317
2006	Mar	0.2	-8.5	9.6	2.74	1.246	1.205	1.287
2006	Apr	1.8	-3.4	8.1	2.09	1.239	1.211	1.263
2006	May	8.2	-0.5	26.2	6.04	1.211	1.138	1.249
2006	Jun	10.2	5.7	21.0	2.91	1.203	1.158	1.222
2006	Jul	12.3	7.6	23.8	3.03	1.194	1.147	1.213
2006	Aug	13.4	9.2	21.8	2.65	1.189	1.155	1.206

2006	Sep	10.2	5.1	17.5	1.93	1.202	1.172	1.224
2006	Oct	6.5	-2.2	12.1	3.01	1.218	1.194	1.257
All data		**5.1**	-16.3	26.2	6.60	**1.225**	1.138	1.326







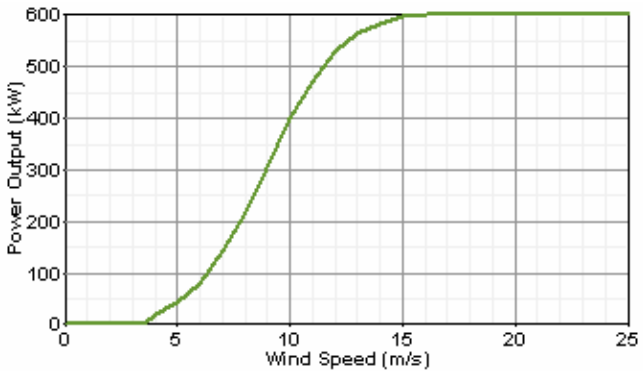
Turbine Performance Predictions for Site 1 (100% availability of turbines)

Predicted turbine performances at Kodiak Site 1 are extremely promising, so much so that one must consider turbines designed for high wind environments. Although the performance predictions are adjusted to air density, they do not account for maintenance and other expected down time of turbines.

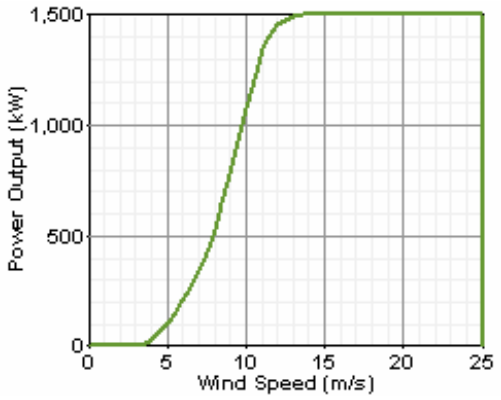
Because the wind speeds are exceptionally high at this site, the data was analyzed for ten-minute blocks of time where 10-minute average wind speeds exceeded 25 m/s, a common cut-off speed

for wind turbines. For the data collection period 11/2/05 through 10/31/06, 75.6 hours met this criterion, or approximately 0.9% of the time (of the testing period). These periods of no wind power production *are* accounted for in the following turbine output data.

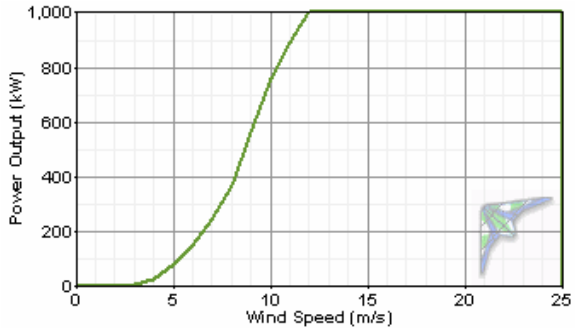
Vestas RRB 47/600: 600 kW output, 47 meter rotor, pitch-controlled (power curve provided by Vestas RRB, India)



General Electric GE1.5S: 1500 kW output, 70.5 m rotor diameter, pitch-controlled (power curve from Windographer® software)



Suzlon S.62/1000: 1000 kW output, 62 m rotor diameter, pitch-controlled (power curve from Windographer® software)



Turbine Power Output Comparison

	Manufacturer	Vestas RRB		General Electric		Suzlon	
	Model	47/600		1.5s		S.62/1000	
	Rated Power	600 kW		1500 kW		1000 KW	
Hub Height (m)	Mean Wind Speed (m/s)	Capacity Factor (%)	Annual Energy Output (kW-hr/yr)	Capacity Factor (%)	Annual Energy Output (kW-hr/yr)	Capacity Factor (%)	Energy Output (kW-hr/yr)
50	8.10	38.4	2,017,000				
60	8.26	39.1	2,054,000				
65	8.33			40.6	5,336,000	41.9	3,669,000

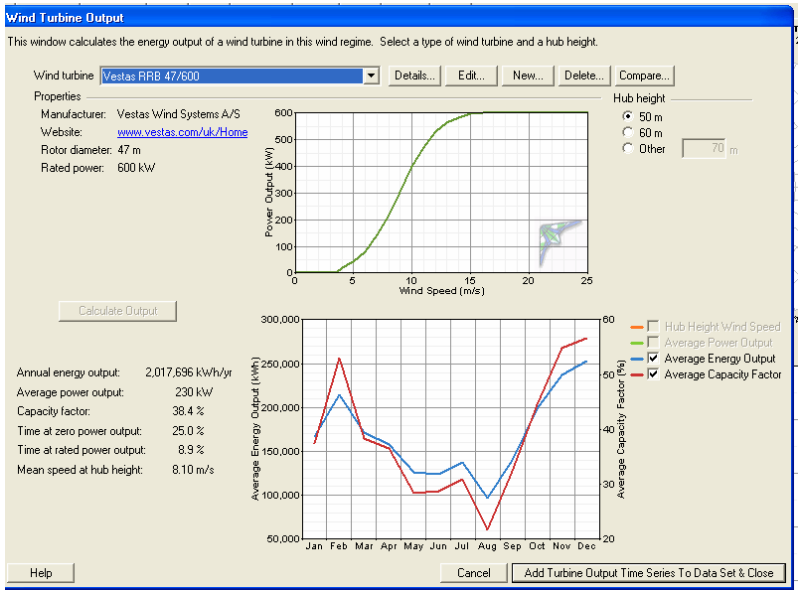
Capacity Factor <20%
Capacity Factor >20%, <30%
Capacity Factor >30%, <40%
Capacity Factor >40%, <50%
Capacity Factor >50%

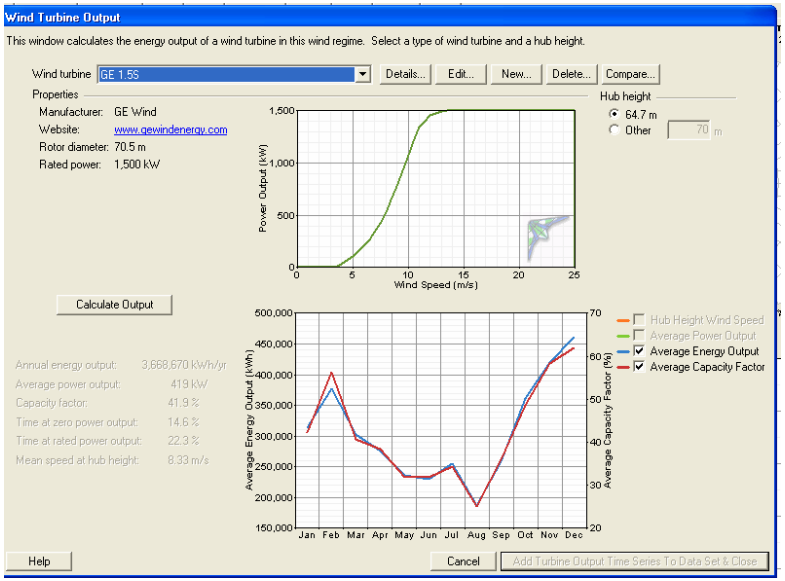
Note: assumes 100% turbine availability

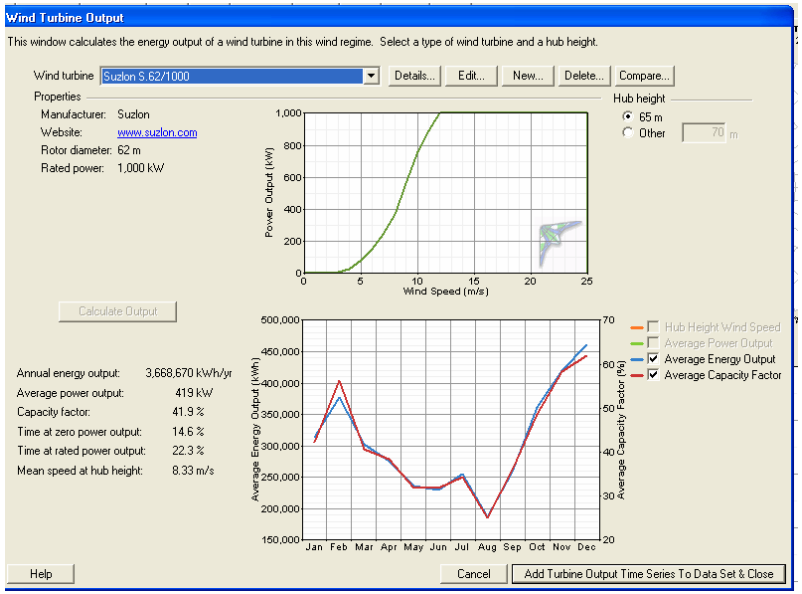
Fuel Cost Avoided for Electrical Energy Generation by Diesel Genset

			Fuel Price (dollars delivered)							
Turbine	Annual Energy Output (kW-hr/yr)	Fuel Quantity Avoided (gallons)	$1.75	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	Hub Height (m)
Vestas RRB 47/600										
	2,017,000	130,129	$227,726	$260,258	$292,790	$325,323	$357,855	$390,387	$422,919	50
	2,054,000	132,516	$231,903	$265,032	$298,161	$331,290	$364,419	$397,548	$430,677	60
General Electric 1.5s										
	5,336,000	344,258	$602,452	$688,516	$774,581	$860,645	$946,710	$1,032,774	$1,118,839	65
Suzlon S.64/1250										
	3,669,000	236,710	$414,242	$473,419	$532,597	$591,774	$650,952	$710,129	$769,306	65

Notes: Energy production efficiency assumed to equal 15.5 kW-hr/gal;
Assumes 100% turbine availability


Wind Turbine Output
This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height.
Wind turbine
Vestas RRB 47/600
Details...
Edit...
New...
Delete...
Compare...
Properties
Manufacturer: Vestas Wind Systems A/S
Website: www.vestas.com/uk/Home
Rotor diameter: 47 m
Rated power: 600 kW
Hub height
50 m
60 m
Other
70 m
Power Output (kW)
Wind Speed (m/s)
Calculate Output
Annual energy output: 2,017,696 kWh/yr
Average power output: 230 kW
Capacity factor: 38.4 %
Time at zero power output: 25.0 %
Time at rated power output: 8.9 %
Mean speed at hub height: 8.10 m/s
Average Energy Output (kWh)
Average Capacity Factor (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Hub Height Wind Speed
Average Power Output
Average Energy Output
Average Capacity Factor
Help
Cancel
Add Turbine Output Time Series To Data Set & Close


Wind Turbine Output
This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height.
Wind turbine
GE 1.5S
Details...
Edit...
New...
Delete...
Compare...
Properties
Manufacturer: GE Wind
Website: www.gewindenergy.com
Rotor diameter: 70.5 m
Rated power: 1,500 kW
Hub height
64.7 m
Other
70 m
Power Output (kW)
Wind Speed (m/s)
Calculate Output
Annual energy output: 3,668,670 kWh/yr
Average power output: 419 kW
Capacity factor: 41.9 %
Time at zero power output: 14.6 %
Time at rated power output: 22.3 %
Mean speed at hub height: 8.33 m/s
Average Energy Output (kWh)
Average Capacity Factor (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Hub Height Wind Speed
Average Power Output
Average Energy Output
Average Capacity Factor
Help
Cancel
Add Turbine Output Time Series To Data Set & Close


Wind Turbine Output
This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height.
Wind turbine
Suzlon S.62/1000
Details...
Edit...
New...
Delete...
Compare...
Properties
Manufacturer: Suzlon
Website: www.suzlon.com
Rotor diameter: 62 m
Rated power: 1,000 kW
Hub height
65 m
Other
70 m
Power Output (kW)
Wind Speed (m/s)
Calculate Output
Annual energy output: 3,668,670 kWh/yr
Average power output: 419 kW
Capacity factor: 41.9 %
Time at zero power output: 14.6 %
Time at rated power output: 22.3 %
Mean speed at hub height: 8.33 m/s
Average Energy Output (kWh)
Average Capacity Factor (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Hub Height Wind Speed
Average Power Output
Average Energy Output
Average Capacity Factor
Help
Cancel
Add Turbine Output Time Series To Data Set & Close

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.