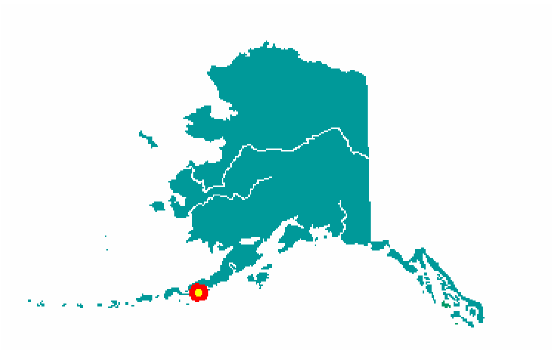
Perryville, Alaska Wind Resource Update Report

Report written by: Douglas Vaught, P.E., V3 Energy, LLC

Photo by Doug Vaught, V3 Energy, LLC



Summary Information

The wind resource study in Perryville defied expectations of measuring strong winds. It appears that local geographic features effectively shield the test site, and the nearby village, from the ferocious winds common to the southern Alaska Peninsula coast. With a measured wind power class of 2 (marginal), Perryville does not appear at this time to be a promising location for village-scale wind power development, although there is always the possibility of successful home-scale wind power development.

Meteorological Tower Data Synopsis

Wind power class	Class 2 – Marginal
Wind speed annual average (30 meters)	4.60 m/s
Maximum wind gust (2 sec. average)	24.4 m/s (Nov 2004)
Mean wind power density (50 meters)	240 W/m^2 (calculated)
Mean wind power density (30 meters)	185 W/m^2 (measured)
Wiebull distribution parameters	k = 1.36, c = 5.02 m/s
Roughness class	1.93 (few trees)
Power law exponent	0.181 (moderate wind shear)
Turbulence intensity	0.158
Data start date	October 9, 2004
Most recent data date	October 4, 2006

Community Profile

Current Population: 114 (2005 State Demographer est.)
Incorporation Type: Unincorporated
Borough Located In: Lake & Peninsula Borough
School District: Lake & Peninsula Schools
Regional Native Corporation: Bristol Bay Native Corporation

Location:
Perryville is located on the south coast of the Alaska Peninsula, 275 miles southwest of Kodiak and 500 miles southwest of Anchorage. It lies at approximately 55.912780° North Latitude and 159.145560° West Longitude. (Sec. 27, T049S, R064W, Seward Meridian.) Perryville is located in the Aleutian Islands Recording District. The area encompasses 9.2 sq. miles of land and 0.1 sq. miles of water.

History:
The community was founded in 1912 as a refuge for Alutiiq people driven away from their villages by the eruption of Mt. Katmai. Many villagers from Douglas and Katmai survived the eruption because they were out fishing at the time. Captain Perry of the ship "Manning" transported people from the Katmai area to Ivanof Bay, and later, to the new village site. The village was originally called "Perry," but the "ville" was added to conform to the post office name, established in 1930.

Culture:
The village maintains an Alutiiq culture and a subsistence lifestyle. Commercial fishing provides cash income.

Economy:
Eleven residents hold commercial fishing permits for the Chignik salmon fishery. During the summer, the majority of residents leave Perryville to fish in Chignik or Chignik Lagoon. Only a few year-round jobs are available. Some trap during the winter, and all rely heavily on subsistence food sources. Salmon, trout, marine fish, crab, clams, moose, caribou, bear, porcupine and seal are harvested.

Facilities:

Water is supplied by a nearby stream and 60,000-gallon timber dam gravity system. It is treated, stored in a new 50,000-gallon tank, and distributed via water mains. Thirty homes and the school have piped water. Individual septic tanks are used by most residents and there is a septic system for community facilities. The landfill is recorded as inactive. A number of homes are used only seasonally.

Transportation:

Perryville is accessible by air and sea. There is a State-owned 2,467' long by 50' wide gravel runway and seaplane base and scheduled and charter flights are available from King Salmon. Cargo barges deliver fuel and supplies each spring. A small boat harbor is needed for the growing fishing community and the west side of Three Star Point has been selected for development. ATVs and skiffs are the primary means of local transportation.

Climate:

Perryville's maritime climate is characterized by cool summers, warm winters and rainy weather. Average summer temperatures range from 39° to 60° F; winter temperatures average 21° to 50° F. Low clouds, rain squalls, fog and snow showers frequently limit visibility. Average annual precipitation is 127 inches, including 58 inches of snow.

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

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	23 m	0.765	0.35	south
3	NRG #40 anemometer	19 m	0.765	0.35	west
7	NRG #200P wind vane	30 m	0.351	265	east
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Site Information and Location

Site number	2858
Site Description	Coastal flat, behind beach dunes, east side of village
Latitude/longitude	N 55° 54.648’; W 159° 08.387’
Site elevation	2 meters
Datalogger type	NRG Symphonie
Tower type	NRG 30-meter tall tower, 152 mm (6-in) diameter


WILDLIFE REFUGE
RIVER
Red Bluff Mountain
Creek
Anchor Bay
ANCHOR BAY
Perryville Met Tower
Coal Cape
Stirni Point
Three Star Point
Shapka Island
CHIACHI ISLANDS
Petrel Island
Pinusuk Island
Chiachi Island
Chiachi Bay
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Data 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 < 2° C. Note that data recovery for the Perryville met tower was excellent with very little data lost to icing events and no data lost to failed sensors. Because sensor icing was so minimal, filtered data was not synthesized and replaced.

		Ch 1 (speed 30 m)		Ch 2 (speed 23 m)		Ch 3 (speed 19 m)	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2004	Oct	3,198	99.2	3,198	99.2	3,198	99.2
2004	Nov	4,198	97.2	4,178	96.7	4,237	98.1
2004	Dec	4,464	100	4,464	100	4,464	100
2005	Jan	4,464	100	4,464	100	4,464	100
2005	Feb	4,032	100	4,032	100	4,032	100
2005	Mar	4,357	97.6	4,357	97.6	4,357	97.6
2005	Apr	4,320	100	4,320	100	4,320	100
2005	May	4,464	100	4,464	100	4,464	100
2005	Jun	4,320	100	4,320	100	4,320	100
2005	Jul	4,464	100	4,464	100	4,464	100
2005	Aug	4,464	100	4,464	100	4,464	100
2005	Sep	4,320	100	4,320	100	4,320	100
2005	Oct	4,464	100	4,464	100	4,464	100
2005	Nov	4,320	100	4,320	100	4,320	100
2005	Dec	4,464	100	4,464	100	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	4,415	98.9	4,464	100
2006	Apr	4,281	99.1	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	486	100	486	100	486	100
All data		104,072	99.7	104,042	99.7	104,150	99.8

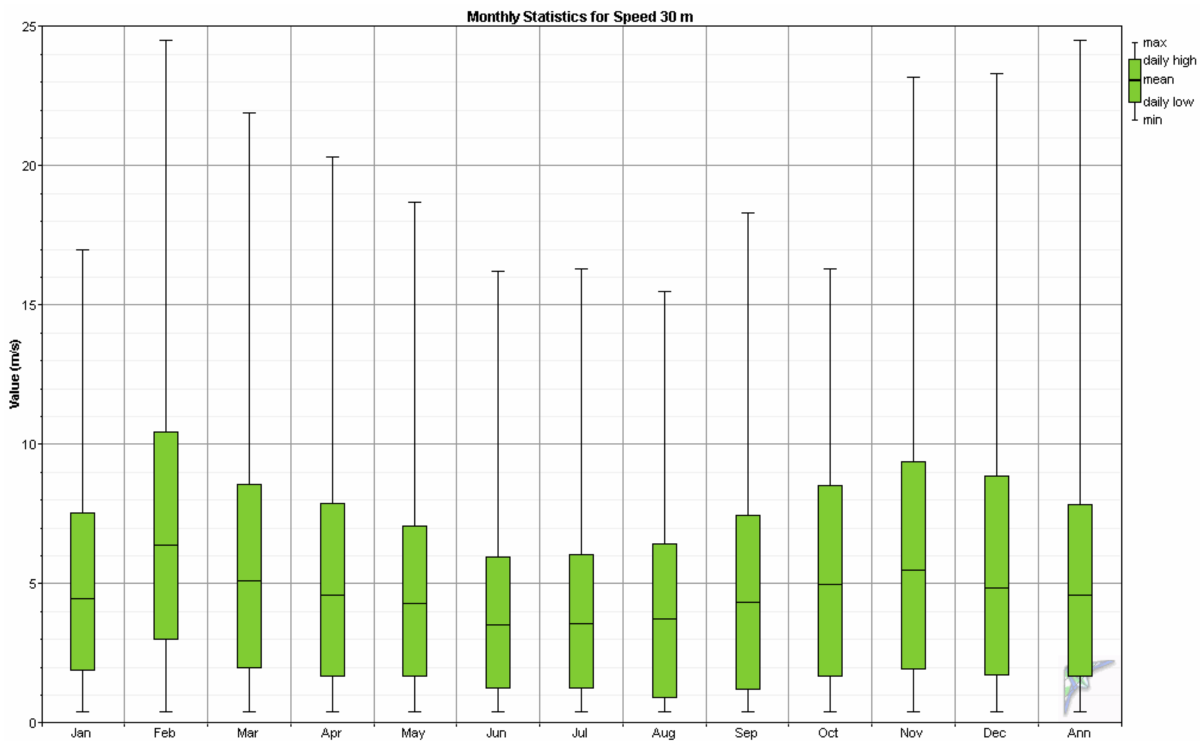
		Ch 7 (wind vane)		Ch 9 (temperature)	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2004	Oct	3,223	100	3,223	100
2004	Nov	4,320	100	4,320	100
2004	Dec	4,464	100	4,464	100
2005	Jan	4,464	100	4,464	100
2005	Feb	4,032	100	4,032	100
2005	Mar	4,464	100	4,464	100
2005	Apr	4,320	100	4,320	100
2005	May	4,464	100	4,464	100
2005	Jun	4,320	100	4,320	100

2005	Jul	4,464	100	4,464	100
2005	Aug	4,464	100	4,464	100
2005	Sep	4,320	100	4,320	100
2005	Oct	4,464	100	4,464	100
2005	Nov	4,320	100	4,320	100
2005	Dec	4,464	100	4,464	100
2006	Jan	4,464	100	4,464	100
2006	Feb	4,032	100	4,032	100
2006	Mar	4,464	100	4,464	100
2006	Apr	4,320	100	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	486	100	486	100
All data		104,365	100	104,365	100

Measured Wind Speeds

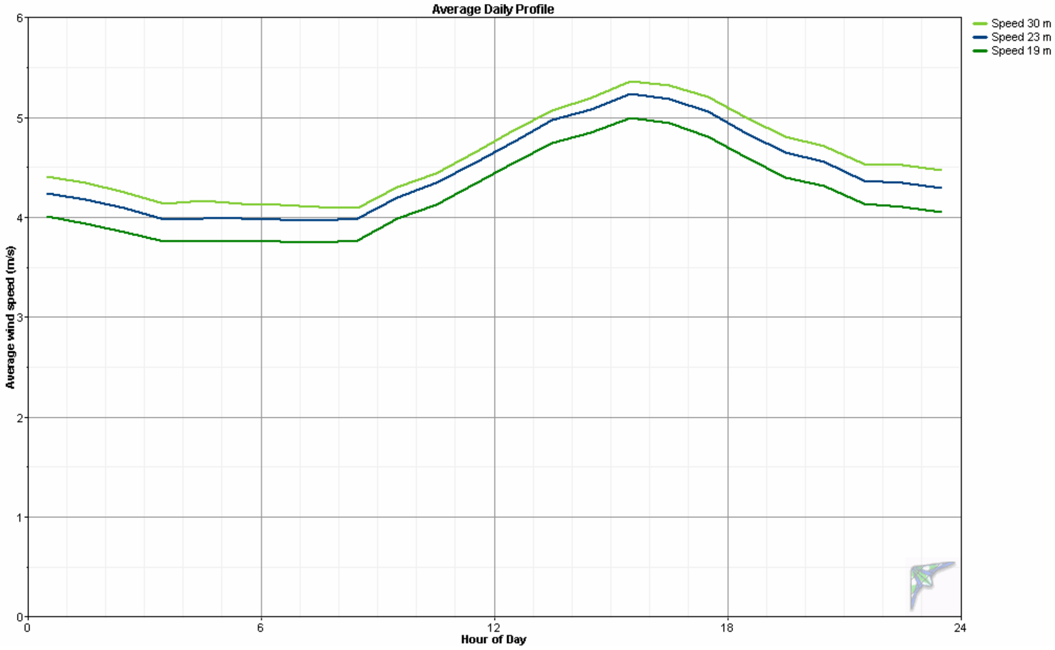
The Channel 1 (30-meter) anemometer annual wind speed average for the reporting period is 4.60 m/s, the Channel 2 (23-meter) anemometer wind speed average is 4.45 m/s, and the Channel 3 (19-meter) anemometer wind speed average is 4.22 m/s.

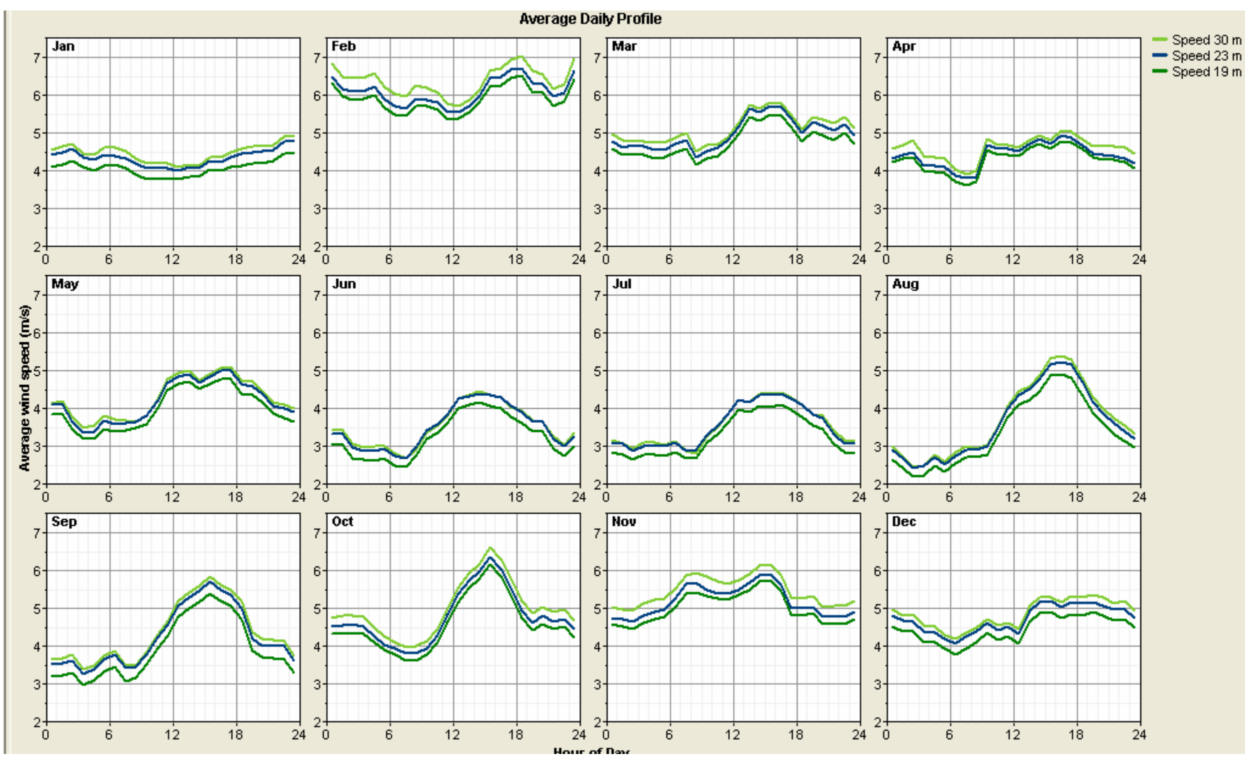
	30 m speed (Ch 1)					23 m speed (Ch 2)		19 m speed (Ch 3)	
Month	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)	Mean (m/s)	Max (m/s)
Jan	4.48	17.0	3.08	1.42	4.91	4.35	16.5	4.07	15.8
Feb	6.38	24.5	4.53	1.39	6.98	6.10	23.7	5.89	23.3
Mar	5.13	21.9	3.46	1.44	5.63	4.99	20.4	4.77	19.6
Apr	4.61	20.3	2.98	1.56	5.12	4.43	19.4	4.29	18.9
May	4.29	18.7	2.78	1.54	4.75	4.20	18.0	4.00	17.4
Jun	3.54	16.2	2.65	1.37	3.87	3.50	16.7	3.25	15.1
Jul	3.56	16.3	2.66	1.33	3.87	3.53	16.2	3.27	14.3
Aug	3.72	15.5	2.69	1.33	4.03	3.63	14.8	3.38	14.3
Sep	4.35	18.3	3.05	1.36	4.73	4.23	18.4	3.93	16.6
Oct	4.98	16.3	3.38	1.43	5.47	4.77	15.5	4.57	15.3
Nov	5.47	23.2	3.71	1.50	6.06	5.19	22.4	5.01	21.9
Dec	4.87	23.3	3.71	1.29	5.26	4.73	21.6	4.44	20.8
Annual	**4.60**	24.5	3.35	1.36	5.02	**4.46**	23.7	**4.22**	23.3



Daily Wind Profile

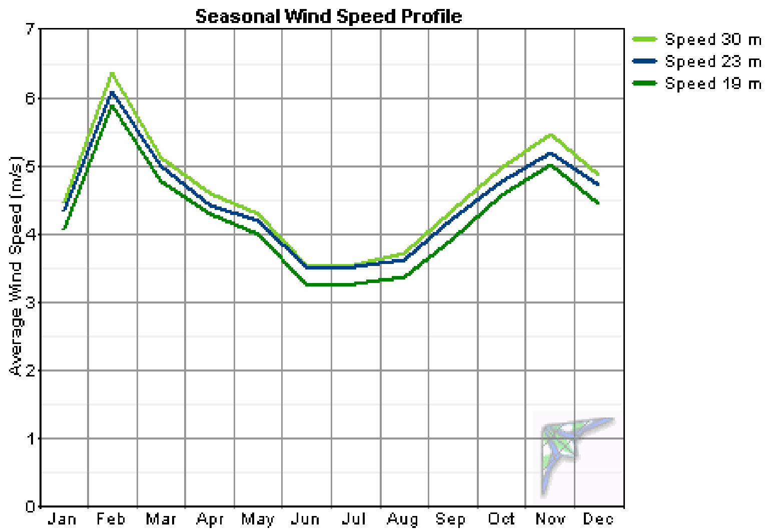
The daily wind profile indicates a strong daily variation of wind speeds with the lowest wind speeds occurring in the morning hours of 3 to 9 a.m. and the highest wind speeds of the day occur during the afternoon and early evening hours of 2 to 6 p.m. The daily variation of wind speed, which is relatively pronounced on an annual basis, is quite more pronounced on a monthly basis.

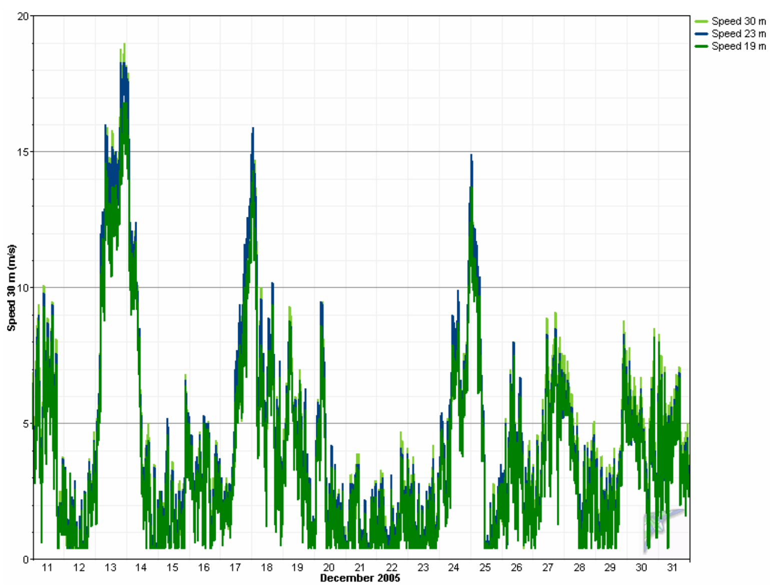


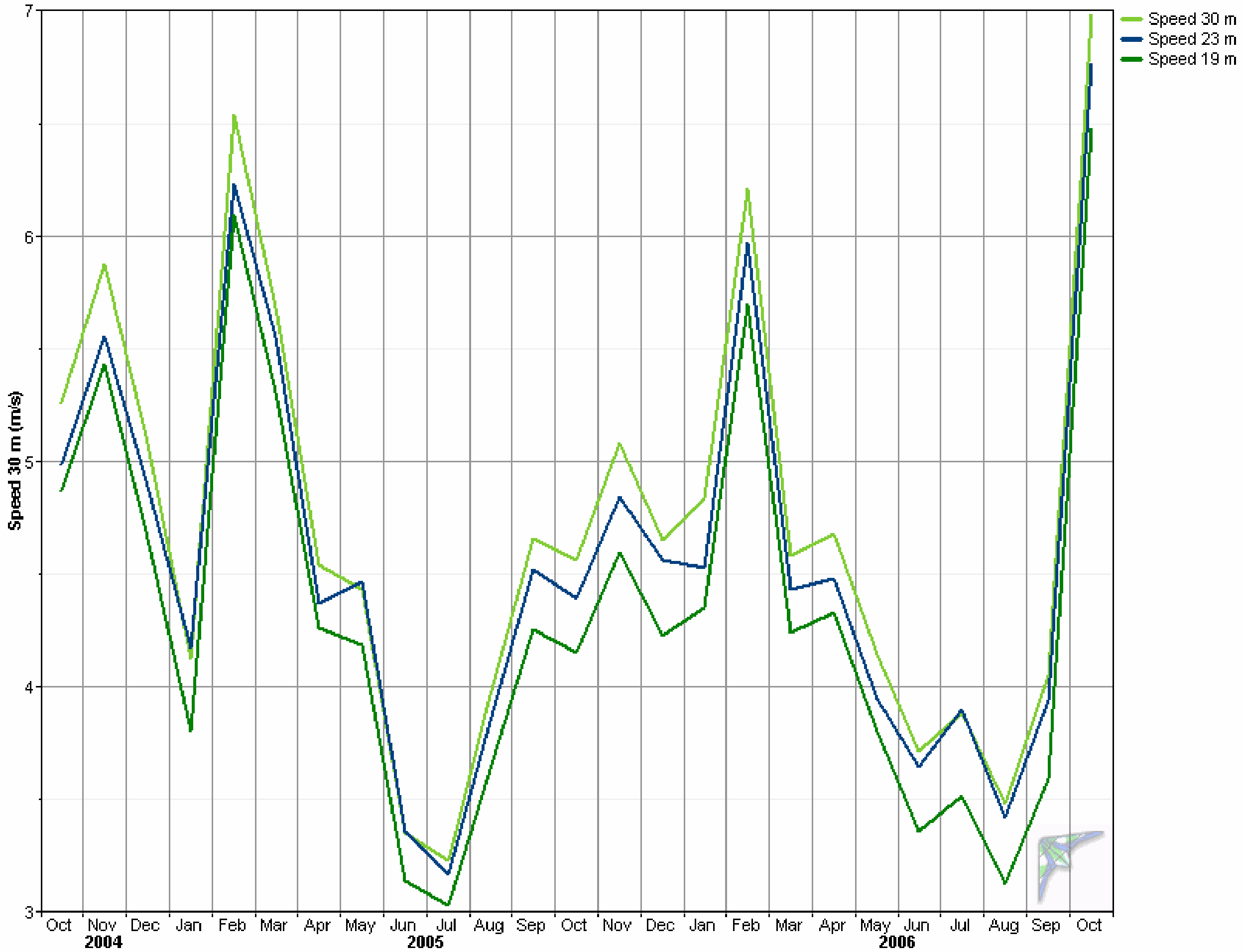


Time Series of Wind Speed Averages

As expected, the highest winds occurred during the fall through spring months with relatively light winds during the summer months of June through August. Interestingly, Perryville's winds are much lighter than had been expected given its geographic location on the Pacific coast of the Alaska Range. This may be due to the presence of significant mountainous terrain immediately west, north and east of the village as well as a large and high island just only a mile offshore that may act to block onshore winds. Perryville does experience strong winds sufficient for excellent wind energy recovery, but these winds tend to be quite short-lived, and then quickly drop off to very low speeds for long periods. A daily time series of the three wind vanes in late December, 2005 illustrates the typical dynamic of winds in Perryville and helps to explain the rather low average wind speed measured through the two year test period.



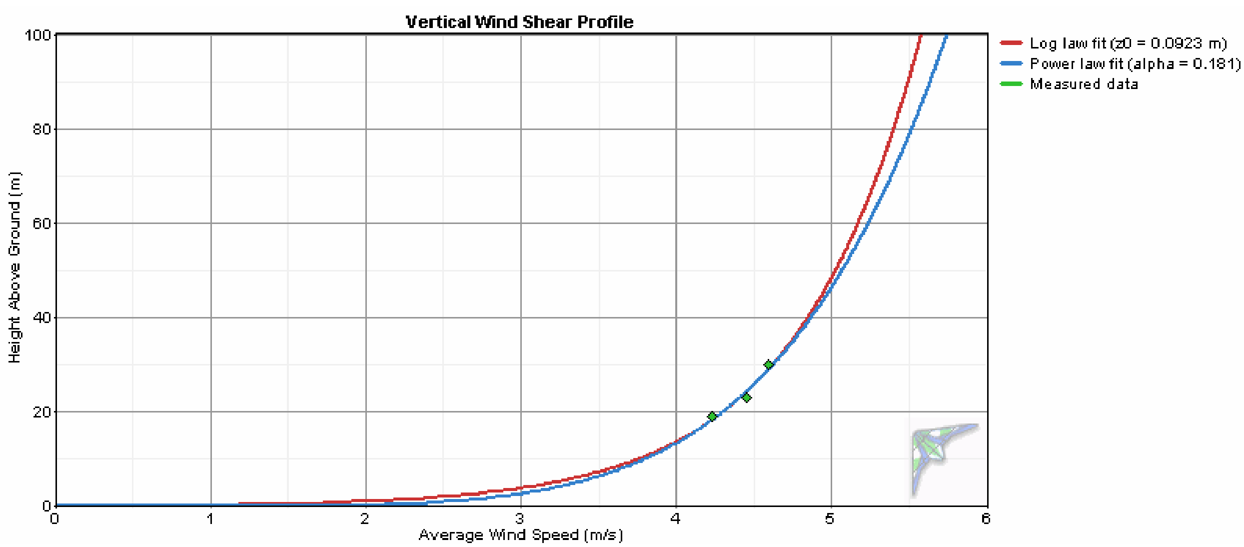


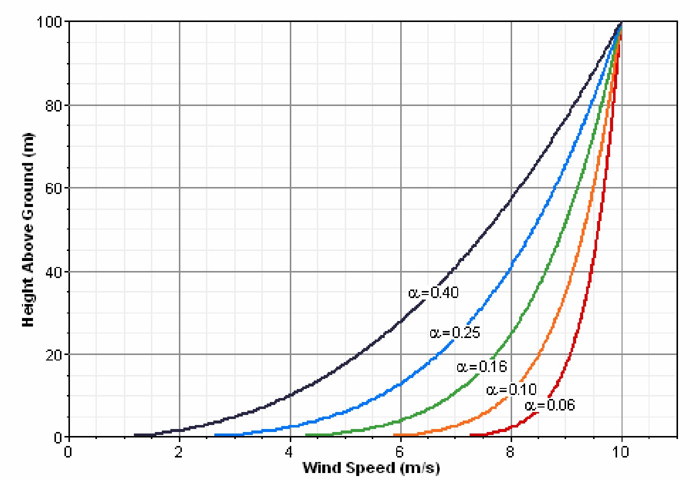


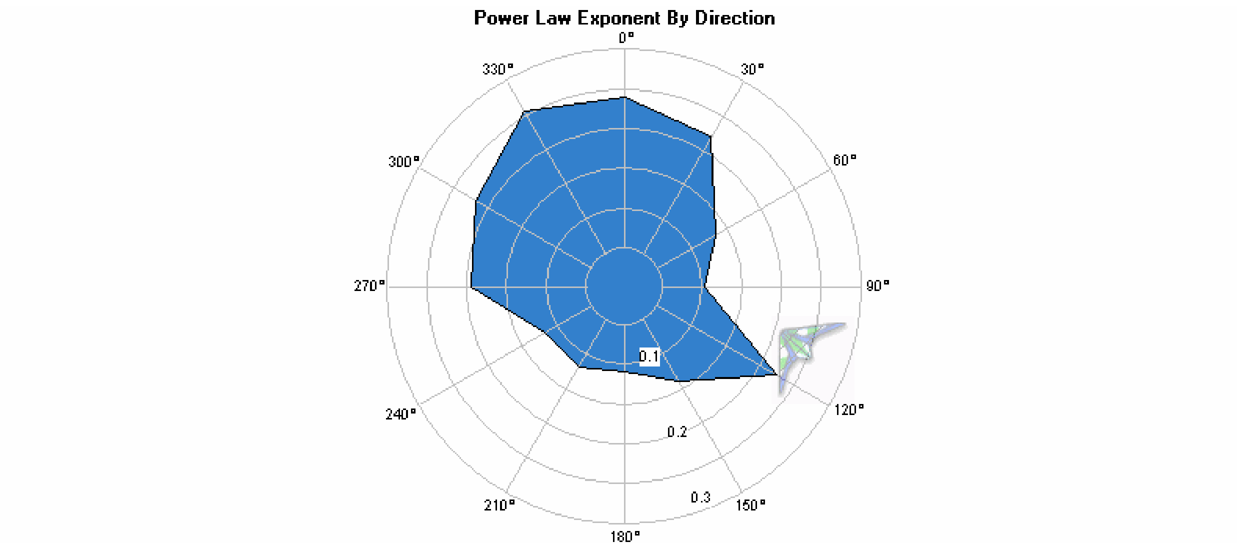
Speed 30 m
Speed 23 m
Speed 19 m
Speed 30 m (m/s)
7
6
5
4
3
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
2004
2005
2006

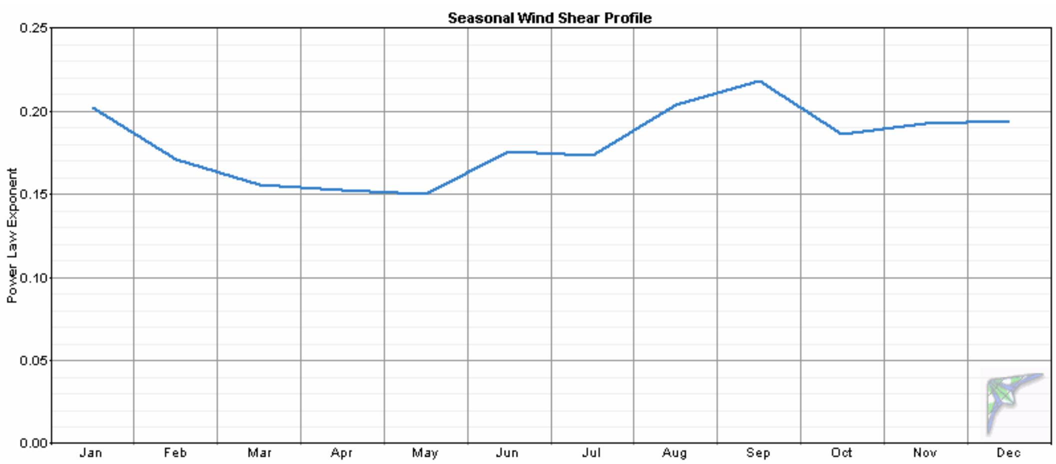
Wind Shear Profile

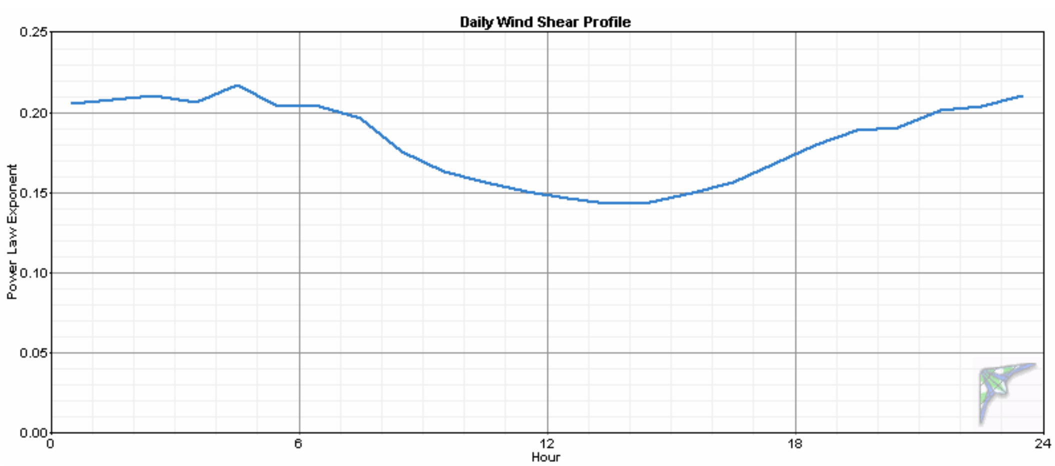
The average power law exponent was calculated at 0.181, indicating moderate wind shear at the Perryville met tower test site. The practical application of this information is that a higher turbine tower height is advantageous as there is an appreciable marginal gain in average wind speed with height. However, a tower height/power recovery/construction cost tradeoff study would be advisable should a wind power project be initiated.





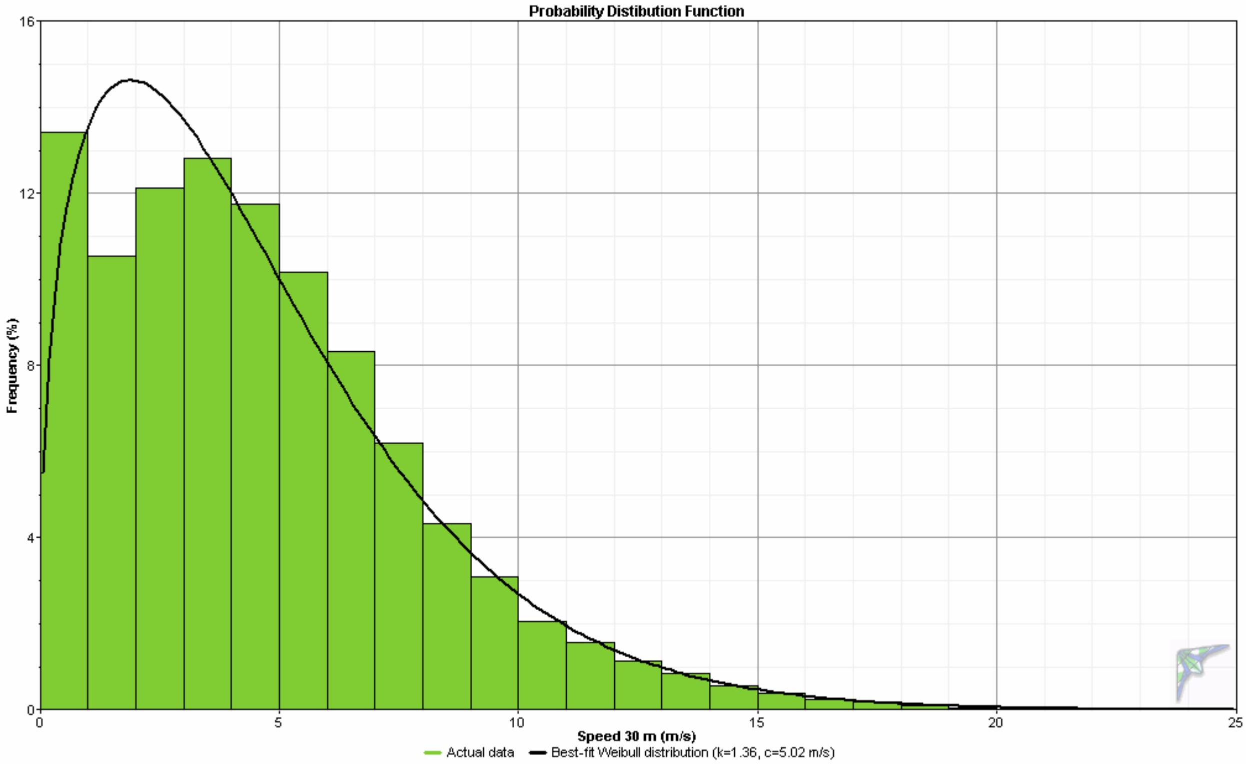

Power Law Exponent By Direction
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
0.1
0.2
0.3

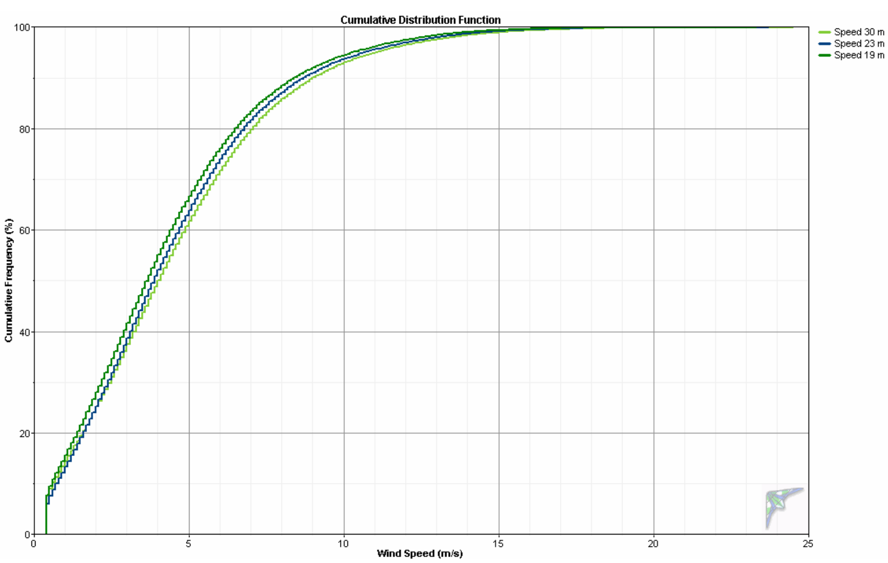

Seasonal Wind Shear Profile
Power Law Exponent
0.25
0.20
0.15
0.10
0.05
0.00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Daily Wind Shear Profile
Power Law Exponent
0.25
0.20
0.15
0.10
0.05
0.00
0
6
12
18
24
Hour

Probability Distribution Function

The probability distribution function (PDF) 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 = 1.36 (indicates a moderate distribution of wind speeds) and c = 5.02 m/s (scale factor for the Weibull distribution). The PDF information is shown visually in another manner in the second graph, the Cumulative Distribution Function.



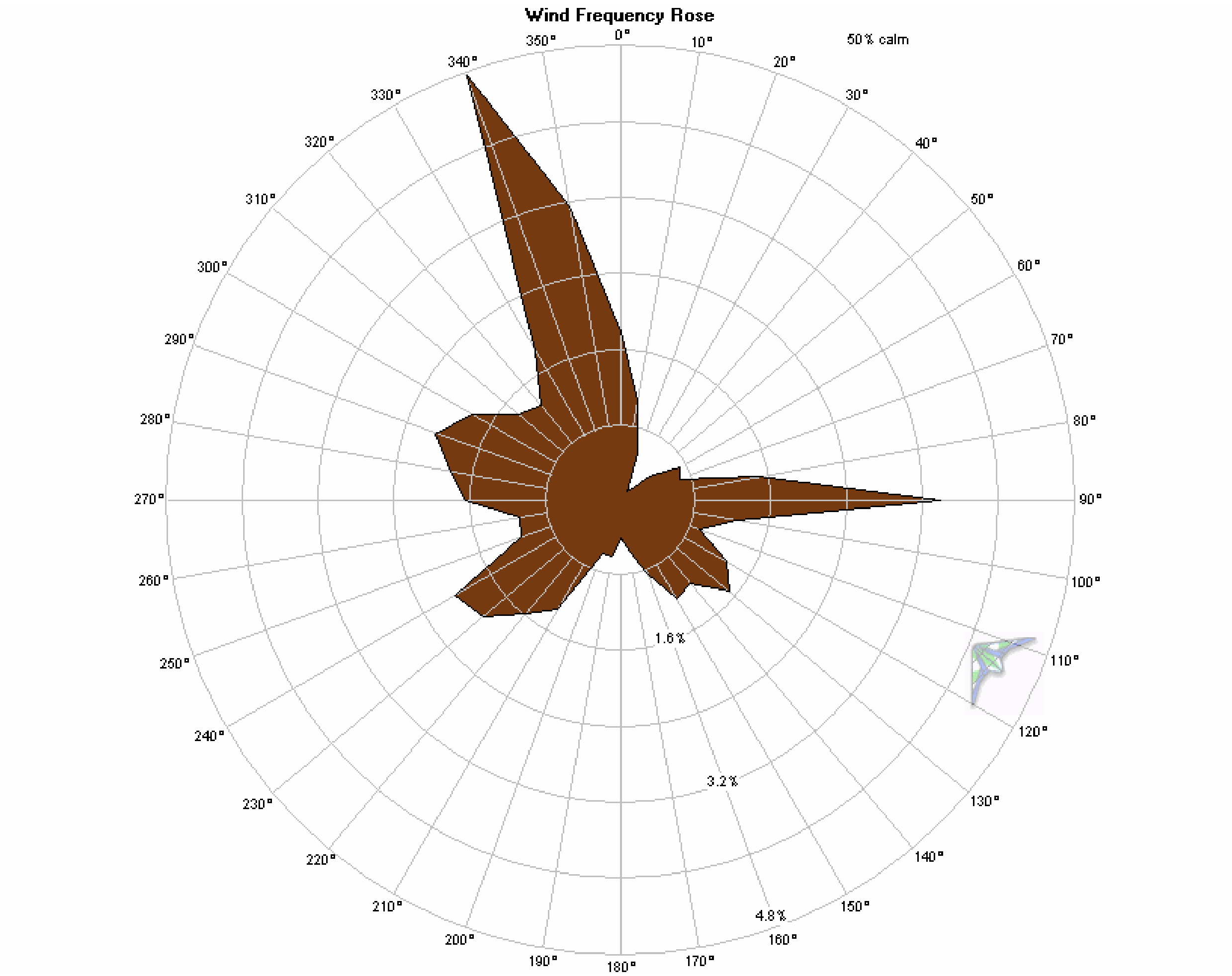


Wind Roses

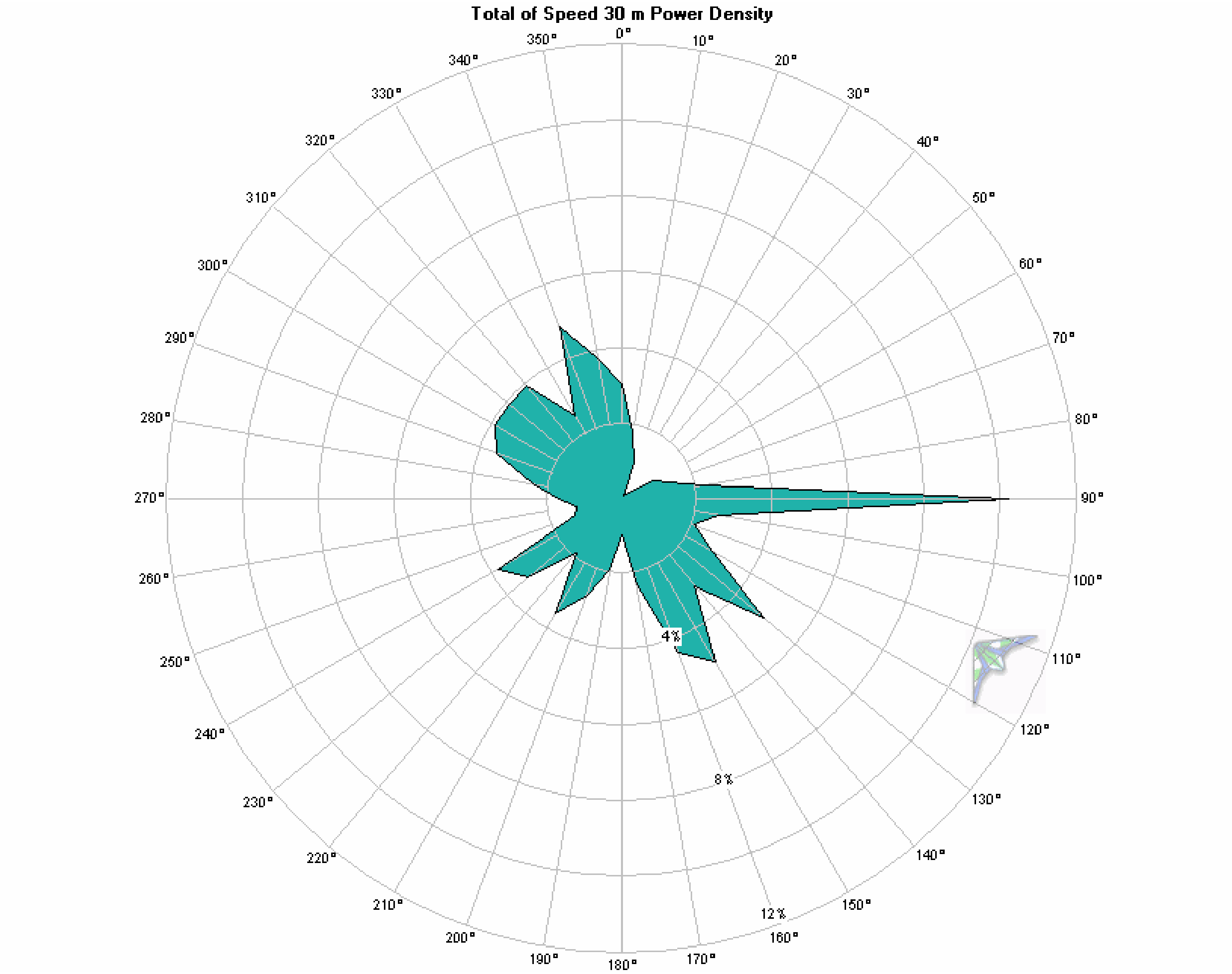
Perryville's winds are not strongly directional; the wind frequency rose indicates predominately northwest winds with a lesser component of easterly and westerly winds. This data observation changes somewhat upon consideration of the power density rose (second wind rose). As one can see, the power producing winds are almost equally east, southeast, southwest, and northwest. The practical application of this information is that multiple turbines must be space rather far apart to prevent power loss to downwind machines.

Note also that a wind threshold of 4 m/s was selected for the definition of calm winds. This wind speed represents the cut-in wind speed of most wind turbines. Remarkably, Perryville experiences fifty percent calm conditions by this definition (see wind frequency rose below), much higher than most other Alaska coastal locations.

Wind frequency rose (30 meters)

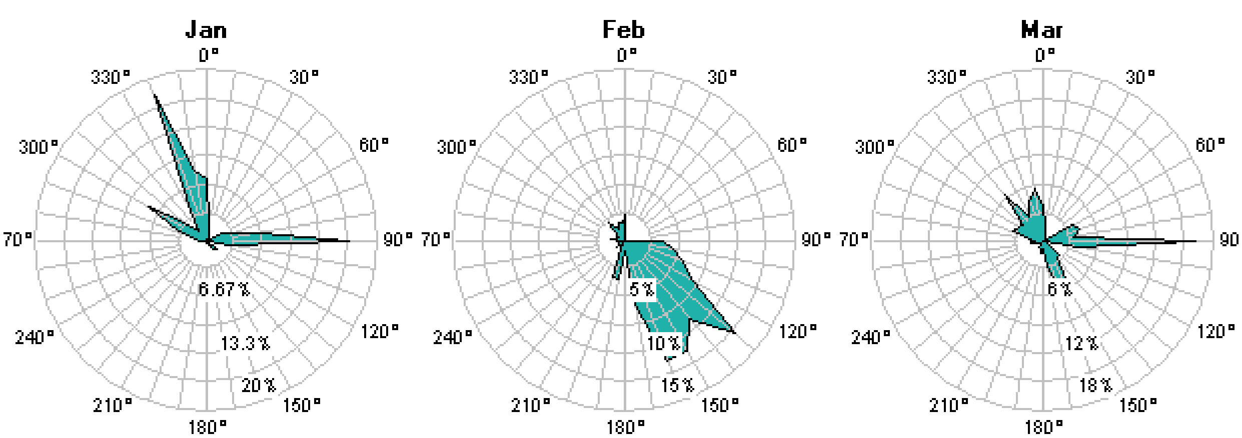


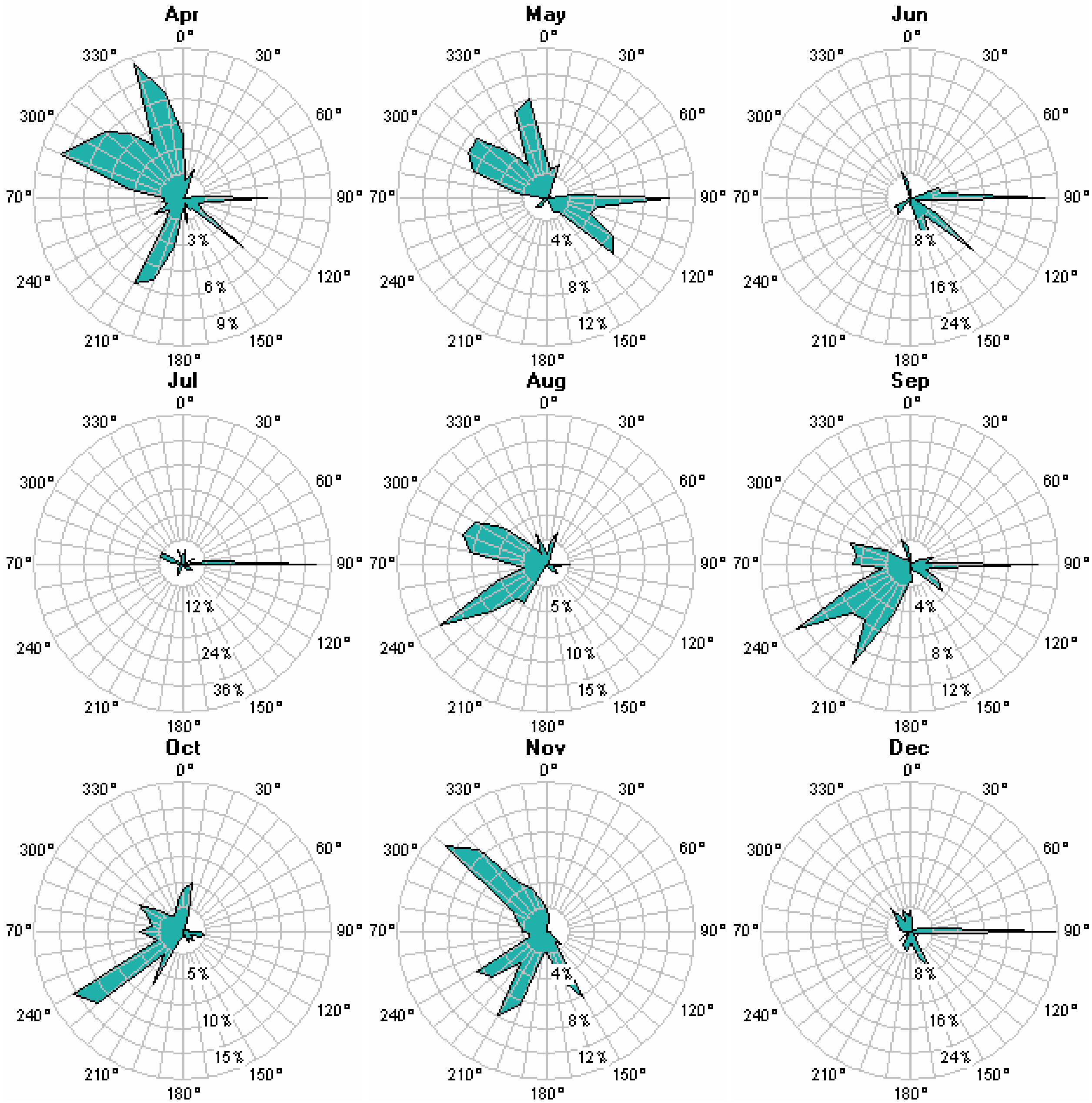
Wind Power Density Rose (30 meters)



Wind Power Density Rose by Month (30 meters)

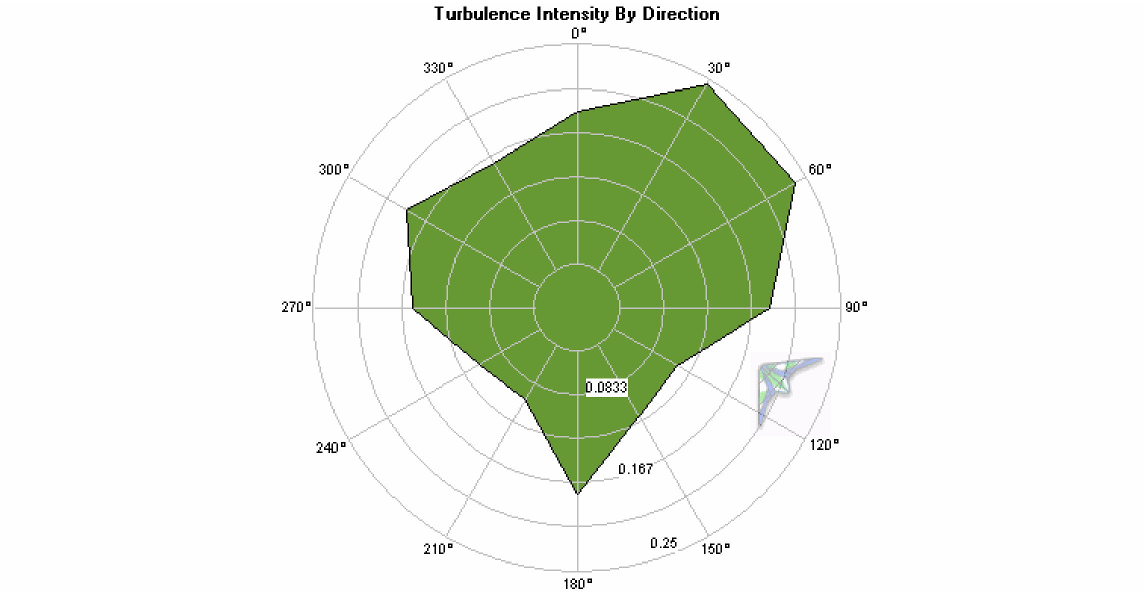
Note: for easier visualization of monthly wind power variation, the scale is <u>not</u> common




Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°

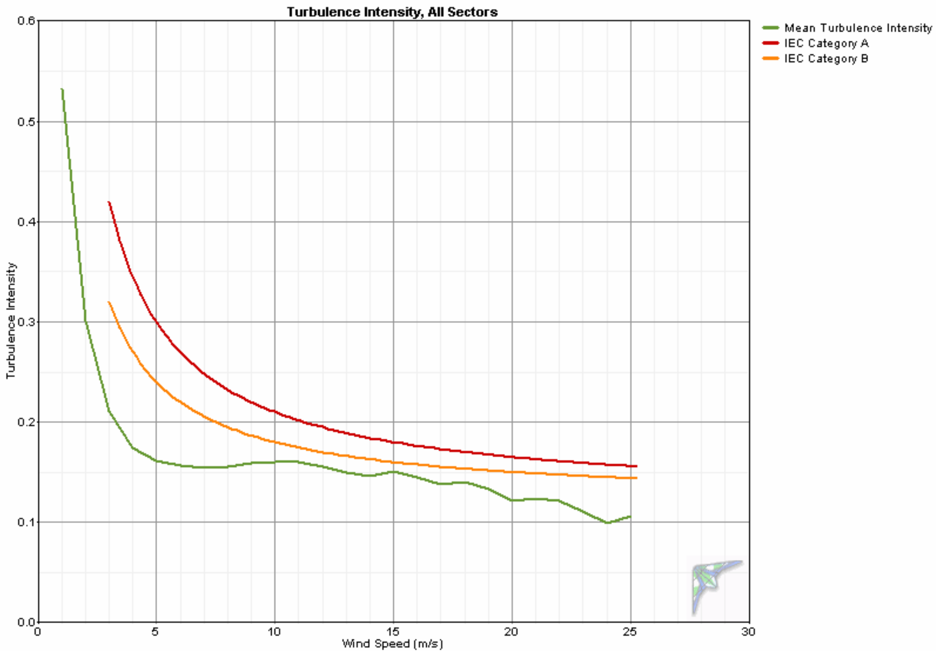
Turbulence Intensity

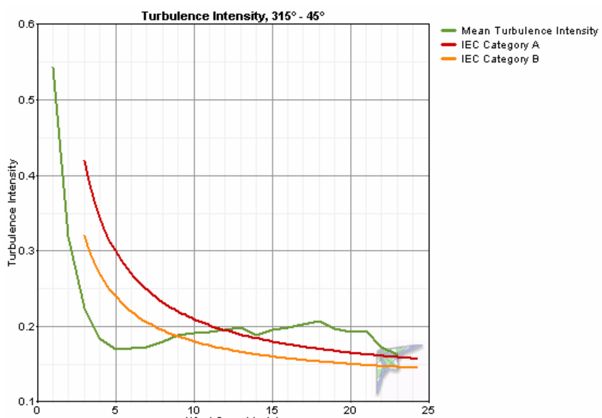
The turbulence intensity is marginally acceptable to unacceptable for the most frequent wind directions, with mean turbulence intensity at 30 meters of 0.158 (threshold wind speed is 4 m/s), indicating somewhat turbulent air for wind power development. The high turbulence intensities to the northeast and south are insignificant as winds rarely blow from these sectors, but the relatively high turbulence intensities to the east and west-northwest are more significant as a reasonable percentage of Perryville's power producing winds blow from these sectors.

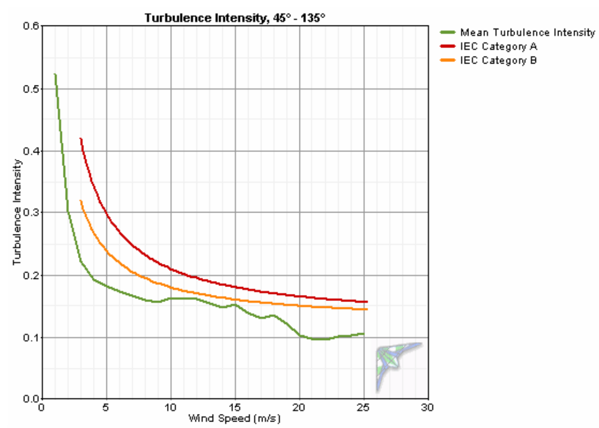


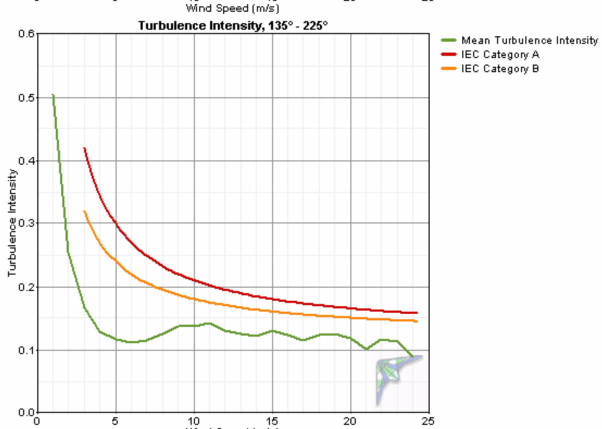
IEC turbulence intensity standards

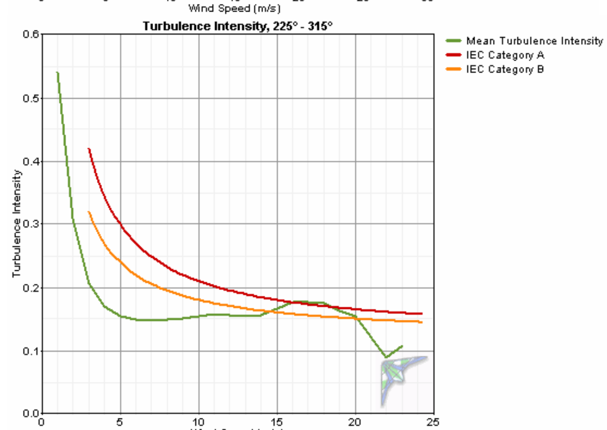
The turbulence intensities at 30 meters at the Perryville project test site do not meet International Electrotechnical Commission (IEC) standards in southwest to northeast sectors at higher wind speeds.


Turbulence Intensity, All Sectors
Mean Turbulence Intensity
IEC Category A
IEC Category B
Turbulence Intensity
Wind Speed (m/s)


Turbulence Intensity, 315° - 45°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Turbulence Intensity
Wind Speed (m/s)


Turbulence Intensity, 45° - 135°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Turbulence Intensity
Wind Speed (m/s)


Turbulence Intensity, 135° - 225°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Turbulence Intensity
Wind Speed (m/s)


Turbulence Intensity, 225° - 315°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Turbulence Intensity
Wind Speed (m/s)

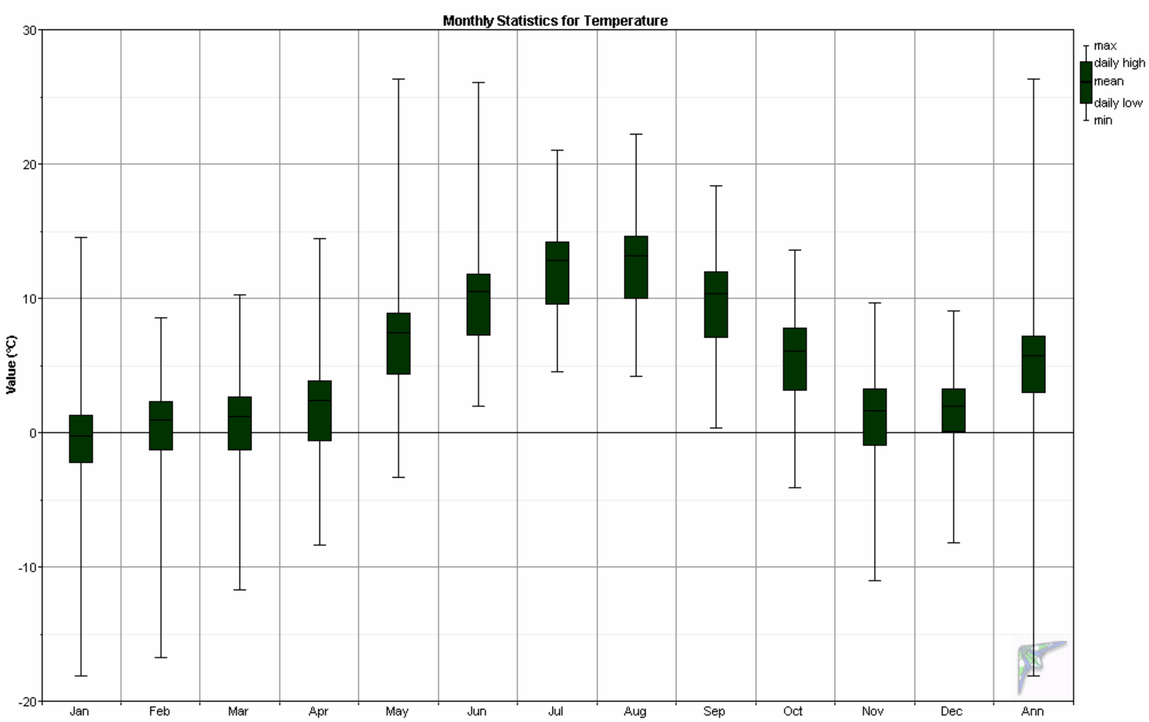
Turbulence Table

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records In Bin	Standard Deviation of Wind Speed (m/s)	Mean Turbulence Intensity	Standard Deviation of Turbulence Intensity	Characteristic Turbulence Intensity
1	0.5	1.5	11,379	0.473	0.533	0.168	0.700
2	1.5	2.5	11,781	0.580	0.302	0.140	0.442
3	2.5	3.5	13,178	0.618	0.211	0.101	0.312
4	3.5	4.5	13,025	0.686	0.175	0.083	0.258
5	4.5	5.5	11,382	0.795	0.161	0.072	0.233
6	5.5	6.5	9,743	0.931	0.157	0.067	0.224
7	6.5	7.5	7,630	1.071	0.154	0.064	0.218
8	7.5	8.5	5,249	1.231	0.155	0.061	0.216
9	8.5	9.5	3,805	1.414	0.159	0.060	0.218
10	9.5	10.5	2,695	1.591	0.161	0.059	0.219
11	10.5	11.5	1,823	1.756	0.161	0.059	0.220
12	11.5	12.5	1,379	1.860	0.156	0.057	0.213
13	12.5	13.5	1,011	1.941	0.150	0.053	0.203
14	13.5	14.5	737	2.031	0.146	0.050	0.196
15	14.5	15.5	505	2.257	0.151	0.047	0.198
16	15.5	16.5	313	2.300	0.145	0.046	0.191
17	16.5	17.5	224	2.341	0.138	0.046	0.184
18	17.5	18.5	153	2.514	0.140	0.044	0.185
19	18.5	19.5	75	2.507	0.133	0.037	0.169
20	19.5	20.5	44	2.409	0.121	0.037	0.158
21	20.5	21.5	18	2.589	0.124	0.044	0.168
22	21.5	22.5	16	2.669	0.122	0.037	0.159
23	22.5	23.5	12	2.550	0.111	0.020	0.131
24	23.5	24.5	4	2.375	0.100	0.012	0.112
25	24.5	25.5	1	2.600	0.106	0.000	0.106

Air Temperature and Density

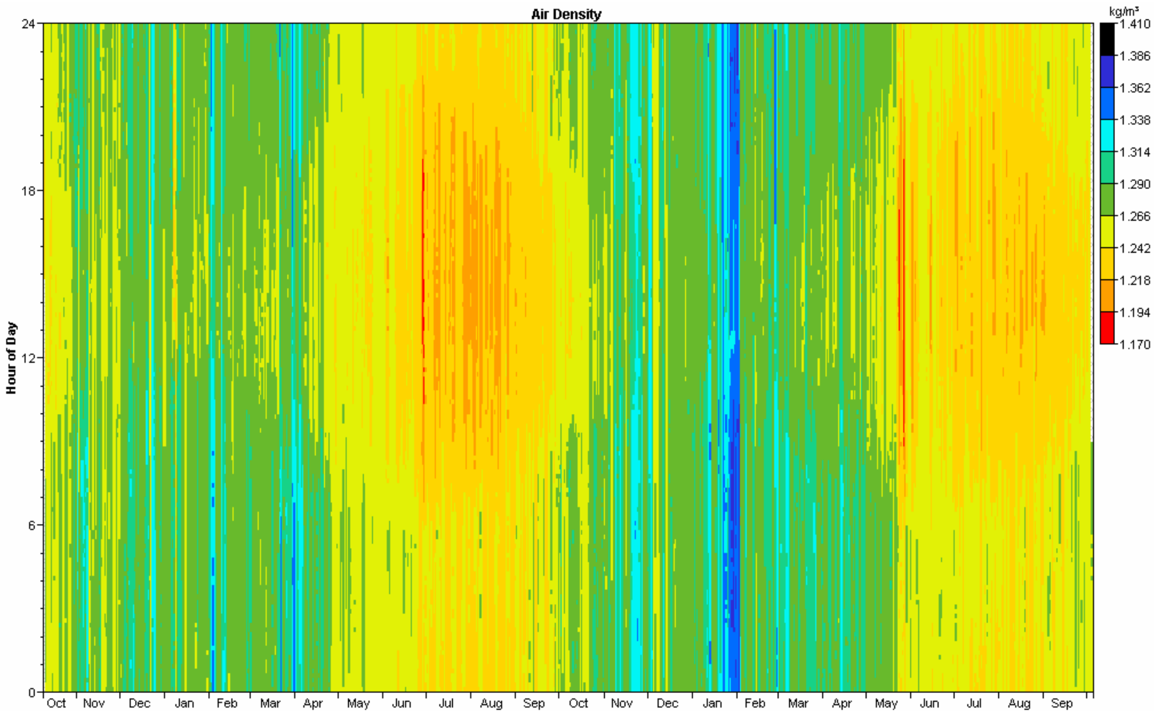
Over the reporting period, Perryville had an average temperature of 5.8° C. The minimum recorded temperature during the measurement period was -18.1° C and the maximum temperature was 26.4° C, indicating a cool to moderate temperate environment for wind turbine operations. Consequent to Perryville's cool temperatures, the average air density of 1.265 kg/m^3 is 3.2 percent higher than the standard air density of 1.225 kg/m^3 (at 15° C).

	Temperature				Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-0.2	-18.1	14.6	5.93	1.293	1.226	1.383
Feb	0.9	-16.7	8.6	4.52	1.287	1.252	1.376
Mar	1.3	-11.7	10.3	3.63	1.286	1.245	1.349
Apr	2.5	-8.3	14.5	3.73	1.280	1.226	1.332
May	7.5	-3.3	26.4	3.84	1.257	1.178	1.307
Jun	10.6	2.0	26.1	3.03	1.244	1.179	1.282
Jul	12.9	4.6	21.1	2.71	1.233	1.199	1.270
Aug	13.2	4.2	22.3	2.65	1.232	1.194	1.272
Sep	10.4	0.4	18.4	2.79	1.244	1.210	1.290
Oct	6.1	-4.1	13.6	3.36	1.263	1.224	1.311
Nov	1.7	-11.0	9.7	4.33	1.284	1.247	1.346
Dec	2.0	-8.2	9.1	3.41	1.282	1.250	1.332
Annual	**5.8**	-18.1	26.4	6.11	**1.265**	1.178	1.383



Air Density DMap

The DMap below is a visual indication of the daily and seasonal variations of air density (and hence temperature). Air densities higher than standard will yield higher turbine power than predicted by the turbine power curve, while densities lower than standard will yield lower turbine power than predicted. Density variance from standard is accounted for in the turbine performance predictions.



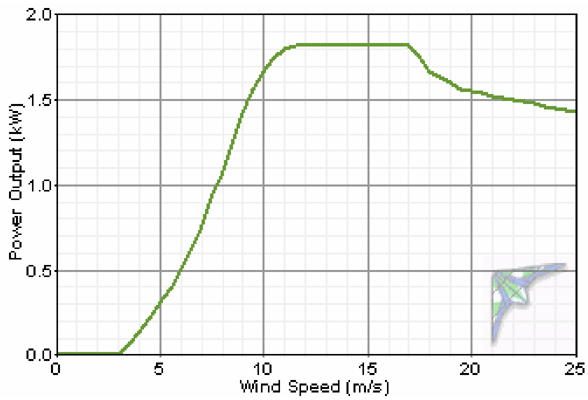
Wind Turbine Performance

The turbine performance predictions noted below are based on 100 percent and 90 percent turbine availabilities. The 100 percent data is for use as a baseline of comparison, but it is realistic to expect ten percent or more of losses or downtime for wind turbines located in a small, remote community.

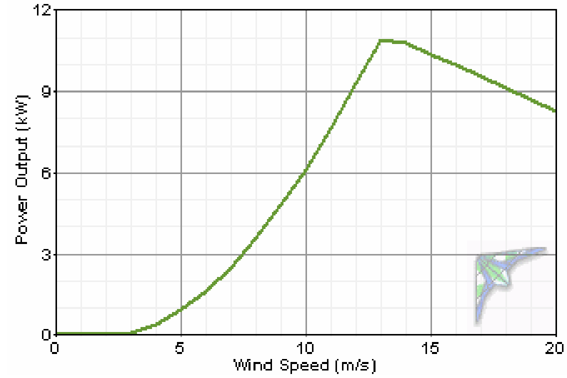
Note that these performance estimates were predicted with use of Windographer® wind analysis software; power curves provided by manufacturers are not independently verified and are assumed to be accurate. The power curves are presented for a standard air density of 1.225 kg/m^3 at sea level and 15° C. 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, accounting for the site elevation.

A number of smaller village-scale grid-connected turbines are profiled in this report for comparison purposes. These turbines were selected because they have market availability and they are deemed to be within a suitable range for consideration of wind power development in a village the size of Perryville.

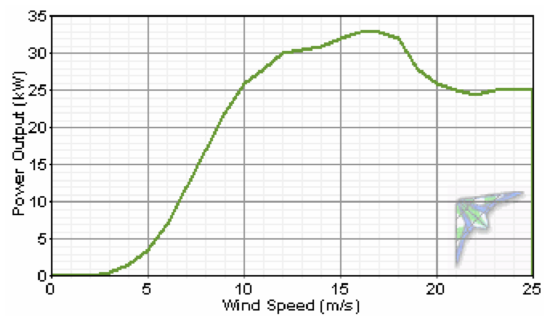
Southwest Skystream 3.7: 1.8 kW rated power output, 3.7 meter rotor diameter, stall-controlled. Available tower heights: 10.7 and 33.5 meters. Additional information is available at www.skystreamenergy.com.



Bergey Excel-S: 10 kW rated power output, 6.7 meter rotor diameter, stall-controlled. Available tower heights: 18, 24, 30, 37 and 43 meters. Additional information is available at www.bergey.com.

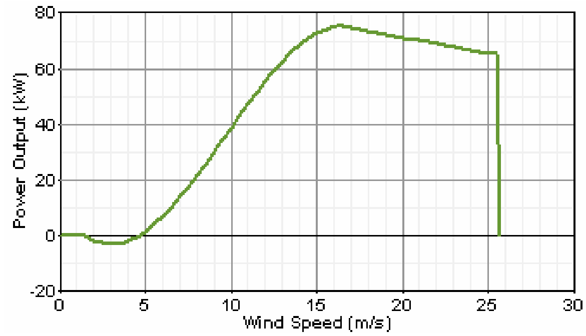


Fuhrländer FL30: 30 kW rated power output, 13 meter rotor, stall-controlled (power curve provided by Lorax Energy, LLC). Available tower heights: 26 and 30 meters. Additional information is available at http://www.fuhrlaender.de/ and http://www.lorax-energy.com/.

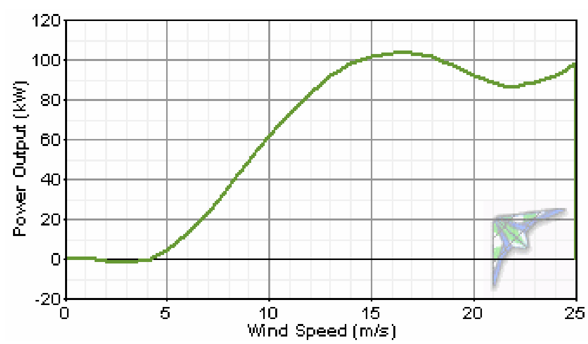


Entegrity eW-15: 65 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Entegrity Energy Systems). Available tower heights: 25 and 31 meters. Additional information is available at http://www.entegritywind.com/.

Vestas V15: 75 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Powercorp Alaska LLC). Available tower heights: 25, 31 and 34 meters. Additional information is available at http://www.pcorpalaska.com/.



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). Available tower heights: 25 and 32 meters. Additional information is available at http://www.northernpower.com/.



Turbine Power Output Comparison

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Net Power Output (kW)	Annual Net Energy Output (kWh/yr)	Average Net Capacity Factor (%)
Southwest Skystream 3.7	10.7	3.85	46.0	3.3	0.30	2,625	16.6
Southwest Skystream 3.7	33.5	4.68	36.2	6.1	0.44	3,847	24.4
Bergey Excel-S	24	4.45	25.3	2.2	1.49	13,082	14.9
Bergey Excel-S	37	4.77	23.9	2.8	1.73	15,117	17.3
Fuhrländer FL30	26	4.50	25.3	0.9	6.20	54,274	18.8
Fuhrländer FL30	30	4.60	25.2	1.0	6.48	56,758	19.6
Entegrity eW-15 60 Hz	25	4.47	51.2	1.3	8.53	74,731	13.1
Entegrity eW-15 60 Hz	31	4.62	49.3	1.6	9.26	81,137	14.2
Vestas V15	25	4.47	58.2	0.8	7.40	64,816	9.9
Vestas V15	34	4.70	55.2	1.1	8.57	75,036	11.4
Northern Power NW 100/20	25	4.47	51.1	1.2	12.60	110,695	12.6
Northern Power NW 100/20	32	4.64	48.9	1.5	13.90	121,704	13.9

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

Assumed turbine losses for predictions of average power output, annual energy output, and average capacity factor:

Downtime (%)	0
Array (%)	0
Icing/soiling (%)	0
Other (%)	0
Total (%)	0

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Net Power Output (kW)	Annual Net Energy Output (kWh/yr)	Average Net Capacity Factor (%)
Southwest Skystream 3.7	10.7	3.85	46.0	3.3	0.27	2,371	15.0
Southwest Skystream 3.7	33.5	4.68	36.2	6.1	0.40	3,474	22.0
Bergey Excel-S	24	4.45	25.3	2.2	1.35	11,814	13.5
Bergey Excel-S	37	4.77	23.9	2.8	1.56	13,652	15.6
Fuhrländer FL30	26	4.50	25.3	0.9	5.60	49,013	17.0
Fuhrländer FL30	30	4.60	25.2	1.0	5.85	51,257	17.7
Entegrity eW-15 60 Hz	25	4.47	51.2	1.3	7.70	67,487	11.9
Entegrity eW-15 60 Hz	31	4.62	49.3	1.6	8.36	73,273	12.9
Vestas V15	25	4.47	58.2	0.8	6.68	58,534	8.9
Vestas V15	34	4.70	55.2	1.1	7.74	67,763	10.3
Northern Power NW 100/20	25	4.47	51.1	1.2	11.40	99,965	11.4
Northern Power NW 100/20	32	4.64	48.9	1.5	12.50	109,907	12.5

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

Assumed turbine losses for predictions of average power output, annual energy output, and average capacity factor:

Downtime (%)	5	
Array (%)	0	
Icing/soiling (%)	3	
Other (%)	2	
Total (%)	9.69	(factors are multiplicative)

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

Turbine	Annual Energy Output (kW-hr/yr)	Fuel Quantity Avoided (liters)	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	
Southwest Skystream 3.7	2,371	718	190	$332	$379	$427	$474	$522	$569	$616	10.7
Southwest Skystream 3.7	3,474	1,052	278	$486	$556	$625	$695	$764	$834	$903	33.5
Bergey Excel-S	11,814	3,578	945	$1,654	$1,890	$2,127	$2,363	$2,599	$2,835	$3,072	24
Bergey Excel-S	13,652	4,134	1,092	$1,911	$2,184	$2,457	$2,730	$3,003	$3,276	$3,550	37
Fuhrländer FL30	49,013	14,843	3,921	$6,862	$7,842	$8,822	$9,803	$10,783	$11,763	$12,743	26
Fuhrländer FL30	51,257	15,522	4,101	$7,176	$8,201	$9,226	$10,251	$11,277	$12,302	$13,327	30
Entegrity eW-15 60 Hz	67,487	20,437	5,399	$9,448	$10,798	$12,148	$13,497	$14,847	$16,197	$17,547	25
Entegrity eW-15 60 Hz	73,273	22,189	5,862	$10,258	$11,724	$13,189	$14,655	$16,120	$17,586	$19,051	31
Vestas V15	58,534	17,726	4,683	$8,195	$9,365	$10,536	$11,707	$12,877	$14,048	$15,219	25
Vestas V15	67,763	20,521	5,421	$9,487	$10,842	$12,197	$13,553	$14,908	$16,263	$17,618	34
Northern Power NW 100/20	99,965	30,273	7,997	$13,995	$15,994	$17,994	$19,993	$21,992	$23,992	$25,991	25
Northern Power NW 100/20	109,907	33,283	8,793	$15,387	$17,585	$19,783	$21,981	$24,180	$26,378	$28,576	32

Notes:
1. Perryville electrical energy production efficiency assumed to be 12.5 kW-hr/gal
2. Assumes **90**% wind turbine availability with no diversion of power to a thermal or other dump load
3. Assumes linear diesel generator fuel efficiency (i.e., 1:1 tradeoff of wind turbine kW-hr to diesel genset kW-hr)

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.