Point Lay Wind Resource Report

By: Douglas Vaught, P.E., V3 Energy, LLC, Eagle River, Alaska
Date: September 16, 2010

Contents

Summary Information 1
Test Site Location 2
Data Recovery 3
Wind Speed 3
  Time Series 4
  Daily Wind Profile 5
Probability Distribution Function 5
Wind Shear and Roughness 6
Temperature and Density 7
Wind Direction 8
Turbulence 9

Summary Information

The wind resource measured in Point Lay is very good, measured at high wind power class 4 (good) to low wind power class 5 (excellent). In addition to strong average wind speed and wind power density, the site experiences highly directional prevailing winds and low turbulence.

Met tower data synopsis

Data dates	October 5, 2006 to September 11, 2007
Wind power class	High 4 (good) to low 5 (excellent)
Power density mean, 30 meters	403 W/m^2
Wind speed mean, 30 meters	6.63 m/s
Weibull distribution parameters	k = 1.74, c = 7.44 m/s
Wind shear power law exponent	0.142 (moderate), June to September data only
Roughness class	0.54 (snow surface), June to September only
IEC 61400-1, 3rd ed. classification	Class III-c (likely, based on nearby Wainwright data)
Turbulence intensity, mean	0.072 (at 15 m/s)
Calm wind frequency	23% (less than 3.5 m/s)

Point Lay community profile (DCCED)

Current Population: 234 (2009 Estimated Population (not Certified))

Pronunciation/Other Names:	a.k.a. Kali
Incorporation Type:	Unincorporated
Borough Located In:	North Slope Borough
School District:	North Slope Borough Schools
Regional Native Corporation:	Arctic Slope Regional Corp.

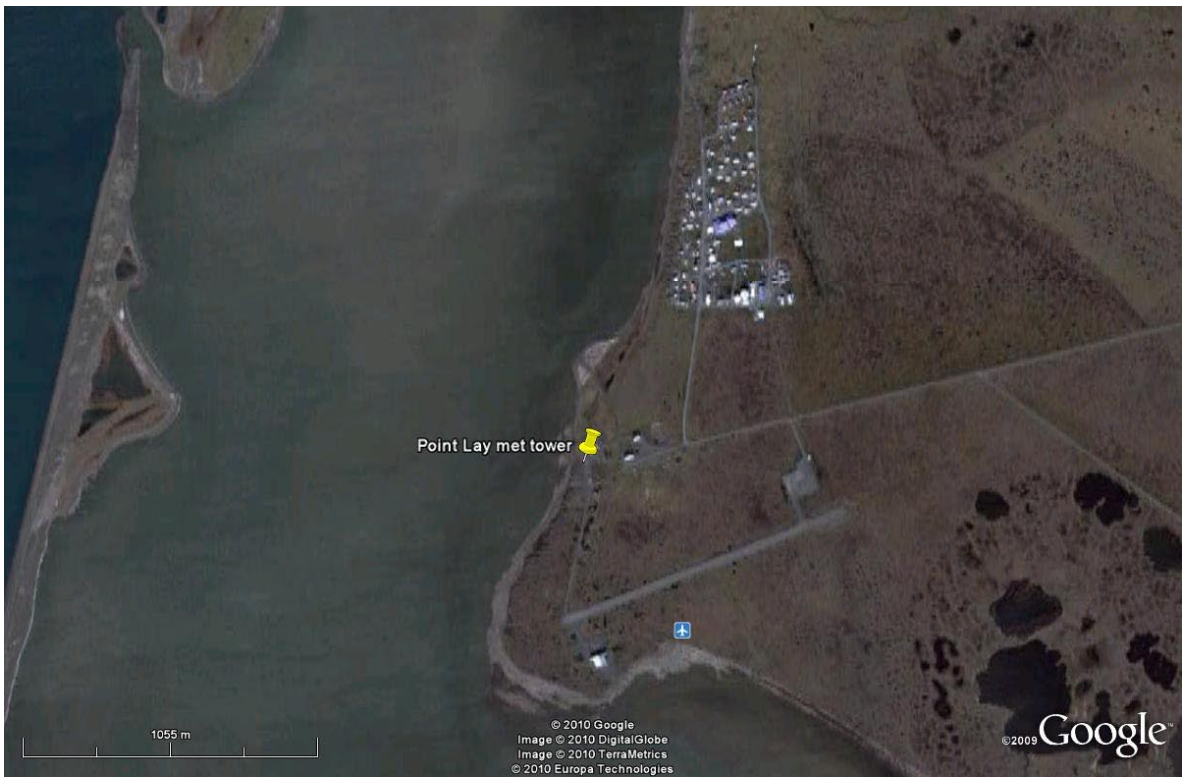
Test Site Location

The Point Lay met tower was supplied to the Cully Corporation in Point Lay in 2006 as part of the National Renewable Energy Laboratory's (NREL) anemometer loan program. Details of the project are not known, such as rationale for choosing the test site, but plotting the latitude and longitude of the met tower (keyed into the datalogger and readable in the data file) with Google Earth indicates a site well away from obstructions such as buildings and well exposed to winds from all directions.

Site information

Site number	5430
Latitude/longitude	N 69° 44.123' W 163° 01.349'
Site elevation	1 meter AMSL
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 30 meter tall tower

Google Earth image



Tower sensor information

Channel	Sensor Type	Height	Scale	Offset	Orientation
1	NRG #40 anemometer	99 ft	1.711	0.78	unknown
2	NRG #40 anemometer	99 ft			
3	NRG #40 anemometer	66 ft			
7	NRG #200P wind vane	99 ft	0.351	0	000°
8	NRG #200P wind vane	66 ft			000°
9	NRG #100S Temperature	5 ft	0.244	-123.5	

Note: logger was programmed with English units and later converted to metric units for analysis

Data Recovery

Specific sensor data recovery problems typical of Alaska met tower operations, such as freezing rain, hoarfrost, and rime icing, likely occurred to some extent during the nearly one year met tower study in Point Lay, but original data was not available, other than in an Excel file with data from June 7 through September 11, 2007. Although this three month data set could be reviewed for data loss typically due to atmospheric icing conditions, such weather does not occur during the months of June, July, August and (early) September. All met tower data (including that not included in the Excel file download of original data) is summarized in several WindPRO software reports prepared by the National Renewable Energy Laboratory.

Wind Speed

Wind data collected from the met tower and summarized in the NREL WindPRO reports, from the perspective of both mean wind speed and mean power density, indicates an excellent wind resource. Note that temperature data was not included in the analysis of power density. Given the extremely cold temperatures, and hence high air densities, of Point Lay, true wind power density will be higher yet, categorizing Point Lay more solidly as wind power class 5. For purposes of analysis, wind data monthly wind speed summaries contained in the 30 meter WindPRO report, along with other statistical data gleaned from the three-month Excel data, was used to synthesize a virtual data set. This enabled certain mathematic and graphical analyses not contained in the WindPRO reports.

Anemometer data summary

Variable	Speed 30 m
Measurement height (m)	30
Mean wind speed (m/s)	6.63
Median wind speed (m/s)	5.99
Max wind speed (m/s)	26.8
Weibull k	1.74
Weibull c (m/s)	7.44
Mean power density (W/m²)	403

Mean energy content (kWh/m²/yr)	3,528
Energy pattern factor	2.26
Frequency of calms (%)	23.4
1-hr autocorrelation coefficient	0.945
Diurnal pattern strength	0.041
Hour of peak wind speed	19

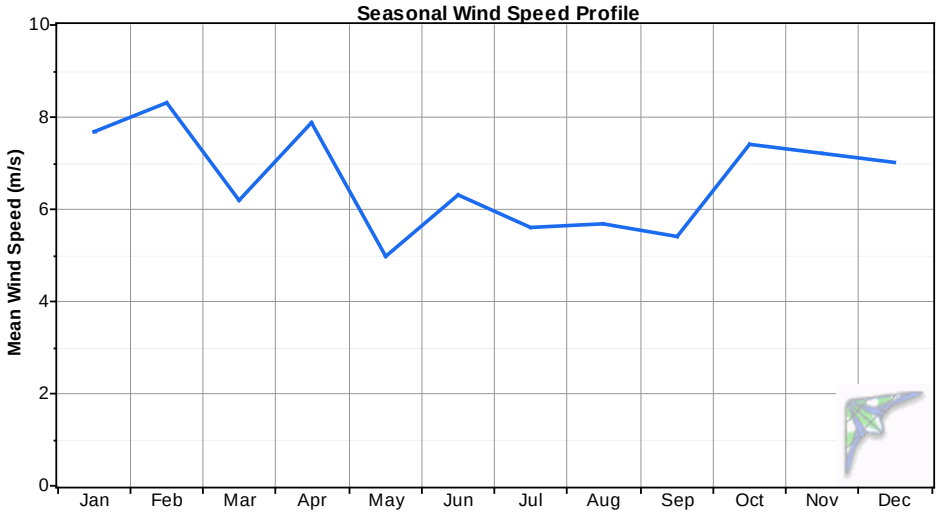
Time Series

Monthly average wind speeds indicate relatively high winds throughout the year, even during summer. Monthly variations appear significant but likely would smooth considerably in a multi-year view.

30 meter anemometer data summary

Month	Mean (m/s)	Median (m/s)	Max 10-min (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)
Jan	7.70	7.11	25.9	4.39	1.82	8.66
Feb	8.30	7.64	26.8	4.73	1.82	9.33
Mar	6.20	5.68	21.1	3.53	1.82	6.97
Apr	7.90	7.22	25.4	4.49	1.81	8.88
May	5.00	4.63	15.9	2.84	1.82	5.62
Jun	6.30	5.79	20.3	3.57	1.83	7.08
Jul	5.60	5.19	18.5	3.18	1.83	6.30
Aug	5.70	5.24	19.8	3.25	1.82	6.41
Sep	5.40	4.94	18.0	3.07	1.82	6.07
Oct	7.40	6.81	24.3	4.21	1.82	8.32
Nov	7.20	6.61	23.4	4.09	1.82	8.10
Dec	7.00	6.48	22.7	3.97	1.83	7.87
Annual	6.63	5.99	26.8	3.95	1.74	7.44

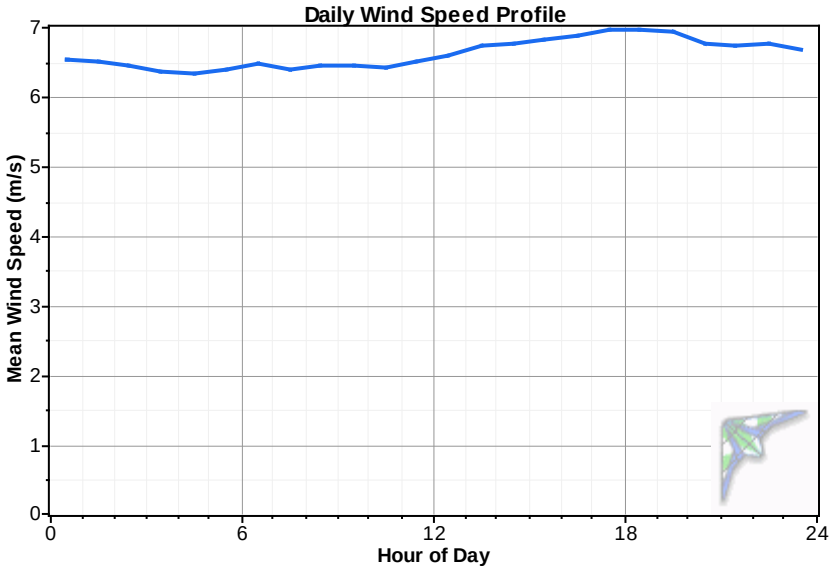
Time series graph



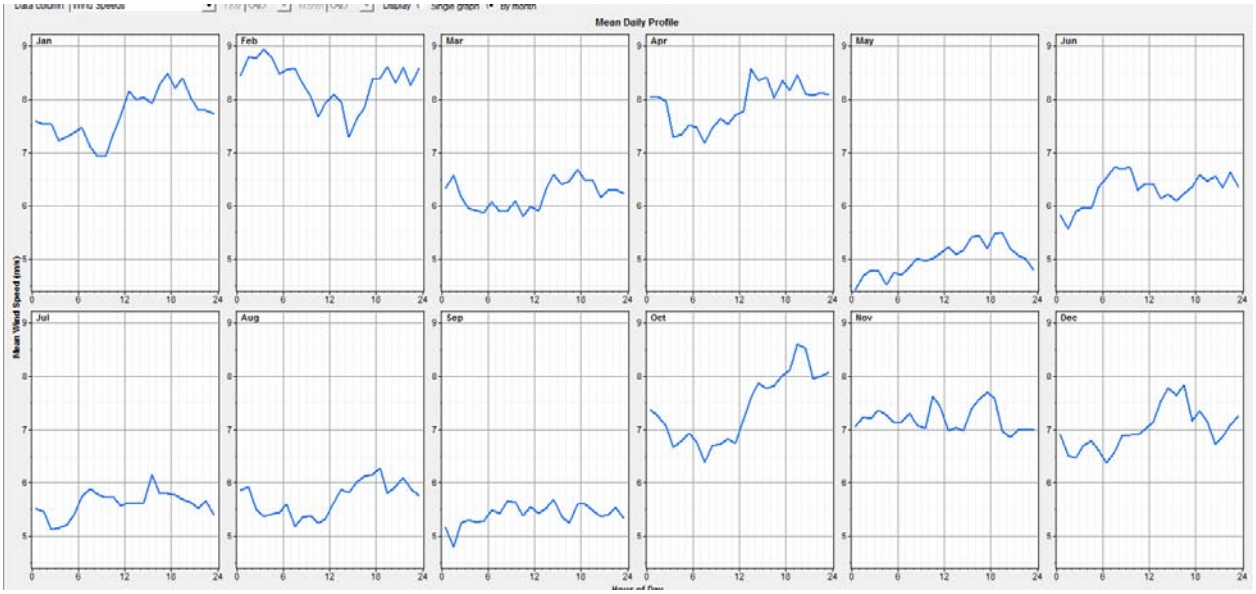
Daily Wind Profile

The daily wind profile indicates a relatively minor variation of wind speeds throughout the day, with lowest wind speeds in the early and mid-morning hours and highest wind speeds during the late afternoon and early evening hours. More variation, however, can be expected with a monthly view of daily wind profiles.

Annual-basis daily wind profile

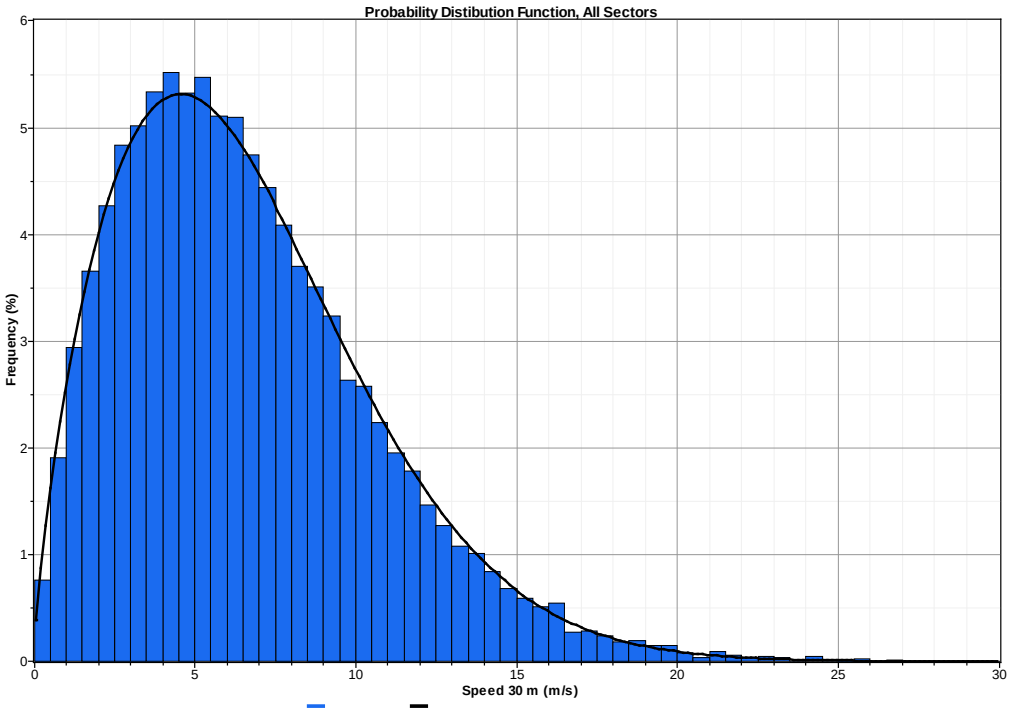


Monthly (daily) wind profiles



Probability Distribution Function

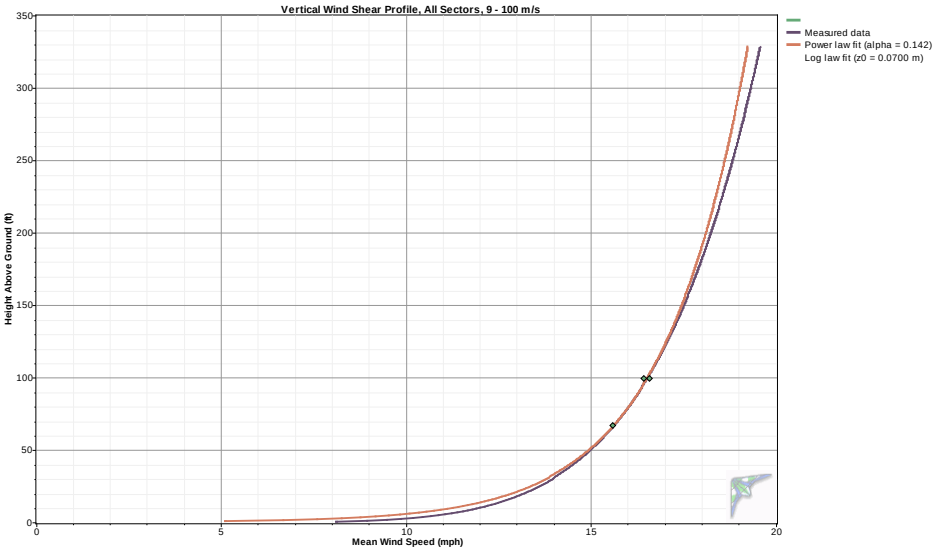
The probability distribution function (or histogram) of wind speed indicates a near-normal shape curve, defined as the Raleigh distribution (where k=2.0), considered standard for wind power sites.



Wind Shear and Roughness

Considering just the June through September data, a calculated wind shear power law exponent of 0.142 indicates relatively low wind shear (change of wind speed with increasing height above the ground) at the site, which is desirable for wind power development. Related to wind shear, a calculated surface roughness of 0.0096 meters (indicating the height above ground level where the wind velocity would be zero) indicates very smooth air terrain (roughness description: snow surface) surrounding the met tower.

Vertical wind shear profile, wind >4 m/s, June thru Sept data



Wind shear by direction table, wind >4 m/s, June thru Sept data

Direction Sector	Time Steps	Mean Wind Speed (m/s) Speed 30m A	Speed 30m B	Speed 20m	Best-fit Power Law Exp	Surface Roughness (m)
348.75° - 11.25°	1,236	6.68	6.71	6.63	0.024	0.000
11.25° - 33.75°	1,003	6.83	6.89	6.45	0.154	0.122
33.75° - 56.25°	1,832	7.64	7.58	7.03	0.193	0.458
56.25° - 78.75°	2,156	9.16	8.98	8.48	0.164	0.178
78.75° - 101.25°	531	6.06	5.92	5.28	0.314	3.324
101.25° - 123.75°	115	6.03	5.91	5.38	0.254	1.581
123.75° - 146.25°	83	4.82	4.86	4.57	0.142	0.070
146.25° - 168.75°	72	5.64	6.50	6.11	-0.018	
168.75° - 191.25°	203	10.09	10.11	9.51	0.150	0.102
191.25° - 213.75°	471	8.20	8.31	7.93	0.099	0.003
213.75° - 236.25°	323	7.06	7.04	6.37	0.249	1.457
236.25° - 258.75°	200	6.37	6.17	5.96	0.125	0.026
258.75° - 281.25°	176	5.39	5.23	5.11	0.093	0.002
281.25° - 303.75°	159	4.80	3.74	4.67	-0.222	
303.75° - 326.25°	131	5.23	5.03	5.19	-0.031	
326.25° - 348.75°	458	5.30	5.30	5.32	-0.010	

Extreme Winds

Data obtained for this wind resource analysis was not sufficient to calculate extreme wind probabilities. However, extreme wind probability calculations for the relatively nearby Wainwright met tower indicate a 50 year V_{ref}, or 50-year probable maximum 10 minute wind speed, of 24.8 m/s, well below the threshold criteria for International Electrotechnical Commission (IEC) 61400-1, 3rd edition, Class III classification. Note that Class III is the lowest defined wind class and all wind turbines are designed for this wind regime.

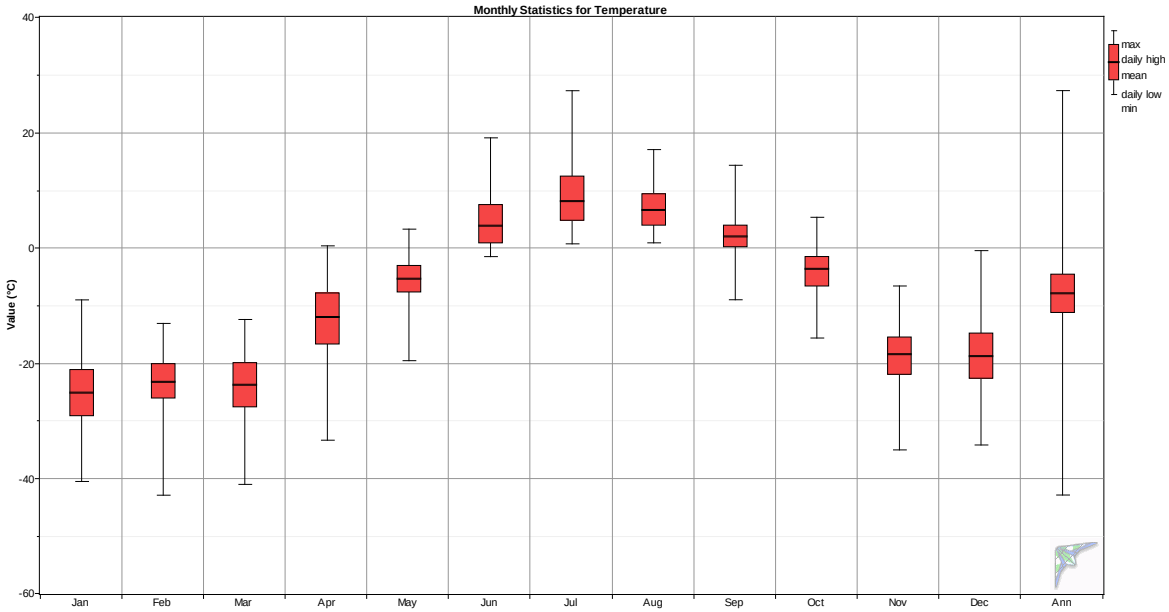
Temperature and Density

Data obtained for this wind resource analysis did not include an annual temperature or air density summary, other than the June through September data in the Excel file. However, it is a reasonable presumption that Point Lay experiences similar temperatures as the village of Wainwright, hence Wainwright temperature and density data is presented below for information. Note that Wainwright experiences cool summers and extremely cold winters. The result is high air density; calculated air density exceeds standard air density for a sea level elevation (1.225 Kg/m^3) by nine percent. This is advantageous in wind power operations as wind turbines produce more power at low temperatures (high air density) than at standard temperature and density.

Temperature and density table, Wainwright, 2009-2010

Month	Temperature Mean (°C)	Temperature Min (°C)	Temperature Max (°C)	Air Density Mean (kg/m³)	Air Density Min (kg/m³)	Air Density Max (kg/m³)
Jan	-25.1	-40.6	-9.1	1.421	1.334	1.515
Feb	-23.1	-43.0	-13.2	1.410	1.355	1.531
Mar	-23.7	-41.1	-12.5	1.413	1.352	1.518
Apr	-11.9	-33.4	0.3	1.349	1.288	1.469
May	-5.3	-19.7	3.2	1.316	1.275	1.390
Jun	4.0	-1.5	19.0	1.272	1.206	1.297
Jul	8.2	0.7	27.2	1.252	1.173	1.286
Aug	6.6	0.9	17.0	1.260	1.214	1.286
Sep	2.1	-9.0	14.3	1.280	1.226	1.334
Oct	-3.7	-15.7	5.2	1.308	1.266	1.368
Nov	-18.5	-35.1	-6.7	1.384	1.322	1.480
Dec	-18.8	-34.3	-0.5	1.386	1.292	1.475
Annual	-9.0	-43.0	27.2	1.337	1.173	1.531

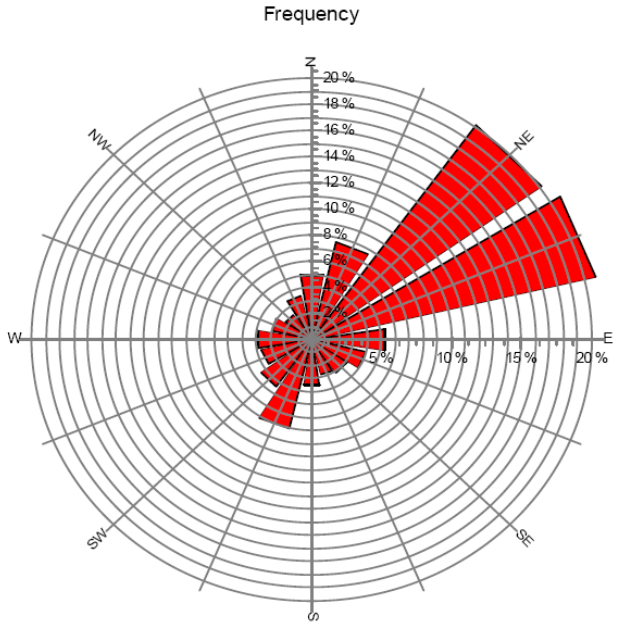
Monthly temperature boxplot, Wainwright, 2009-2010



Wind Direction

Wind frequency rose data (from NREL's WindPRO report) indicates highly directional winds from northeast to east-northeast. Although the NREL report did not show a power density rose, Wainwright data confirms the Point Lay directional frequency and indicates that power winds are nearly exclusively northeast to east-northeast, which presumably is representative of Point Lay.

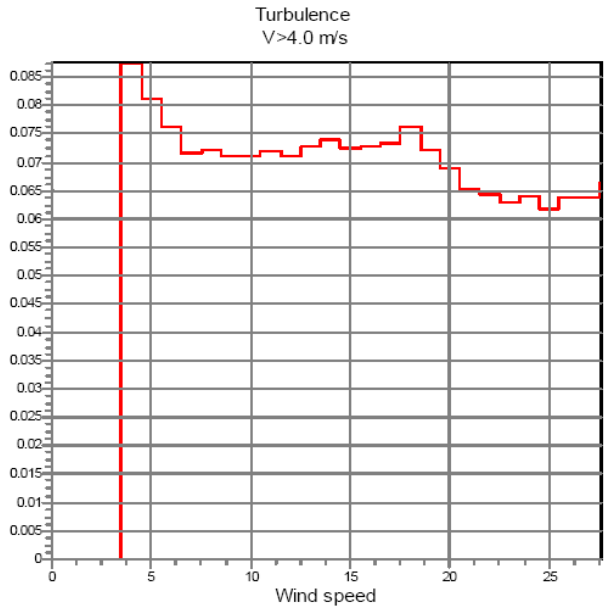
Wind frequency rose

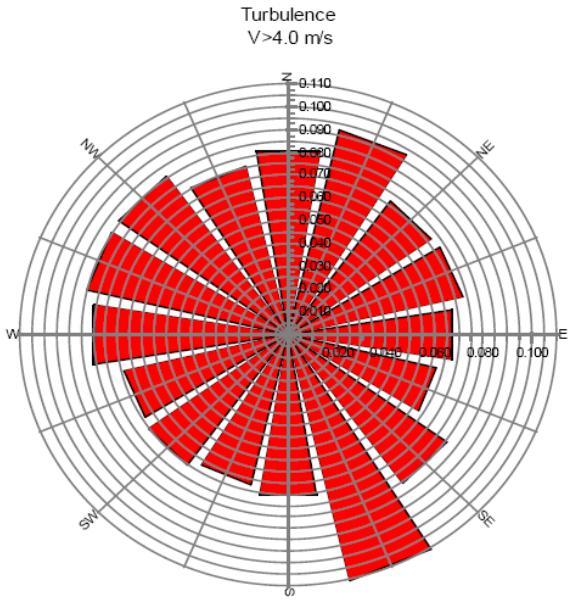


Turbulence

From the NREL report, turbulence intensity at the Point Lay test site is well within acceptable standards with an IEC 61400-1, 3rd edition (2005), classification of turbulence category C, which is the lowest defined. Mean turbulence intensity at 15 m/s is 0.072

Turbulence graphs





Turbulence table

Turbulence

Wind speed	Sum	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0.00 - 0.49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.50 - 1.49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.50 - 2.49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.50 - 3.49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3.50 - 4.49	0.087	0.096	0.104	0.082	0.083	0.090	0.077	0.111	0.118	0.075	0.082	0.072	0.087	0.086	0.090	0.093	0.078
4.50 - 5.49	0.081	0.083	0.101	0.079	0.077	0.077	0.069	0.092	0.118	0.070	0.068	0.069	0.082	0.081	0.091	0.091	0.075
5.50 - 6.49	0.076	0.076	0.093	0.078	0.076	0.070	0.065	0.070	0.107	0.065	0.065	0.067	0.071	0.079	0.087	0.077	0.072
6.50 - 7.49	0.072	0.080	0.089	0.073	0.067	0.062	0.057	0.064	0.122	0.063	0.067	0.066	0.062	0.076	0.083	0.075	0.066
7.50 - 8.49	0.072	0.077	0.092	0.070	0.068	0.060	0.055	0.059	0.111	0.068	0.063	0.067	0.067	0.074	0.089	0.058	0.076
8.50 - 9.49	0.071	0.080	0.089	0.069	0.068	0.059	0.059	0.082	0.107	0.069	0.061	0.070	0.064	0.075	0.069	0.084	0.096
9.50 - 10.49	0.071	0.085	0.083	0.069	0.069	0.061	0.063	0.092	0.094	0.078	0.065	0.086	0.067	0.075	0.062	0.086	0.091
10.50 - 11.49	0.072	0.091	0.085	0.070	0.074	0.056	0.059	0.099	0.090	0.088	0.069	0.078	0.064	0.089	0.074	0.084	0.076
11.50 - 12.49	0.071	0.090	0.089	0.068	0.077	0.074	0.057	0.084	0.091	0.069	0.068	0.076	0.063	0.085	0.072	0.081	0.075
12.50 - 13.49	0.073	0.091	0.083	0.072	0.079	0.059	0.042	0.061	0.088	0.077	0.068	0.073	0.065	0.070	0.077	0.078	0.077
13.50 - 14.49	0.074	0.065	0.084	0.072	0.078	0.064	0.044	0.048	0.085	0.080	0.067	0.072	0.066	0.075	0.078	0.081	0.078
14.50 - 15.49	0.072		0.091	0.071	0.074	0.055	0.049	0.069	0.080	0.085	0.068	0.072	0.064	0.083	0.079		0.070
15.50 - 16.49	0.073			0.062	0.078	0.058	0.034	0.084	0.088	0.075	0.068	0.072	0.072	0.081	0.071	0.080	0.064
16.50 - 17.49	0.073			0.057	0.080					0.074	0.070	0.071	0.066	0.065	0.074	0.071	0.064
17.50 - 18.49	0.076			0.063	0.080					0.064	0.069	0.079	0.058		0.079	0.073	0.084
18.50 - 19.49	0.072			0.059	0.076					0.063	0.072	0.076	0.060				
19.50 - 20.49	0.069			0.056	0.073					0.070	0.071						
20.50 - 21.49	0.065			0.064	0.060					0.066	0.071						
21.50 - 22.49	0.064			0.061	0.059						0.075						
22.50 - 23.49	0.063				0.056						0.070						
23.50 - 24.49	0.064				0.062					0.074	0.070						
24.50 - 25.49	0.062				0.062												
25.50 - 26.49	0.064				0.064												
26.50 - 27.49	0.064				0.064												
27.50 - 28.49	0.066				0.066												
Sum	0.075	0.081	0.093	0.072	0.073	0.068	0.063	0.081	0.111	0.071	0.067	0.070	0.069	0.081	0.085	0.085	0.076