Sonic Detection and Ranging (SODAR) Data Collection and Evaluation Report

ArchCoal, Inc., Birch River Surface Mine Operation

Cowen, Webster County, West Virginia

(Data Evaluation Period: May 19, 2010 to September 29, 2010 and November 5, 2013 to June 24, 2014)

Compiled by:

Marshall University Center for Environmental, Geotechnical and Applied Sciences (CEGAS)

Under Direction of:

West Virginia Division of Energy

Funded by:

Appalachian Regional Commission

West Virginia Division of Energy

November, 2014

Table of Contents

Attachments

1.0 Introduction

Marshall University's Center for Environmental, Geotechnical and Applied Sciences (CEGAS) partnered with the West Virginia Division of Energy to perform initial screening and wind resource data collection to assess wind development opportunities at selected surface mine properties in West Virginia using Sonic Detection and Ranging technologies. Funding for this study provided under joint partnership from the Appalachian Regional Commission and the West Virginia Division of Energy.

1.1 Project Location and Site Conditions

The site is located at the ArchCoal, Inc., Birch River surface mine operations, located near Cowen, Webster County, West Virginia. Wind resource data collection occurred on the site at Latitude 38.441, Longitude -80.611, at an elevation of 2,686 feet (819 meters) above mean sea level. This area is along a ridgeline, part of large reclaimed surface mine area, with active surface mine operations located generally west to southwest. Permitted mining operations, reclaimed and active mining areas, currently total nearly 5,000 acres. A site location map is provided in Attachment A.

The immediately surrounding area consists of reclaimed surface mine property. Minimal ground vegetation is present, and various species of trees have been planted throughout the immediate area. Trees range in age from 1 to 4 years, and are generally less than 8 feet tall. An access road and electric power line are located generally north of the SODAR location, with minimal traffic and/or related noise from surface mine operations. Reclaimed valley areas are located east, south and west of the site.

Property ownership of reclaimed, current and future tracts of the ArchCoal mining complex includes a number of entities. The tract where the SODAR was located is owned by Knight and Ink heirs, and includes approximately 1,200 acres. Other property owners and approximate acreage include: Pardee Resources, 10,000 acres; Beckwith Lumber Company, 5,500 acres; H.R. Deitz et al., 600 acres, and MB, LLC, 600 acres. ArchCoal also currently owns small acreage in the area.

1.2 Data Collection Description

Wind resource data was collected using a Triton Sonic Wind Profiler, manufactured by SecondWind, utilizing Sonic Detection and Ranging (SODAR) technology. Data collection occurred during two separate time periods. The first period was between May 19, 2010 and September 29, 2010. The second period was between November 5, 2013 and June 24, 2014. Photos showing the Triton unit and surrounding area are included in Attachment A. The Triton

unit was set up per SecondWind recommendations, including leveling of the unit to within operating condition (within 3 degrees of level), and proper directional orientation of the unit using Global Positioning System and magnetic compass equipment. The Triton unit is oriented properly when the south sound beam is positioned to within a few degrees of South. A Site Information Form and Checklist was completed during initial setup, which records site conditions, including nearby surface features, site noise, and unit operation parameter checks. A copy of the Site Information Forms and Checklists are included in Attachment A.

1.3 SODAR Configuration

The Triton Sonic Wind Profiler utilizes a hexagonal 36-speaker array to transmit high frequency acoustic pulses, or "chirps", and measures how they scatter and return to the unit. Sources of scattering are irregularities in wind velocities, air temperature and density, causing acoustic refractive index changes. By measuring the Doppler shifted frequency of the returned signal or echo, the SODAR determines wind speed and direction at various altitudes. Additional information on Triton Sonic Wind Profiler's operational details is available at: www.secondwind.com.

The SODAR unit saves records on 10-minute intervals. Each record includes data from 10 heights, ranging from 40 meters to 200 meters above ground surface. Data collected includes wind direction, horizontal and vertical wind speeds, turbulence, and general weather parameters, including temperature and barometric pressure.

2.0 SODAR Data Filtering and Performance

Using guidelines provided by Second Wind, SODAR data was filtered to remove low-quality data before analysis was performed. For this study, a 85% wind speed quality factor, as recommended by Second Wind, was used. During the time frame for this study, the SODAR unit operated continuously.

3.0 Results

All data collected during the study was exported into *Windographer* software for data analysis. *Windographer* is a wind data analysis program that reads data files directly from SODAR wind profilers and performs a number of calculations, including wind shear, turbulence intensity, extreme wind speeds, and wind turbine energy production. *Windographer* software version, Version 2.4.13, released in August of 2013, was used for data analysis. Wind speed mean averages at various elevations above the ground surface ranged from 5.54 meters per second

(m/s) at 40 meters, increasing consistently to just over 7.43 m/s at 200 meters. Wind direction was predominantly from the south to west, with mean wind directions generally South-Southwest. The following table, summarized from *Windographer* data analysis, provides a summary of wind speed, wind direction, vertical wind speed, and power density estimates at specified elevations from 40 to 200 meters above existing ground surface:

Elevation Above Ground Surface (819 m)	Wind Speed (m/s, mean)	Wind Direction (degrees, mean)	Vertical Wind Speed (m/s, mean)	Power Density (W/m^2, mean)
40 Meters	5.54	226.0	0.038	171
50 Meters	5.70	227.1	0.023	186
60 Meters	5.86	228.1	0.012	201
80 Meters	6.18	229.6	0.000	233
100 Meters	6.50	230.4	-0.003	267
120 Meters	6.80	230.7	0.000	306
140 Meters	7.07	230.2	-0.008	348
160 Meters	7.26	229.4	-0.017	382
180 Meters	7.35	228.2	-0.037	411
200 Meters	7.43	228.7	-0.046	438

Monthly wind speed and wind direction graphs are provided in Appendix B. Also in Appendix B is a Data Summary Report, which includes wind frequency, mean wind speed, and total wind energy rose diagrams, plus project period wind speed and diurnal wind speed profiles. A complete SODAR data collection package is available upon request to the West Virginia Division of Energy.

4.0 Estimated Capacity Factor as an Indicator of Performance

Measured wind speeds for the assessment periods were compared to generation data at Beech Ridge wind facility in West Virginia. This wind farm is the closest facility to the ArchCoal site. Generation data is for the same time period as provided by the U.S. Energy Information Administration. The following table summarizes the data:

Year	Month	Beech Ridge Capacity (Megawatts)	Beech Ridge Actual (Megawatthours)	Hours per Month	Beech Ridge Actual (Megawatts)	Beech Ridge Capacity Factor	ArchCoal Site Capacity Factor (Based on same wind turbine)
2010	May	100.5	7,330	744	9.85	9.80%	10.00%
2010	June	100.5	6,193	720	8.60	8.56%	9.80%
2010	July	100.5	3,897	744	5.24	5.21%	6.10%
2010	August	100.5	4,051	744	5.44	5.42%	7.40%
2010	September	100.5	8,523	720	11.84	11.78%	12.90%
2013	November	100.5	28,618	720	39.75	39.55%	25.40%
2013	December	100.5	24,213	744	32.54	32.38%	24.40%
2014	January	100.5	36,199	744	48.65	48.41%	29.20%
2014	February	100.5	25,613	672	38.11	37.92%	23.30%
2014	March	100.5	33,776	744	45.40	45.17%	22.50%
2014	April	100.5	31,214	720	43.35	43.14%	26.90%
2014	May	100.5	19,641	744	26.40	26.27%	10.00%
2014	June	100.5	14,302	720	19.86	19.77%	9.80%
	Average	100.5	18,736		25.77	25.64%	16.75%

Using the Windographer software, the same turbines used at the Beech Ridge site were analyzed with the data collected at the ArchCoal site. The average capacity factor as observed at the Beech Ridge site was 25.64%. The calculated capacity factor at the ArchCoal site was 16.75%.

5.0 Findings Calculated to Specific Wind Turbine Energy Output

Three wind turbines were selected for comparison of energy output based on the findings from this data collection period. The three units selected are representative of small, medium, and large-scale wind turbines that may be utilized for small to large-scale wind power generation. Each turbine was selected with an appropriate hub height and energy output calculated using *Windographer* software. The following table summarizes turbine properties and associated energy output and related information:

Wind Turbine Model Number	Rated Power (kW)	Hub Height (meters)	Hub Height Wind Speed (m/s)	Mean Net Power Output (kW)	Net Capacity Factor (%)
Endurance G-3120	35	42.7	5.48	9.6	27.4
Vestas V52	850	74	5.99	144.9	17.1
GE 2.5xl	2,500	75	6.01	484.5	19.4

Complete wind turbine comparison summaries are provided in Attachment B.

6.0 Conclusions and Recommendations

Wind resource data was collected from the ArchCoal site during two separate time periods. The first period was between May 19, 2010 and September 29, 2010. The second period was between November 5, 2013 and June 24, 2014. Late Spring and Summer months normally experience lower than yearly average wind speeds; winter months normally experience the highest wind speeds for a given 1-year period. These expected results were observed at the Arch Coal site. Recorded wind resource data and associated net capacity factors were somewhat below levels normally associated with commercial wind energy development standards.

New developments in wind turbine design and increases in wind energy generation efficiencies may results in locations with wind resources like the Arch Coal Birch River site being more favorable for commercial wind energy generation in the future. Small-scale wind energy generation appears to be currently more favorable, due to higher net capacity factors normally associated with lower power output rated turbines. This class of wind turbines are favorable for use by a single business, and/or for residential energy generation use. Based on future site use after mining reclamation activities are complete, wind energy generation could be considered for supporting power use needs.

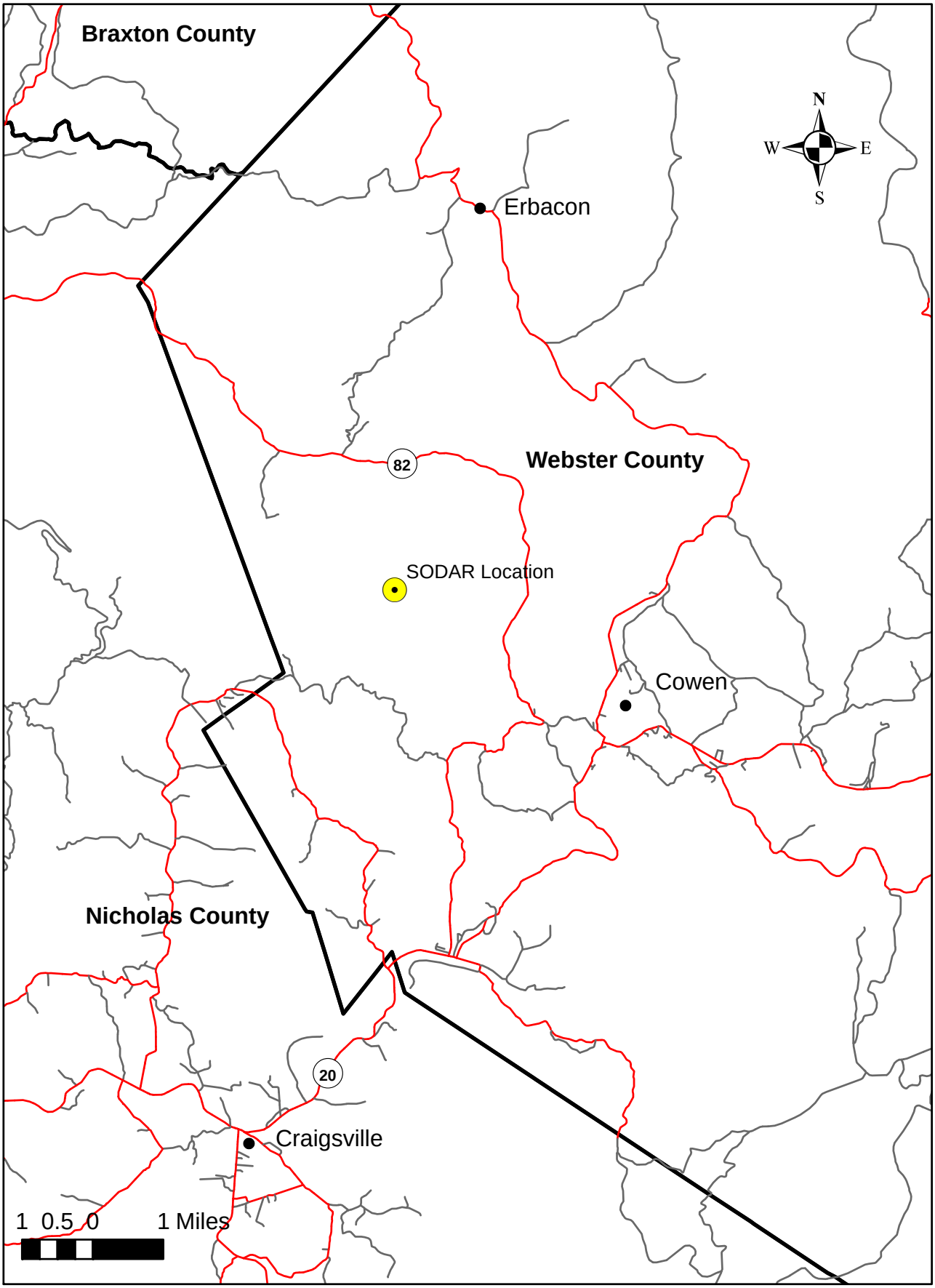
ATTACHMENT A

Site Location Map

Site Photos

SecondWind Site Information Form and Checklist

ArchCoal SODAR Site Map



Top View: SODAR unit looking Southwest

Bottom View: Area immediately North of SODAR unit location

Top View: SODAR unit looking Southeast

Bottom View: Area immediately Northeast of SODAR unit location

SECONDWIND

TRITON SONIC WIND PROFILER

Site Information Form & Checklist

1. Triton Information				
Triton Site Name:	Cowan - ICG / Webster County, WV			
Triton Owner:	Marshall University			
Install Date:				19-May
Triton Serial #:				258
Triton Model:	Circle/Highlight:	STD	HP	HR
Personnel Present:	C. Risch, E. Springer, R. Rutledge, G. Carico, K. O'dell			

2. Site Information	
Surrounding Site Description (i.e. Windfarm, Forest, Field etc.)	reclaimed surface mine, minimal ground cover, no large trees in area
Road Access Description (i.e. 4WD required)	mine haul roads; 4WD required
Gate Key Location/Security Details	Access only through main gate; Must make arrangements to be on site prior to arriva
Front Door Lock Details (Combo or Key Location)	Master Lock (same key required for security gate entrance)
Property Management Contacts	Kieth O'dell, Sn. Environmental Engineer, phone 304/226-2113, cell 304/550-2241

3. Fixed Object Vista Table

Description of Object	Azimuth (Deg)	Distance (m)	Height of Object (m)	Relative Elevation to Triton (m)
Electric Pole	~0 deg. North	76	17	plus 2 meters
Electric Pole	~90 deg. East	64	17	plus 2 meters
Electric Pole	~120 deg. SE	85	17	level to sodar
Electric Poles (4)	~340 deg. NW	122	17	plus 1 meter

4. Installation Checklist			
Item	✓	**Unit**	**Value**
Mechanical Inspection		List Damage/Defects	**NA**
Exterior Warning Sign Cover Removed (Heater Only)		none	**NA**
Triton Properly Oriented		Record Azimuth of B-Beam (deg mag)	**aligned using hand-held compass**
Triton Secured		Method (i.e. earth anchors, trailer, snow platform, etc.)	**leveled trailer w/ 6-foot security fenc**
Batteries Charged (>12.7V)		Record voltage level, V - DC	**16.2**
Solar Panels Installed, Connected		# of Panels	**2**
Solar Panels Charging		V - DC	**14.42**
Antifreeze Fluid Level (Heater Only)		none	**NA**
Propane Tanks installed		Tank capacity and level	**NA**
Propane Leak Test (Heater Only)		none	**NA**
Operator Panel: GPS		Red/Green/Rapid/Off	**green**
Operator Panel: SENSORS		Red/Green/Rapid/Off	**green**
Operator Panel: SUPPLIES		Red/Green/Rapid/Off	**green**
Operator Panel: SD CARD		Red/Green/Rapid/Off	**green**
Operator Panel: HEATER		Off/NA	**NA**
Operator Panel: NOTA (self-test)		Red/Green/Rapid/Off/NA	**NA**
Operator Panel: ARRAY		Red/Green/Rapid/Off	**green**
Operator Panel: SODAR		Red/Green/Rapid/Off	**green**
Operator Panel: SNR		Red/Green/Rapid/Off	**green**
Operator Panel: INTERNET		Red/Green/Rapid/Off	**green**
Operator Panel: TSP		Red/Green/Rapid/Off	**green**
Operator Panel: SKYSERVE		Red/Green/Rapid/Off	**green**
Take Photos or Videos		Pictures of 360deg site and Anchored Triton	**8 photos taken 5/20/2010**
Ambient Noise Level		dB	**minimal**
Ambient Noise Description		(i.e. Birds, Crickets, Highway)	**dozers, trucks (plus 1 mile), birds**
Triton Information (1) Section Complete		none	
Site Information (2) Section Complete		none	
Fixed Obstacle Vista Table (3) Complete		none	

Installer's Signature: _____ Date: 19-May

Installer's Name (print): George Carico

Installer's ID #: _____

SECONDWIND

TRITON
SONIC WIND PROFILER

Site Information Form & Checklist

1. Triton Information				
Triton Site Name:	Cowan - ArchCoal / Webster County, WV			
Triton Owner:	Marshall University			
Install Date:				11/5/2013
Triton Serial #:				258
Triton Model:	Circle/Highlight:	STD	HP	HR
Personnel Present:	G. Carico, J. Wolfe, K. O'dell			

2. Site Information	
Surrounding Site Description (i.e. Windfarm, Forest, Field etc.)	reclaimed surface mine, minimal ground cover, no large trees in area
Road Access Description (i.e. 4WD required)	mine haul roads; 4WD required
Gate Key Location/Security Details	Access only through main gate; Must make arrangements to be on site prior to arriva
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Electric Poles (4)	~340 deg. NW	122	17	plus 1 meter

4. Installation Checklist			
Item	✓	**Unit**	**Value**
Mechanical Inspection		List Damage/Defects	**NA**
Exterior Warning Sign Cover Removed (Heater Only)		none	**NA**
Triton Properly Oriented		Record Azimuth of B-Beam (deg mag)	**aligned using hand-held compass**
Triton Secured		Method (i.e. earth anchors, trailer, snow platform, etc.)	**leveled trailer w/ 6-foot security fenc**
Batteries Charged (>12.7V)		Record voltage level, V - DC	
Solar Panels Installed, Connected		# of Panels	**2**
Solar Panels Charging		V - DC	
Antifreeze Fluid Level (Heater Only)		none	**NA**
Propane Tanks installed		Tank capacity and level	**NA**
Propane Leak Test (Heater Only)		none	**NA**
Operator Panel: GPS		Red/Green/Rapid/Off	**green**
Operator Panel: SENSORS		Red/Green/Rapid/Off	**green**
Operator Panel: SUPPLIES		Red/Green/Rapid/Off	**green**
Operator Panel: SD CARD		Red/Green/Rapid/Off	**green**
Operator Panel: HEATER		Off/NA	**NA**
Operator Panel: NOTA (self-test)		Red/Green/Rapid/Off/NA	**NA**
Operator Panel: ARRAY		Red/Green/Rapid/Off	**green**
Operator Panel: SODAR		Red/Green/Rapid/Off	**green**
Operator Panel: SNR		Red/Green/Rapid/Off	**green**
Operator Panel: INTERNET		Red/Green/Rapid/Off	**green**
Operator Panel: TSP		Red/Green/Rapid/Off	**green**
Operator Panel: SKYSERVE		Red/Green/Rapid/Off	**green**
Take Photos or Videos		Pictures of 360deg site and Anchored Triton	**8 photos taken 5/20/2010**
Ambient Noise Level		dB	**minimal**
Ambient Noise Description		(i.e. Birds, Crickets, Highway)	**dozers, trucks (plus 1 mile), birds**
Triton Information (1) Section Complete		none	
Site Information (2) Section Complete		none	
Fixed Obstacle Vista Table (3) Complete		none	

Installer's Signature: _____ Date: 11/5/2013

Installer's Name (print): George Carico

Installer's ID #: _____

ATTACHMENT B

Windographer Monthly Reports

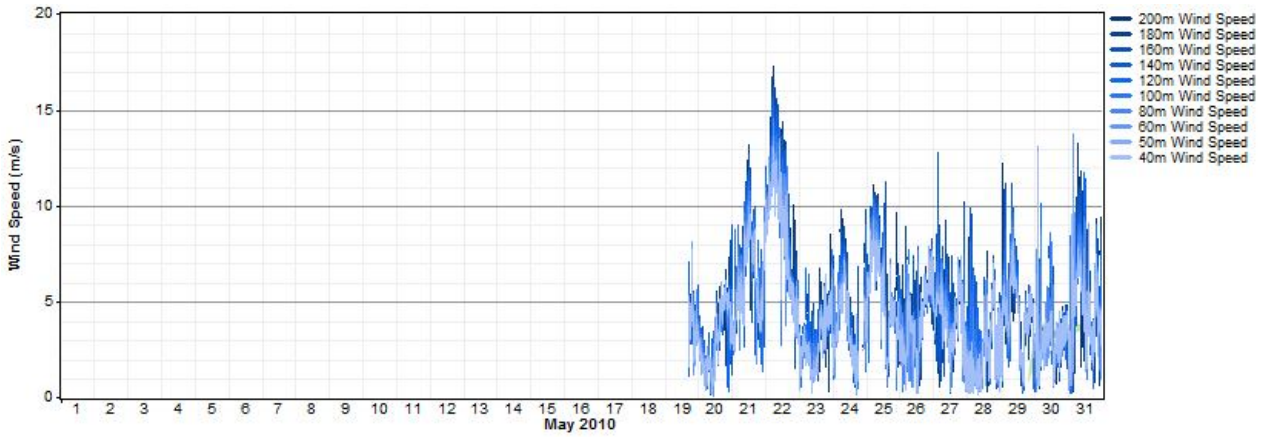
Windographer Summary Report

Wind Turbine Energy Output Summaries

Report Settings

Report Created: 11/19/2014 15:12 using Windographer 2.4.13
Report Period: May 2010

Wind Speed Data



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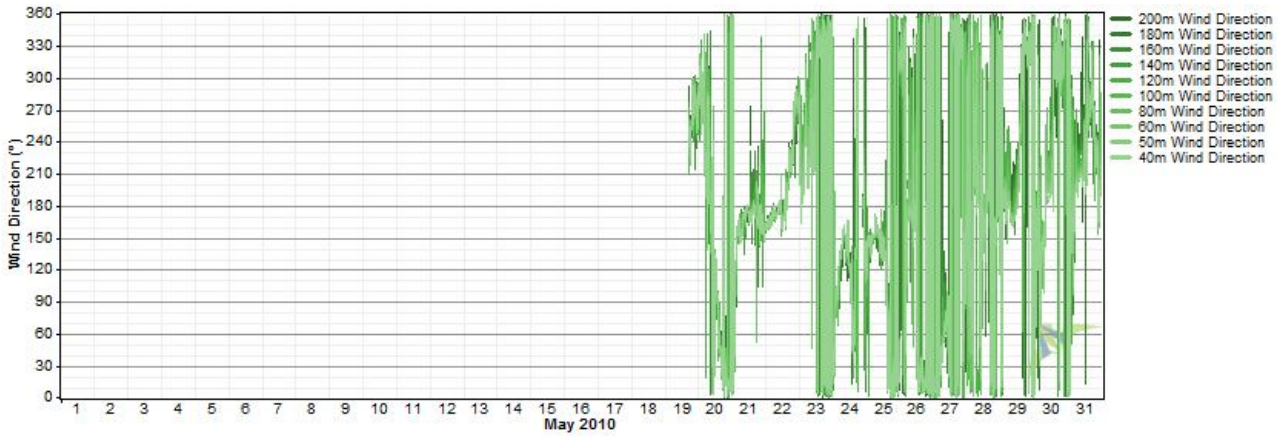

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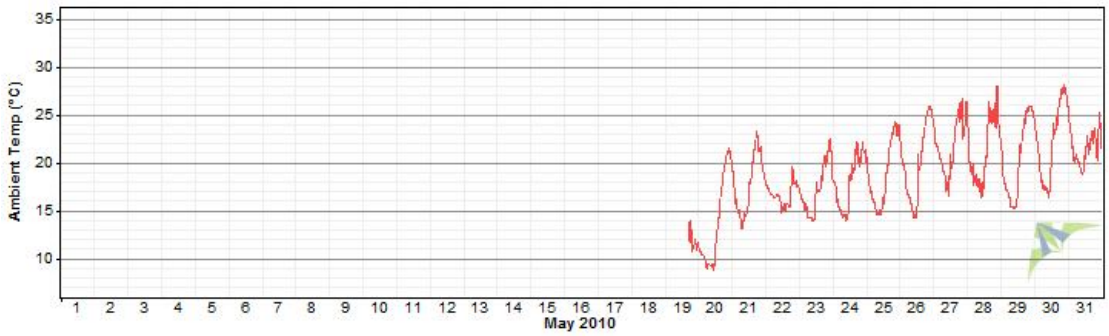

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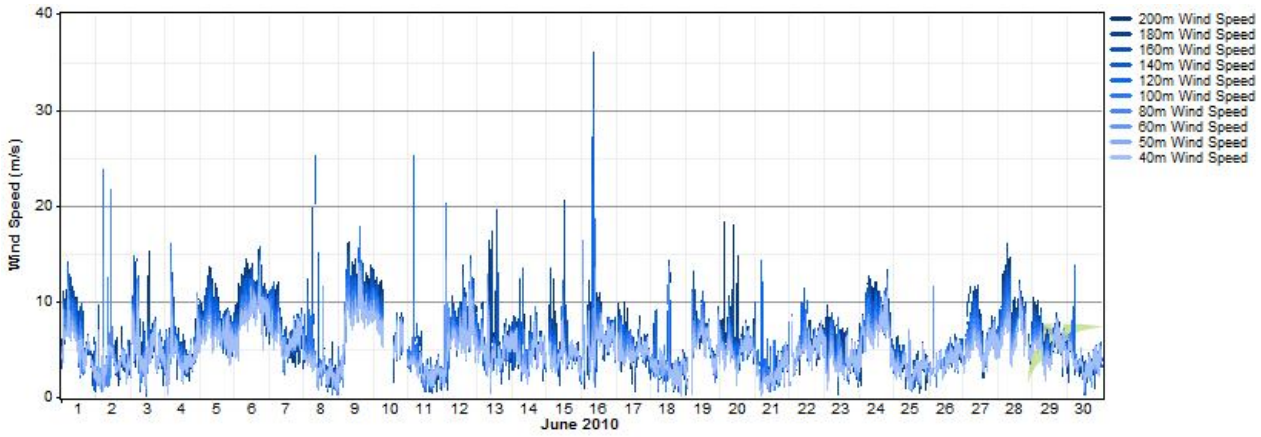

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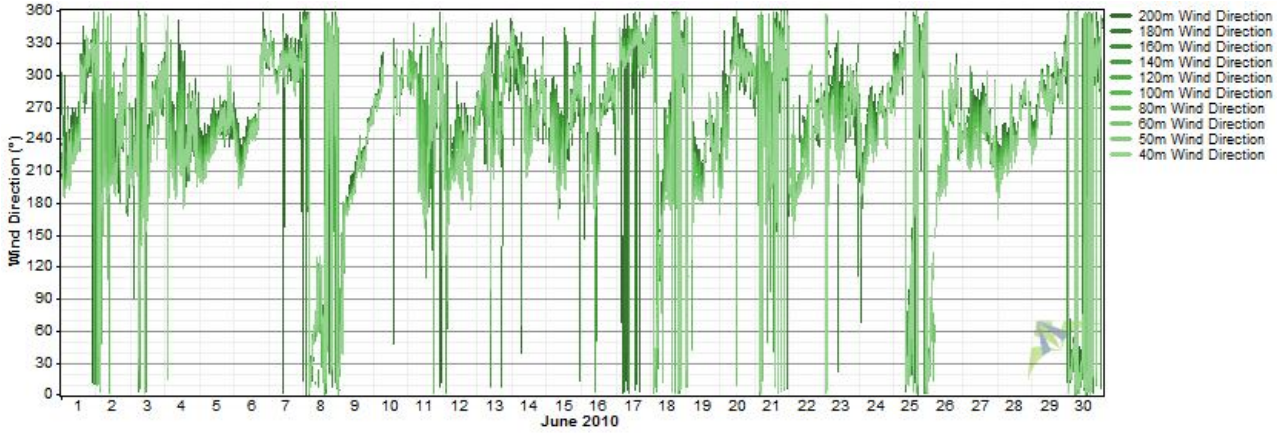

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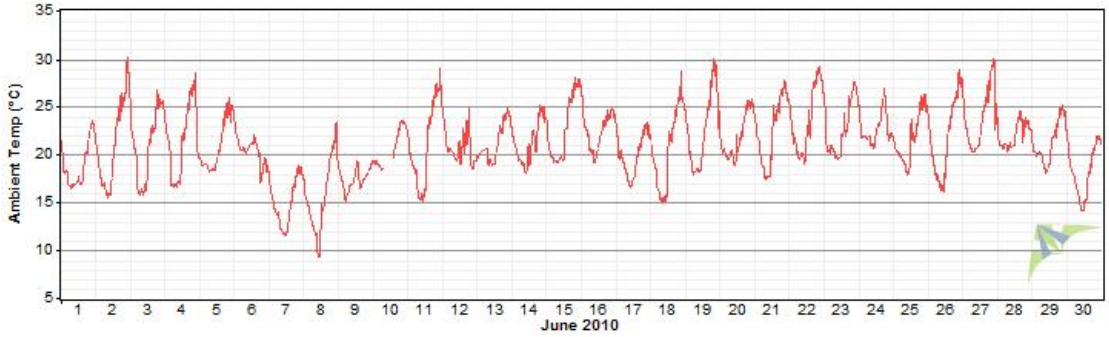

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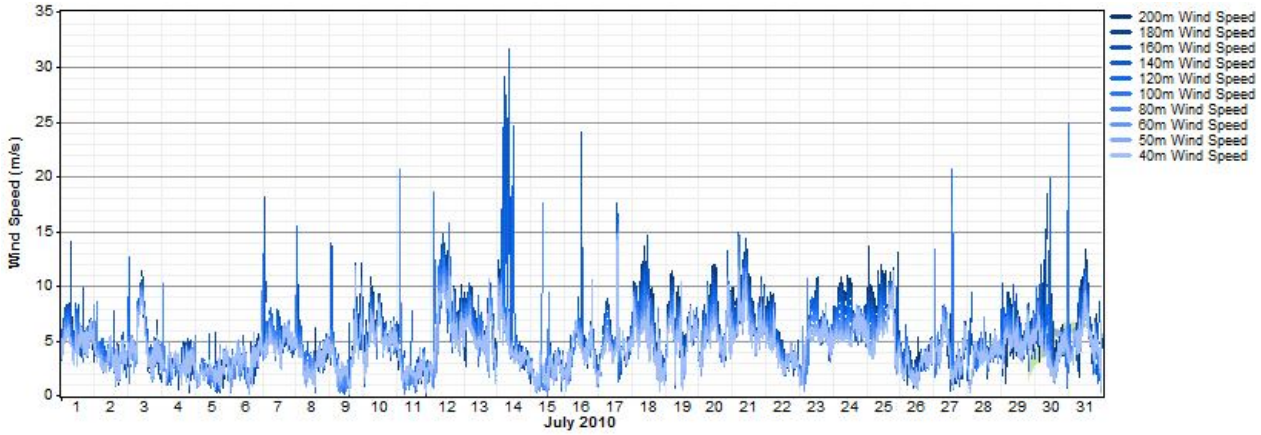

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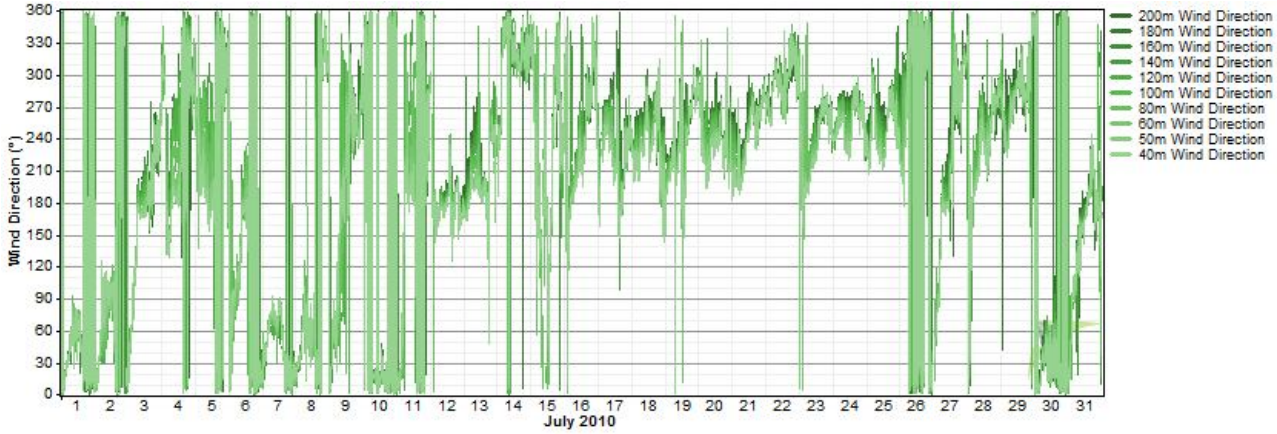

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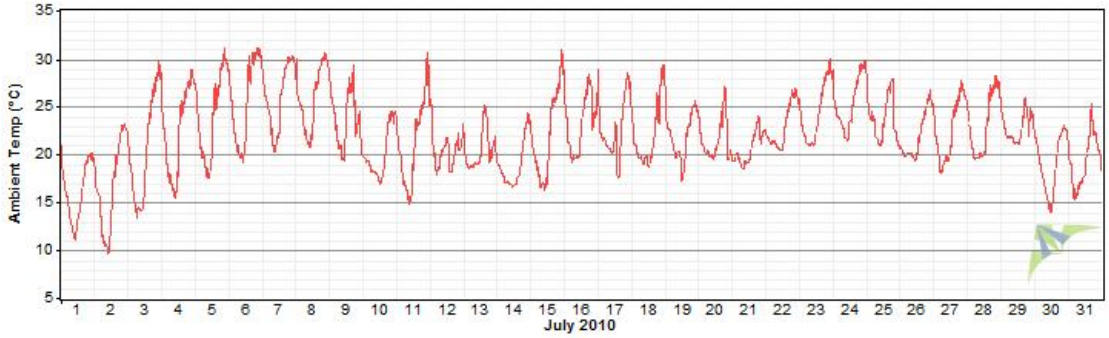

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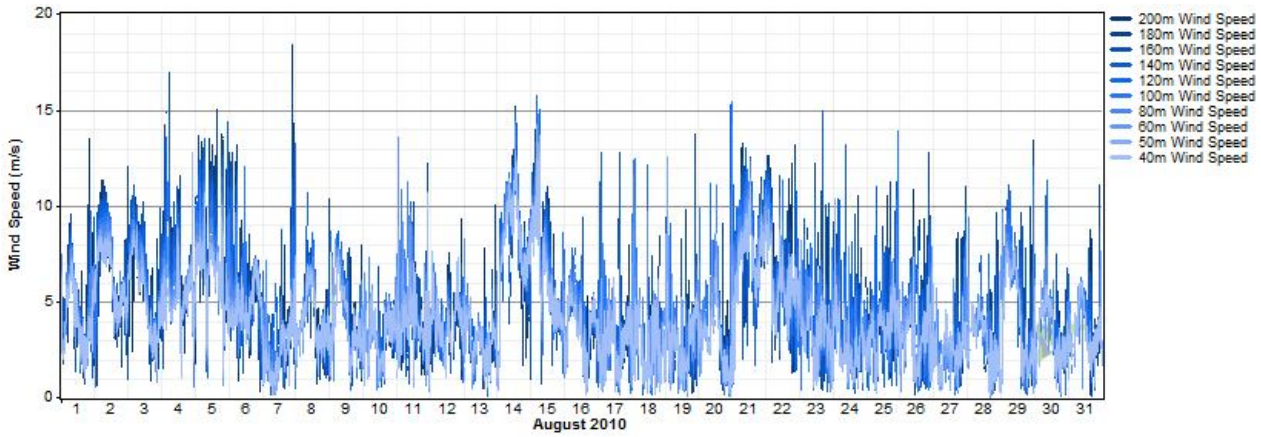

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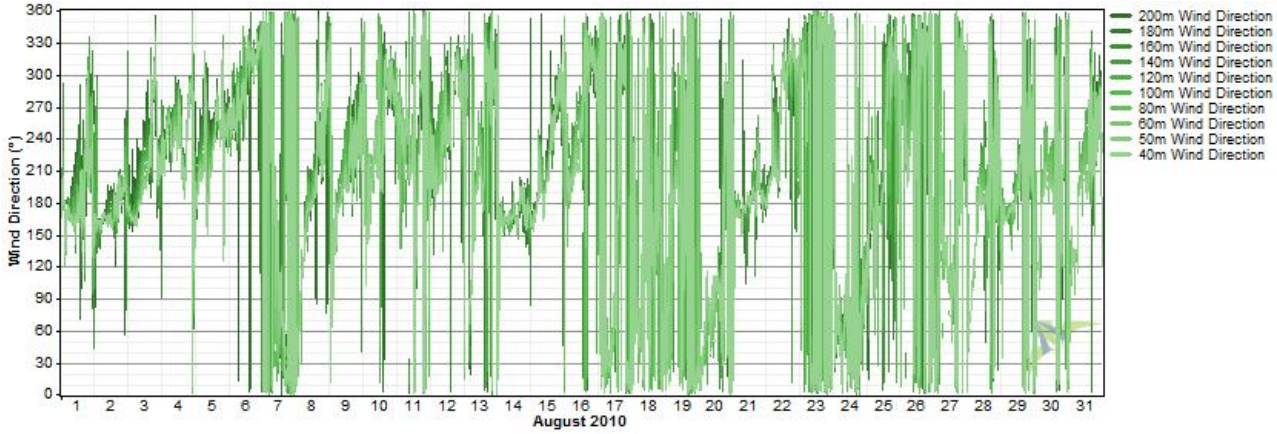

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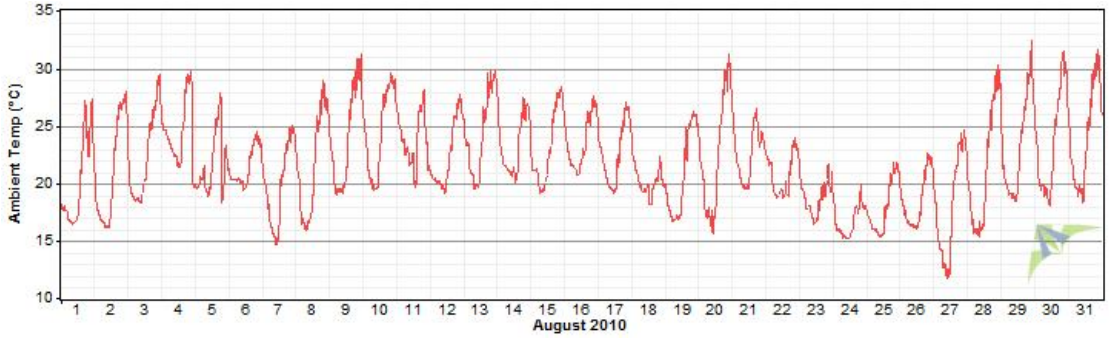

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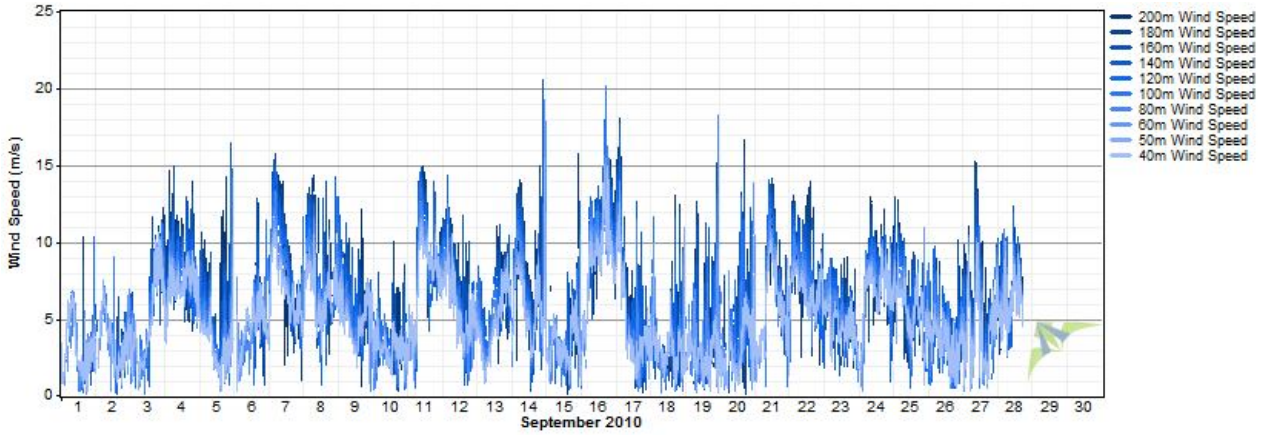

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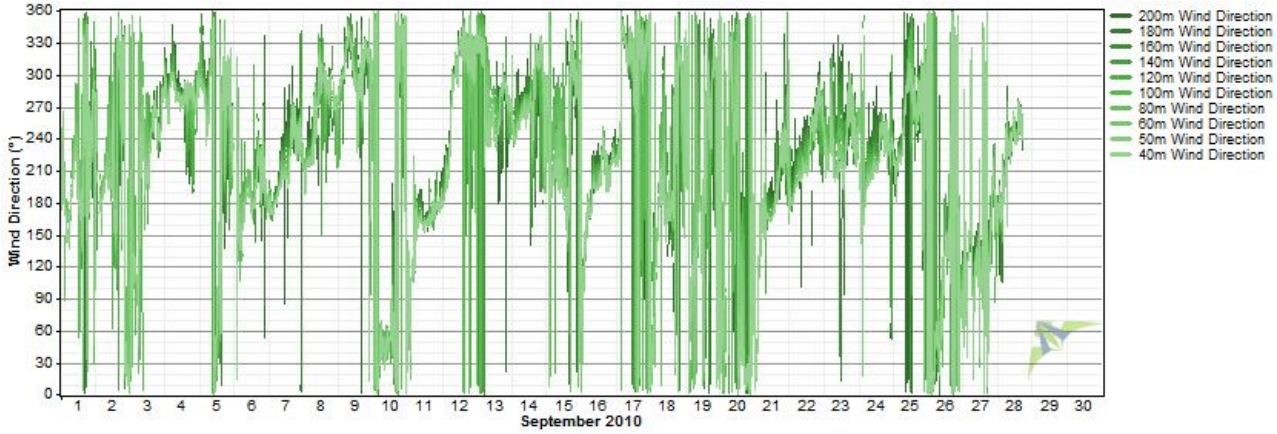

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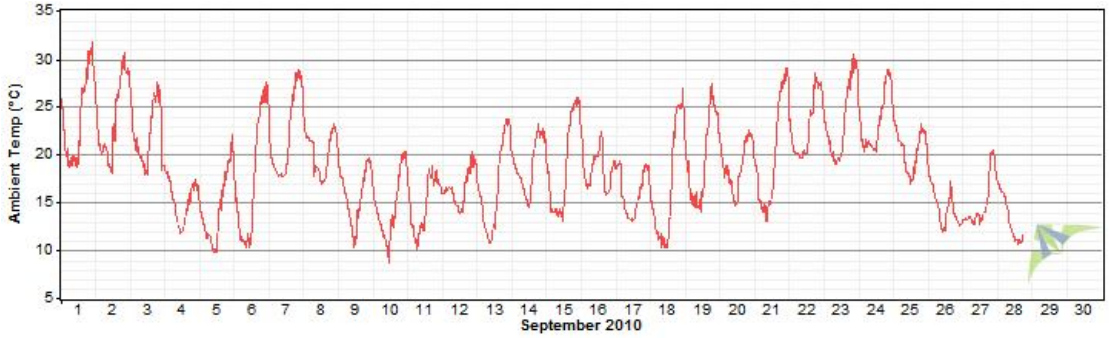

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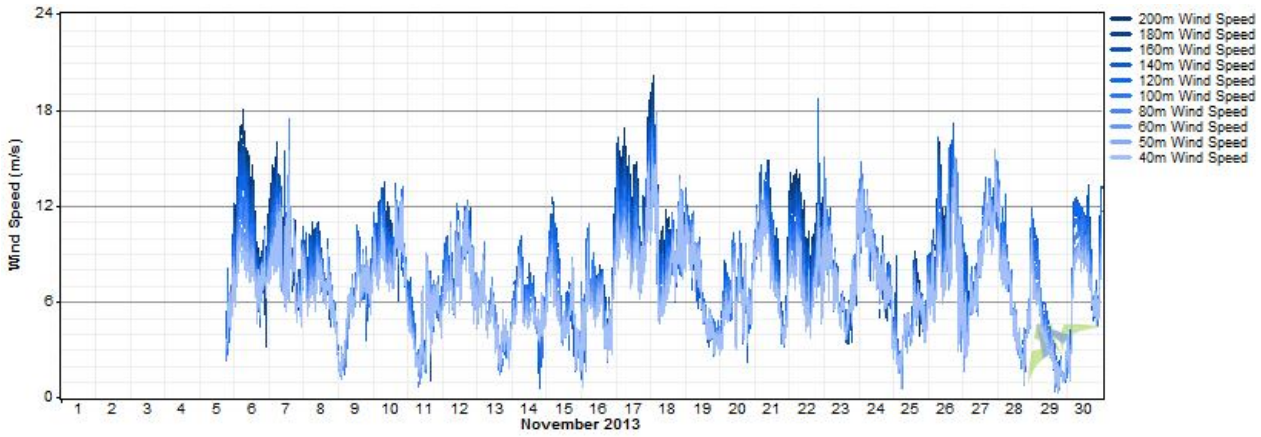

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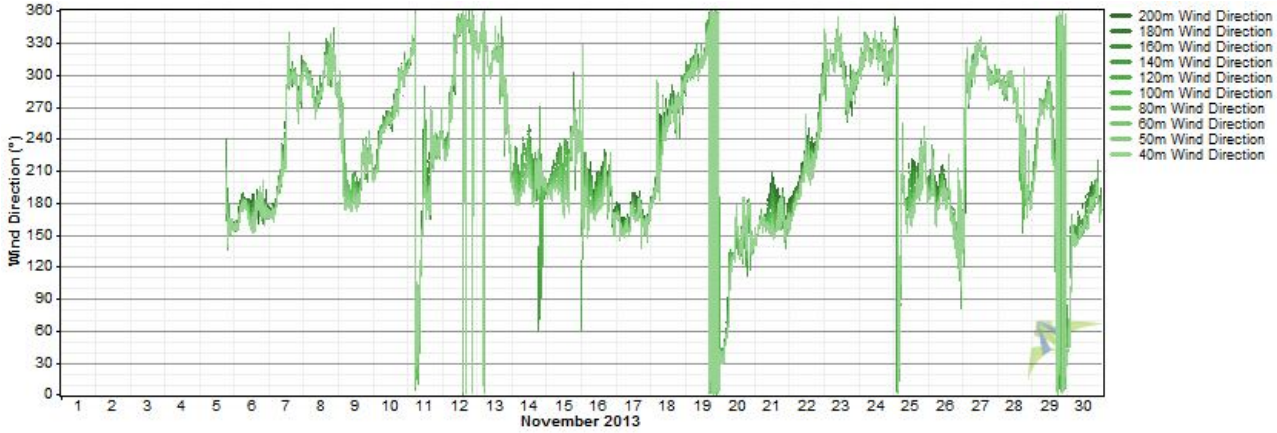

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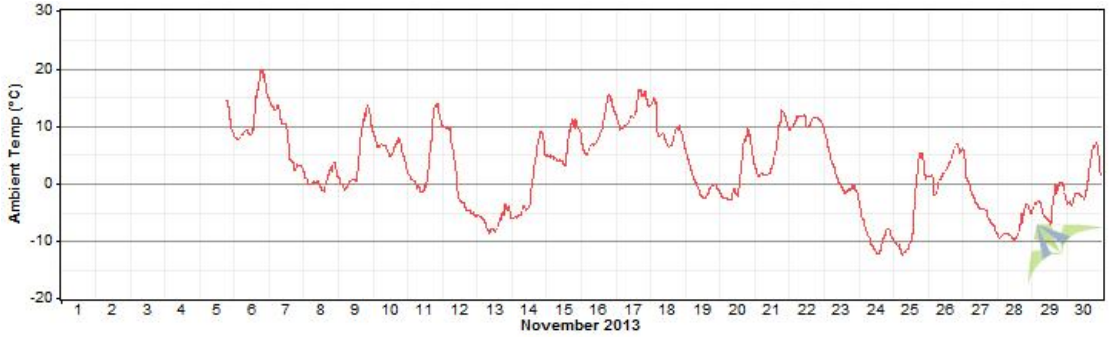

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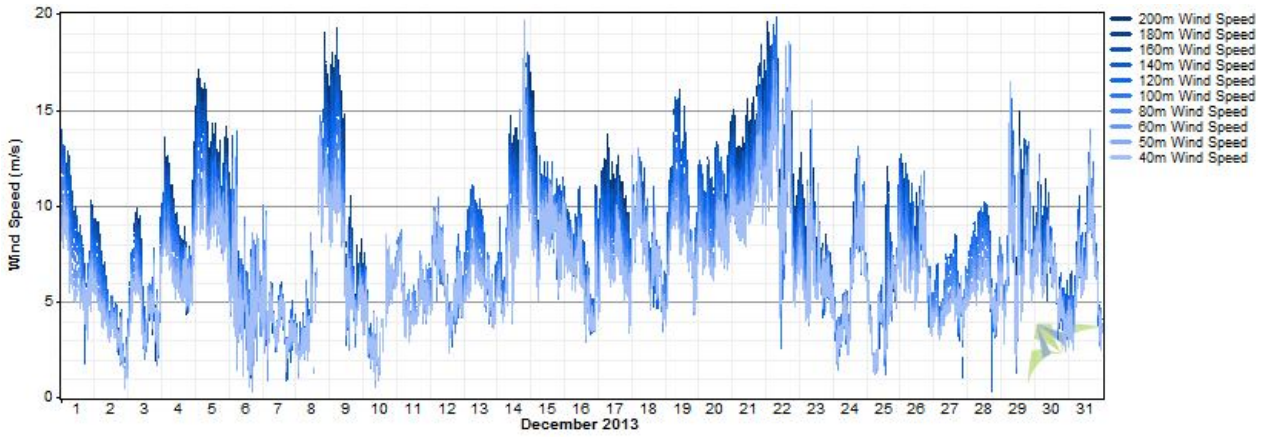

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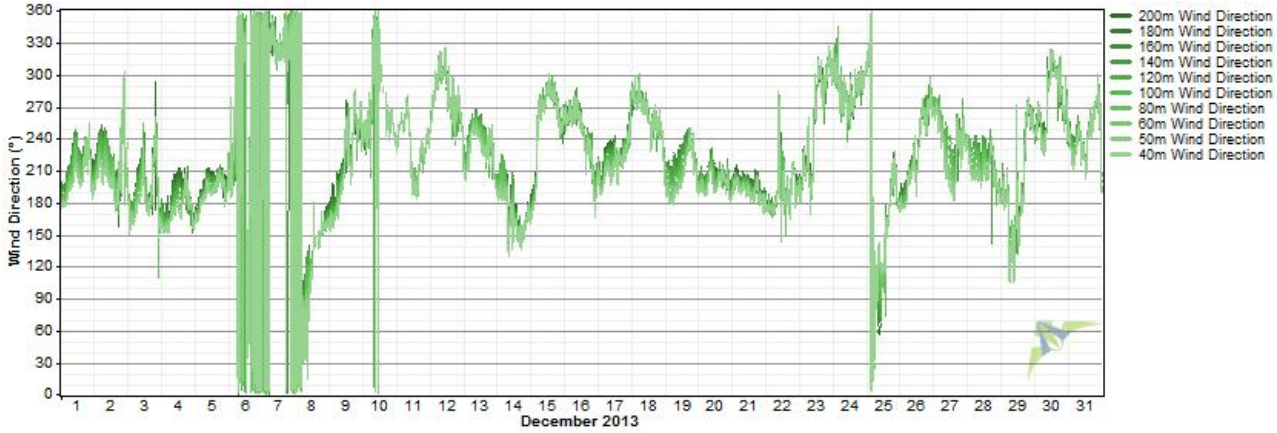
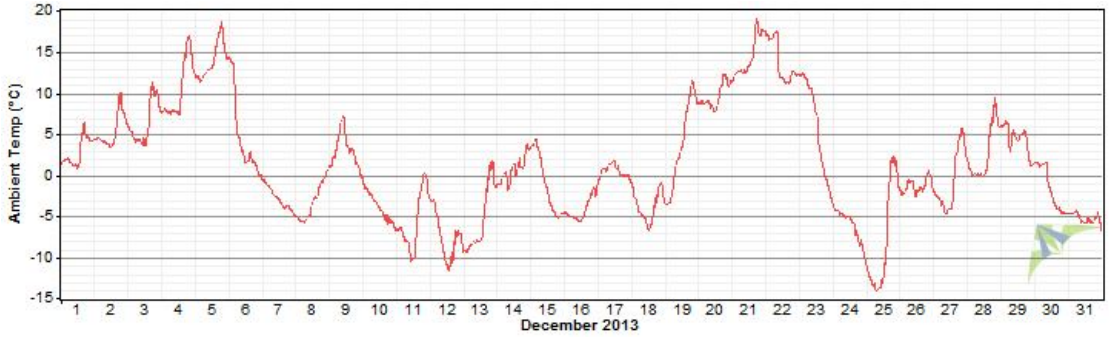


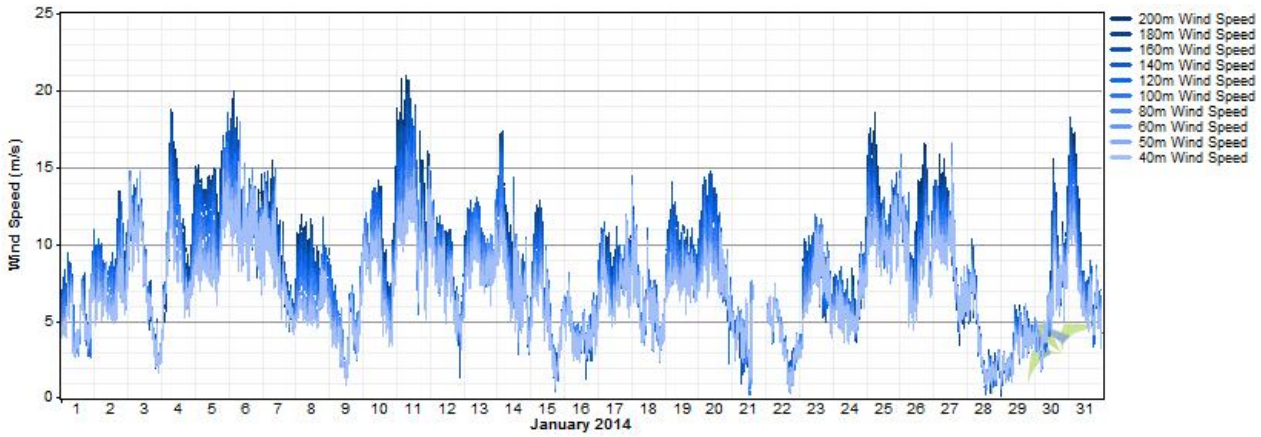
Temperature Data



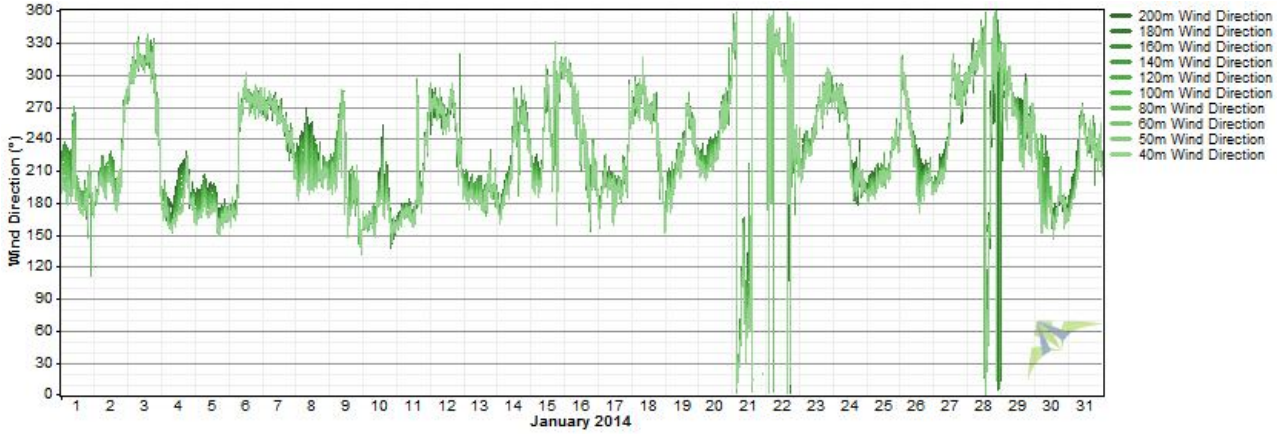
Report Settings

Report Created: 11/19/2014 15:16 using Windographer 2.4.13
Report Period: January 2014

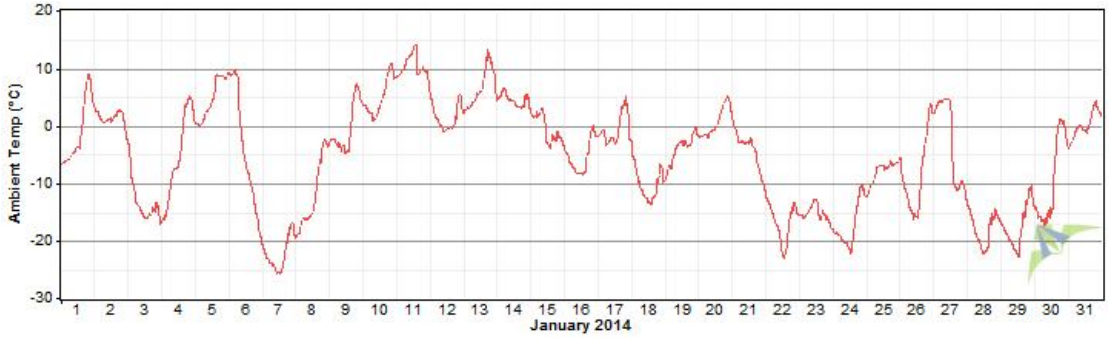
Wind Speed Data



Wind Direction Data



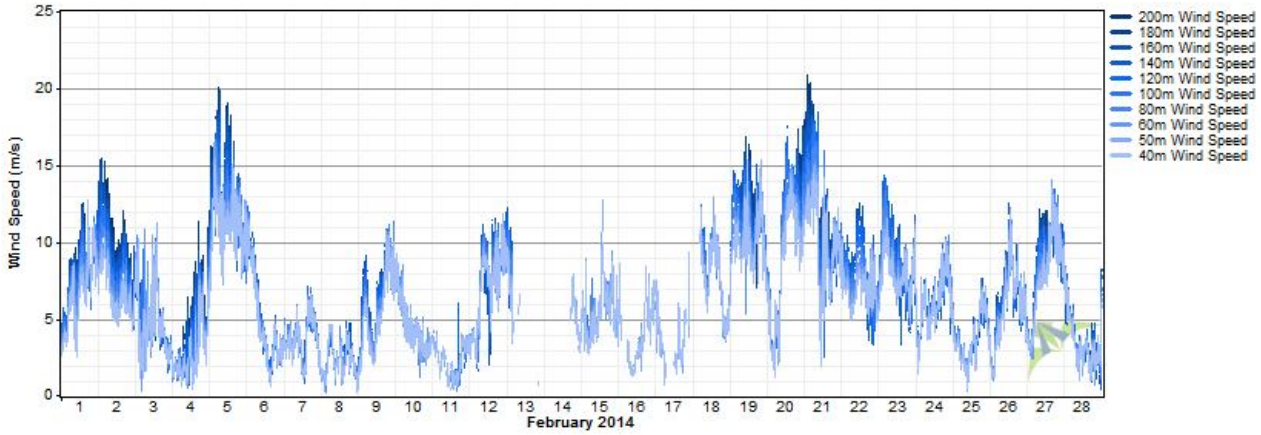
Temperature Data



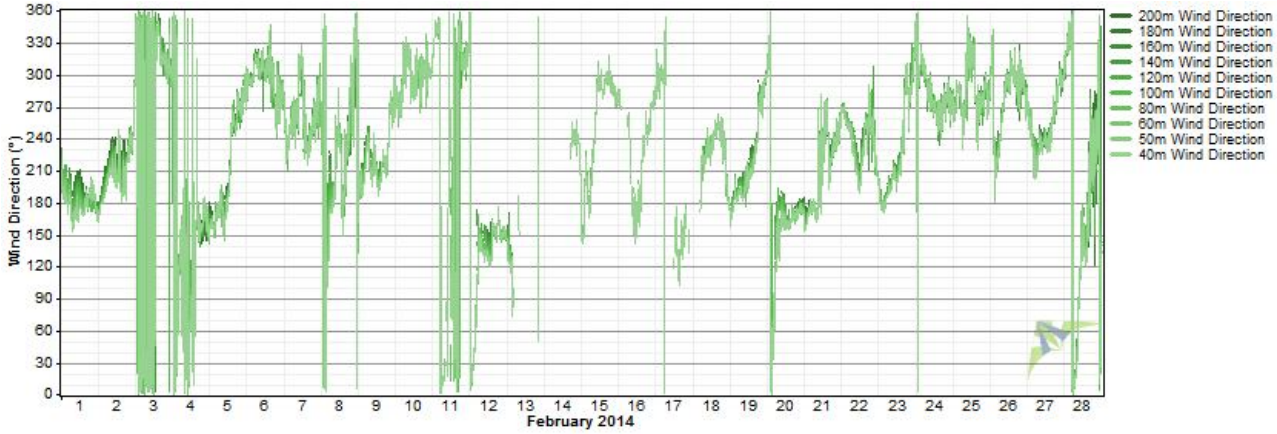
Report Settings

Report Created: 11/19/2014 15:16 using Windographer 2.4.13
Report Period: February 2014

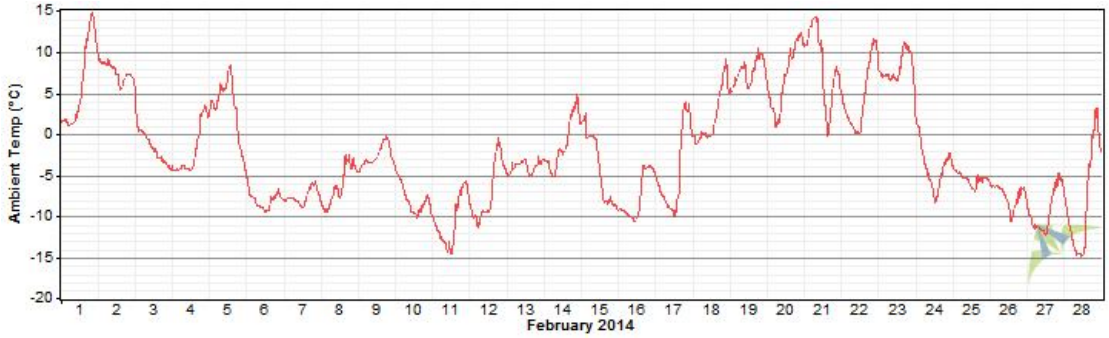
Wind Speed Data



Wind Direction Data



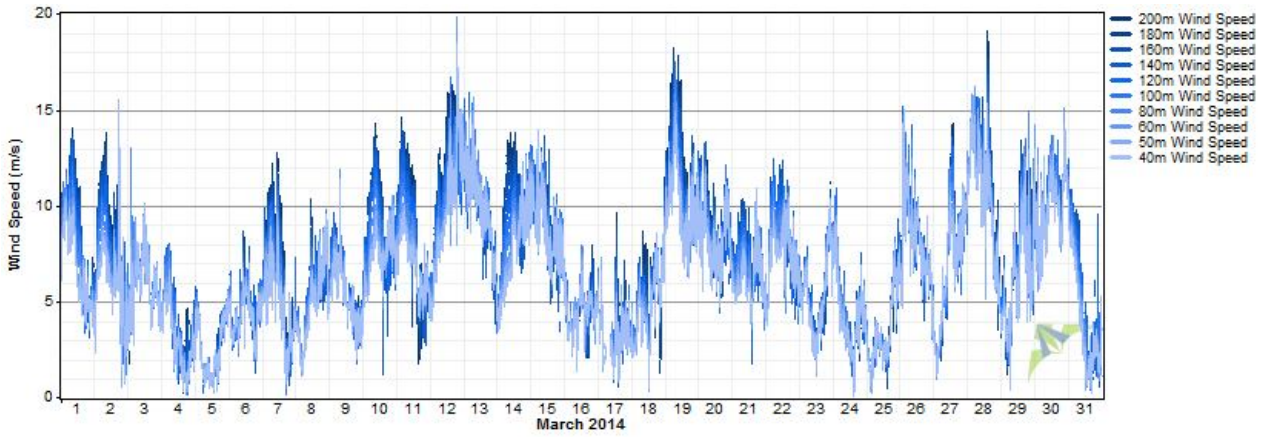
Temperature Data



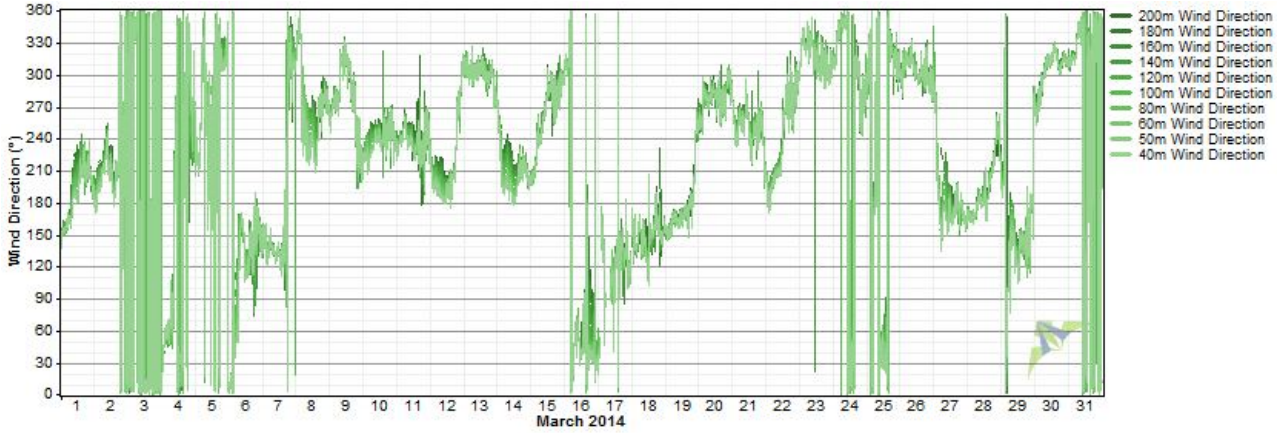
Report Settings

Report Created: 11/19/2014 15:17 using Windographer 2.4.13
Report Period: March 2014

Wind Speed Data



Wind Direction Data

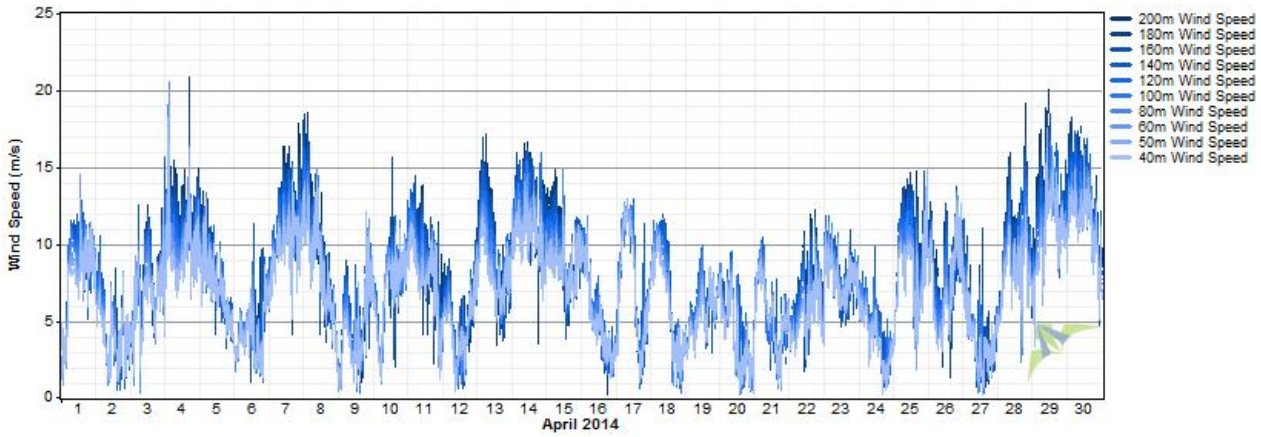


Temperature Data

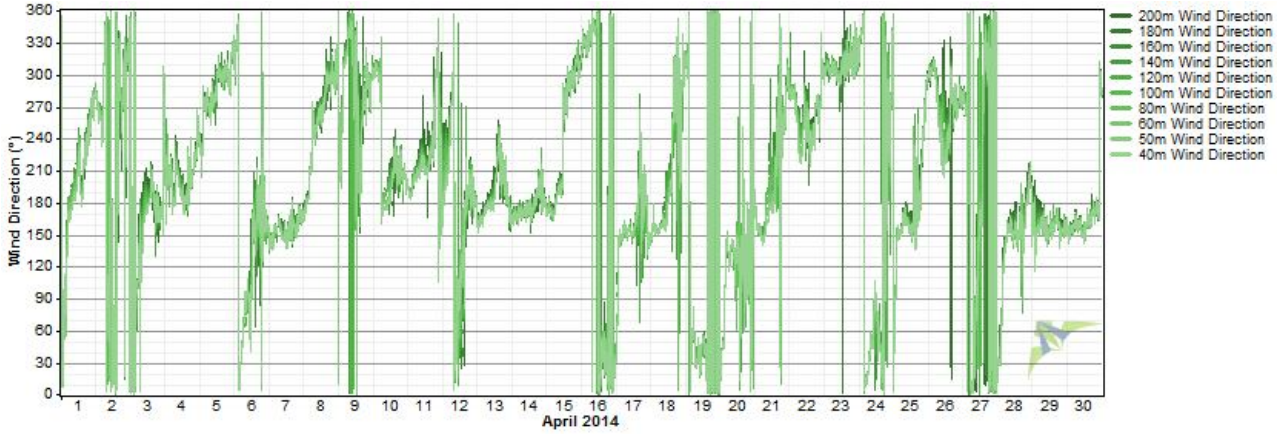
Report Settings

Report Created: 11/19/2014 15:17 using Windographer 2.4.13
Report Period: April 2014

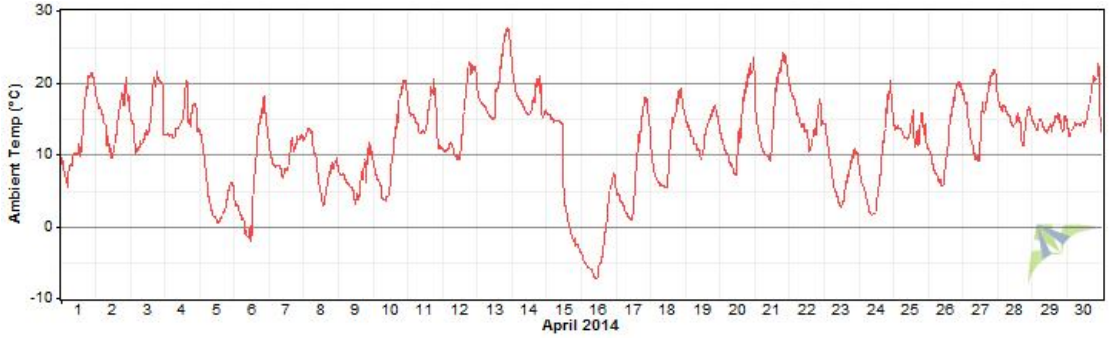
Wind Speed Data



Wind Direction Data



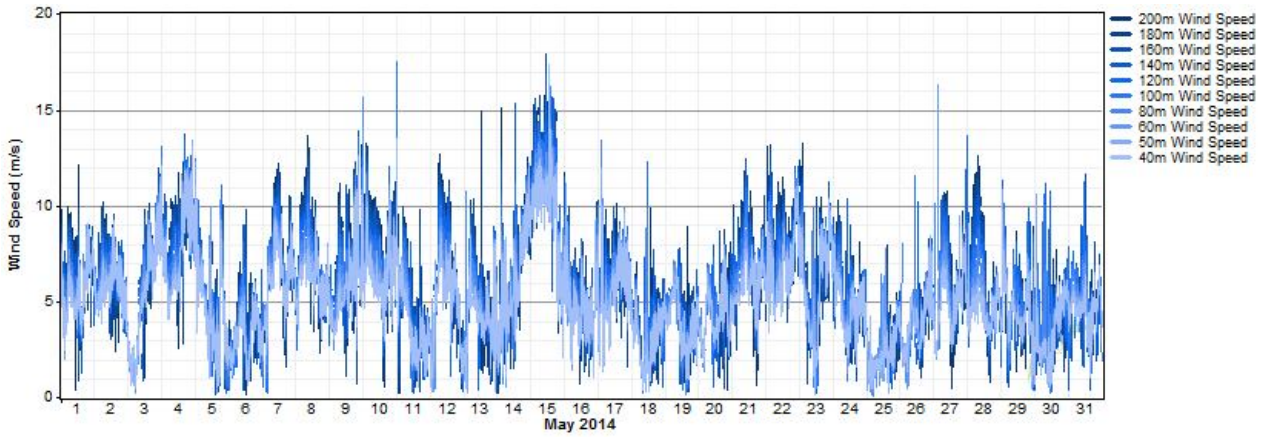
Temperature Data



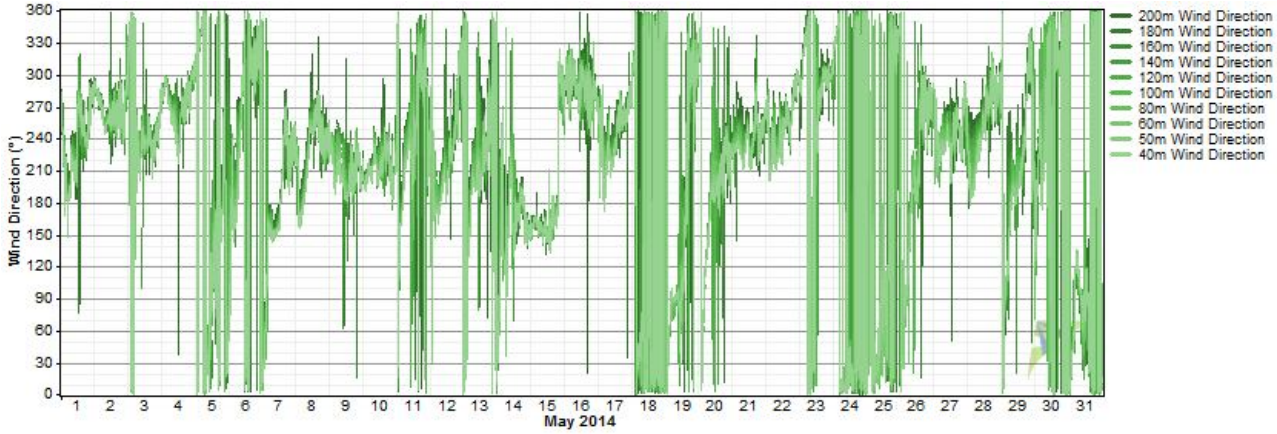
Report Settings

Report Created: 11/19/2014 15:18 using Windographer 2.4.13
Report Period: May 2014

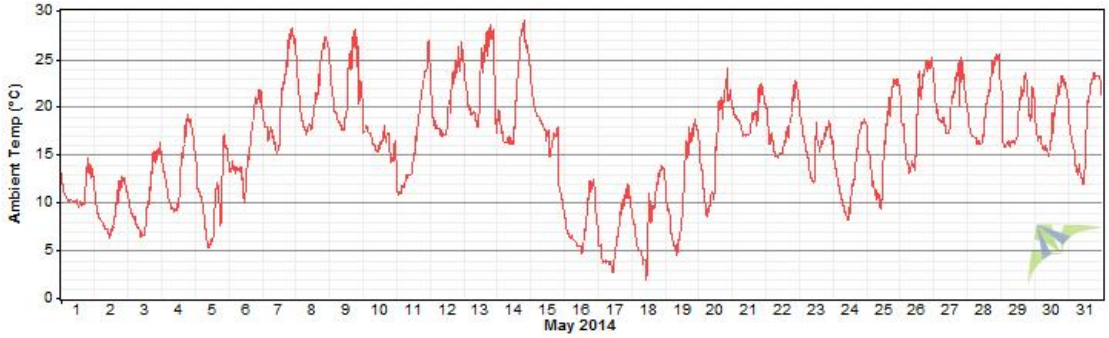
Wind Speed Data



Wind Direction Data



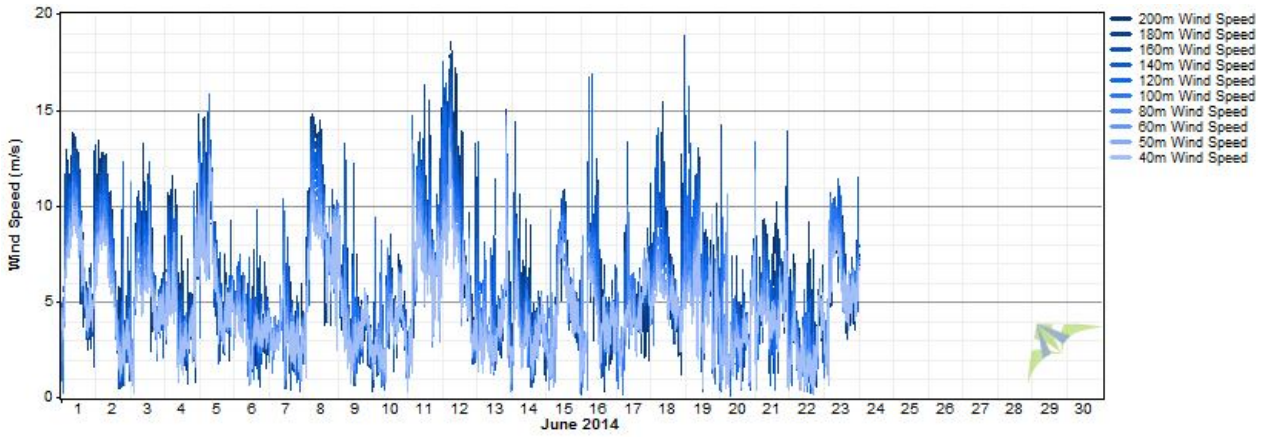
Temperature Data



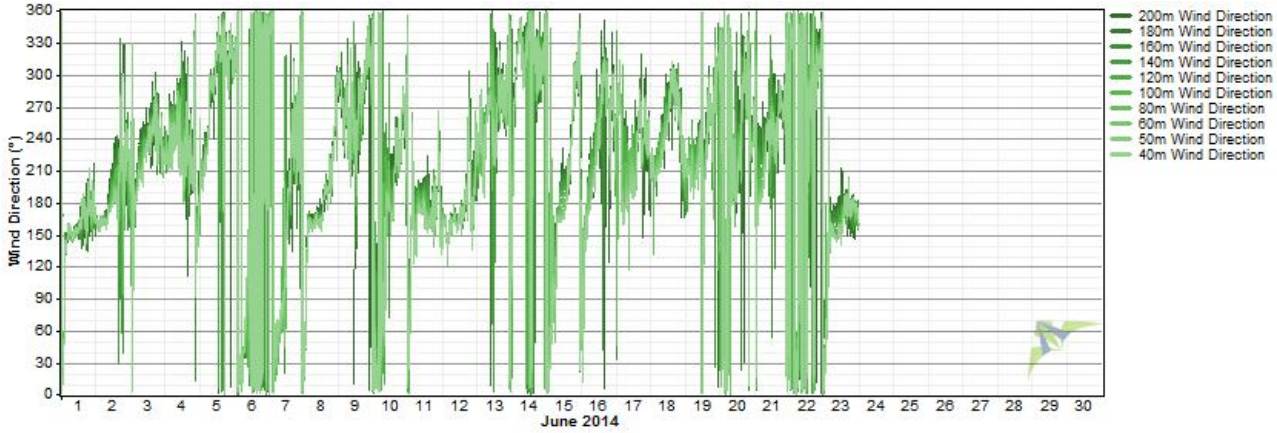
Report Settings

Report Created: 11/19/2014 15:18 using Windographer 2.4.13
Report Period: June 2014

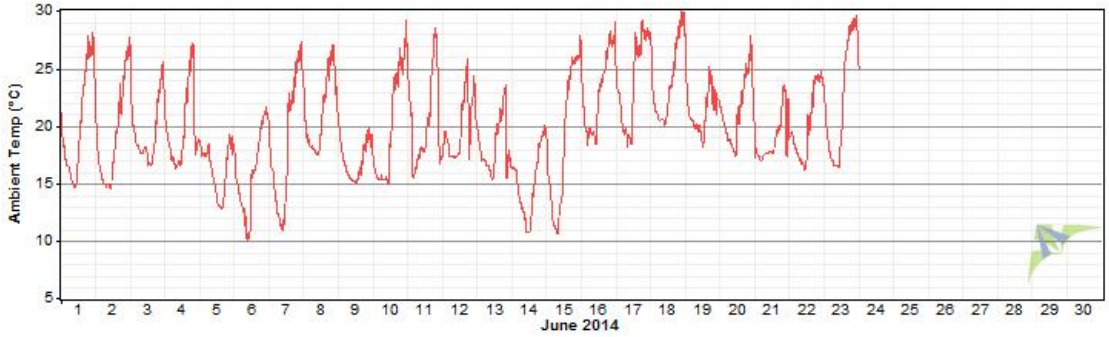
Wind Speed Data



Wind Direction Data



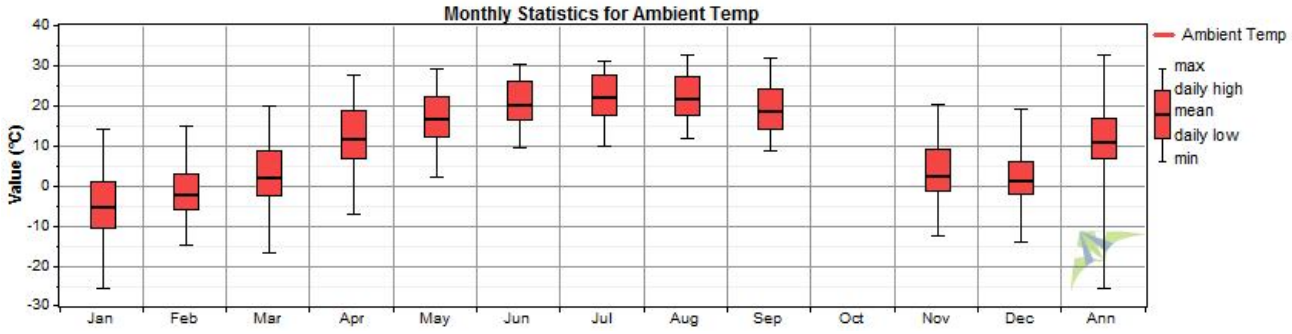
Temperature Data



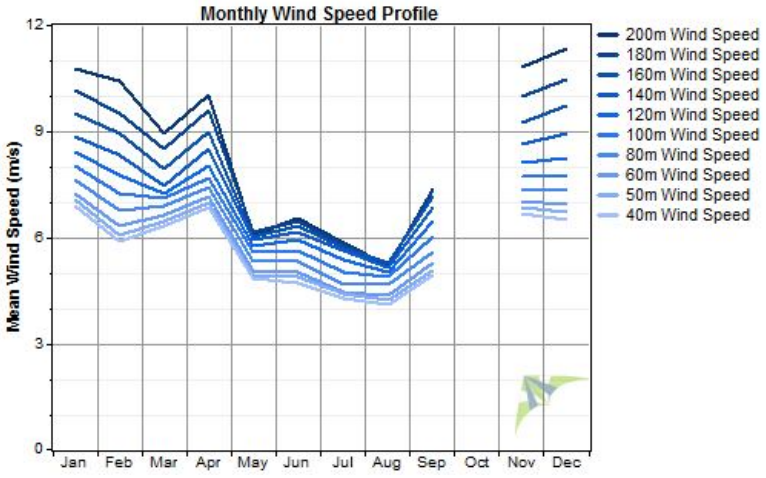
Data Set Properties

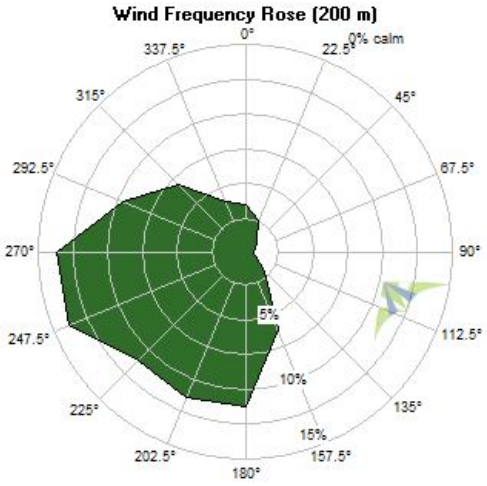
Report Created: 11/19/2014 15:07 using Windographer 2.4.13
Filter Settings: <Unflagged data>

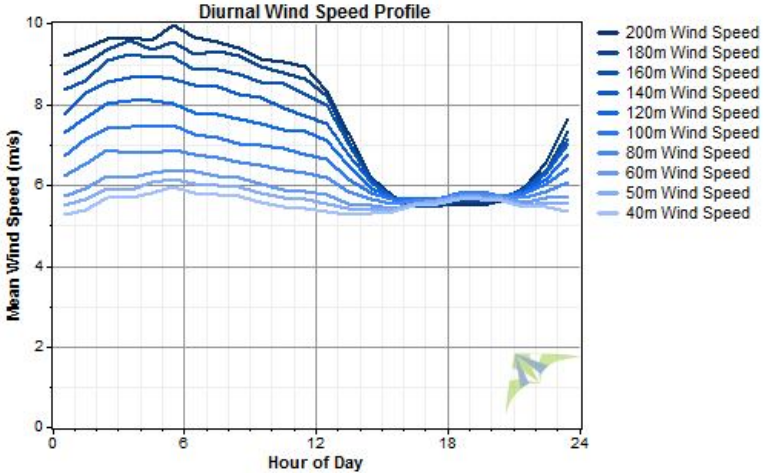
Variable	Value
Latitude	N 38.441000
Longitude	W 80.611000
Elevation	819 m
Start date	5/4/2010 00:10
End date	6/24/2014 00:10
Duration	4.1 years
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	11.0 °C
Mean pressure	923.0 mbar
Mean air density	1.131 kg/m³
Power density at 50m	192 W/m²
Wind power class	1 (Poor)
Power law exponent	0.179
Surface roughness	0.349 m
Roughness class	3.04
Roughness description	Many trees

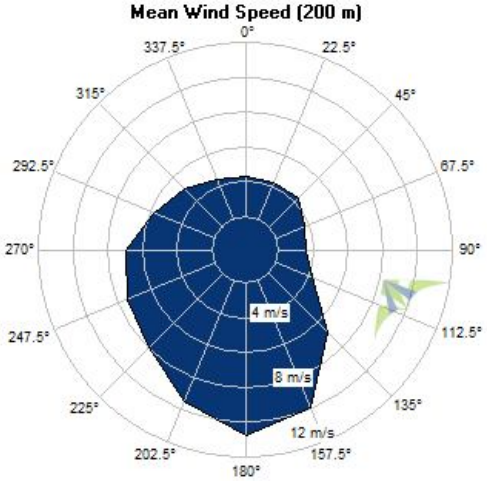


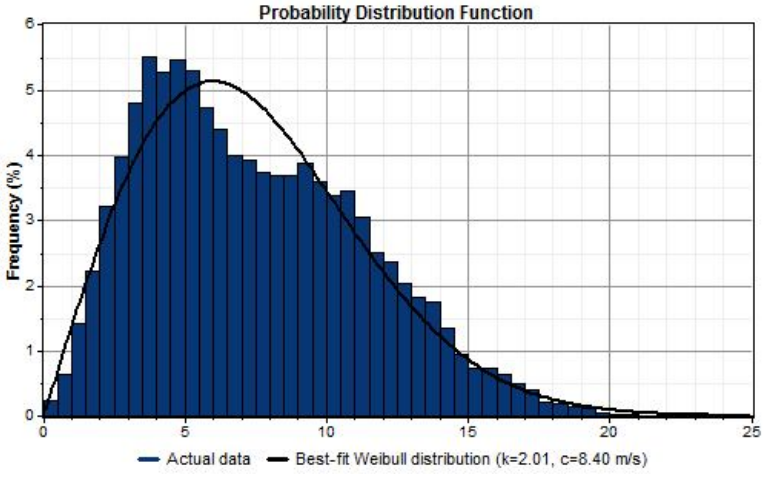
Wind Speed and Direction

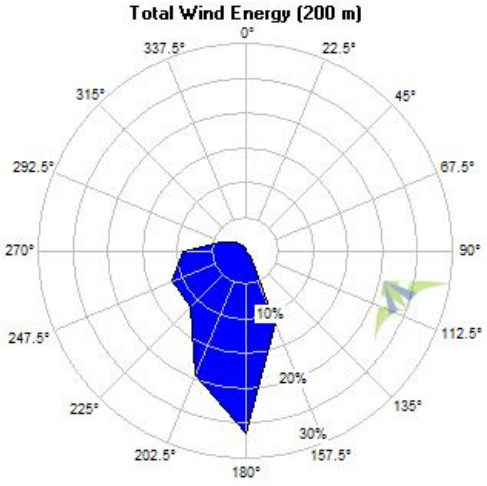




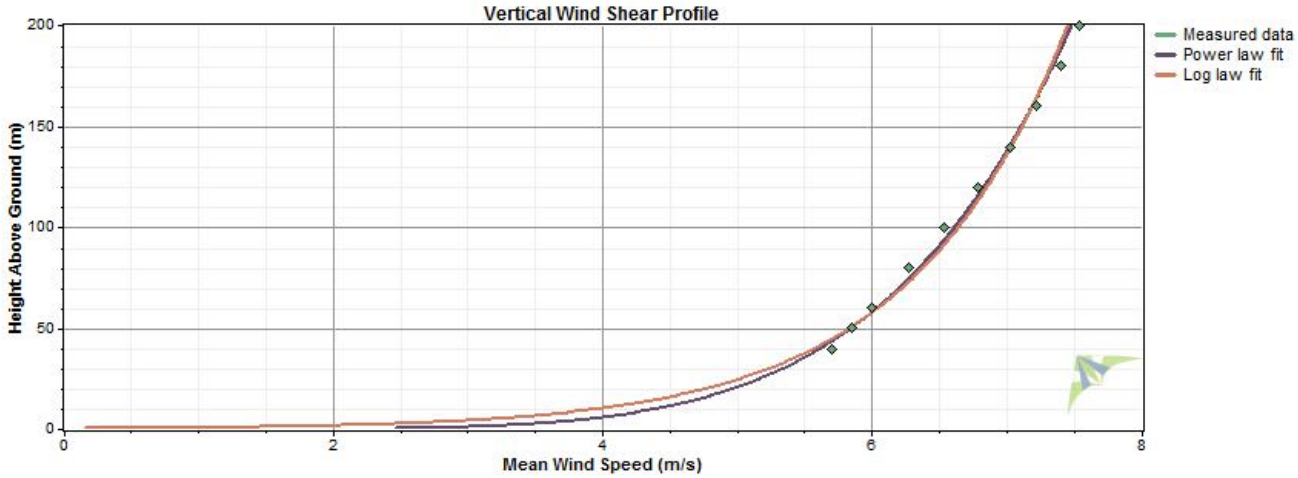


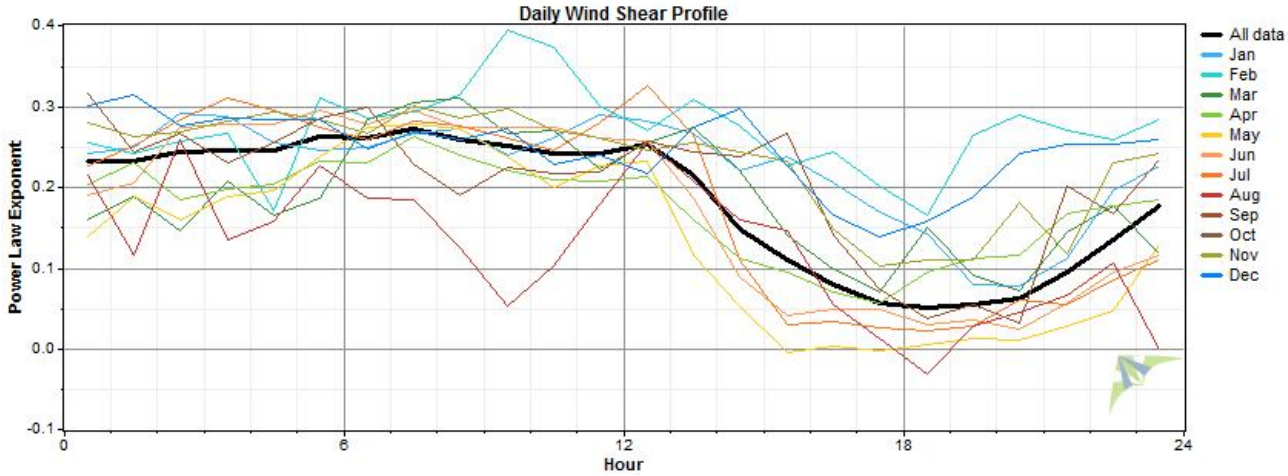


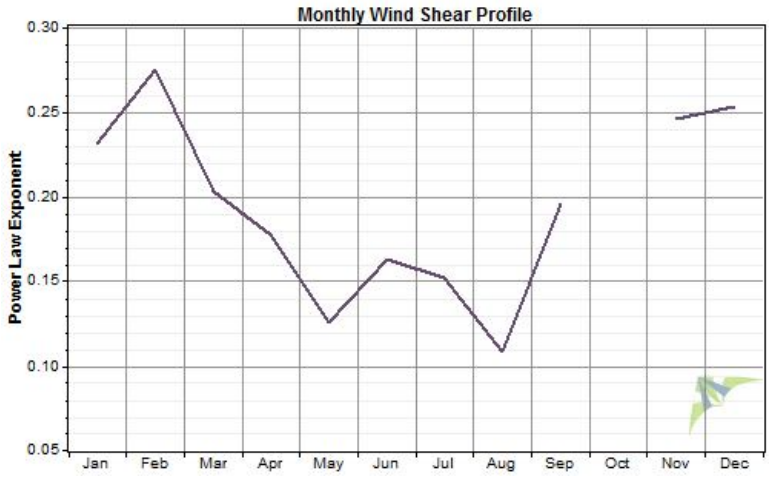


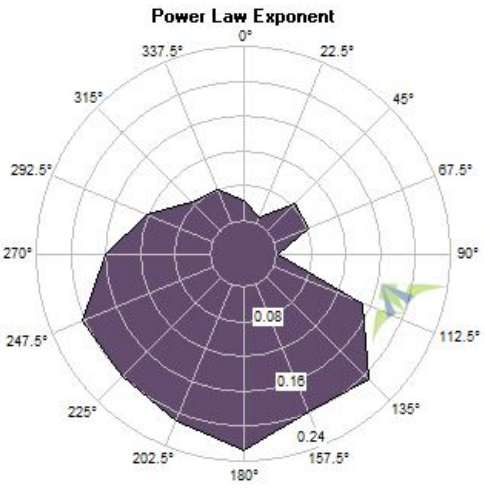


Wind Shear

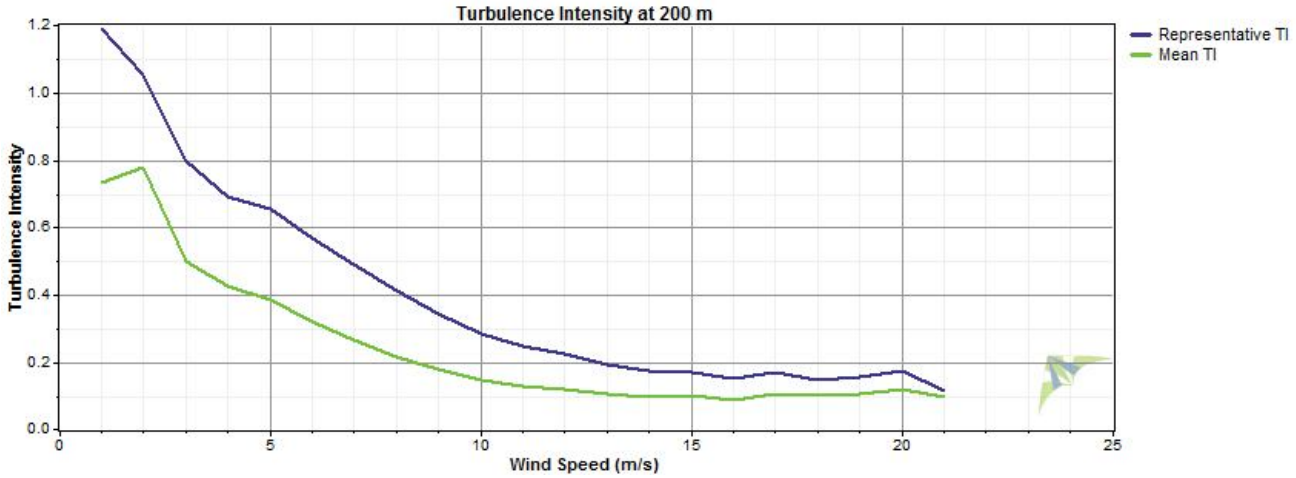

Vertical Wind Shear Profile
Height Above Ground (m)
Mean Wind Speed (m/s)
Measured data
Power law fit
Log law fit

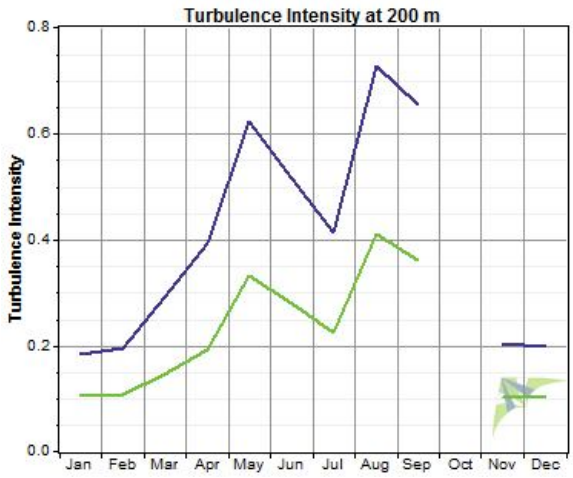

Daily Wind Shear Profile
Power Law Exponent
Hour
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

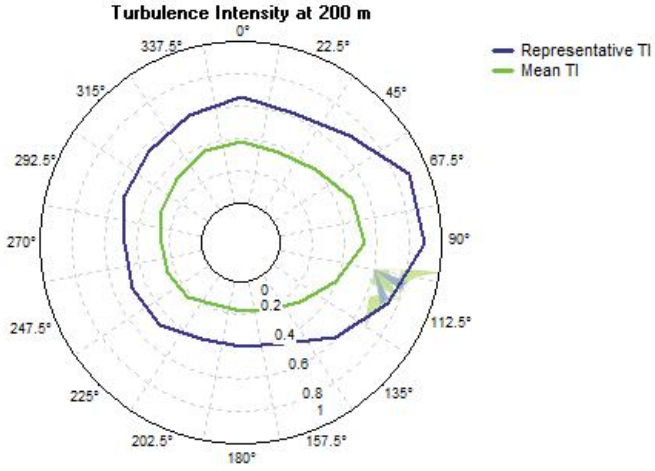

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

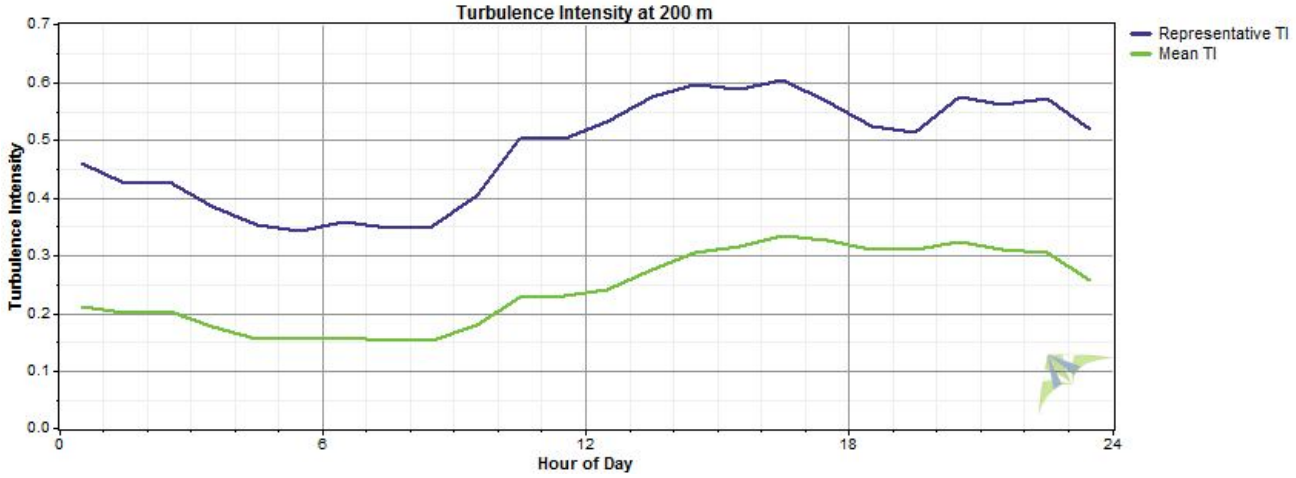

Power Law Exponent
0.08
0.16
0.24

Turbulence Intensity









Data Column Properties

Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	40m Wind Direction	°	40 m	217,728	51,060	23.45	226.0	0.0	360.0	82.9
2	40m Wind Speed	m/s	40 m	217,728	51,060	23.45	5.54	0.06	19.65	2.68
3	40m Wind Vert	m/s		217,728	51,060	23.45	0.038	-9.440	4.660	0.848
4	Quality (Station Height 40m)	%		217,728	51,060	23.45	98.1	85.0	100.0	1.9
5	50m Wind Direction	°	50 m	217,728	50,625	23.25	227.1	0.0	360.0	82.6
6	50m Wind Speed	m/s	50 m	217,728	50,625	23.25	5.70	0.06	19.08	2.75
7	50m Wind Vert	m/s		217,728	50,625	23.25	0.023	-9.500	4.670	0.852
8	Quality (Station Height 50m)	%		217,728	50,625	23.25	98.0	85.0	100.0	2.1
9	60m Wind Direction	°	60 m	217,728	49,890	22.91	228.1	0.0	360.0	82.5
10	60m Wind Speed	m/s	60 m	217,728	49,890	22.91	5.86	0.01	20.19	2.82
11	60m Wind Vert	m/s		217,728	49,890	22.91	0.012	-9.910	4.780	0.852
12	Quality (Station Height 60m)	%		217,728	49,890	22.91	97.8	85.0	100.0	2.3
13	80m Wind Direction	°	80 m	217,728	47,868	21.99	229.6	0.0	360.0	81.4
14	80m Wind Speed	m/s	80 m	217,728	47,868	21.99	6.18	0.03	21.69	2.95
15	80m Wind Vert	m/s		217,728	47,868	21.99	0.000	-9.460	4.750	0.832
16	Quality (Station Height 80m)	%		217,728	47,868	21.99	97.4	85.0	100.0	2.6
17	100m Wind Direction	°	100 m	217,728	45,191	20.76	230.4	0.0	360.0	80.2
18	100m Wind Speed	m/s	100 m	217,728	45,191	20.76	6.50	0.06	24.86	3.06
19	100m Wind Vert	m/s		217,728	45,191	20.76	-0.003	-9.060	5.820	0.831
20	Quality (Station Height 100m)	%		217,728	45,191	20.76	96.8	85.0	100.0	3.0
21	120m Wind Direction	°	120 m	217,728	41,100	18.88	230.7	0.0	360.0	79.0
22	120m Wind Speed	m/s	120 m	217,728	41,100	18.88	6.80	0.10	30.43	3.20
23	120m Wind Vert	m/s		217,728	41,100	18.88	0.000	-9.630	6.790	0.832
24	Quality (Station Height 120m)	%		217,728	41,100	18.88	96.0	85.0	100.0	3.3
25	140m Wind Direction	°	140 m	217,728	35,405	16.26	230.2	0.0	360.0	77.1
26	140m Wind Speed	m/s	140 m	217,728	35,405	16.26	7.07	0.04	36.01	3.38
27	140m Wind Vert	m/s		217,728	35,405	16.26	-0.008	-9.280	6.800	0.877
28	Quality (Station Height 140m)	%		217,728	35,405	16.26	95.3	85.0	100.0	3.6
29	160m Wind Direction	°	160 m	217,728	29,441	13.52	229.4	0.0	360.0	76.0
30	160m Wind Speed	m/s	160 m	217,728	29,441	13.52	7.26	0.05	24.10	3.55
31	160m Wind Vert	m/s		217,728	29,441	13.52	-0.017	-9.750	6.990	0.933
32	Quality (Station Height 160m)	%		217,728	29,441	13.52	94.7	85.0	100.0	3.8
33	180m Wind Direction	°	180 m	217,728	24,197	11.11	228.2	0.1	360.0	75.6
34	180m Wind Speed	m/s	180 m	217,728	24,197	11.11	7.35	0.01	20.87	3.73
35	180m Wind Vert	m/s		217,728	24,197	11.11	-0.037	-9.010	7.380	1.037
36	Quality (Station Height 180m)	%		217,728	24,197	11.11	94.3	85.0	100.0	3.8
37	200m Wind Direction	°	200 m	217,728	19,890	9.14	228.7	0.0	359.9	75.3
38	200m Wind Speed	m/s	200 m	217,728	19,890	9.14	7.43	0.03	21.36	3.89
39	200m Wind Vert	m/s		217,728	19,890	9.14	-0.046	-9.640	7.670	1.130
40	Quality (Station Height 200m)	%		217,728	19,890	9.14	93.7	85.0	100.0	3.7
41	40m Wind Turbulence	m/s	40 m	217,728	41,580	19.10	0.129	0.030	1.670	0.084
42	50m Wind Turbulence	m/s	50 m	217,728	41,701	19.15	0.134	0.020	1.250	0.093
43	60m Wind Turbulence	m/s	60 m	217,728	41,365	19.00	0.138	0.030	1.280	0.101
44	80m Wind Turbulence	m/s	80 m	217,728	40,270	18.50	0.149	0.030	1.350	0.117
45	100m Wind Turbulence	m/s	100 m	217,728	38,666	17.76	0.161	0.030	1.340	0.130
46	120m Wind Turbulence	m/s	120 m	217,728	35,598	16.35	0.177	0.030	1.660	0.148
47	140m Wind Turbulence	m/s	140 m	217,728	30,753	14.12	0.192	0.030	1.440	0.160
48	160m Wind Turbulence	m/s	160 m	217,728	25,522	11.72	0.210	0.030	1.630	0.173
49	180m Wind Turbulence	m/s	180 m	217,728	20,817	9.56	0.231	0.030	1.600	0.189
50	200m Wind Turbulence	m/s	200 m	217,728	16,905	7.76	0.251	0.030	1.670	0.202
51	Turbu. Quality (Station Height 40m)	%		217,728	41,580	19.10	98.1	85.0	100.0	2.6
52	Turbu. Quality (Station Height 50m)	%		217,728	41,701	19.15	97.9	85.0	100.0	2.7

Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	Turbu. Quality (Station Height 60m)	%		217,728	41,365	19.00	97.8	85.0	100.0	2.7
54	Turbu. Quality (Station Height 80m)	%		217,728	40,270	18.50	97.4	85.0	100.0	2.9
55	Turbu. Quality (Station Height 100m)	%		217,728	38,666	17.76	96.8	85.0	100.0	3.2
56	Turbu. Quality (Station Height 120m)	%		217,728	35,598	16.35	95.9	85.0	100.0	3.5
57	Turbu. Quality (Station Height 140m)	%		217,728	30,753	14.12	95.2	85.0	100.0	3.8
58	Turbu. Quality (Station Height 160m)	%		217,728	25,522	11.72	94.6	85.0	100.0	3.9
59	Turbu. Quality (Station Height 180m)	%		217,728	20,817	9.56	94.2	85.0	100.0	3.9
60	Turbu. Quality (Station Height 200m)	%		217,728	16,905	7.76	93.7	85.0	100.0	3.8
61	Ambient Temp	°C		217,728	52,100	23.93	11.03	-25.70	32.50	11.54
62	Barometric Pressure	mbar		217,728	52,100	23.93	923	895	1,056	7
63	Azimuth	Â°		217,728	52,100	23.93	0	0	0	0
64	TiltY	Â°		217,728	52,100	23.93	-0.49	-51.70	53.60	3.40
65	TiltX	Â°		217,728	52,100	23.93	0.01	-68.10	44.60	2.91
66	Humidity	%		217,728	52,100	23.93	69.39	13.00	97.00	14.89
67	Noise Level-A	dB		217,728	52,100	23.93	12.47	5.00	17.20	2.00
68	Noise Level-B	dB		217,728	52,100	23.93	12.51	5.00	17.40	2.02
69	Noise Level-C	dB		217,728	52,100	23.93	12.48	5.00	17.20	2.00
70	Modem Power	W		217,728	52,100	23.93	0.460	0.000	1.700	0.334
71	CPU Power	W		217,728	52,100	23.93	1.889	1.000	2.900	0.589
72	Core Power	W		217,728	52,100	23.93	2.897	2.100	3.700	0.404
73	PWM Power	W		217,728	52,100	23.93	1.137	0.600	2.200	0.188
74	Speaker Power	W		217,728	52,100	23.93	4.31	0.00	19.40	2.80
75	Solar Power	W		217,728	52,100	23.93	0	0	0	0
76	Heater Temp	Â°C		217,728	52,100	23.93	0	0	0	0
77	Mirror Temp	Â°C		217,728	52,100	23.93	13.75	-25.90	52.30	13.82
78	Internal Temp	Â°C		217,728	52,100	23.93	15.07	-24.90	43.90	12.82
79	CPU Temp	Â°C		217,728	52,100	23.93	0	0	0	0
80	VibrationX	g		217,728	52,100	23.93	0	0	0	0
81	VibrationY	g		217,728	52,100	23.93	0	0	0	0
82	Battery	V		217,728	52,100	23.93	12.92	11.30	15.50	0.81
83	Beep Volume	dB		217,728	52,100	23.93	92.9	0.0	100.0	25.6
84	GE 1.5sle Power Output	kW		217,728	47,868	21.99	313	0	1,500	405
85	Air Density	kg/m³		217,728	217,728	100.00	1.131	1.030	1.306	0.024
86	200m Wind Speed WPD	W/m²		217,728	19,890	9.14	438	0	5,475	617
87	180m Wind Speed WPD	W/m²		217,728	24,197	11.11	411	0	5,029	562
88	160m Wind Speed WPD	W/m²		217,728	29,441	13.52	382	0	7,619	506
89	140m Wind Speed WPD	W/m²		217,728	35,405	16.26	348	0	25,732	500
90	120m Wind Speed WPD	W/m²		217,728	41,100	18.88	306	0	15,484	410
91	100m Wind Speed WPD	W/m²		217,728	45,191	20.76	267	0	8,374	349
92	80m Wind Speed WPD	W/m²		217,728	47,868	21.99	233	0	5,698	310
93	60m Wind Speed WPD	W/m²		217,728	49,890	22.91	201	0	4,609	276
94	50m Wind Speed WPD	W/m²		217,728	50,625	23.25	186	0	3,889	258
95	40m Wind Speed WPD	W/m²		217,728	51,060	23.45	171	0	4,416	244

This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height, then click Calculate Output.

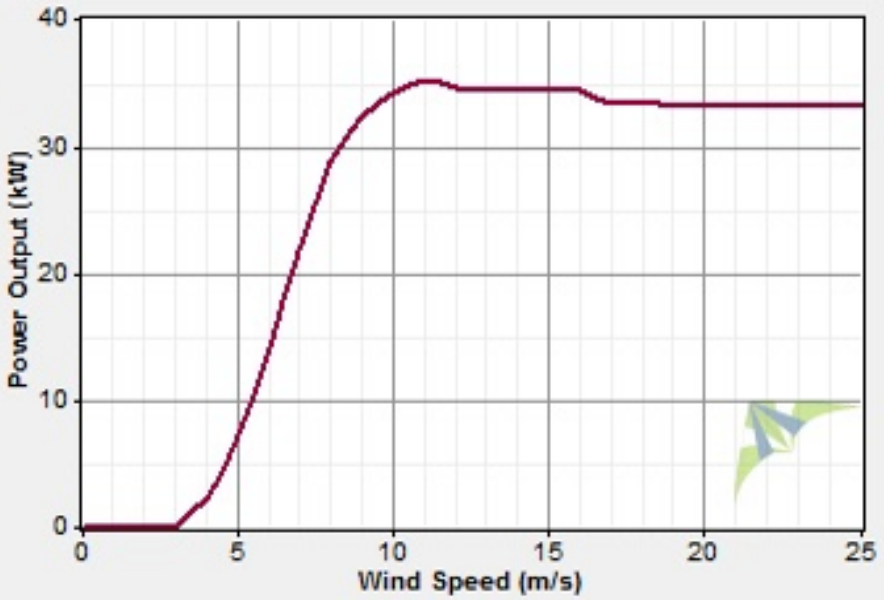
Wind turbine: Endurance G-3120 | Details... | Edit... | New... | Delete... | Compare...

Properties

Manufacturer:	Endurance Wind Power
Website:	www.endurancewindpower.c
Rotor diameter:	19.2 m
Rated power:	35 kW
Power regulation:	Stall control

Hub height

- ○ 30.5 m
- ◉ 42.7 m
- ○ Other 70 m



Losses

Downtime losses (%)	6
Array losses (%)	5
Icing/soiling losses (%)	4
Other losses (%)	4
Overall loss factor (%)	17.70

Calculate Output

◉ Monthly details
○ Turbine comparison

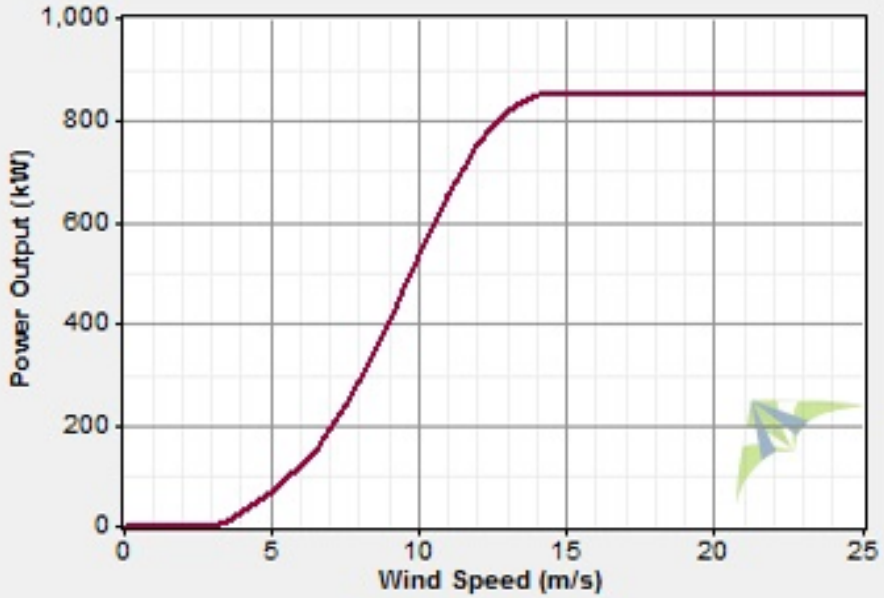
Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,400	6.86	8.23	1.84	15.0	11,177	42.9
Feb	3,692	5.84	20.72	0.00	11.2	7,523	32.0
Mar	4,432	6.29	13.92	0.29	12.6	9,367	36.0
Apr	4,318	6.80	12.02	0.00	14.2	10,192	40.4
May	6,192	4.73	24.50	0.00	6.7	4,978	19.1
Jun	7,429	4.67	23.35	0.00	6.3	4,543	18.0
Jul	4,397	4.20	27.66	0.00	4.7	3,464	13.3
Aug	4,390	3.97	36.86	0.00	4.4	3,287	12.6
Sep	3,928	4.79	28.03	0.00	7.3	5,271	20.9
Oct	0	n/a	n/a	n/a	n/a	n/a	n/a
Nov	3,628	6.65	7.39	0.25	14.3	10,272	40.8
Dec	4,428	6.50	6.32	0.02	13.2	9,835	37.8
Overall	51,234	5.48	19.51	0.20	9.6	84,049	27.4

This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height, then click Calculate Output.

Wind turbine: Vestas V52 - 850 kW | Details... | Edit... | New... | Delete... | Compare...

Properties

Manufacturer: Vestas Wind Systems A/S
Website: www.vestas.com
Rotor diameter: 52 m
Rated power: 850 kW
Power regulation: Pitch control



Hub height

- 40 m
- 44 m
- 49 m
- 55 m
- 60 m
- 65 m
- (•) 74 m
- 86 m
- Other: 70 m

Losses

Downtime losses (%)	6
Array losses (%)	5
Icing/soiling losses (%)	4
Other losses (%)	4
Overall loss factor (%)	17.70

Calculate Output

(•) Monthly details
( ) Turbine comparison

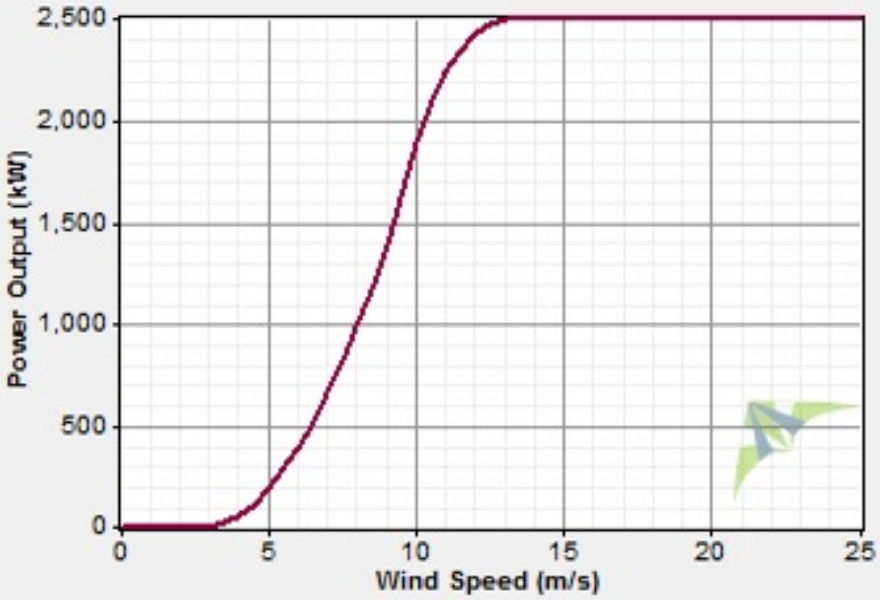
Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,400	7.52	7.32	0.41	243.6	181,252	28.7
Feb	3,692	6.38	17.47	0.65	179.5	120,657	21.1
Mar	4,432	6.76	12.27	0.74	192.7	143,389	22.7
Apr	4,318	7.33	10.75	0.25	226.8	163,280	26.7
May	6,192	5.11	21.87	0.05	88.8	66,074	10.4
Jun	7,429	5.17	19.76	0.00	88.9	64,006	10.5
Jul	4,397	4.60	26.84	0.02	60.8	45,267	7.2
Aug	4,390	4.41	32.82	0.00	60.1	44,696	7.1
Sep	3,928	5.34	22.61	0.10	104.7	75,377	12.3
Oct	0	n/a	n/a	n/a	n/a	n/a	n/a
Nov	3,628	7.24	6.31	0.30	214.5	154,473	25.2
Dec	4,428	7.21	5.31	0.84	209.3	155,694	24.6
Overall	51,234	5.99	17.12	0.28	144.9	1,269,699	17.1

This window calculates the energy output of a wind turbine in this wind regime. Select a type of wind turbine and a hub height, then click Calculate Output.

Wind turbine: GE 2.5xl | Details... | Edit... | New... | Delete... | Compare...

Properties

Manufacturer: GE Wind
Website: www.gepower.com
Rotor diameter: 100 m
Rated power: 2,500 kW
Power regulation: Pitch control



Hub height

- (•) 75 m
- ( ) 85 m
- ( ) 100 m
- ( ) Other 70 m

Losses

Downtime losses (%)	6
Array losses (%)	5
Icing/soiling losses (%)	4
Other losses (%)	4
Overall loss factor (%)	17.70

Calculate Output

(•) Monthly details
( ) Turbine comparison

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,400	7.53	7.32	3.43	818.0	608,609	32.7
Feb	3,692	6.40	17.36	3.22	597.3	401,379	23.9
Mar	4,432	6.77	12.25	2.28	645.2	480,061	25.8
Apr	4,318	7.34	10.65	2.50	761.8	548,510	30.5
May	6,192	5.12	21.80	0.16	292.6	217,679	11.7
Jun	7,429	5.19	19.68	0.11	295.2	212,537	11.8
Jul	4,397	4.61	26.70	0.07	197.5	146,915	7.9
Aug	4,390	4.42	32.57	0.05	196.7	146,368	7.9
Sep	3,928	5.35	22.53	0.41	350.3	252,231	14.0
Oct	0	n/a	n/a	n/a	n/a	n/a	n/a
Nov	3,628	7.25	6.31	1.38	727.3	523,665	29.1
Dec	4,428	7.23	5.31	2.35	704.0	523,789	28.2
Overall	51,234	6.01	17.04	1.31	484.5	4,244,124	19.4