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

Penn Virginia Resource Partners and Eagle Land Holding Company

Republic Energy Surface Mine Operations

Kayford Mountain Area, Raleigh County, West Virginia

(Data Evaluation Period: March 4, 2011 to April 18, 2012)

Compiled by:

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

With Assistance from:

Marshall University Center for Business and Economic Research (CBER)

Under Direction of:

West Virginia Division of Energy

Funded by:

Appalachian Regional Commission

West Virginia Division of Energy

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1.0 Introduction

Marshall University's Center for Environmental, Geotechnical and Applied Sciences (CEGAS) has partnered with the West Virginia Division of Energy to perform initial screening and wind resource data collection to assess wind energy development opportunities at selected surface mine properties in West Virginia using Sonic Detection and Ranging (SODAR) technologies. This report has been compiled with assistance from Marshall University's Center for Business and Economic Research (CBER), with 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 Republic Energy surface mine complex, located in the Kayford Mountain area of Raleigh County, approximately 3 miles West of the community of Kingston and the WV Turnpike (Interstate 64 and 77). The area was accessed using Kayford Mountain Road, then using the Republic Mining haul road. The site includes several thousand acres or existing and reclaimed surface mine lands. The SODAR was placed on a reclaimed ridgeline at Latitude 37.96839, Longitude -81.34753, at an elevation of 2,861 feet (872 meters) above mean sea level. This area is along a network of ridgelines, part of large reclaimed surface mine area, with active surface mine operations located generally west, northwest and northeast. A general site location map is provided in Appendix A.

The immediately surrounding area consists of reclaimed surface mine property. Minimal ground vegetation is present, and much of the immediate area is in the early stages of reclamation. An access road and electric power lines are located generally north of the SODAR location, with minimal traffic and/or related noise from surface mine operations that would affect SODAR data collection. Reclamation activities are ongoing in the immediate area. Republic Mining's maintenance and office facilities are located to the immediate north.

The main property owner of reclaimed, current and future tracts of the Republic mining complex is Penn Virginia Resource Partners with smaller tracts owned by various landowners. The tract where the SODAR was located is owned by Eagle Land Holding Company.

1.2 Data Collection Description

Wind resource data was collected using a Triton™ Sonic Wind Profiler, manufactured by SecondWind, utilizing SODAR technology. Data collection occurred during the period of March 4, 2011 to April 18, 2012. Photos showing the Triton unit and surrounding area are included in Appendix 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, as provided by SecondWind, 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 Form and Checklist is included in Appendix 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 90% wind speed quality factor, as recommended by Second Wind, was used. During the time frame for this study, the SODAR unit operated continuously, with the exception of a non-operational period of approximately 2 weeks in October of 2011, due to a malfunction that occurred during system upgrades conducted by the manufacturer.

3.0 Results and Data Comparisons

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 2.4.8 was used for data analysis. Cumulative wind speed mean averages at various elevations above the ground surface during the study period ranged from 5.7 meters per second (m/s) at 40 meters, increasing fairly consistently to 6.7 m/s at 200 meters. Wind direction was predominantly from the southwest to north-northwest, with mean wind directions generally west-southwest. Table 1 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:

TABLE 1: Wind Speed, Wind Direction, Vertical Wind and Power Density Summary

Elevation Above Ground Surface (872 m)	Wind Speed (m/s, mean)	Wind Direction (degrees, mean)	Vertical Wind Speed (m/s, mean)	Power Density (W/m^2, mean)
40 Meters	5.73	241.5	-0.129	185
50 Meters	5.79	242.5	-0.144	185
60 Meters	5.84	243.6	-0..152	186
80 Meters	5.94	245.4	-0.170	191
100 Meters	6.09	247.3	-0.197	203
120 Meters	6.25	248.7	-0.237	217
140 Meters	6.42	249.0	-0.289	236
160 Meters	6.59	248.9	-0.358	260
180 Meters	6.69	249.1	-0.440	274
200 Meters	6.76	249.8	-0.547	292

Appendix B contains 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. Complete SODAR field data collected is available upon request to the West Virginia Division of Energy.

3.1 Data Comparison to Estimated Wind Speeds

Data collected from the SODAR unit has been compared to available wind data evaluations for similar time periods to assess whether actual data obtained is representative of "normal"

expected wind conditions, or were unusual wind conditions recorded during the period. Three data sets were evaluated for this comparison.

3.1.1 AWS Truewind Monthly Wind Speed Estimates

AWS Truewind™ has formulated estimated average monthly wind speeds at 80 meters above ground surface for the U.S. As part of data collection efforts, CEGAS obtained this information for site-specific evaluation and comparison. According to AWS Truewind™, this data has been compiled based on a distribution of the annual wind speed by month, using various public and authorized private data sources, including data from over 1,400 wind monitoring stations in the U.S. and Canada. AWS Truewind™ states that "values have been determined objectively to be within 0.35 meters per second of the true speed at over 68% of points used". For the Kayford Mountain site, monthly data comparisons between AWS Truepower™ and actual SODAR data have been compared for the period of March 2011 through March 2012, and are provided in Table 2.

Table 2: AWS Truewind and SODAR Comparisons

Month	AWS Truewind Estimate (meters per second)	SODAR Recorded Wind Speed (meters per second)
March 2011	6.25	6.2
April 2011	5.8	7.2
May 2011	5.46	5.3
June 2011	4.67	5.1
July 2011	4.42	4.3
August 2011	4.47	5.2
September 2011	5.02	5.7
October 2011	5.46	6.0
November 2011	5.97	7.0
December 2011	6.46	6.7
January 2012	6.73	7.4
February 2011	6.27	6.1
March 2011	6.25	6.2

As the data reflects, both data sets are generally comparable, within 0.5 meters per second (m/s). SODAR results indicating more than 0.5 m/s above expected results were recorded in April, August, September, October and November 2011, plus January 2012. Monthly summary of SODAR at all elevations recorded, including AWS Truewind estimates, are provided in Appendix C.

3.1.2 AWS Truepower™ Annual Wind Speed Estimates

AWS Truepower™ issues Quarterly reports for the U.S. on wind speeds compared to long-term averages. This data is based on computer simulation of weather conditions dating back to 1997. For the period that most closely parallels the SODAR data collection time period (Second Quarter 2011 through first Quarter 2012), wind speeds were estimated at 0 to 3% above normal wind speeds for most of West Virginia. Complete details can be found at www.awstruepower.com. This data suggests that the SODAR wind speed data collected during this similar timeframe can be considered "normal".

3.1.3 3Tier™ Annual Wind Speed Estimates

Additional data was evaluated from 3Tier™. This company formulates a wind performance map for the U.S each year, using averaged wind condition data sets from 1969 through 2008. Based on 3Tier's™ numerical weather prediction model for 2011, the wind speed variance in the Kayford Mountain area was estimated at <5% above average. Additional details can be found at www.3tier.com. Based on this information, the wind speed data collected at the Kayford Mountain site should generally be considered "normal".

3.2 Data Comparison to Regional Airport Wind Speeds

In addition to wind speed data comparisons previously presented, data from the SODAR was also compared to two regional airports to analyze wind speed variations and trends. The Charleston Yeager Airport (CRW) is located approximately 30 miles north-northwest of the Kayford Mountain site, and the Raleigh County Memorial Airport (BKW) in Beckley is located approximately 17 miles to the southeast. A general site map showing the two airports in relation to the project site is included in Appendix C. A 13-month time period was used (March 2011 through March 2012) for this comparison, in addition to other historical time periods.

3.2.1 Site Elevation Comparisons

The approximate elevation of each location is provided in Table 3.

Table 3: Airport and SODAR Elevations

Location	Elevation (meters)
BKW	758 m
CRW	287 m
SODAR	872 m

The height differences of wind speed measurement devices for each location also vary. Without taking elevation into consideration, the SODAR unit measures wind speeds at multiple heights, from 40 to 200 meters. For the purpose of this comparison, only the 40 m wind speed readings were used. The altitudes of the airport anemometers are unknown, but are unlikely to be higher than 10 or 20 meters.

3.2.2 Wind Speed Comparison: 1-Year Trend

Average monthly wind speeds from March 4, 2011, to March 31, 2012, recorded by the SODAR unit were compared to average monthly wind speeds recorded at each airport location for the same time period. A simple correlation of monthly average wind speed for the SODAR at 40m and each of the two airports provides fairly strong trends. The SODAR and BKW have a simple correlation of 0.97 for the time period, and the SODAR and CRW have a 0.89 correlation. A graphical representation of this trend is provided in Figure 1.

Figure 1: Average Monthly Wind Speeds (March 4th, 2011 to March 31, 2012)

As is evidenced in Figure 1, although actual average monthly wind speeds varied (by as much as 4.5 m/s in November 2011), the trend of increasing and decreasing wind speeds of the 13 month period was consistent in each location.

3.2.3 Wind Speed Comparison: Quarterly Trend

Quarterly tend data can be helpful in analyzing wind speeds over a period of time by dividing the year into four segments. For this comparison, average quarterly wind speed data from BKW and CRW airports was mapped over a 16 quarter period beginning in Quarter 2, 2008. For four quarters as applicable, the average quarterly wind speed recorded by the SODAR unit is also included. For reference, Quarter 1 of any given year corresponds to the months of January, February and March. Subsequent quarters follow in like sequence. Figure 2 provides graphical representation of this relationship.

Figure 2: Average Quarterly Wind Speeds (2nd Quarter 2008 to 1st Quarter 2012)

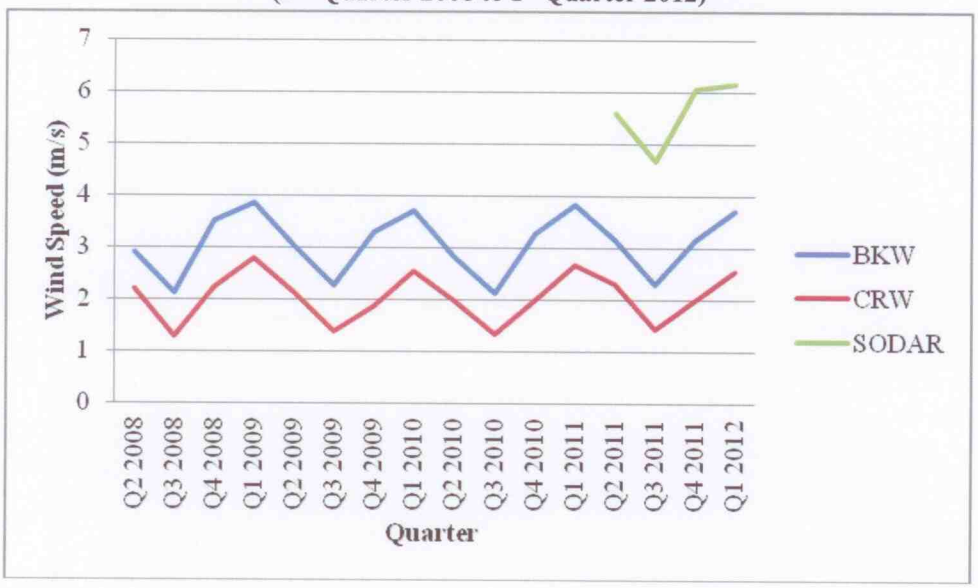
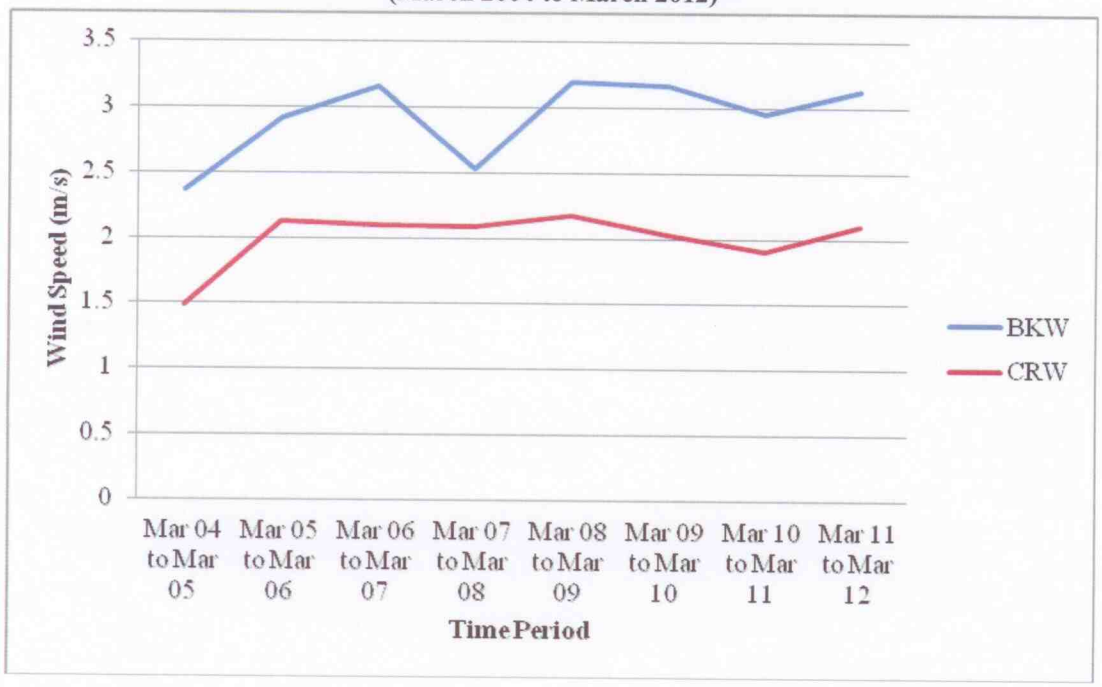


Figure 2 demonstrates a common trend between wind speed data recorded by the BKW and CRW airports over the time period. For available comparable data, the SODAR wind speeds recorded follow the same trend as well. Wind speed data for each of the third quarters—the quarter with the smallest average recorded wind speed—in this time period exhibits a slight increase from Quarter 3 2008 to Quarter 3 2011. By contrast, each of the first quarters—the quarter with the largest average recorded wind speed—in this time period displays a slight decrease in wind speed trend from Quarter 1 2009 to Quarter 1 2012.

3.2.4 Wind Speed Comparison: 8-Year Trend

For further comparison, the trend of annual average wind speeds for the two airports was also evaluated. As the average monthly wind speeds compared in Figure 1 range from the beginning of March 2011 to the end of March 2012, a similar time period is used for the annual trend. The time period from March 2004 to March 2005, for instance, begins on March 1, 2004, and ends on February 28, 2005. Results are provided in Figure 3.

Figure 3: Airport Average Annual Wind Speeds (March 2004 to March 2012)



The graphical representation in Figure 3 demonstrates more wind speed variation in the Beckley area than in Charleston, the most dramatic occurring in the March 2007 to March 2008 time period. Both airports reported a decrease in average annual wind speed for the March 2010 to March 2011 time period followed by an increase from March 2011 to March 2012. The time period from March 2008 to March 2009 reported the highest average annual wind speeds for the data set examined at both airports. The March 2004 to March 2005 time period reported the lowest average annual wind speeds for the data set examined at both airports.

3.3 Data Comparison to Existing Wind Farm Locations in Region

SODAR wind speed results have been compared to four existing wind farms in WV. For this comparison, AWS annual Truewind™ data at 80 meter elevation was used. At each location, the

maximum representative value found within the wind farm layout was used. Table 4 provides a summary of this data.

Table 4: WV Wind Farm Annual Wind Speeds and Capacity Factor

Site Name	80 Meter Wind Speed (meters per second)
Mountaineer Wind Energy Center	7.60
NedPower Mount Storm	7.66
Beech Ridge Energy	7.54
AES Laurel Mountain	7.06
Kayford Mountain Study Area	5.94 (SODAR value)

4.0 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 generally 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. Table 5 summarizes turbine properties and associated energy output and related information:

Table 5: Wind Turbine Energy Output Comparisons

Wind Turbine Model Number	Rated Power (kW)	Hub Height (meters)	Hub Height Wind Speed (m/s)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Endurance G-3120	35	42.7	5.62	87,603	28.6
Vestas V52	850	74	6.07	1,266,739	17.0
GE 2.5xl	2,500	75	6.08	4,237,771	19.4

Complete wind turbine comparison summaries are provided in Appendix D.

5.0 Conclusions and Recommendations

Wind resource data was collected from the Penn Virginia / Republic Energy surface mine site in the Kayford Mountain area of Raleigh County from March 4th, 2011 through April 18th, 2012. As expected, Summer months experienced the lowest wind speeds recorded, and late fall, winter and early Spring months experienced the highest wind speeds. The data compiled has been compared to applicable regional and national datasets and appears to be representative of what would generally be considered "normal" expected wind speeds, wind direction and related factors for this particular location. At the Kayford Mountain site, recorded wind resource data and associated net capacity factors suggest levels are somewhat below but approaching existing commercial wind energy development standards. With recent and on-going advancements in the wind energy industry, including increased turbine and blade efficiencies and the use of higher turbine tower heights, wind resources in the Kayford Mountain area may likely be considered for future potential wind energy development.

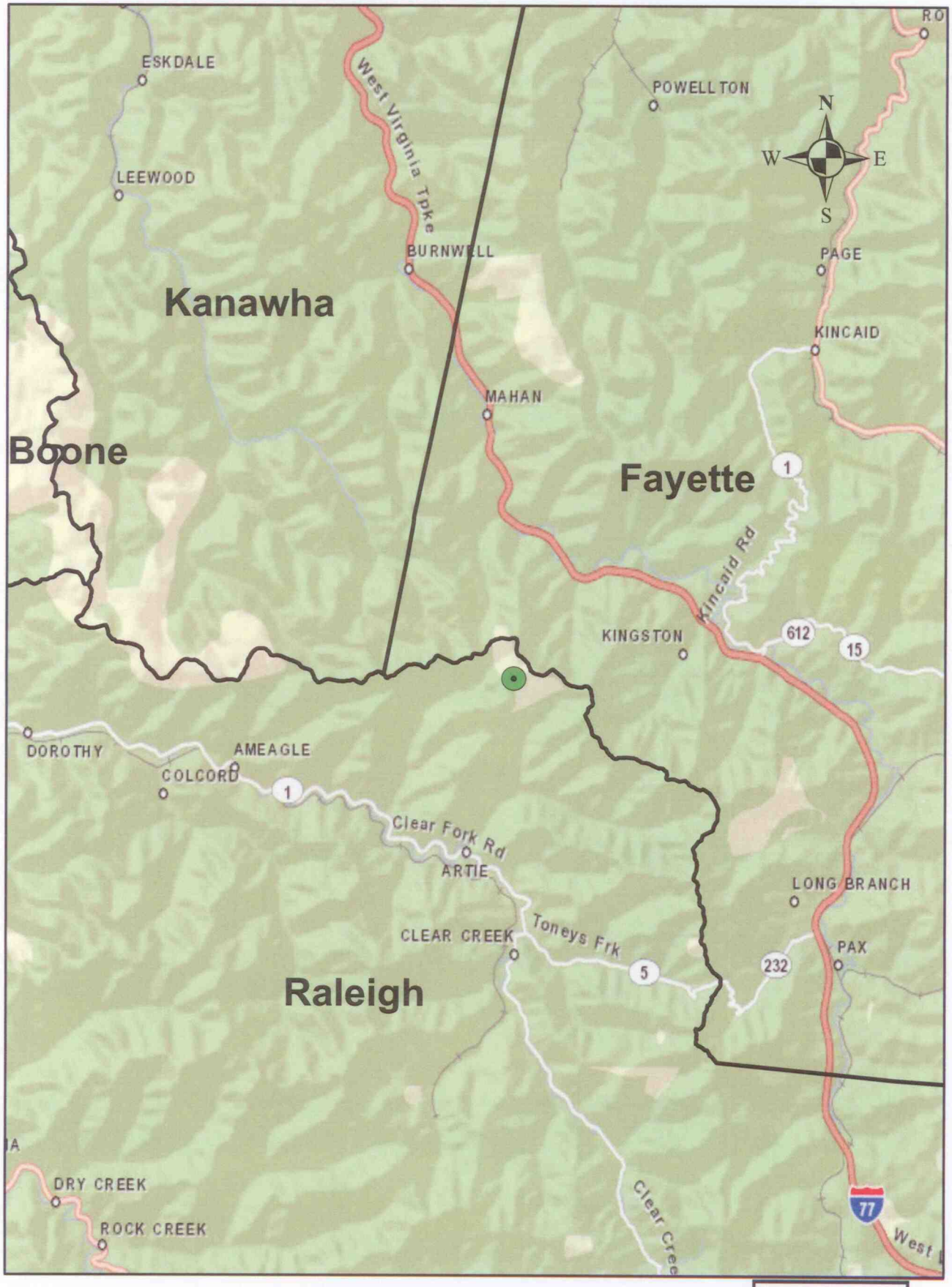
APPENDIX A

Site Location Map

Site Photos

SecondWind™ Site Information Form and Checklist

Kayford Mountain Site Map



Top View: SODAR unit looking East toward additional reclaimed surface mine land

Bottom View: SODAR with Active Surface Mining Operations to the Northwest

Top View: SODAR unit looking North with part of Mining Maintenance Facility in Background

Bottom View: Close-up View of SODAR on Utility Trailer with Security Fence

SECONDWIND

TRITON
SONIC WIND PROFILER

Site Information Form & Checklist

1. Triton Information				
Triton Site Name:	PennVirginia / Republic Energy - Kayford Mountain area, Raleigh County			
Triton Owner:	Marshall University CEGAS			
Install Date:				3-Mar
Triton Serial #:				#258
Triton Model:	Circle/Highlight:	**STD**	HP	HR
Personnel Present:	George Carico, Jamie Wolfe, Gary Begley (Penn Virginia)			

2. Site Information	
Surrounding Site Description (i.e. Windfarm, Forest, Field etc.)	Open ridgeline on reclaimed surface mine; minimal vegetation <1 meters tall
Road Access Description (i.e. 4WD required)	Gravel roads to site, 4WD required to reach area; Must be accompanied by Penn Vir
Gate Key Location/Security Details	Same lock used for security fence and Triton panel access
Front Door Lock Details (Combo or Key Location)	keyed lock, same for security fence
Property Management Contacts	Penn Virginia, Gary Begley, 304/949-5630

3. Fixed Object Vista Table

Description of Object	Azimuth (Deg)	Distance (m)	Height of Object (m)	Relative Elevation to Triton (m)
No objects >1 meters in area				

4. Installation Checklist			
Item	**✓**	**Unit**	**Value**
Mechanical Inspection		List Damage/Defects	**none**
Exterior Warning Sign Cover Removed (Heater Only)		none	
Triton Properly Oriented		Record Azimuth of B-Beam (deg mag)	**oriented south using compass**
Triton Secured		Method (i.e. earth anchors, trailer, snow platform, etc.)	**leveled trailer, security fence**
Batteries Charged (>12.7V)		Record voltage level, V - DC	**17.97**
Solar Panels Installed, Connected		# of Panels	**2**
Solar Panels Charging		V - DC	**charging**
Antifreeze Fluid Level (Heater Only)		none	**ok**
Propane Tanks installed		Tank capacity and level	**tanks turned on**
Propane Leak Test (Heater Only)		none	**ok**
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	**off**
Operator Panel: NOTA (self-test)		Red/Green/Rapid/Off/NA	**red**
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 directional photos taken**
Ambient Noise Level		dB	**minimal**
Ambient Noise Description		(i.e. Birds, Crickets, Highway)	**occasional trucks in area**
Triton Information (1) Section Complete		none	
Site Information (2) Section Complete		none	
Fixed Obstacle Vista Table (3) Complete		none	

Installer's Signature: George Carico

Date: 3-Mar

Installer's Name (print): George Carico

Installer's ID #:

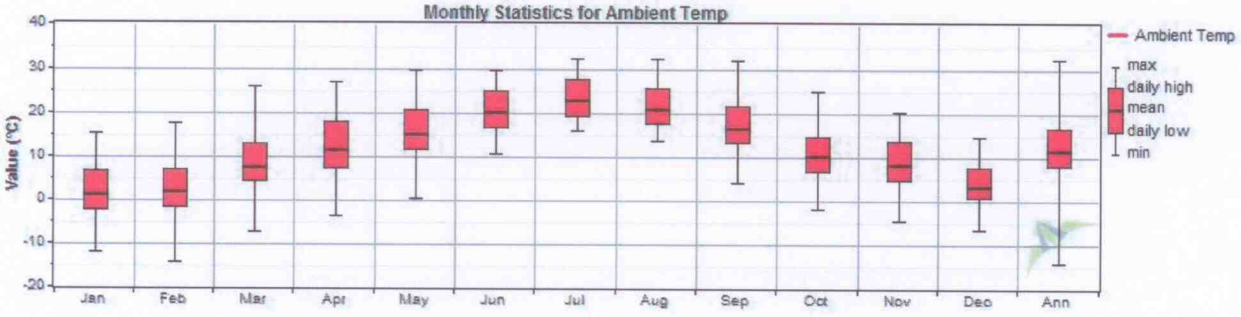
APPENDIX B

Windographer™ Summary Report

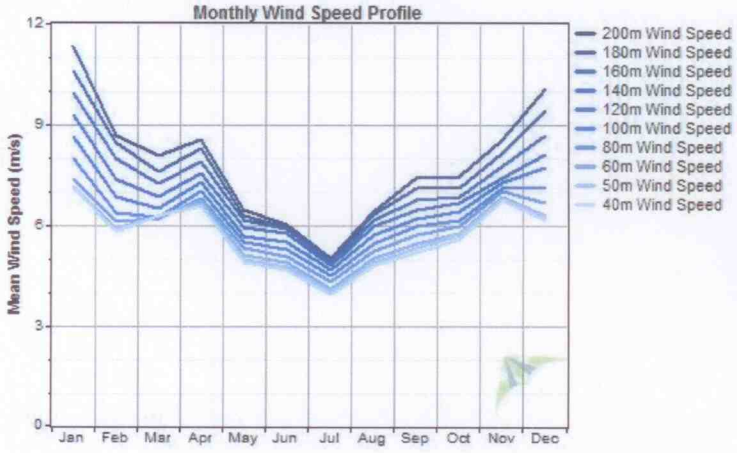
Data Set Properties

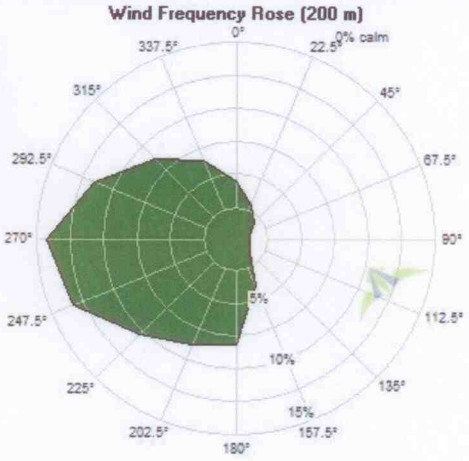
Report Created: 9/5/2012 15:47 using Windographer 2.4.8
Filter Settings: <Unflagged data>

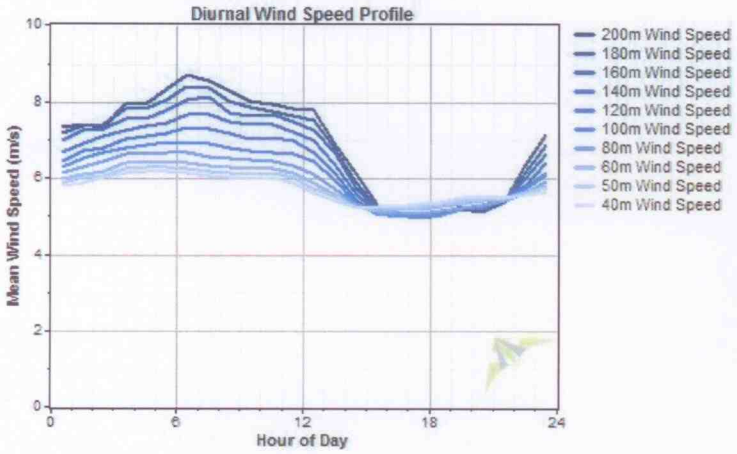
Variable	Value
Latitude	N 37.968390
Longitude	W 81.347530
Elevation	872 m
Start date	3/3/2011 00:10
End date	4/18/2012 15:20
Duration	14 months
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	11.4 °C
Mean pressure	918.7 mbar
Mean air density	1.126 kg/m³
Power density at 50m	173 W/m²
Wind power class	1 (Poor)
Power law exponent	0.16
Surface roughness	0.185 m
Roughness class	2.51
Roughness description	Many trees

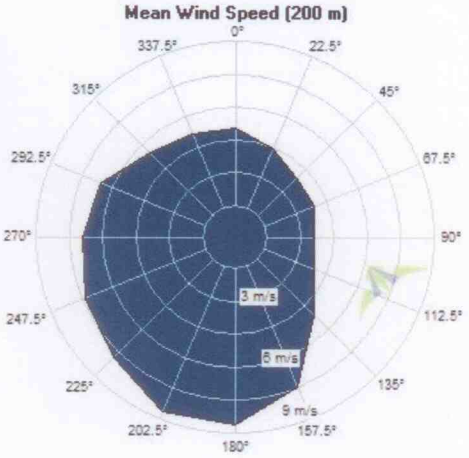


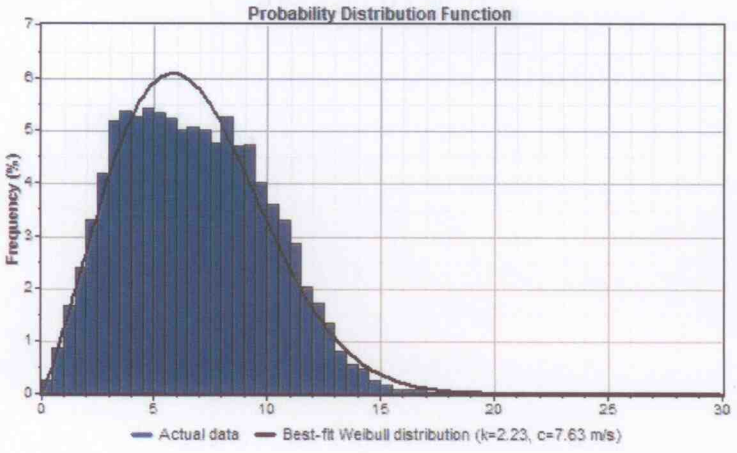
Wind Speed and Direction

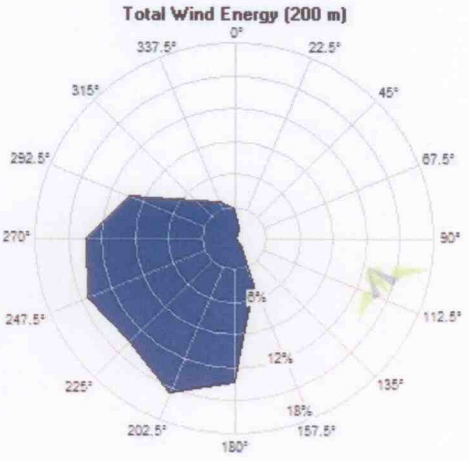




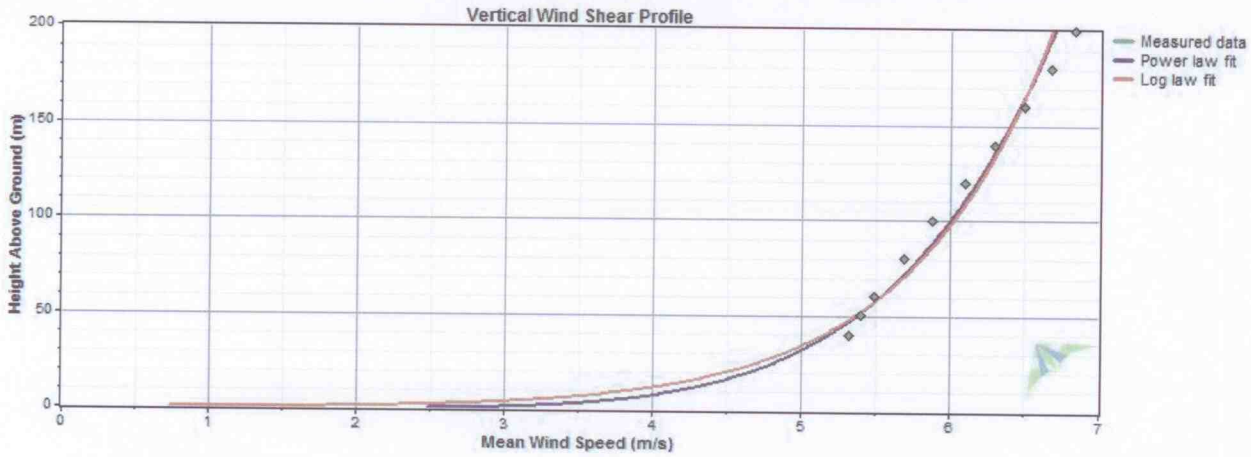


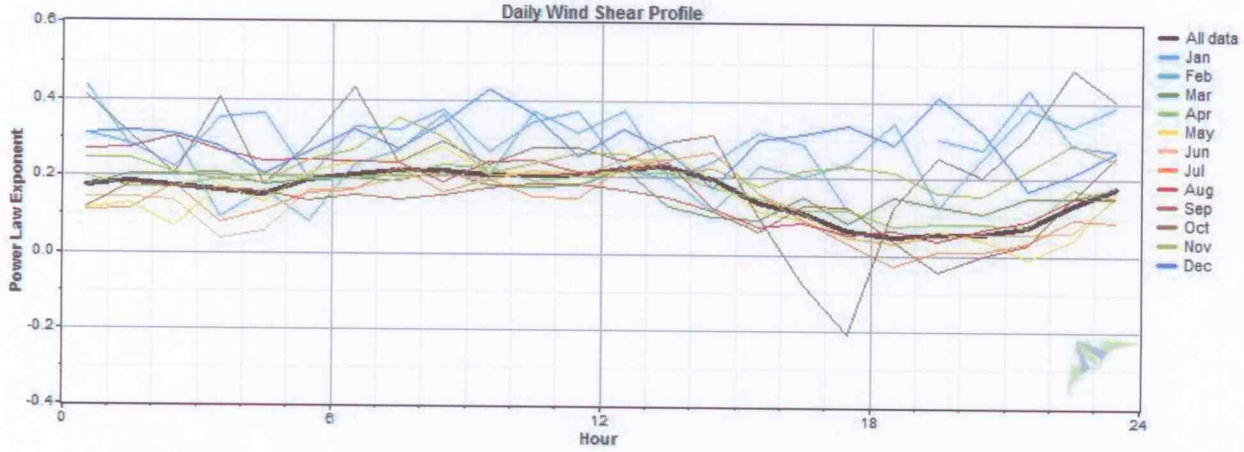


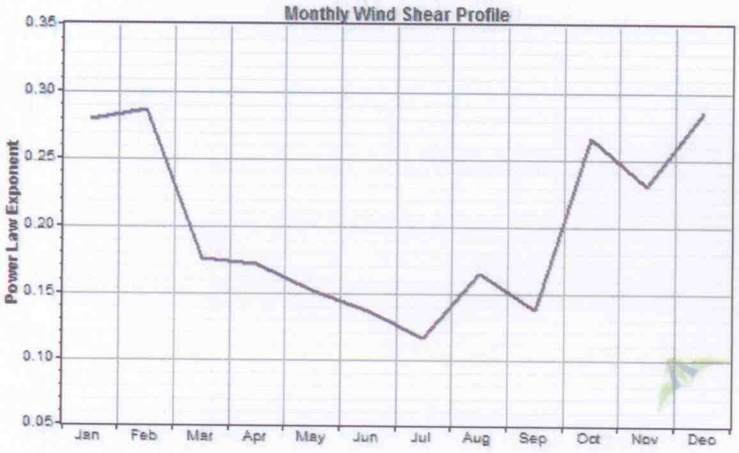


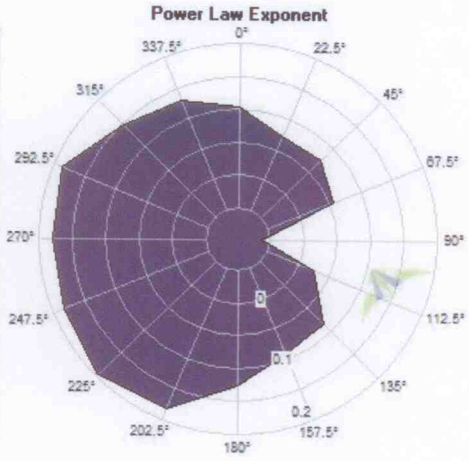


Wind Shear

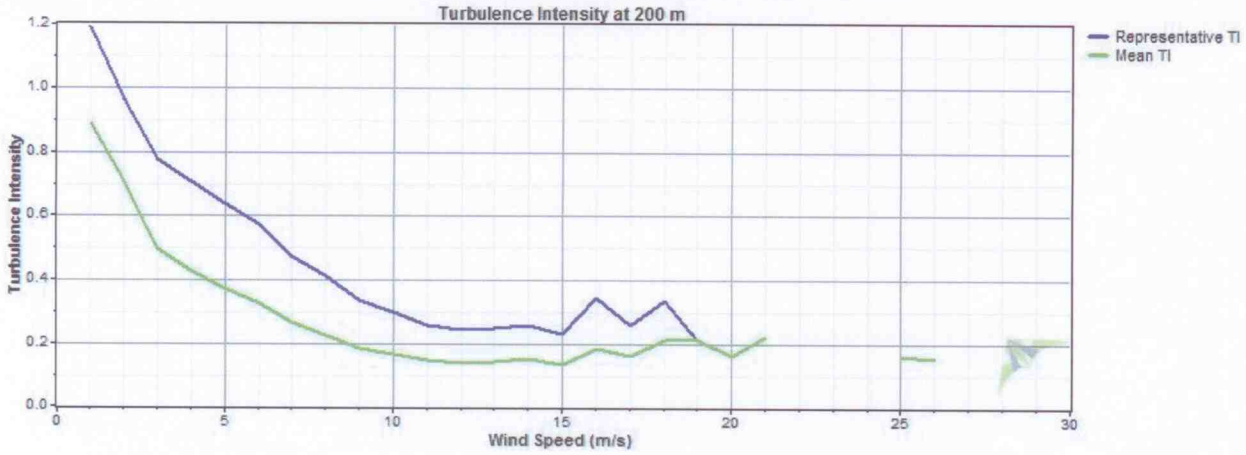

Vertical Wind Shear Profile
Height Above Ground (m)
Mean Wind Speed (m/s)
Measured data
Power law fit
Log law fit

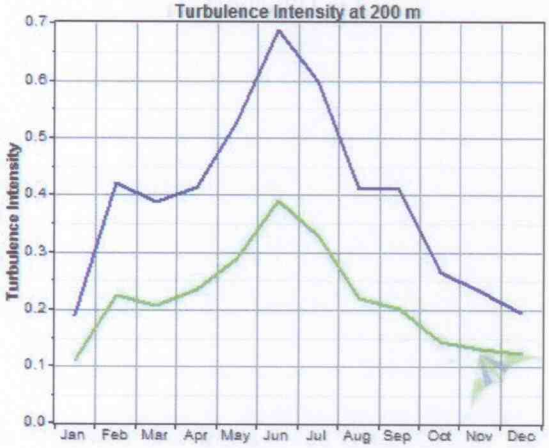

Daily Wind Shear Profile
Power Law Exponent
Hour
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

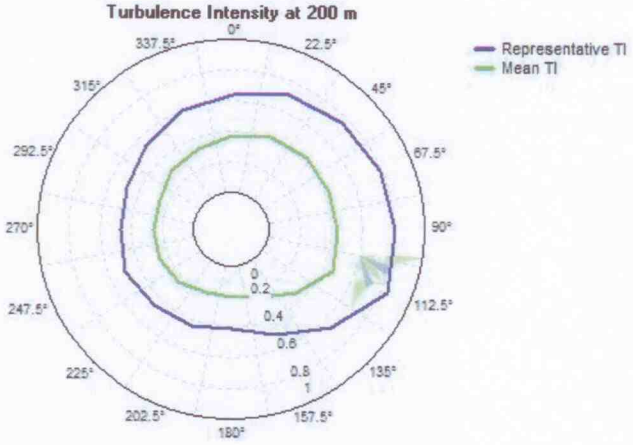

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

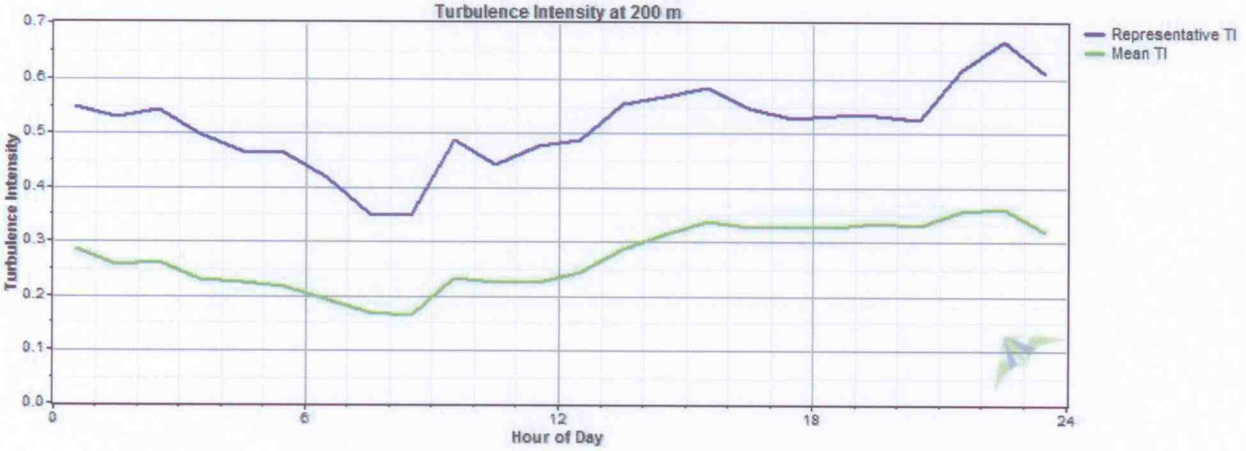

Power Law Exponent

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	59,419	55,422	93.27	241.5	0.0	360.0	86.0
2	40m Wind Speed	m/s	40 m	59,419	55,422	93.27	5.73	0.01	18.94	2.72
3	40m Wind Vert	m/s	40 m	59,419	55,422	93.27	-0.129	-9.240	2.300	0.856
4	Quality (Station Height 40m)	%		59,419	55,422	93.27	97.1	85.0	100.0	2.5
5	50m Wind Direction	°	50 m	59,419	54,161	91.15	242.5	0.0	360.0	85.9
6	50m Wind Speed	m/s	50 m	59,419	54,161	91.15	5.79	0.04	16.68	2.67
7	50m Wind Vert	m/s	50 m	59,419	54,161	91.15	-0.144	-9.370	2.980	0.871
8	Quality (Station Height 50m)	%		59,419	54,161	91.15	96.7	85.0	100.0	2.8
9	60m Wind Direction	°	60 m	59,419	52,199	87.85	243.6	0.0	360.0	86.0
10	60m Wind Speed	m/s	60 m	59,419	52,199	87.85	5.84	0.05	18.83	2.65
11	60m Wind Vert	m/s	60 m	59,419	52,199	87.85	-0.152	-9.310	3.030	0.877
12	Quality (Station Height 60m)	%		59,419	52,199	87.85	96.3	85.0	100.0	3.1
13	80m Wind Direction	°	80 m	59,419	46,497	78.25	245.4	0.0	360.0	86.2
14	80m Wind Speed	m/s	80 m	59,419	46,497	78.25	5.94	0.07	26.30	2.64
15	80m Wind Vert	m/s	80 m	59,419	46,497	78.25	-0.170	-9.040	4.070	0.896
16	Quality (Station Height 80m)	%		59,419	46,497	78.25	95.6	85.0	100.0	3.5
17	100m Wind Direction	°	100 m	59,419	39,631	66.70	247.3	0.0	359.9	86.1
18	100m Wind Speed	m/s	100 m	59,419	39,631	66.70	6.09	0.05	23.84	2.68
19	100m Wind Vert	m/s	100 m	59,419	39,631	66.70	-0.197	-8.870	3.770	0.937
20	Quality (Station Height 100m)	%		59,419	39,631	66.70	95.1	85.0	100.0	3.7
21	120m Wind Direction	°	120 m	59,419	33,088	55.69	248.7	0.0	360.0	85.1
22	120m Wind Speed	m/s	120 m	59,419	33,088	55.69	6.25	0.10	26.24	2.74
23	120m Wind Vert	m/s	120 m	59,419	33,088	55.69	-0.237	-8.490	4.430	0.989
24	Quality (Station Height 120m)	%		59,419	33,088	55.69	94.7	85.0	100.0	3.9
25	140m Wind Direction	°	140 m	59,419	27,343	46.02	249.0	0.0	360.0	83.8
26	140m Wind Speed	m/s	140 m	59,419	27,343	46.02	6.42	0.03	31.50	2.83
27	140m Wind Vert	m/s	140 m	59,419	27,343	46.02	-0.289	-8.410	4.430	1.066
28	Quality (Station Height 140m)	%		59,419	27,343	46.02	94.2	85.0	100.0	3.9
29	160m Wind Direction	°	160 m	59,419	22,341	37.60	248.9	0.0	360.0	82.6
30	160m Wind Speed	m/s	160 m	59,419	22,341	37.60	6.59	0.07	43.73	2.97
31	160m Wind Vert	m/s	160 m	59,419	22,341	37.60	-0.358	-8.500	4.820	1.173
32	Quality (Station Height 160m)	%		59,419	22,341	37.60	93.7	85.0	100.0	4.0
33	180m Wind Direction	°	180 m	59,419	18,102	30.47	249.1	0.1	359.9	81.8
34	180m Wind Speed	m/s	180 m	59,419	18,102	30.47	6.69	0.10	24.36	3.06
35	180m Wind Vert	m/s	180 m	59,419	18,102	30.47	-0.440	-8.650	5.370	1.318
36	Quality (Station Height 180m)	%		59,419	18,102	30.47	93.3	85.0	100.0	3.9
37	200m Wind Direction	°	200 m	59,419	14,563	24.51	249.8	0.1	359.9	81.8
38	200m Wind Speed	m/s	200 m	59,419	14,563	24.51	6.76	0.08	25.55	3.21
39	200m Wind Vert	m/s	200 m	59,419	14,563	24.51	-0.547	-8.650	4.350	1.508
40	Quality (Station Height 200m)	%		59,419	14,563	24.51	92.8	85.0	100.0	3.9
41	40m Wind Turbulence	m/s	40 m	59,419	45,646	76.82	0.159	0.040	1.230	0.096
42	50m Wind Turbulence	m/s	50 m	59,419	45,104	75.91	0.168	0.040	1.240	0.103
43	60m Wind Turbulence	m/s	60 m	59,419	43,782	73.68	0.176	0.030	1.500	0.110
44	80m Wind Turbulence	m/s	80 m	59,419	39,105	65.81	0.190	0.030	1.390	0.125
45	100m Wind Turbulence	m/s	100 m	59,419	33,601	56.55	0.204	0.030	1.290	0.139
46	120m Wind Turbulence	m/s	120 m	59,419	28,177	47.42	0.216	0.030	1.500	0.150
47	140m Wind Turbulence	m/s	140 m	59,419	23,423	39.42	0.227	0.030	1.390	0.160
48	160m Wind Turbulence	m/s	160 m	59,419	19,118	32.17	0.237	0.030	1.620	0.171
49	180m Wind Turbulence	m/s	180 m	59,419	15,442	25.99	0.256	0.030	1.700	0.183
50	200m Wind Turbulence	m/s	200 m	59,419	12,245	20.61	0.271	0.030	1.750	0.195
51	Turbu. Quality (Station Height 40m)	%		59,419	45,646	76.82	97	85	100	3
52	Turbu. Quality (Station Height 50m)	%		59,419	45,104	75.91	96.6	85.0	100.0	3.2

Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	Turbu. Quality (Station Height 60m)	%		59,419	43,782	73.68	96.2	85.0	100.0	3.4
54	Turbu. Quality (Station Height 80m)	%		59,419	39,105	65.81	95.5	85.0	100.0	3.8
55	Turbu. Quality (Station Height 100m)	%		59,419	33,601	56.55	95.0	85.0	100.0	3.9
56	Turbu. Quality (Station Height 120m)	%		59,419	28,177	47.42	94.6	85.0	100.0	4.0
57	Turbu. Quality (Station Height 140m)	%		59,419	23,423	39.42	94.1	85.0	100.0	4.0
58	Turbu. Quality (Station Height 160m)	%		59,419	19,118	32.17	93.6	85.0	100.0	4.0
59	Turbu. Quality (Station Height 180m)	%		59,419	15,442	25.99	93.2	85.0	100.0	4.0
60	Turbu. Quality (Station Height 200m)	%		59,419	12,245	20.61	92.7	85.0	100.0	4.0
61	Ambient Temp	°C		59,419	59,032	99.35	11.36	-14.40	32.10	9.00
62	Barometric Pressure	mbar		59,419	59,032	99.35	918.7	891.8	977.2	5.8
63	TiltX	Â°		59,419	59,032	99.35	0.39	-89.70	57.20	6.25
64	TiltY	Â°		59,419	59,032	99.35	-0.78	-51.80	45.60	4.39
65	Azimuth	Â°		59,419	59,032	99.35	0	0	0	0
66	Humidity	%		59,419	59,032	99.35	133.6	0.0	255.0	86.7
67	Noise Level-A	dB		59,419	59,032	99.35	13.04	5.00	17.00	1.36
68	Noise Level-B	dB		59,419	59,032	99.35	13.08	5.00	17.00	1.38
69	Noise Level-C	dB		59,419	59,032	99.35	13.09	5.00	17.20	1.37
70	Speaker Power	W		59,419	59,032	99.35	3.65	0.00	21.50	2.58
71	Modem Power	W		59,419	59,032	99.35	0.663	0.100	1.700	0.357
72	CPU Power	W		59,419	59,032	99.35	1.073	0.900	1.800	0.080
73	Solar Power	W		59,419	59,032	99.35	0	0	0	0
74	Core Power	W		59,419	59,032	99.35	3.466	3.000	4.200	0.148
75	PWM Power	W		59,419	59,032	99.35	0.993	0.600	1.900	0.134
76	Internal Temp	Â°C		59,419	59,032	99.35	14.48	-13.80	43.80	10.10
77	Mirror Temp	Â°C		59,419	59,032	99.35	13.74	-14.20	54.00	10.73
78	Heater Temp	Â°C		59,419	59,032	99.35	0	0	0	0
79	CPU Temp	Â°C		59,419	59,032	99.35	0	0	0	0
80	VibrationX	g		59,419	59,032	99.35	0	0	0	0
81	VibrationY	g		59,419	59,032	99.35	0	0	0	0
82	Battery	V		59,419	59,032	99.35	12.86	11.50	15.30	0.75
83	Beep Volume	dB		59,419	59,032	99.35	93.3	0.0	100.0	25.0
84	Air Density	kg/m³		59,419	59,419	100.00	1.126	1.049	1.239	0.037
85	200m Wind Speed WPD	W/m²		59,419	14,563	24.51	292	0	9,039	374
86	180m Wind Speed WPD	W/m²		59,419	18,102	30.47	274	0	7,942	327
87	160m Wind Speed WPD	W/m²		59,419	22,341	37.60	260	0	45,174	494
88	140m Wind Speed WPD	W/m²		59,419	27,343	46.02	236	0	16,959	295
89	120m Wind Speed WPD	W/m²		59,419	33,088	55.69	217	0	9,873	252
90	100m Wind Speed WPD	W/m²		59,419	39,631	66.70	203	0	7,388	244
91	80m Wind Speed WPD	W/m²		59,419	46,497	78.25	191	0	10,057	230
92	60m Wind Speed WPD	W/m²		59,419	52,199	87.85	186	0	3,782	232
93	50m Wind Speed WPD	W/m²		59,419	54,161	91.15	185	0	2,532	239
94	40m Wind Speed WPD	W/m²		59,419	55,422	93.27	185	0	3,728	251

APPENDIX C

Monthly SODAR and Truewind Wind Speed Estimates

General Site Map of SODAR and Regional Airports

Kayford Mountain SODAR Monthly Wind Speed Summary

(March 2011 through March 2012 using 90% QF)

(Estimated monthly AWS Truewind™ data at 80 meter height in brackets)

March 2011 (started 03/04/11)

Height (meters above ground surface)	Speed (meters per second)
200	6.7
180	6.5
160	6.4
140	6.3
120	6.1
100	6.1
80	6.2 (6.25)
60	6.5
50	6.7
40	6.8

April 2011

Height (meters above ground surface)	Speed (meters per second)
200	8.5
180	8.3
160	7.9
140	7.7
120	7.6
100	7.5
80	7.2 (5.8)
60	7.2
50	7.1
40	7.1

May 2011

Height (meters above ground surface)	Speed (meters per second)
200	6.5
180	6.3
160	6.2
140	5.9
120	5.7
100	5.5
80	5.3 (5.46)
60	5.1
50	5.0
40	4.9

June 2011

Height (meters above ground surface)	Speed (meters per second)
200	6.0
180	5.9
160	5.9
140	5.8
120	5.5
100	5.3
80	5.1 (4.67)
60	4.9
50	4.7
40	4.7

July 2011

Height (meters above ground surface)	Speed (meters per second)
200	5.0
180	5.0
160	4.9
140	4.8
120	4.7
100	4.5
80	4.3 (4.42)
60	4.1
50	4.0
40	3.9

August 2011

Height (meters above ground surface)	Speed (meters per second)
200	6.4
180	6.3
160	6.2
140	6.0
120	5.7
100	5.5
80	5.2 (4.47)
60	5.0
50	4.9
40	4.8

September 2011

Height (meters above ground surface)	Speed (meters per second)
200	7.4
180	7.1
160	6.8
140	6.5
120	6.2
100	6.0
80	5.7 (5.02)
60	5.5
50	5.3
40	5.2

October 2011 (unit non-operational 10/07 to 10/20)

Height (meters above ground surface)	Speed (meters per second)
200	7.5
180	7.1
160	6.9
140	6.7
120	6.4
100	6.1
80	6.0 (5.46)
60	5.8
50	5.7
40	5.6

November 2011

Height (meters above ground surface)	Speed (meters per second)
200	8.6
180	8.1
160	7.8
140	7.4
120	7.3
100	7.1
80	7.0 (5.97)
60	6.9
50	6.8
40	6.8

December 2011

Height (meters above ground surface)	Speed (meters per second)
200	10.1
180	9.4
160	8.7
140	8.1
120	7.7
100	7.2
80	6.7 (6.46)
60	6.3
50	6.2
40	6.2

January 2012

Height (meters above ground surface)	Speed (meters per second)
200	11.4
180	10.6
160	9.9
140	9.3
120	8.6
100	8.0
80	7.4 (6.73)
60	7.2
50	7.2
40	7.1

February 2012

Height (meters above ground surface)	Speed (meters per second)
200	8.7
180	8.5
160	8.0
140	7.4
120	6.9
100	6.4
80	6.1 (6.27)
60	5.9
50	5.9
40	5.8

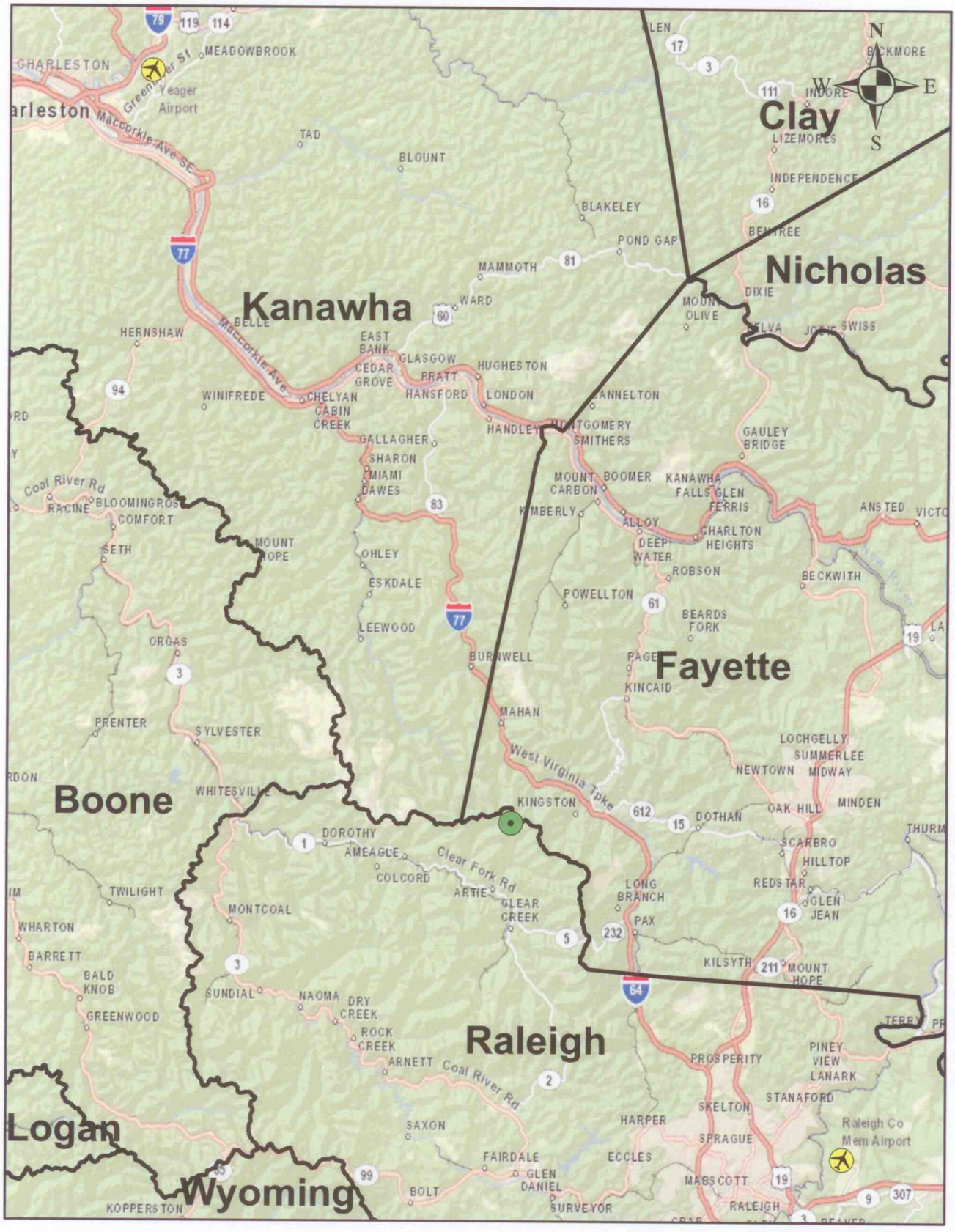
March 2012

Height (meters above ground surface)	Speed (meters per second)
200	8.7
180	8.2
160	7.8
140	7.2
120	6.8
100	6.4
80	6.2 (6.25)
60	6.1
50	6.0
40	5.9

Total Project timeframe (03/04/2011 – 04/18/2012)

Height (meters above ground surface)	Speed (meters per second)
200	6.8
180	6.7
160	6.6
140	6.4
120	6.3
100	6.1
80	5.9 (6.13 annual)
60	5.8
50	5.8
40	5.7

Kayford Mountain Site Map



APPENDIX D

Wind Turbine Energy Output Summaries

Wind Turbine Output

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

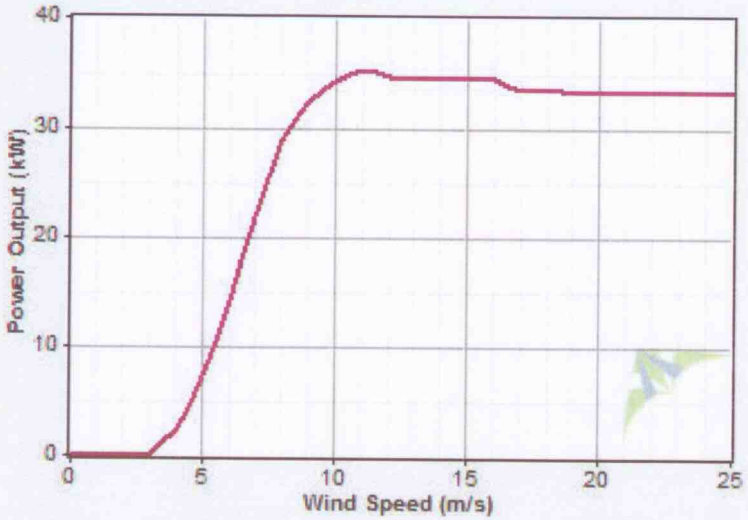
Losses

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

Calculate Output

Hub height

- ○ 30.5 m
- ◉ 42.7 m
- ○ Other 70 m



◉ 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	4,248	7.06	9.18	0.14	15.6	11,628	44.7
Feb	4,063	5.72	16.34	0.37	10.6	7,096	30.2
Mar	8,079	6.19	16.03	0.00	12.0	8,930	34.3
Apr	6,681	6.50	10.36	0.00	12.9	9,268	36.8
May	4,413	4.78	20.73	0.00	6.7	4,971	19.1
Jun	4,297	4.49	23.30	0.00	5.5	3,954	15.7
Jul	4,429	3.78	40.28	0.00	3.7	2,754	10.6
Aug	4,316	4.65	22.13	0.00	6.1	4,569	17.5
Sep	4,196	5.09	22.62	0.00	8.2	5,873	23.3
Oct	2,423	5.55	17.25	0.00	9.8	7,296	28.0
Nov	4,177	6.71	9.70	0.00	13.9	9,988	39.6
Dec	4,275	6.11	12.54	0.00	12.1	9,015	34.6
Overall	55,597	5.62	17.99	0.04	10.0	87,603	28.6

Help | Cancel | Add Turbine Output Time Series To Data Set & Close

Wind Turbine Output

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

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

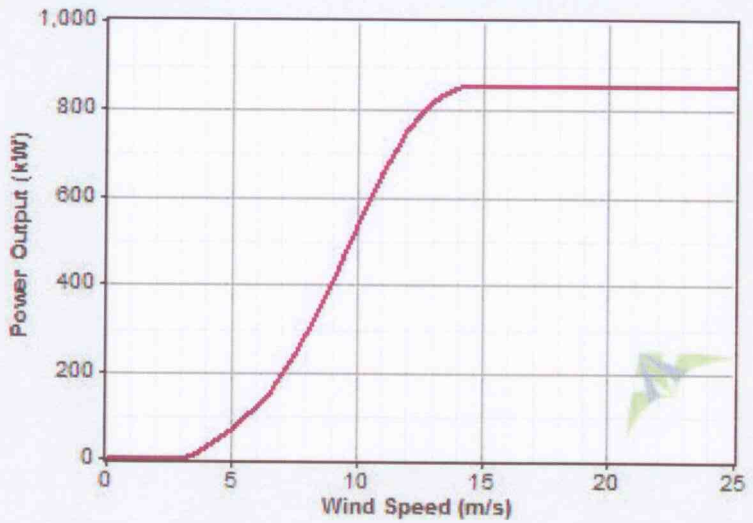
Properties

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

Losses

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

Calculate Output



Hub height

- 40 m
- 44 m
- 49 m
- 55 m
- 60 m
- 65 m
- 74 m
- 86 m
- Other 70 m

- 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	4,248	7.57	7.23	0.49	241.8	179,907	28.4
Feb	4,063	6.18	13.24	0.49	151.1	101,563	17.8
Mar	8,079	6.55	14.06	0.84	177.6	132,115	20.9
Apr	6,681	6.94	8.47	0.55	188.9	135,976	22.2
May	4,413	5.20	18.40	0.02	89.1	66,263	10.5
Jun	4,297	4.89	20.11	0.02	70.1	50,469	8.2
Jul	4,429	4.13	37.14	0.05	48.4	35,999	5.7
Aug	4,316	5.14	18.91	0.05	81.8	60,879	9.6
Sep	4,196	5.60	19.64	0.05	116.1	83,618	13.7
Oct	2,423	6.05	14.07	0.33	140.2	104,286	16.5
Nov	4,177	7.18	8.00	0.65	207.8	149,618	24.4
Dec	4,275	6.62	9.68	0.44	174.3	129,711	20.5
Overall	55,597	6.07	15.46	0.37	144.6	1,266,739	17.0

Help | Cancel | Add Turbine Output Time Series To Data Set & Close

Wind Turbine Output

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

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

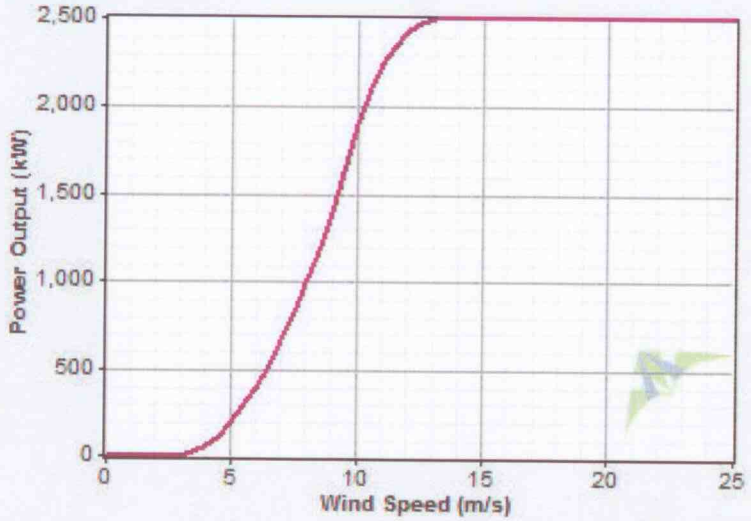
Properties

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

Losses

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

Calculate Output



Hub height

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

- (•) 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	4,248	7.59	7.16	2.54	814.8	606,232	32.6
Feb	4,063	6.19	13.12	1.45	504.2	338,789	20.2
Mar	8,079	6.56	14.01	2.43	593.5	441,569	23.7
Apr	6,681	6.95	8.43	1.72	635.9	457,824	25.4
May	4,413	5.21	18.31	0.09	294.3	218,971	11.8
Jun	4,297	4.91	19.94	0.07	228.6	164,581	9.1
Jul	4,429	4.14	36.98	0.11	156.4	116,332	6.3
Aug	4,316	5.16	18.79	0.07	269.5	200,534	10.8
Sep	4,196	5.61	19.40	0.41	389.3	280,268	15.6
Oct	2,423	6.06	13.91	0.99	468.6	348,644	18.7
Nov	4,177	7.19	7.92	2.11	699.6	503,704	28.0
Dec	4,275	6.63	9.61	1.38	588.3	437,691	23.5
Overall	55,597	6.08	15.36	1.22	483.8	4,237,771	19.4

Help | Cancel | Add Turbine Output Time Series To Data Set & Close