Wind Energy Development in Bangladesh: Prospect and Way Forward

Submitted by-

Wind Energy Development Committee Power Division

Acknowledgments

We extend our gratitude to the Power Division for forming the committee to review the Wind assessment report of Bangladesh done by NREL and find some suitable approach to accelerate the wind energy sector in Bangladesh.

We would like to extend special thanks to the honorable Chairman of SREDA for the logistic support and proper direction to prepare the report.

Special thanks to all the members of the committee who has allocated their valuable time from their busy schedule to support the committee voluntarily. We are grateful to all of the members for their hard work and effort to develop this report in a very short time.

Executive Summary

Wind energy is going to play a vital role in upcoming days in renewable energy sector of Bangladesh. Bangladesh government is giving priority to develop wind project to meet the SDG target. SREDA along with power division is working jointly to select the proper approach to move forward about project implementation of wind energy. Previous experience of Solar parks can be a lesson for us to think out of the box about wind energy.

To assess the potential of wind energy in Bangladesh there had been many studies and Bangladesh government has the reports and data on which decision can be taken. Specially the most recent and comprehensive study which has been conducted by NREL (National Renewable Energy Laboratory, USA) during 2014-2017 can direct the appropriate path for wind energy development in Bangladesh. Also these data can be bankable. To review the report and recommend further steps for wind energy development, a working committee has been formed by the Power division of Ministry of Energy, Power and Mineral Resources (MoPEMR), GoB, consisting of government officials of SREDA, Powercell, BPDB, EGCB, CPCBL, EPRC and a professor from BUET. The committee carefully considers all the factors for possible wind energy development in Bangladesh. The committee has reviewed the report of NREL, relevant literatures and case studies of neighboring countries (for example India and China).

NREL uses sophisticated resource modeling that was validated by a real time field measurement campaign. Measurement has been taken at nine metrological sites; namely- Rajshahi, Chandpur, Sitakundu, Parkay Beach, Mymensign, Mirzapur, Mongla, Inani Beach, Rangpur. NREL report includes a long-term, correlated wind data set; validated high-resolution wind resource maps; and publicly available data accessible through RE Data Explorer (https://www.re-explorer.org/). According to the NREL, wind resource potential of Bangladesh at 120 m height is shown in Figure ES-1.

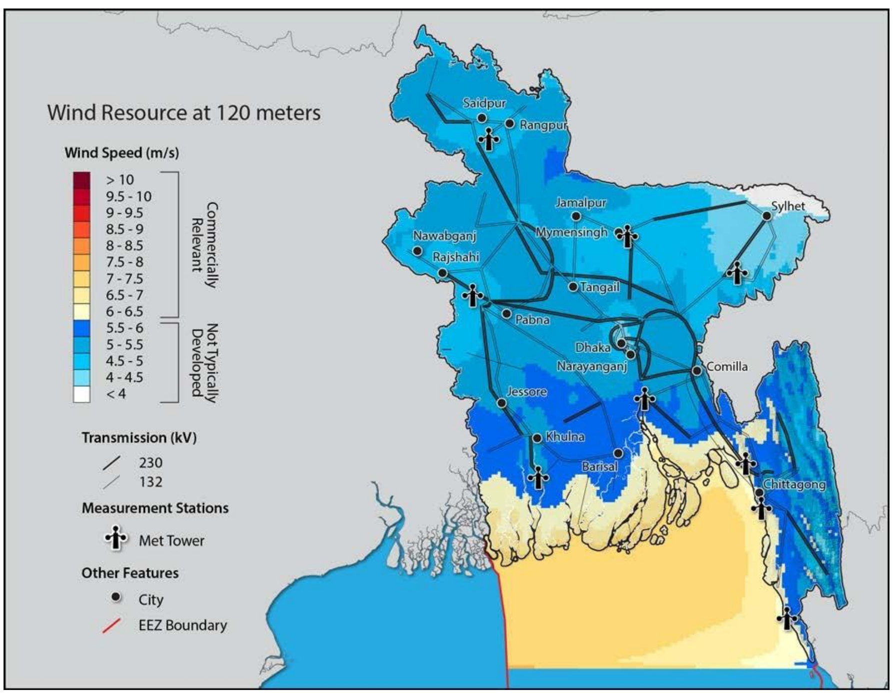

Figure ES-1: Wind resource map of Bangladesh at 120 m height (NREL RE data)

According to the NREL report the coastal belt is very potential for wind energy but more site specific data is needed to do plant design and feasibility study. More wind measuring Mast (Met Tower) should be installed in more locations to collect data for long time. Capacity building and technology transfer is also needed. Analyzing the data, committee finds that two approaches can be worked in short term basis by which Power division can start the wind project. IPP based unsolicited BOO model/ Solicited tender model have their own advantages and disadvantages. But to start the project immediately, desperate measures should be taken. This committee also identifies the challenges that were faced by the wind sector in India and China. It is expected that some incentives might be required to expand the wind energy market in Bangladesh.

Committee has recommended some actions to be taken which are as follows:

Short term actions: To develop wind power sector some steps need to be taken immediately which will be a benchmark for power producers to follow on and invest in wind sector. There can be two approaches-

1. IPP based unsolicited BOO (Build, Own, Operate) model:

   Power Division can keep the project identification open for IPP. Unsolicited proposal can be accepted and a reasonable tariff can be settled by negotiation. This approach is needed at least for initial 2/3 successfully completed projects to identify the challenges and sort out a baseline tariff for wind power. Negotiation can be of two stage or reverse bidding also can be considered.

2. Solicited Tender model:

   With the prefixed benchmark/Baseline tariff, BPDB/utilities can float the tender and receive proposal from different international companies who will work on BOO (Build, Own, Operate) basis. This process can take some time to process the whole system but implementation will be much faster. Normally open bidding may find out the proper pricing of wind energy but at the beginning of development stage as there is no standard setup is available, the price may be little higher than unsolicited approach.

A policy to be adopt "**Wind (VRE) Must Run"** for feeding energy to the grid when available to be decided to prioritized the renewable energy utilization and to save fossil fuel but to avoid grid penetrations by VRE wind energy forecast circulation before two/three days must be sent to NLDC. The Grid should have some operating reserve to cope the grid penetrations by VRE wind.

Long term actions: To build a sustainable wind energy development working committee has identified some steps to be taken for long term basis.

1. Land preparation: Land crisis is a big issue for renewable energy development. It has been observed that it is very difficult and also not cost effective to arrange and develop land and evacuation facility by the private entrepreneur. So Power Division/ SREDA can take a "Wind Energy Development" Program to find some potential lands for wind according to the data of NREL provided. Potential lands with evacuation plan will be developed and Open Tender method will be applied for setting wind farms.

2. Policy Support: Without concrete and declared facilities provided by government policy, it will be difficult to develop this sector and increase renewable energy share. Tariff Mechanism development for Wind based Power Generation projects should be considered by the government. 'Wind Power Development Guideline for Bangladesh' should be prepared and followed to develop the sector.

3. Long term data assessment: SREDA can set required met masts in the countrywide potential regions for long term basis and a collection and data processing center in SREDA head office to interpret the data and help the investors. These data set could be used to enhance the present wind map considering weather forecast modeling.

4. Offshore wind resources assessment: As we observed offshore wind technology improvement is in remarkable position from few years past and Bangladesh having huge flatter offshore area may be opportunity of feasible wind site. So a program for wind measurement campaign could be taken at the earliest.

5. Capacity building: SREDA can take initiatives under the Wind Development Program to train engineers from different organizations on Wind data assessment, Plant design, Wind project management, Wind farm maintenance and operation etc. SREDA can also work with different institutions like BUET, Dhaka University and other

prominent public as well as private universities to create a wind knowledge hub which will be helpful for technology transfer.

6. One stop service for government agencies as well as private investors: To avoid long process and scattered documentation system, SREDA with the help of NREL or any other organizations can start a one stop service for wind energy development. After evaluation of the proposal by SREDA, they can go forward to develop the project following the government policy. Investors also will be able to go with the process easily and motivation will be increased.

Incentives:

From the previous experience of Solar projects and lesson learnt from neighboring country, this is obvious that incentives should be provided to the investors in renewable energy. Bangladesh government also should think to provide some incentives to make the wind energy sector more competitive with conventional energy. There are many types of incentives are provided by the governments in different countries. Among them Bangladesh can choose the followings:

a. Flexible accelerated depreciation within 10 years after COD.

b. Similar incentives that other Independent Power Producer enjoys in conventional energy

c. Incentive for clean energy generation that can be included in tariff

In this regard, SREDA can play an important role by taking the wind energy development program as a long term basis. Land identification, infrastructure development, evacuation line preparation, transportation for mobilization of large wind turbine components etc. will expedite the speed of wind energy development. Proper incentive and policy guidance can reduce the energy generation cost and wind power can be equally competitive with conventional energy in Bangladesh which has been demonstrated in many countries in the world.

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List of Acronyms

ADB	Asia Development Bank
AGL	above ground level
GBI	Generation based incentive
GFS	Global Forecast System
GIS	geographic information system
GOB	Government of Bangladesh
GOB-PD	Government of Bangladesh, Power Division
MAE	mean absolute error
ME	mean error or bias
MET	meteorological
NREL	National Renewable Energy Laboratory
QC	quality control
QF	quality factor
RE Data Explorer	Renewable Energy Data Explorer
RFP	request for proposal
RMSE	root-mean-square error
SODAR	sonic detection and ranging
USAID	United States Agency for International Development

1. Introduction

Bangladesh is one of the most densely populated countries in the world, with more than 160 million people living in an area the size of the U.S. State of Louisiana. Approximately 92% (with off grid power solutions) of the population has access to electricity, and the price of energy is subsidized. With limited natural gas resources waning and a costly energy subsidy system, the Government of Bangladesh (GOB) is evaluating multiple paths to ensure reliable and affordable power. Under its Power System Master Plan, 2016 Bangladesh set a goal to generate 35% of electricity from coal by 2030. An alternative path being evaluated by the GOB involves identifying, quantifying, and exploiting the country's domestic renewable energy resources to support the 2016 Power System Master Plan's goal of generating 10% of electricity from renewable energy by 2021. In support of this low-emission development strategy, this project seeks to unlock one natural resource that has been largely unexplored in Bangladesh wind.

One of the prime challenges to the expanded use of wind and other renewable energy technologies globally is understanding regional renewable energy potential. The variable nature of the wind resource and its strict location dependency impose additional and often new challenges compared with traditional energy technologies. Annual wind maps developed for Bangladesh over the last 15 years have been useful in demonstrating national wind potential, but the measurement and modeling methodologies used to create these maps do not adequately represent the wind resource available to modern wind turbines. Consequently, they are not sufficiently rigorous to attract investors and spur growth in the wind technology sector. Today's much more sophisticated tools and techniques, such as validated wind resource models based on years of actual wind data measured at turbine hub height, reduce uncertainty and generate a wealth of data products including annual, monthly, seasonal, and hourly wind distribution data and annual wind-speed maps needed to attract private and government investment. After acquiring the data, an appropriate approach is needed to develop the sector in a systematic way. Hence, Bangladesh government is now trying to harness energy from wind and wants to develop the sector in a sustainable way.

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2. Review of study reports

Bangladesh has approximately 724 km long coastal belt, more than 200 km long hilly coastline and few islands in the Bay of Bengal. The strong south/south-westerly monsoon wind coming from the Indian Ocean, after travelling a long distance over the water surfaces, enters into the country over the coastal areas of Bangladesh. This trade-wind blows over our country from March to October. The wind is enhanced when it enters the V-shaped coastal regions of our country. Since this trade wind strikes the coastal belt of Bangladesh, after travelling a long distance over ocean, it becomes energetic. In an early study report in 1982, a 30-year meteorological data from a number of stations throughout the country were considered and it was found that wind speeds in only coastal area and the bay might have a promise for possible electricity generation from wind.

In the financial year 2003-04, the government of Bangladesh took up a wind profile survey program for installation of 4 x 225 KW wind mills in different places of coastal area. The source of fund was from GOB own resource. Besides this, several wind speed measurement studies have been conducted by various national and international organizations namely BUET, BCAS, BCSIR, BAEC, ETSU of UK, LGED, REVB1 of GIZ in the last few decades which could be summerized in the Table 1 below.

Table 1: Previous studies of wind resource assessment

Sl no	Name of the Organization	Data Collection Period	Location	Measurement Height and instrument	No of sites	Average wind speed
1	Bangladesh Meteorological Department (BMD)	monitoring from 1961 and 2000	-	Anemometers between 5m-15m	12	2.5 m/s or lower
2	Wind Energy Study Project (WEST)- Conducted by Bangladesh Center for Advanced Studies (BCAS) Supported by Energy Technical Support Unit (ETSU) of UK & LGED	1996-1997	south and southeastern coastal region- Kuakata, Kutubdia Teknaf	Cup anemometer with data logger collected at 10m and 25 m	7	Kuakata: 4.5 m/s Kutubdia: 4.2 m/s m/s 2.8
3	Technical Expertise for Renewable Application Project (TERNA)- Conducted by Bangladesh Atomic Energy Commission (BAEC) Supported by REVB1 of GIZ	1995-1997	southern Bangladesh	Cup anemometer with data logger- 20 m anemometer height	4	Teknaf 2 0 m: 4.3m/s
4	Wind Energy Resource Mapping Project (WERM)- Conducted by Local Government Engineering Department (LGED)	2003-2006	-	Cup anemometer with data logger- Towers height at 20m, 30m, and 40m	20 sites	Kuakata at 30 m: 4.2 m/s Kutubdia at 20 m: 3.6 m/s
5	Bangladesh Council for Scientific and Industrial Research (BCSIR)	Jan 2001-Apr 2002	Saint Martin, Teknaf and Meghnaghat	Cup anemometer with data logger at 10m, 30m	3	Saint Martin at 30 m: 4.7 m/s Teknaf at10 m: 3.5 m/s
6	Wind Resource Assessment Program (WRAP) of BPDB- Conducted by Pan Asia Power Services Ltd	One year of data between 2003 and 2005	Muhuri Dam Mognamagh at Parky beach Kuakata	Cup anemometer with data logger at 50 m	4	6.5-6.9 m/s

Sl no	Name of the Organization	Data Collection Period	Location	Measurement Height and instrument	No of sites	Average wind speed
7	Wind Monitoring in Mognama and Mahuri Dam Conducted by Regen Powertech	October 2012 to December 2013	Muhuri Dam Mognamagh	85m meteorological MET mast	2	Mognama-5.09 m/s Mahuri Dam-4.96 m/s

The data collected by the meteorology department were usually used for weather forecasting and were not found to be useful for assessing wind potential. There were inconsistencies in the studies conducted by WEST and TERNA for overlapping data. WERM data were also found somewhat lower than observed by WEST. The wind speed measurements by BCAS Group and GIZ group confirmed that wind speed was much higher in summer months (due to monsoon wind) than in winter months. Actual wind speed found by GIZ group was slightly higher than those of BCAS Group; but the frequency distribution was similar. Diurnal variation confirmed the trend observed by the meteorological department. Power curves of wind turbines with two different installed capacities from two different manufacturers were used to calculate energy generation. The estimated annual energy outputs for Kutubdia and Kuakata were calculated as 133 MWh and 160 MWh respectively for a 150 kW wind turbine; while the outputs were calculated as 200 MWh and 230 MWh respectively for a 250 kW station at those places. Data obtianed form Pan Asia indicated there could be a good resource exist in the 4 coastal areas investigated. But conflicting information from previous mapping and monitoring results in a need for comprehensive monitoring campaign. So, long term and systematic wind resource monitoring study needs to be completed for wind power development in Bangladesh.

Realizing the importance of wind resource assessment, Government of Bangladesh has taken systematic approaches towards deployment of wind power projects. Considering the previous wind mapping and monitoring program and Wind Atlas Map developed so far, Power Division selected 22 potential sites around the country for detail Wind Resource Assessment (WRA). To assess the potential of wind energy of those sites, a project named “Technical Assistance Project for Wind Resources Mapping” has been initiated on December 20, 2012 by Power Division. Total cost of the project was Tk. 1197.60 lac. The purpose of this project was to make a wind resources map of Bangladesh in view to build up wind power projects in private and government sector as IPP basis. This project is being implemented by National Renewable Energy Laboratory (NREL) of USA. All instrumentations have been done under the guidance of NREL of USA. As per Memorandum of Understanding (MoU) between US Government and the Government of Bangladesh, Power Division in coordination with USAID set up guyed lattice towers at 07 locations and SODAR (Sonic Detection and Ranging) at 02 locations. At present data collection is finished and a detailed report is submitted to Power Division by NREL. Any person can access the report and data of those sites.

The detail of the location and monitoring stations are listed in the Table 2-

Table 2: NREL wind resource assessment

Sl.	Location of the Site	Type of Tower/Station and Height	Coordinates of Tower/Station	Data Collection Started	Data Quantity (Months)	Average Wind Speed (m/s) at 80 m height	Power density W/m^2 at 100m height
1	Lalpur, Natore	Guyed Lattice Tower-80m	24.17035° N 88.90734° E	June 2014	40	4.16	90
2	Chandpur	Guyed Lattice Tower-60m	23.21116° N 90.64237° E	June 2014	33.5	5.10	96
3	Inani Beach, Cox'sbazar	SODAR 40-200m	21.14732° N 92.07575° E	July 2014	11.6	5.81	195
4	Sitakunda, Chittagong	Guyed Lattice Tower-80m	22.60416° N 91.6601° E	December 2014	22	5.68	86
5	Parky Beach, Chittagong	Guyed Lattice Tower-80m	22.18513° N 91.81767° E	December 2014	27.3	5.92	147
6	Badargonj, Rangpur	SODAR 20-200m	25.60641° N 89.06877° E	August 2015	15.1	4.26	134
7	Gouripur, Mymenshingh	Guyed Lattice Tower-80m	24.71546° N 90.4668° E	August 2015	27.3	4.13	60
8	Modhupur Tea Garden, Habigonj	Guyed Lattice Tower-80m	24.37778° N 91.57462° E	October 2015	19.1	4.17	58
9	Dacop, Khulna	Tower-80m	22.47342° N 89.56826° E	October 2015	25.4	4.86	101

*** This data is based on revised NREL model data dated on 18.02.19

Till now this project is the largest project of Bangladesh to collect wind data. Some other entities like EGCB, Coal Power Generation Company of Bangladesh also have done wind resource assessment in different locations. EGCB has collected the data of wind at Feni, Chattogram by Lidar from 01 June 2017 to 30 September 2018.

The report shows that the average wind speed of this period is around 5.38 m/s at 100m height which is significant for wind energy generation. On the other hand Coal Power Generation Company has finished the wind study at Matarbari from 21 February 2017 to 20 February 2018. They found that the wind speed at Matarbari at 100m height is near about 5.76 m/s. Data shows that both the sites are technically feasible and wind turbine can be installed.

Table 3: Most recent data collection of wind in Bangladesh

Sl no	Name of the Organization	Data Collection Period	Measurement Height and instrument	No of sites	Average wind speed
1	Wind Resource Assessment (WRA) By Power Division	2014- 2017	Guyed Lattice Tower-80m (anemometer) and SODAR 20-200m	9 (Natore, Chandpur, Cox'sbazar Sitakunda, Parky Beach, Rangpur, Mymenshingh, Habigonj, Khulna)	As per Table 2
2	Electricity Generation Company of Bangladesh	June 2017-Sept. 2018	LiDAR- 100m	1 (Feni)	5.38 m/s at 100m
3	Coal Power Generation Company of Bangladesh	Feb 2017-Feb 2018	Guyed Lattice Tower-100m (anemometer)	1 (Matarbari Island of Moheshkhali Upazila under Cox's bazar District)	5.76 m/s at 100m

Now Bangladesh has the required data to realize the potentiality of wind energy in different regions of the country. But "Wind Guideline" is required to develop the sector accordingly. Unfortunately it will take time to formulate a guideline and then starting commercial project. Power division and SREDA are interested to start few projects immediately to achieve the target of 2021. So power division has formulated a "Wind Working Committee" to set a way forward to start wind power plant project along with proper future plan for wind energy. Committee has reviewed all the data available and going to set some recommendations to develop the sector in a planned way. Committee has also reviewed the case studies of Wind Energy Development of Europe and Asia.

3. Global Status of Wind Energy

3.1 Wind Power Markets

Wind power had a relatively modest year of 2017 compared with 2015 and 2016, but still saw its third strongest 12-month period, with more than 52 GW added globally in 2017. Cumulative capacity increased nearly 11%, to around 539 GW (Figure 1) while the global renewable energy capacity of 2195 GW. As in 2016, a decline in Chinese installations accounted for much of the contraction, while several other markets, including Europe and India, had record years. By the end of 2017, more than 90 countries had seen commercial wind power activity, and 30 countries - representing every region- had more than 1 GW in operation.

Strong growth in some of the largest markets (e.g., Germany, India and the United Kingdom) was driven by significant policy and regulatory changes, which pushed many developers to commission projects quickly to take advantage of expiring support schemes; elsewhere, deployment was driven by wind energy's cost-competitiveness and its potential environmental and other benefits. Rapidly falling prices for wind power, both onshore and offshore, have made it the least-cost option for new power generating capacity in a large and growing number of markets. Around the world, wind power is quickly becoming a mature and cost-competitive technology.

China added nearly 19.7 GW in 2017, for a total installed capacity of approximately 188.4 GW (Figure 2). The decline in new installations, for the second year running, was due primarily to restrictions on deployment in regions with high curtailment rates and to a shift in focus to lower wind speed areas to better harmonise wind power expansion with grid infrastructure investments and to reduce curtailment. About 15 GW was integrated into the national grid and started receiving the FIT premium in 2017, with approximately 164 GW considered officially grid-connected by year's end. Although the northern and western provinces were still home to a significant portion of China's wind power capacity, new installations declined further in regions with the worst curtailment rates, and they continued to rise in some of the most populous provinces, with significant construction in low-wind speed regions of eastern, central and southern China. The top provinces for capacity additions in 2017 were Shandong (2.2 GW), Henan (1.3 GW) and Shaanxi (1.1 GW), all of which are relatively close to demand centers.

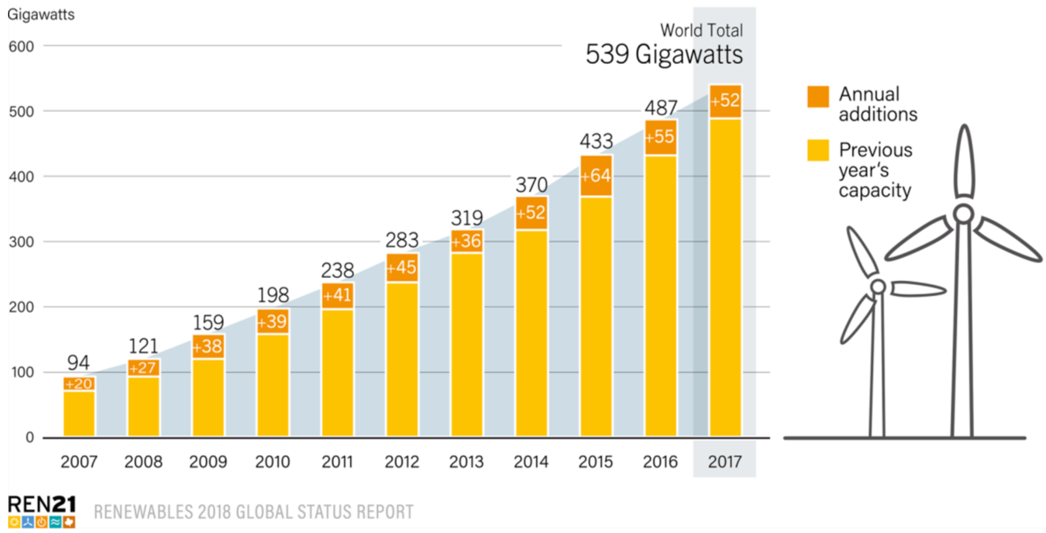


Figure 1. Wind Power Global Capacity and Annual Additions, 2007-2017

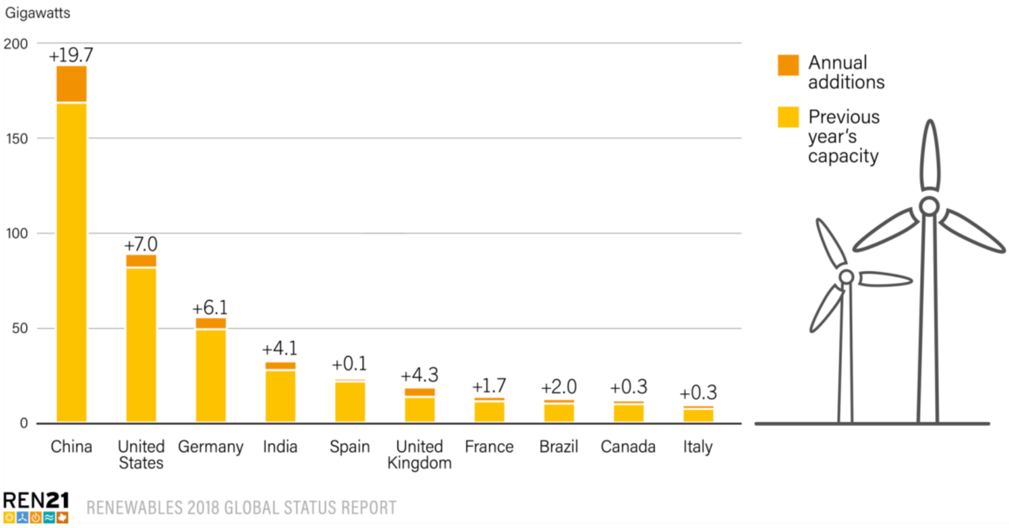


Figure 2. Wind Power Capacity and Additions, Top 10 Countries, 2017

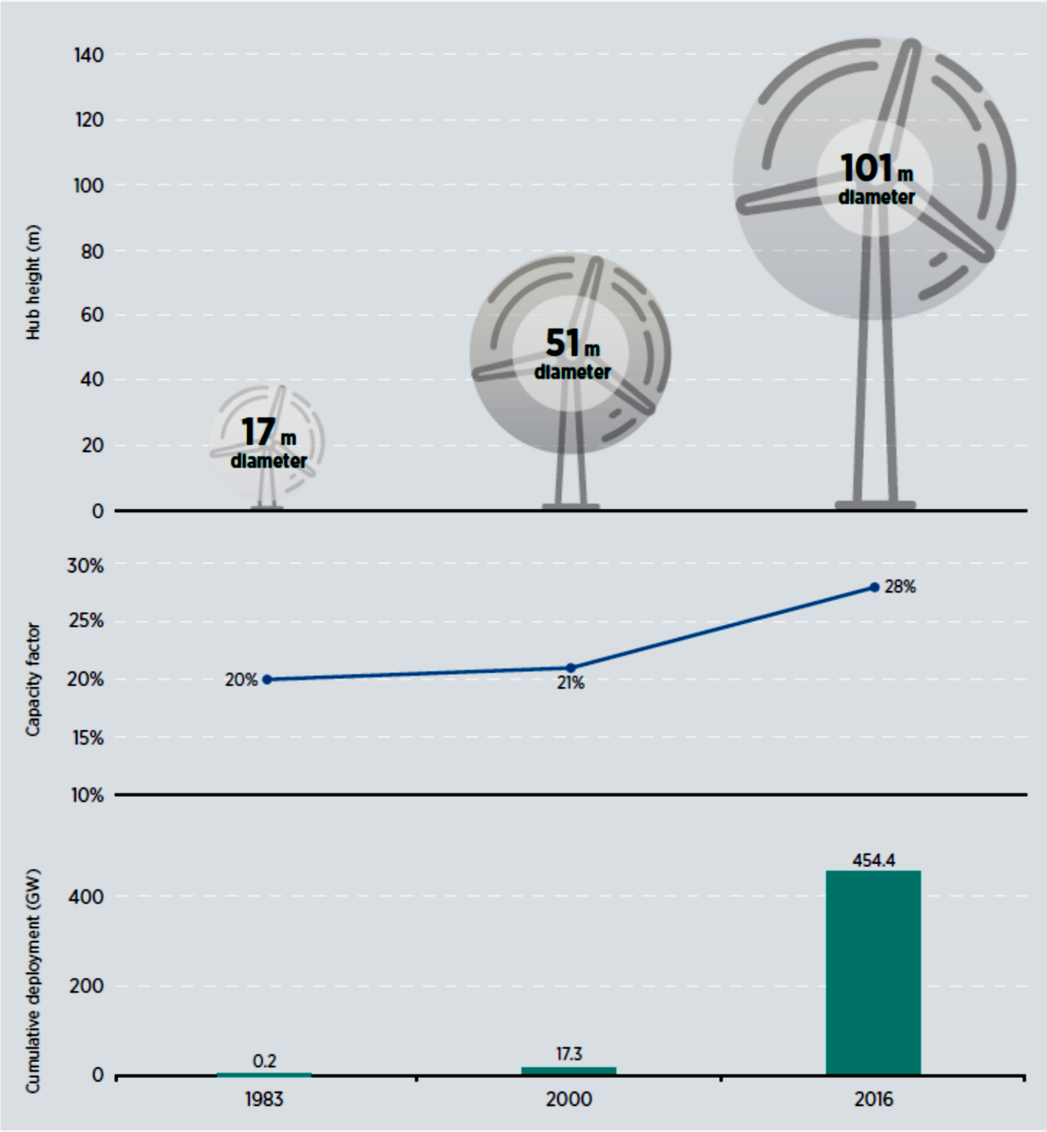
Overall, an estimated 41.9 TWh of potential wind energy was curtailed in 2017 in China – a national average of 12% for the year, down from 17% in 2016. Most curtailment was concentrated in a handful of provinces, all of which saw significant reductions relative to 2016 in response to a number of policies, including those to expand electrification (especially of heating in industry), to encourage direct trade of renewable energy among large consumers and to construct new transmission lines. Even with curtailment, wind power's share of total generation in China has increased steadily in recent years, reaching 4.8% in 2017 (up from 4% in 2016 and 3.3% in 2015).

Elsewhere in Asia, India installed a record 4.1 GW to rank fifth for additions, and easily maintained its fourth-place global position for cumulative capacity, ending the year with more than 32.8 GW. Record installations early in 2017 were due largely to a rush to capitalize on national incentives before they expired and to the country's transition from FIT-based PPAs to auctions. But the pace of additions slowed significantly during the year due to an abrupt end to the generation-based incentives scheme and to a reduction in accelerated depreciation benefits, combined Statistics differ among Chinese organisations and agencies as a result of what they count and when.

Six EU countries – Germany, the United Kingdom, France, Belgium (0.5 GW), Ireland (0.4 GW) and Croatia (0.1 GW) – set records for newly added capacity in 2017. Ireland added the most wind power capacity relative to its electricity consumption. Finland (0.5 GW) also was among the top EU countries for installations as the last projects under its FIT came online. In all, 17 countries added capacity, but the market was highly concentrated with the top three countries accounting for 80% of the EU's newly installed capacity.

North America ranked third globally for new capacity brought into operation in 2017. The United States held onto the second spot for annual additions (7 GW), although the market was down (by 15% relative to 2016) for the second consecutive year. Much of the year's activity focused on partial repoweringi (upgrading of existing projects). The country also was second, after China, for cumulative capacity at year's end (89 GW) and for electricity generation from wind power. Wind power ranked second after solar PV for net US capacity additions.

The capacity factors of wind projects are determined by the quality of the wind resource and the technology employed. There has been a trend towards the use of more advanced turbine technologies. As a result, there has been a consistent trend towards higher capacity factors globally, but with significant variations by market. This has been driven by the growth in the average hub height, turbine rating and rotor diameters of installed turbines, but also by the trends in resource quality at new projects in individual markets. The global weighted average capacity factor for onshore wind increased from around 20% in 1983 to around 29% in 2017 – a rise of about 45%. Figure 3 presents the evolution of the global weighted average hub height, rotor diameter and capacity factor. Hub heights increased from around 20 metres in 1983 to more than 100 metres in 2016, while capacity factors increased from 23% in 1983 to 28% in 2016 – more than 25% over the entire period. This has been achieved as installed capacity of onshore wind has increased exponentially, growing from 0.2 GW in 1983 to more than 454 GW at the end of 2016.



Source: IRENA Renewable Cost Database.

Figure 3. Global weighted average hub height, rotor diameter and capacity factors, and cumulative capacity for onshore wind, 1983-2016

Although onshore wind power continues to account for the vast majority (more than 96%) of global installed capacity, nine countries connected a total 4.3 GW of offshore wind capacity during 2017, increasing total world offshore capacity 30%, to 18.8 GW (Figure 4). The top countries for offshore additions were the United Kingdom (1.7 GW), Germany (1.2 GW), China (1.2 GW) and Belgium (0.2 GW). Europe connected a record 3.1 GW, for a total approaching 15.8 GW, with an additional 1.9 GW awaiting connection at year's end. Germany increased its offshore capacity by nearly one-third, Finland added its first commercial offshore plant, France installed a 2 MW floating demonstrator turbine, and Denmark decommissioned the world's first offshore wind farm (5 MW). Hywind Scotland (30 MW), the world's first commercial floating project, was commissioned in October 2017.

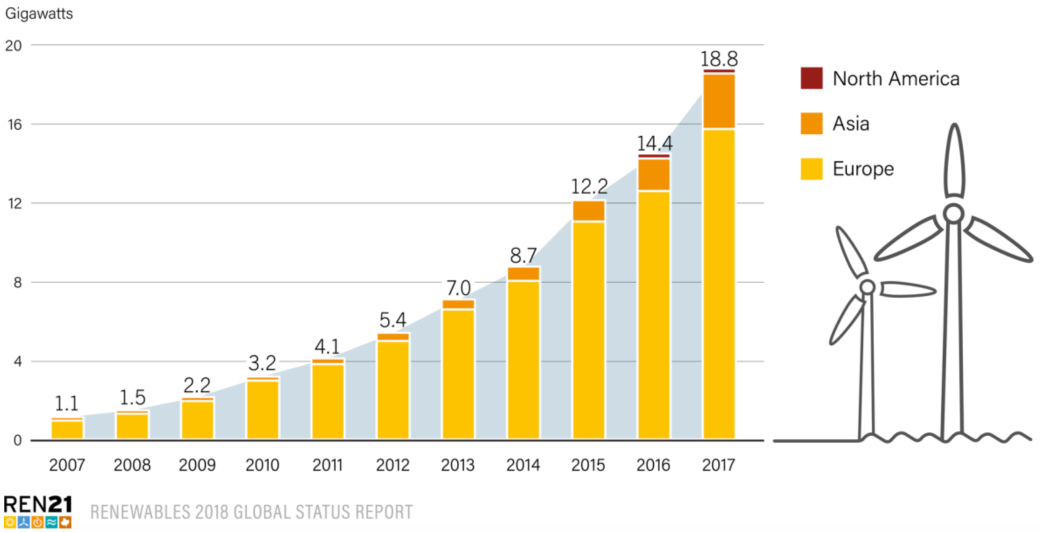


Figure 4. Wind Power Offshore Global capacity by Region, 2007-2017.

Wind power is providing a significant share of electricity in a growing number of countries. In 2017, wind energy covered an estimated 11.6% of EU annual electricity consumption and equal or higher shares in at least 8 EU member states, including Denmark, which met 43.4% of its annual electricity consumption with wind power. At least 13 countries around the world – including Costa Rica, Nicaragua and Uruguay – met 10% or more of their annual electricity consumption with wind power. Uruguay saw its share of generation from wind power increase more than four-fold in just three years, from 6.2% in 2014 to 26.3% in 2017, and Nicaragua generated over 15% of its electricity with wind power. Globally, wind power capacity in operation by the end of 2017 was enough to account for an estimated 5.6% of total electricity generation.

3.2 Levelised Cost of Electricity (LCOE) for Wind Energy

The average cost of electricity – measured in unsubsidized levelised cost of electricity (LCOE) - from renewable power generation technologies either is already very competitive or is continuing to fall to competitive levels for new projects commissioned in 2017 (Figure 6). Costs of the more mature geothermal, bio-power and hydropower technologies are relatively stable (Figure 7). Most of the recent reductions in cost have been associated with solar PV and wind power technologies; after years of steady cost declines, solar and wind power are becoming ever more competitive technologies for meeting new generation needs.

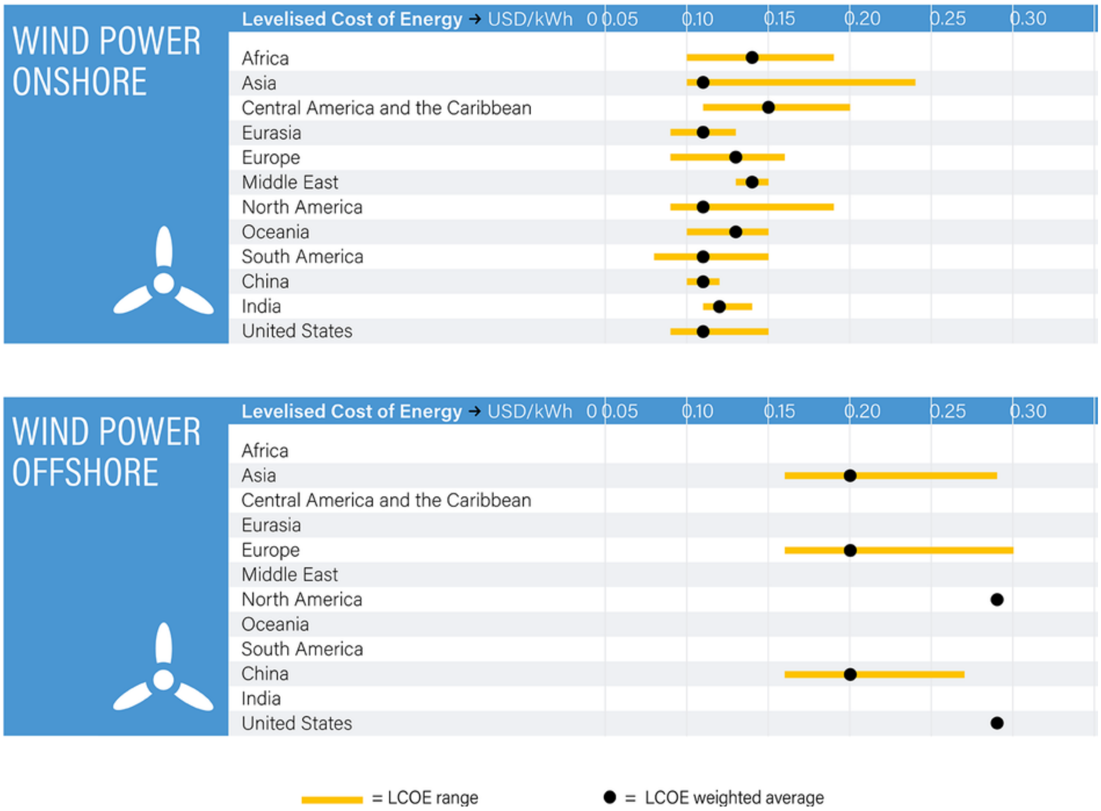
Three key drivers are increasingly important for reducing the cost of solar and wind power generation. These are: competitive procurement; a large and growing base of experienced and internationally active project developers; and ongoing technology improvements. Regulatory and institutional frameworks are transitioning to set the stage for competitive procurement of renewable power generation. In response, project developers are bringing to the international market their significant experience as well as their increasing access to international capital markets.

Particularly for solar and wind power, technology advances are improving efficiencies in manufacturing, reducing installed costs and improving the performance of power generation equipment. Innovations include larger wind turbines with greater swept areas, which enable them to harvest more energy from the same resource, and new solar PV cell architectures, which offer greater efficiency. At the same time, the maturity and the proven track record of these renewable technologies are lowering perceived project risk, which greatly reduces the cost of capital.

Bio-power, hydropower and geothermal power are all mature technologies that exhibit fairly stable cost profiles, although innovation in these technology groups continues. The estimated costs of these technologies, as well as of onshore wind power projects commissioned in 2017, were largely within the range of fossil fuel-fired electricity generation costs. Indeed, the LCOE for these technologies was estimated to be at the lower end of the LCOE range for fossil fuel options.

The global weighted average LCOE of new hydropower plants commissioned in 2017 was around USD 50 per MWh. For new bio-power and geothermal power projects, the global average was approximately USD 70 per MWh. Onshore wind power has become one of the most competitive sources of new generation. Wind turbine prices have fallen 37-56% since their peaks in 2007-2010, depending on the market. In combination with more modest reductions in balance-of-project costs, total installed costs for onshore wind power fell by a fifth between 2010 and 2017; at the same time, the global weighted average capacity factor for new projects increased from 27% to 30%. The LCOE of onshore wind power projects in 2017 fell to as low as USD 30 per MWh, with a global weighted average of USD 60 per MWh.

What has been truly remarkable, however, is the continued cost declines for solar PV. Driven by an 81% decrease in solar PV module prices since the end of 2009, along with reductions in balance of system costs, the global weighted average LCOE of utility-scale solar PV fell 73% between 2010 and 2017, to USD 100 per MWh. The global weighted-average capacity factor of commissioned utility-



Note: All monetary values are expressed in USD$_{2016}$. LCOE is computed using a weighted average cost of capital of 7.5% for OECD countries and china and 10% for the rest of the world, and excludes subsidies and/or taxes. Where only the weighted average is shown for specific regions/countries and technologies (i.e., without minimum and maximum amounts for LCOE, investment cost or capacity factor), there is only one project in the IRENA Renewable Costing Database. www.irena.org/costs.

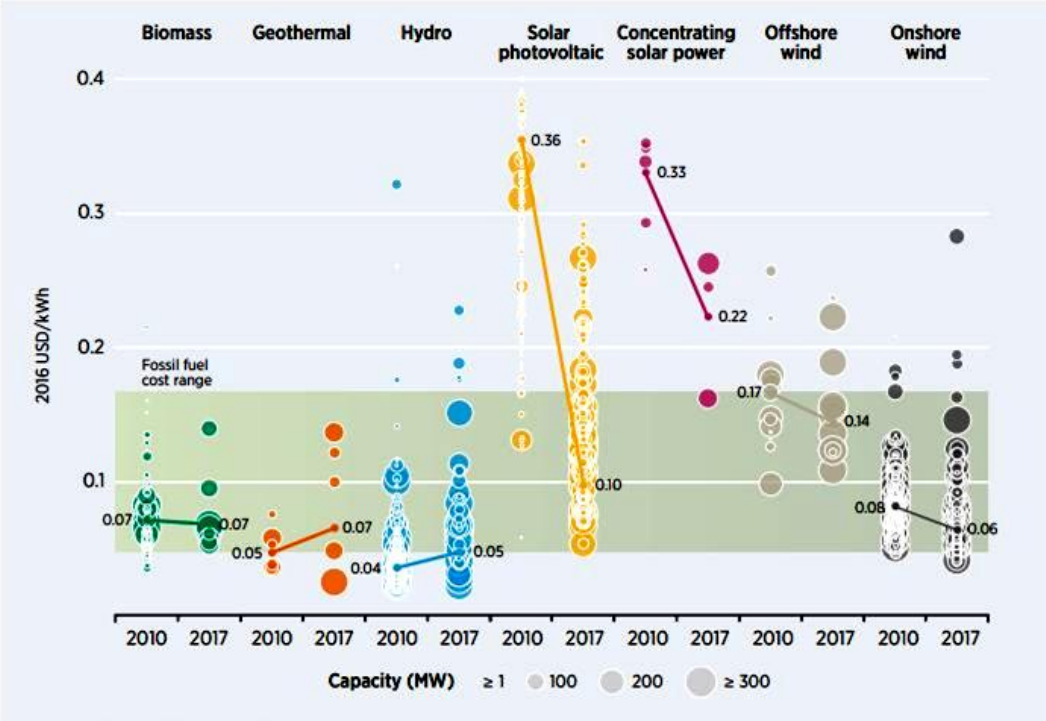
Figure 6. LCOE in Different Regions of the World for Wind Power Generation, 2017

scale solar PV has risen since 2010, although this increase has been driven more by a growing share of projects in the sunbelt than by technology improvements. As a result of all these factors, solar PV is increasingly competing head-to-head with conventional power sources, and doing so without financial support in a growing number of locations.

Offshore wind power and concentrating solar thermal power (CSP), although still at relatively early stages in deployment, both saw their costs fall between 2010 and 2017 to a global weighted average LCOE of USD 140 per MWh and USD 220 per MWh, respectively. These values are still relatively high, but the cost reduction potential for these technologies is strong.

The years 2016 and 2017 saw record low auction prices for solar PV in Abu Dhabi and Dubai in the United Arab Emirates, as well as in Chile, Mexico, Peru and Saudi Arabia. Similarly, very low auction results for onshore wind power in countries such as Brazil, Canada, Germany, India, Mexico and Morocco have made onshore wind power one of the most competitive sources of new generating capacity in those locations. For CSP and offshore wind power, 2016 and 2017 were breakthrough years: auction results for projects that will be commissioned in 2020 and beyond signal a step-change, with the costs of electricity under these contracts being significantly lower than the costs of projects commissioned in 2017.

The lowest auction prices for renewable power reflect a nearly constant set of key competitiveness factors. These include: a favorable regulatory and institutional framework; low off take and country risks; a strong, local civil engineering base; favourable taxation regimes, low project development costs; and excellent renewable energy resources.



Source: IRENA Renewable Cost Database.

Note: The diameter of the circle represents the size of the project, with its center the value for the cost of each project on the Y axis. The thick lines are the global weighed average LCOE value for plants commissioned in each year. Real weighted average cost of capital is 7.5% for OECD countries and China and 10% for the rest of the world. The band represents the fossil fuel-fired power generation cost range.

Figure 7. Global LCOE from utility-scale renewable power generation technologies, 2010-2017

Projects contracted via competitive procurement in 2017 may represent a relatively small subset of renewable power capacity additions over the next few years, and trends in auction results may not be representative of LCOE trends at a project level. Nevertheless, based on the auction prices in 2017 and 2018, the outlook for solar and wind electricity prices to 2020 presages the lowest yet seen for these modular technologies, which can be deployed in every country of the world.

3.3 Cost Reduction Potentials to 2025 for Wind Power Generation

Despite the substantial cost reductions that have occurred since the deployment of wind power on a commercial scale in the early 1980s, onshore wind still holds significant cost reduction potential for the period out to 2025. IRENA has assessed the cost reduction potential for onshore wind from a top-down and bottom-up perspective. The top-down analysis is based on a learning curve analysis, while the bottom-up analysis looked at trends in wind turbine technologies and wind farm development to estimate the shift to higher performance turbines in different markets and cost implications of new technology innovations. Estimates of the contribution of increased market scale and maturity are harder to assess, but have been estimated based on trends in turbine pricing and analysis by consultants of supply chain efficiencies. In terms of deployment, the next doubling of onshore wind is likely to occur between 2020 and 2022, depending on deployment rates. Accelerated deployment in the IRENA RE map 2030 analysis, however, suggests that under an aggressive deployment scenario, a doubling from 2014 values could occur as soon as 2019.

The key directions in technological innovation that will allow for the reduction of the LCOE of onshore wind out to 2025 are the following:

- **Larger turbines:** The continued trend towards larger turbines will have a small but important impact in lowering installed costs through economies of scale, as well as reducing per-kilowatt wind farm development costs. But may be cost-neutral in some markets due to offsetting cost increases for towers and foundations if not accompanied by light-weighting.

- **Advanced blades:** These will have a modest impact on reducing installed costs, but can raise electricity output.

- **Advanced towers:** These can reduce installed costs, relative to conventional steel towers, in order to access higher average wind speeds or "smoother" winds at greater heights.

- **Improved turbine reliability and O&M best practices:** These can reduce turbine downtime and raise electricity yields, while reducing maintenance costs from unscheduled malfunctions.

- **Lean supply chains and increased competition:** This will help reduce installed costs by ensuring the most competitive supply chains are maintained.

- **Wind farm best practices:** These can reduce development and installation costs by using industry best practices more widely.

There will be significant variations in the cost reduction potential depending on the market. More competitive markets using today's latest technologies are going to benefit from incremental technological improvements and greater economies of scale, as well as competitive pressures. Yet they will not see as large cost reduction potentials as in markets where there is more scope for cost reductions due to inefficient supply chains, lack of competition and other factors. However, it is worth noting that the markets with the lowest cost reduction potential are also often markets with very competitive costs today relative to other new power generation capacity options.

Turbines and towers account for the largest share of the installed cost reduction potential to 2025 (Figure 8). These account for 27% and 29%, respectively of the total reduction in the global weighted average installed cost of onshore wind farms (IRENA analysis and MAKE Consulting, 2015b). Yet, the increased application of best practices in wind farm development by project developers and regulators could yield around one-quarter of the total cost reduction. Best practices include streamlined project approval procedures and nationally agreed evaluation criteria for local consultation. Supply chain and manufacturing economies of scale account for around 13% of the total cost reductions and advanced blades for the balance. Overall, the global weighted average total installed cost for onshore wind could fall from around USD 1560/kW in 2015 to USD 1370/kW in 2025 (Figure 8).

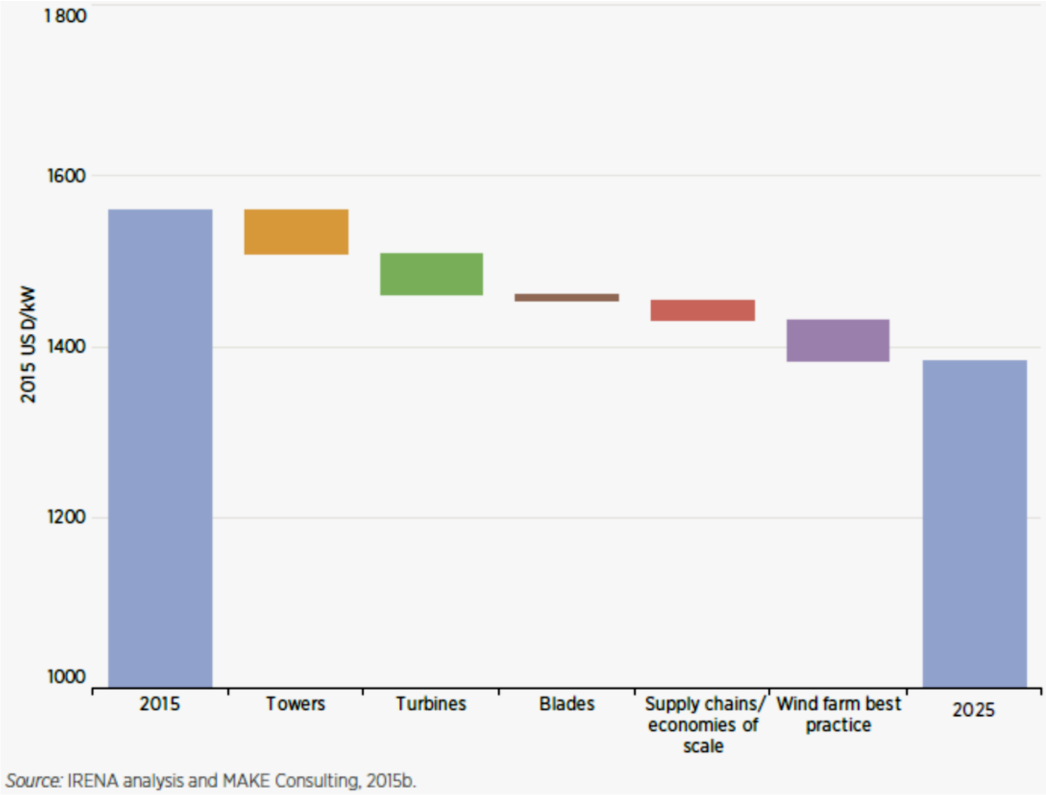


Figure 8. Total Installed Cost Reduction for Onshore Wind Farms by Sources, 2015-2025

As has already been highlighted, the growth in global weighted average capacity factors has been driven by improvements in turbine technology; including larger turbines, more efficient blades, higher hub-heights (accessing better wind resources) and larger swept areas. In Germany, rotor diameters increased from 48 m in 1998 to 99 m in 2014. In Denmark, they increased from 45 m to 104 m, while in the United States, they rose from 48 m to 99 m. Rotor diameters are estimated to reach 125 m in Denmark, 119 m in the United States and 120 m in Germany by 2025. Accordingly, the wind turbine hub heights have been increased in recent decades. Higher hub height allows developers to access better wind resources and exploit rougher terrain in countries where land constraints are an issue. However, higher hub height can raise tower and foundation costs. In recent years, this cost escalation has been relatively modest as light-weighting of the nacelle and components has helped reduce any impact.

When combining the trends in the increasing use of today's latest technology, availability increases from improved reliability, as well as new innovations in turbine controls, advanced and more efficient blades, and the improvements in micro-siting and wind farm development, the global weighted average capacity factor could increase from 27% in 2015 to 32% in 2025 (Figure 9). At a global level, the average contribution of increased capacity factors would be to reduce the global weighted average LCOE by around USD 0.01/kWh. However, there are a range of factors that mean the actual weighted average value of the capacity factor in 2025 could be higher or lower (represented by the shaded range in Figure 9). This is due to uncertainty around the rate of increase in hub heights and rotor diameters in key markets, such as India and China, where the rate of adoption of larger machines has a significant impact on the global weighted average. Perhaps the largest uncertainty remains the trends in resource quality for new wind farm developments to 2025.

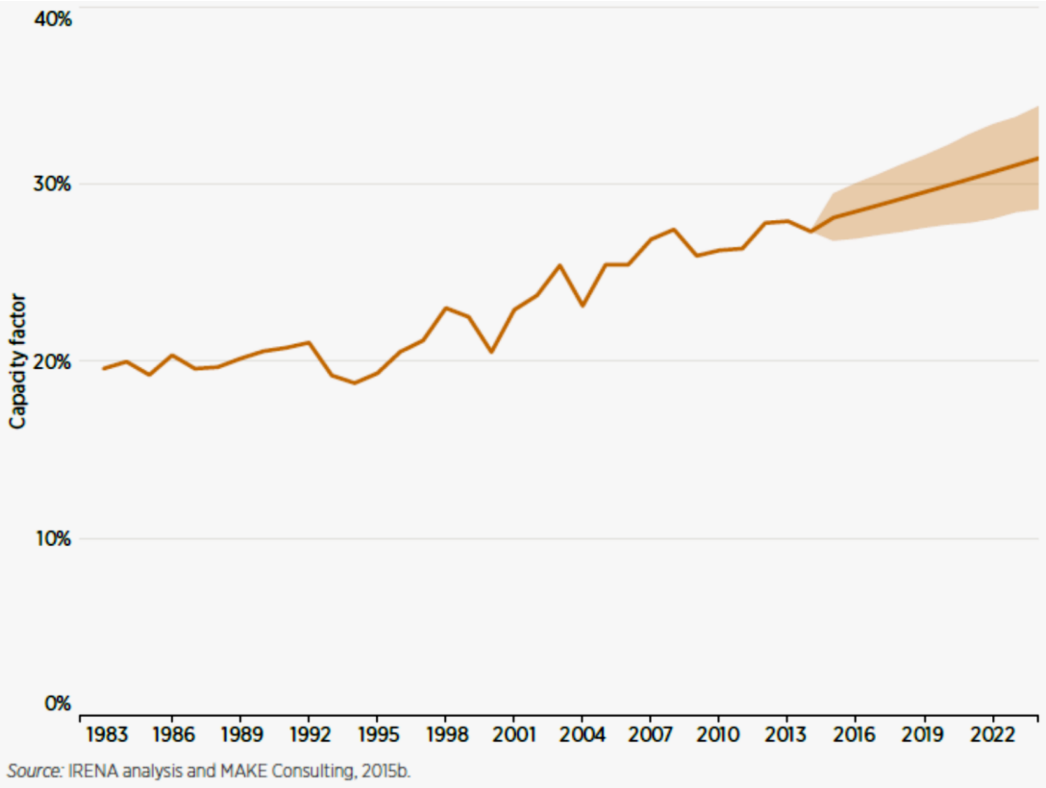


Figure 9. Global Weighted Average Onshore Wind Farm Capacity Factor, 1983-2025

In a conclusion it could be said that the onshore wind is now a highly competitive source of new power generation capacity, with medium-and even low-wind speed sites now economically viable with recent wind turbine improvements. This has greatly broadened the competitive situation of what is already a modular and versatile power generation technology. The potential improvement in capacity factors by 2025 could result in reducing the global weighted average LCOE of onshore wind by around USD 0.01/kWh, or 49% of the total projected reduction in onshore wind LCOE of USD 0.018/kWh as the global weighted average LCOE falls to USD 0.053/kWh by 2025. Reductions in total installed costs, driven mostly by cost reductions for towers, turbines and wind farm development, contribute around USD 0.006/ kWh (34%) of the total reduction in the LCOE. Improvements in turbine reliability, improved predictive maintenance schedules and the more widespread application of best practice O&M strategies reduce the LCOE by around USD 0.003/ kWh by 2025, or 17% of the total reduction (Figure 10). Looking at the evolution of the LCOE cost range for individual projects highlights that there will remain a wide variation in project LCOEs. At the lower end of the LCOE range, LCOEs are unlikely to fall below USD 0.03/kWh for the 5th percentile of projects. However, exceptional projects where excellent wind resources, very low installed cost structures and highly competitive O&M costs exist will challenge this lower bound.

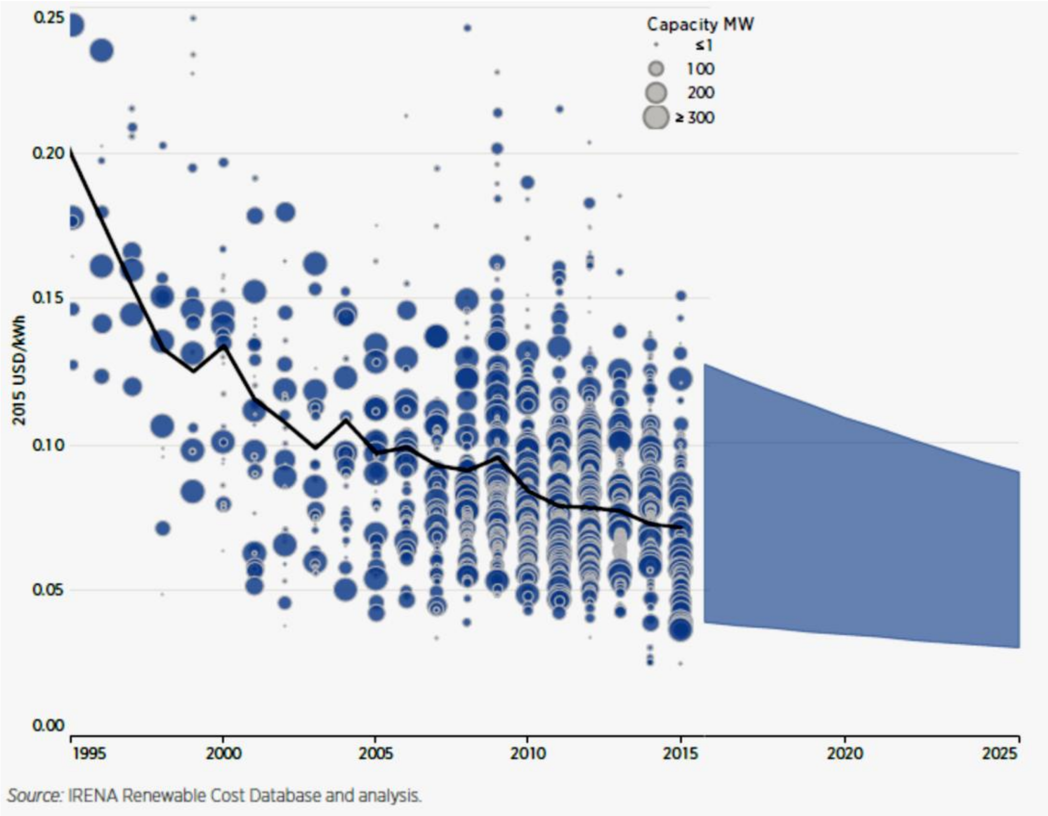


Figure 10.Levelised Cost of Electricity of onshore Wind, 1983-2025.

Summarizing all the information of Bangladesh and Global wind status, Wind Working Committee has come to a conclusion that wind is going to be a game changer in power sector if the sector is developed in a planned manner. Despite of having some big constraints like- poor infrastructure and transport, crisis of lands, lack of wind guideline, challenge of grid integration etc Bangladesh can be a versatile in power generation by using wind.

4. Recent Studies

4.1 Feasibility Study for Installation of Wind Farm in Matabari Island of Moheshkhali Upazila Under Cox's Bazar District:

Coal Power Generation Company Bangladesh Ltd. (CPGCBL) has envisaged the implementation of a wind farm project around Matarbari Island to harness the wind potential of the area as a green initiative. The proposed Matarbari Wind Project, located in Chittagong, is approximately 30 km to the northwest of Cox's Bazar, and 75 km south of Chittagong. Its location is indicated on the regional map as shown below, with an inset map showing the approximate location of the project within Bangladesh and is in proximity to the proposed 2x600 MW Coal Power Plant. TUV SUD-AWS Truepower JV was awarded the contract for performing "Wind Mapping and Wind Modelling" along with conducting Feasibility study for installation of wind farm in the Island.

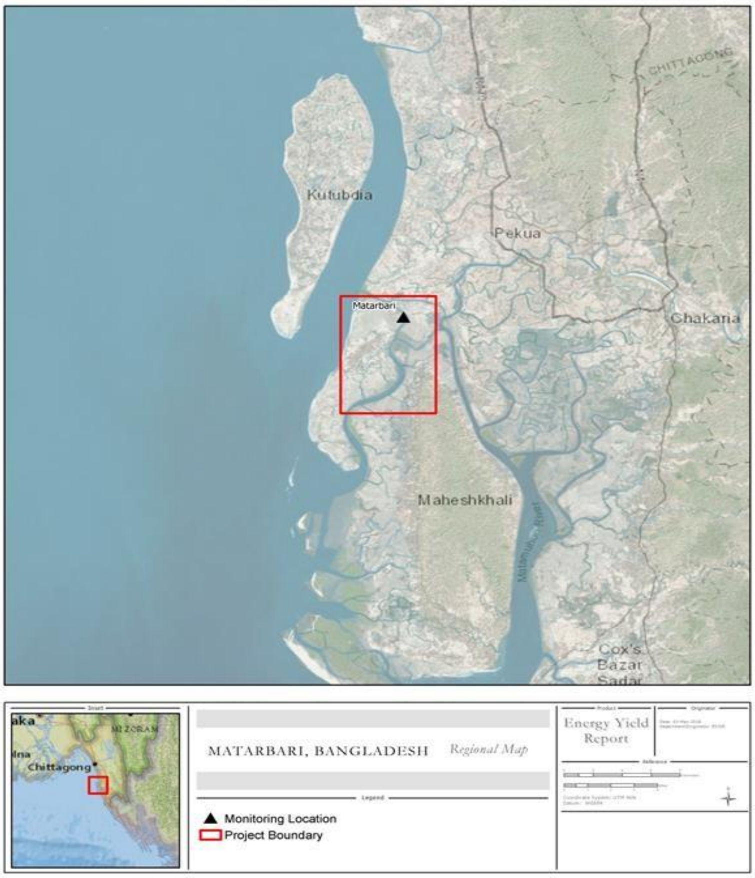


Figure 11: Wind assessment site of Matarbari

4.1.1 Wind Resource Characteristics:

A 100 m height wind mast was installed along with all the accessories on 16th February 2017 at Matarbari for measurement of wind potential at site, which was satisfactorily commissioned on 21st February 2017. After analysis & validation of wind measurement records of one year, it is observed that the annualized mean speed, which takes into account repeated months in the data record and weights each calendar month by its number of days, comes out to be 5.76 m/s with wind shear of 0.27 from 80m to 100m height measurements. Wind power density estimated to 197 W/m2 at 80m height. The Matarbari wind mast observed turbulence intensity at 15 m/s, 0.080, is consistent with the surface roughness at the site. These data conclude that site has a potential and is technically feasible for the installation of wind turbines.

Table 4: Matarbari Observed Wind Resource Characteristics

Parameter	Value
Measurement Height (m)	100.0
Mean Wind Speed (m/s)	5.76
Annualized Speed (m/s)	5.76
Data Recovery (%)	99.1
Annualized Wind Shear Exponent* (Heights)	0.270 (100.0 m / 80.0 m)
Turbulence Intensity @15 m/s Speed Bin	0.080
Annual Weibull Parameters (*A*/*k*)	7.70 m/s / 2.34
Annual Prevailing Wind and Energy Direction	SSE / SSE
Energy-Weighted Air Density (kg/m^3)	1.167
50-m Wind Power Density (W/m^2)	150
80-m Wind Power Density (W/m^2)	197

Since the wind climate can vary significantly over time scales of months to years, it is important to adjust the data collected at a site to represent historical wind conditions as closely as possible. The method used to make this adjustment is known as measure-correlate-predict, or MCP.

The observed annual average wind speed of 5.76 m/s at 100m is corrected to 5.87 m/s at 100m height by measure correlate-predict method (MCP). The mean wind speed was extrapolated to the anticipated 90.0-m, 91.5-m and 140 m hub heights using the power law which takes into account observed shear factor at mast. The extrapolated wind speed at anticipated 90.0-m, 91.5-m and 140 m hub heights is 5.70 m/s, 5.73 m/s and 6.42 m/s respectively.

4.1.2 Turbine Selection:

TUV SUD-AWS Truepower JV studied the various available data from regional data sources including the tropical cyclones which had occurred in that region and used it for the calculation of 50-year return period for tropical cyclone extreme wind speeds. Though the average annual wind speed observed 5.76 m/s at 100m height which falls under low wind speed region suitable for class three turbine installation, however looking at 50-year gust wind speed (history of cyclone at site) Vestas V117 3.45 MW and GE 4.1 MW 113 RD Class-I wind turbine models are considered for installation at propose site and prepared layout for financial modeling. Also, as per suggestion of Vestas (OEM), their class-III wind turbine model V150 4.2 MW has also been considered in the study.

An optimized turbine layout for Vestas 3.45 MW, GE 4.1 MW & Vestas 4.2 MW model was prepared to ensure the minimum wake effect and with best suitable location for the installation. Total eight number of wind turbine location for Vestas 3.45 MW & GE 4.1 MW and six number location for Vestas 4.2 MW wind turbine model identified at boundary shared by CPGCBL.

Table 5: Turbine selection options

Turbine Manufacturer/Model:	**Vestas V117-3.45 MW**	**GE 4.1-113**	**Vestas V150-4.2 MW**
IEC Class:	IB	IB	SB
Rated Capacity (kW):	3450	4100	4200
Rotor Diameter (m):	117	113	150
Hub Height:	91.5	90	140
Cut-in wind speed (m/s):	3	4	3
Cut-out wind speed (m/s):	25	25	24.5
Annual Average Wind Speed (m/s)	10	10	7.0
Extreme wind speed (10-minute Average; m/s)	50	50	37.5
Reference Turbulence Intensity (I_{ref}; %)	14	14	14
Type of Generator	Three phase induction generator with squirrel cage rotor	Permanent magnet synchronous generator	Three phase induction generator
Protection Class	IP54	IP54	IP54
Protection Used	Grid code compliant, Over voltage	Grid code compliant, Over voltage	Grid code compliant, Over voltage

It is recommended that before award of contract to OEM for supply of wind turbine models at proposed site, OEM should visit the site for necessary analysis and offer best suitable wind turbine model to optimize both low wind speed and cyclone condition at site to make project techno-economically viable.

4.1.3 Energy Estimation Results:

The energy production was simulated for the Vestas V117-3.45 MW (117.0-m rotor diameter, 91.5-m hub height), GE 4.1 MW (113m RD 90m hub height) and Vestas V150 4.2 MW wind turbine model. Each turbine in the layout was associated with the wind speed and direction distribution file from Matarbari. Turbine wise estimated energy generation is summarized below:

The average air density was calculated from the wind speed and temperature data at Matarbari and adjusted to the mean elevation of the turbines using a standard atmospheric lapse rate. The study relied on in-house power curve of proposed wind turbine models. The necessary extrapolations of power curve data to accommodate the site-specific air densities have been conducted automatically by openWind@software based on standard IEC methods.

Table 6 : Matarbari wind assessment details

Project Name	CPGCBL Matarbari Proposed Wind Power Project					
Project Location	Matarbari island of Moheshkhali Upazila under Cox'sbazar District					
Project Scenarios	**Case-1 JICA Project**			**Case-2 JICA + Singapore Project**		
Rated Capacity	**27.6 MW**	**32.8 MW**	**25.2 MW**	**48.3 MW**	**57.4 MW**	**42.0 MW**
Turbine Model	Vestas V117-3.45 MW (3.45-MW) 117.0-m Rotor Diameter Standard Weather Package	GE4.1-113 (4.10-MW) 113.0-m Rotor Diameter Standard Weather Package	Vestas V150-4.2 MW (4.20-MW) 150.0-m Rotor Diameter Standard Weather Package	Vestas V117-3.45 MW (3.45-MW) 117.0-m Rotor Diameter Standard Weather Package	GE 4.1-113 (4.10-MW) 113.0-m Rotor Diameter Standard Weather Package	Vestas V150-4.2 MW (4.2-MW) 150.0-m Rotor Diameter Standard Weather Package
Hub Height	91.5 m	90 m	140 m	91.5 m	90 m	140 m
Number of Turbines	8	8	6	14	14	10
Array-Average Free-Stream Speed	5.79 m/s	5.76 m/s	6.47 m/s	5.77 m/s	5.75 m/s	6.46 m/s
Gross Annual Production	58.4 GWh/yr	54.6 GWh/yr	83.3 GWh/yr	101.3 GWh/yr	94.7 GWh/yr	138.3 GWh/yr
Plant, Wake, and Total Losses	Plant-16.8%; Wake – 3.9%; Total–20.0%	Plant – 17.8%; Wake – 3.7%; Total – 20.9%	Plant – 15.4%; Wake – 3.0 %; Total – 18.0 %	Plant – 16.8%; Wake – 6.7 %; Total – 22.4%	Plant – 17.8%; Wake – 6.6 %; Total – 23.3%	Plant – 15.4%; Wake – 4.1 %; Total – 18.8 %
Net Annual Production (Plant Load Factor)	46.7 GWh/yr (19.3%)	43.2 GWh/yr (15.0%)	68.4 GWh/yr (30.9%)	78.6 GWh/yr (18.6%)	72.6 GWh/yr (14.4%)	112.3 GWh/yr (30.5%)
P90 Production [Years 2-20] (Plant Load Factor)	39.6 GWh/yr (16.4%)	36.2 GWh/yr (12.6%)	59.7 GWh/yr (27.0%)	66.6 GWh/yr (15.7%)	60.8 GWh/yr (12.1%)	98.0 GWh/yr (26.6%)
P90 /P50 ratio	0.85	0.84	0.87	0.85	0.84	0.87

4.1.4 Project Cost and Tariff Estimation:

Wind Turbine Generator includes cost of wind turbine generator components like rotor, Nacelle, tower and power transformer. The estimated onshore wind turbine equipment cost is based on interaction with WTG supplier and NREL report on cost of wind energy in 2016. It is estimated to $1.07 MN per MW.

Balance of System includes cost of engineering, wind turbine foundation, civil work at unit substation, preparation of approach road, SCADA monitoring center, evacuation line, unit substation and erection commissioning of wind turbine. The cost is estimated on the basis of interaction with WTG supplier,

Table 7: Estimated project cost for selected wind turbine models for Case-1 JICA Project

Indicators	Unit	Vestas V117, 3.45 MW	GE4.1 -113, 4.1 MW	Vestas V150, 4.2 MW
Project Capacity	MW	27.6	32.8	25.2
Project Cost	Mn $	61.03	72.53	55.72
Tariff Rate (that will generate return required by CBGCBL i.e.14.5%)	$/Unit	0.2060	0.2663	0.127
IRR	%	14.51%	14.50	14.50
DSCR		1.23	1.23	1.23
No of yrs. DSCR < 1	Yrs	0	0	0
Payback	Yrs	11	11	11

Table 8: Estimated project cost for selected wind turbine models for Case-2 JICA + Singapore Project

Indicators	Unit	Vestas V117, 3.45 MW	GE4.1 -113, 4.1 MW	Vestas V150, 4.2 MW
Project Capacity	MW	48.3	57.4	42
Project Cost	Mn $	106.81	126.93	92.87
Tariff Rate (that will generate return required by CBGCBL i.e.14.5%)	$/Unit	0.2143	0.2774	0.1285
IRR	%	14.5	14.50	14.50
DSCR		1.23	1.23	1.23
No of yrs. DSCR < 1	Yrs	0	0	0
Payback	Yrs	11	11	11

NREL report on cost of wind energy in 2016 and proposed site condition. It is estimated to $0.94 MN per MW.

Preliminary and Preoperative expense includes expenditure towards consultancy services, bank appraisal charges, govt. and statutory charges incurred by promotor prior to commencement of the project. The estimated preliminary and preoperative expense is 2% of project cost.

Contingency expense is estimated to cover the unknown uncertainty may occur during project execution which will have the cost impact over and above the estimated project cost. The estimated contingency expense to 2% of project cost. Interest during construction cost is derived based on estimated project construction period of one year and interest on term loan to be paid to bank during construction period. It is estimated to 3.1 to 4.0 MN $ for the models considered in the study.

4.1.5 Environmental Impact Assessment:

The project is likely to generate some environmental and social impacts due to construction, operation and establishment of associated facilities. Mitigation measures for attenuation of potential impacts on Air, Water, Land, Soil, Noise, Traffic, Ecology, and Socio-economics have been specified through different remedies, such as:

- To emulate best practice of public disclosure about the project to the local community, and grievance management;
- Planning & designing of wind farm sites, WTGs location preparation and access route, construction, drainage, traffic movement etc.;
- Application of standards for Health and Safety; and
- Clearances and permits required for each sub activity.

Based on the ESIA study conducted the proposed project can be categorized as **Category B** (***as per IFCs categorization of projects***), which is likely to have very insignificant and limited, short term adverse social and/or environmental impacts that can be readily addressed through mitigation measures.

4.2 Assessing the Wind Energy Potential in Bangladesh by NREL:

Since 2011, the USAID Bangladesh Wind Resource Assessment Project has provided technical assistance to support the GOB's goal of promoting wind development as a low-emission, domestic energy resource that will meet growing energy needs and stimulate rural economic development within the country.

Assessing the deployment of utility-scale wind technologies requires a large investment in measurement campaigns and a high level of technical knowledge to identify and prioritize potential development opportunities. Wind experts from NREL worked with GOB experts and partners to install, operate, and maintain state-of-the-art wind-measurement systems in nine strategic and geographically diverse locations across Bangladesh. Once these measurement systems became operational, over 3 years of wind data were collected and put through a rigorous quality-control (QC) process. The results of the data collection were used to validate a sophisticated (and open-source) weather-prediction model. To ensure generation of investment-quality wind resource data, the project team used internationally recognized best practices and state-of-the-art measurement and modeling tools to assess Bangladesh's coastal and inland wind power potential.

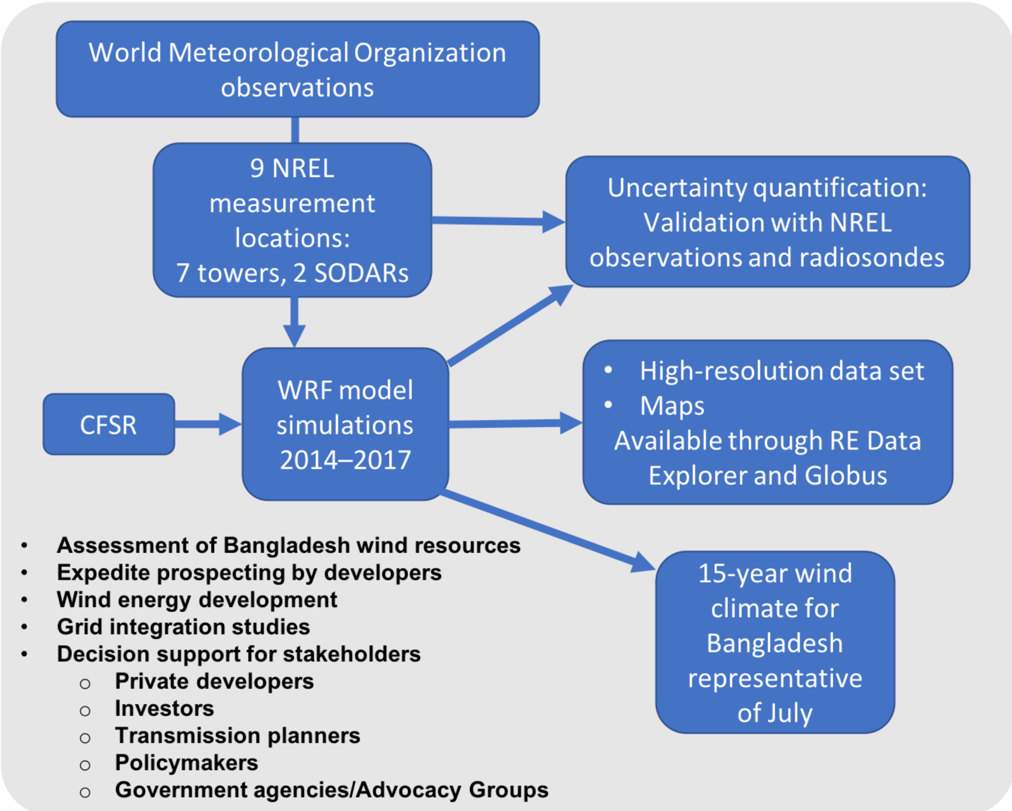


Figure 12. The project's approach of using observational data to inform the model simulations. *The applications of the data product are bulleted in the lower left. CFSR = Climate Forecast System Reanalysis data set.*

4.2.1 Measurement Site Selection

The process of determining the final locations for the towers and SODAR equipment began with a desktop analysis, was followed by micrositing in the field, and was concluded after final land-lease agreements were executed.

Step 1. Desktop Analysis

The first step in the site-selection process was a desktop analysis using computer-based mapping tools to determine potential site areas for further inspection. The desktop analysis began by superimposing layers that represented each level of the site-selection criteria to Bangladesh's map. After all layers were added to the map, it became more straightforward to identify the most effective locations (based on criteria noted below) for the modeling effort while continuing to meet the access and construction requirements for the installation and maintenance of the MET towers and remote-sensing equipment.

Selection Criteria

When considering the selection criteria for this project, three primary goals were established to inform the final list of layers used to isolate potential measurement locations.

i. Represent many geographic regions. The measurement sites should represent as many geographic regions of the country as possible and add as much value to the country-wide modeling effort as possible. A key objective of the overall project was to create a resource tool that could be trusted to inform investment decisions accurately for Bangladesh. Knowing about low-wind-speed areas could be just as important as knowing about high-wind-speed areas if it reduced the potential for investment in underperforming projects.

ii. Properly position the towers, considering terrain and nearby obstacles. Proper positioning minimizes air disturbance and improves the site-representativeness of the measured data. The locations must be capable of hosting the measurement asset and providing high-quality data. This meant meeting construction space requirements but limiting environmental impact, meeting established budgets, and ensuring that the area was safe for crews to stay and work. Where possible, the tower was located away from any significant trees or manmade obstacles. This was especially important if the tower was similar in height to the trees or obstacles nearby. Any obstacle at a height similar to that of the instrumentation has the potential to influence the speed and direction of the wind before it is measured. This could lead to a data set that misrepresents the available resource with undervalued wind speeds or overestimated turbulence.

iii. Provide project areas with potential development. Go beyond the development of a wind resource data product for Bangladesh and provide areas of potential project development, assuming the wind speeds are sufficiently strong. A potential developer for any new wind site needs site data to verify investment decisions. Using site data from this project instead of setting up new measurement assets could reduce development costs and shorten development timelines. For the terrain, the sites were located in areas representative of future proposed turbine locations. If a proposed future wind project was located in an area having diverse slope angles, hills, and ridges, then it was important to place MET towers in several areas that represent the diversity of terrain present on the site. Additionally, to improve development potential, the sites were located near a utility-scale transmission line.

Considering these goals, a list of selection criteria was established to focus the search. The following factors were considered:

- Geographic diversity. Ideally, these sites would meet the diversity requirement, and all eight divisions of Bangladesh would receive at least one measurement site.
- Proximity to major load centers. Sites near city centers with the highest populations or major industrial zones (e.g., Dhaka, Chittagong, Sylhet, Jessore, Mymensingh) were prioritized in an attempt to match electricity supply to the areas with the greatest demand. This opened up the potential for distributed projects.
- Proximity to existing high-voltage transmission. The construction of transmission equipment can be cost prohibitive. The potential for utilizing existing transmission infrastructure could help those areas with lower wind speeds meet internal rate of return limits.
- Primarily open areas. To capture the best data, the sites had to be clear of obstructions, both natural and manmade. Areas near rivers, open agricultural zones, ocean shorelines, and ridgelines were considered.
- Limited environmental impact. Tree clearing and significant impact to the area beyond the disturbance necessary to install the measurement asset were avoided.
- Sufficient tower area. The clearing had to be large enough to accommodate the tower footprint.
- Wind turbulence reduction. The clearing in the north/south directions had to be large enough to provide uninhibited wind flow.
- Access. The existing roads had to be large enough to allow transport of crew and materials to and from the site.
- Safety. The area had to be physically safe for the crew.

After all of the criteria were applied, the remaining areas represented potential measurement locations that would be acceptable for project execution. With a target of nine measurement locations, the team needed to select nine areas from the map for further investigation.

A site area was selected in each division except Barisal. The Barisal Division posed some logistical challenges for construction. Given its close proximity to Khulna to the west and Chittagong to the east, the team decided that the Barisal site could be moved east without negatively affecting the overall modeling effort. The final site was placed in the Chittagong Division, along the coast further to the south. With most of the expected high winds coming from the south off the Bay of Bengal, it was important to make sure the coastline was well represented.

Step 2. Micrositing

After potential locations were targeted during the desktop analysis, a field team was deployed to inspect the sites, confirm the information that was identified during the desktop analysis, apply the next layer of more-detailed site requirements, and begin the process of establishing lease agreements (led by the GOB) with the landowners. During this process, the team was looking for the following:

- Good exposure. The available wind rose for these areas showed that the predominant winds come from the south in the summer and from the north in the winter. Thus, the areas to the north and to the south of the site had to be clear of obstructions to allow for uninterrupted wind flow from these predominant directions.

- Clear area. The open land area had to be large enough to host the footprint of the tower and guard house or the SODAR platform and guard house. It also had to allow for the orientation of the equipment to maximize the data availability and quality.

- Access. The site had to have existing transportation routes in place to allow vehicles to bring tower materials, concrete materials, and crew members to and from the site.

- Appropriate land use. Most of the open land in Bangladesh is used for agriculture or aquaculture activities. Land used for rice cultivation is flooded during the summer months but dry during the winter months. Land used for fish farming is flooded year-round. Land used for tea or fruit farming is often dry year-round. It is difficult to use satellite imagery to determine how the land is used or how conditions change seasonally at that specific location. Ideally, the site area had to be dry for most of the year for construction and continued site access.

- Safety. There are inherent risks of working in Bangladesh that applied to the entire project, but each site could pose a unique set of risks. It was important that each site was free from aggressive or dangerous wildlife and that the area was politically stable, supported the project, and was hospitable for a team from the United States.

- Minimal number of landowners. The land area for the tower footprint (base and anchors), the guard house, and the access right of way often covered the land owned by more than one entity. For fewer complications during the land-lease negotiation process, it was important to try to find an area with the fewest landowners.
- Supportive landowners. It was critical that the landowners supported the project. The landowners would become the local project representatives and provide ongoing support and critical information throughout the project. They needed to be respected as stakeholders from the beginning of the process.

Experience had proven that it was critical to have at least one representative from the data team, the construction team, and the land-acquisition team on each micrositing trip. The data and construction representatives confirmed that the site met all of the requirements to make it a good data-collection location, and then the land-acquisition team immediately started speaking with landowners and began the process of establishing lease agreements. This approach gave the team the flexibility needed to find a new site quickly if land negotiations stalled.

Step 3. Land Lease

After the final site was selected and the site-selection criteria had been verified, the process of reaching a lease agreement between the GOB, Power Division (GOB-PD) and the landowner was initiated. The land- acquisition process was led by the GOB-PD and occurred at all nine measurement sites. Drawings that detailed the areas impacted during construction and the areas occupied during the measurement period were provided to the GOB-PD and used to identify the total area of impacted land for the lease agreement. The GOB-PD representative would start the negotiation during the micrositing visit and would travel between the site area and Dhaka until the final formal contract was executed. We found land deeds and proof of land ownership difficult to find and verify. Figure 5 demonstrates the typical layout map used to communicate with the contractor in charge of tower installation (Harness Energy), the GOB, NREL, and the landowner.

Figure 13 . Layout for the Sitakunda tower

4.2.2 Results

(a) Field measurement data

The measured data sets containing the measured data are publicly available via Globus Connect (https://www.globus.org/ (retrieved on 05 March 2019)). Two different types of measured data sets are available: raw data and quality-controlled data.

The raw (text) data files are available via the RE Data Explorer. The raw data files from the towers are available in different types and time-step intervals. The daily files are the data packets pushed daily from the data logger to the server; these files typically contain a day's worth of data. Occasionally, a daily file is less than a full day's data, either due to collection/transmission errors or because the file is from the first or last day of monitoring. Daily data files are available with either 1-minute or 10-minute time steps. To make identification easier, the daily files are named using the follow convention: four-character site code then time step (oneMin or tenMin), then eight-digit date, and then a letter (if more than one file is available for a given date). For example, the file from Parkay Beach for October 12, 2015, has the filename PKAY_tenMin_2015_10_12.dat.

The other type of raw files from the towers are the "logger" files. These files are data that were downloaded from the data loggers during site visits by Harness Energy personnel (http://www.harnessre.com/(retrieved on 05 March 2019)). These files each generally contain several months of data. The data in these logger files have a time step of either 1 minute, 10 minutes, or 1 hour. These files are named using the following convention: Site name-(time step)-start date-end date. An example is "Mongla (Ten Min)-20160313-20160806."

The SODAR raw data files are different from the tower raw data files. The data from the SODAR unit are pushed several times a day to the SODAR manufacturer's server. The analyst can then download the data from the server by selecting data from a specific period. The analyst also can choose to only download data with a QF equal to or greater than a specified minimum. Values for QF can range from 0 (worst) to 100 (best). The SODAR raw data files in the RE Data Explorer contain the data for the whole monitoring period and with no minimum QF. The QF for each data point is provided within the file, allowing users to filter the data to whatever value of QF desired. There are two raw data files for each SODAR site. One file has the wind speed and direction measurements. The other file, dubbed the "operational" file, contains additional measurements, such as temperature, as well as data streams regarding the status of the SODAR unit.

Table 11 provides details of the raw data files for each monitoring site. In contrast to the raw data files, there is only one processed data file for each site. The processed data file names are listed in Table 12. The situation for the files created for the modeling team is the same as for the processed files; there is one file per site.

The summary reports which includes the measured wind speed, direction (wind rose), Weibull distribution, wind shear profile, power law exponent, turbulence intensity etc. at all the stations (9 sites) are given in Appendix.

(b) Wind Model Simulation

To complete the wind resource assessment in Bangladesh, a rigorous model simulation has been done by NREL. The model setup that was chosen based on the results of the sensitivity study was used to conduct the 3-year numerical simulations that ingested the observations set up during the measurement campaign. The simulations were compared with observations; that is, a validation was performed to assess the accuracy of the model simulations and to estimate the uncertainty of the resulting wind resource assessment.

i. Validation of the Model Simulations

ii. Validation Methodology

To validate the multi-year simulations with the WRF model and FDAA, we used the above-surface wind- speed observations from the seven NREL MET towers set up around Bangladesh, the NREL SODAR that was set up in sequence at two primary measurement locations (after being co-located for a month near the Rajshahi tower) around Bangladesh, and any publicly available radiosondes within the third domain.

Radiosondes generally were available twice per day, at 0000 Coordinated Universal Time (UTC) and 1200 UTC. To focus on validation of rotor layer winds, only observations between 10 m AGL and 200 m AGL were used. A secondary validation was performed against observations that were taken at 80 m AGL (+/- 5 m) to assess model performance at hub height.

The WRF-FDDA simulations began at 0000 UTC on June 1, 2014, and continued to 2300 UTC on December 29, 2017, to encompass the full operational period of every NREL MET tower and the NREL SODAR and to guarantee that at least 2 full years of data were collected from each MET tower and 1 full year of data from both primary sites at which the SODAR was deployed (the initial deployment of the SODAR at Rajshahi was for testing purposes and only lasted for about 1 month). All available observations within the simulation window were used for assimilation.

The FDDA assimilated all publicly available WMO observations (e.g., radiosondes, surface observations, aircraft observations) plus the special NREL observations. This experiment is called "WMO+NREL." To assess the impact of the special NREL observations, another WRF-FDDA simulation was run that assimilated only the standard WMO observations. This experiment is called "WMO_only." For both experiments, the same set of observations was used for validation.

Prior to assimilation, the observations were passed through the "wrfqc" QC program (Liu et al. 2004), where they were processed for QC against a first-guess model field and compared to the expected error of the type and height of the observation. The expected observational error is based on static statistics from NCEP's operational Global Forecast System (GFS) model and data assimilation system. Based on this evaluation, observations were assigned an integer value from 0 (bad) to 10 (excellent); the nudging coefficient was made proportional to this QC value. Thus, observations that received a QC value of 0 were given no weight and were not assimilated, but observations with a QC value of 10 were given maximum weight in the assimilation. For this validation, observations with a wrfqc value of 0 were withheld from the validation. Less than 0.1% of the MET tower, SODAR, and radiosonde observations received a QC value of 0, and more than 90% of the observations received a "good" QC value of 8, 9, or 10.

The WRF-FDDA simulations were validated using the metrics RMSE, mean absolute error (MAE), and mean error (ME), all of which are commonly used. In addition to the RMSE, MAE, and ME, we also explored the distributions of the WRF and observed wind speed through both scatterplots and binned histograms.

At each observation location, the WRF wind speeds first were interpolated horizontally using inverse distance weight interpolation from the surrounding grid points. Then the model wind speeds were interpolated linearly in height to the observation heights. Model levels generally were spaced about 20– 25 m apart in the rotor layer; thus, linear interpolation is deemed an acceptable approximation, especially in regions of relatively flat terrain such as Bangladesh (e.g., Drechsel et al. 2012). Once the model/observation pairs were calculated, these pairs were aggregated into monthly and yearly groups before calculating means, standard deviations, or any of the metrics. For the scatterplots and binned histograms, the full 3.5-year set of model/observation pairs were aggregated. All validation was done separately by observation platform (MET tower, SODAR, radiosonde) to allow more granular analysis.

The first aspect of the modeling runs analyzed is the benefit attained by assimilating the NREL MET tower and SODAR observations. This is accomplished by examining scatterplots and binned histograms from both the "WMO_only" and "WMO+NREL" experiments. Scatterplots for the two experiments for validation against the MET tower, SODAR, and radiosonde observations are shown in Figure 31, Figure 32, and Figure 2Figure 33, respectively. For those three figures, the scatterplots were validated against all observation heights between 10 m and 200 m AGL. A scatterplot for the two experiments only validating against the 80-m AGL SODAR observations is shown in Figure, which indicates that similar results are found when examining the 80-m height only as when including all heights. For each of these scatterplots below, a linear regression fit was calculated. The thin black line is the 1:1 line, the regression line is shown in red, and the regression coefficient (r) is printed in the upper-right corner of each scatterplot.

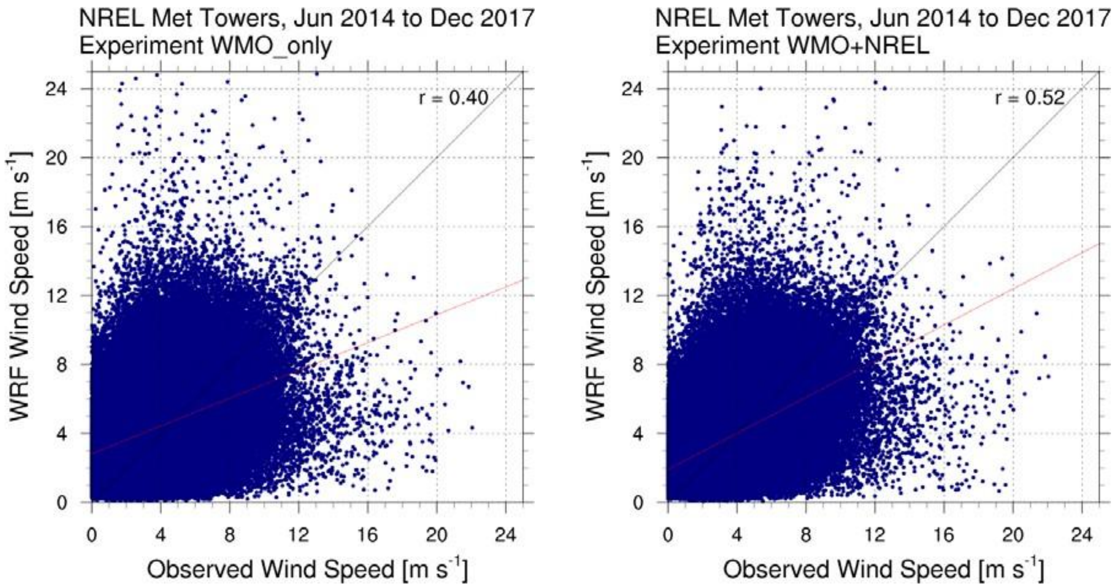


Figure 14. Scatterplots of WRF versus observed wind speed at the NREL MET tower locations

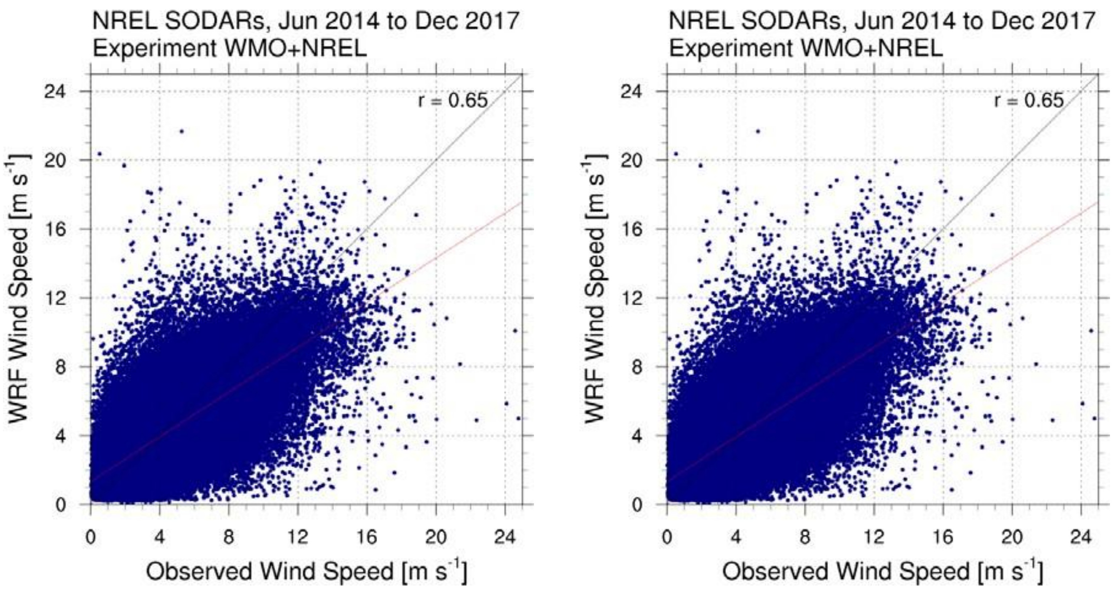


Figure 15. Scatterplots of WRF versus observed wind speed at the NREL SODAR locations

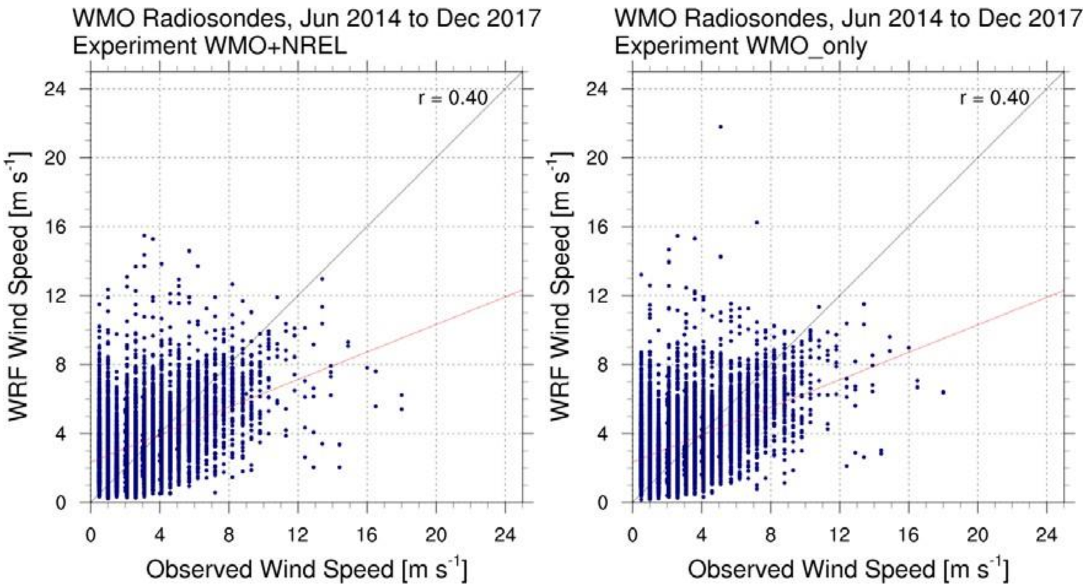


Figure 16. Scatterplots of WRF versus observed wind speed at the WMO radiosonde locations between 10 m and 200 m AGL

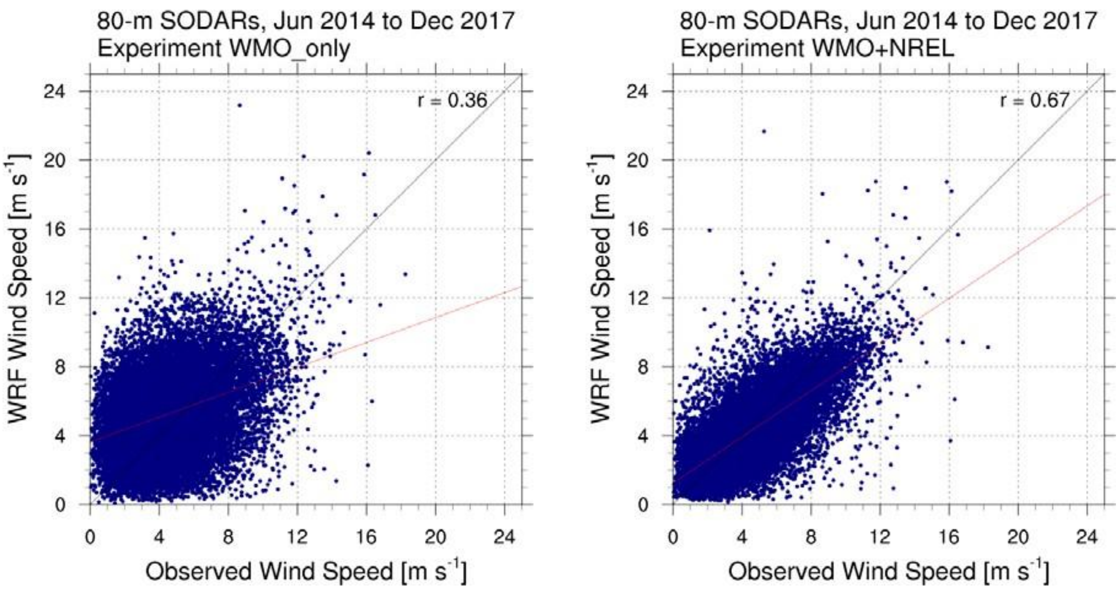


Figure 17. Scatterplots of WRF versus observed wind speed at the NREL SODAR locations at 80 m AGL height only

For the plots validating against MET tower and SODAR observations, the "WMO+NREL" experiment had both a larger regression coefficient and a regression line that was closer to the 1:1 line than did the "WMO_only" experiment. For instance, the regression coefficient increased from 0.41 to 0.65 at the SODAR sites when all the NREL observations were assimilated (Figure 32). This is expected, because the "WMO+NREL" experiment nudged the WRF simulation toward those observations and the "WMO_only" experiment did not. This result showed that assimilating these observations yielded an improved wind-speed analysis, at least in the vicinity of these observation locations.

For the rotor-layer radiosonde scatterplots (Figure 33), the regression coefficient was 0.40 for both experiments. The correlation between the WRF forecasts and observations at these locations illustrates one of the limitations of FDDA—that assimilating near-surface observations has limited impact on simulations at locations that are relatively distant from the observation. It is also interesting to note the vertical stripes on the radiosonde scatterplots. Those are artifacts resulting from the instrument on the radiosonde reporting wind speed to the nearest 0.5 m/s. WRF has much greater numerical precision (as do the MET tower anemometers and the SODAR), although that does not necessarily imply greater accuracy.

4.2.3 Maps

Developing resource maps is an important step in any wind resource assessment campaign. Increasing the distance away from the collection station increases the uncertainty of the data used to validate the model. Financing entities will probably require additional testing depending on factors such as distance from the MET tower, size of project, and complexity of terrain. However, in the initial prospecting or feasibility stage, developers and financiers may want to evaluate the wind resource from a macro perspective. As an example, the following figure demonstrates the wind resource in Bangladesh at 120 m. In this figure, the MET stations are identified by an anemometer icon.

More wind maps are generated by this committee at different heights using the NREL RE Data Explorer (*https://maps.nrel.gov/gst-bangladesh* (*retried on* 07 *March* 2019)). Wind maps at heights of 80 m, 100 m, 120 m, and 160 m are given in Appendix.

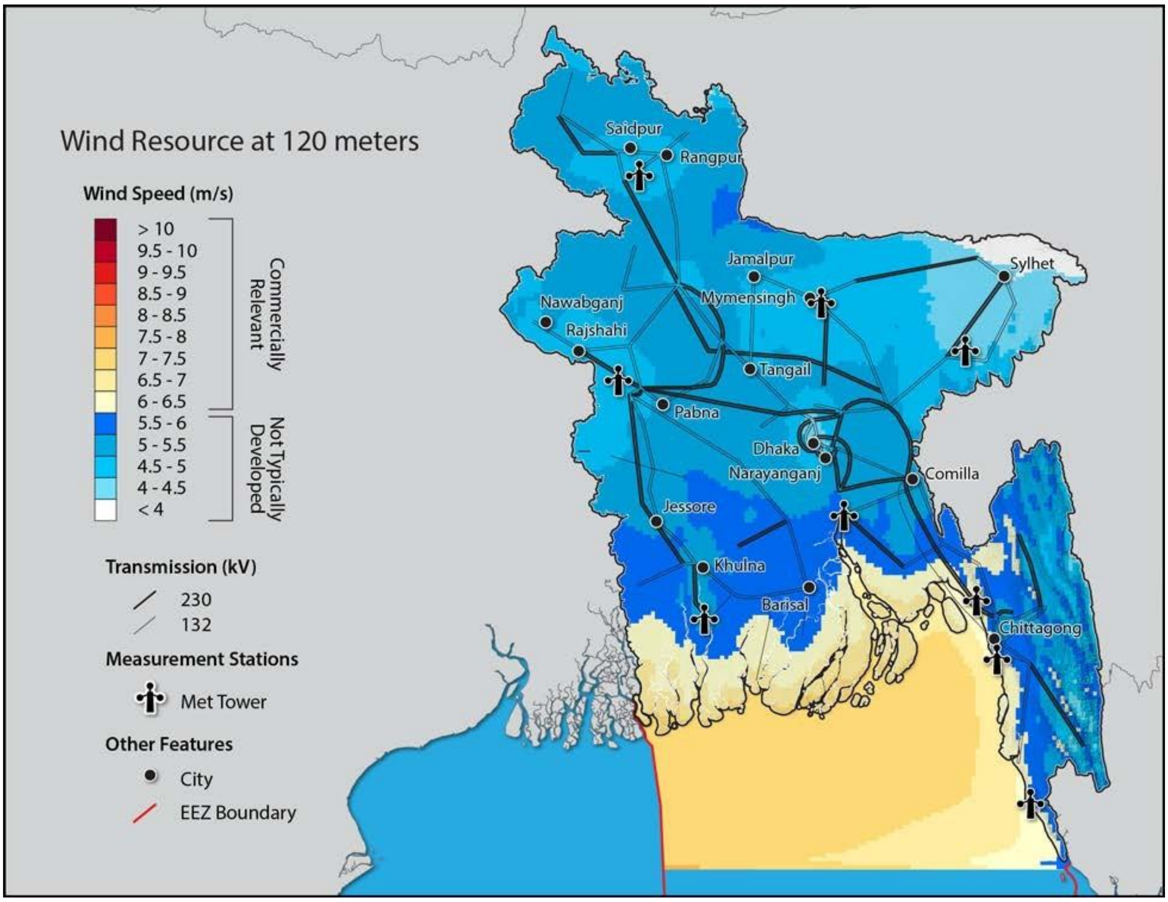


Figure 18: Bangladesh wind resource map at 120 m

This report provides a detailed discussion of the modeling approach, methods, instrumentation, and data-collection QC techniques used in the Bangladesh Wind Resource Assessment. High-quality instrumentation, proper siting, and detailed installation commissioning reports are the required first steps to generate high-fidelity models producing high-quality data products that can be used in decision making. These high-quality data products are used to develop proper tools for varied audiences to ensure usability and accessibility of the data for the public. This report describes our methods, documents the work completed, and demonstrates what types of data products are now available following completion of a 3.5-year resource-assessment campaign. In support of the USAID Bangladesh Mission, NREL, in collaboration with the GOB, completed the project, which included the following components:

- Development of a national wind resource assessment that involved creation of a preliminary and final wind resource model. As a result of this project, the wind profile and specific attributes are now well understood. A clear annual cycle in the winds was identified, with a peak in the spring and summer and a low in the autumn and winter. We further found that WRF slightly underpredicted the observed wind speed at the SODAR locations year-round but with near-zero bias in the summer, underpredicted the observed wind speed at the MET towers in winter and overpredicted it the rest of the year, and overpredicted the observed wind speed at the radiosonde locations year-round. However, in general, the WRF model reasonably reproduced the statistics of the observed winds across Bangladesh at 80 m AGL.

- Installation, maintenance, and data-collection activities for nine MET stations with diverse geographical positioning around Bangladesh.
- Generation of a set of high-quality data products:
  - o Raw MET data set
  - o Quality-controlled MET data set
  - o Final modeled long-term correlated wind data set
  - o Validated high-resolution wind resource maps
- Customized GIS-based tool called the RE Data Explorer, which graphically represents the Bangladesh data for users (https://www.re-explorer.org/bangladesh-data.html).
- Conducted a workshop in Bangladesh that presented final project results and provided training on the RE Data Explorer, wind resource modeling, and wind development process.

The preliminary technical potential analysis calculates gross potential and does not filter out already- developed land, environmentally sensitive land, or land unsuitable for other reasons. However, these preliminary results demonstrate that, for wind speeds of 5.75–7.75 m/s, there are more than 20,000 km2 of land with a gross wind potential of over 30,000 MW. Although this estimate is not realistic when proper filters are applied to screen out undesirable land for wind development, it suggests that Bangladesh's 10% renewable target by 2021 is achievable.

Can wind energy compete with the local wholesale energy market? It is the first question asked after every wind resource assessment presentation. Although this work is an important first step, other data inputs are needed to answer this question, including turbine selection (i.e., power curve assumed) and knowledge of the unsubsidized cost of wholesale power.

Recommendations for further work by the GOB are to analyze installation and financing costs for wind energy and compare against current 20-year forecasts for Bangladesh's cost of power, assemble more land-use layers in GIS format to enable more detailed filters to be applied within the technical potential tool, and continue to find opportunities to disseminate the data set and tools developed within this scope of work. Additionally, a detailed introduction to best practices for grid-integration strategies would support decision making for investors and power system planners as they look for renewable energy integration solutions.

In summary, the most important project deliverable is the collection of the data products highlighted in the report, the RE Data Explorer, and the public access to both. With the continued dissemination of these data products and complementary future analyses of others, the intended result will be more informed decision making, which will likely increase renewable investment and advance wind development in Bangladesh.

5. Lesson learnt from neighboring countries

5.1 Case study 1: India

India's wind energy capacity addition is set to grow by up to 76 per cent to 3,000 Megawatt (Mw) in the current financial year (2018-19) from around 1,700 Mw added last fiscal. This has provided a visibility for substantial wind-based capacity addition in 2018-19 and 2019-20. The bid tariffs discovered in the recent wind power auctions increased slightly from a low of Rs 2.43 per unit to Rs 2.77 per unit discovered during August 2018 to September 2018, though continuing to remain less than Rs 3 per unit.

While the wind energy bid tariff levels are still competitive as compared to conventional energy sources, the viability of such tariffs depends on the developers' ability to identify locations with high generation potential, availability of long-tenure debt at cost competitive rates and capital cost. Generation from wind-based capacity at an all-India level increased by 21 per cent in the first six months of the current fiscal as compared to the corresponding period last fiscal. This increased generation came despite the slowdown in addition of new capacity in 2017-18 and the first half of 2018-19.

Electricity in India is managed jointly by the central and state governments. Hence, the central government decides its set of policies and incentives for the development of wind energy while each individual state issues its own policies in line with the central government schemes.

5.1.1 Central government incentives for wind energy development

The Electricity Act of 2003 made major changes in the Indian energy sector such as open access to transmission, deregulation of power generation and allowing SERCs to fix the renewable energy obligations. Currently, the Indian government provides a number of incentives to renewable energy such as accelerated depreciation (AD), generation based incentive (GBI), income tax exemptions, renewable energy credits (REC) and clean development mechanism (CDM). The GBI scheme issued by the Indian government recently provides incentive exclusively to independent power producer (IPP) for feeding wind energy into the grid. Under this scheme, GBI of Indian rupee (INR) 0.50/kWh is given to renewable energy generator for the electricity fed into the grid. The Indian government also provides AD benefit to investors for putting up wind energy projects. By this benefit, the wind energy investor can claim 80% of the cost of wind energy generator as depreciation within 10 years after COD . AD is very helpful in reducing the tax liability of the wind energy investor. In India Wind Energy Outlook, 2011, the GWEC observed that AD played a crucial role in the growth of Indian wind energy sector. Moreover, for the first 10 years, the Indian government will not charge any tax on the income generated by the sale of wind energy. A National Clean Energy Fund is also available to provide funds for research and development in renewable energy. This fund provides capital by imposing a cess on coal, peat and lignite. These policies are issued with the sole objective of increasing the share of wind energy.

5.1.2 State government incentive for wind energy development

Various states have determined the feed-in tariff (FIT) for selling wind energy to electricity companies. FIT is a price guaranteed by SERCs for wind energy. This tariff varies across the states depending upon project cost, state resources and tariff regulation in the respective state. Various state governments also allow industrial energy consumers to install wind energy project for their captive consumption (CC). Some large energy intensive industries such as cement and textile are generating wind energy to meet their captive requirement.

State governments also provide various other financial incentives to promote wind energy. These financial incentives include subsidies provided at installation or during operation of the project. With these incentives, state governments wish to reduce those financial hurdles which make renewable technologies less attractive in comparison to the conventional sources. Maharashtra provides the subsidy for wind energy projects. This state government of Maharashtra returns 50%of the evacuation cost at the end of the first year. According to GWEC, the average evacuation cost of wind power project is 4 to 5 million per megawatt.

As mentioned earlier, the Electricity Act of 2003 provides provision for fixing renewable energy to be procured by different entities. These entities include distribution companies, open access users and captive consumers who are buying or generating energy from non-renewable sources. These renewable purchase obligation (RPO) targets vary according to the conditions of respective state. It can be as high as 10.15%in Tamil Nadu or as low as 0.25%in Karnataka. This policy also has penalty provision if anybody fails to meet their RPO target. This policy also motivates companies to develop renewable energy projects. Some states have issued RPO exclusively for wind energy. To overcome the disparity in the renewable energy conditions among states, the Indian government has launched the renewable energy credits (REC) mechanism. The REC framework provides an open market from where obligated entities can purchase RECs to meet their RPO obligations. The Indian government has set the value of one REC equivalent to one MWh of renewable energy fed into the grid. Since March2011, trading of RECs is happening on the platforms of power exchange of India (PXI) and Indian energy exchange (IEX) to encourage manufacturing of wind turbine and its components, some state governments do not put excise duty on various parts of the wind turbine. Tamil Nadu charges less price for the electricity provided to the wind turbine manufacturing units. The Indian government has also established special economic zones to promote export of renewable energy technologies. Some states, like Gujarat and Rajasthan, facilitate project developers by providing land to set up wind energy project.

These information stated above shows that if Bangladesh wants to reduce per unit cost of wind energy, strong policy support as well as infrastructure development will be needed.

5.2 Case Study 2: China

China has enacted a number of policies in recent years to boost its supply of renewable energy. A key turning point arose with the Renewable Energy Law of the People's Republic of China, passed in 2005 and implemented in 2006, which empowered key government players at the national and provincial level to draft renewable energy development and utilization plans (Schuman and Lin, 2012). Currently, the government is planning for 20% of China's primary energy consumption to come from renewable energy sources by 2030 (UNFCCC, 2015).

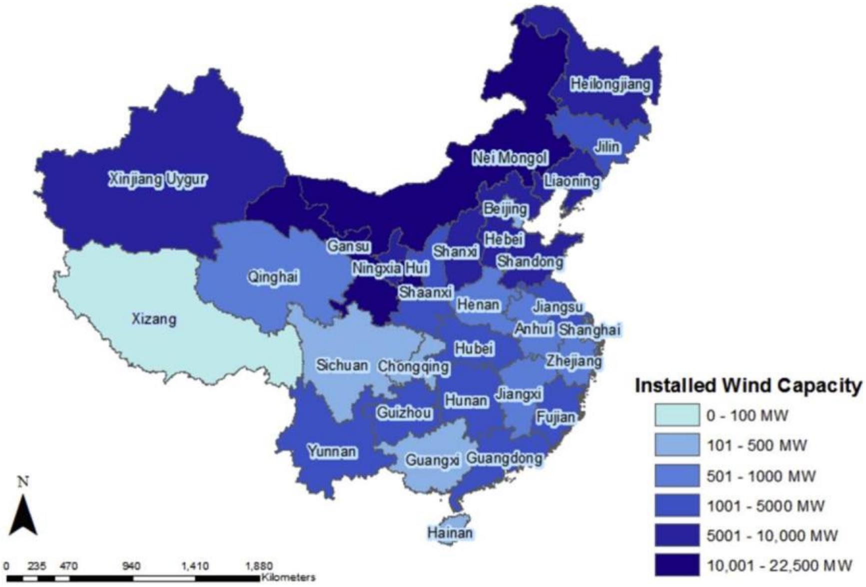


Fig. 19. China's wind power installation by province in 2014. Provinces with most wind power installed are also those that have significant wind resources. Data from CWEA (2015).

5.2.1 Investment on wind energy

The foreign or local economic organizations together with the individuals are all welcomed to invest on the wind energy. This right is guaranteed by the Electricity Law (P. R. China) and Re- newable Energy Law (P. R. China).

5.2.2 Grid construction for renewable energies

Generally, the transmission lines for connecting renewable energies to the grid should be constructed and operated by the grid company. For the large or medium renewable energy projects (which will be connected to the power transmission network), in principle, the connection systems should be invested by the grid companies (only two companies, State Grid and China Southern Grid). For small renewable energy projects (which will be connected to the power distribution network), the renewable energy company (or individuals) could also be involved into the construction of the connection system with the agreement of the grid company. Therefore, the grid companies play a dominant role on the construction and management of the connection systems be- tween renewable energies and the power grid.

5.2.3 Connections of electricity generated by the wind energy to the grid

The grid companies own the electricity transmission systems and are responsible for the related management issues. Specifically if the wind energy company wish to transmit their electricity to the grid, they must sign an agreement with the grid companies. Additionally, there are some extra national standards or industrial standards to be followed in order to avoid the negative impacts of the fluctuations of wind energy on the grid.

5.2.4 Price of the electricity generated by wind energy

Principally, this price is setup by the central government (e.g. State Council, China). The electricity price of wind energy is higher than ones generated by the traditional ways (e.g. thermal).

In the current status, the electric power system of China is still based on a planned economy system. Specifically, the grid company will make a plan for electricity generation for all the power stations within its management regions. As a result, the traditional thermal power station (serving as the dominant energy generation type in China) could obtain the quotation to ensure their connections to the grid. However, for the wind energy company, it could be difficult or even impossible to obtain the quotation for electricity transmission to the grid. The situation will be further deteriorated due to the protections of local government on the thermal power plants, which could contribute more tax and serve as the base load.

In some provinces (e.g. Gansu province), the local government tried to facilitate the exchange of the above quotations between wind energy companies and thermal power plants. Basically, the subsidy from the government for the wind energy companies is calculated based on the amount of the generation of electricity. If no electricity is generated (e.g. during wind energy rejection), those subsidies (together with the electricity selling income) could not be obtained by the wind energy companies. In order to avoid rejection, the wind energy company needs the electricity quotations for the connections to the grid. Hence, under the support of the local government's policies, some thermal power plants could transfer their electricity quotations to the wind energy companies. For the thermal power plants, they could be profitable from the electricity price difference between the grid and the wind energy companies. During the exchange of quotation, the thermal power plants do not need to generate the electricity their self at all. At current status with serious wind energy rejection, the wind energy companies are forced to decease their electricity price (even up to zero) in order to obtain the quotations. The wind energy companies tolerate this low electricity price because comparing with rejection (zero profit), they could reduce the lost through the subsidies provided by the central government.

As a result, the thermal power plants benefit a lot from such kind of quotation system as they could earn profits without the generations of the electricity just through exchanging the quotation with the wind energy companies. At the same time, the quotation system do great harm to the wind energy companies, leading to serious economic losses. Due to its negative effects, most of the quotation exchange polices have been halted by the central government.

However, China will still have to overcome several hurdles in order to increase renewable energy production. With this in mind, we examine the factors that have allowed China to deploy wind power so successfully, and the challenges it will need to address in order to continue to progress.

5.2.5 Reasons for China’s success in wind power so far

a. Using proven technologies

One of the reasons that the Chinese wind turbine industry has been able to progress so rapidly is that several of the leading firms were large heavy-machinery manufacturers and utility firms, which already had capabilities in fields relating to manufacturing, as well as in large-scale project management for deployment. In addition, licensing agreements between Chinese firms and European design houses have proved an effective method of driving forward technological advancements, allowing Chinese lead firms to develop technology using the pre-existing expertise of foreign partners.

b. Ambitious government targets

In 2015 the Chinese government committed to 20% of its energy coming from wind, solar, nuclear and other zero-emission sources by 2030. Beijing also says it plans to increase China’s wind power capacity to 200,000 MW by 2020. In comparison, nuclear is only predicted to rise to 58,000 MW over that period.

The government is also focused on cutting the cost of wind power so it can compete with the ‘golden standard’ set by nuclear and the low costs now experienced by coal. With recent reductions in wind subsidies, the government continues to place higher demands on technology including greater efficiency and reliability and most importantly, MW hours.

c. Quick learners and move fast

Chinese firms tend to work in a much faster and more agile manner, learning quickly, trying different techniques and learning from experience. The country also benefits from a number of state owned organizations which are incredibly focused on developing their own expertise within wind power, ensuring that new skills, techniques and technologies are adopted across the country.

All of this helps accelerate new wind farm deployments.

5.2.6 Future challenges China needs to address to continue growth in wind

a. More unconventional locations

As wind farms become saturated in densely populated areas, many wind firms are forced to move to more remote and less conventional locations. Offshore is one of the areas where expansion is possible; here wind power could remain close enough to demand centers such as the big coastal cities, but would be away from residential areas. However, offshore does also present a number of logistical complications, from initially building the farms through to issues with servicing and maintenance. A large storm may put you down for three weeks if the conditions remain unfavorable.

Constructing wind farms at high altitude is another option. However, this puts additional stress on the equipment. As the air gets thinner due to the reduced pressure, it loses some of its insulating properties, meaning that equipment built to work at high altitudes needs to be designed with sufficient safety spacing distances to prevent high voltage arcs or breakdowns between conductors and other electronic components. Cosmic rays are also more pronounced at higher altitude. These interact with silicon in such a way that they can cause it to puncture, which in turn, can cause the converters to fail. Therefore, additional technological considerations need to be taken into account in some regions.

b. Embracing digital technologies

Embracing new technologies, such as software that can monitor and optimize the wind farm as it generates electricity, could help Chinese firms to boost a wind farm's energy production by as much as 20% and create $100 million in extra value over the lifetime of a 100 MW farm. It works by installing dozens of sensors inside each turbine, which monitor everything from the yaw of the nacelle, to the torque of the generator and the speed of the blade tips. This data can then be used to optimize the wind equipment and power output. A select number of companies in the region have already embraced this new technology. For example, GE's Brilliant wind turbines, which harness the power of the Industrial Internet to analyze tens of thousands of data points every second, have been installed at the Huaneng Corporation's Huaneng Dali Longquan wind farm in the Yunnan province of China.

The challenge for wind companies throughout China, however, is to select partners with the technological expertise to drive innovation in the market and bring high-quality, reliable power to the region for many years to come.

c. Reforming grid operations

Large distances between wind farm locations and areas of demand are also an issue due to the need for investment to improve transmission and distribution capacity. While the government is adding new transmission lines, the integration to the grid network remains one of the most serious challenges facing the wind industry in China. A recent report from the GWEC stated that the lack of flexibility in the grid system, coupled with general lack of a real electricity market where electricity can be traded, were some of the key barriers to wind development. For example, northern China boasts good wind resources, but rapid development of wind power in this area has outpaced the local grid, leading to substantial requirement to curtail excess wind power. To help overcome this, a number of new transmission lines need to be developed, in order to link power from its source to its demand center.

The rapid development of the wind power industry has created a new set of challenges for China to address. Despite this, the GWEC still predicts that China will install an additional 100 GW by the end of 2019, exceeding the country's 200 GW target for 2020 a year ahead of time. To grow sustainably to meet this target, wind companies throughout the region must develop long-term partnerships with industry experts, such as GE, at every phase, from conception and design to installation and continued optimization and maintenance, to drive innovation and efficiency. If this collaboration continues the future will be bright for the Chinese wind industry.

6. Market potential: SWOT Analysis

Based upon the previous chapters and paragraphs, a SWOT analyses can be performed. The following sub-paragraphs will described the strengths, weaknesses, opportunities and threats of the Bangladeshi market, concerning wind energy developments.

6.1 Strength

The high density of its population, alongside with the prosperous economic growth of recent years, can be seen as a strength of the energy market in Bangladesh. Economies of scale can be easily reached, especially given the high energy demand on both short term and long term. Also, the high sense of urgency on the implementation of renewable energy within GoB, the Asian Development Bank and the World Bank can be seen as an asset for the energy market.

6.2 Weakness

Given the current available data, wind resources are low in Bangladesh. An average wind speed of 5 meter per second at a height of 80 meters is expected to be standard for onshore locations. Besides these low average wind speeds, many locations also have to deal with occasionally very high wind speeds during typhoons, flooding of land and limited grid connection and stability. The downside of the previous mentioned high density of population, is that (viable) land is a scarce commodity. Also, a limited availability of commercial funding and limited track record on private financing and no local expertise on wind energy developments are of negative influence on the market potential of wind energy in Bangladesh.

6.3 Opportunities

The market can be seen as a green field development. Several initiatives are starting up, but no large scale development did take place. There is only a small field of competition. Offshore wind shows some potential, off the coast from Chittagong. The Bangladesh Power Development Board intends to tender 100-200 MW offshore wind farm near Chittagong. Also, off-grid projects show some potential, due to the before mentioned economies of scale and vast agricultural land-use all over Bangladesh (wind energy for irrigation pumps e.g.).

6.4 Threats

The current lack of substantial policy incentives for renewable energy (budget for wind energy) and the absence of a comprehensive legal and regulatory framework for renewable energy are of negative influence on the market potential for wind energy.

7. Challenges for large-scale grid-connected Wind projects

Challenges for the large-scale grid-connected wind project development in Bangladesh are linked with (a) land related barriers, (b) Transportation Infrastructure, (c) Lack of expertise, (d) Grid connectivity, (e) Cost of wind energy and energy pricing (f) Administrative and technical support and (g) Financial resources to finance a wind farm project. To ease the purpose of analysis, the challenges are tabulated in a few major categorizes as presented below-

a. Land related barriers	• The pressure on space is high in Bangladesh because of the large number of inhabitants per square kilometers and the mainly agriculture-based economy. However a combination of wind energy and agriculture seems to be possible. Points of attention are the large almost yearly flooded areas. In technical terms wind turbines in these areas are possible but this will come with higher costs. Maintenance and operation will be more difficult in these areas and projects will be more costly because of supplementary technical provisions (foundations, adjusted tower access). Another point of attention with regard to the noise levels of wind farms is the presence of houses/residences close to the wind turbines. This seems insurmountable due to the high population density. Specific legislation in this regard does not exist however. Offshore limitation in space seems not to be a problem. Interference with shipping traffic is a concern, but this seems soluble considering the practices in the Netherlands (one of the busiest seas in the world in combination with the largest port in Europe and large scale wind farms), but will involve (time consuming) regulation of shipping routes. Offshore soil conditions require further consideration. Water depth is relatively low (a large area has depths up to 20 to 40 metres), however the soil structure (mud, sediment, deeper soil layers) is not yet studied in detail.
b. Transportation Infrastructure	• Large parts of Bangladesh are not well accessible with large trucks to transport modern wind turbine parts, due to infrastructure limitations. An advantage is however the presence of rivers that might be usable for transportation of heavy and large components. Transportation of Wind power plant equipment like turbines, hub etc is a big challenge. Because the connecting road from port to project site is very narrow and hard to turn. Moreover bringing crane will be a big challenge which will be needed to build the turbines.
c. Lack of expertise	• Wind energy generation is a new endeavor for Bangladesh. So Bangladesh is having lack of experience to do large-scale wind power plant. Technical deficiency will hamper the fixing of price tariff and operation and maintenance of the project.
d. Grid connectivity	• The power grid of Bangladesh is expanding rapidly. Grid connection of larger wind farms (tens of MW's) is a concern and will need to be considered further for specific locations. Certainly in many remote areas there will be insufficient grid connection capacity available. Also the grid stability is a point of concern. Delivering wind energy is the only source of income for a windfarms, an uninterrupted grid connection is vital. Overseeing this, it can be concluded that in its present status the national grid will not be suitable to connect large scale wind farms. This means that the costs for grid connection of wind farms will be relatively high because of the large distances to nearest suitable national grid connection point (cable costs) and large investments in hard ware (transformer stations, switches, regulators etc.). However connecting eventual future wind farms could be combined with the (already scheduled) development of the national grid in these areas

and costs could be 'socialised' and not charged at account of the windfarm. Because there is no history or experience in doing so, this has to be sorted out and agreed upon, before the development of a specific windfarm can become concrete.

e. Cost of wind energy and energy pricing	• Combining the not very promising wind resources and the expected rather high investments for grid connection, means that wind energy in Bangladesh will be rather expensive. The combination of low average wind speeds and sometimes harsh stormy conditions (typhoons) and floods will require dedicated wind turbine designs, making wind energy even more expensive. This compared to wind energy prices in quite some other countries, and compared to the present fossil fuel based energy prices in Bangladesh, although these prices are kept low with subsidies by the government. On the other hand wind energy needs significantly less space than solar energy, can easily be combined with agriculture and is therefore an interesting option for renewable energy. The economic feasibility of wind energy is therefore a matter of pricing, or maybe better, of amount of available subsidy per kilowatt-hour (kWh) to close the gap between the current market price and the cost price of wind energy. Only after extensive feasibility study it will be possible to determine a price per kWh which will be location specific. The government of Bangladesh has not yet specified a maximum reimbursement per kWh. Setting up a stable subsidy system with a long term perspective will be crucial to attract investors in wind energy. Such a program is not in development at the moment.
f. Administrative and technical support	• Good and early administrative coordination is essential. Also political support is needed. A positive attitude towards renewable energy projects is increasingly present since the founding of the Sustainable and Renewable Energy Development Authority (SREDA). Bangladesh has little to no experience with wind energy projects. This is of concern and means that a lot of knowledge and experience has to be brought in from outside of Bangladesh. This offers opportunities for export of specific knowledge and technology, services and materials from countries with a lot of wind energy experience. For Bangladesh wind energy projects offer opportunities for technology development, employment and participation by national and local parties (contractors, maintenance technicians et cetera)
g. Financial resources to finance a wind farm project	• Besides a steady long term income for wind farms in the form of a price per kWh (for example market price + subsidy) to cover the total costs, financial resources are needed to finance a wind farm. The financial resources and willingness to self-realise large wind farm projects by the government of Bangladesh are expected to be limited. That means that project finance for wind energy projects will be necessary. Another possibility is balance financing wind farm projects by large companies, such as utilities. When a sufficient kWh price can be agreed upon and enough certainty on the realization and operations of the project can be gained, project finance could be set up with commercial banks combined with contributions from funds

of (for example) Asia Development Bank and Climate Investment Fund. Stability and long term certainty with respect to yearly revenues and project execution (see next paragraphs) will be vital for any form of financing, to reach financial close and to keep financing costs reasonable. Despite some funds that are active at the moment in the field of renewable energy, the level of stability is perceived to be limited.

8. Recommendations

8.1 Short term actions: To develop wind power sector some steps need to be taken immediately which will be a benchmark for power producers to follow on and invest in wind sector. Wind working committee has identified some actions to be taken in short term basis. There can be two approaches-

1. IPP based unsolicited BOO (Build, Own, Operate) model:

Power Division can keep the project identification open for IPP. Unsolicited proposal can be accepted and a reasonable tariff can be settled by negotiation. This approach is needed at least for initial 2/3 successfully completed projects to identify the challenges and sort out a baseline tariff for wind power. Negotiation can be of two stage or reverse bidding also can be considered. In this process the actual unit price of wind energy may be determined by power division. Bangladesh lacks sufficient infrastructure to develop wind projects. So negotiated tariff initially may be little high but one or two successful commercial projects will boost up the sector and investors will have confidence to invest. This approach may have some drawbacks like land acquisition and evacuation problem or slow implementation problem which can be solved by close monitoring and co-ordination of SREDA & related agencies.

2. Solicited Tender model:

Power Sector Development and Capacity Building Project of Power Division supported by Asian Development Bank has done a Pre-feasibility Study for suitable wind sites where BPDB and utilities have available land to implement wind power plant. In this report, Parki Beach and Sitakunda is suggested to do so. Based on the feasibility study a generalized tariff mechanism to be formulated to find out the reference tariff range in the local contest of the country and also international market to be done by in house study / consultant considering all the component that influence the tariff for different categories of wind potential and sites.

With the prefixed benchmark/Baseline tariff, BPDB/utilities can float the tender and receive proposal from different international companies who will work on BOO (Build, Own, Operate) basis. This process can take some time to process the whole system but implementation will be much faster. Normally open bidding may find out the proper pricing of wind energy but at the beginning of development stage as there is no standard setup is available, the price may be little higher than unsolicited approach.

A policy to be adopt "**Wind (VRE) Must Run"** for feeding energy to the grid when available to be decided to prioritized the renewable energy utilization and to save fossil fuel but to avoid grid penetrations by VRE wind energy forecast circulation before two/three days must be sent to NLDC. The Grid should have some operating reserve to cope the grid penetrations by VRE wind.

This short term actions will start the wind development work and will be a lesson learning method for future planning.

8.2 Long term actions: To build a sustainable wind energy development working committee has identified some steps to be taken for long term basis.

1. Land preparation: Land crisis is a big issue for renewable energy development. It has been observed that it is very difficult and also not cost effective to arrange and develop land and evacuation facility by the private entrepreneur. There was lot of failure in the past for arranging and developing land for RE project by the private entrepreneur. So Power Division/ SREDA can take a "Wind Energy Development" Program to find some potential lands for wind according to the data of NREL provided. Potential lands with evacuation plan will be developed and Open Tender method will be applied for setting wind farms. According to the lesson learnt from INDIA, we can see that if the land and other infrastructure is developed by Government, the unit price of power stays much lower than other IPP projects. This process will take some time to come in action but it will be effective to do the projects successfully and increase the share of wind energy in Bangladesh.

2. Policy Support: From the lesson of INDIA, it is clear that wind energy sector should be supported by Government to be more competitive with the conventional energy sources. Strong policy support along with financial facilities will be needed to full fill the target of 2030. Different incentives, tax rebate, concessional loan, infrastructure development etc should be reflected in the wind energy policy of Bangladesh government. Without concrete and declared facilities provided by government policy, it will be difficult to develop this sector and increase renewable energy share. Tariff Mechanism development for Wind based Power Generation projects should be considered by the government. 'Wind Power Development Guideline for Bangladesh' should be prepared and followed to develop the sector.

3. Long term data assessment: According to NREL report, every data set can be varied by 3 years of duration. More over data from a single met mast is valid for only 3km radius area. If any investor wants to set a wind power plant far from the met mast point, they are needed to collect raw data again. So a strong and continuous data assessment system is needed to develop this sector. SREDA can set required met masts in the countrywide potential regions for long term basis and a collection and data processing center in SREDA head office to interpret the data and help the investors. These data set could be used to enhance the present wind map considering weather forecast modeling.

4. Offshore wind resources assessment: As we observed offshore wind technology improvement is in remarkable position from few years past and Bangladesh having huge flatter offshore area may be opportunity of feasible wind site. So a program for wind measurement campaign could be taken at the earliest.

5. Capacity building: Capacity building is very important for sector development. We have lot of engineers working under power division. SREDA can take initiatives under the Wind Development Program to train engineers from different organizations on Wind data assessment, Plant design, Wind project management, Wind farm maintenance and operation etc. SREDA can also work with different institutions like BUET, Dhaka University and other prominent public as well as private universities to create a wind knowledge hub which will be helpful for technology transfer.

6. One stop service for government agencies as well as private investors: To avoid long process and scattered documentation system, SREDA with the help of NREL or any other organizations can start a one stop service for wind energy development. After evaluation of the proposal by SREDA, they can go forward to develop the project following the government policy. Investors also will be able to go with the process easily and motivation will be increased.

8.3 Incentives:

From the previous experience of Solar projects and lesson learnt from neighboring country, this is obvious that incentives should be provided to the investors in renewable energy. Bangladesh government also should think to provide some incentives to make the wind energy sector more competitive with conventional energy. There are many types of incentives are provided by the governments in different countries. Among them Bangladesh can choose the followings:

a. Flexible accelerated depreciation within 10 years after COD.

b. Similar incentives that other Independent Power Producer enjoys in conventional energy

c. Incentive for clean energy generation that can be included in tariff

9. Conclusions

This report describes the findings of different wind resource assessment data done so far and tries to find a proper approach to move forward with these data. The committee formed by power division tried to consider all the aspects to start a sustainable wind energy market and sorted out some points to monitor closely. This report will highlight the advantages as well as drawbacks of different methods of project implementation.

The committee has recommended two types of action. Short term and long term actions. In short term actions two approaches have been identified. Both of the approaches have pros and cons but decision has to be taken considering the time and effectiveness. Pricing is a major concern for wind energy but neighboring countries have showed us that infrastructure development can bring radical change in pricing and sustainability. So Bangladesh government also has to think about the infrastructural development to gain long term benefit from wind energy.

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Appendix-

Wind Maps of Bangladesh at different heights

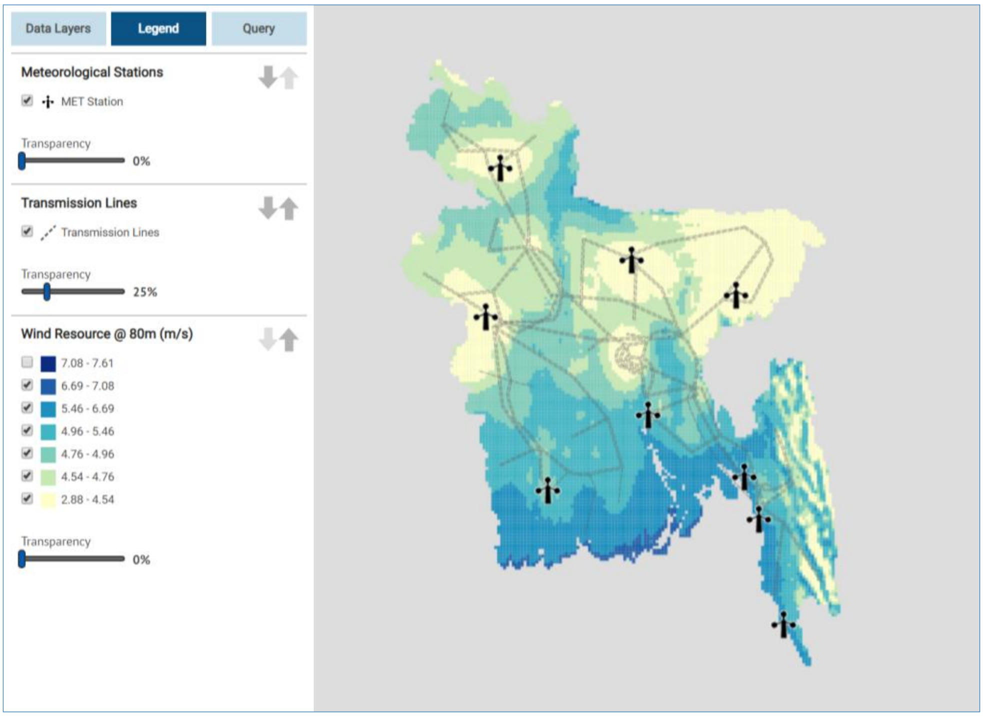

Figure 20 : Wind Map of Bangladesh at 80 m height

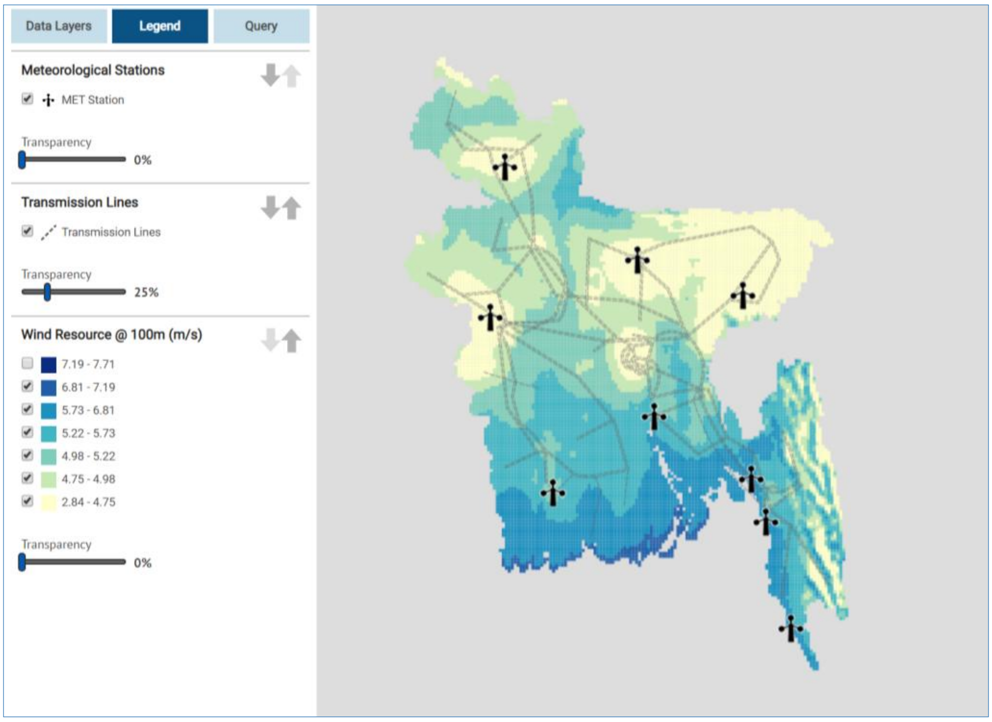

Figure 21: Wind Map of Bangladesh at 100 m height

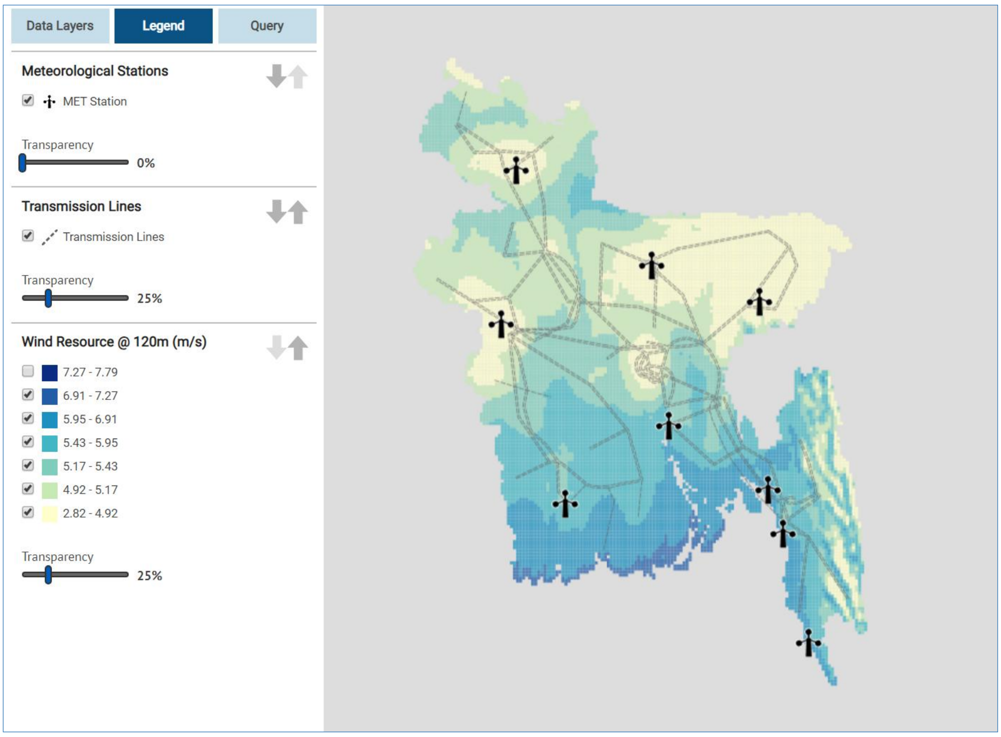

Figure 22 : Wind Map of Bangladesh at 120 m height

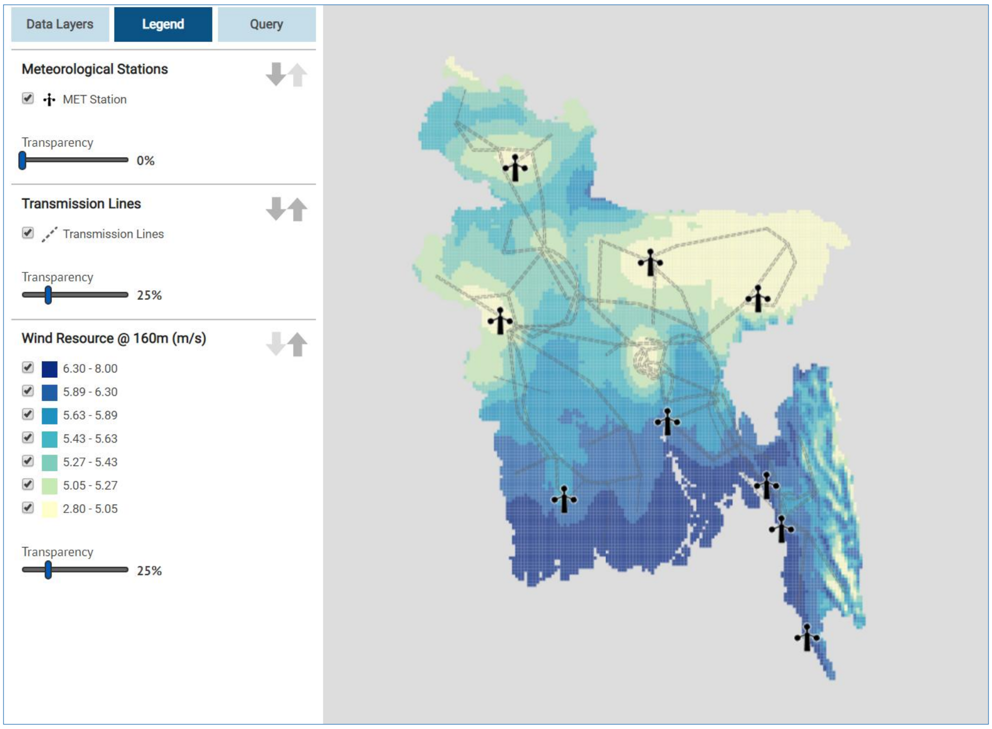

Figure 23: Wind Map of Bangladesh at 160 m height

Appendix

The following pages summarize the data collection in Bangladesh for the whole monitoring period. There are data for each of the seven MET towers as well as the SODAR unit, which was deployed at Inani Beach and then Rangpur.

For each site, the following information is included:

- Data set properties: general statistics from the site.
- Wind-speed and direction summary: six graphs that illustrate the average wind speed for each month, the directional properties of the wind, the average behavior relative to time of day, and the distribution of wind speeds (**NOTE: the plots include raw wind-speed measurements, not modeled or validated data, and should not be used for decision-making purposes**).
- Wind shear: four graphs characterize the wind shear at the site; the wind shear characterizes how the wind speed changes with height above the ground.
- Turbulence intensity: four graphs that characterize the turbulence intensity at the site; the turbulence intensity value is a measure of the "gustiness" of the wind at the site.
- Data column properties: each data field includes height, units, the recovery rate, and the average mean, minimum, maximum, and standard deviation for all of the data.

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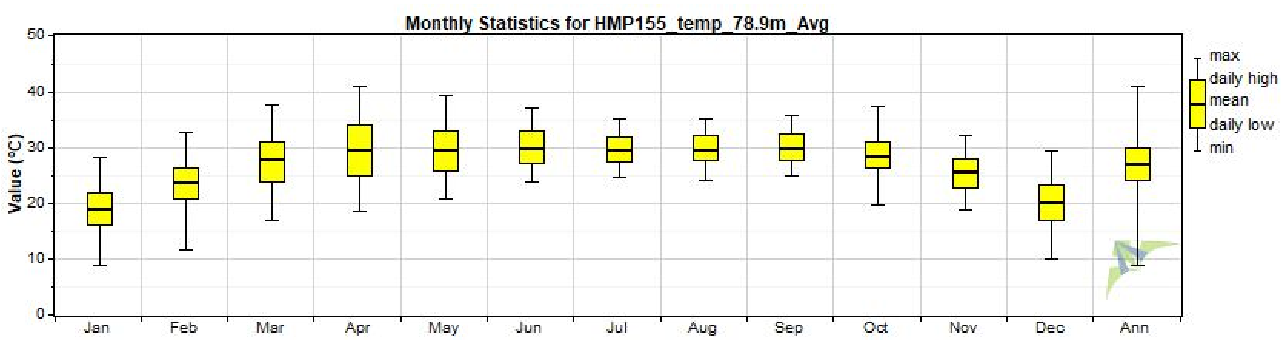
For each site, the following information is included:

- Data Set Properties – general statistics from the site
- Wind Speed and Direction Summary – six graphs which illustrate: the average wind speed for each month, the directional properties of the wind, the average behavior relative to time of day and the distribution of wind speeds (**NOTE: The plots include raw wind speed measurements, not modeled or validated data and should not be used for decision-making purposes**).
- Wind Shear – four graphs characterize the wind shear at the site. The wind shear characterizes how the wind speed changes with height above the ground.
- Turbulence Intensity – four graphs which characterize the turbulence intensity (TI) at the site. The turbulence intensity value is a measure of the "gustiness" of the wind at the site.
- Data Column Properties – each data field includes the following information: height, units, the recovery rate and the average: mean, min, max and standard deviation for all of the data.

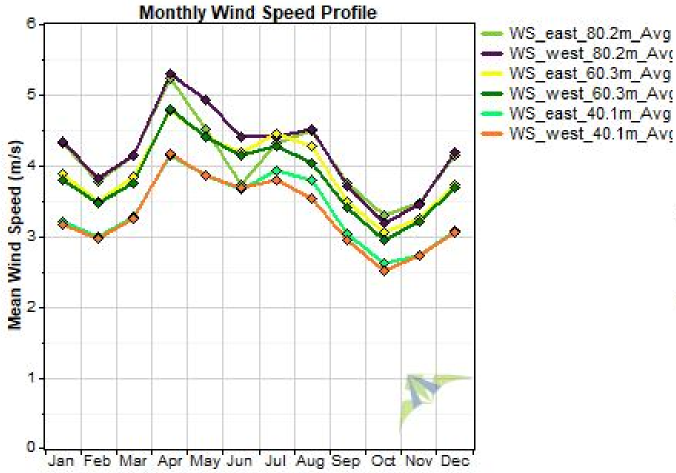
Data Set Properties

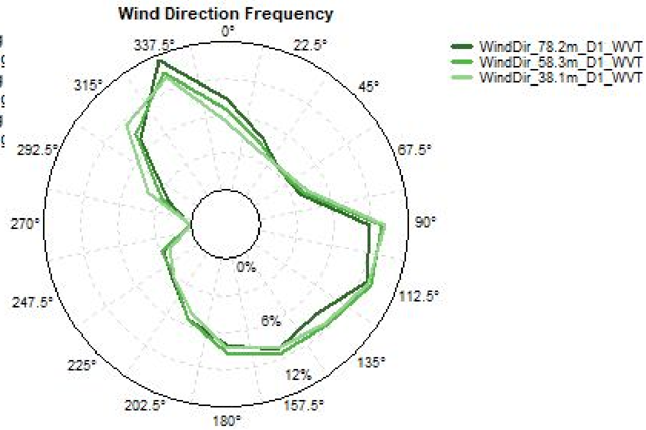
Report Created: 4/11/2018 10:34 using Windographer 3.3.10
Filter Settings: <Unflagged data>

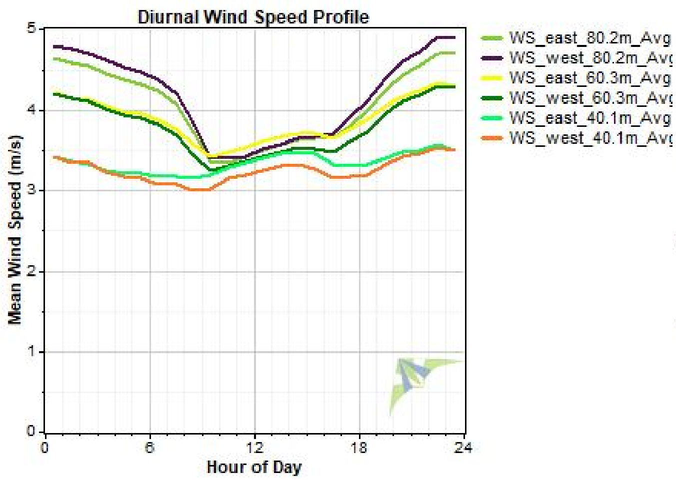
Variable	Value
Latitude	N 24.170350
Longitude	E 88.907340
Elevation	12 m
Start date	6/11/2014 15:10
End date	12/20/2017 14:30
Duration	3.5 years
Length of time step	10 minutes
Calm threshold	1 m/s
Mean temperature	27.2 °C
Mean pressure	998.5 mbar
Mean air density	1.179 kg/m³
Power density at 50m	47 W/m²
Wind power class	1
Power law exponent	0.35
Surface roughness	3.17 m
Roughness class	4.87

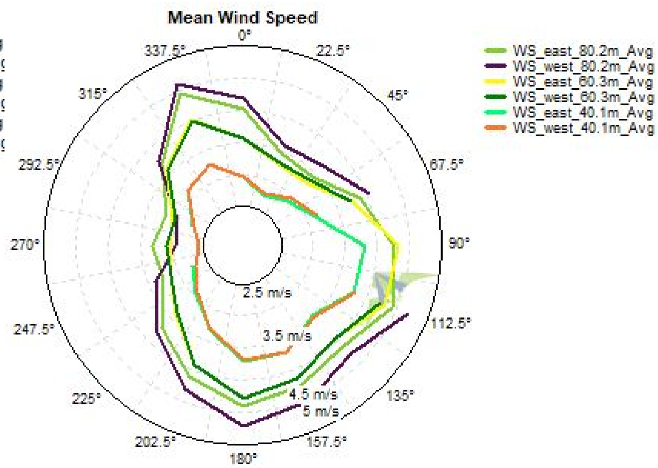


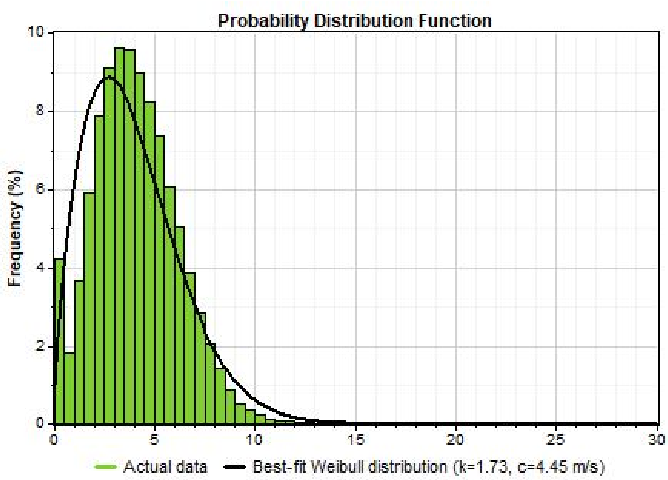
Wind Speed and Direction

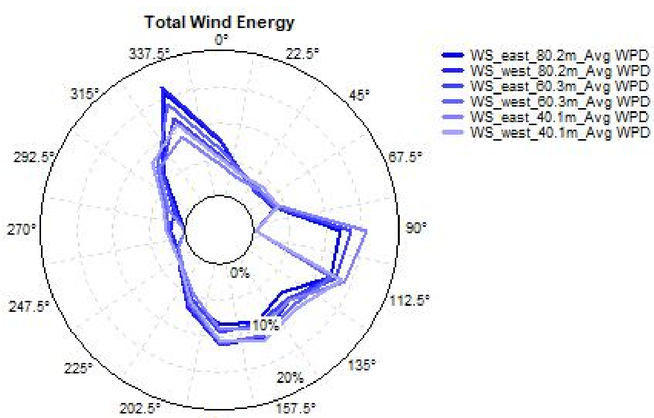




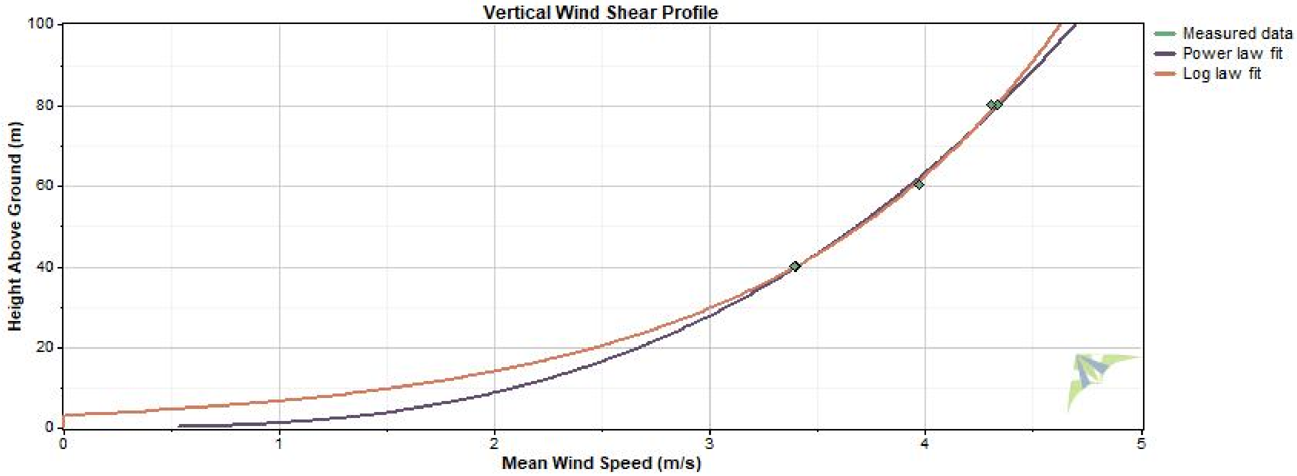


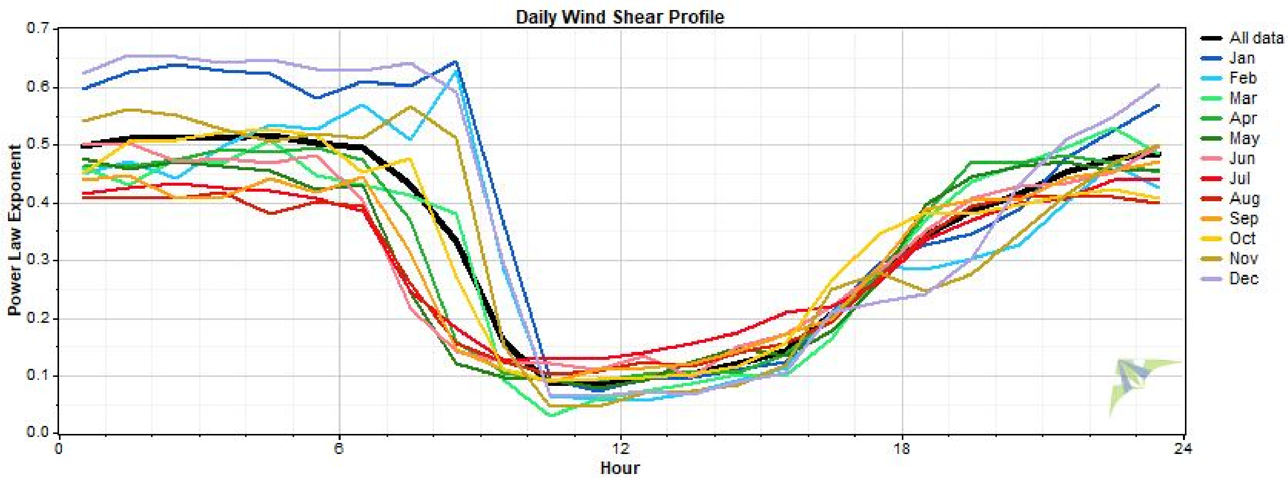


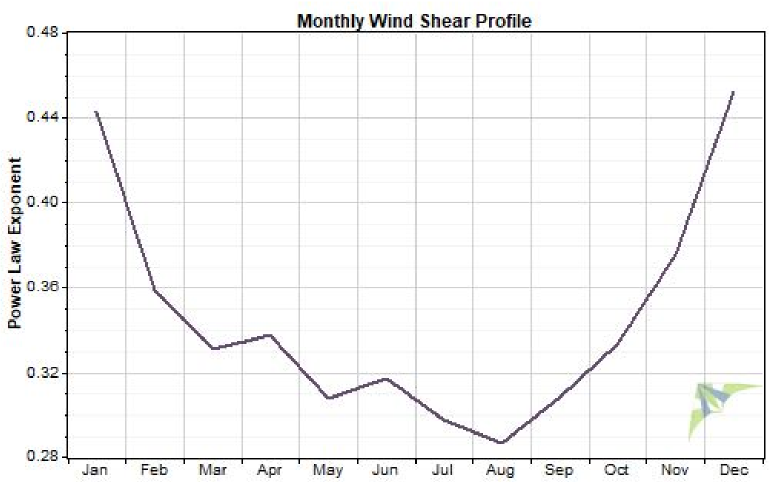




Wind Shear


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


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


Monthly Wind Shear Profile
Power Law Exponent
Jan
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Jul
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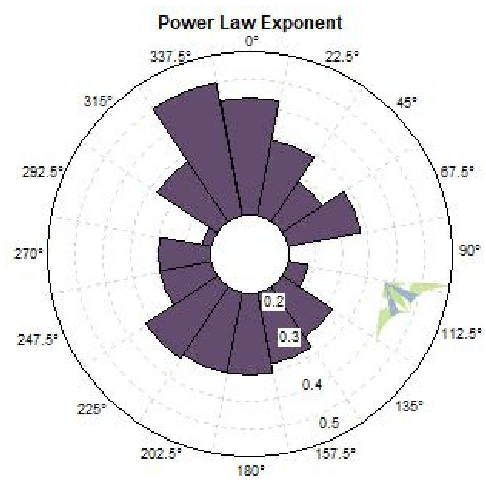
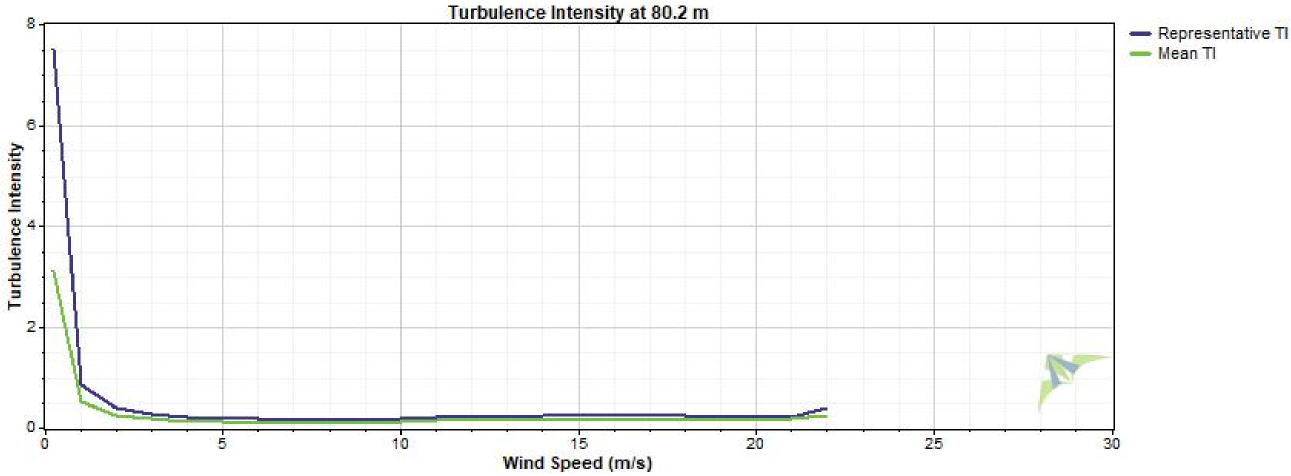
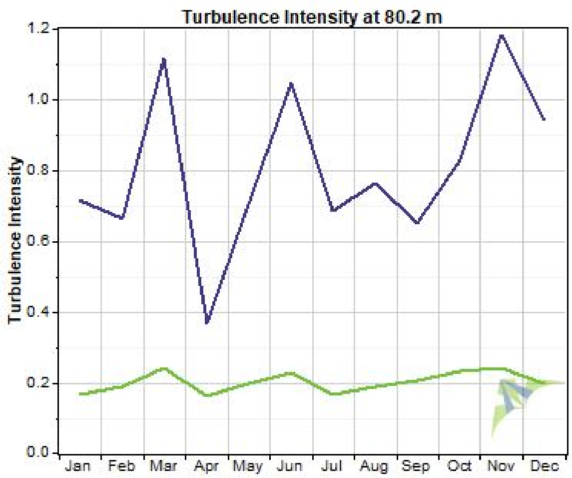
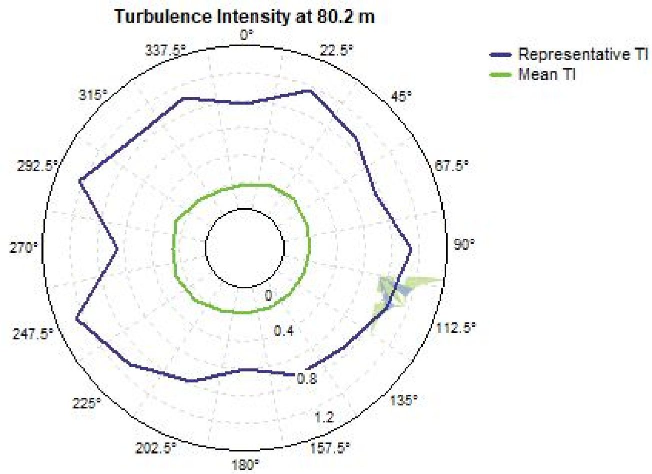
Nov
Dec

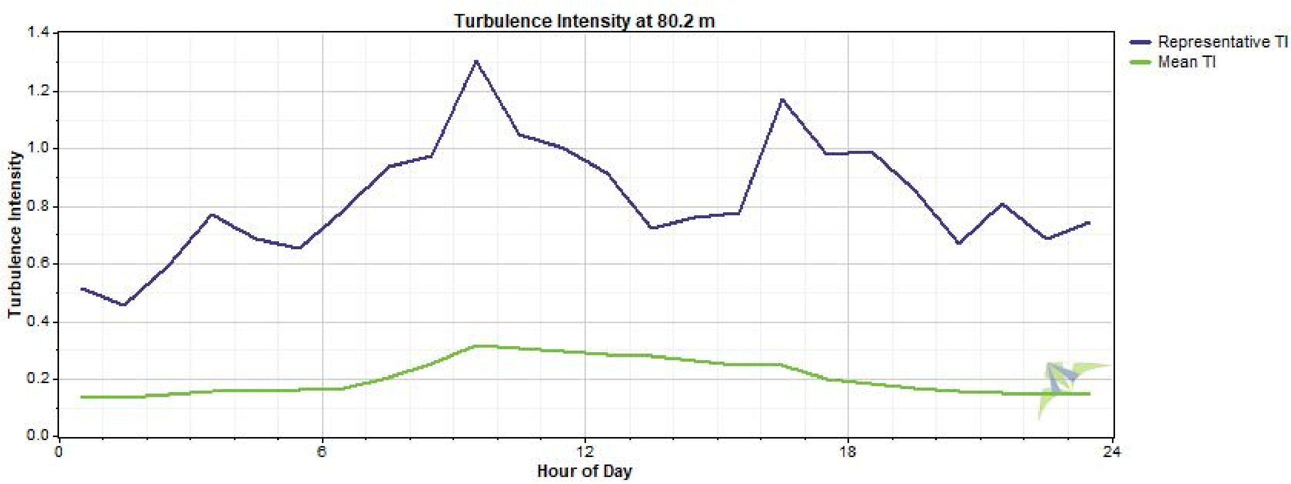

Power Law Exponent

Turbulence Intensity









Data Column Properties

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28	WindDir_58.3m_D1_WVT	°	58.3 m	185,468	175,418	94.58	106.5	0.0	360.0	103.9
29	WindDir_58.3m_SD1_WVT	°	58.3 m	185,468	175,418	94.58	8.1	0.0	79.7	7.7
30	WindDir_38.1m_D1_WVT	°	38.1 m	185,468	175,261	94.50	105.7	0.0	360.0	103.4
31	WindDir_38.1m_SD1_WVT	°	38.1 m	185,468	175,418	94.58	8.4	0.0	80.9	7.8
32	RTD_temp_C_78.4m_Avg	°C	78.4 m	185,468	175,418	94.58	26.0	7.9	39.4	4.3
33	RTD_temp_C_78.4m_Max	°C	78.4 m	185,468	175,418	94.58	26.1	8.0	39.7	4.3
34	RTD_temp_C_78.4m_Min	°C	78.4 m	185,468	175,418	94.58	25.8	7.8	39.0	4.3
35	RTD_temp_C_78.4m_Std	°C	78.4 m	185,468	175,418	94.58	0.1	0.0	6.0	0.1
36	RTD_temp_C_3.1m_Avg	°C	3.12 m	185,468	175,218	94.47	24.9	4.9	39.7	5.8
37	RTD_temp_C_3.1m_Max	°C	3.12 m	185,468	175,218	94.47	25.0	5.1	39.8	5.8
38	RTD_temp_C_3.1m_Min	°C	3.12 m	185,468	175,218	94.47	24.8	4.8	39.6	5.8
39	RTD_temp_C_3.1m_Std	°C	3.12 m	185,468	175,218	94.47	0.1	0.0	2.3	0.1
40	HMP155_temp_78.9m_Avg	°C	78.9 m	185,468	113,603	61.25	27.2	8.8	40.8	4.7
41	HMP155_temp_78.9m_Max	°C	78.9 m	185,468	113,603	61.25	29.0	10.3	60.4	4.7
42	HMP155_temp_78.9m_Min	°C	78.9 m	185,468	113,603	61.25	26.4	-21.8	39.9	4.7
43	HMP155_temp_78.9m_Std	°C	78.9 m	185,468	113,603	61.25	0.7	0.3	5.5	0.2
44	HMP155_RH_78.9m_Avg	%		185,468	175,406	94.57	75.9	-0.1	100.0	21.2
45	HMP155_RH_78.9m_Max	%		185,468	175,406	94.57	78.1	-0.1	100.0	20.8
46	HMP155_RH_78.9m_Min	%		185,468	175,406	94.57	74.2	-0.4	100.0	21.6
47	HMP155_RH_78.9m_Std	%		185,468	175,406	94.57	0.83	0.00	40.94	0.75
48	BP_78.7m_Avg	mbar	78.7 m	185,468	173,692	93.65	998.5	977.5	1,033.0	5.9
49	BP_78.7m_Max	mbar	78.7 m	185,468	173,692	93.65	998.7	978.5	1,034.0	5.9
50	BP_78.7m_Min	mbar	78.7 m	185,468	173,692	93.65	998.4	977.5	1,032.5	6.0
51	BP_78.7m_Std	mbar	78.7 m	185,468	173,692	93.65	0.1	0.0	15.7	0.2
52	BP_3.5m_Avg	mbar	3.49 m	185,468	154,700	83.41	1,006.9	990.0	1,021.5	6.0

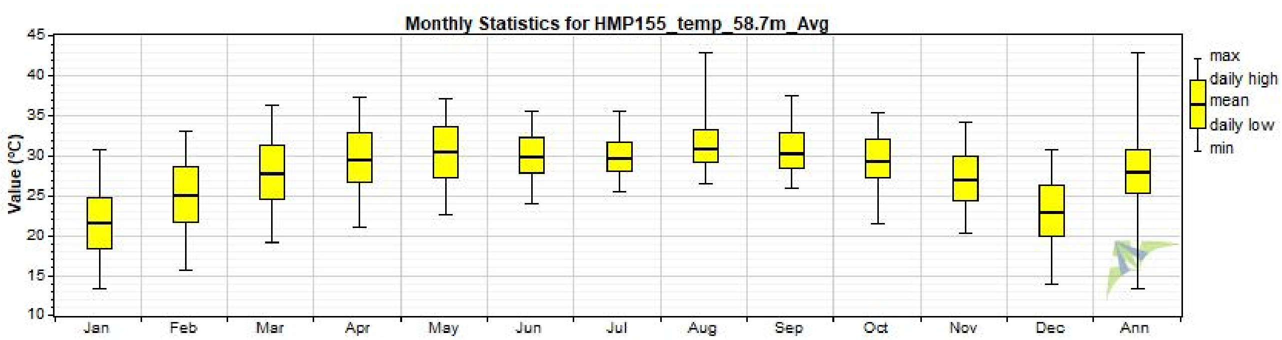
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	BP_3.5m_Max	mbar	3.49 m	185,468	154,700	83.41	1,007.0	990.0	1,022.0	6.0
54	BP_3.5m_Min	mbar	3.49 m	185,468	154,700	83.41	1,006.8	989.5	1,021.5	6.0
55	BP_3.5m_Std	mbar	3.49 m	185,468	154,700	83.41	0.1	0.0	3.4	0.1
56	SlrW_Avg	W/m2		185,468	3,765	2.03	165	0	1,156	249
57	SlrW_Max	W/m2		185,468	3,765	2.03	199	0	1,332	302
58	SlrW_Min	W/m2		185,468	3,765	2.03	129	0	1,064	197
59	SlrW_Std	W/m2		185,468	3,765	2.03	20.6	0.0	426.4	47.3
60	VWC_Avg	m^3/m^3		185,468	173,692	93.65	14	0	7,999	337
61	VWC_Max			185,468	173,692	93.65	14	0	7,999	337
62	VWC_Min			185,468	173,692	93.65	14	0	7,999	336
63	VWC_Std			185,468	173,692	93.65	0	0	7,999	27
64	SoilT_Avg	°C	0 m	185,468	175,418	94.58	26.2	0.0	44.8	4.6
65	SoilT_Max	°C	0 m	185,468	175,418	94.58	26.2	0.0	44.8	4.6
66	SoilT_Min	°C	0 m	185,468	175,418	94.58	26.2	0.0	44.7	4.6
67	SoilT_Std	°C	0 m	185,468	175,418	94.58	0.0	0.0	16.0	0.1
68	LWmV_Avg	%		185,468	175,418	94.58	900.1	877.0	919.0	6.4
69	LWmV	%		185,468	175,418	94.58	900.1	877.0	919.0	6.4
70	HMP155_temp_3.75m_Avg	°C	3.75 m	185,468	171,613	92.53	25.0	5.2	40.0	5.8
71	HMP155_temp_3.75m_Max	°C	3.75 m	185,468	171,613	92.53	25.3	5.6	40.2	5.8
72	HMP155_temp_3.75m_Min	°C	3.75 m	185,468	171,613	92.53	24.9	5.0	39.9	5.8
73	HMP155_temp_3.75m_Std	°C	3.75 m	185,468	171,613	92.53	0.1	0.0	3.6	0.1
74	HMP155_RH_3.75m_Avg	%		185,468	173,588	93.59	80.37	-0.11	98.50	16.91
75	HMP155_RH_3.75m_Max	%		185,468	173,588	93.59	80.9	-0.1	108.6	16.8
76	HMP155_RH_3.75m_Min	%		185,468	173,588	93.59	79.92	-2.23	98.40	17.04
77	HMP155_RH_3.75m_Std	%		185,468	173,588	93.59	0.235	0.001	8.130	0.334
78	VBatt_Min	Volts		185,468	171,652	92.55	12.68	0.00	13.80	0.66
79	IBatt_Min	Amps		185,468	171,653	92.55	-0.008	-0.257	1.085	0.188
80	ILoad_Min			185,468	171,653	92.55	0.134	0.000	0.200	0.013
81	V_in_chg_Min			185,468	171,653	92.55	8.63	0.00	20.70	7.75
82	I_in_chg_Min			185,468	171,653	92.55	0.111	-0.004	1.174	0.158
83	Chg_TmpC_Avg	°C	2 m	185,468	171,653	92.55	27.3	0.0	46.6	7.7
84	Chg_State	Smp		185,468	171,653	92.55	0.923	0.000	3.000	1.153
85	Ck_Batt	Smp		185,468	171,653	92.55	0.016	0.000	1.000	0.126
86	BattV_Min	Volts		185,468	171,653	92.55	12.30	9.20	13.42	0.65
87	PTemp_C_Avg	°C	2 m	185,468	171,653	92.55	26.7	5.2	43.0	6.7
88	latitude_a	Smp		185,468	171,523	92.48	24	24	24	0
89	latitude_b	Smp		185,468	171,523	92.48	10.22	10.21	10.25	0.00
90	longitude_a	Smp		185,468	171,523	92.48	88	88	88	0
91	longitude_b	Smp		185,468	171,523	92.48	54.45	54.44	54.46	0.00
92	magnetic_variation	Smp		185,468	171,523	92.48	-0.4	-0.4	-0.4	0.0
93	fix_quality	Smp		185,468	171,523	92.48	2	1	2	0
94	nmbr_satellites	Smp		185,468	171,523	92.48	9.19	5.00	12.00	0.89
95	altitude	Smp		185,468	171,523	92.48	14.69	-53.20	43.30	5.85
96	max_clock_change			185,468	171,523	92.48	-87	-1,050	300	300
97	nmbr_clock_change	Smp		185,468	171,523	92.48	0.221	0.000	2.000	0.504
98	Air Density	kg/m³		185,468	185,468	100.00	1.179	1.099	1.246	0.032
99	WS_east_80.2m_Avg TI			185,468	151,777	81.83	0.20	0.02	20.25	0.50
100	WS_west_80.2m_Avg TI			185,468	135,084	72.83	0.23	0.02	23.33	0.67
101	WS_east_60.3m_Avg TI			185,468	167,097	90.09	0.20	0.02	19.50	0.33
102	WS_west_60.3m_Avg TI			185,468	153,755	82.90	0.21	0.02	20.00	0.36
103	WS_east_40.1m_Avg TI			185,468	163,714	88.27	0.25	0.03	23.67	0.53
104	WS_west_40.1m_Avg TI			185,468	144,783	78.06	0.26	0.03	24.00	0.60
105	WS_east_80.2m_Avg WPD	W/m²		185,468	156,625	84.45	74	0	9,929	131
106	WS_west_80.2m_Avg WPD	W/m²		185,468	139,729	75.34	79	0	9,814	141

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
107	WS_east_60.3m_Avg WPD	W/m²		185,468	167,785	90.47	58	0	8,835	100
108	WS_west_60.3m_Avg WPD	W/m²		185,468	154,448	83.27	54	0	8,664	101
109	WS_east_40.1m_Avg WPD	W/m²		185,468	165,813	89.40	38	0	7,570	71
110	WS_west_40.1m_Avg WPD	W/m²		185,468	147,438	79.50	35	0	7,397	71

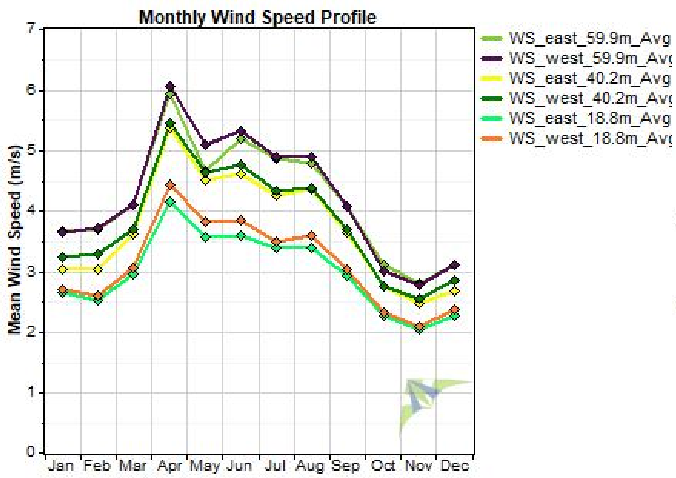
Data Set Properties

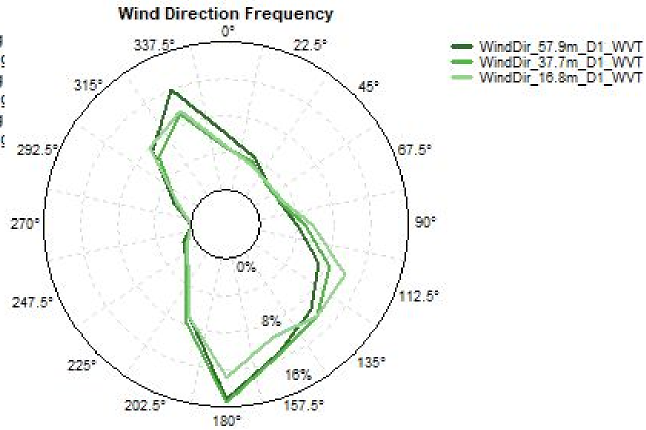
Report Created: 4/11/2018 10:11 using Windographer 3.3.10
Filter Settings: <Unflagged data>

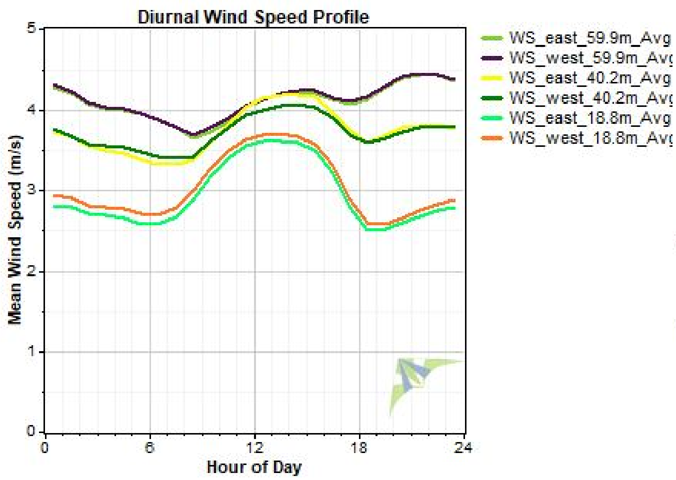
Variable	Value
Latitude	N 23.211160
Longitude	E 90.642370
Elevation	10 m
Start date	6/11/2014 00:10
End date	12/4/2017 12:00
Duration	3.5 years
Length of time step	10 minutes
Calm threshold	1 m/s
Mean temperature	27.9 °C
Mean pressure	1,002 mbar
Mean air density	1.171 kg/m³
Power density at 50m	70 W/m²
Wind power class	1
Power law exponent	0.273
Surface roughness	0.825 m
Roughness class	3.75

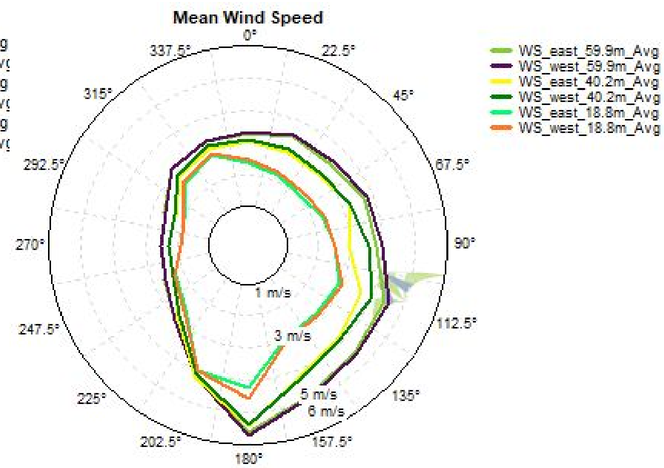


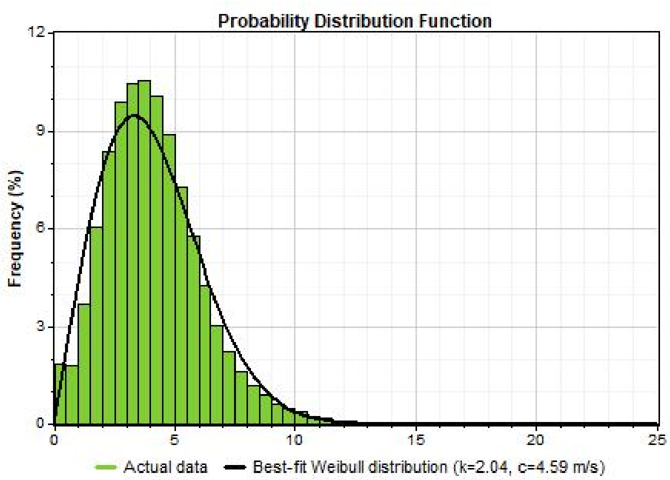
Wind Speed and Direction

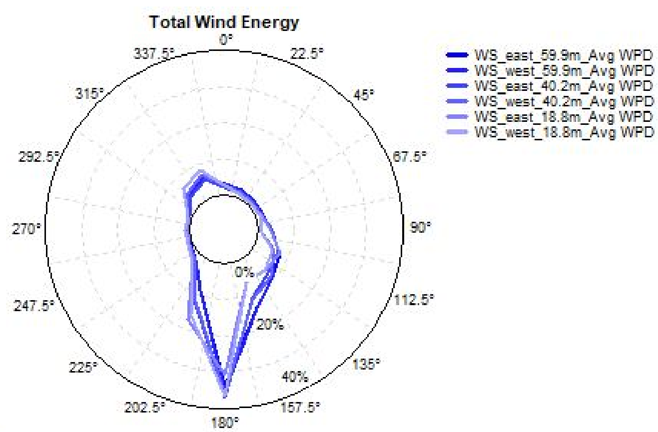




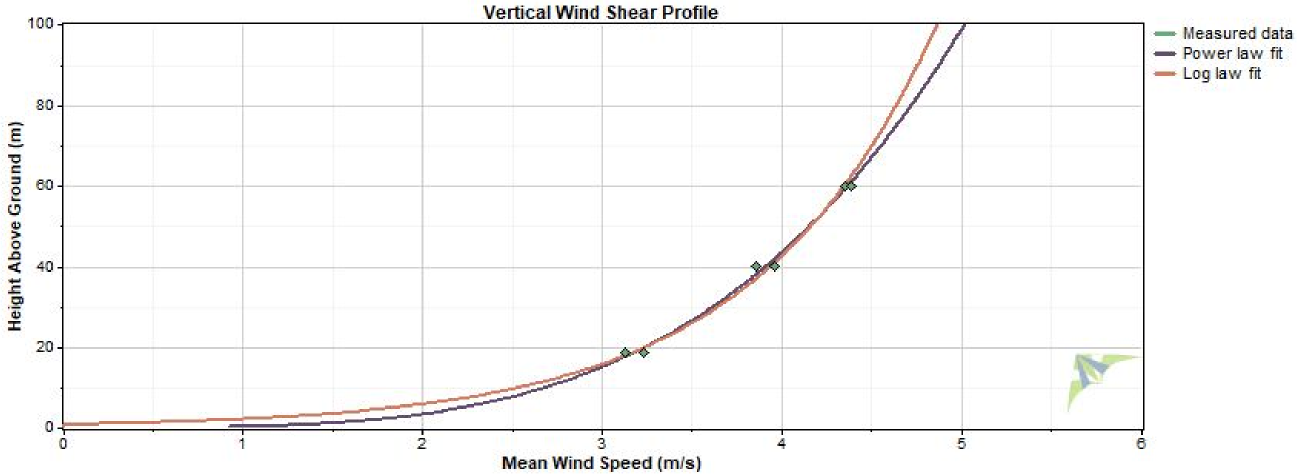


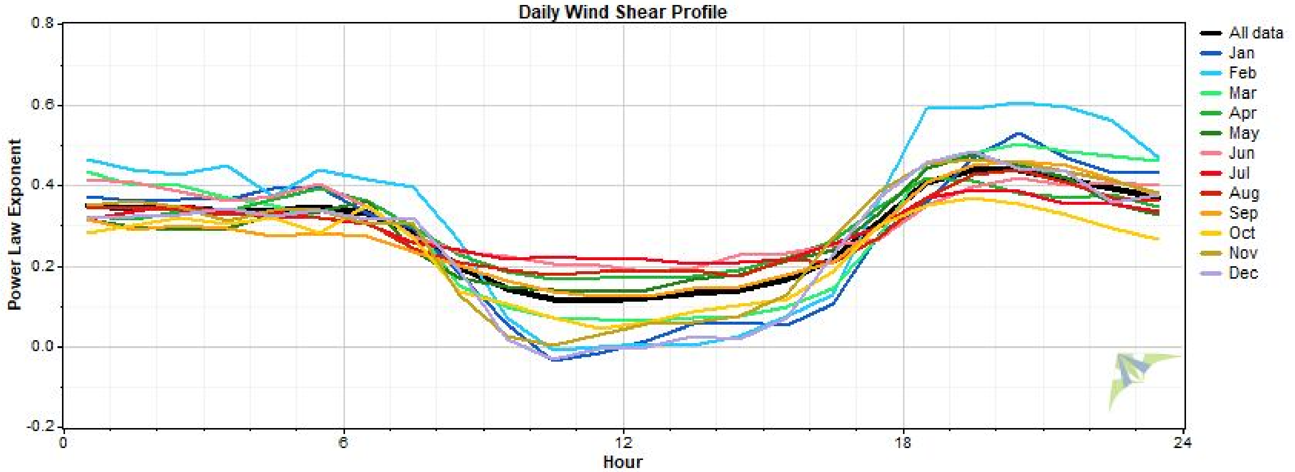


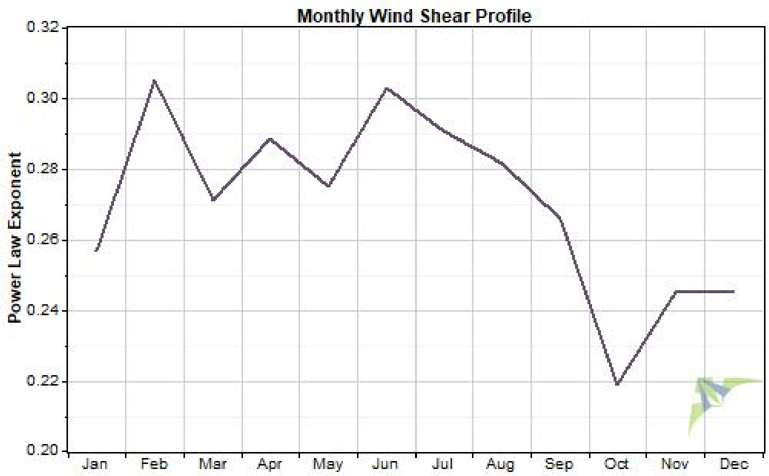


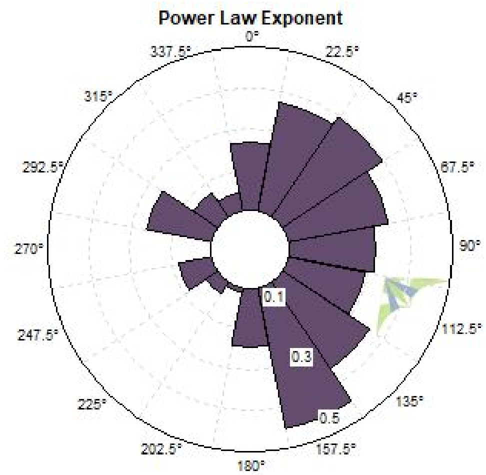


Wind Shear

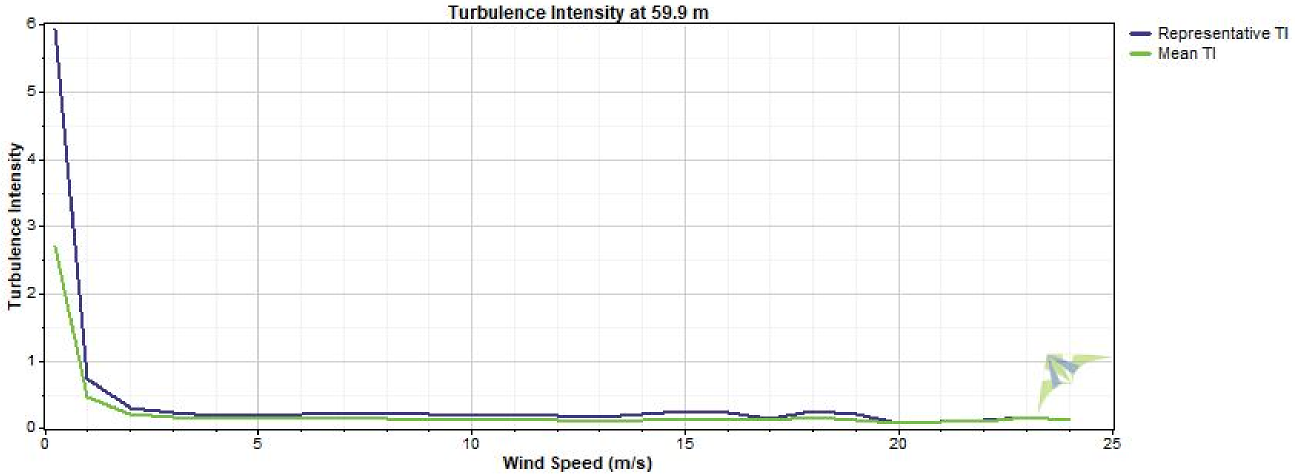

Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
Mean Wind Speed (m/s)

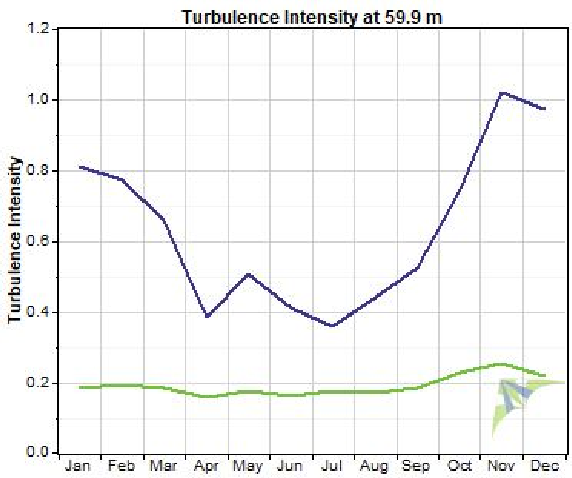

Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
Hour

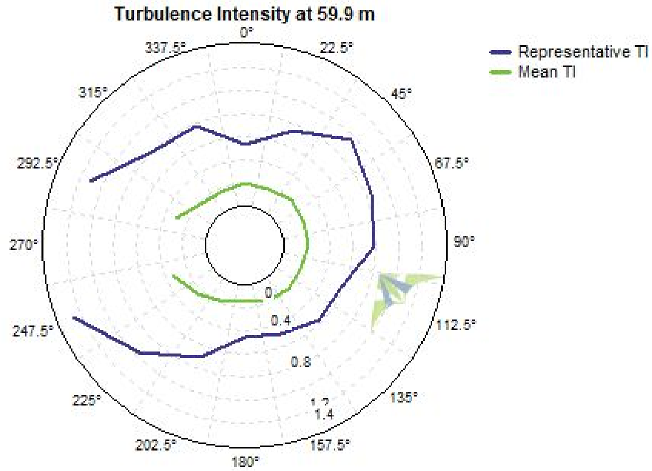

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

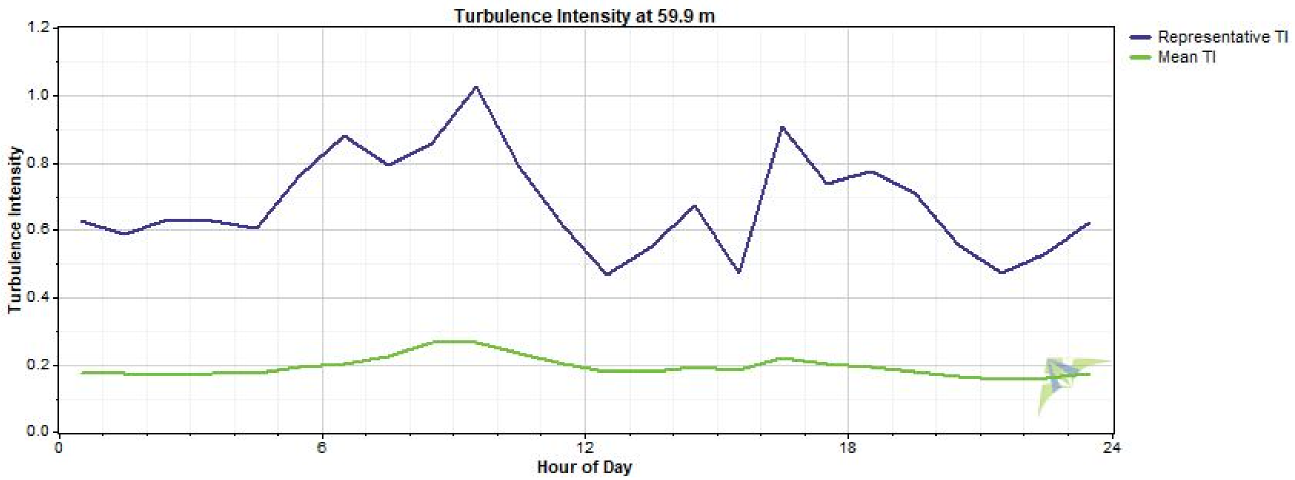

Power Law Exponent
0°
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
202.5°
225°
247.5°
270°
292.5°
315°
337.5°
0.1
0.3
0.5

Turbulence Intensity









Data Column Properties

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	RECORD	RN		183,239	146,725	80.07	24,627	0	58,583	16,934
2	WS_east_59.9m_Avg	m/s	59.9 m	183,239	141,776	77.37	4.093	0.000	23.920	2.042
3	WS_east_59.9m_Max	m/s	59.9 m	183,239	141,776	77.37	5.517	0.000	38.570	2.689
4	WS_east_59.9m_Min	m/s	59.9 m	183,239	141,776	77.37	2.631	0.000	17.860	1.577
5	WS_east_59.9m_Std	m/s	59.9 m	183,239	141,776	77.37	0.588	0.000	9.150	0.315
6	WS_west_59.9m_Avg	m/s	59.9 m	183,239	137,180	74.86	4.123	0.000	23.640	2.111
7	WS_west_59.9m_Max	m/s	59.9 m	183,239	137,180	74.86	5.539	0.000	37.000	2.753
8	WS_west_59.9m_Min	m/s	59.9 m	183,239	137,180	74.86	2.675	0.000	17.850	1.645
9	WS_west_59.9m_Std	m/s	59.9 m	183,239	137,180	74.86	0.584	0.000	9.030	0.316
10	WS_east_40.2m_Avg	m/s	40.2 m	183,239	117,312	64.02	3.728	0.000	23.220	2.028
11	WS_east_40.2m_Max	°C	40.2 m	183,239	117,312	64.02	5.310	0.000	34.760	2.787
12	WS_east_40.2m_Min	m/s	40.2 m	183,239	117,312	64.02	2.111	0.000	17.100	1.521
13	WS_east_40.2m_Std	°C	40.2 m	183,239	117,312	64.02	0.644	0.000	7.426	0.379
14	WS_west_40.2m_Avg	m/s	40.2 m	183,239	135,817	74.12	3.720	0.000	23.090	1.924
15	WS_west_40.2m_Max	m/s	40.2 m	183,239	135,817	74.12	5.200	0.000	36.350	2.623
16	WS_west_40.2m_Min	m/s	40.2 m	183,239	135,817	74.12	2.240	0.000	17.130	1.459
17	WS_west_40.2m_Std	°C	40.2 m	183,239	135,817	74.12	0.601	0.000	8.830	0.328
18	WS_east_18.8m_Avg	m/s	18.8 m	183,239	138,999	75.86	2.943	0.000	22.040	1.663
19	WS_east_18.8m_Max	m/s	18.8 m	183,239	138,999	75.86	4.596	0.000	32.370	2.446
20	WS_east_18.8m_Min	°C	18.8 m	183,239	138,999	75.86	1.350	0.000	16.290	1.164
21	WS_east_18.8m_Std	m/s	18.8 m	183,239	138,999	75.86	0.652	0.000	8.060	0.354
22	WS_west_18.8m_Avg	m/s	18.8 m	183,239	132,676	72.41	3.047	0.000	21.980	1.750
23	WS_west_18.8m_Max	m/s	18.8 m	183,239	132,676	72.41	4.641	0.000	32.590	2.496
24	WS_west_18.8m_Min	m/s	18.8 m	183,239	132,676	72.41	1.535	0.000	16.400	1.284
25	WS_west_18.8m_Std	m/s	18.8 m	183,239	132,676	72.41	0.627	0.000	7.951	0.342
26	WindDir_57.9m_D1_WVT	°	57.8 m	183,239	146,725	80.07	153.1	0.0	360.0	99.0
27	WindDir_57.9m_SD1_WVT	°	57.8 m	183,239	146,725	80.07	6.5	0.0	79.6	5.9
28	WindDir_37.7m_D1_WVT	°	37.7 m	183,239	146,725	80.07	155.9	-7,999.0	360.0	133.6
29	WindDir_37.7m_SD1_WVT	°	37.7 m	183,239	146,725	80.07	7.9	0.0	79.3	6.3
30	WindDir_16.8m_D1_WVT	°	16.8 m	183,239	146,725	80.07	153.2	0.0	360.0	98.2
31	WindDir_16.8m_SD1_WVT	°	16.8 m	183,239	146,725	80.07	9.4	0.0	79.8	7.4
32	RTD_temp_C_58m_Avg	°C	58 m	183,239	1,780	0.97	27.8	15.6	34.4	2.2
33	RTD_temp_C_58m_Max	°C	58 m	183,239	1,780	0.97	28.0	16.6	34.8	2.2
34	RTD_temp_C_58m_Min	°C	58 m	183,239	1,780	0.97	27.7	12.8	34.0	2.2
35	RTD_temp_C_58m_Std	°C	58 m	183,239	1,780	0.97	0.1	0.0	2.5	0.1
36	RTD_temp_C_3.7m_Avg	°C	3.65 m	183,239	103,119	56.28	23.8	9.5	33.8	4.4
37	RTD_temp_C_3.7m_Max	°C	3.65 m	183,239	103,119	56.28	23.9	9.9	34.1	4.4
38	RTD_temp_C_3.7m_Min	°C	3.65 m	183,239	103,119	56.28	23.6	9.3	33.5	4.4
39	RTD_temp_C_3.7m_Std	°C	3.65 m	183,239	103,119	56.28	0.1	0.0	2.8	0.1
40	HMP155_temp_58.7m_Avg	°C	58.7 m	183,239	146,723	80.07	27.9	13.2	42.9	3.9
41	HMP155_temp_58.7m_Max	°C	58.7 m	183,239	146,723	80.07	31.0	15.9	53.2	4.3
42	HMP155_temp_58.7m_Min	°C	58.7 m	183,239	146,723	80.07	26.7	-83.0	38.6	3.8
43	HMP155_temp_58.7m_Std	°C	58.7 m	183,239	146,723	80.07	1.1	0.8	12.7	0.3
44	HMP155_RH_58.7m_Avg	%		183,239	146,287	79.83	82.1	14.1	100.5	16.8
45	HMP155_RH_58.7m_Max	%		183,239	146,287	79.83	84.9	16.6	108.9	15.9
46	HMP155_RH_58.7m_Min	%		183,239	146,287	79.83	80.2	-0.0	100.0	17.5
47	HMP155_RH_58.7m_Std	%		183,239	146,287	79.83	1.00	0.00	33.70	0.81
48	Hmp155_temp_4.5m_Avg	°C	4.45 m	183,239	103,117	56.27	24.8	10.8	34.6	4.4
49	Hmp155_temp_4.5m_Max	°C	4.45 m	183,239	103,117	56.27	25.2	11.3	35.2	4.4
50	Hmp155_temp_4.5m_Min	°C	4.45 m	183,239	103,117	56.27	24.5	10.5	34.4	4.4
51	Hmp155_temp_4.5m_Std	°C	4.45 m	183,239	103,117	56.27	0.1	0.1	2.7	0.1
52	HMP155_RH_4.5m_Avg	%		183,239	146,725	80.07	85.9	15.3	100.0	12.4

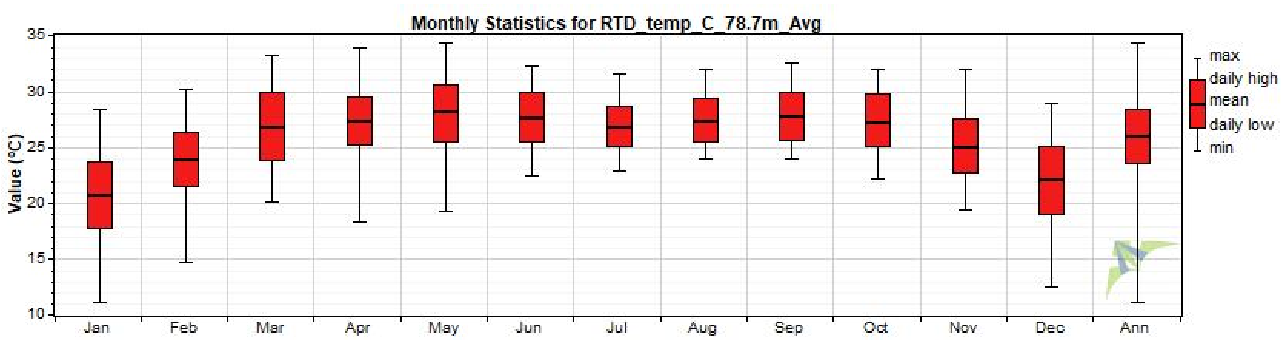
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	HMP155_RH_4.5m_Max	%		183,239	146,725	80.07	87.4	17.2	100.0	11.4
54	HMP155_RH_4.5m_Min	%		183,239	146,725	80.07	84.5	-0.0	100.0	13.4
55	HMP155_RH_4.5m_Std	%		183,239	146,725	80.07	0.68	0.00	37.49	0.72
56	BP_58.2m_Avg	mbar	58.3 m	183,239	146,724	80.07	1,002.4	972.5	1,021.0	5.5
57	BP_58.2m_Max	mbar	58.3 m	183,239	146,724	80.07	1,002.5	974.5	1,022.0	5.4
58	BP_58.2m_Min	mbar	58.3 m	183,239	146,724	80.07	1,002.3	970.5	1,020.5	5.5
59	BP_58.2m_Std	mbar	58.3 m	183,239	146,724	80.07	0.1	0.0	18.1	0.2
60	BP_3.4m_Avg	mbar	3.4 m	183,239	146,724	80.07	1,008.0	989.5	1,022.0	5.6
61	BP_3.4m_Max	mbar	3.4 m	183,239	146,724	80.07	1,008.1	990.0	1,022.0	5.6
62	BP_3.4m_Min	mbar	3.4 m	183,239	146,724	80.07	1,007.9	989.5	1,022.0	5.6
63	BP_3.4m_Std	mbar	3.4 m	183,239	146,724	80.07	0.1	0.0	3.8	0.1
64	SlrW_Avg	W/m^2		183,239	14,383	7.85	16	-7,999	1,006	256
65	SlrW_Max			183,239	14,383	7.85	21	-7,999	1,218	265
66	SlrW_Min			183,239	14,383	7.85	12	-7,999	916	249
67	SlrW_Std			183,239	14,383	7.85	-4	-7,999	342	232
68	VWC_Avg	m^3/m^3		183,239	146,725	80.07	2.58	0.01	32.33	7.72
69	VWC_Max			183,239	146,725	80.07	2.58	0.09	32.35	7.73
70	VWC_Min			183,239	146,725	80.07	2.57	0.00	32.31	7.71
71	VWC_Std			183,239	146,725	80.07	0.00	0.00	11.02	0.03
72	SoilT_Avg	°C	0 m	183,239	146,725	80.07	92.8	0.5	903.0	230.3
73	SoilT_Max	°C	0 m	183,239	146,725	80.07	92.8	18.3	903.0	230.2
74	SoilT_Min	°C	0 m	183,239	146,725	80.07	25.8	0.0	36.5	4.8
75	SoilT_Std	°C	0 m	183,239	146,725	80.07	0.0	-0.2	12.3	0.1
76	LWmV_Avg	mV		183,239	146,725	80.07	832.0	0.0	914.0	238.1
77	LWmV	mV		183,239	146,725	80.07	832.6	0.0	914.0	235.9
78	VBatt_Min	Volts		183,239	144,709	78.97	12.25	-0.00	17.81	3.56
79	IBatt_Min	Amps		183,239	144,709	78.97	2.24	-0.20	39.10	7.94
80	ILoad_Min			183,239	144,709	78.97	0.199	0.000	3.000	0.476
81	V_in_chg_Min			183,239	144,709	78.97	8.87	0.00	21.33	8.55
82	I_in_chg_Min			183,239	144,709	78.97	1.05	-0.00	13.72	3.40
83	Chg_TmpC_Avg	°C	2 m	183,239	144,709	78.97	27.0	0.0	43.7	5.7
84	Chg_State	Smp		183,239	144,709	78.97	2.96	0.00	23.00	5.93
85	Ck_Batt	Smp		183,239	144,709	78.97	0.97	0.00	12.68	3.38
86	BattV_Min	Volts		183,239	144,709	78.97	18.83	11.87	90.00	20.52
87	PTemp_C_Avg	°C	2 m	183,239	144,709	78.97	27.7	10.8	43.0	6.0
88	latitude_a	Smp		183,239	144,709	78.97	21.20	-0.50	23.00	6.27
89	latitude_b	Smp		183,239	144,709	78.97	11.85	2.00	12.68	2.83
90	longitude_a	Smp		183,239	144,709	78.97	83.78	5.00	90.00	21.62
91	longitude_b	Smp		183,239	144,709	78.97	36.25	-12.70	38.55	8.10
92	magnetic_variation	Smp		183,239	144,709	78.97	225	-1	7,999	1,324
93	fix_quality	Smp		183,239	144,709	78.97	1.903	0.000	2.000	0.430
94	nmbr_satellites	Smp		183,239	144,709	78.97	9.07	5.00	12.00	0.92
95	altitude	Smp		183,239	144,709	78.97	8.37	-28.60	36.60	6.08
96	max_clock_change			183,239	144,709	78.97	467	-1,020	7,999	2,464
97	nmbr_clock_change	Smp		183,239	144,709	78.97	0.819	0.000	5.000	1.260
98	Air Density	kg/m³		183,239	183,239	100.00	1.171	1.095	1.231	0.029
99	WS_east_59.9m_Avg TI			183,239	140,765	76.82	0.19	0.03	20.00	0.39
100	WS_west_59.9m_Avg TI			183,239	136,263	74.36	0.20	0.03	20.50	0.42
101	WS_east_40.2m_Avg TI			183,239	113,461	61.92	0.24	0.03	19.50	0.57
102	WS_west_40.2m_Avg TI			183,239	135,121	73.74	0.22	0.04	20.00	0.42
103	WS_east_18.8m_Avg TI			183,239	136,257	74.36	0.32	0.05	19.50	0.61
104	WS_west_18.8m_Avg TI			183,239	131,440	71.73	0.30	0.05	20.00	0.59
105	WS_east_59.9m_Avg WPD	W/m²		183,239	141,776	77.37	73	0	8,049	142
106	WS_west_59.9m_Avg WPD	W/m²		183,239	137,180	74.86	77	0	7,764	153

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
107	WS_east_40.2m_Avg WPD	W/m²		183,239	117,312	64.02	61	0	7,363	134
108	WS_west_40.2m_Avg WPD	W/m²		183,239	135,817	74.12	58	0	7,240	127
109	WS_east_18.8m_Avg WPD	W/m²		183,239	138,999	75.86	32	0	6,297	87
110	WS_west_18.8m_Avg WPD	W/m²		183,239	132,676	72.41	37	0	6,245	97

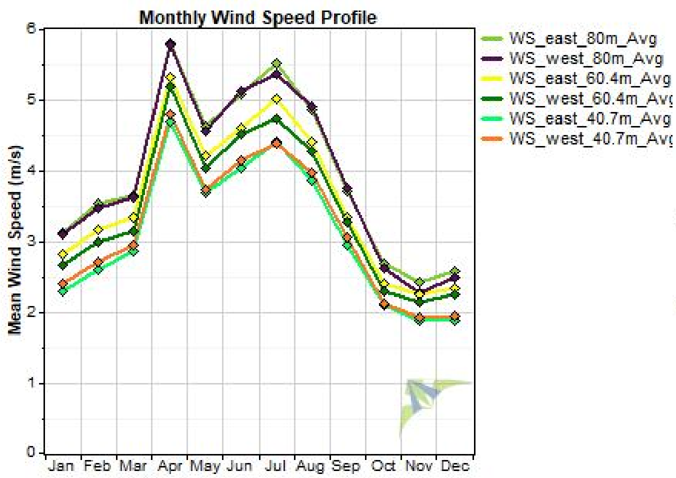
Data Set Properties

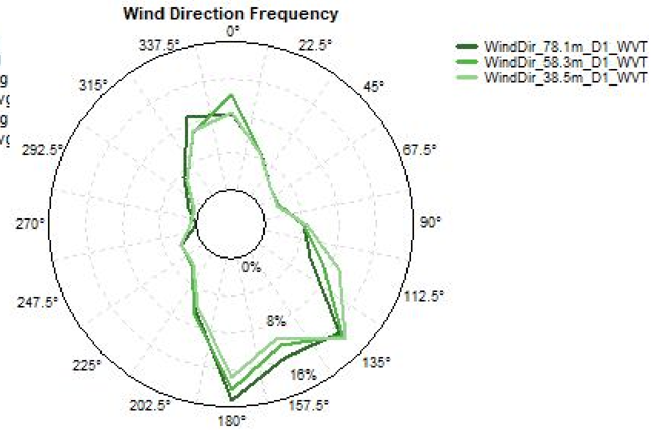
Report Created: 4/11/2018 10:43 using Windographer 3.3.10
Filter Settings: <Unflagged data>

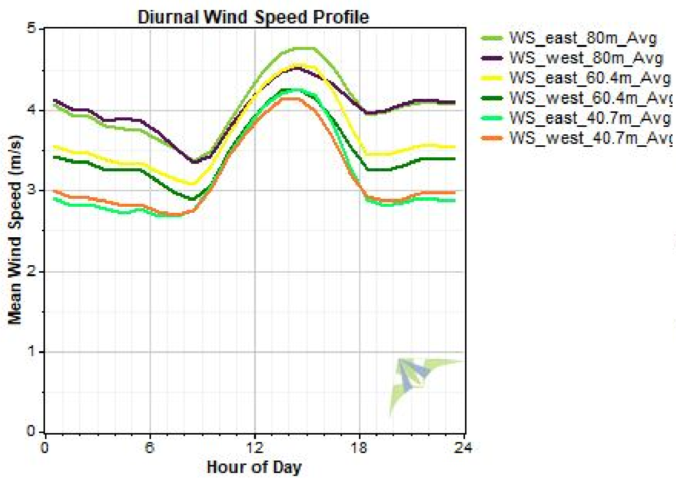
Variable	Value
Latitude	N 22.604160
Longitude	E 91.660100
Elevation	0 m
Start date	12/18/2014 09:50
End date	12/20/2016 00:10
Duration	24 months
Length of time step	10 minutes
Calm threshold	1 m/s
Mean temperature	26.0 °C
Mean pressure	999.9 mbar
Mean air density	1.169 kg/m³
Power density at 50m	49 W/m²
Wind power class	1
Power law exponent	0.334
Surface roughness	2.84 m
Roughness class	4.78

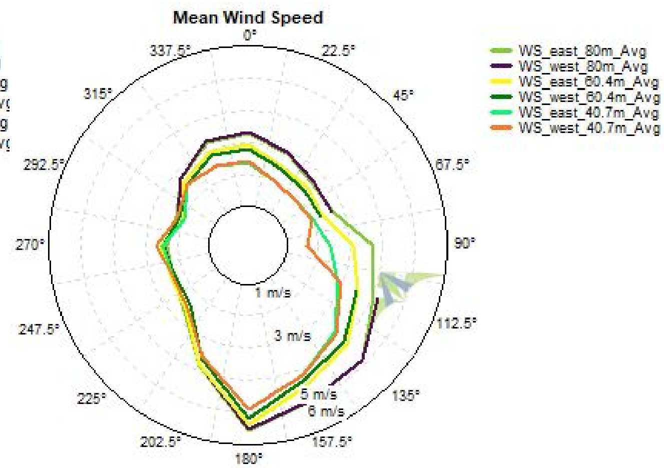


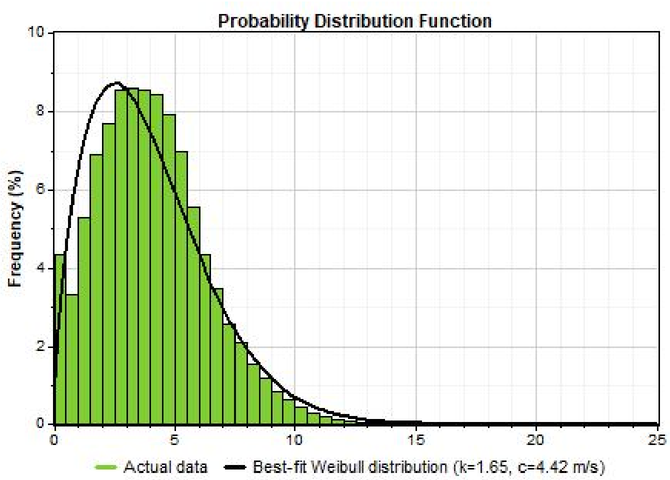
Wind Speed and Direction

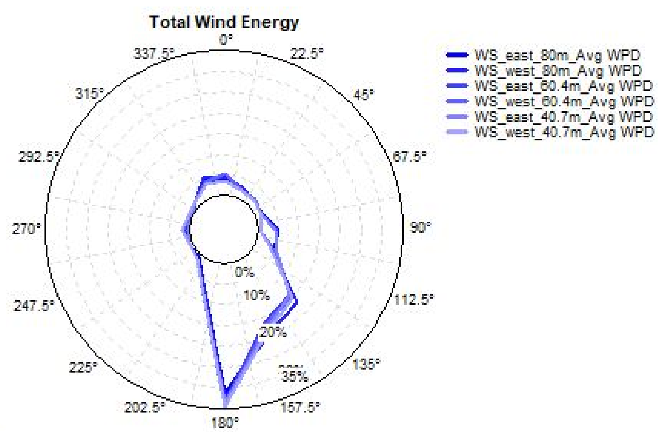




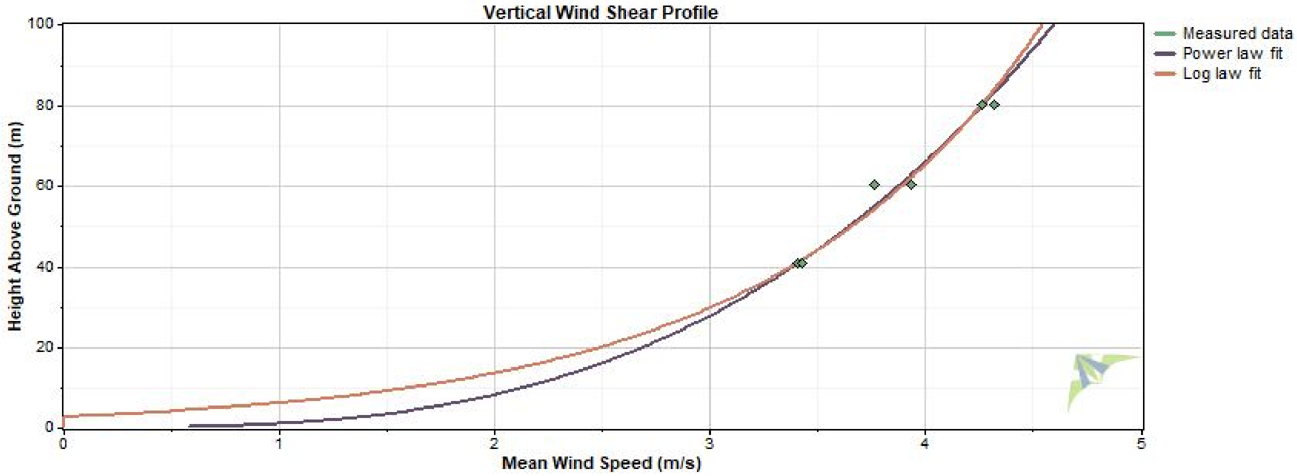


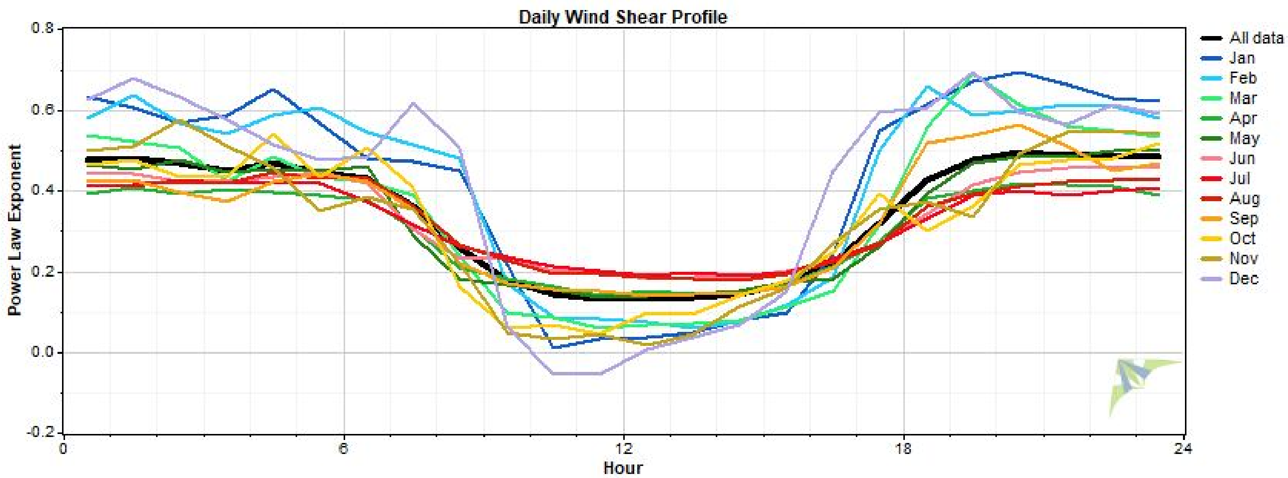


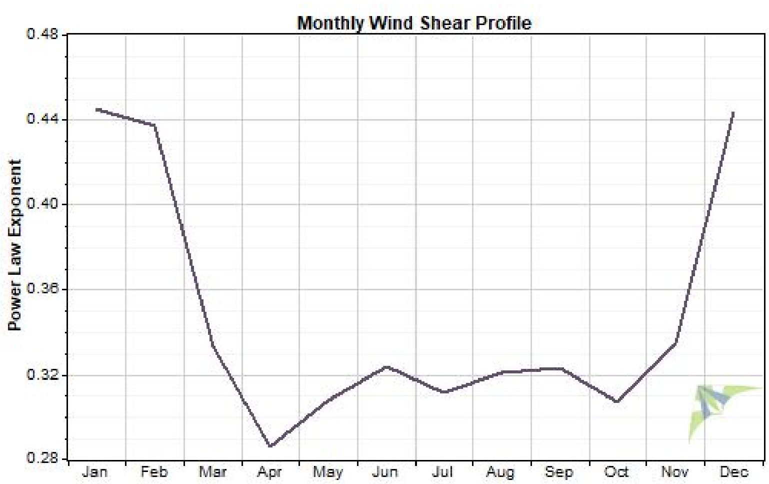


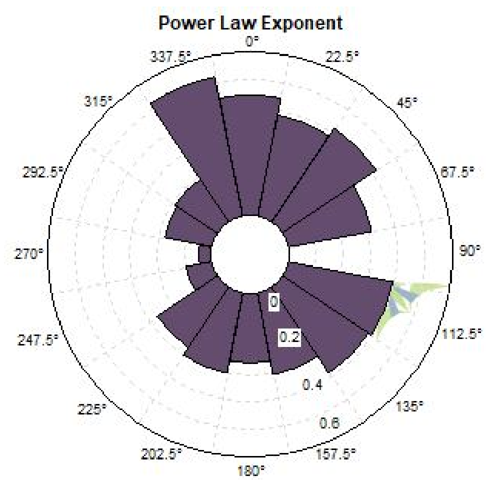


Wind Shear

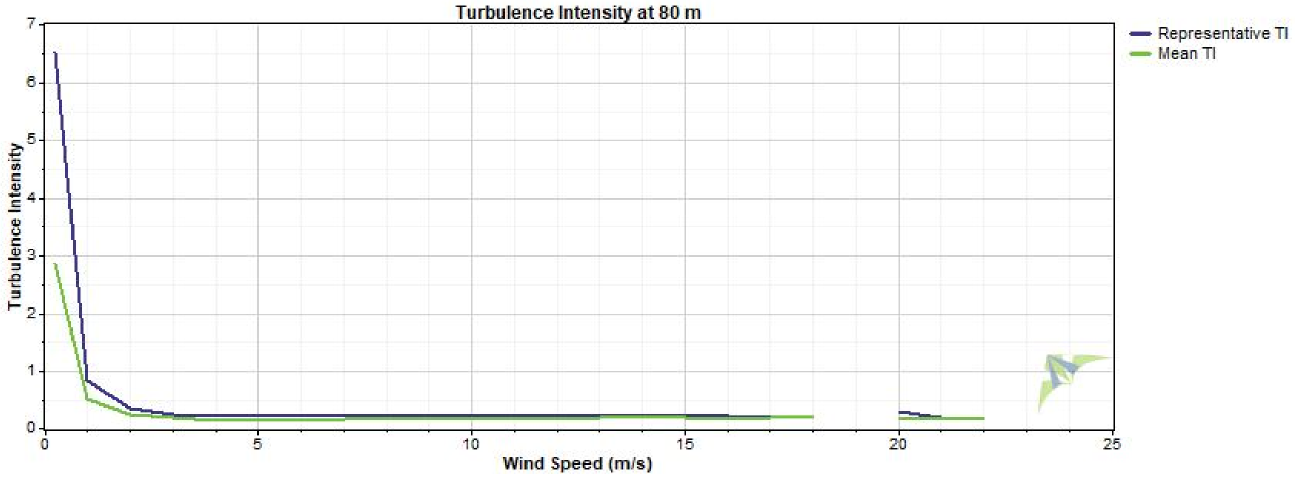

Vertical Wind Shear Profile
Height Above Ground (m)
Mean Wind Speed (m/s)
Measured data
Power law fit
Log law fit

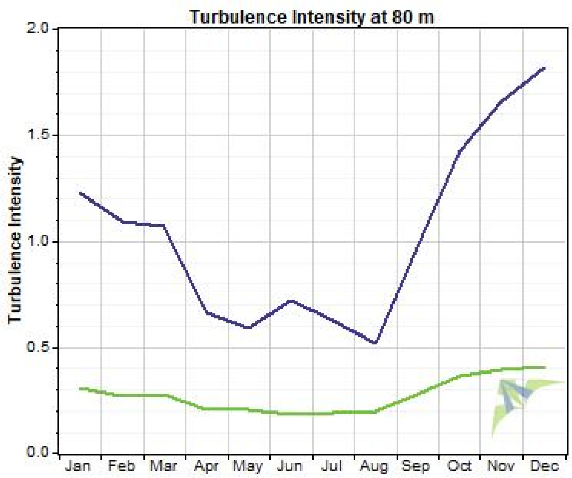

Daily Wind Shear Profile
Power Law Exponent
Hour
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

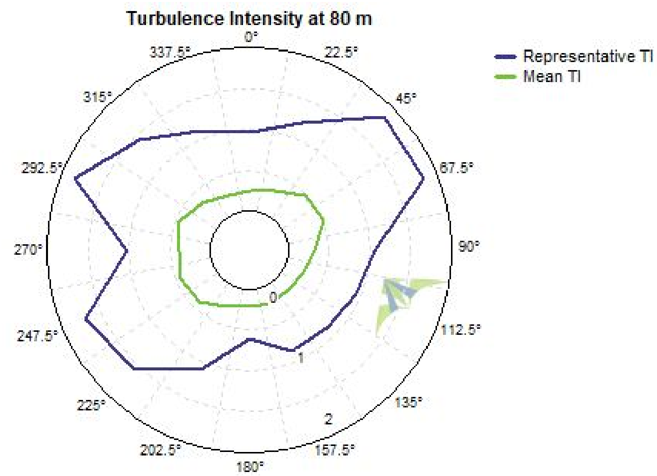

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

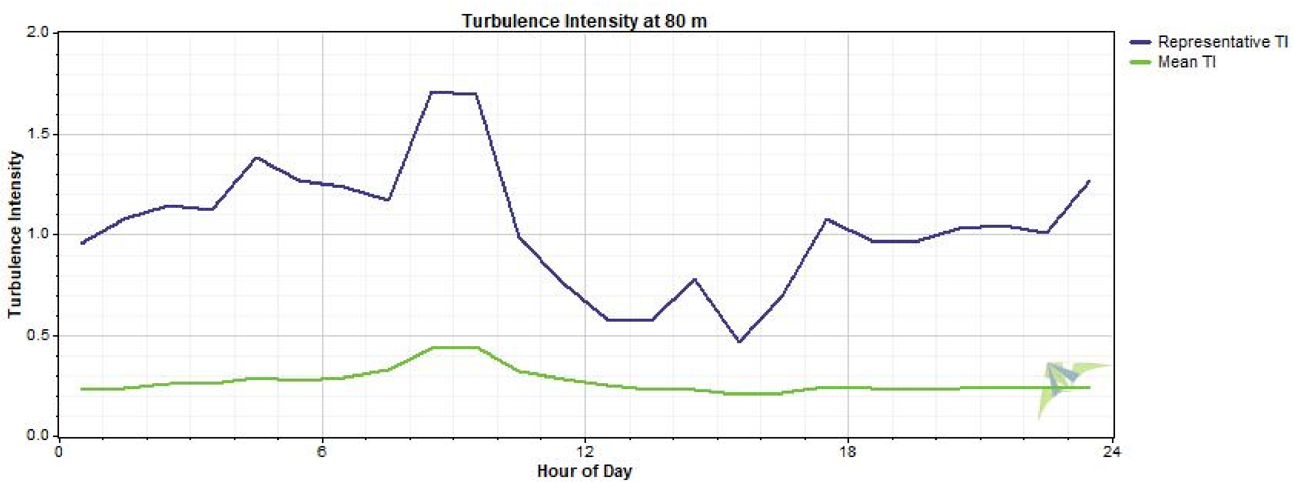

Power Law Exponent

Turbulence Intensity









Data Column Properties

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	RECORD	RN		105,494	96,567	91.54	22,630	0	53,062	14,763
2	WS_east_80m_Avg	m/s	80 m	105,494	91,476	86.71	4.015	0.000	21.730	2.296
3	WS_east_80m_Max	m/s	80 m	105,494	91,476	86.71	5.704	0.000	31.020	3.163
4	WS_east_80m_Min	m/s	80 m	105,494	91,476	86.71	2.350	0.000	14.070	1.575
5	WS_east_80m_Std	m/s	80 m	105,494	91,476	86.71	0.676	0.000	6.838	0.373
6	WS_west_80m_Avg	m/s	80 m	105,494	85,589	81.13	4.009	0.000	21.490	2.311
7	WS_west_80m_Max	m/s	80 m	105,494	85,589	81.13	5.720	0.000	31.010	3.170
8	WS_west_80m_Min	m/s	80 m	105,494	85,589	81.13	2.303	0.000	13.290	1.597
9	WS_west_80m_Std	m/s	80 m	105,494	85,589	81.13	0.687	0.000	6.486	0.386
10	WS_east_60.4m_Avg	m/s	60.4 m	105,494	92,008	87.22	3.638	0.000	20.430	2.125
11	WS_east_60.4m_Max	m/s	60.4 m	105,494	92,008	87.22	5.353	0.000	31.730	3.047
12	WS_east_60.4m_Min	m/s	60.4 m	105,494	92,008	87.22	1.987	0.000	12.510	1.385
13	WS_east_60.4m_Std	°C	60.4 m	105,494	92,008	87.22	0.678	0.000	6.575	0.373
14	WS_west_60.4m_Avg	m/s	60.4 m	105,494	89,834	85.16	3.480	0.000	19.600	2.115
15	WS_west_60.4m_Max	m/s	60.4 m	105,494	89,834	85.16	5.190	0.000	30.640	2.983
16	WS_west_60.4m_Min	m/s	60.4 m	105,494	89,834	85.16	1.818	0.000	11.700	1.397
17	WS_west_60.4m_Std	m/s	60.4 m	105,494	89,834	85.16	0.679	0.000	6.123	0.371
18	WS_east_40.7m_Avg	m/s	40.7 m	105,494	92,586	87.76	3.144	0.000	18.710	1.919
19	WS_east_40.7m_Max	m/s	40.7 m	105,494	92,586	87.76	4.918	0.000	36.860	2.939
20	WS_east_40.7m_Min	°C	40.7 m	105,494	92,586	87.76	1.477	0.000	10.230	1.095
21	WS_east_40.7m_Std	m/s	40.7 m	105,494	92,586	87.76	0.694	0.000	6.451	0.384
22	WS_west_40.7m_Avg	m/s	40.7 m	105,494	88,302	83.70	3.194	0.000	18.530	1.910
23	WS_west_40.7m_Max	m/s	40.7 m	105,494	88,302	83.70	4.977	0.000	30.230	2.913
24	WS_west_40.7m_Min	m/s	40.7 m	105,494	88,302	83.70	1.516	0.000	11.000	1.102
25	WS_west_40.7m_Std	m/s	40.7 m	105,494	88,302	83.70	0.699	0.000	6.059	0.381
26	WindDir_78.1m_D1_WVT	°	78.1 m	105,494	96,567	91.54	150.1	0.0	360.0	98.2
27	WindDir_78.1m_SD1_WVT	°	78.1 m	105,494	96,567	91.54	8.4	0.0	79.5	7.6
28	WindDir_58.3m_D1_WVT	°	58.3 m	105,494	96,567	91.54	149.5	0.0	360.0	99.6
29	WindDir_58.3m_SD1_WVT	°	58.3 m	105,494	96,567	91.54	9.3	0.0	80.1	7.9
30	WindDir_38.5m_D1_WVT	°	38.5 m	105,494	96,567	91.54	148.7	0.0	360.0	98.9
31	WindDir_38.5m_SD1_WVT	°	38.5 m	105,494	96,567	91.54	10.3	0.0	80.4	8.4
32	RTD_temp_C_78.7m_Avg	°C	78.7 m	105,494	96,567	91.54	26.0	11.2	34.3	3.2
33	RTD_temp_C_78.7m_Max	°C	78.7 m	105,494	96,567	91.54	26.3	11.3	34.4	3.2
34	RTD_temp_C_78.7m_Min	°C	78.7 m	105,494	96,567	91.54	25.7	11.0	34.1	3.2
35	RTD_temp_C_78.7m_Std	°C	78.7 m	105,494	96,567	91.54	0.1	0.0	2.4	0.1
36	RTD_temp_C_3.9m_Avg	°C	3.88 m	105,494	72,429	68.66	24.8	7.8	34.9	5.2
37	RTD_temp_C_3.9m_Max	°C	3.88 m	105,494	72,429	68.66	25.0	7.9	35.1	5.2
38	RTD_temp_C_3.9m_Min	°C	3.88 m	105,494	72,429	68.66	24.7	7.7	34.6	5.1
39	RTD_temp_C_3.9m_Std	°C	3.88 m	105,494	72,429	68.66	0.1	0.0	2.3	0.1
40	HMP155_temp_78.7m_Avg	°C	78.7 m	105,494	96,567	91.54	25.9	11.1	33.8	3.2
41	HMP155_temp_78.7m_Max	°C	78.7 m	105,494	96,567	91.54	26.0	11.1	34.0	3.2
42	HMP155_temp_78.7m_Min	°C	78.7 m	105,494	96,567	91.54	25.8	11.0	33.8	3.2
43	HMP155_temp_78.7m_Std	°C	78.7 m	105,494	96,567	91.54	0.1	0.0	2.2	0.1
44	HMP155_RH_78.7m_Avg	%		105,494	96,567	91.54	75.6	10.4	100.0	16.1
45	HMP155_RH_78.7m_Max	%		105,494	96,567	91.54	76.8	11.7	100.0	15.8
46	HMP155_RH_78.7m_Min	%		105,494	96,567	91.54	74.38	9.09	99.90	16.48
47	HMP155_RH_78.7m_Std	%		105,494	96,567	91.54	0.61	0.02	14.47	0.62
48	BP_79m_Avg	mbar	79 m	105,494	96,567	91.54	999.9	976.0	1,014.0	5.2
49	BP_79m_Max	mbar	79 m	105,494	96,567	91.54	1,000.1	976.0	1,015.0	5.2
50	BP_79m_Min	mbar	79 m	105,494	96,567	91.54	999.7	835.0	1,014.0	5.9
51	BP_79m_Std	mbar	79 m	105,494	96,567	91.54	0.1	0.0	27.4	0.2
52	BP_3.9m_Avg	mbar	3.88 m	105,494	96,567	91.54	1,008.3	984.0	1,022.0	5.4

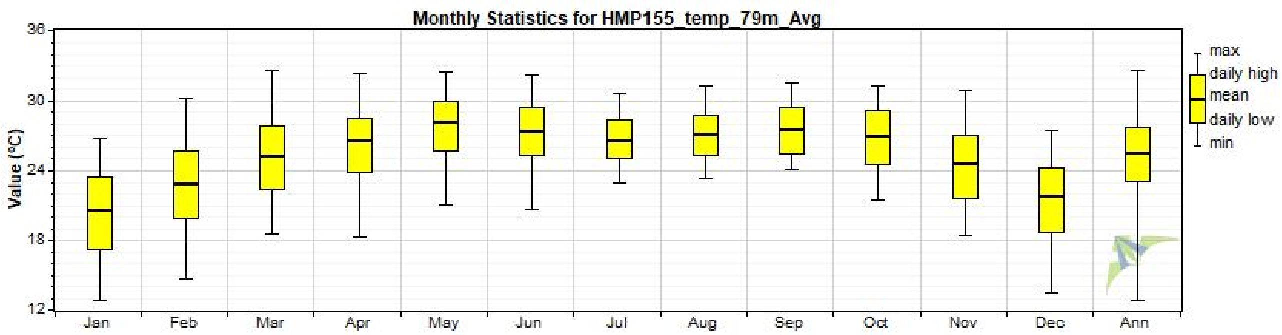
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	BP_3.9m_Max	mbar	3.88 m	105,494	96,567	91.54	1,008.4	984.0	1,022.0	5.4
54	BP_3.9m_Min	mbar	3.88 m	105,494	96,567	91.54	1,008.2	983.0	1,021.0	5.4
55	BP_3.9m_Std	°C	2 m	105,494	96,567	91.54	0.0	0.0	1.0	0.0
56	SlrW_Avg	W/m2		105,494	31,255	29.63	999	980	1,014	6
57	SlrW_Max	W/m2		105,494	31,255	29.63	999	981	1,015	6
58	SlrW_Min	W/m2		105,494	31,255	29.63	999	835	1,014	6
59	SlrW_Std	W/m2		105,494	31,255	29.63	0.07	0.02	19.26	0.17
60	VWC_Avg	m^3/m^3		105,494	31,255	29.63	1,007	989	1,021	6
61	VWC_Max			105,494	31,255	29.63	1,007	990	1,021	6
62	VWC_Min			105,494	31,255	29.63	1,007	989	1,021	6
63	VWC_Std			105,494	31,255	29.63	0.0514	0.0200	0.9500	0.0312
64	SoilT_Avg	°C	0 m	105,494	31,255	29.63	320.4	246.4	840.0	98.3
65	SoilT_Max	°C	0 m	105,494	31,255	29.63	320.4	243.5	839.0	99.9
66	SoilT_Min	°C	0 m	105,494	31,255	29.63	12.9	0.0	13.7	0.5
67	SoilT_Std	°C	0 m	105,494	31,255	29.63	-0.0	-0.3	1.4	0.4
68	LWmV_Avg	%		105,494	96,567	91.54	217.8	0.0	737.6	168.0
69	LWmV	%		105,494	96,567	91.54	220.6	0.0	794.6	164.8
70	HMP155_temp_4.6m_Avg	°C	4.63 m	105,494	65,422	62.01	24.8	0.0	35.0	4.9
71	HMP155_temp_4.6m_Max	°C	4.63 m	105,494	65,422	62.01	25.0	8.3	35.2	4.9
72	HMP155_temp_4.6m_Min	°C	4.63 m	105,494	65,422	62.01	24.7	0.0	34.8	4.9
73	HMP155_temp_4.6m_Std	°C	4.63 m	105,494	65,422	62.01	0.1	0.0	2.0	0.1
74	HMP155_RH_4.6m_Avg	%		105,494	65,422	62.01	85.65	12.10	99.80	13.81
75	HMP155_RH_4.6m_Max	%		105,494	65,422	62.01	86.98	13.53	99.90	12.75
76	HMP155_RH_4.6m_Min	%		105,494	65,422	62.01	84.50	22.00	99.70	14.73
77	HMP155_RH_4.6m_Std	%		105,494	65,422	62.01	0.60	0.03	36.25	0.71
78	VBatt_Min	Volts		105,494	96,567	91.54	37.86	0.00	91.00	36.64
79	IBatt_Min	Amps		105,494	96,567	91.54	12.76	-0.35	39.61	18.51
80	ILoad_Min			105,494	96,567	91.54	-0.0058	-0.6000	0.3200	0.4098
81	V_in_chg_Min			105,494	96,567	91.54	6.53	0.00	19.96	7.55
82	I_in_chg_Min			105,494	96,567	91.54	3.11	-0.00	11.00	4.20
83	Chg_TmpC_Avg	°C	2 m	105,494	96,567	91.54	22.4	-28.5	46.8	12.8
84	Chg_State	Smp		105,494	96,567	91.54	-40	-1,350	340	308
85	Ck_Batt	Smp		105,494	96,567	91.54	0.169	0.000	2.000	0.487
86	BattV_Min	Volts		105,494	96,567	91.54	12.66	0.00	13.71	0.49
87	PTemp_C_Avg	°C	2 m	105,494	96,567	91.54	27.2	8.3	40.2	5.8
88	latitude_a	Smp		105,494	96,567	91.54	22	22	22	0
89	latitude_b	Smp		105,494	96,567	91.54	36.25	36.24	36.26	0.00
90	longitude_a	Smp		105,494	96,567	91.54	91	91	91	0
91	longitude_b	Smp		105,494	96,567	91.54	39.60	39.59	39.61	0.00
92	magnetic_variation	Smp		105,494	96,567	91.54	-0.6	-0.6	-0.6	0.0
93	fix_quality	Smp		105,494	96,567	91.54	2	1	2	0
94	nmbr_satellites	Smp		105,494	96,567	91.54	9.16	5.00	12.00	0.87
95	altitude	Smp		105,494	96,567	91.54	8.19	-37.50	37.00	6.38
96	max_clock_change			105,494	96,567	91.54	-156	-1,350	340	478
97	nmbr_clock_change	Smp		105,494	96,567	91.54	0.981	0.000	3.000	1.070
98	Air Density	kg/m³		105,494	105,494	100.00	1.169	1.126	1.234	0.021
99	WS_east_80m_Avg TI			105,494	89,873	85.19	0.27	0.03	20.00	0.64
100	WS_west_80m_Avg TI			105,494	82,399	78.11	0.28	0.04	20.25	0.70
101	WS_east_60.4m_Avg TI			105,494	90,318	85.61	0.30	0.03	20.00	0.70
102	WS_west_60.4m_Avg TI			105,494	86,721	82.20	0.38	0.03	25.00	1.04
103	WS_east_40.7m_Avg TI			105,494	91,288	86.53	0.36	0.05	20.00	0.81
104	WS_west_40.7m_Avg TI			105,494	87,343	82.79	0.35	0.04	20.50	0.75
105	WS_east_80m_Avg WPD	W/m²		105,494	91,476	86.71	79	0	5,880	147
106	WS_west_80m_Avg WPD	W/m²		105,494	85,589	81.13	78	0	5,687	141

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
107	WS_east_60.4m_Avg WPD	W/m²		105,494	92,008	87.22	61	0	4,891	117
108	WS_west_60.4m_Avg WPD	W/m²		105,494	89,834	85.16	55	0	4,319	106
109	WS_east_40.7m_Avg WPD	W/m²		105,494	92,586	87.76	42	0	3,757	86
110	WS_west_40.7m_Avg WPD	W/m²		105,494	88,302	83.70	43	0	3,649	86

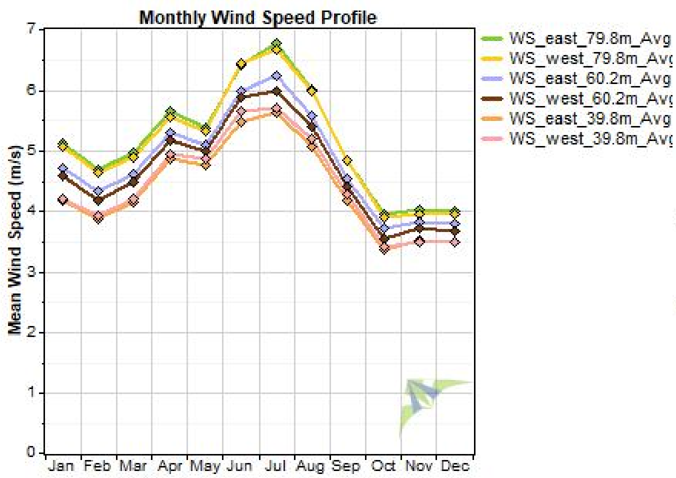
Data Set Properties

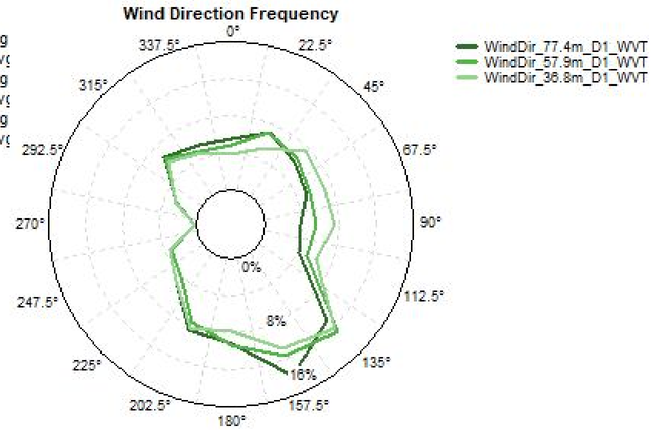
Report Created: 4/11/2018 10:23 using Windographer 3.3.10
Filter Settings: <Unflagged data>

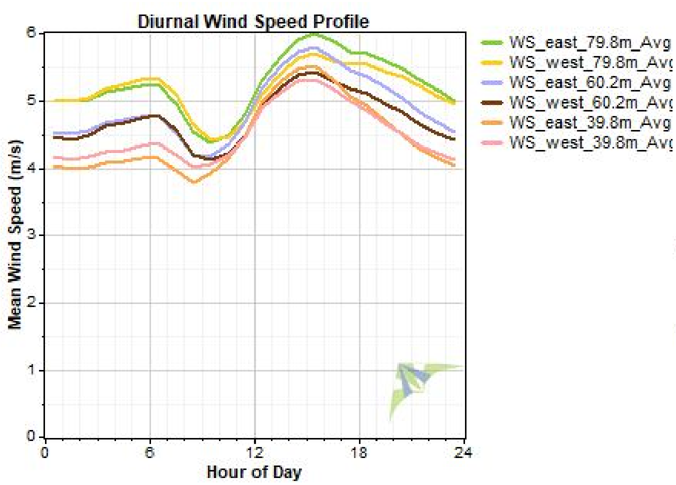
Variable	Value
Latitude	N 22.185130
Longitude	E 91.817670
Elevation	2 m
Start date	12/21/2014 19:50
End date	7/14/2017 08:50
Duration	31 months
Length of time step	10 minutes
Calm threshold	1 m/s
Mean temperature	25.5 °C
Mean pressure	1,000 mbar
Mean air density	1.172 kg/m³
Power density at 50m	100 W/m²
Wind power class	1
Power law exponent	0.223
Surface roughness	0.647 m
Roughness class	3.55

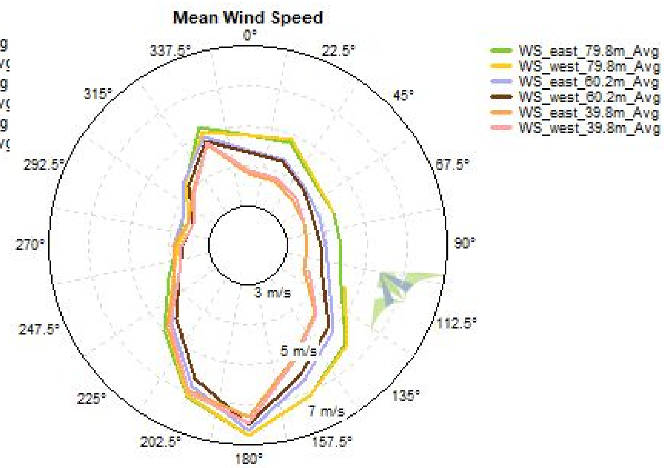


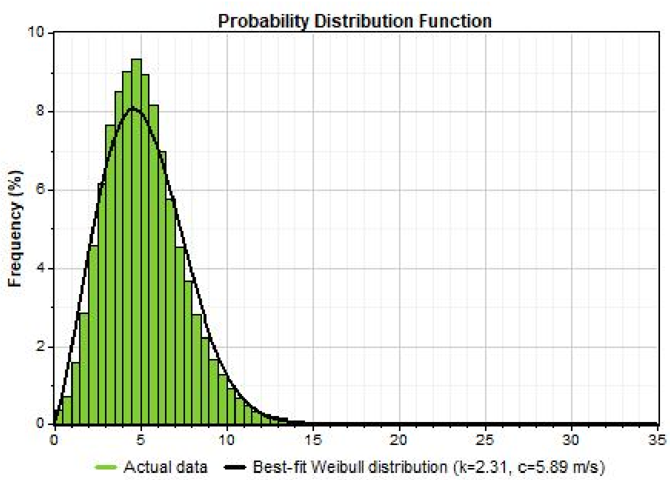
Wind Speed and Direction

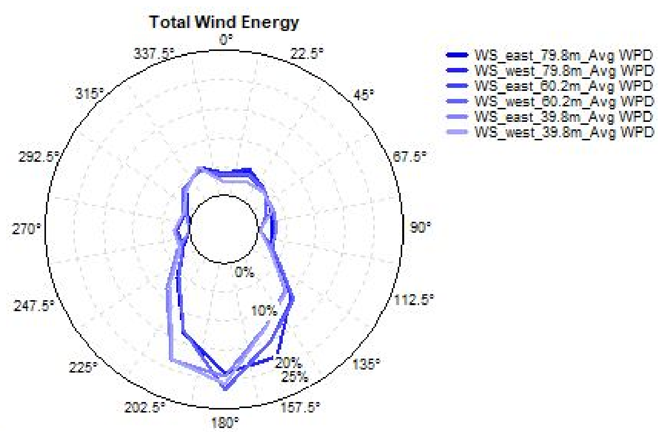




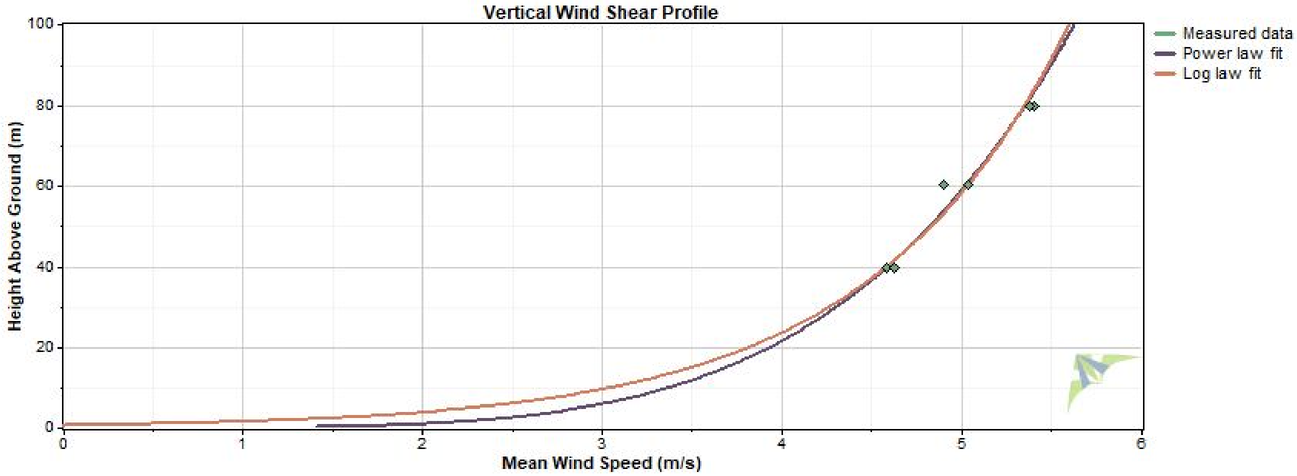


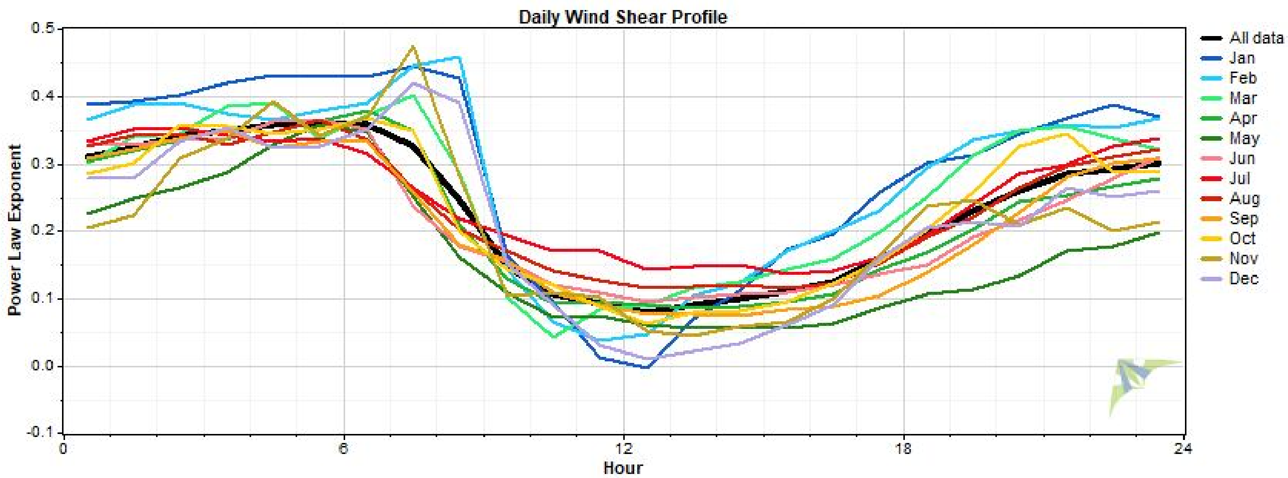


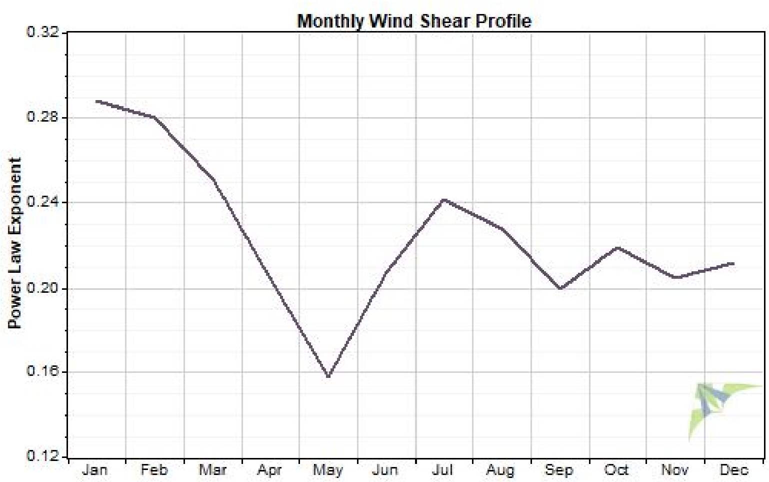


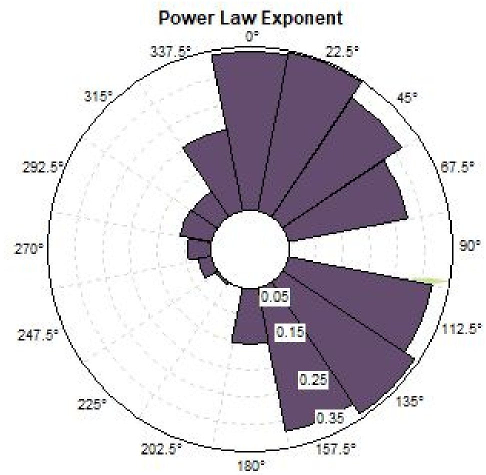


Wind Shear

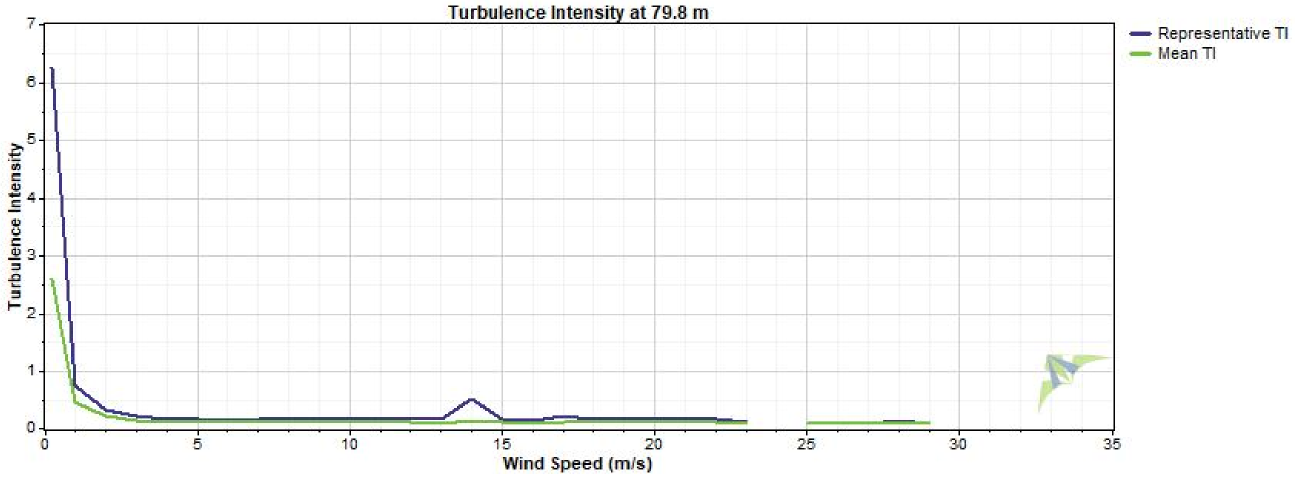

Vertical Wind Shear Profile
Height Above Ground (m)
Mean Wind Speed (m/s)
Measured data
Power law fit
Log law fit

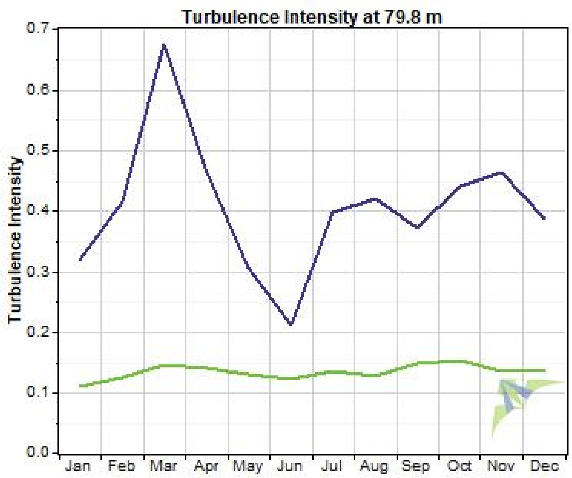

Daily Wind Shear Profile
Power Law Exponent
Hour
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

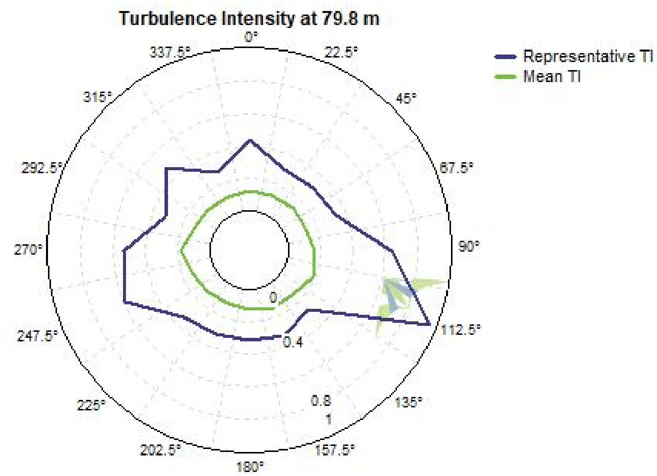

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

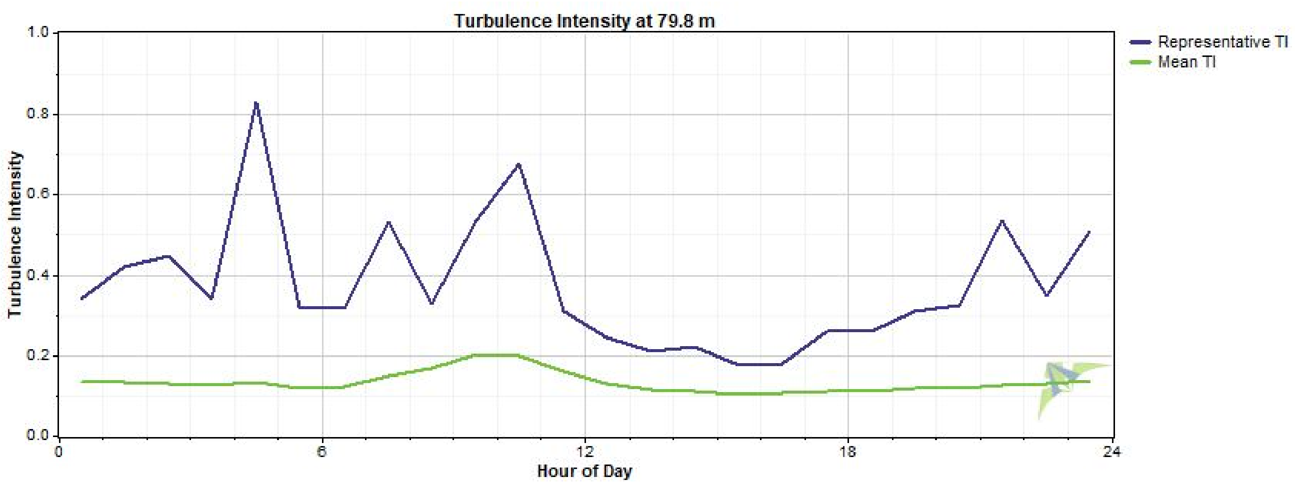

Power Law Exponent
0°
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
202.5°
225°
247.5°
270°
292.5°
315°
337.5°
0.05
0.15
0.25
0.35

Turbulence Intensity









Data Column Properties

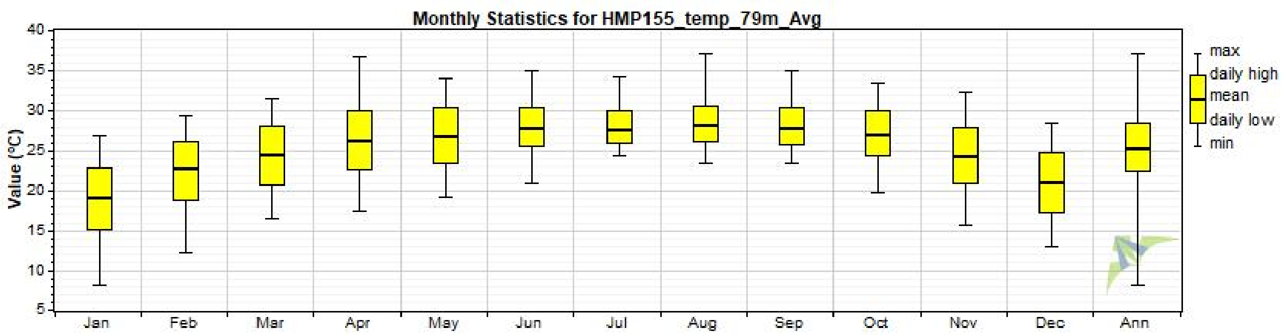
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	RECORD	m/s		134,718	119,944	89.03	33,139	0	73,595	19,618
2	WS_east_79.8m_Avg	m/s	79.8 m	134,718	113,856	84.51	5.218	0.000	31.390	2.362
3	WS_east_79.8m_Max	m/s	79.8 m	134,718	113,856	84.51	6.611	0.000	769.500	3.697
4	WS_east_79.8m_Min	m/s	79.8 m	134,718	113,856	84.51	3.761	0.000	26.430	1.948
5	WS_east_79.8m_Std	m/s	79.8 m	134,718	113,856	84.51	0.577	0.000	54.960	0.343
6	WS_west_79.8m_Avg	m/s	79.8 m	134,718	114,124	84.71	5.167	0.000	31.320	2.374
7	WS_west_79.8m_Max	m/s	79.8 m	134,718	114,124	84.71	6.540	0.000	770.700	3.705
8	WS_west_79.8m_Min	m/s	79.8 m	134,718	114,124	84.71	3.728	0.000	25.690	1.949
9	WS_west_79.8m_Std	m/s	79.8 m	134,718	114,124	84.71	0.572	0.000	55.050	0.341
10	WS_east_60.2m_Avg	m/s	60.2 m	134,718	113,953	84.59	4.872	0.000	30.340	2.204
11	WS_east_60.2m_Max	m/s	60.2 m	134,718	113,953	84.59	6.316	0.000	406.800	3.046
12	WS_east_60.2m_Min	m/s	60.2 m	134,718	113,953	84.59	3.366	0.000	24.170	1.784
13	WS_east_60.2m_Std	m/s	60.2 m	134,718	113,953	84.59	0.595	0.000	28.840	0.325
14	WS_west_60.2m_Avg	m/s	60.2 m	134,718	111,431	82.71	4.745	0.000	29.420	2.235
15	WS_west_60.2m_Max	m/s	60.2 m	134,718	111,431	82.71	6.179	0.000	36.930	2.800
16	WS_west_60.2m_Min	m/s	60.2 m	134,718	111,431	82.71	3.233	0.000	23.200	1.850
17	WS_west_60.2m_Std	m/s	60.2 m	134,718	111,431	82.71	0.594	0.000	6.682	0.315
18	WS_east_39.8m_Avg	m/s	39.8 m	134,718	114,410	84.93	4.434	0.000	28.520	2.029
19	WS_east_39.8m_Max	m/s	39.8 m	134,718	114,410	84.93	5.970	0.000	729.200	3.430
20	WS_east_39.8m_Min	m/s	39.8 m	134,718	114,410	84.93	2.833	0.000	21.850	1.616
21	WS_east_39.8m_Std	m/s	39.8 m	134,718	114,410	84.93	0.623	0.000	52.080	0.366
22	WS_west_39.8m_Avg	m/s	39.8 m	134,718	109,067	80.96	4.522	0.000	29.000	2.088
23	WS_west_39.8m_Max	m/s	39.8 m	134,718	109,067	80.96	6.062	0.000	759.400	3.567
24	WS_west_39.8m_Min	m/s	39.8 m	134,718	109,067	80.96	2.921	0.000	23.370	1.667
25	WS_west_39.8m_Std	m/s	39.8 m	134,718	109,067	80.96	0.623	0.000	54.250	0.375
26	WindDir_77.4m_D1_WVT	°	77.4 m	134,718	119,944	89.03	150.7	0.0	360.0	97.5
27	WindDir_77.4m_SD1_WVT	°	77.4 m	134,718	119,944	89.03	5.2	0.0	78.5	5.0
28	WindDir_57.9m_D1_WVT	°	57.9 m	134,718	119,944	89.03	145.3	0.0	360.0	96.4
29	WindDir_57.9m_SD1_WVT	°	57.9 m	134,718	119,944	89.03	5.9	0.0	80.0	5.2
30	WindDir_36.8m_D1_WVT	°	36.8 m	134,718	119,944	89.03	146.7	0.0	360.0	94.2
31	WindDir_36.8m_SD1_WVT	°	36.8 m	134,718	119,944	89.03	6.9	0.0	79.9	5.6
32	RTD_temp_C_78m_Avg	°C	78 m	134,718	119,944	89.03	26.6	13.6	33.8	3.1
33	RTD_temp_C_78m_Max	°C	78 m	134,718	119,944	89.03	26.9	14.0	35.4	3.1
34	RTD_temp_C_78m_Min	°C	78 m	134,718	119,944	89.03	26.3	13.3	33.5	3.1
35	RTD_temp_C_78m_Std	°C	78 m	134,718	119,944	89.03	0.1	0.0	2.9	0.1
36	RTD_temp_C_4.9m_Avg	°C	4.9 m	134,718	119,944	89.03	25.4	11.1	37.1	4.0
37	RTD_temp_C_4.9m_Max	°C	4.9 m	134,718	119,944	89.03	25.5	11.2	37.2	4.0
38	RTD_temp_C_4.9m_Min	°C	4.9 m	134,718	119,944	89.03	25.2	11.0	36.9	4.0
39	RTD_temp_C_4.9m_Std	°C	4.9 m	134,718	119,944	89.03	0.1	0.0	3.6	0.1
40	HMP155_temp_79m_Avg	°C	79 m	134,718	119,300	88.56	25.5	12.7	32.6	3.1
41	HMP155_temp_79m_Max	°C	79 m	134,718	119,300	88.56	25.6	12.8	32.7	3.1
42	HMP155_temp_79m_Min	°C	79 m	134,718	119,300	88.56	25.4	12.7	32.5	3.1
43	HMP155_temp_79m_Std	°C	79 m	134,718	119,300	88.56	0.1	0.0	3.1	0.1
44	HMP155_RH_79m_Avg	%		134,718	119,944	89.03	80.8	0.4	100.0	16.6
45	HMP155_RH_79m_Max	%		134,718	119,944	89.03	82.2	0.5	100.0	16.0
46	HMP155_RH_79m_Min	%		134,718	119,944	89.03	79.31	0.41	99.90	17.24
47	HMP155_RH_79m_Std	%		134,718	119,944	89.03	0.75	0.01	13.79	0.84
48	HMP155_temp_5.7m_Avg	°C	5.65 m	134,718	118,371	87.87	25.4	11.2	35.8	4.0
49	HMP155_temp_5.7m_Max	°C	5.65 m	134,718	118,371	87.87	25.5	11.3	36.0	4.0
50	HMP155_temp_5.7m_Min	°C	5.65 m	134,718	118,371	87.87	25.2	-79.3	35.6	4.0
51	HMP155_temp_5.7m_Std	°C	5.65 m	134,718	118,371	87.87	0.1	0.0	8.6	0.1
52	HMP155_RH_5.7m_Avg	%		134,718	119,061	88.38	84.0	0.4	100.0	13.0

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	HMP155_RH_5.7m_Max	%		134,718	119,061	88.38	85.3	0.4	100.0	12.3
54	HMP155_RH_5.7m_Min	%		134,718	119,061	88.38	82.82	0.39	99.90	13.73
55	HMP155_RH_5.7m_Std	%		134,718	119,061	88.38	0.61	0.00	49.55	0.88
56	BP_78.6m_Avg	mbar	78.6 m	134,718	119,944	89.03	1,000.4	962.0	1,018.0	5.2
57	BP_78.6m_Max	mbar	78.6 m	134,718	119,944	89.03	1,000.5	971.0	1,019.0	5.2
58	BP_78.6m_Min	mbar	78.6 m	134,718	119,944	89.03	1,000.2	809.0	1,017.0	5.9
59	BP_78.6m_Std	mbar	78.6 m	134,718	119,944	89.03	0.1	0.0	84.6	0.3
60	BP_4.1m_Avg	mbar	4.1 m	134,718	119,944	89.03	1,007.8	978.0	1,020.0	5.3
61	BP_4.1m_Max	mbar	4.1 m	134,718	119,944	89.03	1,007.9	979.0	1,021.0	5.3
62	BP_4.1m_Min	mbar	4.1 m	134,718	119,944	89.03	1,007.7	929.0	1,020.0	5.3
63	BP_4.1m_Std	mbar	4.1 m	134,718	119,944	89.03	0.0	0.0	5.0	0.0
64	LWmV_Avg	Avg		134,718	119,944	89.03	291	119	1,076	141
65	LWmV	Smp		134,718	119,944	89.03	291	118	1,076	141
66	VBatt_Min	Volts		134,718	119,943	89.03	12.71	0.00	14.03	0.56
67	IBatt_Min	Amps		134,718	119,944	89.03	-0.000	-0.491	3.455	0.433
68	ILoad_Min			134,718	119,944	89.03	0.260	0.000	0.383	0.052
69	V_in_chg_Min			134,718	119,944	89.03	8.34	0.00	20.42	8.22
70	I_in_chg_Min			134,718	119,944	89.03	0.234	-0.003	3.503	0.362
71	Chg_TmpC_Avg	°C	2 m	134,718	119,944	89.03	29.5	0.3	64.0	6.4
72	Chg_State	Smp		134,718	119,944	89.03	1.074	0.000	3.000	1.319
73	Ck_Batt	Smp		134,718	119,944	89.03	0.002	0.000	1.000	0.043
74	BattV_Min	Volts		134,718	119,944	89.03	12.33	9.23	13.63	0.54
75	PTemp_C_Avg	°C	2 m	134,718	119,944	89.03	27.3	10.7	38.4	4.9
76	latitude_a	Smp		134,718	119,944	89.03	22	22	22	0
77	latitude_b	Smp		134,718	119,944	89.03	11.11	11.10	11.12	0.00
78	longitude_a	Smp		134,718	119,944	89.03	91	91	91	0
79	longitude_b	Smp		134,718	119,944	89.03	49.06	49.05	49.07	0.00
80	magnetic_variation	Smp		134,718	119,944	89.03	-0.7	-0.7	-0.7	0.0
81	fix_quality	Smp		134,718	119,944	89.03	2.000	1.000	2.000	0.006
82	nmbr_satellites	Smp		134,718	119,944	89.03	9.12	5.00	12.00	0.88
83	altitude	Smp		134,718	119,944	89.03	12.38	-61.80	35.80	6.16
84	max_clock_change			134,718	119,944	89.03	2,782	-4,210	7,999	4,027
85	nmbr_clock_change	Smp		134,718	119,944	89.03	1.88	0.00	41.00	4.59
86	Air Density	kg/m³		134,718	134,718	100.00	1.172	1.122	1.230	0.022
87	WS_east_79.8m_Avg TI			134,718	113,797	84.47	0.13	0.02	20.50	0.22
88	WS_west_79.8m_Avg TI			134,718	114,029	84.64	0.14	0.02	20.00	0.22
89	WS_east_60.2m_Avg TI			134,718	113,839	84.50	0.15	0.03	20.00	0.25
90	WS_west_60.2m_Avg TI			134,718	110,850	82.28	0.18	0.02	22.50	0.47
91	WS_east_39.8m_Avg TI			134,718	114,318	84.86	0.16	0.04	20.50	0.23
92	WS_west_39.8m_Avg TI			134,718	108,950	80.87	0.16	0.04	20.50	0.22
93	WS_east_79.8m_Avg WPD	W/m²		134,718	113,856	84.51	142	0	17,598	295
94	WS_west_79.8m_Avg WPD	W/m²		134,718	114,124	84.71	139	0	17,447	305
95	WS_east_60.2m_Avg WPD	W/m²		134,718	113,953	84.59	116	0	15,860	258
96	WS_west_60.2m_Avg WPD	W/m²		134,718	111,431	82.71	111	0	14,461	259
97	WS_east_39.8m_Avg WPD	W/m²		134,718	114,410	84.93	90	0	13,174	218
98	WS_west_39.8m_Avg WPD	W/m²		134,718	109,067	80.96	96	0	13,850	240

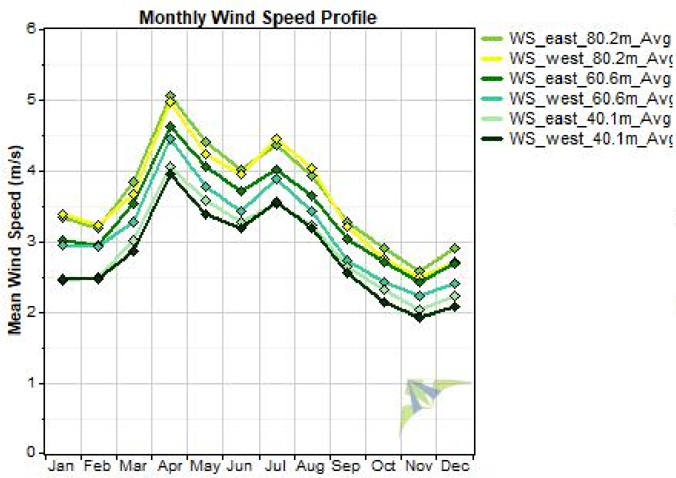
Data Set Properties

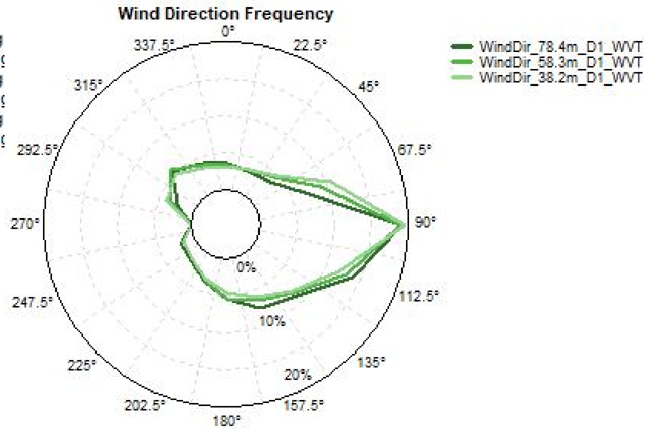
Report Created: 4/11/2018 10:21 using Windographer 3.3.10
Filter Settings: <Unflagged data>

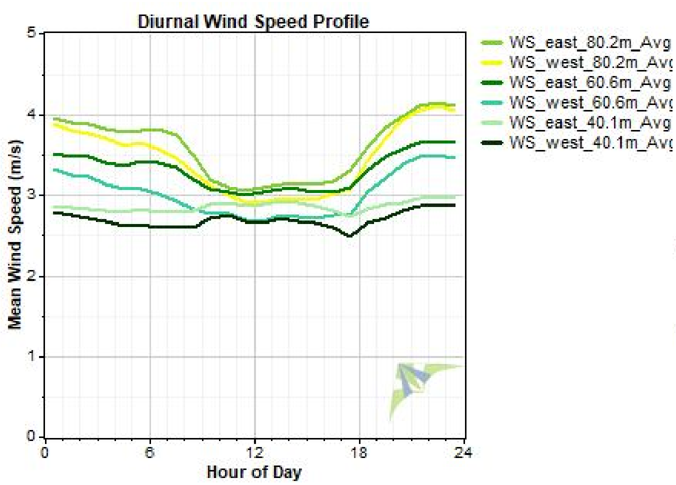
Variable	Value
Latitude	N 24.715460
Longitude	E 90.466800
Elevation	0 m
Start date	8/13/2015 14:50
End date	12/13/2017 00:10
Duration	28 months
Length of time step	10 minutes
Calm threshold	1 m/s
Mean temperature	25.4 °C
Mean pressure	999.6 mbar
Mean air density	1.168 kg/m³
Power density at 50m	33 W/m²
Wind power class	1
Power law exponent	0.34
Surface roughness	2.96 m
Roughness class	4.81

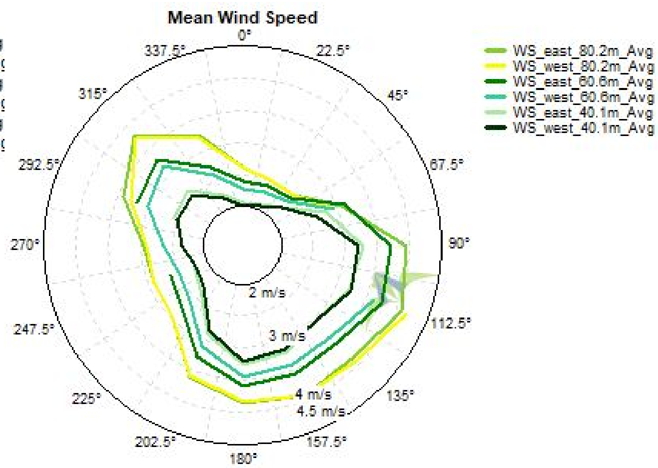


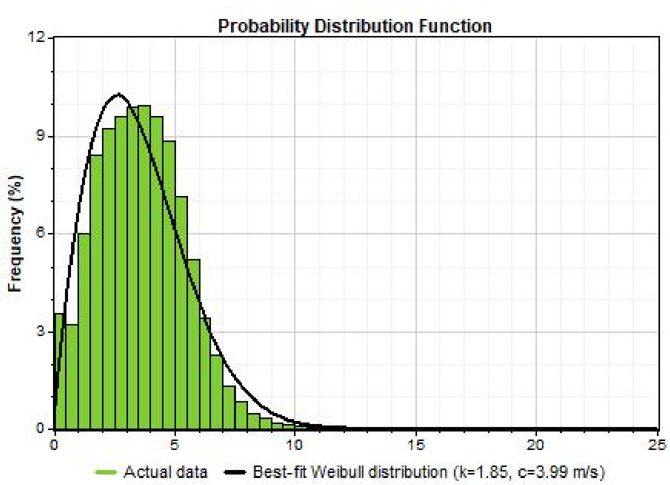
Wind Speed and Direction

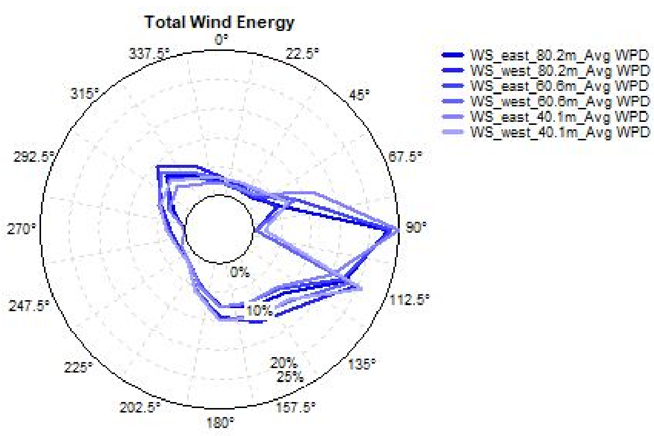




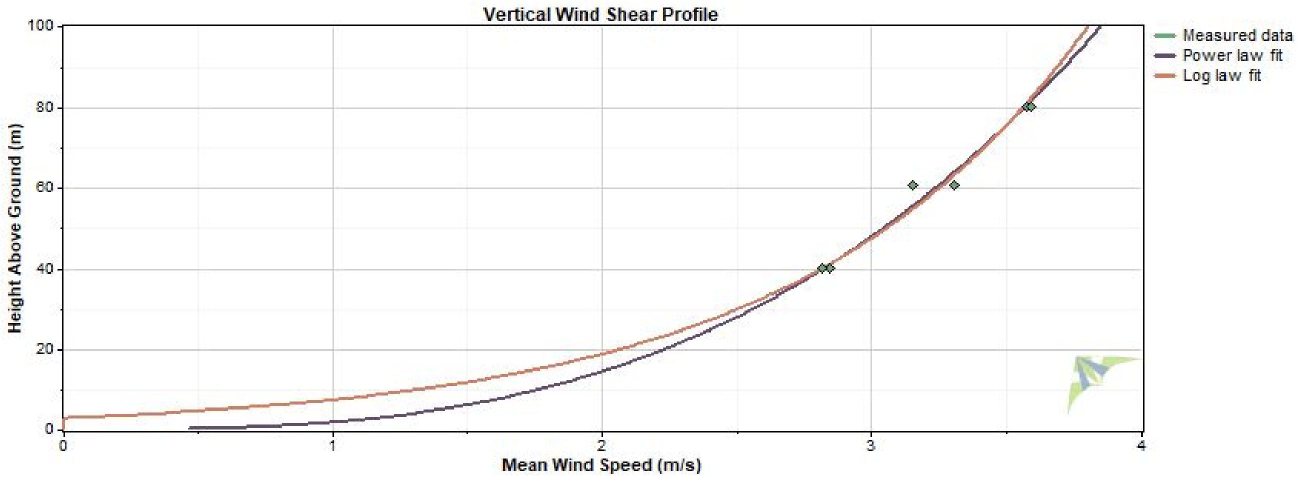


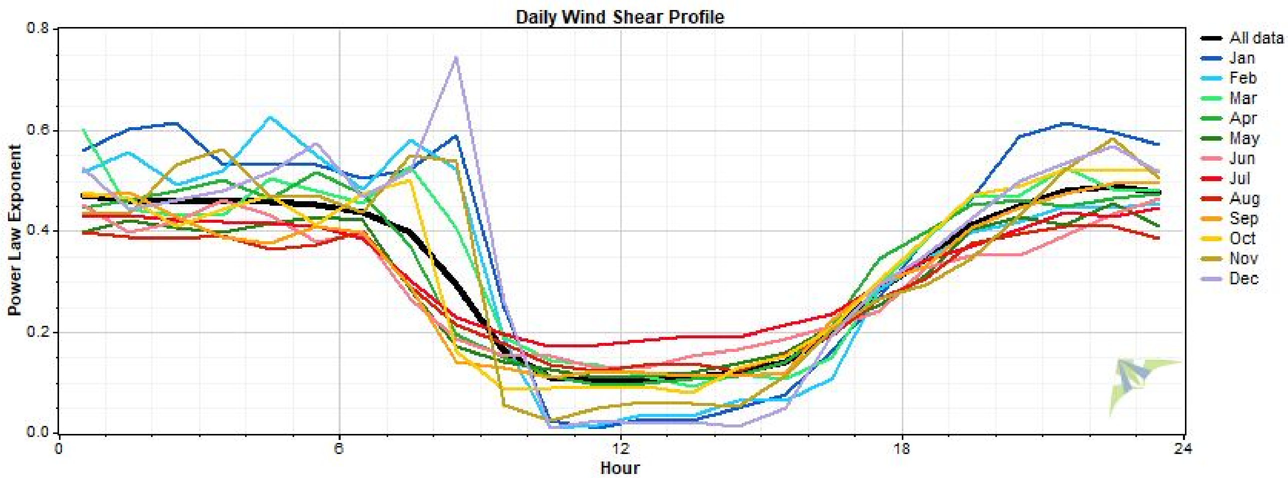


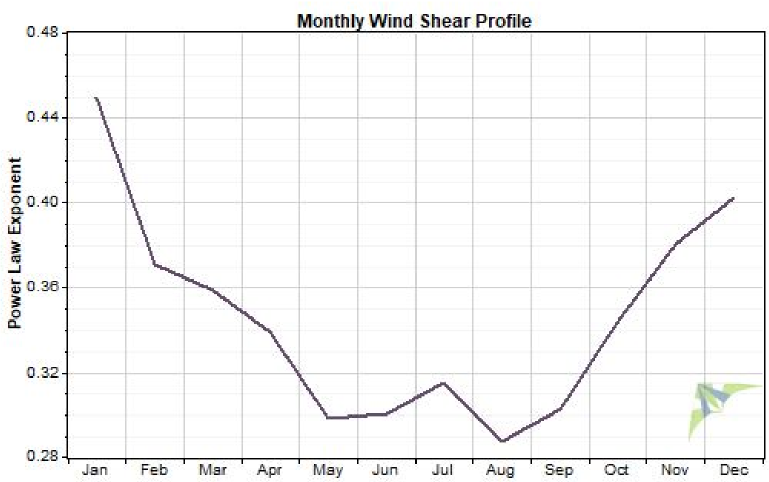


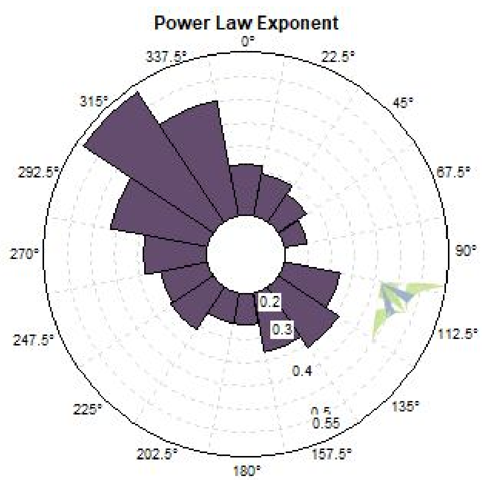


Wind Shear

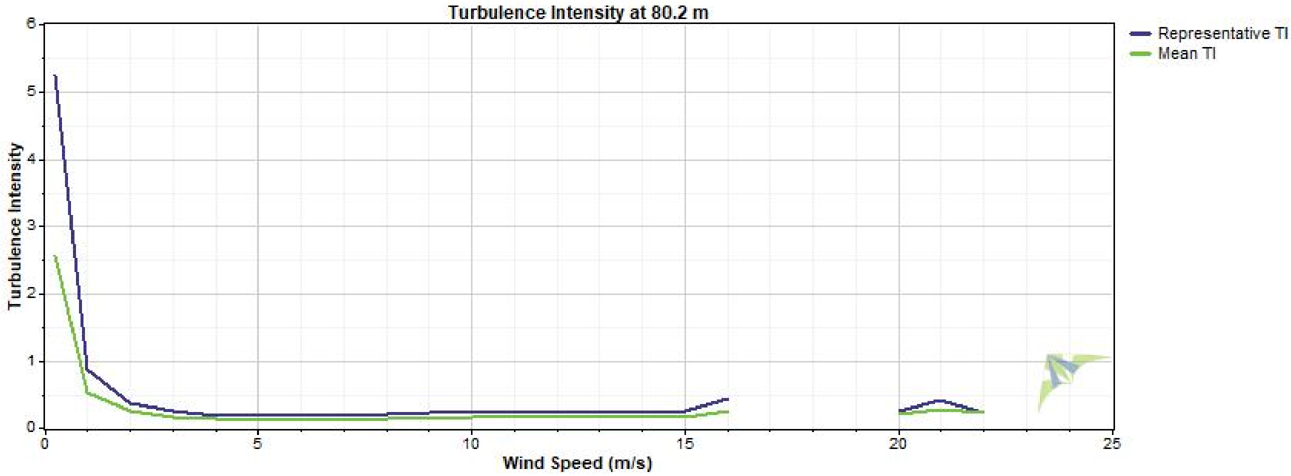

Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
Mean Wind Speed (m/s)

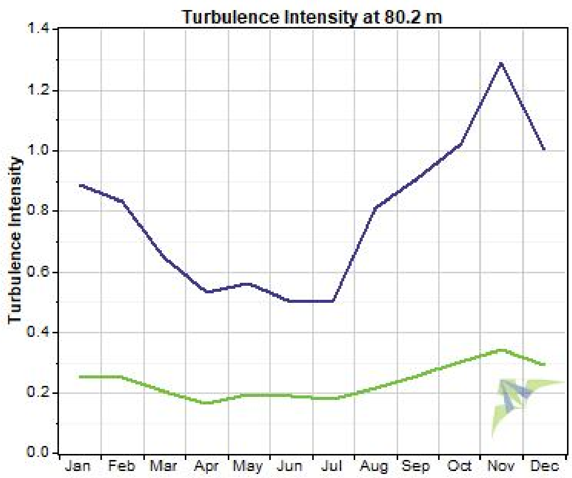

Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
Hour

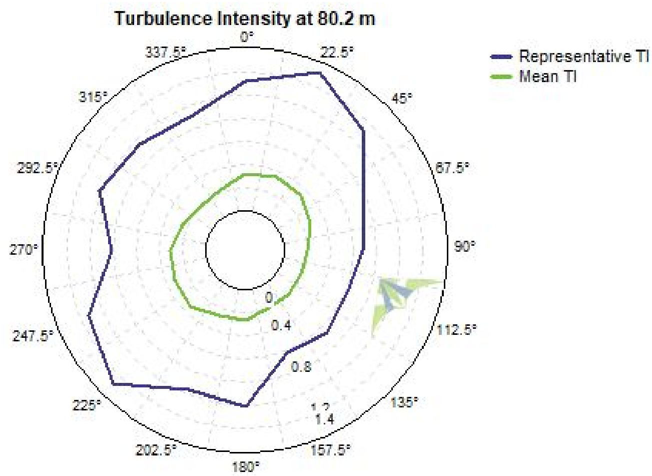

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

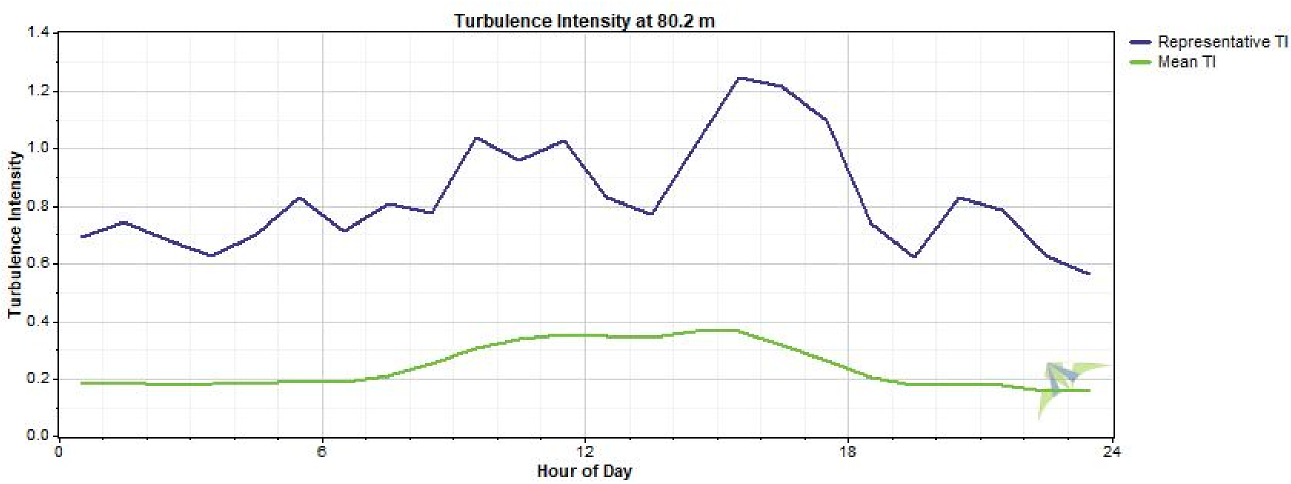

Power Law Exponent

Turbulence Intensity









Data Column Properties

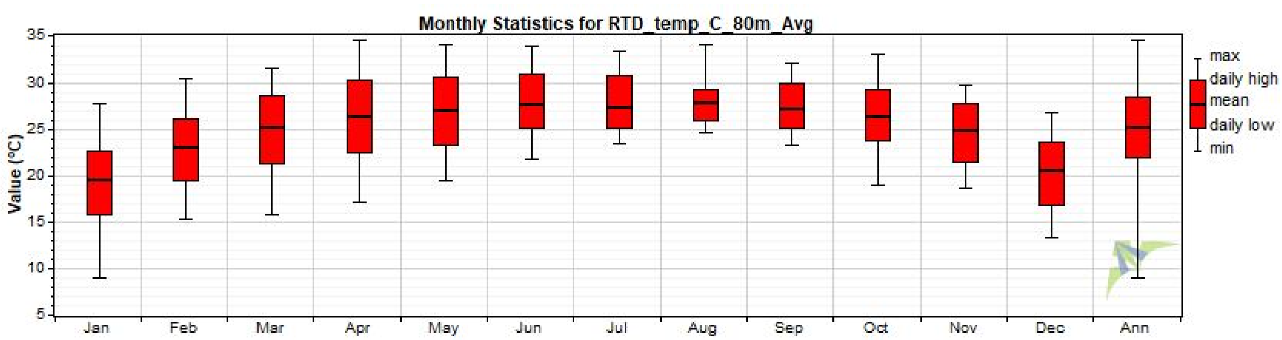
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	RECORD			122,744	119,620	97.45	44,699	0	104,116	31,551
2	WS_east_80.2m_Avg	m/s	80.2 m	122,744	112,865	91.95	3.591	0.000	22.420	1.879
3	WS_east_80.2m_Max	m/s	80.2 m	122,744	112,865	91.95	4.885	0.000	38.730	2.362
4	WS_east_80.2m_Min	m/s	80.2 m	122,744	112,865	91.95	2.302	0.000	13.320	1.574
5	WS_east_80.2m_Std	m/s	80.2 m	122,744	112,865	91.95	0.548	0.000	8.780	0.278
6	WS_west_80.2m_Avg	m/s	80.2 m	122,744	91,254	74.34	3.461	0.000	22.330	1.880
7	WS_west_80.2m_Max	m/s	80.2 m	122,744	91,254	74.34	4.722	0.000	40.300	2.367
8	WS_west_80.2m_Min	m/s	80.2 m	122,744	91,254	74.34	2.226	0.000	13.320	1.579
9	WS_west_80.2m_Std	m/s	80.2 m	122,744	91,254	74.34	0.535	0.000	8.560	0.279
10	WS_east_60.6m_Avg	m/s	60.6 m	122,744	114,523	93.30	3.305	0.000	20.940	1.652
11	WS_east_60.6m_Max	m/s	60.6 m	122,744	114,523	93.30	4.615	0.000	34.850	2.190
12	WS_east_60.6m_Min	m/s	60.6 m	122,744	114,523	93.30	2.020	0.000	11.780	1.328
13	WS_east_60.6m_Std	m/s	60.6 m	122,744	114,523	93.30	0.550	0.000	8.280	0.269
14	WS_west_60.6m_Avg	m/s	60.6 m	122,744	91,141	74.25	3.025	0.000	20.570	1.707
15	WS_west_60.6m_Max	m/s	60.6 m	122,744	91,141	74.25	4.331	0.000	33.990	2.215
16	WS_west_60.6m_Min	m/s	60.6 m	122,744	91,141	74.25	1.755	0.000	12.570	1.391
17	WS_west_60.6m_Std	m/s	60.6 m	122,744	91,141	74.25	0.554	0.000	8.170	0.288
18	WS_east_40.1m_Avg	m/s	40.1 m	122,744	113,520	92.49	2.855	0.000	18.950	1.457
19	WS_east_40.1m_Max	m/s	40.1 m	122,744	113,520	92.49	4.204	0.000	34.140	2.086
20	WS_east_40.1m_Min	m/s	40.1 m	122,744	113,520	92.49	1.570	0.000	9.470	1.080
21	WS_east_40.1m_Std	m/s	40.1 m	122,744	113,520	92.49	0.557	0.000	7.923	0.266
22	WS_west_40.1m_Avg	m/s	40.1 m	122,744	91,969	74.93	2.693	0.000	18.640	1.450
23	WS_west_40.1m_Max	m/s	40.1 m	122,744	91,969	74.93	4.003	0.000	34.790	2.070
24	WS_west_40.1m_Min	m/s	40.1 m	122,744	91,969	74.93	1.453	0.000	9.450	1.076
25	WS_west_40.1m_Std	m/s	40.1 m	122,744	91,969	74.93	0.548	0.000	7.666	0.274
26	WindDir_78.4m_D1_WVT	°	78.4 m	122,744	119,618	97.45	107.6	0.0	360.0	93.6
27	WindDir_78.4m_SD1_WVT	°	78.4 m	122,744	119,620	97.45	7.3	0.0	79.4	7.8
28	WindDir_58.3m_D1_WVT	°	58.3 m	122,744	119,618	97.45	102.6	0.0	360.0	94.7
29	WindDir_58.3m_SD1_WVT	°	58.3 m	122,744	119,620	97.45	8.4	0.0	79.8	8.3
30	WindDir_38.2m_D1_WVT	°	38.2 m	122,744	119,618	97.45	99.9	0.0	360.0	95.0
31	WindDir_38.2m_SD1_WVT	°	38.2 m	122,744	119,620	97.45	9.5	0.0	80.2	8.7
32	RTD_temp_C_78.3m_Avg	°C	78.3 m	122,744	119,599	97.44	25.4	7.8	37.0	3.7
33	RTD_temp_C_78.3m_Max	°C	78.3 m	122,744	119,599	97.44	25.7	7.9	37.1	3.7
34	RTD_temp_C_78.3m_Min	°C	78.3 m	122,744	119,599	97.44	25.1	7.7	36.7	3.8
35	RTD_temp_C_78.3m_Std	°C	78.3 m	122,744	119,599	97.44	0.1	0.0	3.1	0.1
36	RTD_temp_C_3.7m_Avg	°C	3.72 m	122,744	119,514	97.37	24.6	8.0	37.0	5.0
37	RTD_temp_C_3.7m_Max	°C	3.72 m	122,744	119,514	97.37	24.7	8.1	37.2	5.0
38	RTD_temp_C_3.7m_Min	°C	3.72 m	122,744	119,514	97.37	24.4	8.0	36.8	5.0
39	RTD_temp_C_3.7m_Std	°C	3.72 m	122,744	119,514	97.37	0.1	0.0	2.3	0.1
40	HMP155_temp_79m_Avg	°C	79 m	122,744	119,480	97.34	25.4	8.0	37.1	3.8
41	HMP155_temp_79m_Max	°C	79 m	122,744	119,480	97.34	25.5	8.1	37.5	3.8
42	HMP155_temp_79m_Min	°C	79 m	122,744	119,480	97.34	25.2	7.9	36.6	3.8
43	HMP155_temp_79m_Std	°C	79 m	122,744	119,480	97.34	0.1	0.0	2.5	0.1
44	HMP155_RH_79m_Avg	%		122,744	119,619	97.45	78.6	14.4	100.0	16.1
45	HMP155_RH_79m_Max	%		122,744	119,619	97.45	79.9	16.4	100.0	15.7
46	HMP155_RH_79m_Min	%		122,744	119,619	97.45	77.46	-0.03	99.90	16.47
47	HMP155_RH_79m_Std	%		122,744	119,619	97.45	0.64	0.01	18.70	0.70
48	HMP155_temp_4.5m_Avg	°C	4.49 m	122,744	119,361	97.24	24.6	7.8	37.2	5.0
49	HMP155_temp_4.5m_Max	°C	4.49 m	122,744	119,361	97.24	24.7	7.9	37.2	5.1
50	HMP155_temp_4.5m_Min	°C	4.49 m	122,744	119,361	97.24	24.4	7.8	37.1	5.0
51	HMP155_temp_4.5m_Std	°C	4.49 m	122,744	119,361	97.24	0.1	0.0	2.1	0.1
52	HMP155_RH_4.5m_Avg	%		122,744	119,226	97.13	86.9	-22.7	100.0	13.9

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	HMP155_RH_4.5m_Max	%		122,744	119,226	97.13	88.3	-20.6	100.0	12.7
54	HMP155_RH_4.5m_Min	%		122,744	119,226	97.13	85.77	-23.44	99.90	14.88
55	HMP155_RH_4.5m_Std	%		122,744	119,226	97.13	0.60	0.01	33.71	0.72
56	BP_78.7m_Avg	mbar	78.7 m	122,744	119,605	97.44	999.6	982.0	1,025.0	5.3
57	BP_78.7m_Max	mbar	78.7 m	122,744	119,605	97.44	999.8	983.0	1,026.0	5.3
58	BP_78.7m_Min	mbar	78.7 m	122,744	119,605	97.44	999.4	814.0	1,025.0	5.5
59	BP_78.7m_Std	mbar	78.7 m	122,744	119,605	97.44	0.1	0.0	11.3	0.1
60	BP_4.7m_Avg	mbar	4.69 m	122,744	119,620	97.45	1,007.2	992.0	1,021.0	5.4
61	BP_4.7m_Max	mbar	4.69 m	122,744	119,620	97.45	1,007.3	992.0	1,021.0	5.4
62	BP_4.7m_Min	mbar	4.69 m	122,744	119,620	97.45	1,007.1	958.0	1,020.0	5.4
63	BP_4.7m_Std	mbar	4.69 m	122,744	119,620	97.45	0.1	0.0	5.0	0.0
64	LWmV_Avg	Avg		122,744	119,620	97.45	326.1	167.8	968.0	88.4
65	LWmV	Smp		122,744	119,620	97.45	326.1	167.4	959.0	89.1
66	VBatt_Min	Volts		122,744	119,620	97.45	12.41	0.00	13.75	0.89
67	IBatt_Min	Amps		122,744	119,620	97.45	0.045	-0.430	3.389	0.501
68	ILoad_Min			122,744	119,620	97.45	0.283	0.000	0.350	0.019
69	V_in_chg_Min			122,744	119,620	97.45	8.34	0.00	20.44	8.21
70	I_in_chg_Min			122,744	119,620	97.45	0.285	-0.004	3.163	0.411
71	Chg_TmpC_Avg	°C	2 m	122,744	119,620	97.45	30.0	9.2	64.4	8.4
72	Chg_State	Smp		122,744	119,620	97.45	1.095	0.000	3.000	1.296
73	Ck_Batt	Smp		122,744	119,620	97.45	0.017	0.000	1.000	0.130
74	BattV_Min	Volts		122,744	119,618	97.45	12.01	9.24	13.39	0.92
75	PTemp_C_Avg	°C	2 m	122,744	119,618	97.45	27.2	8.8	47.1	6.5
76	latitude_a	Smp		122,744	119,620	97.45	24	24	24	0
77	latitude_b	Smp		122,744	119,620	97.45	42.92	42.92	42.93	0.00
78	longitude_a	Smp		122,744	119,620	97.45	90	90	90	0
79	longitude_b	Smp		122,744	119,620	97.45	28.01	28.00	28.02	0.00
80	magnetic_variation	Smp		122,744	119,620	97.45	-0.4	-0.4	-0.4	0.0
81	fix_quality	Smp		122,744	119,620	97.45	2	1	2	0
82	nmbr_satellites	Smp		122,744	119,620	97.45	9.13	5.00	12.00	0.89
83	altitude	Smp		122,744	119,620	97.45	8.42	-33.80	45.70	6.11
84	max_clock_change			122,744	119,620	97.45	221	-1,000	7,999	1,969
85	nmbr_clock_change	Smp		122,744	119,620	97.45	1.346	0.000	7.000	2.009
86	Air Density	kg/m³		122,744	122,744	100.00	1.168	1.113	1.250	0.021
87	WS_east_80.2m_Avg TI			122,744	111,111	90.52	0.24	0.03	20.50	0.48
88	WS_west_80.2m_Avg TI			122,744	90,198	73.48	0.24	0.03	20.00	0.46
89	WS_east_60.6m_Avg TI			122,744	113,916	92.81	0.24	0.03	20.50	0.44
90	WS_west_60.6m_Avg TI			122,744	89,147	72.63	0.34	0.03	22.50	0.77
91	WS_east_40.1m_Avg TI			122,744	112,690	91.81	0.28	0.04	20.00	0.47
92	WS_west_40.1m_Avg TI			122,744	90,947	74.09	0.31	0.04	20.50	0.58
93	WS_east_80.2m_Avg WPD	W/m²		122,744	112,865	91.95	52	0	6,597	102
94	WS_west_80.2m_Avg WPD	W/m²		122,744	91,254	74.34	48	0	6,518	100
95	WS_east_60.6m_Avg WPD	W/m²		122,744	114,523	93.30	39	0	5,375	80
96	WS_west_60.6m_Avg WPD	W/m²		122,744	91,141	74.25	34	0	5,095	76
97	WS_east_40.1m_Avg WPD	W/m²		122,744	113,520	92.49	26	0	3,984	60
98	WS_west_40.1m_Avg WPD	W/m²		122,744	91,969	74.93	23	0	3,791	57

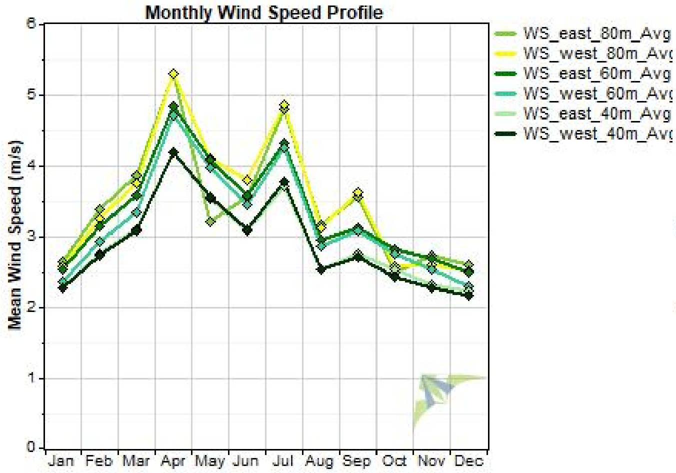
Data Set Properties

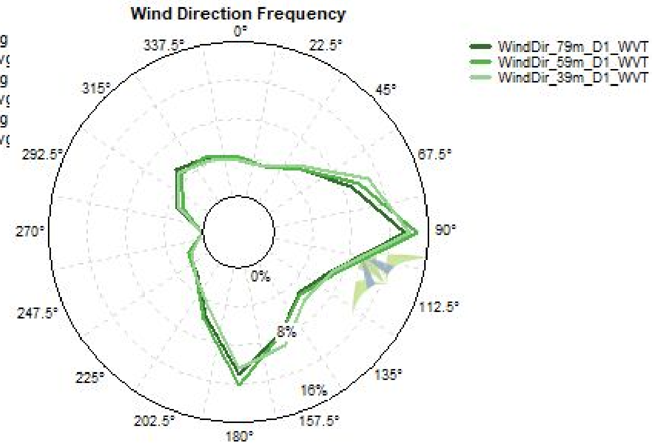
Report Created: 4/11/2018 10:14 using Windographer 3.3.10
Filter Settings: <Unflagged data>

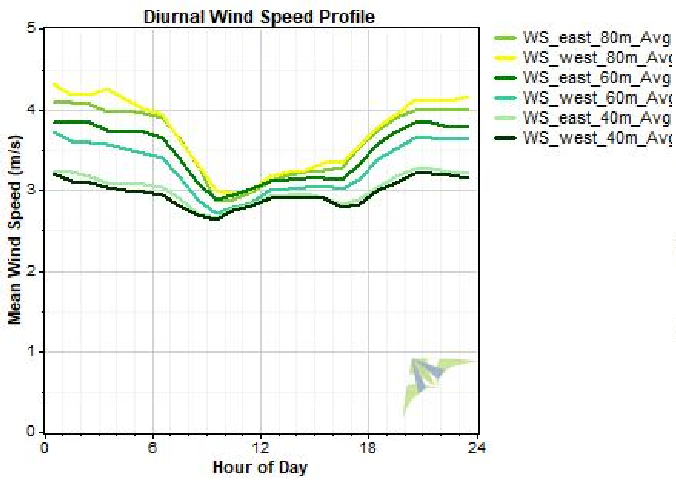
Variable	Value
Latitude	N 24.377780
Longitude	E 91.574620
Elevation	35 m
Start date	10/19/2015 16:50
End date	11/22/2017 10:10
Duration	25 months
Length of time step	10 minutes
Calm threshold	1 m/s
Mean temperature	25.3 °C
Mean pressure	997.4 mbar
Mean air density	1.175 kg/m³
Power density at 50m	35 W/m²
Wind power class	1
Power law exponent	0.288
Surface roughness	1.72 m
Roughness class	4.36

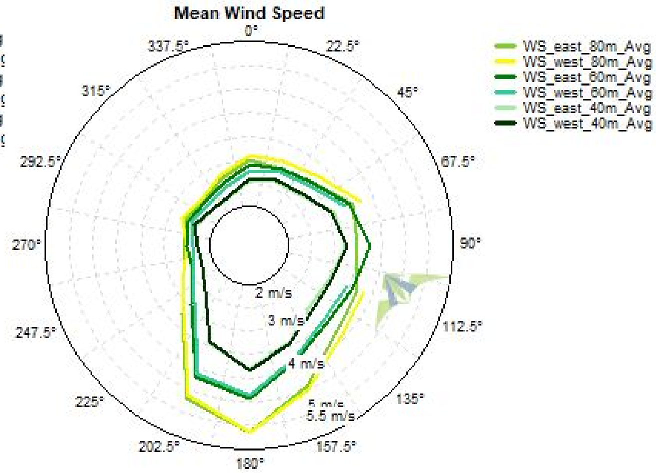


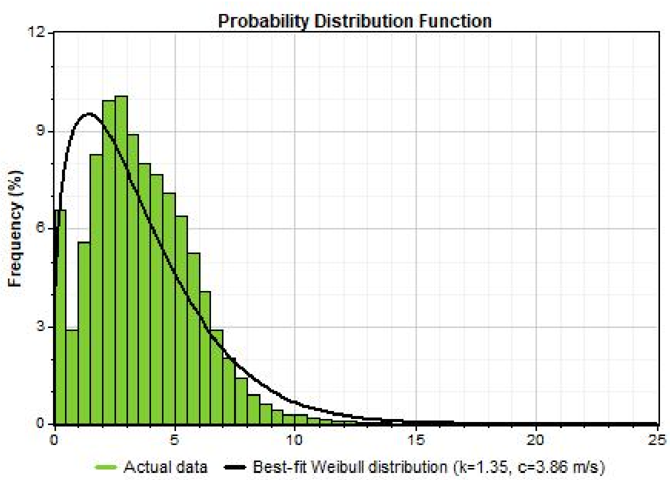
Wind Speed and Direction

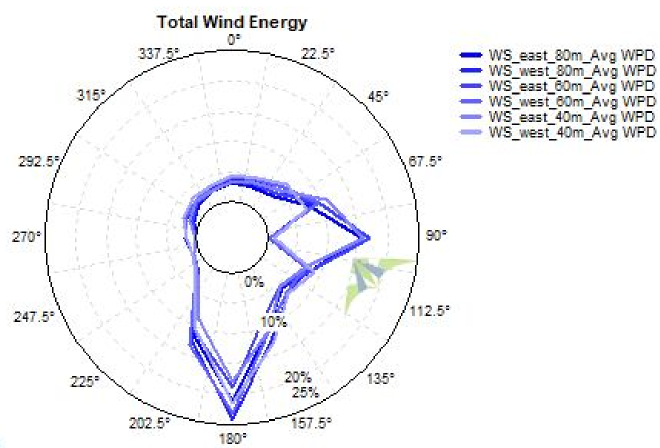




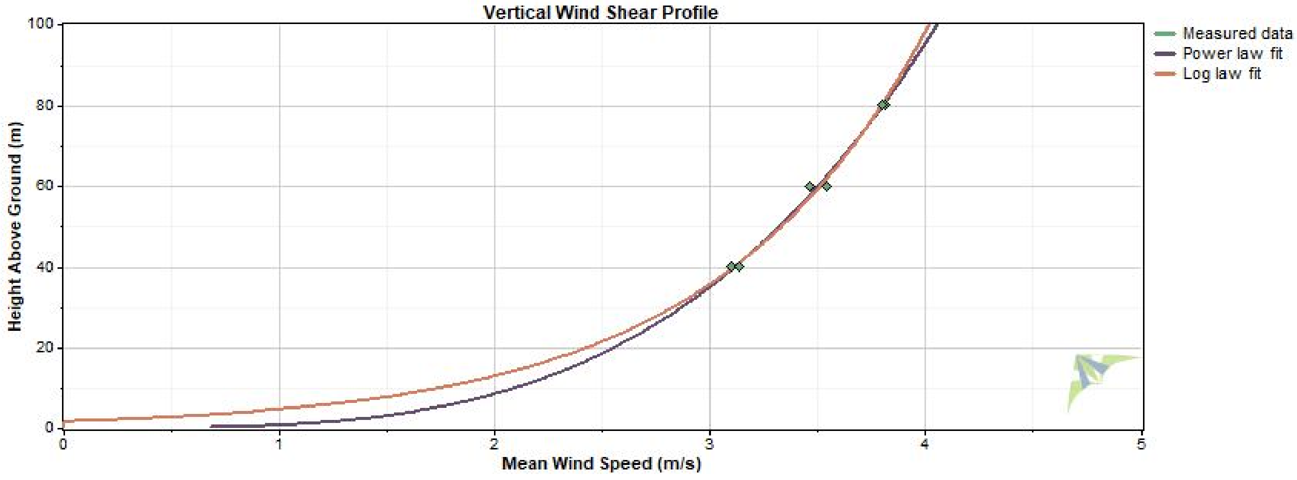


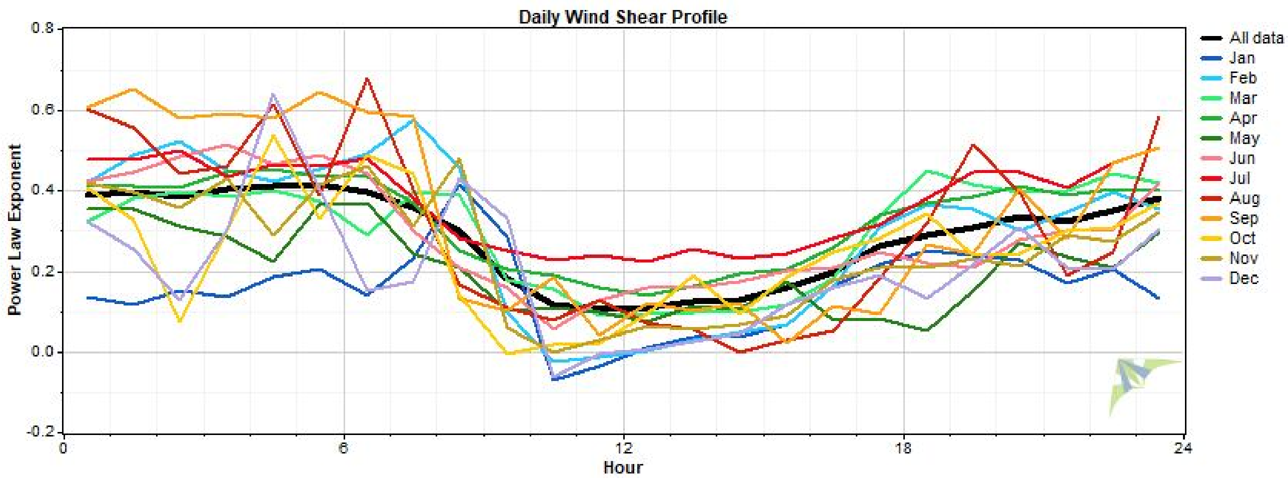


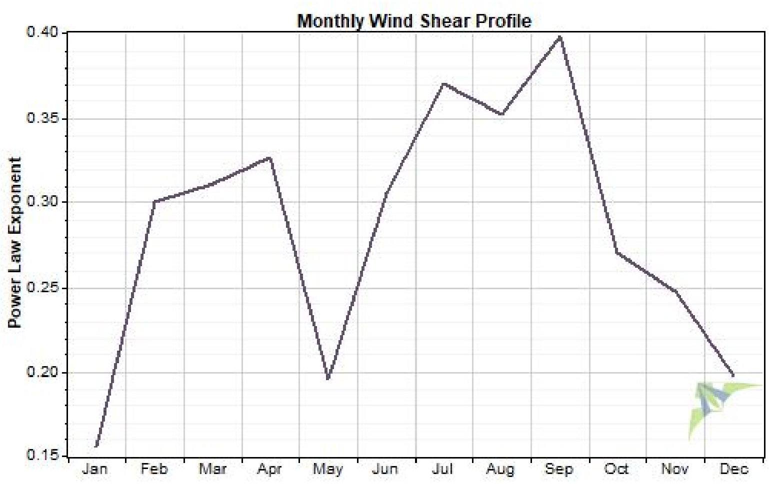


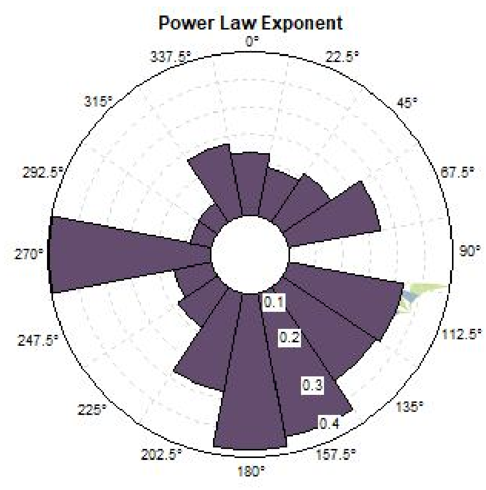


Wind Shear

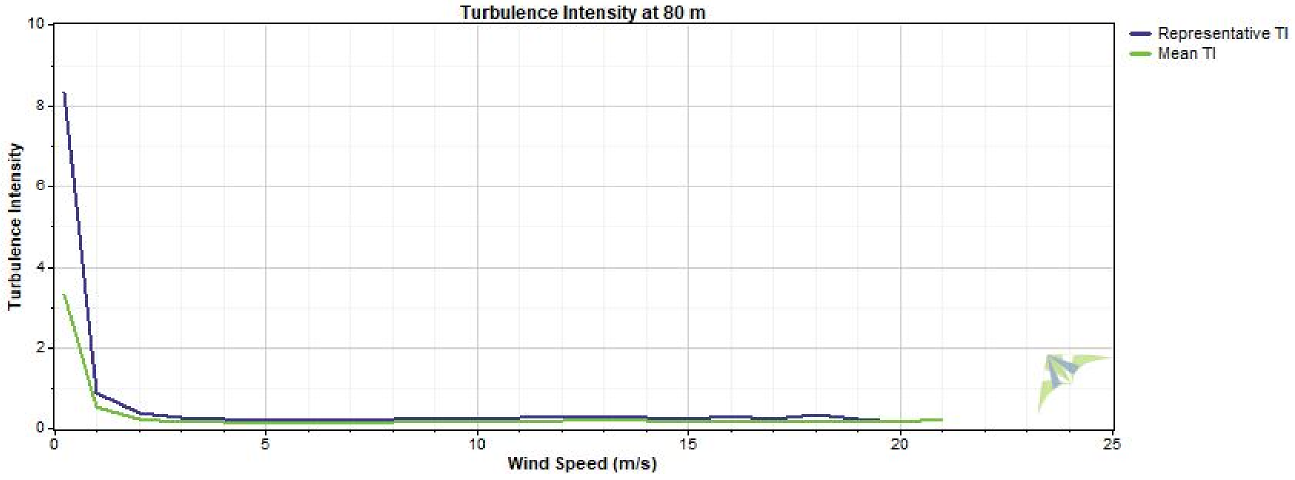

Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
Mean Wind Speed (m/s)

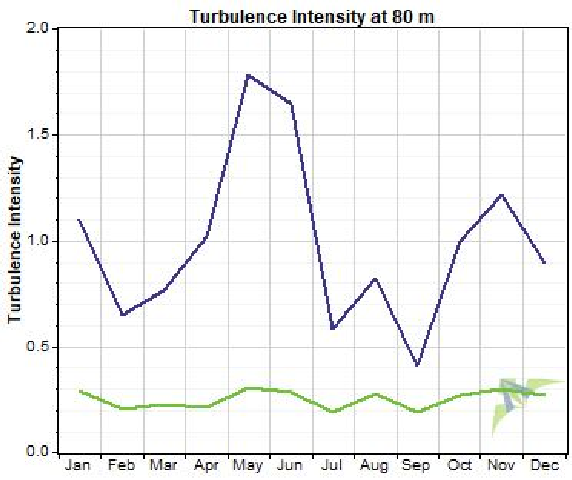

Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
Hour

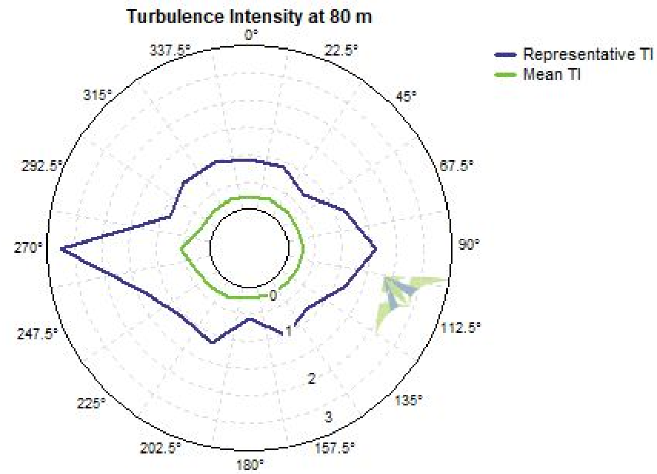

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

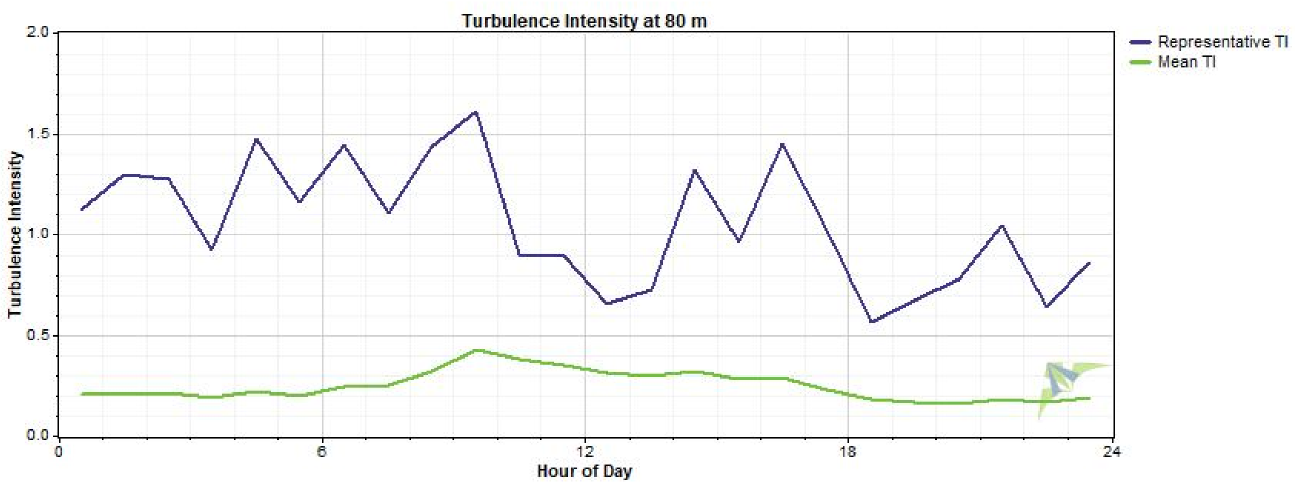

Power Law Exponent

Turbulence Intensity









Data Column Properties

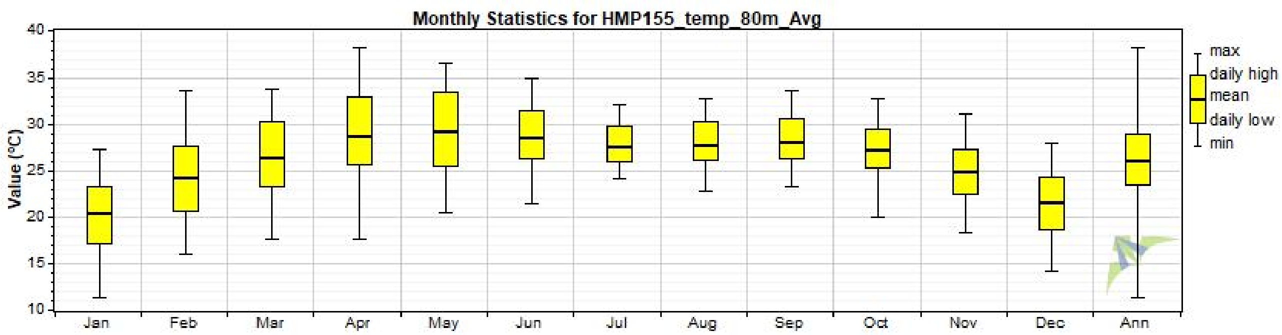
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	RECORD	%		110,120	69,819	63.40	17,410	0	44,208	12,698
2	WS_east_80m_Avg	m/s	80 m	110,120	51,649	46.90	3.630	0.000	20.810	2.182
3	WS_east_80m_Max	m/s	80 m	110,120	51,649	46.90	4.991	0.000	34.000	2.891
4	WS_east_80m_Min	m/s	80 m	110,120	51,649	46.90	2.268	0.000	14.030	1.713
5	WS_east_80m_Std	m/s	80 m	110,120	51,649	46.90	0.572	0.000	7.954	0.377
6	WS_west_80m_Avg	m/s	80 m	110,120	45,830	41.62	3.700	0.000	20.980	2.186
7	WS_west_80m_Max	m/s	80 m	110,120	45,830	41.62	5.221	0.000	34.840	2.905
8	WS_west_80m_Min	m/s	80 m	110,120	45,830	41.62	2.143	0.000	12.550	1.716
9	WS_west_80m_Std	m/s	80 m	110,120	45,830	41.62	0.652	0.000	8.120	0.417
10	WS_east_60m_Avg	m/s	60 m	110,120	65,759	59.72	3.471	0.000	19.670	1.824
11	WS_east_60m_Max	m/s	60 m	110,120	65,759	59.72	4.920	0.000	34.020	2.535
12	WS_east_60m_Min	m/s	60 m	110,120	65,759	59.72	2.032	0.000	11.750	1.420
13	WS_east_60m_Std	m/s	60 m	110,120	65,759	59.72	0.604	0.000	7.544	0.352
14	WS_west_60m_Avg	m/s	60 m	110,120	57,070	51.83	3.289	0.000	19.360	1.850
15	WS_west_60m_Max	m/s	60 m	110,120	57,070	51.83	4.758	0.000	34.430	2.561
16	WS_west_60m_Min	m/s	60 m	110,120	57,070	51.83	1.844	0.000	10.960	1.435
17	WS_west_60m_Std	m/s	60 m	110,120	57,070	51.83	0.612	0.000	7.416	0.362
18	WS_east_40m_Avg	m/s	40 m	110,120	67,320	61.13	3.015	0.000	17.230	1.524
19	WS_east_40m_Max	m/s	40 m	110,120	67,320	61.13	4.526	0.000	33.290	2.333
20	WS_east_40m_Min	m/s	40 m	110,120	67,320	61.13	1.555	0.000	9.450	1.098
21	WS_east_40m_Std	m/s	40 m	110,120	67,320	61.13	0.617	0.000	7.676	0.344
22	WS_west_40m_Avg	m/s	40 m	110,120	54,879	49.84	2.968	0.000	17.130	1.549
23	WS_west_40m_Max	m/s	40 m	110,120	54,879	49.84	4.483	0.000	34.730	2.390
24	WS_west_40m_Min	m/s	40 m	110,120	54,879	49.84	1.523	0.000	9.450	1.102
25	WS_west_40m_Std	m/s	40 m	110,120	54,879	49.84	0.618	0.000	7.780	0.353
26	WindDir_79m_D1_WVT	°	79 m	110,120	69,641	63.24	123.2	0.0	360.0	96.2
27	WindDir_79m_SD1_WVT	°	79 m	110,120	69,695	63.29	8.5	0.0	78.8	9.0
28	WindDir_59m_D1_WVT	°	59 m	110,120	69,641	63.24	118.7	0.0	360.0	95.6
29	WindDir_59m_SD1_WVT	°	59 m	110,120	69,695	63.29	9.2	0.0	80.2	9.3
30	WindDir_39m_D1_WVT	°	39 m	110,120	67,417	61.22	113.5	0.0	360.0	94.9
31	WindDir_39m_SD1_WVT	°	39 m	110,120	67,471	61.27	10.3	0.0	79.3	9.5
32	RTD_temp_C_80m_Avg	°C	80 m	110,120	69,632	63.23	25.3	8.9	34.5	3.7
33	RTD_temp_C_80m_Max	°C	80 m	110,120	69,632	63.23	25.5	9.6	52.3	3.7
34	RTD_temp_C_80m_Min	°C	80 m	110,120	69,632	63.23	25.0	7.6	34.4	3.7
35	RTD_temp_C_80m_Std	°C	80 m	110,120	69,632	63.23	0.1	0.0	3.6	0.1
36	RTD_temp_C_4m_Avg	°C	4 m	110,120	69,554	63.16	24.6	7.9	35.9	4.8
37	RTD_temp_C_4m_Max	°C	4 m	110,120	69,554	63.16	24.8	8.0	36.3	4.8
38	RTD_temp_C_4m_Min	°C	4 m	110,120	69,554	63.16	24.3	7.9	35.6	4.7
39	RTD_temp_C_4m_Std	°C	4 m	110,120	69,554	63.16	0.1	0.0	2.4	0.1
40	HMP155_temp_80m_Avg	°C	80 m	110,120	69,673	63.27	25.2	8.9	34.4	3.7
41	HMP155_temp_80m_Max	°C	80 m	110,120	69,673	63.27	25.3	9.0	34.5	3.7
42	HMP155_temp_80m_Min	°C	80 m	110,120	69,673	63.27	25.1	8.5	34.4	3.7
43	HMP155_temp_80m_Std	°C	80 m	110,120	69,673	63.27	0.1	0.0	3.3	0.1
44	RH_80m_Avg	%		110,120	69,695	63.29	77.0	23.0	99.9	15.5
45	RH_80m_Max	%		110,120	69,695	63.29	78.3	24.0	100.0	15.1
46	RH_80m_Min	%		110,120	69,695	63.29	75.60	17.23	99.90	15.85
47	RH_80m_Std	%		110,120	69,695	63.29	0.74	0.01	14.99	0.80
48	HMP155_temp_4m_Avg	°C	4 m	110,120	69,654	63.25	24.5	7.8	35.5	4.7
49	HMP155_temp_4m_Max	°C	4 m	110,120	69,654	63.25	24.7	7.9	36.0	4.7
50	HMP155_temp_4m_Min	°C	4 m	110,120	69,654	63.25	24.3	7.7	35.3	4.7
51	HMP155_temp_4m_Std	°C	4 m	110,120	69,654	63.25	0.1	0.0	2.4	0.1
52	RH_4m_Avg	%		110,120	69,764	63.35	82.7	21.5	100.0	14.7

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	RH_4m_Max	%		110,120	69,765	63.35	84.0	-29.9	100.0	14.0
54	RH_4m_Min	%		110,120	69,765	63.35	81.45	-54.29	99.90	15.35
55	RH_4m_Std	%		110,120	69,765	63.35	0.65	0.02	10.65	0.63
56	BP_80m_Avg	mbar	2 m	110,120	69,681	63.28	997.4	975.0	1,013.0	5.0
57	BP_80m_Max	mbar	2 m	110,120	69,681	63.28	997.6	976.0	1,013.0	5.0
58	BP_80m_Min	mbar	2 m	110,120	69,681	63.28	997.2	828.0	1,012.0	5.4
59	BP_80m_Std	mbar	2 m	110,120	69,681	63.28	0.1	0.0	44.9	0.3
60	BP_4m_Avg	mbar	2 m	110,120	69,695	63.29	1,005.4	986.0	1,018.0	5.1
61	BP_4m_Max	mbar	2 m	110,120	69,695	63.29	1,005.5	987.0	1,018.0	5.1
62	BP_4m_Min	mbar	2 m	110,120	69,695	63.29	1,005.3	834.0	1,018.0	5.2
63	BP_4m_Std	mbar	2 m	110,120	69,695	63.29	0.1	0.0	42.2	0.2
64	LWmV_Avg	Avg		110,120	69,765	63.35	229	-1,205	845	271
65	LWmV	Smp		110,120	69,765	63.35	229	-1,209	763	271
66	VBatt_Min	Volt		110,120	69,819	63.40	12.87	0.00	13.75	0.51
67	IBatt_Min	Amp		110,120	69,819	63.40	0.017	-0.482	1.273	0.323
68	ILoad_Min	m/s		110,120	69,819	63.40	0.215	0.000	0.550	0.087
69	V_in_chg_Min	m/s		110,120	69,819	63.40	8.70	0.00	20.44	8.54
70	I_in_chg_Min	°		110,120	69,819	63.40	0.199	-0.003	1.289	0.267
71	Chg_TmpC_Avg	°C	2 m	110,120	69,818	63.40	28.2	0.7	45.5	7.0
72	Chg_State	Smp		110,120	69,819	63.40	1.247	0.000	3.000	1.391
73	Ck_Batt	Smp		110,120	69,819	63.40	0	0	0	0
74	BattV_Min	Min		110,120	69,765	63.35	12.53	10.87	13.44	0.51
75	PTemp_C_Avg	°C	2 m	110,120	69,765	63.35	26.4	9.7	43.0	5.8
76	latitude_a	Smp		110,120	69,692	63.29	24	24	24	0
77	latitude_b	Smp		110,120	69,692	63.29	22.67	22.66	22.68	0.00
78	longitude_a	Smp		110,120	69,692	63.29	91	91	91	0
79	longitude_b	Smp		110,120	69,692	63.29	34.48	34.47	34.48	0.00
80	magnetic_variation	Smp		110,120	69,692	63.29	-0.5	-0.5	-0.5	0.0
81	fix_quality	Smp		110,120	69,819	63.40	1.996	0.000	2.000	0.085
82	nmbr_satellites	Smp		110,120	69,819	63.40	9.09	0.00	12.00	0.96
83	altitude	Smp		110,120	69,692	63.29	32.70	14.20	51.10	3.84
84	max_clock_change	°	39 m	110,120	67,471	61.27	-44.9	-5,970.0	310.0	248.5
85	nmbr_clock_change	Smp		110,120	69,819	63.40	0.604	0.000	4.000	1.161
86	Air Density	kg/m³		110,120	110,120	100.00	1.175	1.106	1.231	0.031
87	WS_east_80m_Avg TI			110,120	49,106	44.59	0.25	0.03	23.67	0.67
88	WS_west_80m_Avg TI			110,120	44,813	40.69	0.29	0.03	20.25	0.66
89	WS_east_60m_Avg TI			110,120	64,971	59.00	0.25	0.03	20.50	0.53
90	WS_west_60m_Avg TI			110,120	55,968	50.82	0.33	0.03	23.00	0.82
91	WS_east_40m_Avg TI			110,120	66,825	60.68	0.29	0.04	20.00	0.62
92	WS_west_40m_Avg TI			110,120	54,369	49.37	0.30	0.04	21.00	0.62
93	WS_east_80m_Avg WPD	W/m²		110,120	51,649	46.90	62	0	5,277	133
94	WS_west_80m_Avg WPD	W/m²		110,120	45,830	41.62	65	0	5,407	143
95	WS_east_60m_Avg WPD	W/m²		110,120	65,759	59.72	47	0	4,456	100
96	WS_west_60m_Avg WPD	W/m²		110,120	57,070	51.83	43	0	4,249	96
97	WS_east_40m_Avg WPD	W/m²		110,120	67,320	61.13	30	0	2,995	68
98	WS_west_40m_Avg WPD	W/m²		110,120	54,879	49.84	30	0	2,943	70

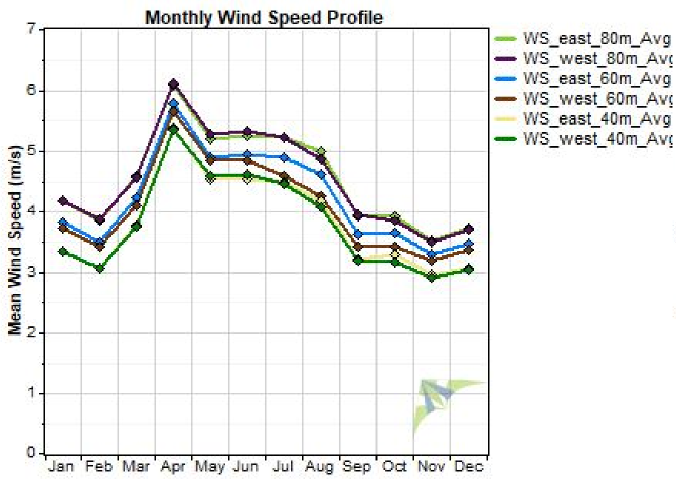
Data Set Properties

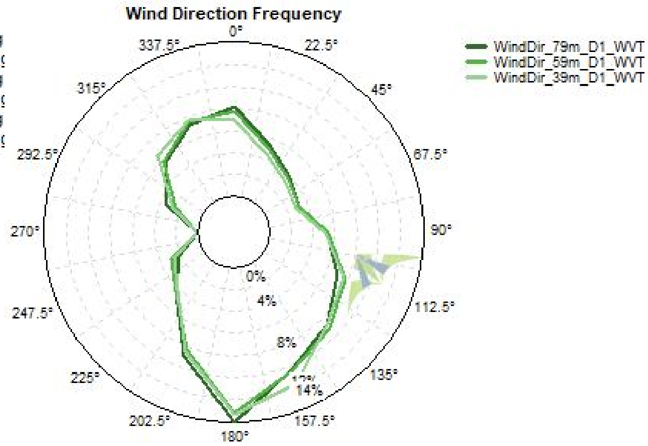
Report Created: 4/11/2018 10:16 using Windographer 3.3.10
Filter Settings: <Unflagged data>

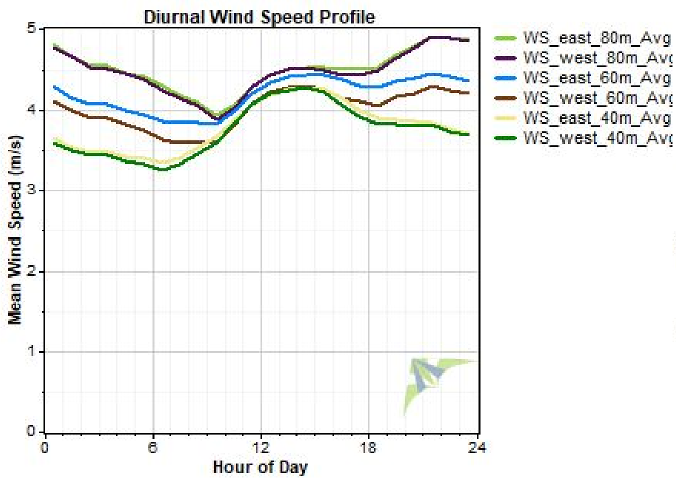
Variable	Value
Latitude	N 22.473420
Longitude	E 89.568260
Elevation	3.05 m
Start date	10/31/2015 13:20
End date	12/25/2017 10:50
Duration	26 months
Length of time step	10 minutes
Calm threshold	1 m/s
Mean temperature	26.1 °C
Mean pressure	1,000 mbar
Mean air density	1.165 kg/m³
Power density at 50m	67 W/m²
Wind power class	1
Power law exponent	0.253
Surface roughness	1.1 m
Roughness class	3.99

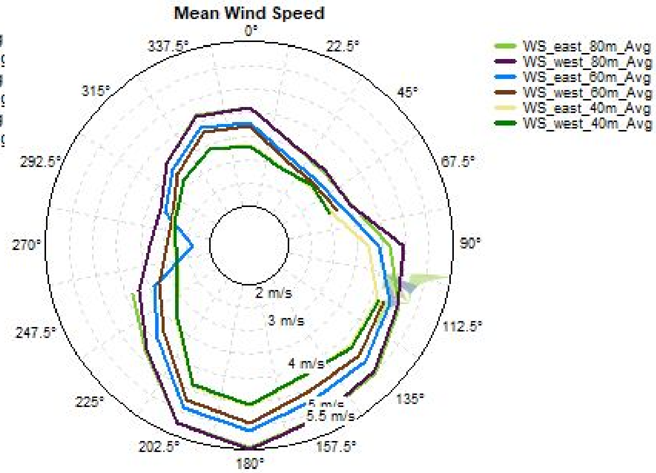


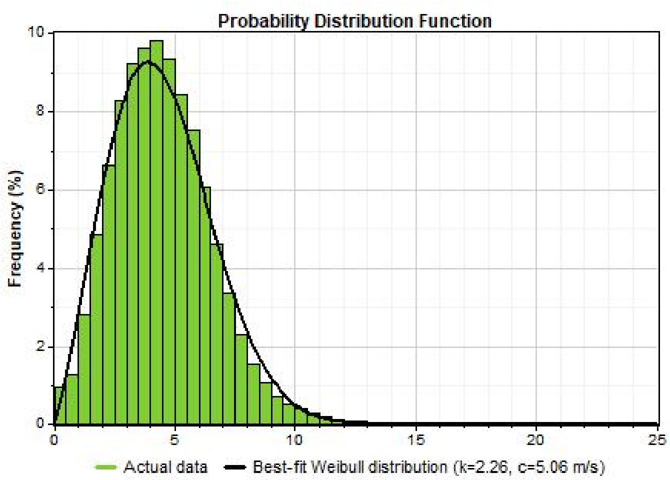
Wind Speed and Direction

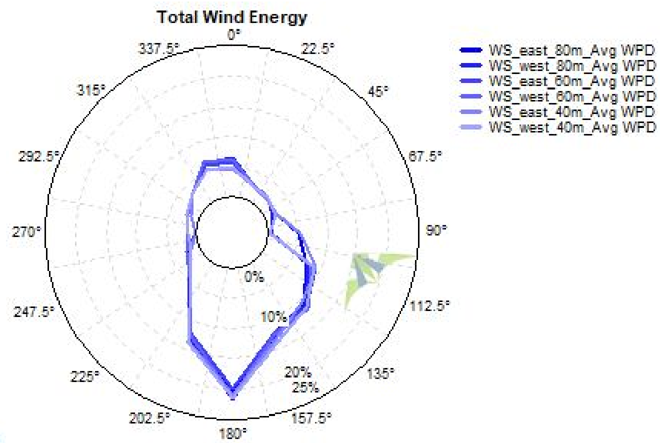




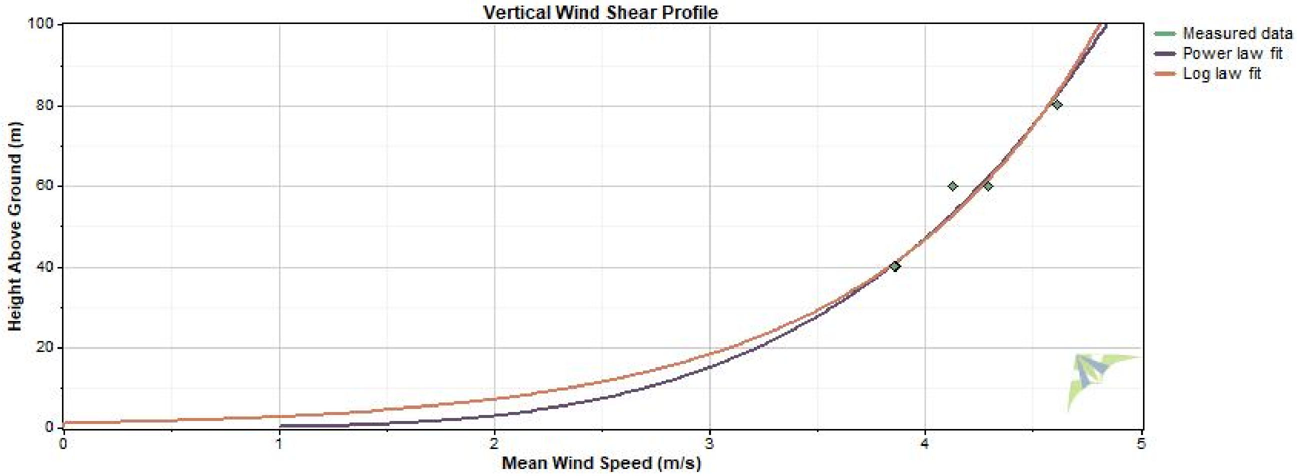


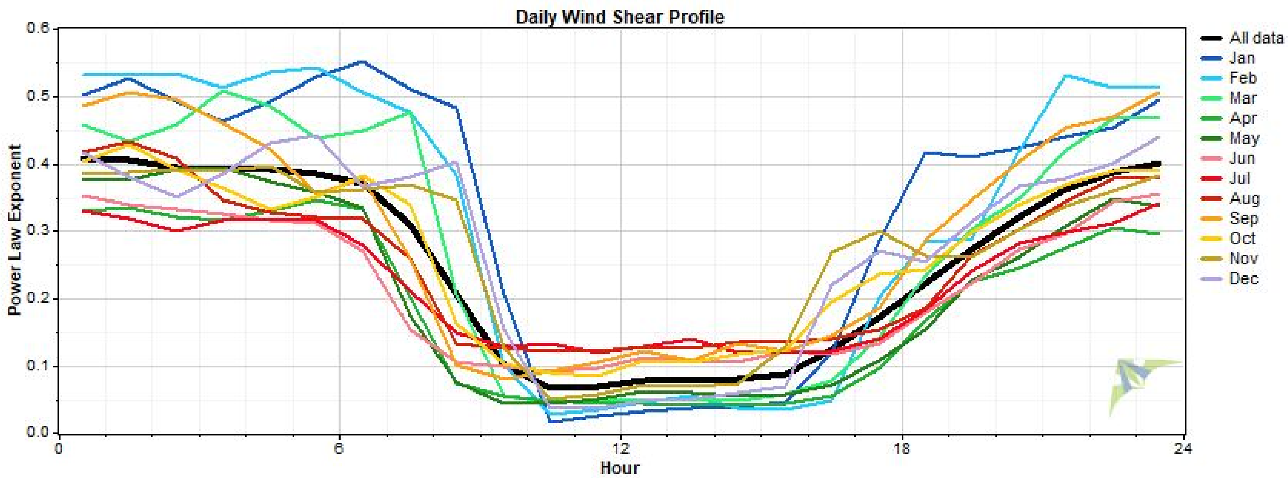


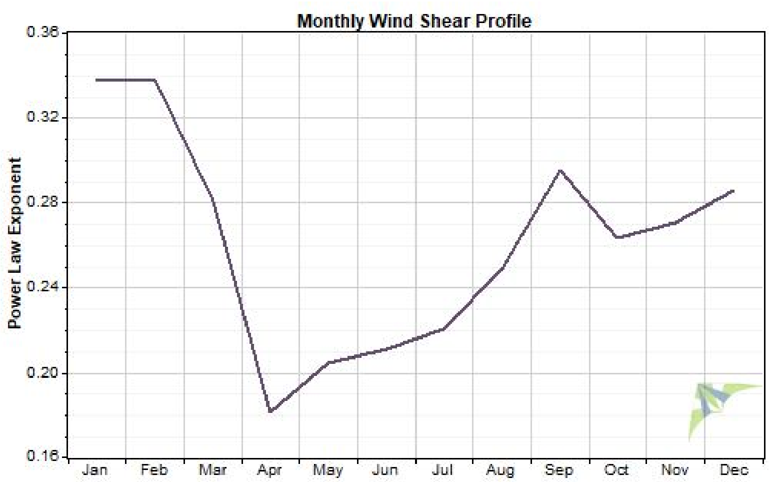


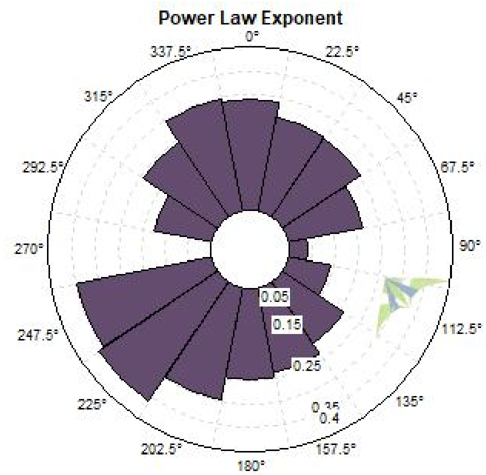


Wind Shear

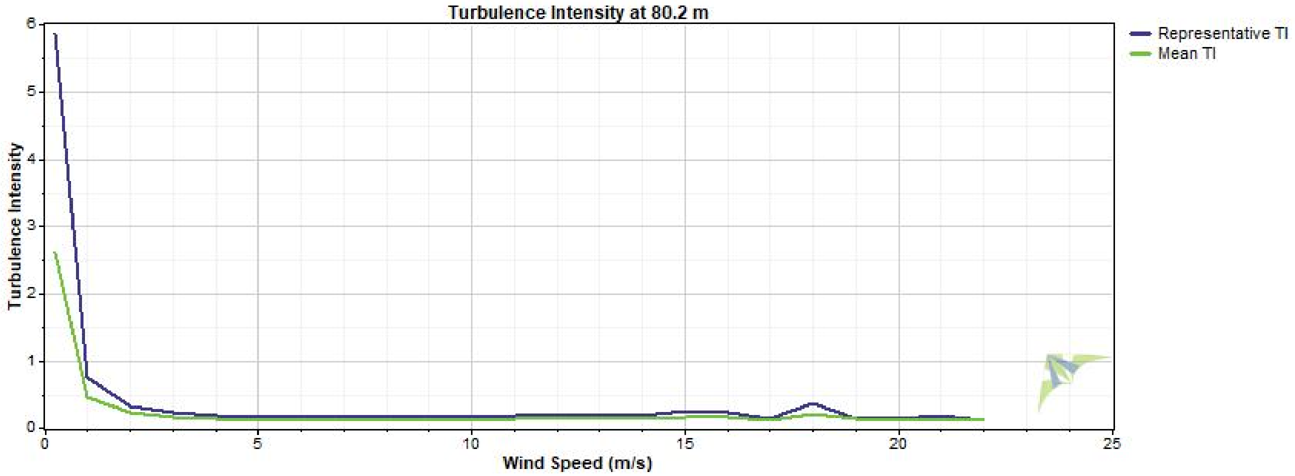

Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
Mean Wind Speed (m/s)

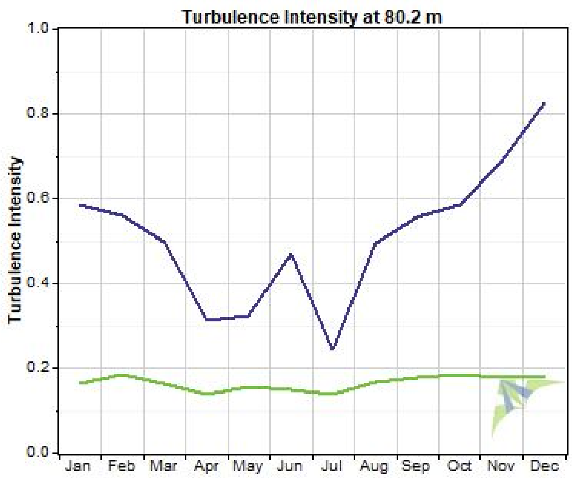

Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
Hour

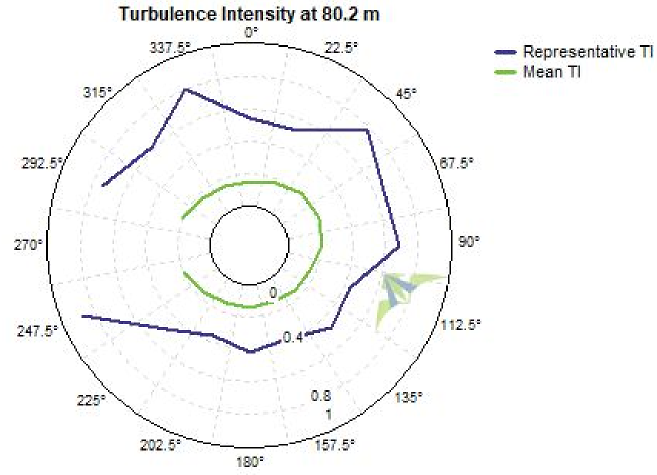

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

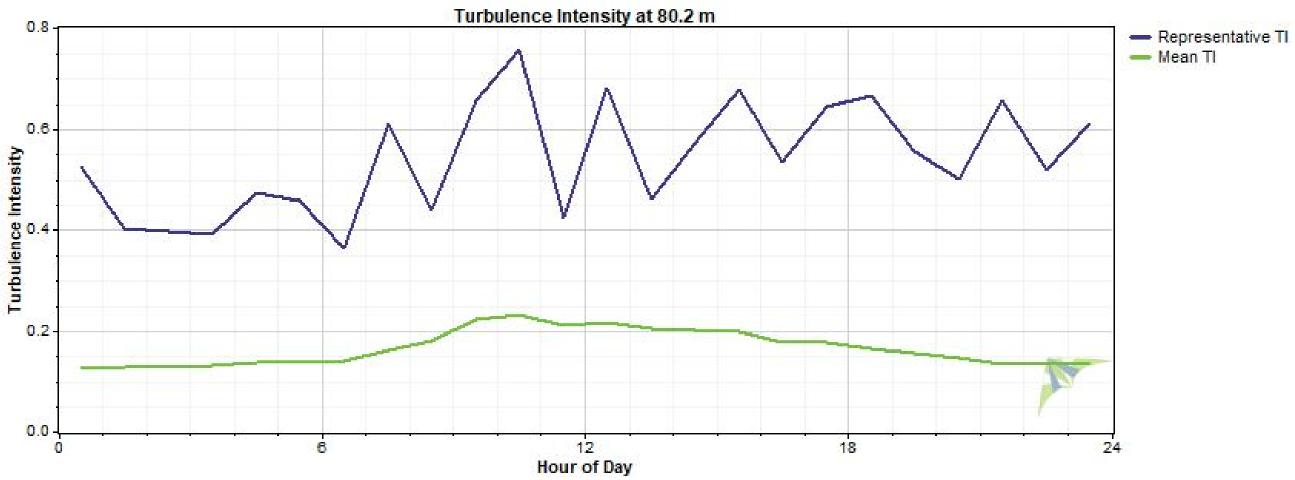

Power Law Exponent

Turbulence Intensity









Data Column Properties

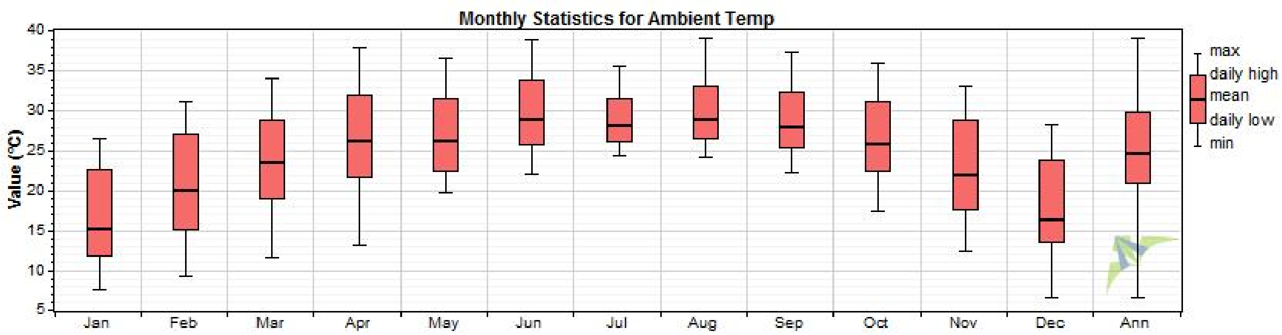
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	RECORD	m/s		113,169	111,576	98.59	50,232	0	105,680	31,681
2	WS_east_80m_Avg	m/s	80.2 m	113,169	107,141	94.67	4.494	0.000	23.920	2.069
3	WS_east_80m_Max	m/s	80.2 m	113,169	107,141	94.67	5.891	0.000	40.280	2.615
4	WS_east_80m_Min	m/s	80.2 m	113,169	107,141	94.67	3.097	0.000	15.640	1.702
5	WS_east_80m_Std	m/s	80.2 m	113,169	107,141	94.67	0.575	0.000	7.920	0.280
6	WS_west_80m_Avg	m/s	80.2 m	113,169	104,972	92.76	4.470	0.000	24.000	2.062
7	WS_west_80m_Max	m/s	80.2 m	113,169	104,972	92.76	5.847	0.000	39.500	2.604
8	WS_west_80m_Min	m/s	80.2 m	113,169	104,972	92.76	3.096	0.000	15.630	1.705
9	WS_west_80m_Std	m/s	80.2 m	113,169	104,972	92.76	0.568	0.000	7.912	0.281
10	WS_east_60m_Avg	m/s	60 m	113,169	106,845	94.41	4.186	0.000	23.050	1.956
11	WS_east_60m_Max	m/s	60 m	113,169	106,845	94.41	5.612	0.000	39.640	2.564
12	WS_east_60m_Min	m/s	60 m	113,169	106,845	94.41	2.785	0.000	14.910	1.542
13	WS_east_60m_Std	m/s	60 m	113,169	106,845	94.41	0.581	0.000	8.110	0.280
14	WS_west_60m_Avg	m/s	60 m	113,169	103,243	91.23	4.009	0.000	22.370	1.955
15	WS_west_60m_Max	m/s	60 m	113,169	103,243	91.23	5.419	0.000	36.900	2.531
16	WS_west_60m_Min	m/s	60 m	113,169	103,243	91.23	2.610	0.000	14.040	1.581
17	WS_west_60m_Std	m/s	60 m	113,169	103,243	91.23	0.579	0.000	7.878	0.283
18	WS_east_40m_Avg	m/s	40 m	113,169	106,770	94.35	3.781	0.000	21.690	1.843
19	WS_east_40m_Max	m/s	40 m	113,169	106,770	94.35	5.224	0.000	40.280	2.507
20	WS_east_40m_Min	m/s	40 m	113,169	106,770	94.35	2.393	0.000	14.870	1.387
21	WS_east_40m_Std	m/s	40 m	113,169	106,770	94.35	0.583	0.000	8.020	0.279
22	WS_west_40m_Avg	m/s	40 m	113,169	104,313	92.17	3.734	0.000	21.680	1.840
23	WS_west_40m_Max	m/s	40 m	113,169	104,313	92.17	5.165	0.000	38.970	2.510
24	WS_west_40m_Min	m/s	40 m	113,169	104,313	92.17	2.364	0.000	14.170	1.386
25	WS_west_40m_Std	m/s	40 m	113,169	104,313	92.17	0.579	0.000	8.100	0.282
26	WindDir_79m_D1_WVT	°	78 m	113,169	111,576	98.59	155.8	0.0	360.0	98.6
27	WindDir_79m_SD1_WVT	°	78 m	113,169	111,576	98.59	6.3	0.0	79.2	6.2
28	WindDir_59m_D1_WVT	°	57.9 m	113,169	111,576	98.59	152.8	0.0	360.0	98.5
29	WindDir_59m_SD1_WVT	°	57.9 m	113,169	111,576	98.59	6.5	0.0	79.2	6.3
30	WindDir_39m_D1_WVT	°	37.9 m	113,169	111,576	98.59	154.4	0.0	360.0	97.0
31	WindDir_39m_SD1_WVT	°	37.9 m	113,169	111,576	98.59	6.9	0.0	78.4	6.5
32	RTD_temp_C_80m_Avg	°C	78.4 m	113,169	111,575	98.59	26.2	11.7	38.3	3.6
33	RTD_temp_C_80m_Max	°C	78.4 m	113,169	111,575	98.59	26.4	11.8	38.7	3.6
34	RTD_temp_C_80m_Min	°C	78.4 m	113,169	111,575	98.59	26.0	11.1	38.0	3.6
35	RTD_temp_C_80m_Std	°C	78.4 m	113,169	111,575	98.59	0.1	0.0	4.1	0.1
36	RTD_temp_C_4m_Avg	°C	3.3 m	113,169	96,308	85.10	25.6	7.2	39.2	5.2
37	RTD_temp_C_4m_Max	°C	3.3 m	113,169	96,308	85.10	25.8	7.4	39.8	5.2
38	RTD_temp_C_4m_Min	°C	3.3 m	113,169	96,308	85.10	25.4	7.0	39.0	5.2
39	RTD_temp_C_4m_Std	°C	3.3 m	113,169	96,308	85.10	0.1	0.0	3.6	0.1
40	HMP155_temp_80m_Avg	°C	79.2 m	113,169	111,521	98.54	26.1	11.4	38.2	3.6
41	HMP155_temp_80m_Max	°C	79.2 m	113,169	111,521	98.54	26.2	11.4	38.7	3.6
42	HMP155_temp_80m_Min	°C	79.2 m	113,169	111,521	98.54	26.0	11.3	37.8	3.6
43	HMP155_temp_80m_Std	°C	79.2 m	113,169	111,521	98.54	0.1	0.0	3.8	0.1
44	RH_80m_Avg	%		113,169	111,576	98.59	76.2	17.2	99.9	16.9
45	RH_80m_Max	%		113,169	111,576	98.59	77.5	17.6	100.0	16.5
46	RH_80m_Min	%		113,169	111,576	98.59	74.99	15.65	99.90	17.37
47	RH_80m_Std	%		113,169	111,576	98.59	0.65	0.03	16.50	0.70
48	HMP155_temp_4m_Avg	°C	4.1 m	113,169	111,459	98.49	25.5	7.9	39.1	5.1
49	HMP155_temp_4m_Max	°C	4.1 m	113,169	111,459	98.49	25.6	8.1	39.5	5.1
50	HMP155_temp_4m_Min	°C	4.1 m	113,169	111,459	98.49	25.3	7.7	38.9	5.1
51	HMP155_temp_4m_Std	°C	4.1 m	113,169	111,459	98.49	0.1	0.0	3.4	0.1
52	RH_4m_Avg	Avg		113,169	111,576	98.59	84.0	19.0	100.0	15.6

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	RH_4m_Max	Max		113,169	111,576	98.59	85.4	21.4	100.0	14.7
54	RH_4m_Min	Min		113,169	111,576	98.59	82.76	16.34	99.90	16.40
55	RH_4m_Std	Std		113,169	111,576	98.59	0.64	0.02	10.65	0.67
56	BP_80m_Avg	mbar	78.7 m	113,169	111,576	98.59	1,000.4	978.0	1,015.0	5.6
57	BP_80m_Max	mbar	78.7 m	113,169	111,576	98.59	1,000.5	978.0	1,016.0	5.6
58	BP_80m_Min	mbar	78.7 m	113,169	111,576	98.59	1,000.2	804.0	1,014.0	5.8
59	BP_80m_Std	mbar	78.7 m	113,169	111,576	98.59	0.1	0.0	12.2	0.1
60	BP_4m_Avg	mbar	3.9 m	113,169	111,576	98.59	1,008.1	986.0	1,022.0	5.7
61	BP_4m_Max	mbar	3.9 m	113,169	111,576	98.59	1,008.2	986.0	1,022.0	5.7
62	BP_4m_Min	mbar	3.9 m	113,169	111,576	98.59	1,007.9	985.0	1,022.0	5.7
63	BP_4m_Std	mbar	3.9 m	113,169	111,576	98.59	0.0	0.0	1.1	0.0
64	LWmV_Avg	Avg		113,169	111,576	98.59	290.1	151.0	910.0	69.3
65	LWmV	Smp		113,169	111,576	98.59	290.1	150.6	966.0	70.1
66	VBatt_Min	°C		113,169	111,576	98.59	12.80	0.00	13.73	0.47
67	IBatt_Min	°C		113,169	111,576	98.59	0.000	-0.376	1.935	0.380
68	ILoad_Min	m/s		113,169	111,576	98.59	0.282	0.000	0.330	0.010
69	V_in_chg_Min	m/s		113,169	111,576	98.59	8.40	0.00	20.15	8.33
70	I_in_chg_Min	kW		113,169	111,576	98.59	0.249	-0.004	1.884	0.310
71	Chg_TmpC_Avg	m/s		113,169	111,576	98.59	29.93	8.62	47.51	7.39
72	Chg_State	m/s		113,169	111,576	98.59	1.194	0.000	3.000	1.367
73	Ck_Batt	Smp		113,169	111,576	98.59	0	0	0	0
74	BattV_Min	°C		113,169	111,576	98.59	12.44	11.12	13.41	0.49
75	PTemp_C_Avg	m/s		113,169	111,576	98.59	27.31	8.27	42.52	5.83
76	latitude_a	Smp		113,169	111,576	98.59	22	22	22	0
77	latitude_b	m/s		113,169	111,576	98.59	28.40	28.40	28.41	0.00
78	longitude_a	Smp		113,169	111,576	98.59	89	89	89	0
79	longitude_b	m/s		113,169	111,576	98.59	34.10	34.09	34.10	0.00
80	magnetic_variation	Smp		113,169	111,576	98.59	-0.6	-0.6	-0.6	0.0
81	fix_quality	Smp		113,169	111,576	98.59	2	2	2	0
82	nmbr_satellites	m/s		113,169	111,576	98.59	9.29	6.00	12.00	0.87
83	altitude	m/s		113,169	111,576	98.59	5.05	-51.30	24.70	4.26
84	max_clock_change	m/s		113,169	111,576	98.59	-528	-1,000	980	486
85	nmbr_clock_change	Smp		113,169	111,576	98.59	1.855	0.000	6.000	1.731
86	Air Density	kg/m³		113,169	113,169	100.00	1.165	1.110	1.238	0.020
87	WS_east_80m_Avg TI			113,169	106,844	94.41	0.17	0.02	20.50	0.30
88	WS_west_80m_Avg TI			113,169	104,642	92.47	0.17	0.02	20.50	0.30
89	WS_east_60m_Avg TI			113,169	106,525	94.13	0.18	0.03	19.00	0.28
90	WS_west_60m_Avg TI			113,169	102,227	90.33	0.21	0.03	22.00	0.49
91	WS_east_40m_Avg TI			113,169	106,273	93.91	0.20	0.03	20.50	0.36
92	WS_west_40m_Avg TI			113,169	103,755	91.68	0.20	0.03	20.50	0.40
93	WS_east_80m_Avg WPD	W/m²		113,169	107,141	94.67	90	0	8,018	154
94	WS_west_80m_Avg WPD	W/m²		113,169	104,972	92.76	89	0	8,098	150
95	WS_east_60m_Avg WPD	W/m²		113,169	106,845	94.41	74	0	7,174	133
96	WS_west_60m_Avg WPD	W/m²		113,169	103,243	91.23	67	0	6,558	123
97	WS_east_40m_Avg WPD	W/m²		113,169	106,770	94.35	57	0	5,978	111
98	WS_west_40m_Avg WPD	W/m²		113,169	104,313	92.17	56	0	5,969	110

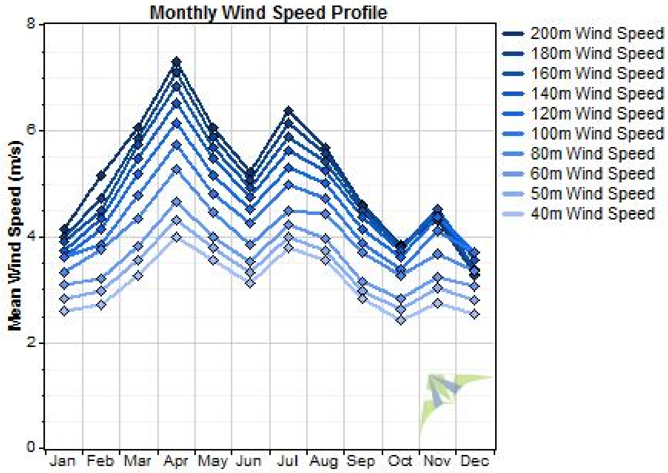
Data Set Properties

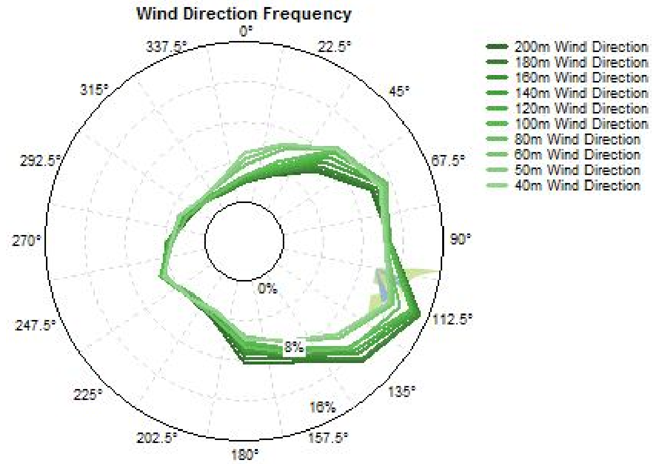
Report Created: 7/14/2017 16:14 using Windographer 3.3.10
Filter Settings: <Unflagged data>

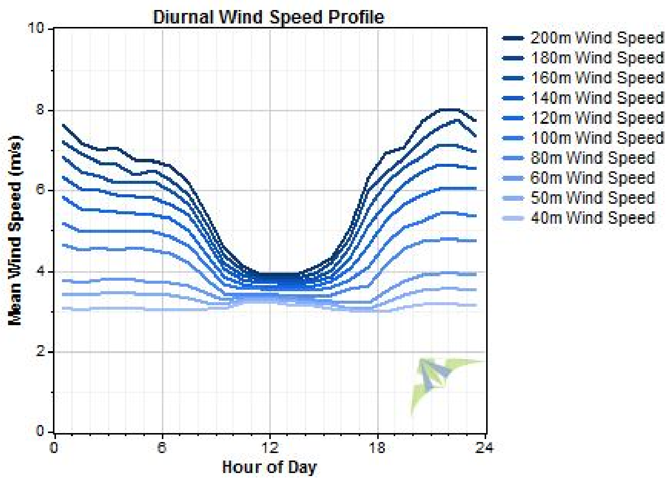
Variable	Value
Latitude	N 25° 36' 22.968"
Longitude	E 89° 4' 7.752"
Elevation	32 m
Start date	8/4/2015 19:10
End date	4/19/2017 06:10
Duration	20 months
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	24.7 °C
Mean pressure	1,590 mbar
Mean air density	1.688 kg/m³
Power density at 50m	58 W/m²
Wind power class	1
Power law exponent	0.289
Surface roughness	2.87 m
Roughness class	4.79

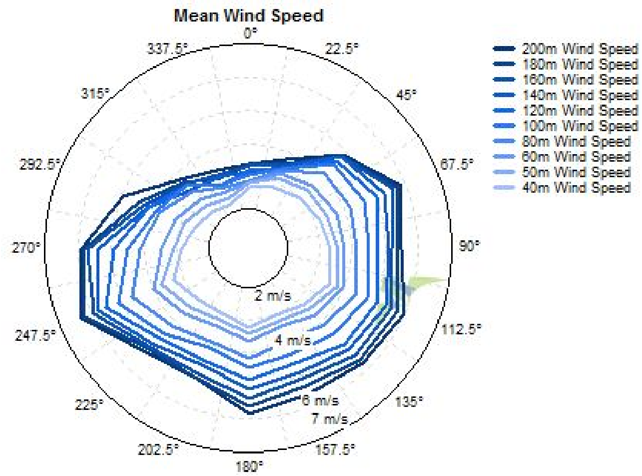


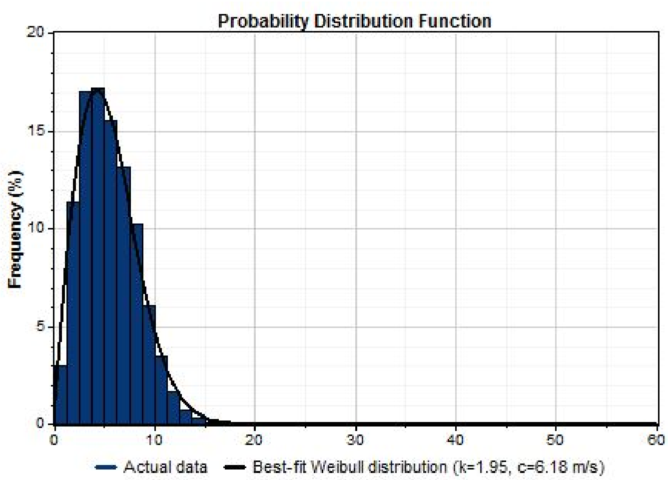
Wind Speed and Direction

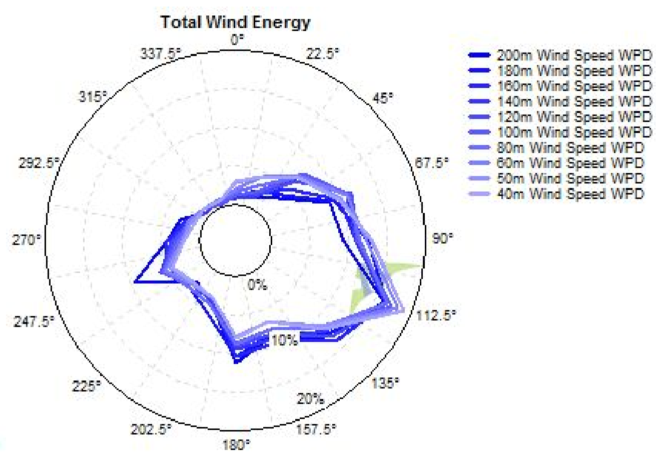




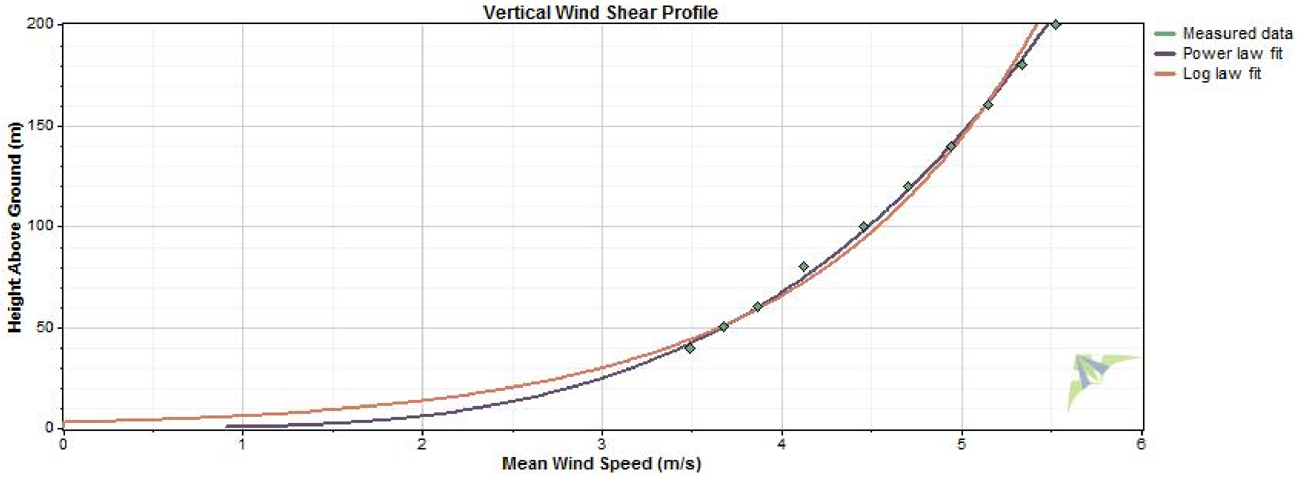


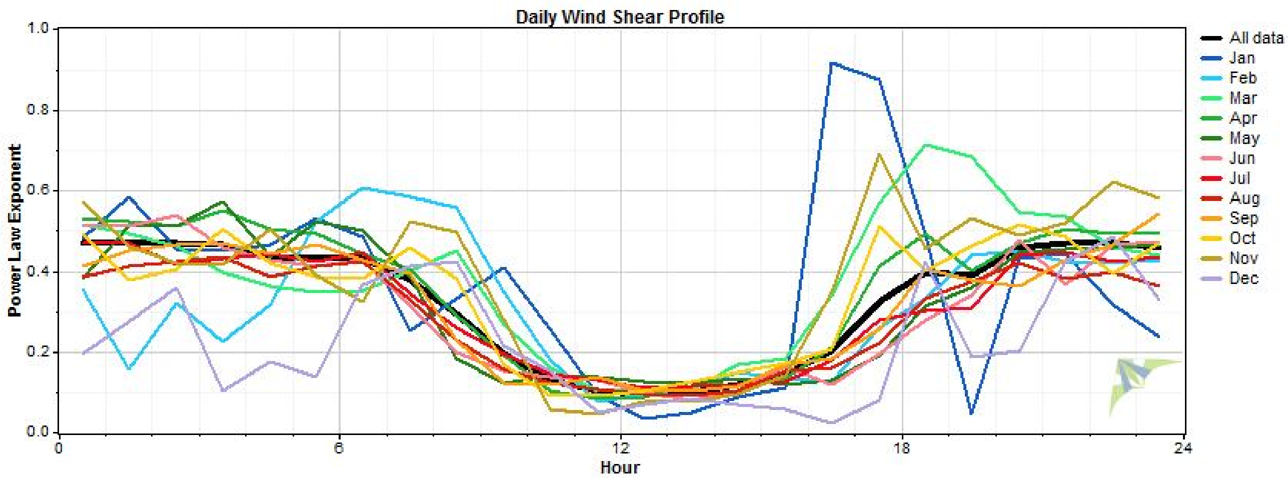


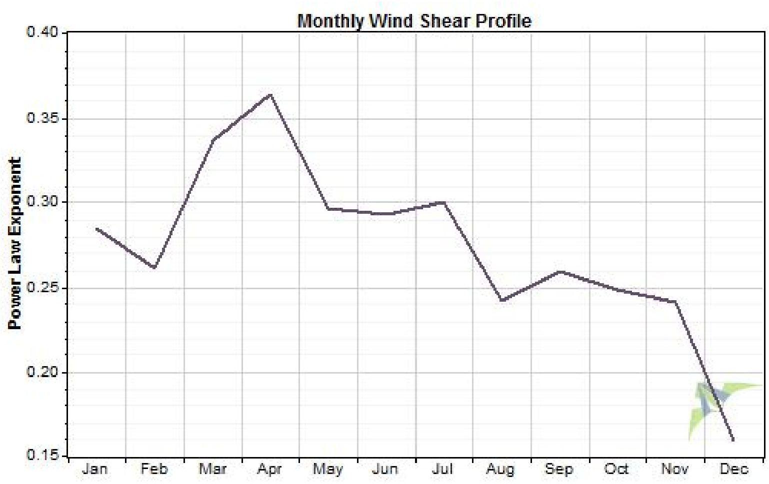


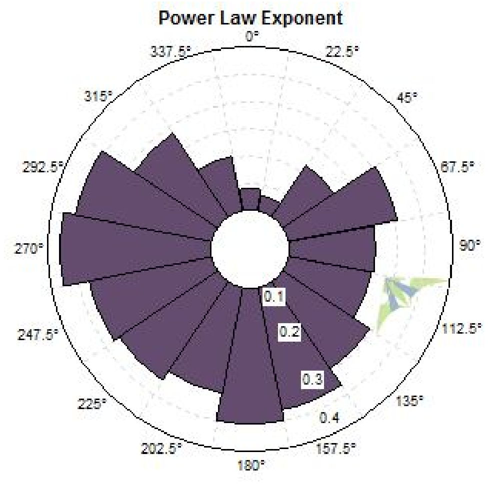


Wind Shear

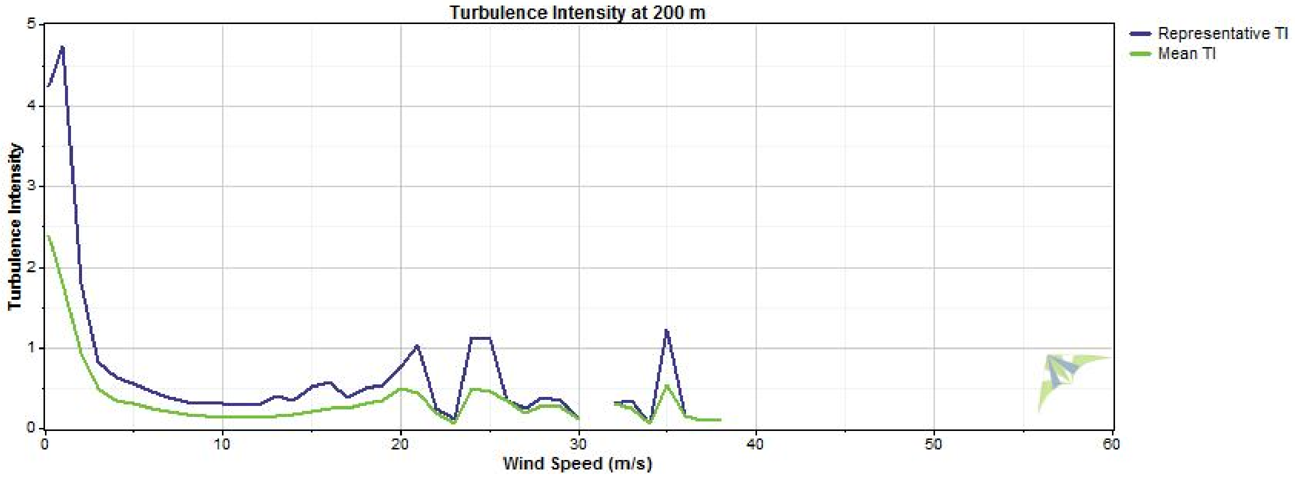

Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
Mean Wind Speed (m/s)

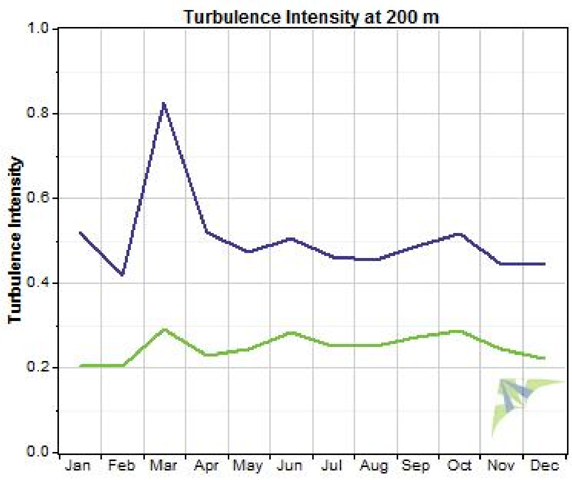

Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
Hour

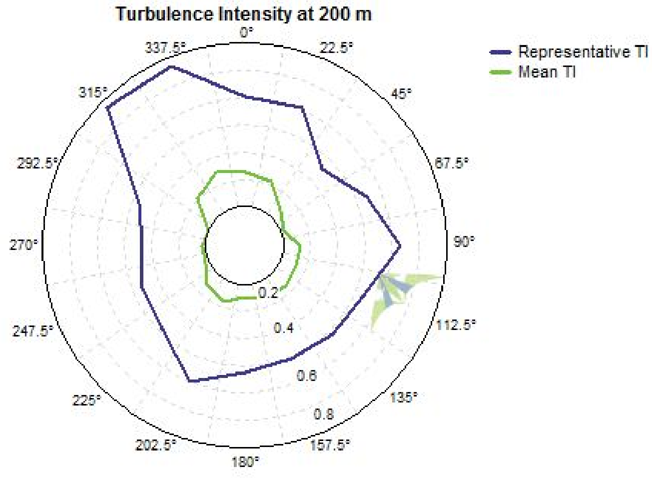

Monthly Wind Shear Profile
Power Law Exponent
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

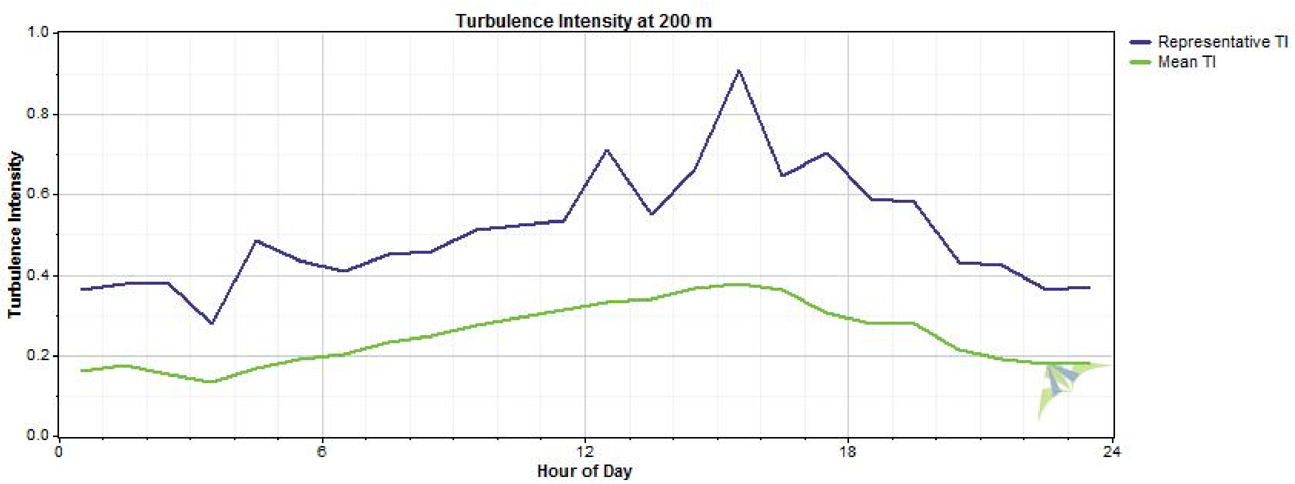

Power Law Exponent

Turbulence Intensity









Data Column Properties

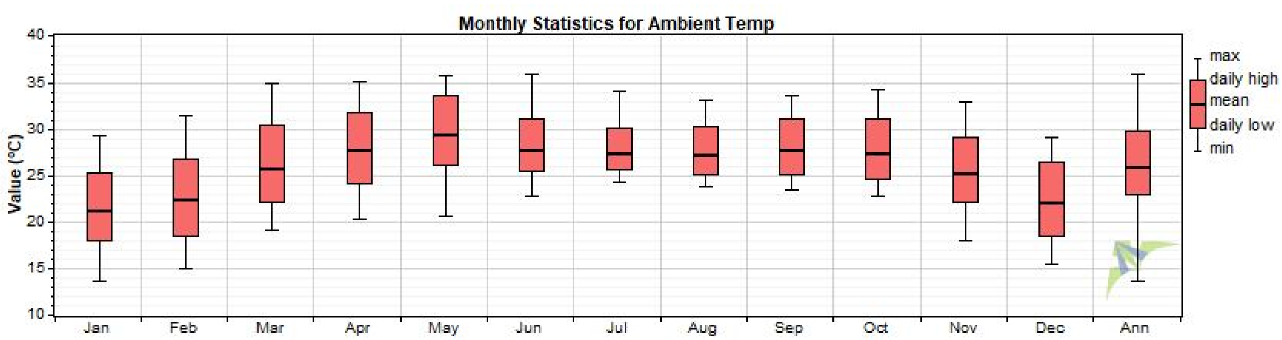
#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	40m Wind Direction	°	40 m	89,778	64,338	71.66	101.4	0.0	360.0	92.0
2	40m Wind Speed	m/s	40 m	89,778	64,338	71.66	3.09	0.01	15.19	1.41
3	40m Wind Vert	m/s	40 m	89,778	64,338	71.66	-0.20	-9.36	0.50	0.94
4	Quality (Station Height 40m)	%		89,778	64,469	71.81	97.3	31.0	100.0	1.6
5	50m Wind Direction	°	50 m	89,778	63,385	70.60	101.5	0.0	360.0	90.9
6	50m Wind Speed	m/s	50 m	89,778	63,385	70.60	3.33	0.02	15.42	1.52
7	50m Wind Vert	m/s	50 m	89,778	63,385	70.60	-0.20	-9.33	0.50	0.94
8	Quality (Station Height 50m)	%		89,778	63,632	70.88	97.3	22.0	100.0	1.9
9	60m Wind Direction	°	60 m	89,778	61,846	68.89	102.9	0.1	360.0	89.6
10	60m Wind Speed	m/s	60 m	89,778	61,846	68.89	3.56	0.02	16.39	1.63
11	60m Wind Vert	m/s	60 m	89,778	61,846	68.89	-0.21	-9.32	0.50	0.94
12	Quality (Station Height 60m)	%		89,778	62,210	69.29	97.3	19.0	100.0	2.1
13	80m Wind Direction	°	80 m	89,778	53,356	59.43	114.5	0.0	360.0	82.6
14	80m Wind Speed	m/s	80 m	89,778	53,356	59.43	4.04	0.02	19.70	1.87
15	80m Wind Vert	m/s	80 m	89,778	53,356	59.43	-0.25	-9.36	0.50	0.94
16	Quality (Station Height 80m)	%		89,778	53,927	60.07	96.7	0.0	100.0	4.4
17	100m Wind Direction	°	100 m	89,778	52,660	58.66	113.0	0.0	360.0	83.9
18	100m Wind Speed	m/s	100 m	89,778	52,660	58.66	4.38	0.01	30.41	2.07
19	100m Wind Vert	m/s	100 m	89,778	52,660	58.66	-0.23	-9.33	0.50	0.89
20	Quality (Station Height 100m)	%		89,778	53,476	59.56	96.8	0.0	100.0	4.1
21	120m Wind Direction	°	120 m	89,778	47,792	53.23	117.2	0.0	360.0	81.9
22	120m Wind Speed	m/s	120 m	89,778	47,792	53.23	4.70	0.03	27.96	2.25
23	120m Wind Vert	m/s	120 m	89,778	47,792	53.23	-0.23	-9.33	0.50	0.84
24	Quality (Station Height 120m)	%		89,778	48,812	54.37	96.4	0.0	100.0	5.3
25	140m Wind Direction	°	140 m	89,778	43,048	47.95	120.4	0.0	360.0	80.3
26	140m Wind Speed	m/s	140 m	89,778	43,048	47.95	4.95	0.05	45.08	2.46
27	140m Wind Vert	m/s	140 m	89,778	43,048	47.95	-0.22	-9.35	0.50	0.76
28	Quality (Station Height 140m)	%		89,778	44,241	49.28	96.0	0.0	100.0	6.3
29	160m Wind Direction	°	160 m	89,778	38,563	42.95	123.1	0.0	360.0	79.5
30	160m Wind Speed	m/s	160 m	89,778	38,563	42.95	5.15	0.04	40.06	2.64
31	160m Wind Vert	m/s	160 m	89,778	38,563	42.95	-0.21	-9.33	0.50	0.67
32	Quality (Station Height 160m)	%		89,778	39,843	44.38	95.5	0.0	100.0	7.3
33	180m Wind Direction	°	180 m	89,778	34,105	37.99	125.5	0.0	360.0	78.2
34	180m Wind Speed	m/s	180 m	89,778	34,105	37.99	5.32	0.04	54.53	2.79
35	180m Wind Vert	m/s	180 m	89,778	34,105	37.99	-0.20	-9.31	0.50	0.58
36	Quality (Station Height 180m)	%		89,778	35,492	39.53	94.9	0.0	100.0	8.2
37	200m Wind Direction	°	200 m	89,778	29,553	32.92	127.4	0.0	360.0	77.1
38	200m Wind Speed	m/s	200 m	89,778	29,553	32.92	5.48	0.04	56.06	2.94
39	200m Wind Vert	m/s	200 m	89,778	29,553	32.92	-0.21	-9.31	0.50	0.57
40	Quality (Station Height 200m)	%		89,778	31,023	34.56	94.1	0.0	100.0	9.5
41	40m Wind Turbulence	m/s	40 m	89,778	23,199	25.84	0.16	0.04	2.37	0.12
42	50m Wind Turbulence	m/s	50 m	89,778	28,017	31.21	0.16	0.03	7.90	0.14
43	60m Wind Turbulence	m/s	60 m	89,778	31,086	34.63	0.16	0.03	6.36	0.15
44	80m Wind Turbulence	m/s	80 m	89,778	31,554	35.15	0.17	0.03	9.57	0.17
45	100m Wind Turbulence	m/s	100 m	89,778	33,352	37.15	0.19	0.02	4.97	0.17
46	120m Wind Turbulence	m/s	120 m	89,778	32,050	35.70	0.20	0.03	34.48	0.26
47	140m Wind Turbulence	m/s	140 m	89,778	29,666	33.04	0.22	0.02	20.64	0.22
48	160m Wind Turbulence	m/s	160 m	89,778	26,856	29.91	0.23	0.00	4.07	0.19
49	180m Wind Turbulence	m/s	180 m	89,778	24,047	26.78	0.24	0.02	9.45	0.23
50	200m Wind Turbulence	m/s	200 m	89,778	21,030	23.42	0.25	0.00	10.00	0.22
51	Turbu. Quality (Station Height 40m)	%		89,778	23,214	25.86	96.0	7.0	100.0	7.5
52	Turbu. Quality (Station Height 50m)	%		89,778	28,045	31.24	96.5	3.0	100.0	6.6

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	Turbu. Quality (Station Height 60m)	%		89,778	31,143	34.69	96.8	2.0	100.0	6.0
54	Turbu. Quality (Station Height 80m)	%		89,778	31,678	35.28	96.1	0.0	100.0	7.5
55	Turbu. Quality (Station Height 100m)	%		89,778	33,570	37.39	96.5	0.0	100.0	6.5
56	Turbu. Quality (Station Height 120m)	%		89,778	32,374	36.06	96.0	0.0	100.0	7.4
57	Turbu. Quality (Station Height 140m)	%		89,778	30,108	33.54	95.5	0.0	100.0	8.4
58	Turbu. Quality (Station Height 160m)	%		89,778	27,351	30.47	94.9	0.0	100.0	9.5
59	Turbu. Quality (Station Height 180m)	%		89,778	24,611	27.41	94.2	0.0	100.0	10.5
60	Turbu. Quality (Station Height 200m)	%		89,778	21,647	24.11	93.4	0.0	100.0	11.9
61	Ambient Temp	°C	2 m	89,778	66,250	73.79	24.7	6.6	39.0	5.7
62	Barometric Pressure	mbar	2 m	89,778	66,252	73.80	1,590.1	341.7	6,397.9	1,152.2
63	TiltX	°		89,778	66,252	73.80	-0.6503	-0.9000	0.0000	0.0733
64	Azimuth	°		89,778	66,252	73.80	0	0	0	0
65	TiltY	°		89,778	66,252	73.80	0.638	0.500	1.000	0.057
66	Humidity	%		89,778	66,252	73.80	79.4	30.0	97.0	10.8
67	Noise Level-A	dB		89,778	66,252	73.80	12.44	5.00	18.40	2.68
68	Noise Level-B	dB		89,778	66,252	73.80	12.48	5.00	18.20	2.69
69	Noise Level-C	dB		89,778	66,252	73.80	12.44	5.00	18.50	2.69
70	Solar Power	W		89,778	66,252	73.80	0	0	0	0
71	Core Power	W		89,778	66,252	73.80	2.786	2.400	3.400	0.083
72	CPU Power	W		89,778	66,252	73.80	2.379	2.000	3.200	0.169
73	Modem Power	W		89,778	66,252	73.80	0.064	0.000	0.600	0.122
74	Speaker Power	W		89,778	66,252	73.80	4.57	0.10	25.20	3.01
75	PWM Power	W		89,778	66,252	73.80	1.209	0.900	2.500	0.201
76	CPU Temp	°C	2 m	89,778	66,252	73.80	0.0	0.0	0.0	0.0
77	Internal Temp	°C	2 m	89,778	66,252	73.80	28.6	7.3	53.4	8.2
78	Mirror Temp	°C	2 m	89,778	66,252	73.80	27.8	5.5	68.6	9.2
79	Heater Temp	°C	2 m	89,778	66,252	73.80	0.0	0.0	0.0	0.0
80	VibrationX	g		89,778	66,252	73.80	0	0	0	0
81	VibrationY	g		89,778	66,252	73.80	0	0	0	0
82	Battery	Volts		89,778	66,252	73.80	12.84	11.70	14.90	0.68
83	Beep Volume	dB		89,778	66,252	73.80	89.4	0.0	100.0	30.8
84	Status	Mask		89,778	0	0.00				
85	Air Density	kg/m³		89,778	89,778	100.00	1.688	0.398	7.438	1.173
86	200m Wind Speed WPD	W/m²		89,778	29,553	32.92	357	0	300,922	2,571
87	180m Wind Speed WPD	W/m²		89,778	34,105	37.99	304	0	282,466	2,058
88	160m Wind Speed WPD	W/m²		89,778	38,563	42.95	259	0	98,921	1,160
89	140m Wind Speed WPD	W/m²		89,778	43,048	47.95	218	0	159,700	1,041
90	120m Wind Speed WPD	W/m²		89,778	47,792	53.23	171	0	30,641	386
91	100m Wind Speed WPD	W/m²		89,778	52,660	58.66	136	0	22,164	288
92	80m Wind Speed WPD	W/m²		89,778	53,356	59.43	104	0	14,644	215
93	60m Wind Speed WPD	W/m²		89,778	61,846	68.89	71	0	11,159	142
94	50m Wind Speed WPD	W/m²		89,778	63,385	70.60	58	0	5,237	118
95	40m Wind Speed WPD	W/m²		89,778	64,338	71.66	48	0	5,897	105

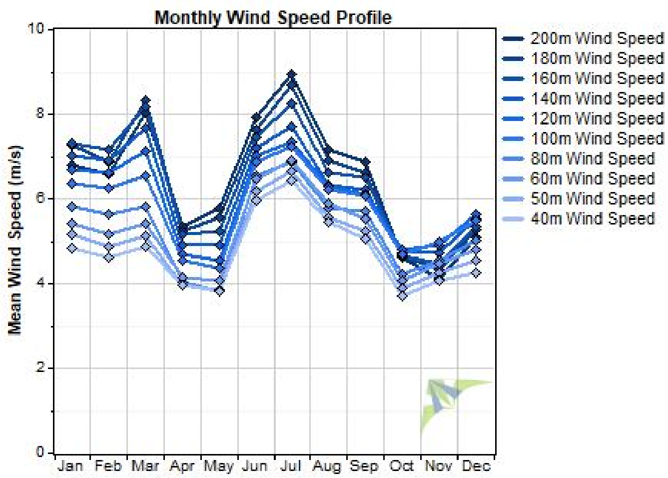
Data Set Properties

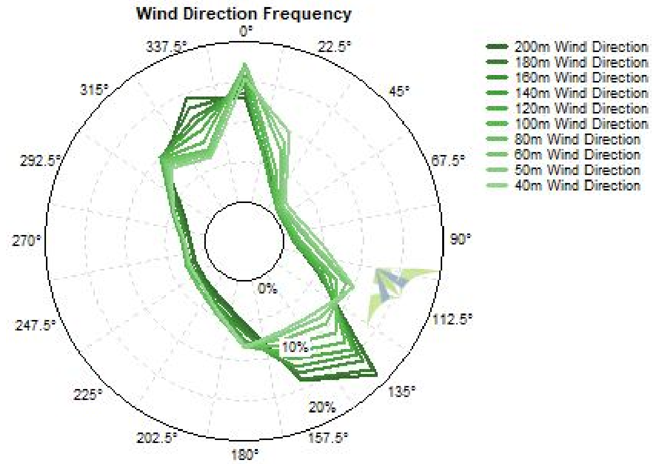
Report Created: 4/11/2018 10:40 using Windographer 3.3.10
Filter Settings: <Unflagged data>

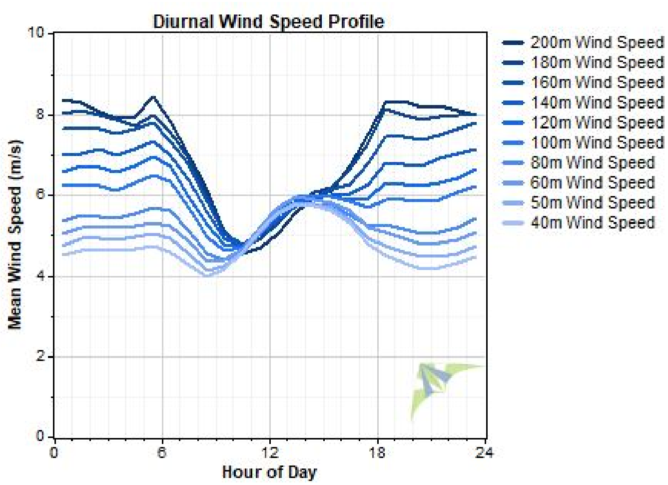
Variable	Value
Latitude	N 21° 8' 50.352"
Longitude	E 92° 4' 32.700"
Elevation	14 m
Start date	7/25/2014 13:30
End date	8/2/2015 10:30
Duration	12 months
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	26.0 °C
Mean pressure	1,009 mbar
Mean air density	1.177 kg/m³
Power density at 50m	120 W/m²
Wind power class	1
Power law exponent	0.209
Surface roughness	0.739 m
Roughness class	3.66

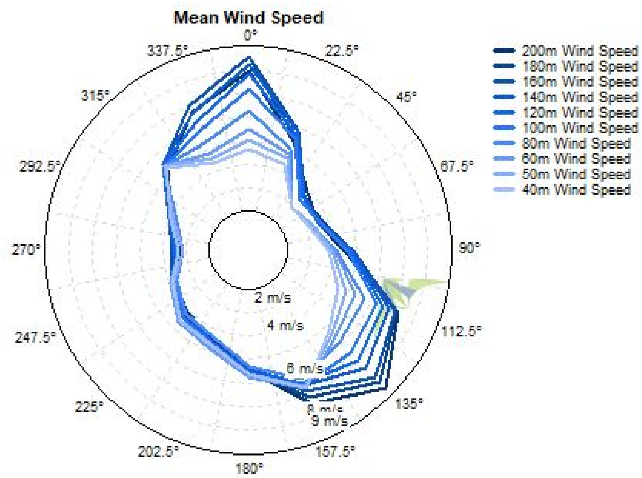


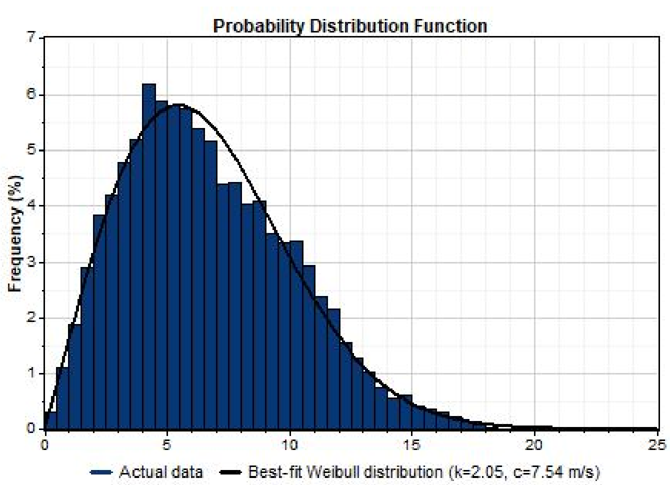
Wind Speed and Direction

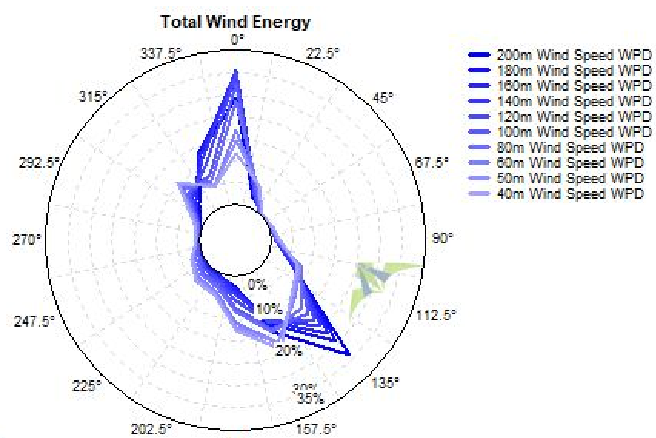




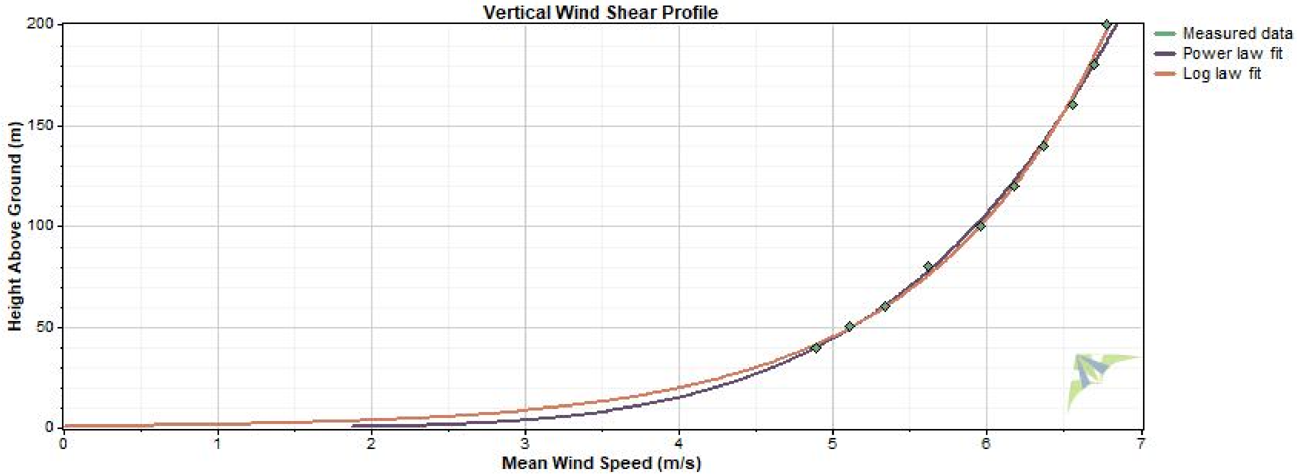


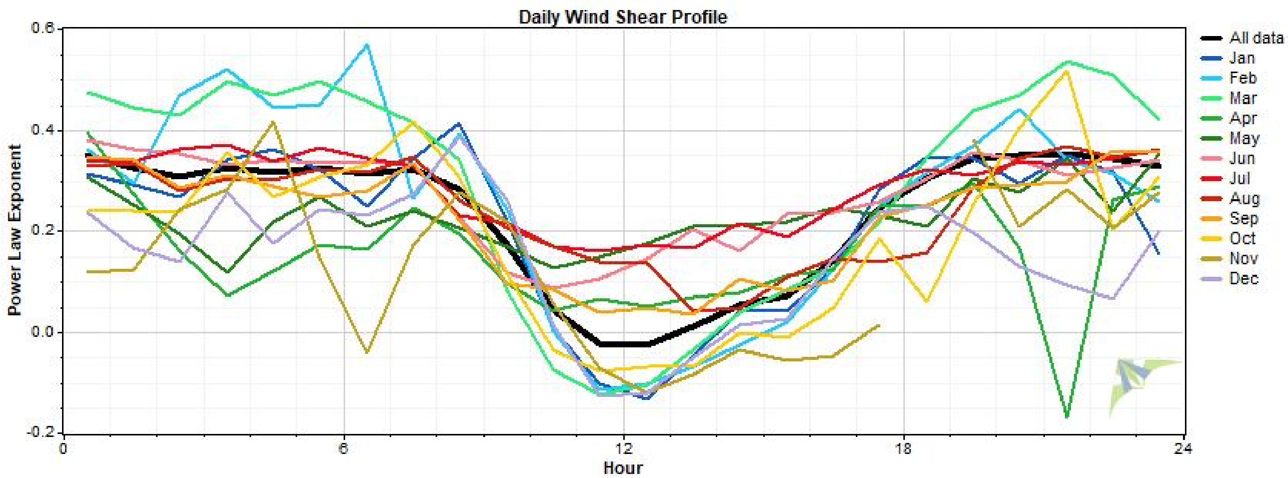


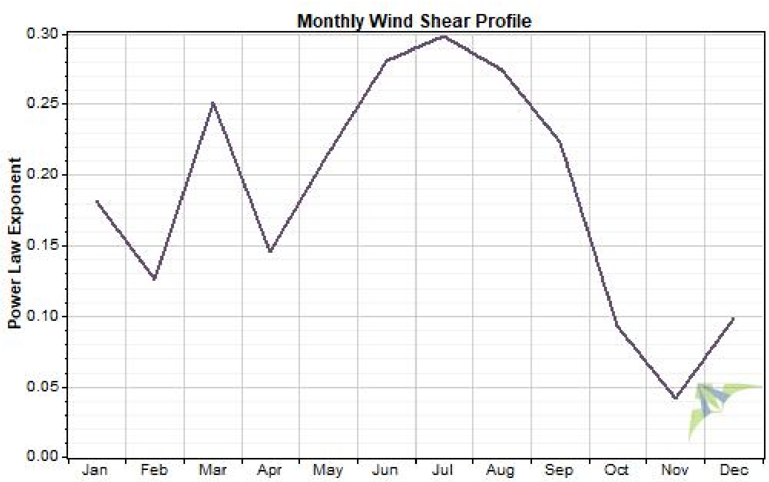


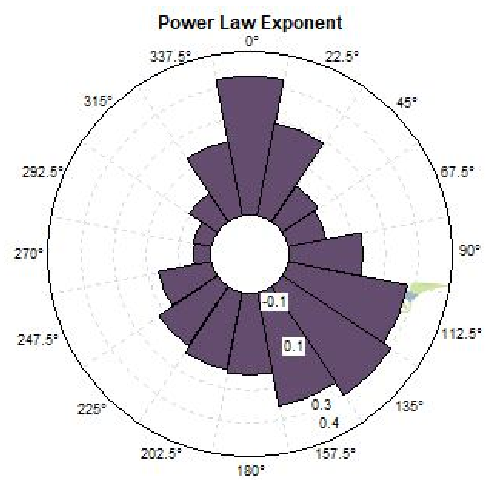


Wind Shear

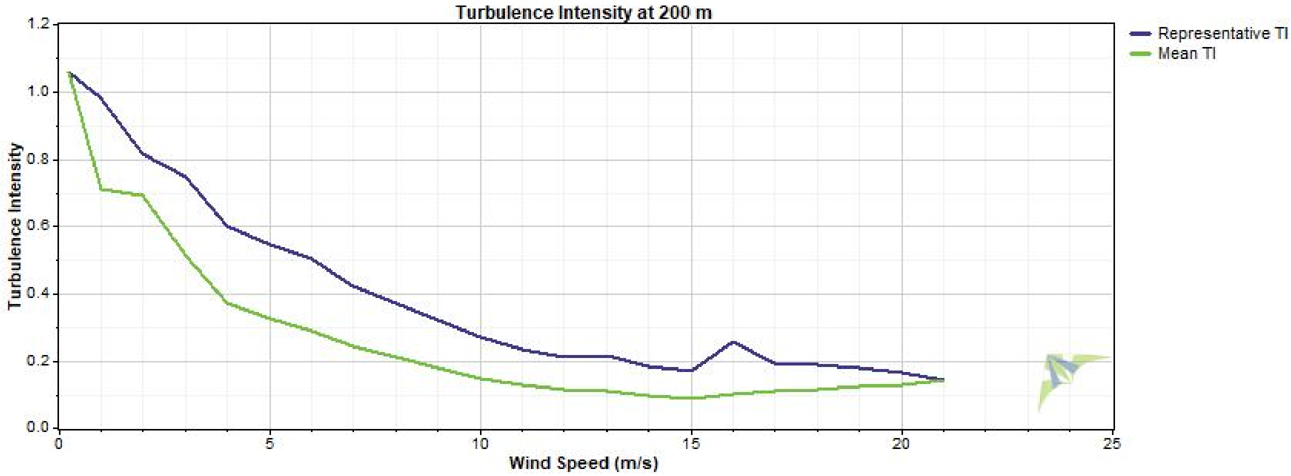

Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
Mean Wind Speed (m/s)
0
50
100
150
200
1
2
3
4
5
6
7

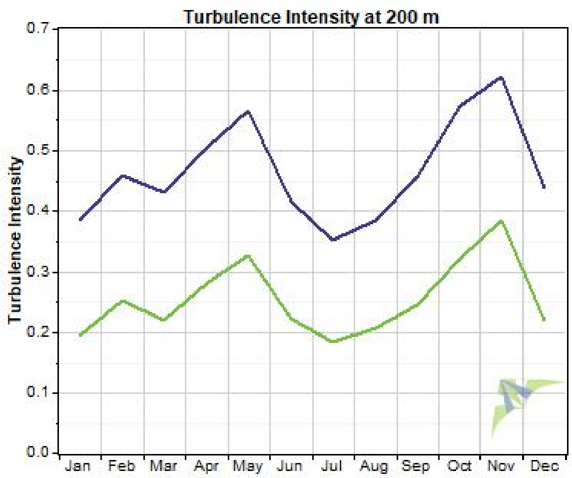

Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
Hour
-0.2
0.0
0.2
0.4
0.6
0
6
12
18
24

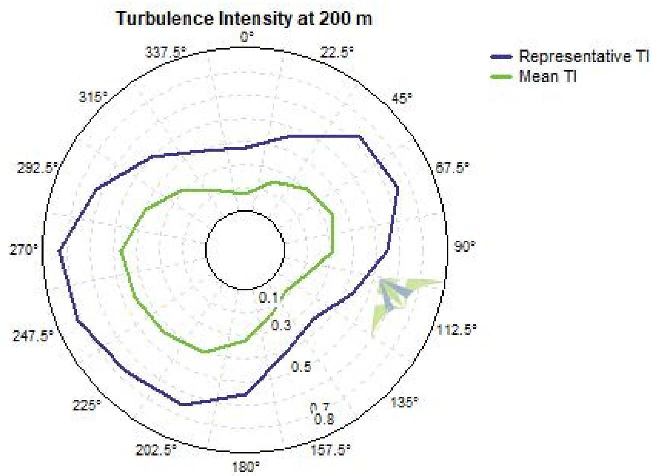

Monthly Wind Shear Profile
Power Law Exponent
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

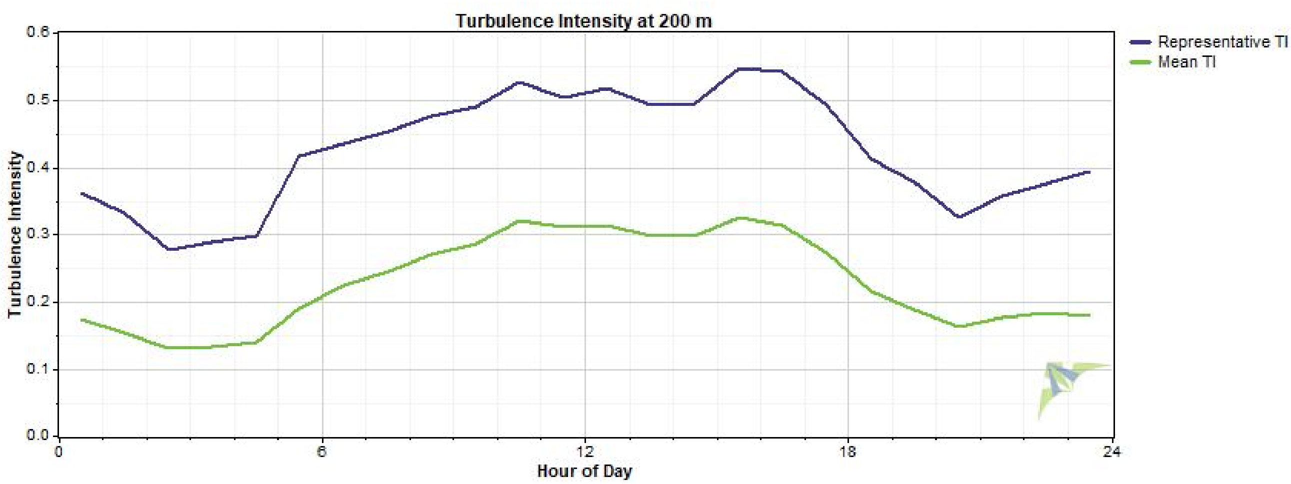

Power Law Exponent
0°
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
202.5°
225°
247.5°
270°
292.5°
315°
337.5°
-0.1
0.1
0.3
0.4

Turbulence Intensity









Data Column Properties

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	40m Wind Direction	°	40 m	53,694	50,865	94.73	66.7	0.0	360.0	114.6
2	40m Wind Speed	m/s	40 m	53,694	50,865	94.73	4.713	0.070	17.730	2.210
3	40m Wind Vert	m/s	40 m	53,694	50,865	94.73	-0.278	-9.050	0.500	1.087
4	Quality (Station Height 40m)	%		53,694	51,077	95.13	98.2	90.0	100.0	1.2
5	50m Wind Direction	°	50 m	53,694	50,348	93.77	59.6	0.0	360.0	114.8
6	50m Wind Speed	m/s	50 m	53,694	50,348	93.77	4.902	0.020	20.010	2.297
7	50m Wind Vert	m/s	50 m	53,694	50,348	93.77	-0.278	-8.970	0.500	1.080
8	Quality (Station Height 50m)	%		53,694	50,760	94.54	98.1	90.0	100.0	1.4
9	60m Wind Direction	°	60 m	53,694	49,795	92.74	57.9	0.0	360.0	114.3
10	60m Wind Speed	m/s	60 m	53,694	49,795	92.74	5.148	0.030	19.790	2.402
11	60m Wind Vert	m/s	60 m	53,694	49,795	92.74	-0.274	-8.950	0.500	1.065
12	Quality (Station Height 60m)	%		53,694	50,409	93.88	98.0	90.0	100.0	1.6
13	80m Wind Direction	°	80 m	53,694	48,147	89.67	48.3	0.0	360.0	112.4
14	80m Wind Speed	m/s	80 m	53,694	48,147	89.67	5.282	0.030	18.310	2.599
15	80m Wind Vert	m/s	80 m	53,694	48,147	89.67	-0.266	-9.040	0.500	1.025
16	Quality (Station Height 80m)	%		53,694	48,994	91.25	97.5	90.0	100.0	2.1
17	100m Wind Direction	°	100 m	53,694	43,176	80.41	51.8	0.0	360.0	110.7
18	100m Wind Speed	m/s	100 m	53,694	43,176	80.41	5.804	0.050	18.610	2.711
19	100m Wind Vert	m/s	100 m	53,694	43,176	80.41	-0.269	-9.140	0.500	0.998
20	Quality (Station Height 100m)	%		53,694	44,666	83.19	97.0	90.0	100.0	2.5
21	120m Wind Direction	°	120 m	53,694	38,645	71.97	51.2	0.0	360.0	108.9
22	120m Wind Speed	m/s	120 m	53,694	38,645	71.97	6.022	0.020	18.660	2.870
23	120m Wind Vert	m/s	120 m	53,694	38,645	71.97	-0.256	-8.880	0.500	0.924
24	Quality (Station Height 120m)	%		53,694	39,915	74.34	96.4	90.0	100.0	2.8
25	140m Wind Direction	°	140 m	53,694	33,172	61.78	58.0	0.0	360.0	108.2
26	140m Wind Speed	m/s	140 m	53,694	33,172	61.78	6.254	0.090	18.690	3.041
27	140m Wind Vert	m/s	140 m	53,694	33,172	61.78	-0.243	-8.830	0.500	0.826
28	Quality (Station Height 140m)	%		53,694	34,272	63.83	95.9	90.0	100.0	2.9
29	160m Wind Direction	°	160 m	53,694	26,555	49.46	69.7	0.0	360.0	108.9
30	160m Wind Speed	m/s	160 m	53,694	26,555	49.46	6.539	0.030	19.750	3.246
31	160m Wind Vert	m/s	160 m	53,694	26,555	49.46	-0.241	-8.800	0.500	0.740
32	Quality (Station Height 160m)	%		53,694	27,678	51.55	95.5	90.0	100.0	3.0
33	180m Wind Direction	°	180 m	53,694	20,819	38.77	83.1	0.0	360.0	108.8
34	180m Wind Speed	m/s	180 m	53,694	20,819	38.77	6.681	0.070	21.590	3.371
35	180m Wind Vert	m/s	180 m	53,694	20,819	38.77	-0.232	-8.530	0.500	0.597
36	Quality (Station Height 180m)	%		53,694	21,870	40.73	95.2	90.0	100.0	2.9
37	200m Wind Direction	°	200 m	53,694	16,279	30.32	96.4	0.0	360.0	109.4
38	200m Wind Speed	m/s	200 m	53,694	16,279	30.32	6.672	0.090	21.100	3.418
39	200m Wind Vert	m/s	200 m	53,694	16,279	30.32	-0.227	-8.020	0.500	0.463
40	Quality (Station Height 200m)	%		53,694	17,219	32.07	94.7	90.0	100.0	2.8
41	40m Wind Turbulence	m/s	40 m	53,694	35,763	66.61	0.14	0.05	1.22	0.09
42	50m Wind Turbulence	m/s	50 m	53,694	36,175	67.37	0.14	0.04	1.35	0.09
43	60m Wind Turbulence	m/s	60 m	53,694	36,885	68.69	0.14	0.04	1.42	0.10
44	80m Wind Turbulence	m/s	80 m	53,694	34,400	64.07	0.15	0.04	1.32	0.11
45	100m Wind Turbulence	m/s	100 m	53,694	33,128	61.70	0.17	0.03	1.71	0.13
46	120m Wind Turbulence	m/s	120 m	53,694	29,850	55.59	0.19	0.03	1.77	0.15
47	140m Wind Turbulence	m/s	140 m	53,694	25,975	48.38	0.21	0.03	1.52	0.16
48	160m Wind Turbulence	m/s	160 m	53,694	21,168	39.42	0.22	0.03	1.40	0.16
49	180m Wind Turbulence	m/s	180 m	53,694	16,671	31.05	0.23	0.03	1.40	0.17
50	200m Wind Turbulence	m/s	200 m	53,694	12,807	23.85	0.24	0.03	1.68	0.17
51	Turbu. Quality (Station Height 40m)	%		53,694	35,890	66.84	98.2	90.0	100.0	1.8
52	Turbu. Quality (Station Height 50m)	%		53,694	36,430	67.85	98.2	90.0	100.0	1.8

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
53	Turbu. Quality (Station Height 60m)	%		53,694	37,231	69.34	98.2	90.0	100.0	1.8
54	Turbu. Quality (Station Height 80m)	%		53,694	34,897	64.99	97.9	90.0	100.0	2.1
55	Turbu. Quality (Station Height 100m)	%		53,694	34,073	63.46	97.3	90.0	100.0	2.5
56	Turbu. Quality (Station Height 120m)	%		53,694	30,710	57.19	96.7	90.0	100.0	2.8
57	Turbu. Quality (Station Height 140m)	%		53,694	26,777	49.87	96.2	90.0	100.0	3.0
58	Turbu. Quality (Station Height 160m)	%		53,694	21,983	40.94	95.7	90.0	100.0	3.0
59	Turbu. Quality (Station Height 180m)	%		53,694	17,462	32.52	95.3	90.0	100.0	3.0
60	Turbu. Quality (Station Height 200m)	%		53,694	13,484	25.11	94.8	90.0	100.0	2.9
61	Ambient Temp	°C	2 m	53,694	51,503	95.92	26.0	13.7	35.9	3.6
62	Barometric Pressure	mbar	2 m	53,694	51,503	95.92	1,008.8	982.6	1,097.6	4.9
63	TiltX	°		53,694	51,503	95.92	-0.3670	-0.6000	0.0000	0.0788
64	TiltY	°		53,694	51,503	95.92	0.4301	0.3000	0.7000	0.0596
65	Azimuth	°		53,694	51,503	95.92	0	0	0	0
66	Humidity	%		53,694	51,503	95.92	77.2	19.0	98.0	11.7
67	Noise Level-A	dB		53,694	51,503	95.92	13.00	5.00	18.30	2.18
68	Noise Level-B	dB		53,694	51,503	95.92	13.01	5.00	18.10	2.18
69	Noise Level-C	dB		53,694	51,503	95.92	12.98	5.00	18.20	2.18
70	PWM Power	W		53,694	51,503	95.92	1.250	0.900	2.400	0.212
71	CPU Power	W		53,694	51,503	95.92	2.348	2.100	3.000	0.123
72	Core Power	W		53,694	51,503	95.92	2.802	2.500	3.100	0.076
73	Solar Power	W		53,694	51,503	95.92	0	0	0	0
74	Modem Power	W		53,694	51,503	95.92	0.036	0.000	0.600	0.076
75	Speaker Power	W		53,694	51,503	95.92	5.13	0.10	21.80	2.99
76	CPU Temp	°C	2 m	53,694	51,503	95.92	0.0	0.0	0.0	0.0
77	Internal Temp	°C	2 m	53,694	51,503	95.92	28.9	14.2	46.7	5.9
78	Heater Temp	°C	2 m	53,694	51,503	95.92	0.0	0.0	0.0	0.0
79	Mirror Temp	°C	2 m	53,694	51,503	95.92	28.3	13.3	62.5	6.9
80	VibrationX	g		53,694	51,503	95.92	0	0	0	0
81	VibrationY	g		53,694	51,503	95.92	0	0	0	0
82	Battery	Volts		53,694	51,503	95.92	12.92	11.60	14.70	0.63
83	Beep Volume	dB		53,694	51,503	95.92	90.1	0.0	100.0	29.8
84	Air Density	kg/m³		53,694	53,694	100.00	1.177	1.129	1.311	0.020
85	200m Wind Speed WPD	W/m²		53,694	16,279	30.32	325	0	5,531	465
86	180m Wind Speed WPD	W/m²		53,694	20,819	38.77	322	0	5,926	463
87	160m Wind Speed WPD	W/m²		53,694	26,555	49.46	298	0	4,539	416
88	140m Wind Speed WPD	W/m²		53,694	33,172	61.78	255	0	3,791	348
89	120m Wind Speed WPD	W/m²		53,694	38,645	71.97	223	0	3,775	291
90	100m Wind Speed WPD	W/m²		53,694	43,176	80.41	195	0	3,725	252
91	80m Wind Speed WPD	W/m²		53,694	48,147	89.67	155	0	3,576	218
92	60m Wind Speed WPD	W/m²		53,694	49,795	92.74	138	0	4,506	212
93	50m Wind Speed WPD	W/m²		53,694	50,348	93.77	121	0	4,658	196
94	40m Wind Speed WPD	W/m²		53,694	50,865	94.73	108	0	3,217	182

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NREL/TP-5000-71007 • September 2018