2-17-12

WIND RESOURCE ASSESSMENT AND TURBINE OUTPUT MODELING

WIND RESOURCE ANALYSIS

In order to calculate the anticipated Annual Energy Production (AEP) of a single wind turbine for the Town of Nantucket, SED used the wind industry standard modeling tool WindPRO, created by EMD International A/S. The models were created by licensed and certified user: Bill Court, SED, USA using WindPRO version: 2.7.486. For this analysis, SED input model data for the following wind turbines and configurations:

- PowerWind 56 900kW (PW900) wind turbine
  - Rotor diameter of 56m (184ft)
  - Hub height of 71m (233ft)
- PowerWind 56 800kW limited (PW800L) wind turbine
  - Rotor diameter of 56m (184ft)
  - Hub height of 71m (233ft)
- Gamesa 850 kW (G58) wind turbine
  - Rotor diameter of 58m (190ft)
  - Hub height of 65m (213ft)
- Vestas RRB 600kW (VRRB) wind turbine
  - Rotor diameter of 47m (154ft)
  - Hub height of 65m (213ft)

In order to accurately calculate the output of the wind turbines, using the WAsP[1] windflow model and methodology the WindPRO model considered:

- A full year (8760hours) of raw meteorological tower wind data validated and correlated by AWS Truepower[2] (AWS) for heights of 50m, 70m, and 90m
- Turbine Sites – (Datum: WGS84*)*
  - Site 1 (Compost Site): 41.276945ºN, 70.164449ºW
- A terrain map of the USGS 7.5 minute Quadrangle-Nantucket, MA

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[1] Wind Atlas Analysis and Application Program (WasP) is the industry-standard wind flow model for predicting wind climates and energy yield including complex terrain, roughness changes and obstacle parameters.
[2] AWS Truepower LLC based out of Albany, New York is an international leader and innovator in renewable energy technology applications, advanced atmospheric modeling and measurement, and engineering services for over 25 years.

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- A roughness map provided by AWS for Nantucket, MA
- The manufacturer provided power curves of the wind turbines

A brief overview of the meteorological tower (designated Mast 0010) is presented in Figure 1.

Figure 1 Met Mast Information

Data Validation Source	AWS Truepower
Measurement Heights	50m - 70m - 90m
Location (WGS84)	41.281ºN, 70.169ºW
Base Elevation	3m
50 Meter Annual Average Wind Speed	7.65 m/s
70 Meter Annual Average Wind Speed	8.52 m/s
90 Meter Annual Average Wind Speed	9.13 m/s

SUMMMARY OF MODEL RESULTS

Once all of the data inputs were completed, the WindPRO model was run via WAsP calculation method with four (4) scenarios for the PowerWind, Gamesa, and Vestas RRB turbines at the identified location. These scenarios consisted of the following:

- Scenario 1: Installation of a single (1) PW 900kW turbine with a hub height of 71m
- Scenario 2: Installation of a single (1) PW 800kW limited turbine with a hub height of 71m
- Scenario 3: Installation of a single (1) Gamesa 850kW turbine with a hub height of 65m
- Scenario 4: Installation of a single (1) Vestas RRB (VRRB) 600kW turbine with a hub height of 65m

Figure 2 is a summary of the results for the models run with the above scenarios.

Figure 2 WindPRO Model Summary

Scenario	Turbine(s)	Hub Height	AEP (MWh)[3]	Mean Wind Speed at Hub Height
1	(1) PowerWind 56* 900kW	71m	3,848.4	8.47 m/s
2	(1) PowerWind 56* 800kW Limited	71m	3,581.6	8.47 m/s
3	(1) Gamesa 850kW	65m	3,654.9	8.21 m/s
4	(1) VRRB 600kW	65m	2,255.7	8.21 m/s

[3] Model outputs for Annual Energy Production (AEP) in Mega Watt Hours (MWh)

The predicted wind resource annual average at 71m hub height approaches that of the IEC Class II standards, which is set at 8.50 m/s. The specific turbine manufacturer would be required to investigate and approve this proposed scenario.

FINAL TURBINE OUTPUT CALCULATIONS

Figure 2 is the energy output assuming that the wind turbine is available 100% of the time and that 100% of the power generated makes it onto the grid or is otherwise consumed on-site. Realistically, a wind turbine experiences downtime for various reasons and not every single unit of power produced at the turbine's generator makes it to the grid or is consumed on-site. The following are considerations used in determining how much power a wind turbine will actually supply.

Assumed Availability: This assumed figure is based on generally accepted performance history for wind turbine size classes and is the percentage of time that the wind turbine would be in working condition. This may be provided by the turbine manufacturer or is otherwise based on the machine's performance history. Availability is the percentage of time that the wind turbine is assumed to be in working condition, able to generate electricity and takes into account the downtime for scheduled maintenance activities and assumes that the wind turbine is properly cared for and maintained by professionals. Availability may be guaranteed by the wind turbine manufacturer.

Electric Line Losses: The power generated at the turbine is transmitted through a certain distance of electric lines and two different transformers before it connects to the grid or is consumed at a facility. Through these conversions, a portion of power will be lost.

General Losses: This category includes downtime due to icing, other weather related events such as high wind speed events and unscheduled maintenance. This loss category reflects an extreme conservative number based upon the islands remote location, and expected increased response time.

Grid Failure: Without the electrical grid operating normally, a wind turbine cannot produce power because it is an asynchronous/induction generator that requires electricity to generate its own electricity. Grid failure takes into account the time when the electrical grid is down due to scheduled or unforeseen events.

A total, assumed loss percentage was calculated taking all of these factors into account (Figure 3).

Figure 3 Assumed Losses

Assumed Availability (98%)	2.0%
Electric Line Losses	2.0%
General Losses	5.0%
Grid Failure	1.0%

Total Losses	10%

The power produced by a turbine as calculated by WindPRO needs to be reduced by 10%. Figure 4 shows the remaining calculations to determine power output of the wind turbines that were examined for the Nantucket site.

Figure 4 Final Output Calculations

Scenario	Turbine(s)	Hub Height	MWh Before Assumed Losses	Final MWh (AEP minus 10% in losses)
1	(1) PowerWind 56 900kW	71m	3,848	3,464
2	(1) PowerWind 56 800kW Limited	71m	3,582	3,223
3	(1) Gamesa 850kW	65m	3,655	3,289
4	(1) VRRB 600kW	65m	2,256	2,030

Probability of Exceedance

Once the final output calculations are made per Figure 4, a probability or uncertainty analysis is a common way to assess the additional uncertainty of a wind project. AWS provided a summary of uncertainty elements for the wind data validation and correlation[4]. For this purpose the uncertainty is defined as standard error for a normal probability distribution. The uncertainty elements that AWS identified are measurement accuracy, representativeness of the monitoring period, project life wind resource, and wind shear. SED then added a power curve uncertainty of 4%, to determine the probability of exceedance which is identified below in Figure 5. This probability table conservatively accounts for associated losses as identified in Figure 3 in addition to wind modeling and turbine power curve uncertainty for a 20 year life period. Note the uncertainty analysis did not take into account the possibility of future reduction to the elevation of the landfill directly north of the project site, reflecting a conservative nature to the following calculations.

[4] "SED_Nantucket_Meteorology_Memo_18-Mar-2011.pdf" Report includes the long-term correlation and associated uncertainties. Prepared by AWS for SED on behalf of the Town of Nantucket, available on the Town's website.

Figure 5 Uncertainty Analysis

20 Year Probability of Exceedance	P50	P75	P84	P90	P95
Scenario 1 (1) PW900 71m Hub AEP (MWh)	3,464	3,326	3,260	3,200	3,125
Scenario 2 (1) PW800L 71m Hub AEP (MWh)	3,224	3,099	3,040	2,986	2,919
Scenario 3 (1) G58 65m Hub AEP (MWh)	3,290	3,159	3,098	3,042	2,971
Scenario 4 (1) VRRB 65m Hub AEP (MWh)	2,030	1,944	1,903	1,866	1,819