SUSTAINABLE ENERGY DEVELOPMENTS™

WIND RESOURCE ASSESSMENT AND TURBINE OUTPUT MODELING

WIND RESOURCE ANALYSIS

In order to calculate the anticipated Annual Energy Production (AEP) of a single and multiple wind turbines 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 from the selected wind turbines - the PowerWind 56 900kW (PW) wind turbine with rotor diameter of 56m (184ft), a hub height of 71m (233ft) and 59m (194ft), along with the GE 1.5MW SLE (GE) wind turbine with a rotor diameter of 77m, a hub height of 80m (262.5ft). Scenarios for the installation of a single GE 1.5MW turbine and single or multiple installations of the PW 900kW turbine for the proposed site at 188 Madaket Rd. were used and are further described below.

In order to accurately calculate the output of the two wind turbines at their specific sites, the WindPRO model considered:

- A full year (8760hours) of raw meteorological tower wind data validated and correlated by AWS Truepower[1] (AWS) for heights of 50m, 70m, and 90m (Detailed report for wind data analysis from AWS can be found in Appendix A)
- Turbine Sites – (Datum: WGS84)
  - Site 1 (Radio Site): 41.280238ºN, 70.169291ºW
  - Site 2 (Compost Site): 41.276945ºN, 70.164449ºW
- A terrain map of the USGS 7.5minute Quadrangle-Nantucket, MA
- A roughness map provided by AWS for Nantucket, MA
- The manufacturer provided power curve of the PW 900kW wind turbine
- The manufacturer provided power curve of the GE 1.5MW wind turbine

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

[1] 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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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 with six (6) scenarios for the PowerWind 56 900kW and GE 1.5MW SLE turbines at the two identified locations. These scenarios consisted of the following:

- Scenario 1: Installation of a single (1) PW 900kW turbine with a hub height of 71m at Site 1
- Scenario 2: Installation of a single (1) PW 900kW turbine with a hub height of 71m at Site 2
- Scenario 3: Installation of a single (1) PW 900kW turbine with a hub height of 59m at Site 2
- Scenario 4: Installation of a single (1) GE 1.5MW turbine with a hub height of 80m at Site 1
- Scenario 5: Installation of two (2) PW 900kW turbines with hub heights of 71m at Sites 1 & 2
- Scenario 6: Installation of two (2) PW 900kW turbines with hub heights of 59m at Sites 1 & 2

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)[2]	Mean Wind Speed at Hub Height
1	(1) PowerWind 56* 900kW	71m	3,939.9	8.56 m/s
2	(1) PowerWind 56* 900kW	71m	3,939.9	8.56 m/s
3	(1) PowerWind 56 900kW	59m	3,566.1	8.05 m/s
4	(1)GE 1.5MW SLE*	80m	6,961.0	8.80 m/s
5	(2)PowerWind 56* 900kW	71m	7,845.2	8.56 m/s
6	(2) PowerWind 56 900kW	59m	7,096.5	8.05 m/s

- **** The predicted wind resource annual average exceeds 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 these proposed scenarios as the average windspeed at hub height exceeds 8.50 m/s.***

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

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.

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[3]

Assumed Availability (98%)	2.0%
Electric Line Losses	2.0%
General Losses	5.0%
Grid Failure	1.0%
Total Losses	**10%**

[3] Wake losses for multiple turbine installations such as in scenarios 5 and 6 are automatically calculated by WindPRO prior to the additional assumed losses identified in Figure 3 above.

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	3,939.9	3,546
2	(1) PowerWind 56 900kW	71m	3,939.9	3,546
3	(1) PowerWind 56 900kW	59m	3,566.1	3,209
4	(1) GE 1.5MW SLE	80m	6,961.0	6,265
5	(2) PowerWind 56 900kW	71m	7,845.2	7,060
6	(2) PowerWind 56 900kW	59m	7,096.5	6,387

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 which can be seen in Appendix A. 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 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.

Figure 5 Uncertainty Analysis

20 Year Probability of Exceedance	P50	P75	P84	P90	P95
Scenario 1 (1) PW 900 71m Hub AEP (MWh)	3,562	3,419	3,351	3,290	3,212
Scenario 2 (1) PW 900 71m Hub AEP (MWh)	3,562	3,419	3,351	3,290	3,212
Scenario 3 (1) PW 900 59m Hub AEP (MWh)	3,224	3,084	3,017	2,957	2,882
Scenario 4 (1) GE 1.5 80m Hub AEP (MWh)	6,293	6,058	5,946	5,845	5,718
Scenario 5 (2) PW 900 71m Hub AEP (MWh)	7,093	6,807	6,672	6,550	6,396
Scenario 6 (2) PW 900 59m Hub AEP (MWh)	6,416	6,137	6,004	5,885	5,734