State of New Jersey
New Jersey Board of Public Utilities (NJBPU)
Bureau of Conservation and Renewable Energy
And
Office of Clean Energy

DE Bay Offshore & Coastal Wind Energy Analysis, Phase 3

(Atmospheric monitoring and analysis in support of Offshore Wind Energy development)

Revised Final Report Submitted By:

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DE Offshore and Coastal Wind Energy Analysis, Phase 3

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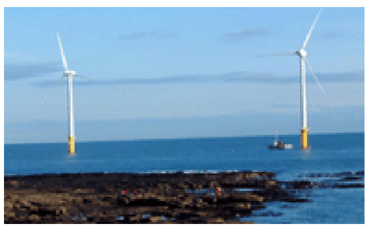
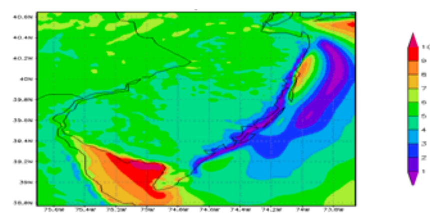
Summary

Adaptive atmospheric monitoring systems along with advanced high-resolution modeling programs are being operated by the Rutgers IMCS Coastal Laboratory for Applied Meteorology (CLAM) in support of New Jersey offshore and coastal wind energy development. The **Phase 3** study domain encompasses the coastal and offshore areas associated with the DE Bay. Through our acquired monitoring and "in-house" modeling efforts, the following results were obtained:

- Offshore areas, especially near the upper portions of the mouth of the DE Bay near the Brandywine Shoal Light, have an Outstanding to Superb wind resource at 50m for sustaining wind power production. The wind resource becomes less significant toward northern portions of the Bay and becomes insignificant near the mouth of the DE River. An adequate wind resource for supporting wind energy development and operations appears to occur offshore near the Ship John Shoal Light. Except for certain coastal areas east and west of the Ship John Shoal Light associated with the respective NJ and DE shorelines, most shoreline areas adjacent to the DE Bay appear to have an inadequate wind resource for supporting effective wind energy applications.



Offshore/Coastal Wind turbines



DE Bay Wind Resource Simulation

- During the summer season, when the dynamics of the atmospheric boundary coupled with the thermal properties of coastal waters and adjacent terrestrial areas are conducive for sea breeze development, prevailing southerly synoptic flow will increase in intensity enhancing the wind resource over the DE Bay. These enhanced southerly flows coincide with peak energy demand and therefore would support effective wind power production that could provide the extra energy that is required during these critical periods.

- As a result of the transition of marine air to terrestrial air in conjunction with the orientation and configuration of the Bay's shorelines in relation to the prevailing synoptic flow, winds within the atmospheric surface layer over the Bay tend to approach their maximum at lower altitudes when compared to downwind and adjacent land areas. Therefore, wind turbine hub heights could be designed to be at 40m to 60m above the surface of the Bay rather than the 60m to 80m hub heights used for most offshore wind energy applications. .

Offshore and coastal wind resource evaluation results can be used to resolve wind farm siting issues and to optimize wind turbine design criteria for the area being evaluated for wind energy development. The results of ***Phase 3*** along with the ***Phase 1 and 2*** portions of the project will be used as a basis for the ***Phase 4: NJ/DE Offshore and Coastal Wind Energy Analysis.***

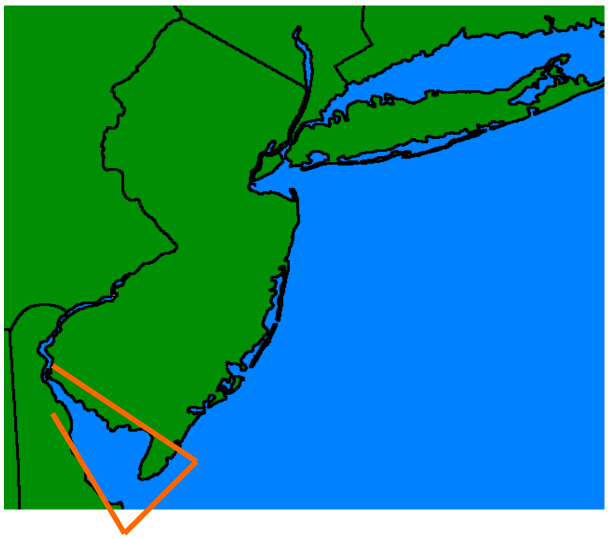
High-resolution computer simulations and diagnostics of the synoptic wind resource and embedded local circulations, along with site-specific monitoring data, are essential components for determining the feasibility and viability for wind energy development for selected offshore and/or coastal locations. Once verified, the diagnostic wind field model could be programmed for prognostic applications that could cost-effectively support wind power production planning and operations.

Disclaimer

The technical information contained in this report regarding the ***DE Bay Offshore and Coastal Wind Energy Analysis*** should only be used for wind energy development applications that conform to the policies, procedures, guidelines, and regulations documented by the NJ Board of Public Utilities (NJBPU) and the New Jersey Department of Protection (NJDEP). The results and implications of this analysis address only the wind resource and do not consider environmental, avian, power transmission/interconnections, regulatory, and/or public issues.

DE Bay Offshore and Coastal Wind Energy Analysis: Phase 3

Using monitoring and high-resolution modeling techniques similar to those used for Phase 2, Phase 3 provides a detailed wind resource analysis of the Delaware Bay and adjacent shoreline areas. The analysis includes the temporal and spatial aspects of the local bay breeze circulation, mesoscale Atlantic sea breeze circulation, and prevailing synoptic flow. The study domain encompasses the NJ and DE coastal areas and offshore waters associated with the Delaware Bay.



Phase 3 Delaware Bay Offshore/Coastal Wind Energy Analysis Area

Wind Resource Monitoring

- Wind and other atmospheric data from three shoreline meteorological towers, including the 100m PSEG Nuclear tower, and two offshore platforms operated by the Coast Guard were used for the wind resource analysis.

- Monitoring stations utilized for the Phase 3 De Bay wind resource analysis are described as follows:

  <u>Shoreline Stations</u>:

  - PSEG Nuclear Plant 100m tower instrumented at 10m, 50m, and 100m. This tower is located on the DE Bay shoreline at the mouth of the DE River near Hancock's Bridge in Lower Alloway Twp, NJ.

  - Cape May 12m tower located north of Cape May Point, NJ on the DE Bay shoreline near the mouth of the DE Bay.

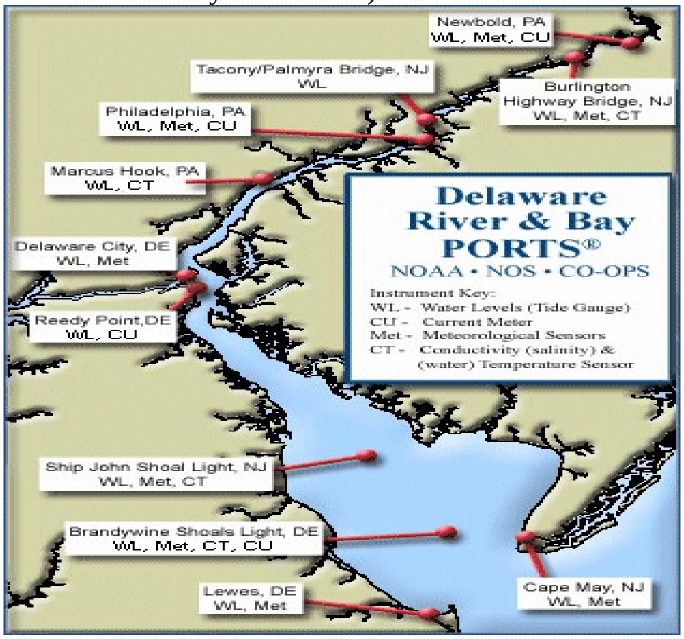
  - Lewes 12m tower located on the DE Bay shoreline near the mouth of the DE Bay at Lewes, DE.

  <u>Offshore Stations:</u>

  - Ship John Shoal Light 16m tower located in the center of the DE Bay ~10 km south of the mouth of the DE River.

  - Brandywine Shoals Light 18m tower located in the center of DE Bay ~10 km north of the mouth of the DE Bay.

- Monitoring station locations used for the Phase 3 analysis are shown on the following map (the PSEG 100m tower is located on the NJ shoreline approximately 5 km to the south and east of the Reedy Point tower):



- **<u>Monitoring analysis and results are summarized as follows</u>:**

  - The four Coast Guard (NOAA) monitoring site data sets (Lewes, Cape May, Brandywine Shoals Light, and Ship John Shoal Light) used for the analysis consisted of two years of data (2003-2004) for each site averaged for 6-minute intervals.

  - The PSEG tower data set consisted of five years of data (1999-2004) averaged for 1-minute intervals.

  - Winds are monitored above mean sea level (msl) at 12m for both the Lewes and Cape May sites, 16m at the Ship John Shoal Light site, and 18m at the Brandywine Shoal Light site. Winds at the PSEG Nuclear tower site are monitored at the 10m, 50m and 100m levels.

  - As a result of decreasing friction at higher altitudes, wind speeds tend to increase with height. To determine the wind intensities at heights associated with offshore and coastal wind turbines (hub and blade heights) the 1/7th power law is generally used as the "standard" for calculating wind speeds at altitudes above sensor heights. The wind profile equation is expressed as follows:

$$\mathbf{v_2 = v_1\ [z_2/z_1]^{\alpha}}$$

where,
$\mathbf{v_2}$ = the calculated wind speed.
$\mathbf{z_2}$ = the height of the calculated wind speed.
$\mathbf{v_1}$ = the observed speed.
$\mathbf{z_1}$ = the wind sensor height
α = the wind shear exponent.

- Winds within the surface boundary layer (sfc to ~200m) over offshore and coastal areas approach their maximum speeds at altitudes significantly lower than winds over land areas. This is a result of less frictional effects relevant to the relatively flat surface features and the overlying stable marine air associated with large water bodies (e.g., the DE Bay) and their adjacent shorelines (e.g., NJ and DE shorelines). This assumption does not apply to irregular shorelines with significant variations in terrain heights and roughness features. Based on the analysis of the PSEG 100m tower data, the $1/7^{th}$ wind shear exponent may not be applicable for offshore and coastal areas associated with the DE Bay. The data suggests that the wind shear exponent from 10m to 50m should be 0.22 and from 50m to 100m should be 0.083. Therefore, the PSEG tower data provides preliminary support for the preceding assumption. Furthermore, the wind shear from 50m to 100m does not appear to be significant. ***Consequently, to realize the full potential of the wind resource over and adjacent to the DE Bay, wind turbines could possibly be designed for lower generator hub heights than are generally considered to be optimum hub heights (e.g., ≥60m) for offshore wind energy applications.***

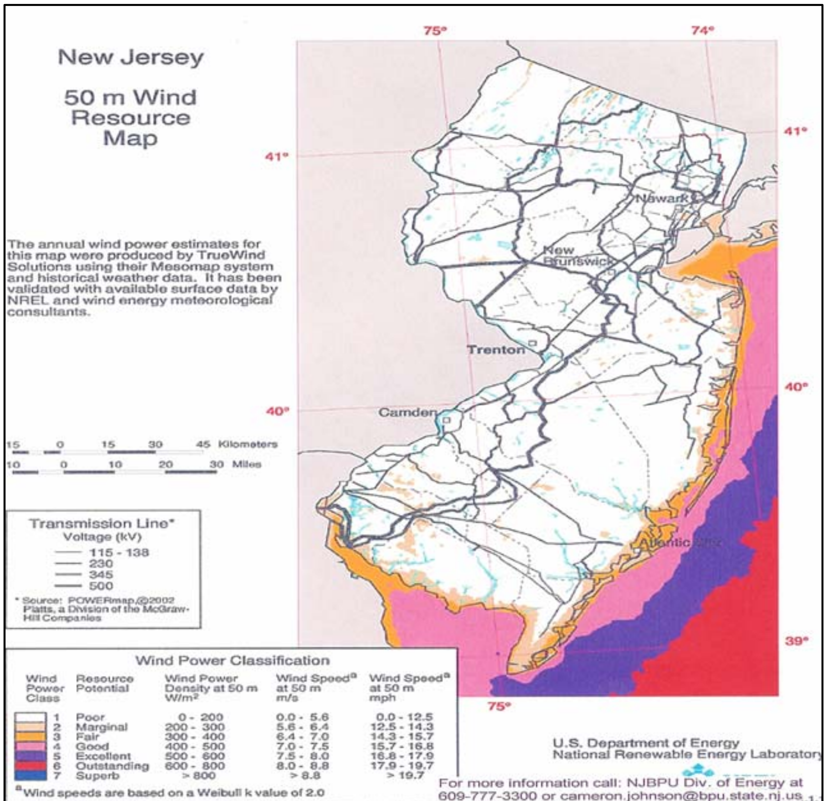
  NOTE: No conclusive evidence regarding wind power potential can be inferred from the estimated coastal wind shear exponent until additional wind profile assessments using valid coastal "tall tower" and SODAR data are analyzed. This analysis will be conducted during Phase 4: NJ/DE Offshore and Coastal Wind Energy Analysis. The 0.22 wind shear exponent will be either verified or adjusted based on the results of the analysis. This wind shear analysis will result in the development of new wind shear exponents or possibly a new wind profile algorithm(s) for NJ and DE coastal areas.

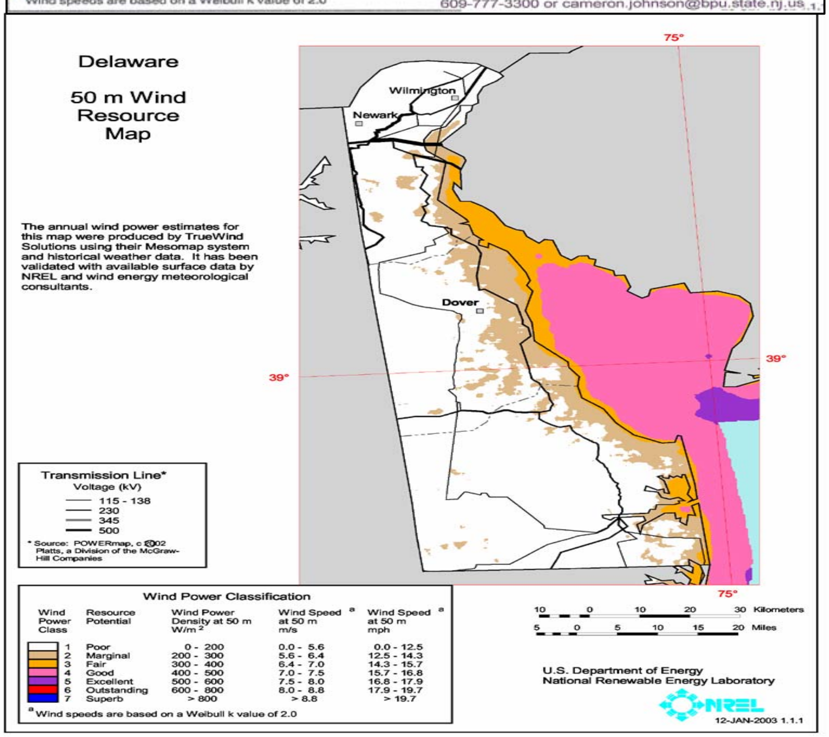
- Using the wind shear exponents derived from the PSEG tower data analysis and the standard $1/7^{th}$ wind shear exponent, winds at 50m and 100m were calculated for the referenced DE Bay monitoring sites. To ensure that the data was representative and to account for potential perturbations during certain monitoring periods ranging from months to years, the data were subjected to Monte Carlo simulations. Approximately 1000 trials for each of the selected monitoring sites were performed. Simulations were run for the PSEG site, which was the only site with multiple monitoring heights, and for those sites that exhibited average 50m wind speeds > 7.0 m/sec (Wind Power Class of Good or better) using both the standard $1/7^{th}$ (0.143) wind shear exponent and the experimental 0.22 coastal wind shear exponent.

- Average winds derived from the actual monitoring data along with Monte Carlo simulations for both Normal and Weibull wind speed distributions and associated wind power classifications are presented in Table 1. ***Although, the Weibull distribution is generally used to determine wind speed parameters, the analysis indicates that offshore and coastal wind speed distributions associated with the DE Bay are more realistically represented by the Normal distribution.*** Simulation results are presented in the attached EXCEL documents.

Table 1: Rutgers CLAM DE Bay Wind Resource Monitoring **Monitoring Site**	**Base-Sensor Ht. Above msl.**	**Mid-Sensor or Calculated Ht. Above msl.**	**Upper-Sensor or Calculated Ht. Above msl**	**Wind Power Class @50m**	**Avg (Prevailing) Wind Dir.**
PSEG Tower (NJ) (NJ shoreline, mouth of DE River)	**10m**	***50m***	**100m**		
Data Average	3.8 m/sec	***5.4 m/sec***	5.8 m/sec	Class 1, Poor	198°, SSW
Simulation: Normal Distribution	3.8 m/sec	***5.4 m/sec***	5.5 m/sec	Class 1, Poor	198°, SSW
Simulation: Weibull Distribution	3.9 m/sec	***5.5 m/sec***	5.6 m/sec	Class 1, Poor	198°, SSW
Cape May, NJ (NJ shoreline, north of Cape May Point)	**12m**	***50m***	**100m**		
Data Average	4.3 m/sec	***5.3 m/sec, 1/7 exponent; 5.9 m/sec, 0.22 coastal exponent***	5.8 m/sec, 1/7 exponent; 6.2 m/sec, coastal exponent	Class 1 to 2, Poor to Marginal	194°, SSW
Lewes, DE (DE shoreline)	**12m**	***50m***	**100m**		
Data Average	5.2 m/sec	***6.4 m/sec, 1/7 exponent; 7.1 m/sec, 0.22 coastal exponent***	7.0 m/sec, 1/7 exponent; 7.5 m/sec, coastal exponent	Class 3, Fair	177°, SSE
Ship John Shoal (NJ) (Offshore, south of mouth of DE River)	**16m**	***50m***	**100m**		
Data Average	5.8 m/sec	***6.8 m/sec, 1/7 exponent; 7.4 m/sec, 0.22 coastal exponent***	7.5 m/sec, 1/7 exponent; 7.8 m/sec, coastal exponent	Class 3 to 4, Fair to Good	218°, SW
Brandywine Shoal (DE) (Offshore, mouth of DE Bay)	**18m**	***50m***	**100m**		
Data Average	7.1 m/sec	***8.2 m/sec, 1/7 exponent; 8.9 m/sec, 0.22 exponent***	9.1 m/sec, 1/7 exponent; 9.4 m/sec, coastal exponent	Class 6 to 7, Outstanding to Superb	204°, SSW
Simulation: Normal Distribution	6.9 m/sec	***8.6 m/sec***	9.5 m/sec	Class 6, Outstanding	
Simulation: Weibull Distribution	8.0 m/sec	***10.1 m/sec***	10.7 m/sec	Class 7, Superb	

- Generally, our (Rutgers CLAM) monitoring analysis is in agreement with the wind resource parameters portrayed by NREL's NJ and DE TrueWind maps. These maps are depicted below:





- The DE Bay Wind Power Classification and Wind Resource Potential as depicted by the NREL Wind Maps are summarized in Table 2:

Table 2: NREL NJ/DE Wind Map Analysis		
Location	**Wind Power class**	**Wind Resource Potential**
DE Bay offshore waters	4	Good, 7.0 to 7.5 m/sec
NJ/DE coastal/shoreline areas	3	Fair, 6.4 to 7.0 m/sec
Egg Island Point and adjacent shoreline areas in the vicinity of Port Norris, NJ	3	Fair, 6.4 to 7.0 m/sec
Eastern section of the Mouth of the DE Bay south of Cape May Point, NJ	5	Excellent, 7.5 to 8.0 m/sec
Inland areas adjacent to the DE Bay and upstream of the Mouth of the DE River	1 to 3	Poor to Fair, <5.6 to 7.0 m/sec

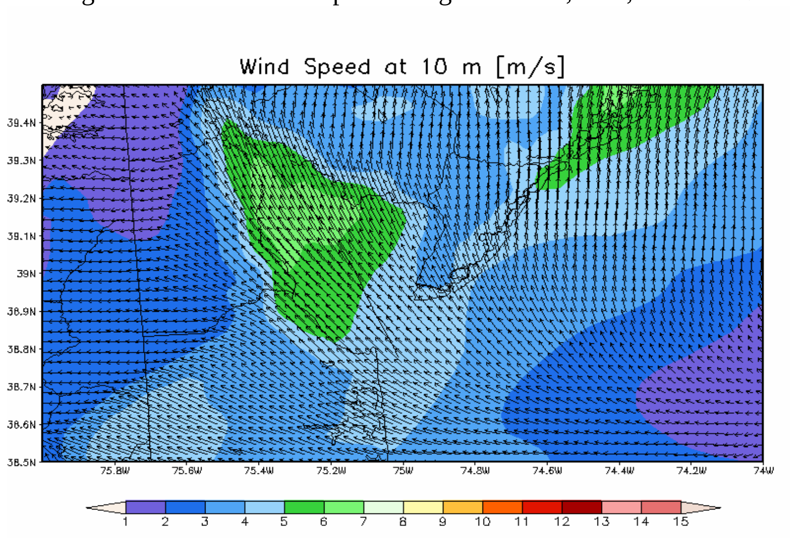
Wind Resource Modeling

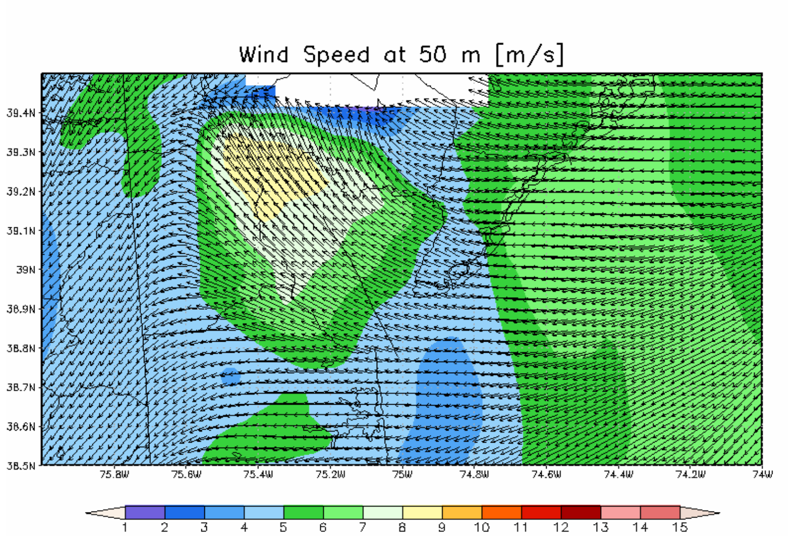
- To make the most effective use of our monitoring results along with the wind resource parameters portrayed by the NREL NJ and DE Wind maps, DE Bay wind field simulations were conducted using the Weather Research Forecast (WRF) model run at 1km to 2km grid resolutions. Although, site-specific monitoring data provides "actual" information pertinent to the wind resource at a designated location, high-resolution wind field modeling is a necessary compliment to the monitoring data for resolving the three-dimensional wind resource over the entire domain of interest. This concept holds especially true for offshore areas where wind monitoring is minimal or non-existent. The monitoring analysis supplemented by the modeling analysis identifies potential Primary and Secondary DE Bay locations for wind energy development.

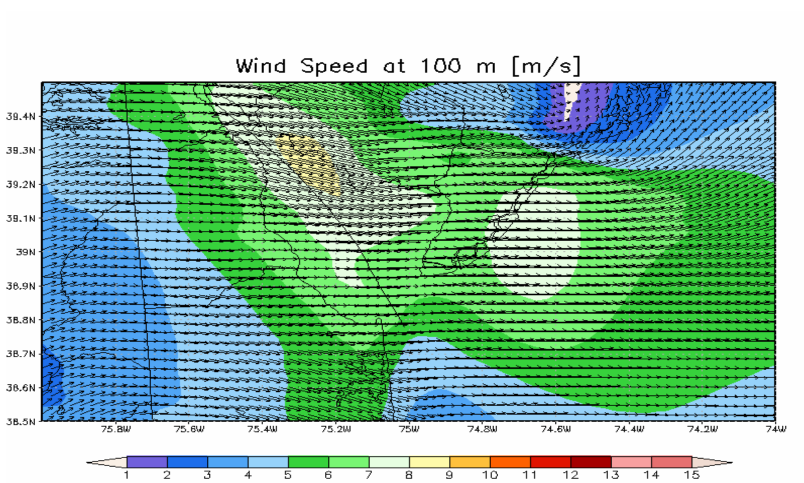
- Model runs indicate that the wind resource over certain offshore areas and coastal areas along the DE Bay would be very productive for wind energy development during certain local and synoptic flow occurrences. The most prevalent flows that are conducive for wind power production exhibit a relatively high frequency of occurrence and are defined as follows:

  - ***Prevailing SW to SSE synoptic flow regimes that occur with a frequency of ~45% over an annual period, which includes both the primary (summer) and secondary (winter) peak energy demand periods.***

- The prevailing annual average DE Bay SW to SSE flow patterns are shown in the following simulations for atmospheric heights of 10m, 50m, and 100m:







- ***The preceding simulations provide support for the assumption that winds approach their maximum speeds at lower heights within the marine surface layer when compared to maximum wind speed heights that occur within the overland boundary layer. Furthermore, model simulations suggest surface boundary layer winds approach their maximum intensity near the 50m height with nearly the same or lower wind speeds estimated at the 100m level (refer to the preceding wind field simulations). After analyzing and comparing model results with monitoring data, it appears that the model grids are spatially out of phase. To enable the model results to be "in-synch" with monitoring results, model grids need to be shifted to the east ~10km and to the south ~20km.***

  Once the spatial adjustments were applied, the simulations show that maximum winds occur near the northern portion of the mouth of the DE Bay near the vicinity of the Brandywine Shoal site. Other areas with an adequate wind resource for wind energy applications appear to be the offshore area associated with the Ship John Shoal site; southern and eastern portions of the Bombay Hook National Wildlife Refuge, which is west and north of the Ship John Shoal site along the DE shoreline; DE shoreline areas directly west of the Brandywine Shoal site; and the area defined by the Egg Island Wildlife Management Area along the NJ shoreline extending eastward toward the Maurice River near Port Norris, NJ.

- Adjusted WRF model simulations for average annual wind speeds are compared with actual monitoring data and resultant monitoring data subjected to Monte Carlo simulation techniques. The comparisons for wind heights at base-level, mid-level, and upper-level surface boundary layer heights are presented respectively in Tables 3a, 3b, and 3c.

Table 3a: DE Bay Wind Modeling vs. Monitoring Results (Base-Level)			
Site	**Wind Level (height); Monitored Speed**	**Monte Carlo Monitoring Simulation**	**WRF Model Simulation**
PSEG Tower (NJ)	10m; 3.82 m/sec	10m; 3.84 m/sec	10m; 3.0 to 4.0 m/sec
Cape May, NJ	12m; 4.3 m/sec	NA	10m; 4.0 to 5.0 m/sec
Lewes, DE	12m; 5.2 m/sec	NA	10m; 4.5 to 5.5 m/sec
Ship John Shoal (NJ)	16m; 5.8 m/sec	NA	10m; 5.0 to 6.0 m/sec
Brandywine Shoal (DE)	18m; 7.10 m/sec	18m; 6.91 m/sec	10m; 6.0 to 7.0 m/sec

Table 3b: DE Bay Wind Modeling vs. Monitoring Results (Mid-Level)				
Site	**Wind Level (height); Monitored Speed**	**Monte Carlo Monitoring Simulation**	**WRF Model Simulation**	**Wind Power Class, Wind Resource Potential**
PSEG Tower (NJ)	50m; 5.43 m/sec	50m; 5.45 m/sec	50m; 4.0 to 6.0 m/sec	1 to 2, Poor to Marginal
Cape May, NJ	50m; 5.89	NA	50m; 5.5 to 6.5 m/sec	2, Marginal
Lewes, DE	50m; 7.12 m/sec	NA	50m; 6.0 to 7.5 m/sec	3 to 4, Fair to Good
Ship John Shoal (NJ)	50m; 7.45 m/sec	NA	50m; 7.0 to 8.0 m/sec	4 to 5, Good to Excellent
Brandywine Shoal (DE)	50m; 8.89 m/sec	50m; 8.65 m/sec	50m; 8.0 to 9.0 m/sec	6 to 7, Outstanding to Superb

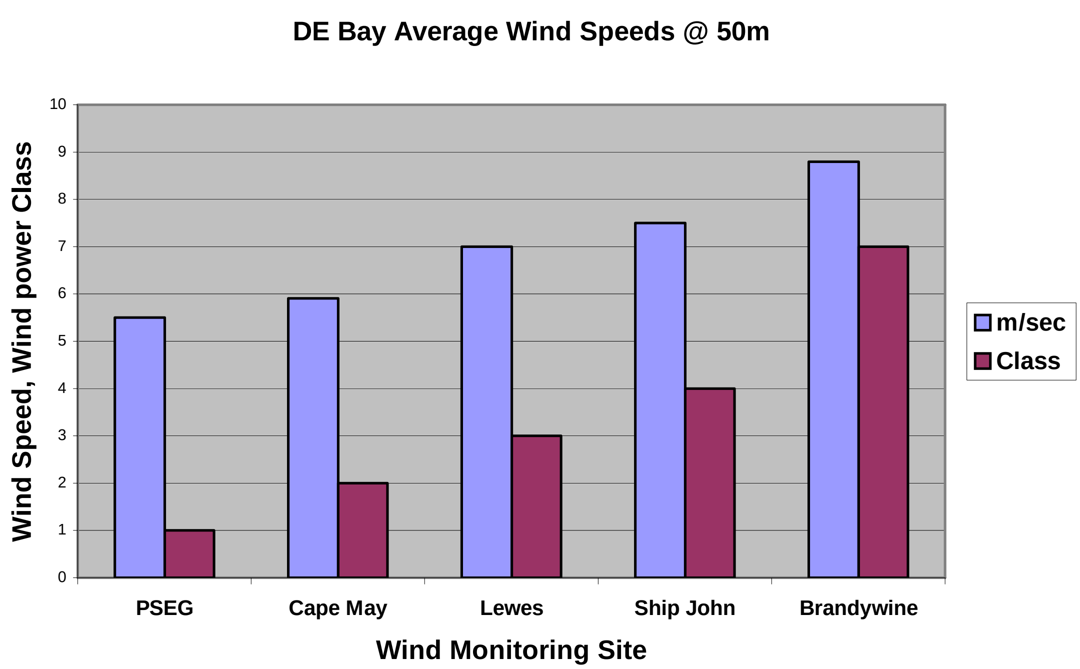
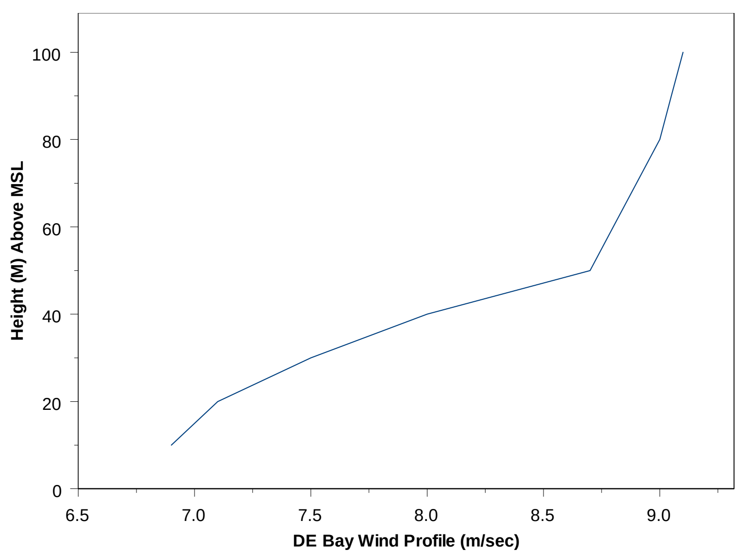


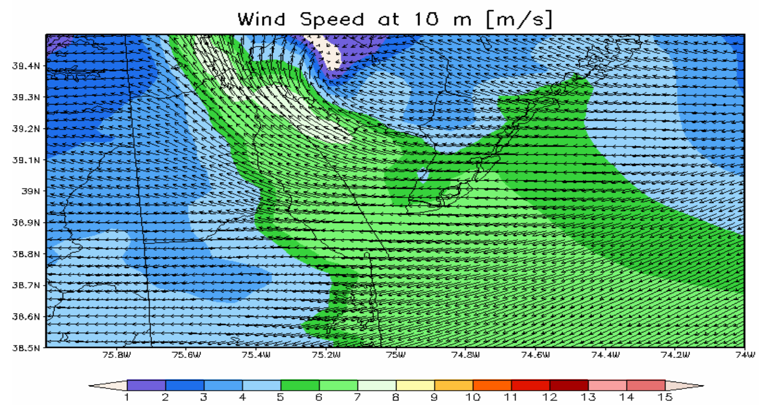
Table 3c: DE Bay Wind Modeling vs. Monitoring Results (Upper-level)			
Site	**Wind Level (height); Monitored Speed**	**Monte Carlo Monitoring Simulation**	**WRF Model Simulation**
PSEG Tower (NJ)	100m; 5.75 m/sec	100m; 5.54	100m; 5.5 to 6.5 m/sec
Cape May, NJ	100m; 6.20 m/sec	NA	100m; 6.0 to 7.0 m/sec
Lewes, DE	100m; 7.50 m/sec	NA	100m; 6.0 to 7.0 m/sec
Ship John Shoal (NJ)	100m; 7.80 m/sec	NA	100m; 7.0 to 8.0 m/sec
Brandywine Shoal (DE)	100m; 9.40 m/sec	100m; 9.1 m/sec	100m; 8.0 to 9.0 m/sec

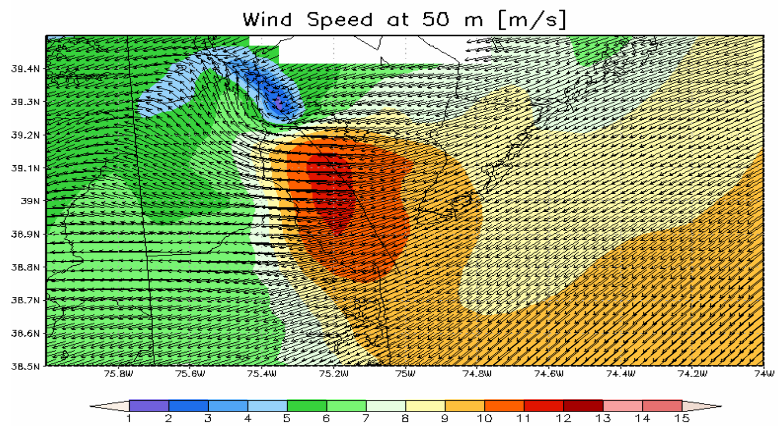
- Using the Brandywine Shoal site data to represent the offshore wind resource near the mouth of the DE Bay, a "typical" wind speed profile was developed and presented in the following graph:

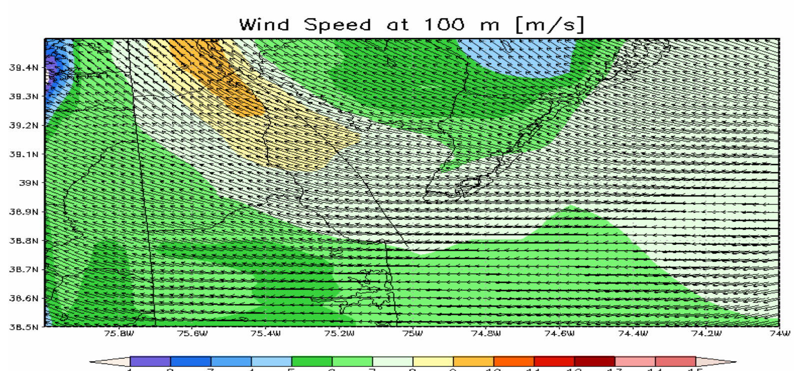


- ***Southerly Enhancement occurs with a frequency of ~25% when sea surface temperatures (SSTs), marine boundary layer air, and adjacent terrestrial thermal properties are favorable for intense sea breeze development. Prevailing synoptic flows from the SW to SSE, will enhance a well-developed Atlantic Sea Breeze producing an intense wind resource over central and southern portions of the DE Bay and adjacent NJ and DE coastal areas. These enhanced flow patterns occur frequently during the period from late spring through early fall, which coincides with the summer season when energy demand approaches peak levels.***

- WRF model runs showing wind fields at 10m, 50m, and 100m during southerly flow enhancement are presented in the following simulations:





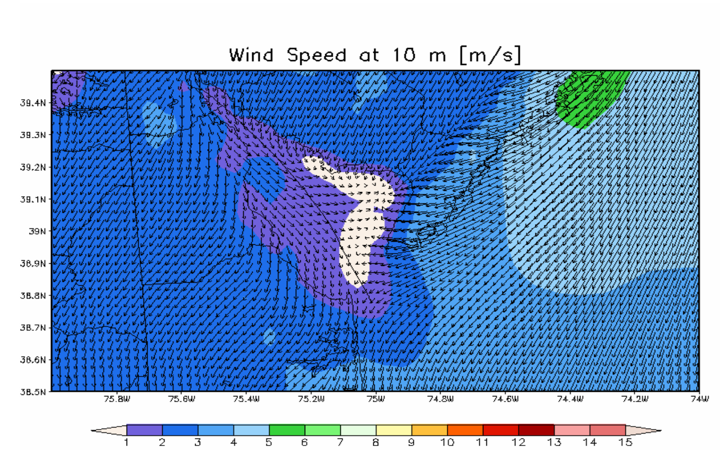


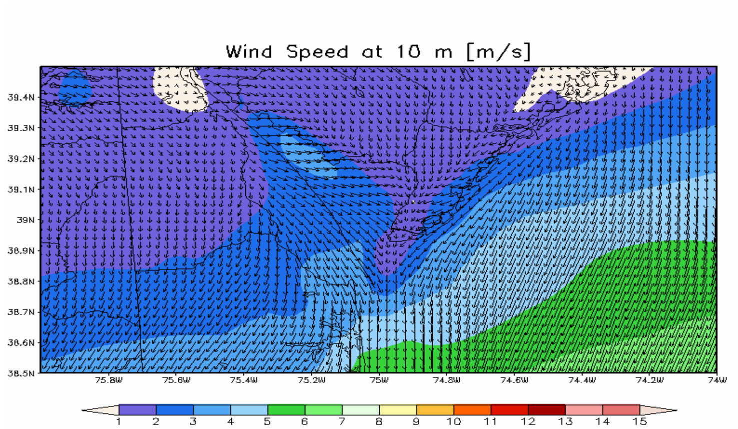
- WRF Model results shown in the preceding wind field simulations for southerly flow enhancement are summarized in Table 4.

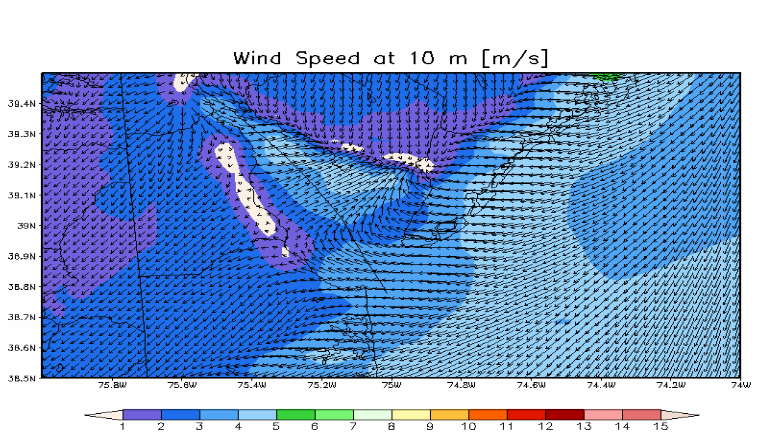
Table 4: WRF Model Wind Field Simulation Results for DE Bay Southerly Wind Flow Enhancement	**Atmospheric Surface Boundary Layer Height**			
Monitoring Site	**10m Wind Speed**	**50m Wind Speed**	**Wind Power Class, Wind Resource Potential @50m**	**100m Wind Speed**
PSEG Tower (NJ)	4.0 to 5.0 m/sec	5.0 to 6.5 m/sec	1 to 2, Poor to Marginal	6.0 to 7.0 m/sec
Cape May, NJ	5.0 to 6.0 m/sec	7.5 to 8.5 m/sec	6 to 7, Outstanding to Superb	7.0 to 8.0 m/sec
Lewes, DE	5.5 to 6.5 m/sec	7.5 to 9.0 m/sec	6 to 7, Outstanding to Superb	7.5 to 8.5 m/sec
Ship John Shoal (NJ)	7.0 to 8.0 m/sec	8.5 to 9.5 m/sec	6 to 7, Outstanding to Superb	9.0 to 10.0 m/sec
Brandywine Shoal (DE)	7.0 to 8.0 m/sec	10.0 to 11.0 m/sec	7, Superb	9.0 to 10.0 m/sec

- Certain atmospheric flows over the DE Bay area are not conducive for wind energy development. These flow regimes have a frequency of occurrence of ~30% and are defined as follows:
    - Northwesterly synoptic flow.
    - Northeasterly synoptic flow.
    - Opposing Atlantic Sea Breeze and DE Bay Breeze circulations.

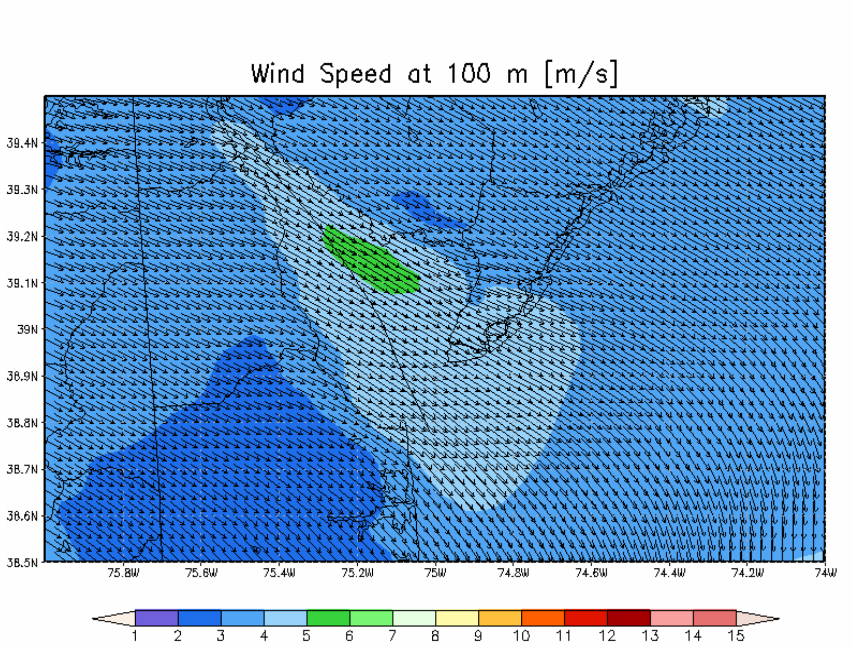
- ***Although, wind intensities during each of the preceding flow patterns can be significant (> 8.0 m/sec) and could be associated with wind regimes (e.g., Northeasters and rapidly moving Artic or Canadian High pressure systems) that potentially result in the most intense winds over the DE Bay area, durations of winds at these intensities are not sustained over time periods long enough for effective wind energy applications***. WRF model runs of these wind flow patterns are shown in the following respective simulations of northwesterly flow (averaged over 72-hrs.), northeasterly flow (averaged over 72-hrs.), and when the Atlantic Sea Breeze and DE Bay Breeze over concurrent temporal periods.







- The preceding “low” intensity wind field simulations indicate that 10 m wind speeds over the DE Bay and adjacent shorelines range from < 1.0 m/sec to 5 m/sec. To determine the DE Bay wind resource potential at higher atmospheric surface boundary layer heights, WRF model runs were run and compiled for the more prevalent northwest flow case at 100m. At this upper level, average wind speeds only range from 3 to 6 m/sec for respectively shoreline and offshore areas. ***Wind speeds associated with these flow scenarios can be equated to a Wind Power Class ranging from 1 to 2 with a Wind Resource Potential ranging from Poor to Marginal. A composite of the associated WRF model runs is shown in the following wind field simulation:***



DE Bay Offshore/Coastal Wind Resource Analysis Results and Implications:

- Prevailing winds north of the DE Bay area interacting with prevailing winds south of DE Bay area, along with the orientation and configurations of the NJ and DE shorelines in relation to the wind resource, produce the unique and complex wind flow patterns discussed in this analysis.

  - ***Resultant prevailing winds for the DE Bay area range from SW to SSE over an annual period with an ~45% frequency-of-occurrence***. ***Prevailing winds approaching the DE Bay will interact with the generally convex shorelines of both the NJ and DE Atlantic coastal areas that are adjacent to the mouth of the Bay. This will cause confluent winds resulting in an increase in offshore wind speeds. As the Bay narrows downwind toward the mouth of the DE River, roughness characteristics associated with land features on both the NJ and DE sides of the Bay, along with the transition from marine air to terrestrially modified air, will cause offshore winds to decrease in intensity. Depending on shoreline configurations and their orientation to the wind, certain shoreline areas could experience an increase or a decrease in wind intensities.***

  - ***Well-developed Atlantic Sea Breeze events with winds from the SSE to SSW that occur concurrently with SSE to SW synoptic flows will enhance the DE Bay wind resource during the late spring through early fall with an ~25% frequency-of-occurrence.***

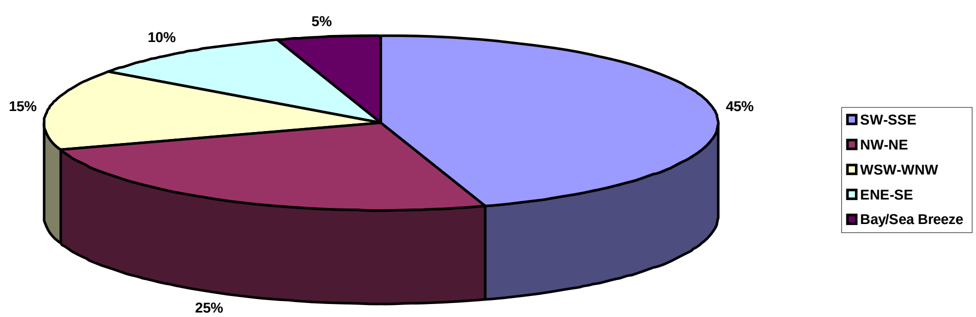
- ***During northerly flow regimes (winds from the NW to NE), upwind topographical characteristics coupled with the DE Bay shoreline configurations cause winds to diverge near the mouth of the DE River downwind over the Bay causing wind speeds to decrease. These wind flow patterns occur with an ~30% frequency-of-occurrence.***

- ***The concurrence of the DE Bay Breeze with the Atlantic Sea Breeze will produce decreasing winds in the vicinity of their convergence. Also, as a result of the opposing air flows, momentum transfer will be less causing wind speeds within the respective Bay and Sea Breeze circulations to decrease. This thermally driven mesoscale event will occur with an ~5% frequency-of-occurrence.***

- ***Winds from the WSW to WNW and from the ENE to SE have a combined frequency-of-occurrence of ~25%.***

- The following diagram defines the DE Bay wind regimes and their frequency-of-occurrence:

DE Bay Wind Regime Frequencies



- ***The Monitoring and modeling analysis of the DE Bay wind regimes reveals that the offshore wind resource is favorable for efficient and effective wind power production, especially near the northern portions of the mouth of the Bay. Depending on wind vector orientation and shoreline configurations, certain NJ and DE coastal areas adjacent to the Bay appear to be adequate for supporting wind energy operations. Furthermore, the DE Bay wind resource is enhanced during the concurrence of synoptic southerly flow and intense Atlantic Sea Breeze development. This wind resource enhancement coincides with the summer peak energy demand.***

Based on the results of our analysis, the following DE Bay offshore and coastal areas could be considered potential candidates for wind energy development:

DE Bay Areas with a *high* Wind Resource Potential; these areas could be considered as *primary* areas for possible wind energy development:

- Offshore area at Brandywine Shoal Light.

- Offshore areas associated with northern portions of the mouth of the Bay adjacent to the Brandywine Shoal Light.

- The annual average wind resource over these areas generally has wind speeds >8.0 m/sec @50m that equates to a Wind Power Class ranging from 6 to 7 with a Wind Resource Potential of Outstanding to Superb.

DE Bay Areas with an *adequate* Wind Resource Potential; these areas could be considered as *secondary* or alternative areas for possible wind energy development:

- Offshore areas at and adjacent to the Ship John Shoal Light.

- NJ coastal areas associated with the Egg Island Wildlife Management Area eastward to the Maurice River near Port Norris, NJ.

- DE coastal areas associated with the southern and eastern portions of the Bombay Hook Wildlife Refuge.

- The annual average wind resource over the areas suggested as (secondary) sites for potential wind energy development has wind speeds ranging from 7.0 to 8.0 m/sec @50m that equates to a Wind Power Class ranging from 4 to 5 with a Wind Resource Potential of Good to Excellent.

- ***The results and implications of the Phase 3: DE Bay Offshore and Coastal Wind Energy Analysis address only the wind resource and do not consider environmental, avian, power transmission/interconnections, regulatory, and/or public issues. The results of this study will be further analyzed and verified during Phase 4: NJ/DE Offshore and Coastal Wind Energy Analysis, which will encompass the entire NJ and DE coasts and offshore waters out to 50 nautical miles.***