Maryland's Offshore Wind Power Potential

A Report Sponsored by the Abell Foundation and Prepared by the University of Delaware's Center for Carbon-free Power Integration, College of Earth, Ocean, and Environment

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SUMMARY FOR POLICYMAKERS – February 18, 2010

Researchers at the University of Delaware's Center for Carbon-free Power Integration (CCPI) were contracted by the Abell Foundation to conduct a preliminary study of Maryland's offshore wind power potential. The study used as its basis a methodology previously employed by University researchers to assess the social, ecological, and economic feasibility of offshore wind power in Delaware's state and adjacent federal waters (Dhanju et al., 2008), with several refinements for the new study. Only Maryland's oceanic waters were considered, not the potential for wind power in the Chesapeake Bay. The findings of the study are summarized in two parts—An Executive Summary and a Technical Summary.

Executive Summary

The results of this study indicate that Maryland's offshore wind resource is large enough to supply the state with 67% of its electric needs, even if using only existing offshore wind power technology (monopile, <35m). Offshore wind could provide 179% of its electric needs as the industry matures and deeper water technologies become commercialized. The resource is large enough to not only satisfy all of Maryland's demand for electricity, but part or all of the demand in neighboring inland states as well.

Maryland has a commitment to renewable energy. The state's legislature passed a Renewable Energy Portfolio Standard (RPS) that requires all Maryland utilities and competitive retail suppliers to obtain an increasing percentage of their electric power from renewable energy sources. By 2022, 22.5% of retail sales must be sourced from renewables, 18% of which can be from wind energy. The amount of capacity needed to fulfill the portion of Maryland's RPS that can be satisfied by offshore wind energy is 4,588 MW, and thus, can be met by the available near-shore resource.

Building out Maryland's offshore wind potential could benefit the state's economy for offshore construction, maintenance, supply chain, and/or turbine manufacturing. Each aspect represents a separate opportunity; including turbine installation, and operations and maintenance facilities, which need to be located near the project. Also, with manufacturing anywhere in the region, some sourcing of turbine components would likely be from Maryland's manufacturing sector. In contrast, continuing to buy fossil electricity from the market, delivered from distant fossil power plants, will not meet environmental goals and is unlikely to have any beneficial effect on the Maryland economy. Moreover, the Delaware Bluewater Wind Project bid and power purchase agreement suggests that large-scale offshore wind projects can be cost competitive with new fossil fuel generation after accounting for future fossil fuel prices, likely costs to emit carbon into the atmosphere, and other factors.

In sum, Maryland's offshore wind power potential appears to be very large, on a scale comparable to the entire state's need for electricity. Development of this resource appears to be the easiest and most cost-effective way to meet Maryland's renewable portfolio standard with instate generation, serve increasing electric load with new generation as needed, improve on environmental goals of reducing CO_2 and improving air quality, and modernize and diversify its economy.

Technical Summary

Available Area for Offshore Wind Development

In order to develop a total estimate of the wind power potential in Maryland, the total area in which wind turbines could be installed was calculated by combining a number of factors. First, the study area was defined. For this analysis, we defined the study area as Maryland's northern and southern land borders, extended due east in the ocean. Using detailed, satellite bathymetric (water depth) data obtained from the National Oceanographic and Atmospheric Administration (NOAA), the study area was divided into four segments based on the turbine foundation technology most suitable within a particular depth range. The four depth segments were labeled by turbine foundation technology as follows: Monopile (0-35m), Jacket (35-50m), Advanced Jacket (50-100m), and Floating (100-1,000m) (See Figure SP-2, below). The study area did not go beyond 1,000 m to keep the results tied to existing offshore wind technologies; no existing turbines have been demonstrated beyond that depth. Understanding the resource associated with each depth region, rather than just producing an estimate for the study area as a whole, provides insight into the timing and feasibility of building out the resource. For example, monopile technology has over fifteen years of operation experience in Europe and can be implemented today in the U.S. Jacket structures have been deployed on a limited basis and have only a couple of years of operational experience. Floating turbines are just now beginning prototyping and have years of testing and further development before they are available in the market.

For the purposes of this study, the 'available area' for development is defined as the area left after excluding for conflicting ocean uses that are not compatible with offshore wind development, be they nautical, navigational, ecological or socio-economic. This study identifies nautical exclusions by using NOAA nautical navigation charts and GIS software to accurately trace and map conflict areas such as artificial reefs and dump sites.

Shipping accounts for the largest potential conflict area and exclusion zone within the study area. There are no official shipping lanes, as identified by the International Maritime Organization (IMO), in Maryland's oceanic waters. As a result, we do not categorically exclude any area on the basis of commercial shipping. However, because there nonetheless exists significant ship traffic in these waters as ships move in and out of the Delaware Bay and up and down the Atlantic seaboard, we identify potential areas of conflict with commercial ship traffic.

The most prominent ecological conflict that offshore wind turbines pose is with respect to seabirds. The potential for avian impacts (collision with a wind turbine and/or habitat exclusion from the wind turbine project area) has been studied at North Sea wind projects and is now an expanding research area in the U.S. It is outside the scope of this analysis to collect data on avian migration patterns and species composition within the Maryland study area. To identify a reasonable conflict area for avian exclusion, we relied on the advice of renowned ornithologist Paul Kerlinger, who advised that we exclude the area within one nautical mile (nm) of the shore. This area was recommended because it is within the Atlantic flyway for migratory bird species and fits with the behavior of migratory birds, which tend to hug the shoreline. Other potential ecological conflicts, such as the disruption of benthic organisms or marine mammals, were not included in the scope of this study. Notwithstanding our first order approximation of where avian conflicts are likely to be greatest, the State of Maryland may wish to consider data collection to facilitate development, and in any event, such data collection will be required of any potential offshore wind developer by state and/or federal permitting authorities.

Finally, a visual exclusion zone was incorporated into the study area. This area represents a zone in which coastal residents or beachgoers may prefer to not have offshore wind turbines installed due to the visual disamenity they might pose. Previous scientific research at the University of Delaware has found that the value placed on moving turbines further out to sea is significantly diminished once the turbines reach a distance of nine miles (8 nm) from shore. There are two coastal areas where residents and/or visitors would likely be most sensitive to visual impairments – Ocean City, being a tourist destination, and Assateague Island, being a national seashore. After affixing an eight nautical mile semi-circle around each of those areas, it was determined that the overlap was such that it warranted an eight nautical mile visual exclusion zone for the entire coastline.

Through this process, it was determined that the area available for offshore wind development in Maryland up to 1000 meters depth is 9,526 km^2. See Figure SP-1

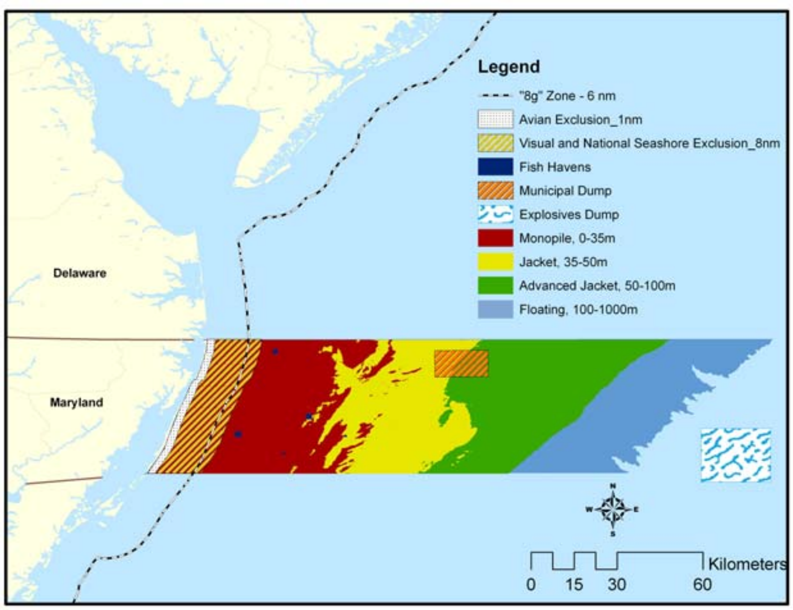

Figure SP-1. All exclusion zones for the Maryland study area

As noted above, there are no IMO identified shipping lanes. Although less precise than lanes designated by latitude and longitude, it is possible to identify habitual vessel traffic routes. In order to understand where ships travel within the Maryland study area and where conflict areas appear to be most prevalent, we utilized the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). ICOADS is a data set of global marine surface conditions collected and reported by a fleet of about 4,000 ships known as the Voluntary Observing Ships (VOS). These ships also report their location. In a separate, extensive analysis done by the University of Delaware, the ICOADS database was analyzed and imported into GIS software. For the Maryland study, potential conflict areas between heavy ship traffic and wind turbine placement were identified and mapped. The total potential conflict area was estimated at 3,300 km^2, still leaving 6,226 km^2 available for wind turbines. See Figure SP-2.

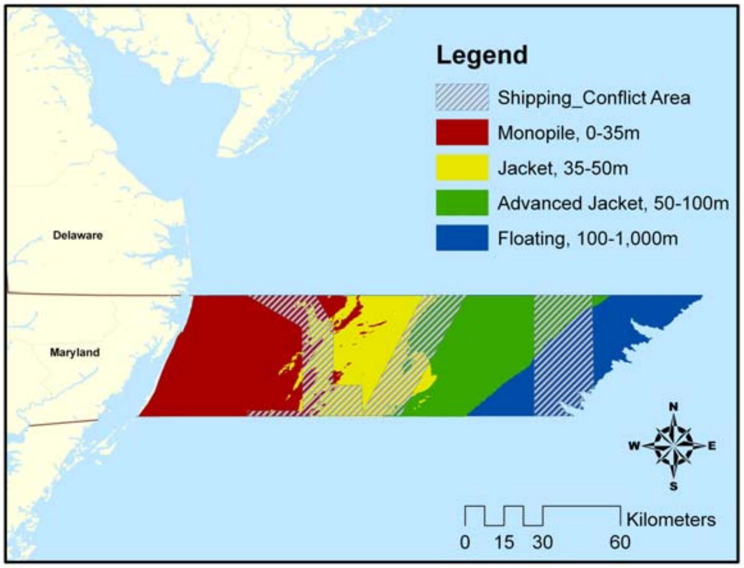

Figure SP-2. Potential shipping conflict areas within the Maryland study area

Offshore Wind Power Potential and Energy Production

After identifying the total available area for offshore wind development, the wind power potential was calculated by combining (a) an analysis of the most accurate wind speed data available for the study area, (b) an offshore wind turbine power output model that estimates power generation from wind speed data, and (c) the spacing of turbines and therefore the number of turbines that could be installed per km^2.

NOAA maintains meteorological buoys throughout the coastal waters of the United States' Territorial Sea (0-12 nm) and the Exclusive Economic Zone (12-200 nm) that record information about marine conditions including water and air temperature, wind speed and direction, and wave height. This data is available to the public via the NOAA National Data Buoy Center. Unfortunately, NOAA does not operate any meteorological buoys within the study area. It was determined that the closest buoy, Buoy 44009, located twelve (12) nautical miles off the southern coast of Delaware, would be the most accurate representation of the wind regime within the study area. A detailed summary of the statistical analysis behind this decision can be found in the full report.

Because buoy data is measured at a much lower height than an offshore wind turbine's blades, all wind speeds were extrapolated from the height at which they were recorded to the height of the wind turbine's hub. The turbine selected for this study is a Repower 5M, a five (5) megawatt (MW) machine with a hub height of ninety (90) meters. The power output of a single turbine is calculated using the manufacturer's power curve – a graph of power output vs. wind speed.

Wind turbines must be spaced at some distance from each other in order to minimize to the extent practicable the amount of wind that is extracted from an upwind turbine that is no longer available to turbines downwind (known as the wake effect). To determine the amount of power that can be extracted from a given area, turbine spacing must be considered. In this study, we draw on previous wind turbine spacing research and use a spacing factor of five by ten – five turbine rotor diameters crosswind and ten turbine rotor diameters downwind. The Repower 5M has a rotor diameter of 126 meters and thus a spacing factor of 0.794 km^2 per turbine is required. Given this spacing factor, a total of 11,999 turbines can be installed in the available area.

With that information in hand, Maryland's offshore wind power potential and energy production capabilities can be calculated. They are presented here, and in the full report, using four different metrics:

- Total installed power capacity (Nameplate Capacity in Megawatts (MW))
  - This is based on the maximum amount of power that a wind turbine can generate at any one time (in this case 5MW) multiplied by the number of turbines.
- Average power output (MW_a)
  - Because the wind is intermittent, at times a wind turbine will produce the maximum amount of power, at other times it will generate no power, and still other times some amount of power between zero and the maximum. The average output is the amount of power that the wind turbines can be expected to generate on average, from winds of the speed found here.
- Average annual energy production (Megawatt-hours (MWh))
  - This is simply the average power output of all of the turbines in the study area multiplied by the number of hours (8760) in a year)
- Percentage of Maryland's total electric load
  - This is based on a comparison of the average annual energy production to Maryland's total annual electric load.

The results for each depth-foundation category are presented in Tables SP-1 and SP-2.

Nearly 3,000 turbines could be installed within the 0-35m depth zone, which on average could supply 67% of the Maryland electric load. Considering from 0 to 50m depth, offshore wind has the potential to fulfill 133% of Maryland's load. If fully developed out to 1000m depth, offshore wind power has the potential to generate over 179,000 Gigwatt-hours (GWh) per year.

Table SP-1. Power generation potential and cumulative percentage of load by depth

Depth (m)	Available Area (km^2)	Wind Turbines	Nameplate Capacity (MW)	Average Output (MW_a)	Total Annual Generation (MWh/year)	Cumulative Percentage of Load
0-35	2,322	2,925	14,625	4,982	43,642,320	67%
35-50	2,310	2,910	14,550	4,956	43,414,560	133%
50-100	2,723	3,430	17,150	5,842	51,175,920	211%
100-1000	2,171	2,734	13,670	4,656	40,786,560	274%
Total	**9,526**	**11,999**	**59,995**	**20,436**	**179,019,360**	**274%**

Accounting for areas of heavy ship traffic reduces the available area for offshore wind projects by 35%, and therefore the total annual generation.

Table SP-2. Power generation potential and percentage of load accounting for potential shipping conflicts

	Available Area (km^2)	Wind Turbines	Nameplate Capacity (MW)	Average Output (MW_a)	Total Annual Generation (MWh/year)	Percentage of Load
Before Subtracting Shipping Conflict Areas	9,526	11,999	59,995	20,436	179,019,360	274%
After Subtracting Shipping Conflict Areas	6,226	7,843	39,214	13,359	117,024,840	179%