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Offshore Wind Energy in the U.S. Mid-Atlantic Region and the EPA Clean Power Plan Proposed Rule

Kamil E. Armaiz Nolla

A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

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LIST OF ACRONYMS & ABBREVIATIONS

AWC – Atlantic Wind Connection
BNL – Brookhaven National Laboratory
BOEM – Bureau of Ocean Energy Management
BSER – Best system of emission reduction
BTU – British thermal unit
CO_2 – Carbon Dioxide
COP – Construction and Operations Plan
DOE – U.S. Department of Energy
DOS – U.S. Department of State
EE – End-use Energy Efficiency
EGU – Electric generating unit
EIA – U.S. Energy Information Administration
EPA – U.S. Environmental Protection Agency
EWEA – European Wind Energy Association
gen. – generation
GHG – Greenhouse gas
GIS – Geographic Information System
GPRA – Government Performance and Results Act
GW – Gigawatt
GWh/year – gigawatt hours per year
IEA – International Energy Agency
IEA Wind – International Energy Agency Wind
IPCC – Intergovernmental Panel on Climate Change
JEDI – Jobs and Economic Development Impact
km^2 – square kilometers
kW – Kilowatt
kWh – kilowatt-hours
lbs/MWh – pounds per megawatt-hour
m – meter
MARCO – Mid-Atlantic Regional Council on the Ocean
MARKAL – Market Allocation
MMS – Minerals Management Service
MOU – Memorandum of Understanding
MW – Megawatt
MWh – Megawatt hour
NGCC – Natural Gas Combined Cycle
NREL – National Renewable Energy Laboratory
Nuclear gen. uc + ar – Nuclear generation under construction and at risk of being retired
OAPEC – Organization of Arab Petroleum Exporting Countries
OCS – Outer Continental Shelf
OG – Oil and Gas
OpenEI – Open Energy Information

OREC – offshore wind renewable energy certificate
OSW – Offshore wind
OSW gen. – Offshore wind generation
OSWInD – Offshore Wind Innovation and Demonstration Initiative
OWC – U.S. Offshore Wind Collaborative
OWEDA – Offshore Wind Economic Development Act
PPA – Power Purchase Agreement
RE – Renewable Energy
ReEDS – Regional Energy Deployment System
RGGI – Regional Greenhouse Gas Initiative
RPS – Renewable portfolio standard
RTO – Regional transmission organization
SAP – Site Assessment Plan
SEAC – Strategic Energy Analysis Center
SRREN – Special Report on Renewable Energy Sources and Climate Change Mitigation
TWh – terawatt hours
UNFCCC – United Nations Framework Convention on Climate Change
U.S. – United States
VCERC – Virginia Coastal Energy Research Consortium
VOWDA – Virginia Offshore Wind Development
VOWTAP – Virginia Offshore Wind Technology Advancement Project
WEA – Wind Energy Area

ABSTRACT

Offshore Wind Energy in the U.S. Mid-Atlantic Region and the EPA Clean Power Plan Proposed Rule

Kamil E. Armaiz Nolla

Carbon dioxide (CO_2) levels in the atmosphere have been experiencing a rapid rise since the start of the Industrial Era. Human activities have been recognized by the scientific community as the main contributors to CO_2 emissions by way of the combustion of fossil fuels such as coal, oil, and natural gas. Scientific consensus about human-induced climate change has been recognized since 1992 by the work of the United Nations Framework Convention on Climate. Since then, global efforts to mitigate climate change have been underway. On June 2, 2014 the U.S. Environmental Protection Agency published a proposal to reduce the emissions of carbon dioxide produced by existing power plants. The plan is based on state-specific emission rate targets for the power sector in order to achieve a national carbon emission reduction of 30 percent by 2030 from 2005 levels.

The plan proposes measures known as the Best System of Emission Reduction, or BSER, to achieve the required targets. One of these measures is to use renewable energy technology that is already part of the renewable portfolio standards that have been established by each state. This work looks at the role of offshore wind (OSW) energy as a significant contributor to CO_2 reductions. The U.S. Mid-Atlantic Region, specifically the

states of Delaware, Maryland, New Jersey, and Virginia, holds an abundance of strong and steady offshore winds already identified by the Bureau of Ocean Energy Management in Wind Energy Areas.

The Clean Power Plan does not include OSW energy as part of the BSER due to the current absence of operational OSW facilities in the United States, preventing the calculation of a benchmark development rate target. However, this dissertation makes a compelling case for the integration of OSW energy as a significant player in the EPA Clean Power Plan Proposed Rule through scenarios that consider different levels of OSW deployment for the Mid-Atlantic Region within the Plan's methodology calculations.

1 INTRODUCTION

1.1 BACKGROUND

1.1.1 PREAMBLE

The pursuit to mitigate the risk associated with climate change, address the problems of growing energy demands, and accomplish the conversion to a long-term, low-carbon energy economy at a national level has propelled the development and deployment of renewable energy systems. As a result, the efforts over the past few decades to harness the strong and steady winds that blow above the world's oceans have helped make great strides towards the production of clean energy.

This research study explores the potential contributions of offshore wind (OSW) energy in the United States Mid-Atlantic bight toward reducing carbon dioxide (CO_2) emissions from existing power plants, which represent the largest single source of carbon pollution in the United States (U.S.) (EPA, 2014d). This study is motivated by concerns at the national level regarding climate change policy, and recognizes that while the U.S. Environmental Protection Agency (EPA) has limits in place for criteria pollutants such as sulfur and nitrogen oxides, there are currently no national limits on greenhouse gases (GHG) including CO_2 and methane that are associated with power generation.

This study first addresses international requirements as mandated by the United Nations Framework Convention on Climate Change (UNFCCC), the organization responsible for

identifying and addressing worldwide climate change threats. This section is followed by an analysis of energy consumption patterns in the United States and the current actions to develop and deploy offshore wind power generators to reduce reliance on legacy fossil-fueled power plants, subsequently reducing the emission of carbon-based pollutants.

1.1.2 FOSSIL FUELS, ENERGY, & CLIMATE CHANGE

In 1992, an international political reaction to explain the causes and address the consequences of climate change was set into motion with the United Nations Framework Convention on Climate Change. At the time, Article 1 of the Convention defined the concept of climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (UNFCCC, 2014a). Since then, the UNFCCC has modified this definition as follows: "Climate change is a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use" (IPCC, 2013). Thus, this new definition recognizes two main causes attributable to climate change – both natural causes *and* human activities are altering the composition of the Earth's atmosphere (IPCC, 2013).

Since the beginning of the Industrial Revolution, the atmospheric composition has experienced a rapid increase in the concentration of greenhouse gases, especially CO_2

(National Academy of Sciences, 2010). It is very likely that this increase is mainly the consequence of human activities as a result of CO_2 emissions from the burning of fossil fuels (IPCC, 2013; National Academy Of Sciences, 2010). The scientific community has been able to establish this relationship because the composition of CO_2 from fossil fuels exhibits a chemical signal different from the molecules of CO_2 derived from natural processes such as the decay of plants (Levin & Hesshaimer, 2000; Böhm et al., 2002; National Academy Of Sciences, 2010).

Identified as the single largest human driver of climate change, the combustion of fossil fuels such as coal, oil, and natural gas provides the energy needed to generate electricity (IPCC, 2013; National Academy Of Sciences, 2010). The EPA most recent greenhouse gas emissions inventory estimates that in the United States, the electricity sector is accountable for approximately 38 percent of total U.S. carbon dioxide emissions and one-third of greenhouse gas emissions (EPA, 2014d).

Article 2 of the UNFCCC treaty states: "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (UNFCCC, 2014b)." At present, there are 195 countries that have

signed and ratified the treaty, including the United States, subsequently becoming Parties to the Convention (UNFCCC, 2014c). Since then, we have seen an increasingly more serious response to the issue of climate change; major efforts include the implementation of mechanisms and technology to stabilize greenhouse gas emissions and improvements in general public acceptance of the situation (DOS, 2010, 2014).

1.1.3 ENERGY CONSUMPTION IN THE UNITED STATES

The rate of energy consumption in the United States has been on a continuous rise since the beginning of the industrial revolution. There are a number of reasons that explain this phenomenon. Large quantities of available energy, mainly coming from non-renewable sources such as oil, resulted in improvements in standards of living. These improvements made life more convenient by changing what used to be expensive and nonessential domestic gadgets into common daily life necessities.

Moreover, in the past 35 years, consumer electronics such as personal computers and cellular telephones have become more affordable and are now commonly found in most typical U.S. households (EIA, 2011). The U.S. Energy Information Administration (EIA) reports that in 2009 at least one computer was found in 76 percent of U.S. homes and one or more rechargeable electronic devices where found in 90 percent of households (EIA, 2011). The number of televisions per household has also increased from an average of one television in 1978 to 2.5 televisions in 2009 (EIA, 2011). In addition to the increasing number of televisions per household, the average energy consumption and the screen size per television has played a part in increasing consumption of energy (EIA, 2011).

Americans have become highly dependent on the existence and incorporation of handheld electronic devices into their daily lives. Yet, because most of these devices depend on electricity as their source of power, their proliferation has added significantly to our overall demand for electricity. According to the EIA's Monthly Energy Review released in July 2014, the overall residential energy consumption in the United States for 2013 was 21.3 quadrillion BTU, an increase of nearly 3.5 times the amount reported in 1950 (6.0 quadrillion BTU). However, electricity consumption increased considerably more than overall energy consumption. In 1950, the U.S. residential sector consumed close to 72.2 million kilowatt-hours (kWh) of electricity; in 2013 it was 1.4 trillion kWh, almost a 19-fold increase (EIA, 2014b).

1.2 TOPIC STATEMENT

1.2.1 OFFSHORE WIND ENERGY AS A KEY PLAYER TO DIVERSIFY THE U.S. ENERGY PORTFOLIO

Current lifestyles are driven by the acquisition and use of multiple appliances and myriad electronic devices. In order to sustain these practices, individuals rely upon copious amounts of low-cost energy to power the modern lifestyle (Rosenberg, 2008). Three essential forces can impact the future of the energy supply: the economy, national and energy security, and the environment. Many sectors of the economy such as agriculture, manufacturing, and commerce are powered by energy (Rosenberg, 2008). As such, the consequences of oil price volatility on the economy are immediately noticeable. U.S. national and energy security are constantly threatened by our dependence on importation of oil from volatile regions and hostile governments (Rosenberg, 2008).

The environment, however, faces the most adverse and direct impacts from the use of carbon-based fuel combustion. The combustion of coal, oil, and natural gas produces high levels of greenhouse gas emissions that threaten the environment and contribute to climate change (Rosenberg, 2008). While conservation can reduce the rate of energy use, the EIA 2014 Annual Energy Outlook predicts a growth in energy consumption of 0.4 percent per annum between 2012 and 2040 with slightly higher growth in electricity consumption at 0.6 percent per annum (EIA, 2014a).

A means to secure our energy supply is to diversify our national energy portfolio (NREL, 2008; Rosenberg, 2008). Diversification using wind energy can help address energy security concerns by providing stability of energy rates, dispersing risks, increasing security, and minimizing the dependence on energy sources from nations located in regions experiencing political instability (NREL, 2008). Wind energy is, by default, domestic energy; its use reduces reliance on imported fuels and creates both domestic and international markets for manufacturing and supply of wind turbines and components (NREL, 2008).

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), developed under the leadership of the IPCC Working Group III, determined that the energy coming from renewable sources could more than meet the world's energy demands. The report determined that by mid-century, on the order of eighty percent of the world's energy supply could be produced by renewables as assuming that appropriate and consistent

public policies are developed that support green energy (IPCC Working Group III, 2011).

Wind energy is one of the six renewable technologies reviewed by the SRREN that will help mitigate climate change. In the case of carbon dioxide emission reduction, strategic interventions for mitigation could rely on finding and applying electricity generation technologies that emit little to no carbon. Wind energy represents an alternative that will help shift the dependence on power generation away from fossil fuels. Large, grid-connected offshore wind turbines utilize the energy created by ocean winds to generate electricity (Arvizu et al. 2011; Environmental and Energy Study Institute, 2010).

In the United States, the Mid-Atlantic bight holds great potential for offshore wind energy generation due to favorable factors such as a gently sloping and shallow continental shelf, steady and strong winds, and close proximity to population centers (Environmental Law Institute, 2013). This corridor, located between the states of New York and Virginia, covers an area of eighty-two thousand (82,000) square kilometers (km^2) (Environmental Law Institute, 2013). It is estimated that within fifty (50) nautical miles from shore there exists approximately 410 gigawatts (GW) of offshore wind power potential (Environmental Law Institute, 2013). In 2009, the Mid-Atlantic Regional Council on the Ocean (MARCO), a regional ocean partnership established by the Governors of responsible for the states of New York, Delaware, Maryland, New Jersey, and Virginia, was established to address the region's ocean management challenges such as ocean's health, and opportunities concerning quality of life and economic stability and self-reliance through smart development of renewable offshore energy (Environmental Law

Institute, 2013). Jurisdiction over one quarter of this area falls under these five adjacent coastal states up to three nautical miles offshore (Environmental Law Institute, 2013). The remaining three-quarters, between three and fifty nautical miles from shore, are in federal waters and fall under the authority of the Department of the Interior with regard to management and development (Environmental Law Institute, 2013).

In the mid-Atlantic region of the United States, PJM Interconnection is the regional transmission organization (RTO) that coordinates the movement of wholesale electricity and manages the electricity grid (PJM Interconnection, 2014). As the manager of the electricity grid, the electricity generated by offshore wind turbines will be integrated into PJM's grid, eventually transmitting the electricity to its consumers.

The research reported herein considers future offshore wind projects in the states of Delaware, Maryland, New Jersey, and Virginia. Not only have these four states already designated lease areas (Wind Energy Areas or WEAs) for offshore wind development in conjunction with the Bureau of Ocean Energy Management (BOEM), but they may also participate in a proposed submerged transmission backbone project, the Atlantic Wind Connection (AWC) (AWC, 2010). The AWC intends to deploy underwater transmission that will connect the wind power plants built in the WEAs from northern New Jersey to Virginia to the grid (AWC, 2014).

1.2.2 OFFSHORE WIND ENERGY CONTRIBUTIONS TO RENEWABLE PORTFOLIO STANDARDS

In the United States, a renewable portfolio standard (RPS) serves as a regulatory mandate to ensure that a defined percentage of a state's retail electricity production is supplied by renewable sources such as wind, solar, biomass, geothermal, and some types of hydroelectricity (EIA, 2012). In addition, an RPS functions as a policy mechanism to achieve diversity in sources of energy production and development of an in-state economy (Cory & Swezey, 2007).

Each state's RPS is different, presenting challenges to their successful implementation (Cory & Swezey, 2007). In general, a minimum level of demand is determined by an RPS, and then the market has the freedom to decide on the types of renewable energy sourced to fulfill that demand (Cory & Swezey, 2007). This market mandate quality causes a complete reliance of the RPS implementation on the private market. As a result, the design of an RPS will differ from state to state (Cory & Swezey, 2007). Differences include time, scope, technology adequacy, geographic suitability, and other appropriate methods that will allow attaining compliance and implementation procedures (Cory & Swezey, 2007).

Within the context and scope of this study, the states of Delaware, Maryland, and New Jersey have a mandatory RPS, while Virginia offers a voluntary renewable energy portfolio goal. One of the first states in the United States to implement an RPS was New Jersey; their RPS is described by the U.S. Department of Energy (DOE) as one of the

most aggressive in the United States. It calls for each supplier and provider of retail energy to obtain 22.5 percent of electricity sold to come from qualified renewable sources by 2021 (DSIRE, 2013c). New Jersey's offshore wind goal set by the RPS is 1,100 megawatts (MW) (DSIRE, 2013c).

The National Renewable Energy Laboratory's report on the Assessment of Offshore Wind Energy Resources for the United States estimates total offshore wind potential within fifty nautical miles of shore for a number of different states. New Jersey's total offshore wind potential has been estimated at 99.7 GW (Schwartz, Heimiller, Haymes, & Musial, 2010). Delaware's RPS requires retail electricity suppliers to purchase twenty- five percent of the electricity from renewable sources by 2025 (DSIRE, 2013c). Although offshore wind is part of Delaware's RPS eligible renewable technologies, no carve-out has been allocated for offshore wind (DSIRE, 2013c). Delaware's estimated total offshore wind power potential stands at 14.7 GW (Schwartz et al., 2010).

Maryland's RPS requires all electricity utilities and competitive retail suppliers to generate a total of twenty percent of their retail sales using renewable energy sources by 2022 (DSIRE, 2013b). From this twenty percent, Maryland is required to carve-out 2.5 percent for offshore wind beginning in 2017 (DSIRE, 2013b). Maryland's total offshore wind power potential has been estimated at 53.8 GW (Schwartz et al., 2010).

The Commonwealth of Virginia enacted a voluntary RPS in 2007 that encourages investor-owned utilities (IOUs) to procure a portion of the power sold in Virginia from

eligible sources of renewable energy (DSIRE, 2013d). Virginia's RPS goal is to have fifteen percent of the electricity sales from its base year (2007) derived from renewable sources by 2025 (DSIRE, 2013d). Virginia's total offshore wind power potential is estimated to be approximately 94.4 GW (Schwartz et al., 2010).

1.2.3 THE CLEAN POWER PLAN PROPOSED RULE: REDUCING CARBON POLLUTION FROM EXISTING POWER PLANTS

The United States has taken a serious stand in addressing anthropogenic greenhouse gas emissions, one of the most serious threats to the environment and human health. Considered the leading cause of long-term climate change, carbon dioxide is the primary greenhouse gas pollutant accounting for close to three-quarters of global greenhouse gas emissions (EPA, 2014f). In the United States, stationary sources such as fossil fuel-fired electric generating units (EGUs) emit the greatest amounts of greenhouse gases (EPA, 2014f). Carbon dioxide undoubtedly represents the primary form of greenhouse gases, making up 84 percent of these emissions in the United States (EPA, 2014f).

On June 2, 2014, the EPA delivered a key element of President Obama's Climate Action Plan by means of a proposal to cut carbon dioxide pollution from power plants. The Clean Power Plan aims to reduce nationwide carbon emissions from the power sector to 30 percent below 2005 levels by the year 2030 (EPA, 2014b).

The proposed plan includes a set of guidelines to be followed by states as they implement measures that reduce greenhouse gas emissions produced by active fossil fuel-fired EGUs

(EPA, 2014f). These guidelines are focused on two main goals proposed by the EPA. The first is a series of state-specific rate-based goals directed at power sector emissions (EPA, 2014f). The second is composed of emission guidelines that will help direct states as they develop plans to achieve the goals specific to each state (EPA, 2014f). The expected outcome will be to trigger a process that reduces CO_2 emissions linked to existing fossil-fueled power generation sources (EPA, 2014f).

Recognizing the inherent policy differences between states, the EPA has designated these regulations as "guidelines," offering states the primary authority to implement them (McCarthy, Meltz, Leggett, Ramseur, & Dolan, 2014). Some of these policy differences include (i) varying approaches to reduce emissions; (ii) differences in existing state programs and measures; and (iii) diverse electricity system characteristics including utility regulatory structures, generation mix, and electricity demand, among others (EPA, 2014f). In order to consider the diversity in state approaches, these guidelines offer opportunities for the states to establish their own standards of performance (EPA, 2014f).

By mandate of Section 111(d) of the Clean Air Act (CAA), the performance standards of each state plan should indicate the scope of emission limitations that can be managed when applying the "best system of emission reduction (BSER)" (EPA, 2014f). The state-specific goals consist of EPA reduction emission calculations that a state can carry out by applying BSER (EPA, 2014f). These emission rate goals for each state are defined on the basis of four broad categories called "building blocks" (EPA, 2014f). These building blocks depict different potential reduction measures in order to:

1. "Reduce the carbon intensity of generation at individual affected EGUs through heat-rate improvements" (EPA, 2014f). This measure aims at increasing fossil fuel power plants efficiency (EPA, 2014e).
2. "Reduce emissions from the most carbon-intensive affected EGUs in the amount that results from substituting generation at those EGUs with generation from less carbon-intensive affected EGUs (including natural gas combined cycle [NGCC] units that are under construction)" (EPA, 2014f). This measure aims at increasing the use of low-emitting power sources (EPA, 2014e).
3. "Reduce emissions from affected EGUs in the amount that results from substituting generation at those EGUs with expanded low- or zero-carbon generation" (EPA, 2014f). This measure aims at increasing zero- and low-emitting power sources (EPA, 2014e).
4. "Reduce emissions from affected EGUs in the amount that results from the use of demand-side energy efficiency that reduces the amount of generation required" (EPA, 2014f). This measure aims at using electricity more efficiently (EPA, 2014e).

Taking into account these four building blocks, the EPA generated a national formula for emission reductions that could be applied consistently across all states (EPA, 2014e). The national formula is based on analysis of historical data relating to emissions and the power sector as well as on the rate of "CO_2 emissions from fossil fuel-fired power plants in pounds (lbs) divided by state electricity generation from fossil-fuel fired power plants and certain low- or zero-emitting power sources in megawatt hours (MWh)" (EPA,

2014e). This method takes into account "megawatt hours from fossil fuel power plants plus other types of power generation like renewables and nuclear, as well as megawatt-hour savings from energy efficiency in the state" (EPA, 2014e). Since the mix of emissions and power plants is unique to each state, the formula's information will be state- and region-specific resulting in state-specific goals (EPA, 2014e).

This study focuses on the contribution of the third building block in reducing CO_2 emissions. Through increases in the capacity of low-carbon and renewable generation, Building Block 3 seeks to expand the amount of lower carbon intensity generation (EPA, 2014f). A shift in the electric system from generation with the current EGUs characterized by high carbon intensity will experience a gradual replacement by renewable or nuclear generating capacity (EPA, 2014f) In terms of renewable energy, the methodology used by the EPA to calculate the target generation levels for each state only considers the following technology types: solar, onshore wind, geothermal, and select existing biopower capacity types (EPA, 2014a, 2014f). The absence of operational offshore wind facilities in the United States made it impossible to calculate a benchmark development rate that could be included in the methodology (EPA, 2014f). While considering the current trends in offshore wind development in the Mid-Atlantic, this study is particularly interested in the potential contributions of offshore wind energy into the state-specific goals associated with Delaware, Maryland, New Jersey, and Virginia.

1.3 THESIS STATEMENT

The overall purpose of this study is to investigate to what extent carbon emissions from fossil-fired power generation in the states of Delaware, Maryland, New Jersey, and Virginia can be offset by offshore wind deployment, and whether the new EPA Clean Power Plan Proposed Rule realistically captures the projected impacts of offshore wind in the Mid-Atlantic region.

The main objectives of this research study are to determine:

1. the extent to which state-specific, rate-based goals for carbon dioxide emissions (intensity) from the power sector as calculated by the EPA in its Clean Power Plan Proposed Rule are attributable to offshore wind for each state considered; and
2. whether these goals are reasonable and consistent with offshore wind energy development projection calculations for the United States through 2030.

1.4 METHODOLOGY OVERVIEW

Driven by the compelling need to mitigate climate change and other environmental impacts produced by the burning of fossil fuels for electricity generation, offshore wind energy has become an appealing resource of renewable energy and a means to reduce and prevent greenhouse gas emissions, specifically carbon dioxide. A close examination of the offshore wind energy industry reveals the large group of policies, regulations, and programs design to advance this energy source and resulting in a considerable number of government agencies and stakeholders involved in the decision making process. As such, the focus of this dissertation was to investigate to what extent carbon emissions from

fossil-fired power generation in the states of Delaware, Maryland, New Jersey, and Virginia can be offset by offshore wind deployment in the new EPA Clean Power Plan Proposed Rule and how realistic these projections can be.

The first part of the analysis consisted in constructing six scenarios using offshore wind energy capacity data to create projection plots of cumulative total potential capacity over time for the states of Delaware, Maryland, New Jersey, and Virginia. The data was obtained from four different sources: EPA Clean Power Plan Proposed Rule, the Bureau of Ocean Energy Management, the Mid-Atlantic JEDI report, and the National Renewable Energy Laboratory. The year 2030 was selected because it represents the target framework established both globally and agreed upon at the U.S. national level to reduce carbon emissions. The scenarios chosen for this study include valid OSW deployment potentials ranging from zero deployment in Scenario 1 to the largest deployment calculated for the Mid-Atlantic in Scenario 6. Scenarios 1, 2, and 6 show the total amount of wind capacity expected to be built by 2030. For Scenarios 3, 4, and 5, this dissertation applies data of offshore wind energy deployment from the 2013 study titled *"Potential Economic Impacts from Offshore Wind in the United States – The Mid- Atlantic Region"* (Mid-Atlantic JEDI report) by Michelle Kraemer, Dane Zammit and Dr. Jonathan J. Miles, specifically Tables 3, 4, and 5. In this case, the timeframe from 2015 to 2030 was applied in this dissertation's analysis, so that it aligns with the timeframe from the study. The scenarios intend to depict a projection of offshore wind energy deployment for the Mid-Atlantic Region using potential offshore wind energy resource capacity.

The second part of our methodological approach for this dissertation consisted in exploring the contributions of the potential deployment of offshore wind energy in the Final State Goal of the EPA Clean Power Plan Proposed Rule for the four states (Delaware, Maryland, New Jersey, and Virginia). The offshore wind energy capacity data belonging to each state and Scenario was converted to offshore wind generation by applying an average capacity factor. Finally, a "new" Final State Goal for emissions' rates (lb/MWh) was calculated for each state and Scenario by applying offshore wind generation (OSW gen.) as part of the equation's denominator in the final EPA equation for state emissions.

2 CHARTING THE COURSE FOR AN OFFSHORE WIND ENERY REVOLUTION

2.1 PRE-2000 OFFSHORE WIND ENERGY – EUROPE

2.1.1 WIND ENERGY

Energy plays a critical role in all aspects of life. The majority of human activities are closely dependent on the consumption of several forms and sources of energy to accomplish work, carry out daily activities, and even maintain life (Deal, 2010). For instance, energy is an essential constituent of the entire food chain, from planting and harvesting, to processing and transportation (Deal, 2010). In its variety of forms, energy serves a wide spectrum of applications such as transportation, communications, chemical reactions, manufacturing, construction, as well as cooling, heating, and lighting of structures (Deal, 2010).

From a historical standpoint, the utilization of fossil-based fuels for energy purposes is a relatively recent innovation, while wind has been used for thousands of years (Deal, 2010). As one of the oldest energy sources for humans, wind energy is believed to have originated in Persia where the borders of Pakistan and Afghanistan are currently located (Goffman, 2008). By employing the same concepts used for sailing, civilizations in antiquity used windmills to harness wind energy; with the help of blades, they created mechanical energy that was mainly used for grinding grains and pumping water (Goffman, 2008; Manwell, McGowan, & Rogers, 2009). After fossil fuels became the

predominant source of power generation, the 1970s oil embargo enforced by members of the Organization of Arab Petroleum Exporting Countries (OAPEC) resulted in an energy crisis and sparked the start of a conversation regarding energy production and its sources. However, it wasn't until the late 1980s and early 1990s when climate change and pollution generated by fossil fuels prompted actions for research into alternative sources of energy (Goffman, 2008; Luterbacher & Sprinz, 2001). These actions were preceded by the findings of the stratospheric "ozone hole" and the groundwork laid by the Brundtland Commission report, *Our Common Future* (World Commission on Environment and Development, 1987) which led to the 1992 Earth Summit held by the United Nations in Rio de Janeiro (Luterbacher & Sprinz, 2001). Based on the same principles of energy harvest, advancements in design, technology, and construction have resulted in a complete transformation of the windmill to a more efficient and sophisticated piece of equipment that we now call the wind turbine (Deal, 2010).

At present, wind energy stands as the most mature and well-developed renewable energy industry and is the fastest growing energy industry in the world (Makridis, 2013; Bilgili, Yasar, & Simsek, 2011; Leung & Yang, 2012; Sun, Huang, & Wu, 2012). According to Esteban et al. (2011), a combination of two factors justifies the importance of wind energy over other renewable technologies. The first is that as a resource, wind can be found anywhere on the planet with varying degrees of density and intermittency (Manwell et al., 2009; Esteban, Diez, López, & Negro, 2011). Second, the use of wind throughout history in activities such as sailing, irrigation, and milling makes it a mature industry

compared to the shorter evolution of solar, wave, tidal, and ocean energy technologies (Esteban et al., 2011).

2.1.2 OFFSHORE WIND ENERGY – THE BEGINNING

The idea of offshore wind turbines dates back to the beginning of the 20th Century. In 1932, Hermann Honnef, a German structural engineer, pioneered the idea of utilizing large-scale wind power plants to generate electricity (Hau, 2013). This is considered the earliest documentation of the theoretical concept of wind turbine installations at sea for the purpose of offshore wind energy generation (Musial & Ram, 2010; Kaldellis & Kapsali, 2013). In the 1970s, Professor William E. Heronemus, a civil engineering professor at the University of Massachusetts, and his research team lay the groundwork for the concept of using large-scale offshore wind turbines to generate power in mass quantities (Musial & Ram, 2010; Kaldellis & Kapsali, 2013). Heronemus's main idea consisted of the use of large floating wind turbine platforms called "windships" located off the eastern coast of the United States (Musial & Ram, 2010; Kaldellis & Kapsali, 2013). However, these visions and concepts remained only on paper.

Following the commercial achievements of the land-based wind industry, research efforts focused once again on studying offshore wind energy with the aim of making it a reality. The first test facility harvested offshore wind with a pilot project located off the coast of Sweden in the year 1990 (Maegaard, Krenz, & Palz, 2013; Esteban et al., 2011; Makridis, 2013; Bilgili, Yasar, & Simsek, 2011; Musial, Butterfield, & Ram, 2006; Sun, Huang, & Wu, 2012; EWEA, 2011a; Kaldellis & Kapsali, 2013). This prototype consisted of a

single 220 kW turbine with a 24 meter (m) radius installed on a tripod platform built by Wind World (Esteban et al., 2011; Kaldellis & Kapsali, 2013;Tong, 2010; Maegaard et al., 2013). This offshore wind turbine was situated in Nogersund, 250 meters off the north coast of Sweden at a water depth of 7 meters (Bilgili, Yasar, & Simsek, 2011; Kaldellis & Kapsali, 2013).

2.1.3 OFFSHORE WIND ENERGY – THE TECHNOLOGY

The modern wind turbine is described as a machine that harnesses the power of wind (moving air) and converts it into electricity (Manwell et al, 2009). In other words, a turbine takes the kinetic energy of the wind and transforms it to mechanical energy that is then converted to electrical energy (Tong, 2010). This conversion process is based on the fundamental force of aerodynamics (interactions of the blade with the wind) called lift (Manwell et al., 2009). When lift is applied it "produces a net positive torque on a rotating shaft, resulting first in the production of mechanical power and then in its transformation to electricity in a generator" (Manwell et al., 2009).

The main difference between wind turbines and other types of energy generators is the inability to store wind for future use. As a result, production of energy only occurs as a reaction to the immediate availability of the wind resource (Manwell et al., 2009). Functioning as generators of electricity, wind turbines need to be connected to an electrical transmission network such as large utility grids, battery-charging circuits, or residential scale power systems (Manwell et al., 2009).

Wind turbines can be found both on land and at sea. Energy harnessed by turbines located on land is referred as onshore wind energy, while energy from the ones located out at sea is referred as offshore wind energy. There are many benefits offshore wind energy has over its on-land counterpart, location being the primary driving force behind these. The ocean's physical characteristics such as its large, flat, and wide extents of open space with an absence of building structures or objects helps create winds with higher speeds and frequencies with less turbulent currents (Kaldellis & Kapsali, 2013). Characteristics such as these allow for the construction of bigger projects with larger wind turbines than onshore (Tong, 2010; Manwell et al, 2009; Kaldellis & Kapsali, 2013).

There are pros and cons to both onshore and offshore wind turbines. Onshore wind turbines' size, including height and rotor diameter, are often limited due to negative visual impacts of oversized structures; far from view of most humans as a result of their location in the marine environment, offshore wind turbines' size are not limited by visual impacts (Kaldellis & Kapsali, 2013). Offshore wind turbines then benefit from their larger sizes, as they have the capacity to capture more power and therefore produce more energy (Tong, 2010). Installation of offshore wind turbines happens at sea, however, creating unique challenges not experienced during onshore wind turbine installation. The nature of the marine environment puts structural integrity of wind turbine towers at risk due to corrosion, high surf conditions, salt-water spray, and low temperatures (Tong, 2010).

Since the construction of the first offshore wind farm in 1990, with a rated power output below one megawatt (MW), offshore wind turbine capacity has been on a steady rise

(EWEA, 2013a). Considered the leader in offshore wind energy, the European Wind Energy Association (EWEA) is an excellent place to review statistical trends of power output. In 2003, installed commercial offshore wind turbines had a capacity of 2 MW; in 2005 their capacity was increased to 3 MW (EWEA, 2013a). Since then, the installed capacity has ranged between 2 and 5 MW, with an average capacity for wind turbines in European waters in 2013 of 3.9 MW (Kaldellis & Kapsali, 2013; EWEA, 2013a). The largest offshore wind turbines to date were installed in Belgium in 2013 with a capacity of 6 MW (4C Offshore Limited, 2014i).

The trend toward larger turbines means that average wind farm size also reflects increases in capacity. Prior to 2000, offshore wind farm size averaged 20 MW, or 4.1% of the average size in 2013 (485MW) (Kaldellis & Kapsali, 2013; EWEA, 2013a). 2013 experienced a 78 percent increase in the average offshore wind farm size compared to 2012, increased from 271 MW to 485 MW (EWEA, 2013a).

Another important consideration of offshore wind power plants, especially as large-scale commercial projects take off, is their distance from shore and the depth of water in which they are located. Offshore wind technology companies continue to install turbines with fixed-bottom substructures in relatively shallow waters of less than 30 m deep, with an average of 20 m for European installations in 2013 (Kaldellis & Kapsali, 2013; EWEA, 2013a). The bottom structures are installed by directing monopoles, hollow steel pipes, into the seabed or by relying on conventional concrete gravity bases (Stiesdal, 2009). However, in 2009, the first large-scale offshore floating wind turbine was installed in

Norway at a water depth of approximately 220 m (Stiesdal, 2009; Biester, 2009). Along with the migration toward increasing water depths, the average distances from shore have also increased from an average of 5 kilometers (km) at the beginning of the decade to 30 km today (Kaldellis & Kapsali, 2013; EWEA, 2013a). As wind farm developers improve wind turbine technology and maritime spatial planners make offshore plots available, offshore wind farm construction will take place further from shore, in deeper waters, while using larger turbines (EWEA, 2013a). Lastly, while the expenditures for offshore wind power are larger than onshore, there are possibilities of reductions in costs, logistics, and long-term operations and maintenance (REN21, 2013).

2.1.4 OFFSHORE WIND ENERGY IN EUROPE – PRE-2000

In the years preceding 2000, the offshore wind power industry experienced erratic and intermittent growth (EWEA, 2011b). Only a small quantity of near-shore projects composed of turbines with less than 2 MW capacities were built (Snyder & Kaiser, 2009).

In 1991, Denmark inaugurated the first commercial offshore wind farm (EWEA, 2011a; Bilgili, Yasar, & Simsek, 2011; Danish Energy Authority, 2005). This development was located 2.5 kilometers (km) off the north coast of the Danish Island Lolland near Vindeby at a water depth between 2.5 to 5 meters and was composed of eleven turbines of 450 kW each, totaling a capacity of 4.95 MW (EWEA, 2011a; Bilgili, Yasar, & Simsek, 2011). Still in operation, this wind farm annually produces 11,200 megawatt hours of power (SEAS-NVE, 2014). The second European commercial offshore wind farm, Lely, was

built in the Netherlands. Commissioned in 1994, it features a total installed capacity of 2 MW generated by 4 turbines of 0.5 MW each (4C Offshore Limited, 2014f).

In 1995, the Danish built their second offshore wind farm and the third in European waters with the same capacity as their first one, Vindeby. This offshore wind farm, known as Tunø Knob, comprises 10 Vestas wind turbines of 500 kW each. It features a power output of 5 MW with depths raging from 0.8 to 4 meters (Bilgili, Yasar, & Simsek, 2011; Danish Energy Authority, 2005; EWEA, 2007). Its annual energy production is equivalent to 16 gigawatt hours per year (GWh/year) (Bilgili, Yasar, & Simsek, 2011).

Three more offshore wind power plants follow this initial development in Europe. In 1996, the Netherlands built the highest capacity offshore wind farm of the 1990s, the Irene Vorrink/Dronten offshore wind farm. It consisted of a near shore project with a total capacity of 16.8 MW containing 28 turbines of 0.6 MW each (4C Offshore Limited, 2014e). A year later, Sweden built its first commercial offshore wind farm. With a total capacity of 2.75 MW, the Bockstigen offshore wind farm is comprised of 5 turbines with a capacity of 0.55 MW each (4C Offshore Limited, 2014b). The United Kingdom also assembled its first offshore wind farm in this decade. The Blyth is a 4 MW capacity offshore wind farm with 2 turbines of 2 MW each (4C Offshore Limited, 2014a).

This initial deployment of offshore wind power projects was primarily motivated by the European government's acknowledgment that the oceans represent a viable answer to shortages in land-based sites and the European wind industry's commercial goals

(Kaldellis & Kapsali, 2013). Government planning recognized placement of offshore wind energy in the shallow waters of the North Sea relied on the benefits of having a substantial amount of locations that exhibited stronger and steadier winds than alternative locations on land; as a result, capacity factors were higher and wind power plants were more productive (Musial et al., 2006; Kaldellis & Kapsali, 2013).

2.2 POST-2000 OFFSHORE WIND ENERGY – EUROPE

2.2.1 RECENT ENTERPRISE OFF EUROPEAN OFFSHORE WIND MARKETS

Development of post-2000 offshore wind energy was led by Denmark. The coastal nation built 20 turbines with a total capacity of 40 MW, becoming the first large-scale offshore wind farm in Europe (EWEA, 2011a). The construction of this third Danish offshore wind facility known as Middelgrunden was finalized in 2001 (Danish Energy Authority, 2005; Bilgili, Yasar, & Simsek, 2011; Kaldellis & Kapsali, 2013). During this same year, Sweden connected 7 turbines of 1.5 MW each to the Utgrunden grid with a total production capacity of 10.5 MW (EWEA, 2011a; (4C Offshore Limited, 2014j). By the end of 2001, one percent of the annual European wind capacity came from the production of 50.5 MW of offshore wind energy (EWEA, 2011a).

Since then, European installations of offshore wind power plants have been making major contributions to the total global wind capacity every year. The Middelgrunden project in Denmark was followed by two of the largest offshore wind projects of the decade. In 2002, Denmark built the Horns Rev I offshore wind farm, capable of producing a total of 160 megawatts (MW) with 80 wind turbines of 2 MW each (Bilgili, Yasar, & Simsek,

2011; Danish Energy Authority, 2005; Snyder & Kaiser, 2009). Horns Rev I wind turbines were built at distances ranging between 14 to 17 km, and water depths of 6 to 14 meters (4C Offshore Limited, 2014d). The second offshore wind farm is located in Nysted; known as Rodsand I, it was commissioned in 2003, comprised of 72 wind turbines at water depths of 6 to 10 meters, and provided a total electrical production power of 165.6 MW (Nysted Havmøllepark, 2014).

This upsurge period was followed by a few slower years between 2004 and 2006. Experts attribute this abatement to exceeding costs and failure rates caused by exposure to the severe marine conditions (Musial & Ram, 2010). Regardless of this temporary slow down in production, the wind energy industry demonstrated a proactive commitment to identify, correct, and resolve manufacturing and development problems linked to this first chapter of the modern offshore wind development (Musial & Ram, 2010). As a result of these effort and European energy policies, new commercial offshore wind farm installations in European northwest countries have been on the rise even since.

As of 2010, annual offshore wind installations accounted for 9.8 percent and 883 MW of European wind power (EWEA, 2013a). The United Kingdom installed the largest offshore wind farm up to date, the Thanet project, with a capacity of 300 MW and a total of 100 turbines of 3 MW each (EWEA, 2011a; (4C Offshore Limited, 2014h). The second offshore wind farm in 2010 was the Horns Rev 2 in Denmark. Built in 2009, the Horns Rev 2 featured a capacity of 209 MW and 91 wind turbines located approximately 32 km offshore (South Baltic Offshore Wind Energy Regions, 2013). Also in Danish waters, the

third largest offshore wind farm is the Rødsand II, also called Nysted II, comprised of 90 wind turbines totaling a capacity of 207 MW (IEA Wind, 2013). Rødsand II is located about 9 km offshore at a depth ranging from 4 to 12 meters (4C Offshore Limited, 2014g).

In 2011, the European offshore wind market grid connected 866 MW of power by means of 235 new offshore wind turbines from nine wind power plants, staying behind by 17 MW from 2010 capacity (EWEA, 2012). The United Kingdom led the offshore wind market with close to 750 MW produced by 200 turbines distributed between its five new wind power plants representing 87 percent of the total capacity added in 2011 (EWEA, 2012). Behind the United Kingdom were Germany with 108 MW supplied by 33 turbines from two wind power plants, Denmark with 3.6 MW from one wind turbine, and Portugal with 2 MW produced by one wind turbine, becoming the first full-scale offshore wind turbine in southern European waters (EWEA, 2012).

The year 2012 experienced one of the biggest increases in offshore wind power development since the start of commercial installations. A total of 293 fully grid connected new offshore wind turbines allocated in nine wind turbine power plants summed to 1,166 MW of capacity, 33 percent more than the previous year (EWEA, 2013b). For a second consecutive year, the United Kingdom became the biggest contributor to the European offshore wind energy's annual capacity with 73 percent (854 MW) of 2012's total grid connection (EWEA, 2013b). The largest project of this year was the Greater Gabbar from the United Kingdom with a total capacity of 504 MW supplied

by 140 turbines of 3.6 MW each (4C Offshore Limited, 2014c; Renewable UK, 2014). The European offshore wind energy market hit a record high in 2013 with new installations adding up to 1,567 MW, an increase of 34 percent from 2012 and 16 percent of the total European wind market (EWEA, 2014a). Six European countries installed offshore wind projects to supply electricity: Belgium, United Kingdom, Germany, Denmark, Sweden, and Spain (EWEA, 2014a). A total of 418 new turbines distributed in 13 wind power plants between the North Sea, Baltic Sea, and Atlantic Ocean produced new offshore wind power capacity connected to the electricity grid in 2013 (EWEA, 2014a). The largest project, the London Array, was located in the United Kingdom comprising 175 wind turbines of 3.6 MW each totaling a capacity of 630 MW (Renewable UK, 2014).

As of 2013, the list of the top five EU countries with the highest installed offshore wind capacity is led by the United Kingdom with 56 percent of total grid connected installations followed by Denmark with 19 percent, Belgium with 8.7 percent, Germany with 8 percent, and the Netherlands with 3.8 percent (EWEA, 2014a).

The first half of 2014 is led by grid connections from the United Kingdom with 532 MW followed by Belgium with 141 MW, and Germany with 108 MW for a total of 781 MW (EWEA, 2014b).

2.2.2 LATEST STATISTICS IN THE EUROPEAN OFFSHORE WIND ENERGY MARKETS

As the global leader in offshore wind energy, Europe's cumulative offshore wind market is spread throughout 11 countries with a total of 85 offshore wind power plants composed of 2,304 wind turbines installed and connected to the electricity grid providing 7393 MW of offshore wind power (EWEA, 2014a; EWEA, 2014 b; Leung & Yang, 2012). In comparison, by the end of 2013 the EWEA reported that offshore wind produced 0.7% of the European Union's total electricity consumption, reflecting a total installed capacity of 6,562 MW and generating an equivalent of 24 terawatt hours (TWh) in a normal wind year (EWEA, 2014a). The European cumulative offshore wind market by the first half of 2014 is as follows:

Table 2.1 Cumulative Installed Offshore Wind Capacity in the European Union by the first half of 2014

Country	Number of power plants	Number of turbines connected	Capacity installed (fully connected to the grid) (MW)
Norway	1	1	2
Portugal	1	1	2
Ireland	1	7	25
Finland	2	9	26
Spain	1	1	5
Sweden	6	91	212
Netherlands	4	124	247
Germany	14	146	628
Belgium	6	182	712
Denmark	12	513	1271
United Kingdom	25	1229	4213
Total	**73**	**2304**	**7343**

Note. Adapted from *The European offshore wind industry - key trends and statistics 2013*, p. 10, by EWEA, 2014a, and from *The European offshore wind industry – key trends and statistics 1st half 2014*, p. 3-4, by EWEA, 2014b.

2.3 POST-2000 OFFSHORE WIND ENERGY – UNITED STATES

2.3.1 U.S. OFFHORE WIND ENERGY INDUSTRY DEVELOPMENT

In the United States, development of the offshore wind energy industry at state and federal levels has found a strong stimulus from the need and ambition to improve energy security, stimulate economic development, and achieve better environmental quality by means of a zero-emissions generation technology (Musial & Ram, 2010). However, offshore wind energy development did not always enjoy full support and collaboration between stakeholders, especially from the federal government (OWC, 2009). Complex relationships and intricate dynamics characterize the network of stakeholders involved in the offshore wind market (OWC, 2009). In general, these come from the industry sector, academic and research institutions, non-government and environmental organizations, the public, state governments, and a variety of federal agencies (OWC, 2009).

2.3.2 U.S. FEDERAL GOVERNMENT COLLABORATIONS

Meaningful involvement from the federal government was prompted by the proposal of the first offshore wind project in the United States in 2001, the Cape Wind project, and the events that followed (OWC, 2009). As the first proposal of this kind, Cape Wind generated enthusiastic advocates but also severe resistance from different stakeholder groups accompanied by plenty of community debates regarding the permitting processes (OWC, 2009).

As the chosen supplier of the Cape Wind project wind turbines and interested in deep water-wind resource technology, General Electric took the first steps to assemble joint

efforts with the Massachusetts Technology Collaborative (state agency), Department of Energy, and academic institutions doing this type of work (University of Massachusetts, Massachusetts Institute of Technology, and Woods Hole Oceanographic Institution) to create offshore wind energy systems tailored to this location (OWC, 2009). This represented the first step in pursuing broader participation that involved regulatory agencies, policy makers, environmental advocacy groups, grass-roots groups, social groups, and industry partners (OWC, 2009). This initial phase resulted in the formation the Offshore Wind Collaborative made up of General Electric, Massachusetts Technology Collaborative, and the Department of Energy to assist in the development and growth of a U.S. offshore wind industry (OWC, 2009).

After bringing together stakeholders to examine the positive and negative aspects posed by technology designed to generate electricity from offshore wind, the result was an extensive sustainable development plan for the offshore wind market: A Framework for Offshore Wind Energy Development in the United States (OWC, 2009). Completed in 2005, the main goal of the Framework was to forecast and prepare for concerns related to economic and social issues as well as to form unified and effective partnerships between stakeholders so that through technology design mitigation of adverse impacts could achieved (OWC, 2009).

Subsequently, General Electric and the Department of Energy digressed from offshore wind forcing the Offshore Wind Collaborative to create a volunteer, ad-hoc Steering Committee that focused on offshore wind advocacy among different levels within the

political arena, industry, environmental organization, and academia (OWC, 2009). As a result of the expanding participation and changing levels of involvement from stakeholders in this Committee, an interdisciplinary nonprofit organization called the U.S. Offshore Wind Collaborative (OWC) was launched. The OWC currently assists in the development and growth of the U.S. offshore wind industry by helping to coordinate state, federal, and stakeholder actions (Musial & Ram, 2010; OWC, 2014).

Prior to 2005 and following on the developments of Cape Wind, there was no clearly defined regulatory authority to manage the approval process for the development of offshore wind in federal waters (OWC, 2009). The Energy Act of 2005 authorized the Secretary of the Interior to grant the Minerals Management Service (MMS), now replaced by the Bureau of Ocean Energy Management (BOEM), with jurisdictional authority over any offshore energy related activities on the Outer Continental Shelf (OCS) (OWC, 2009; Lawrence, Ostrander, Smith, & McDermott Will & Emery LLP, 2009). In summary, the Energy Act of 2005 initiated the involvement of the federal government in creating programs and regulations for offshore wind energy in the United States (Musial & Ram, 2010).

In 2007, the MMS examined the OCS renewable energy uses in terms of potential environmental impacts over the next five to seven years (OWC, 2009). This assessment, the Programmatic Environmental Impact Statement, also helped identify key issues and mitigation measures for future projects, and included policy guidelines and best management practices to be incorporated into new regulations (OWC, 2009). This same

year, installations for offshore data collection and technology testing facilities were approved by MMS through an interim policy (OWC, 2009).

Two years later in June 2009, five limited leases permitting wind energy resource data collections activities was issued by MMS to be conducted on the OCS offshore from New Jersey and Delaware and authorized the construction of meteorological towers. These five leases were to be split between five OCS block for a term of five years: four OCS blocks were located off the coast of New Jersey, and the last one off the coast of Delaware (OWC, 2009).

The United States' short history with offshore wind energy reflects this recent emergence in regulatory and institutional structures to manage offshore wind energy (Musial & Ram, 2010). However, there are a number of other national and regional organizations focusing on channeling efforts and finding answers to offshore wind development matters such as the environment, regulations, economy, technology, and public perception (Musial & Ram, 2010). By coordinating cross-sector engagement between state governments, industry, clean energy supporters, and academia, the offshore wind energy sector may be capable of accommodating and evolving along with the challenges presented by the changing nature of the regulatory and policy structures (Musial & Ram, 2010; OWC, 2009). Some of these organizations include:

- National Renewable Energy Laboratory: carries out offshore wind energy research and development to address critical areas that reflect the long-term needs of the offshore wind energy industry and the U.S. Department of Energy (NREL, 2014).

- Offshore Wind Working Group: a policy subcommittee launched in 2006 by the American Wind Energy Association that provides a space for stakeholders to work together on legislative guidance, public education, media outreach, and research and development (North American Wind Power, 2006; Musial & Ram, 2010).
- Offshore Wind Development Coalition: a group of businesses advocating for federal policy initiatives promoting the development of offshore wind power plants. Founded in 2010 by seven offshore wind developers and the American Wind Energy Association (AWEA) (Offshore Wind Development Coalition, 2011).
- Atlantic Offshore Wind Energy Consortium: an association formed by U.S. Department of the Interior and ten East Coast states: Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, and Virginia (BOEM, 2010a). Signed in 2010, the Consortium works together "to coordinate issues of regional applicability for the purpose of promoting the efficient, expeditious, orderly and responsible development of the wind resources of the Atlantic outer continental shelf" (BOEM, 2010a).
- Great Lakes Wind Collaborative: "a multi-sector coalition of wind energy stakeholders working to facilitate the sustainable development of wind power in the Great Lakes region" (Great Lakes Wind Collaborative, 2010).
- Southeastern Coastal Wind Coalition: a nonprofit helping to advance the coastal and offshore wind industry in the U.S. Southeast region by focusing on supply chain growth, economic development, job growth, and wind energy development. Currently five coastal states form part of the coalition: Virginia, North Carolina,

South Carolina, Georgia, and Florida (Southeastern Coastal Wind Coalition, 2013).

- Mid-Atlantic Regional Council on the Ocean (MARCO): established in 2009 as a partnership with the Mid-Atlantic Governors' Agreement on Ocean Conservation, which included the Governors of New York, Delaware, Maryland, New Jersey, and Virginia, to address shared regional priorities and provide a collective voice (MARCO, 2014). As one of its four shared regional priorities, MARCO aids in creating a collaborative regional approach to support the sustainable development of renewable energy in offshore areas (MARCO, 2014).
- Offshore Wind Accelerator Project: functions "as an information portal on offshore development priorities by producing reports, polls, and other resources on top challenges and issues like project siting, power procurement, and offshore wind supply chains." It exists under the leadership of the nonprofit, Clean Energy States Alliance, formed in 2002 by "a coalition of state and municipal clean energy programs to facilitate state and federal partnerships to advance clean energy technologies" (International Economic Development Council, 2013).

More recently, in 2010, the wide range of co-benefits from supporting renewable energy development such as energy supply security, health improvements, job creation, emissions' reductions, grid capacity stress reduction, and climate change resilience and mitigation has brought a renewed and stronger interagency interest (REN21, 2014: Deal, 2010). In June 2010, the U.S. Department of the Interior and Department of Energy "announced a new Memorandum of Understanding (MOU) that will strengthen the

working relationship between the two agencies on the future development of commercial renewable offshore energy projects on the U.S. Outer Continental Shelf (OCS)" (DOE, 2010b). The MOU's main goal was "to spur the development of future commercial-scale offshore wind and water energy projects" through "priority leasing and efficient regulatory processes"(DOE, 2010b). This agreement will also enable the two agencies to "exchange information on resources and technologies, conduct stakeholder engagements, and collaborate on research projects," resulting in an increase in scientific and technical knowledge sharing (DOE, 2010b).

Another interagency collaboration was announced in October 2010 between the U.S. Department of Energy, the Bureau of Ocean Energy Management, and the U.S. Department of Commerce's National Oceanic and Atmospheric Administration to join forces in pursuing environmental research projects that advance ocean renewable energy (DOE, 2010a). A total of eight research awards aimed at supporting "responsible siting and permitting of offshore wind energy facilities and ocean energy generated from waves, tides, currents and thermal gradients" by addressing "key information gaps regarding the potential environmental effects of renewable ocean energy" (DOEa, 2010). The research topic areas were designed to gather information to "help reduce the environmental risks and regulatory uncertainties associated with offshore renewable energy deployment" (DOE, 2010a). The awards following awards were granted:

- "Bayesian Integration for Marine Spatial Planning and Renewable Energy Siting," Parametrix in Auburn, Washington;

- “Characterization & Potential Impacts of Noise Producing Construction & Operation Activities on the Outer Continental Shelf,” the Cornell Lab of Ornithology's Bioacoustics Research Program in Ithaca, New York;
- “Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship,” the University of Rhode Island in Kingston, Rhode Island;
- “Evaluating Acoustic Technologies to Monitor Aquatic Organisms at Renewable Sites,” the University of Washington - School of Aquatic and Fishery Scientists in Seattle, Washington;
- “Protocols for Baseline Studies and Monitoring for Ocean Renewable Energy,” Pacific Energy Ventures in Portland, Oregon;
- “Renewable Energy Visual Evaluations,” the University of Arkansas Center for Advanced Spatial Technologies in Fayetteville, Arkansas;
- “Sub-Seabed Geologic Carbon Dioxide Sequestration Best Management Practices,” the University of Texas at Austin - Bureau of Economic Geology in Austin, Texas; and
- “Technology Roadmap for Cost Effective, Spatial Resource Assessments for Offshore Renewable Energy,” the University of Massachusetts - Marine Renewable Energy Center in Dartmouth, Massachusetts (DOE, 2010a).

A more regionally targeted initiative was launched in November 2010 by the U.S. Department of the Interior. The ‘Smart from the Start’ wind energy initiative’s main goal was to spur offshore wind development on the Atlantic Outer Continental Shelf (DOE,

2010c). The approach focuses on using "appropriate designated areas, coordinated environmental studies, large-scale planning and expedited approval processes to speed offshore wind energy development" to facilitate how new projects are sited, leased, and constructed (DOE, 2011b; DOE, 2010c). In February 2011, the U.S. Department of the Interior identified four Wind Energy Areas offshore the Mid-Atlantic on the Outer Continental Shelf to receive "early environmental reviews that will help to lessen the time required for review, leasing and approval of offshore wind turbine facilities" (DOE, 2011b). The states where these areas are located are Delaware (122 nautical square miles (nm^2)), Maryland (207 nm^2), New Jersey (417 nm^2), and Virginia (165 nm^2) (DOE, 2011b).

Simultaneously, continued collaboration between the U.S. Department of the Interior and Department of Energy to accelerate the development of offshore wind energy were presented by means of a coordinated strategic plan, the joint "National Offshore Wind Strategy: Creating an Offshore Wind Industry in the United States" (DOE, 2011b). This plan represents the "first-ever interagency plan on offshore wind energy" and the federal government's commitment "to expeditiously develop a sustainable, world-class offshore wind industry in a way that reduces conflict with other ocean uses and protects resources" (DOE, 2011b). The plan's main focus is to address three key challenges: "the relatively high cost of offshore wind energy; technical challenges surrounding installation, operations, and grid interconnection; and the lack of site data and experience with project permitting processes" (DOE, 2011b).

In addition, this plan will undertake these activities by serving as a guide for the U.S. Department of Energy's Offshore Wind Innovation and Demonstration (OSWInD) Initiative (DOE, 2011a). The initiative's main goal is to promote and accelerate responsible commercial offshore wind development in the United States and is designed "to achieve two critical objectives: reduce the cost of offshore wind energy and reduce the timeline for deploying offshore wind energy" (DOE, 2011a). Finally, these actions are aimed at achieving the "development of a world-class offshore wind industry in the United States able to achieve 54 gigawatts of offshore wind deployment at a cost of 7-9 cents per kilowatt-hour by the year 2030, with an interim target of 10 gigawatts at 13 cents per kilowatt-hour by 2020" (DOE, 2011a; DOE, 2011b).

In 2014, the U.S. Department of Energy Wind Program along with the National Renewable Energy Laboratory published the "Assessment of Offshore Wind System Design, Safety, and Operation Standards," which "summarizes the regulations, standards, and guidelines for the design and operation of offshore wind projects in the United States" (DOE, 2014a). This report comes as a response to conclusions drawn from an offshore resource assessment report published by the U.S. Department of Energy in 2011 (2011 Offshore Resource Assessment and Design Conditions Public Meeting). This 2011 assessment concluded that "the current meteorological-ocean datasets (e.g., hub-height conditions, joint wind-wave conditions, or atmospheric stability) are inadequate to support U.S. offshore wind development. As a result, the need for new or revised offshore wind guidelines for U.S. waters informed by a robust set of ocean-based measurements is seen as a primary driver to advance a national offshore resource and design data

campaign" (DOE, 2014a). This follow up 2014 assessment "introduces the pertinent international and domestic offshore design standards, discusses their relative applicability and shortcomings for the nation's offshore wind development, and provides a snapshot of industry and government efforts underway (or planned) to develop guidelines for U.S. offshore wind" (DOE, 2014a).

In addition to interagency collaborations and partnerships to advance the U.S. offshore wind industry, there has also been a tremendous amount of ongoing support for offshore wind research and development efforts. In May 2014, the U.S. Department of Energy selected three projects that will serve as pioneering offshore wind demonstrations (DOE, 2014b). Located off the coast of New Jersey, Oregon and Virginia, their purpose is to "help speed the deployment of more efficient offshore wind power technologies" in the U.S. waters by 2017 (DOE, 2014b). The projects are described below:

- Five 5-megawatt direct-drive wind turbines: to be installed approximately three miles off the coast of Atlantic City, New Jersey by Fishermen's Energy (DOE, 2014b). This project will "act as a laboratory for researchers to learn about offshore wind and investigate interactions between turbines" (DOE, 2014b).
- Five 6-megawatt direct-drive wind turbines: to be installed approximately 18 miles off the coast of Coos Bay, Oregon by Principle Power (DOE, 2014b). Due to the fact that more than 60 percent of U.S. offshore wind resources are found in deep waters, this projects looks at testing a U.S.-developed WindFloat semi-submersible floating foundation at waters of more that 1,000 fee deep (DOE, 2014b). The group is looking at "demonstrating an innovative solution for deep

water wind turbine projects and lowering costs by simplifying installation and eliminating the need for highly specialized ships" (DOE, 2014b).

- Two 6-megawatt direct-drive wind turbines: to be installed 26 miles off the coast of Virginia Beach by Dominion Virginia (DOE, 2014b). By utilizing a U.S.-designed twisted jacket foundation, this projects looks at studying "installation, operation and maintenance methods for wind turbines located far from shore" (DOE, 2014b). Simultaneously, the project will incorporate research on hurricane-resiliency design with the purpose of providing information on reliability, safety and costs for offshore wind facilities placed in hurricane-prone U.S. waters (DOE, 2014b).

Along with federal production tax incentives and government loan guarantees, these efforts demonstrate that in the past decade the federal government has certainly recognized the high level of importance offshore wind energy in contributing to a secure and clean U.S. energy portfolio. In addition, partnerships and collaborations among federal, regional, state, and local levels play a critical role in the development of a healthy offshore wind energy industry. The following sections will illustrate the numerous entities involved in siting, permitting, and installation of offshore wind power plants, and the important role state bodies have played in advancing the U.S. offshore wind industry.

2.3.3 U.S. OFFSHORE WIND ENERGY PERMITTING COMPLEXITIES AND CHALLENGES

As an untapped energy resource and emerging industry in the United States, offshore wind power developments are bound to confront a wide range of obstacles including complex and conflicting state and federal regulatory guidelines along with immature permitting processes. However, recently federal and state agencies have addressed and reduced the amount of time for project development by putting into effect initiatives to streamline these complicated processes. Nonetheless, the site selection and permitting process entails numerous steps, as it has to take into account multiple considerations in regards to environment, protected areas, recreation, navigation, business, wildlife, archeology, geophysics, geology, and conflicts of use, among others (DOE, 2011a). The two main federal agencies involved in offshore wind energy permitting are:

- U.S. Department of the Interior by means of the Bureau of Ocean Energy Management: the lead agency in permitting offshore wind energy on the Outer Continental Shelf (DOE, 2011a).
- U.S. Army Corps of Engineers: in charge of overseeing and permitting any potential obstruction or alteration of U.S. navigable waters, in addition to being the lead federal agency for offshore wind permitting in state waters and the Great Lakes (DOE, 2011a).

There are additional federal entities responsible for other aspects of the offshore wind energy permitting process. The following table lists these agencies along with key statutes:

Table 2.2 Key statutes and agencies involved in offshore wind permitting

Statutes	*Key Agencies*	*Description*
National Environmental Policy Act of 1969 (NEPA)	All federal agencies	Requires federal agencies to consider the potential environmental impacts of proposed federal actions. For any major federal action that is likely to result in significant environmental impacts, agencies must prepare an Environmental Impact Statement (EIS).
Endangered Species Act of 1973	Fish and Wildlife Service (U.S Department of the Interior); National Oceanographic and Atmospheric Administration; National Marine Fisheries Service	Requires federal agencies to consult with the Fish and Wildlife Service and National Oceanographic and Atmospheric Administration National Marine Fisheries Service to ensure that proposed Federal actions are not likely to jeopardize the continued existence of any species listed at the federal level as endangered or threatened, or result in the destruction or adverse modification of critical habitat.
Marine Mammal Protection Act of 1972	Fish and Wildlife Service (U.S Department of the Interior); National Oceanographic and Atmospheric Administration; National Marine Fisheries Service	Prohibits, with certain exceptions, the take of marine mammals in U.S. waters by U.S. citizens on the high seas, and importation of marine mammals and marine mammal products into the U.S.
Magnuson-Stevens Fishery Conservation and Management Act	National Oceanographic and Atmospheric Administration; National Marine Fisheries Service	Requires federal agencies to consult with the National Marine Fisheries Service on proposed federal actions that may adversely affect essential fish habitats necessary for spawning, breeding, feeding, or growth to maturity of federally managed fisheries.
Marine Protection, Research, and Sanctuaries Act of 1972	U.S. Environmental Protection Agency; U.S. Army Corps of Engineers; National Oceanographic and Atmospheric Administration	Prohibits the dumping of certain materials without a permit from the U.S. Environmental Protection Agency. For ocean dumping of dredged material, the U.S. Army Corps of Engineers is given permitting authority.
National Marine Sanctuaries Act	National Oceanographic and Atmospheric Administration	Prohibits the destruction, loss of, or injury to any sanctuary resource managed under the law or permit.

Coastal Zone Management Act of 1972	National Oceanographic and Atmospheric Administration Office of Ocean and Coastal Resource Management (OCRM)	Specifies that coastal states may protect coastal resources and manage coastal development.
National Historic Preservation Act of 1966	National Park Service; Advisory Council on Historic Preservation; State or Tribal Historic Preservation Officer	Requires each federal agency to consult with the Advisory Council on Historic Preservation and the State or Tribal Historic Preservation Officer before allowing a federally licensed activity to proceed in an area where cultural or historic resources might be located.
Federal Aviation Act of 1958	Federal Aviation Administration	Requires that, when construction, alteration, establishment, or expansion of a structure is proposed, adequate public notice be given to the Federal Aviation Administration as necessary to promote safety in air commerce and the efficient use and preservation of the navigable airspace.
Federal Power Act	Federal Energy Regulatory Commission; Bureau of Ocean Energy Management	Establishes Bureau of Ocean Energy Management as the lead authority to regulate offshore wind in federal waters. (Note that under the Federal Power Act, per an MOU between U.S. Department of the Interior and Federal Energy Regulatory Commission, Federal Energy Regulatory Commission has the lead role in regulating offshore kinetic energy, such as wave energy devices.)
Ports and Waterways Safety Act	U.S. Coast Guard	Authorizes the U.S. Coast Guard to implement measures for controlling or supervising vessel traffic or for protecting navigation and the marine environment.
Rivers and Harbors Act of 1899	U.S. Army Corps of Engineers	Delegates to the U.S. Army Corps of Engineers the authority to review and regulate certain structures and work that are located in or that affect navigable waters of the United States, including submarine cable systems.

Outer Continental Lands Act of 1953	U.S. Department of the Interior	Granted the Department of the Interior with the authority to lease submerged lands on the Outer Continental Shelf. The Energy Policy Act of 2005 amended this act to give U.S. Department of the Interior the authority to lease renewable energy, including offshore wind, on the OCS.
Clean Water Act	U.S. Environmental Protection Agency, U.S. Coast Guard	Prohibits the discharge of oil or hazardous substances into waters or adjoining shorelines, which may affect natural resources belonging to the United States.
Clean Air Act	U.S. Environmental Protection Agency, Bureau of Ocean Energy Management	Prohibits federal agencies from providing financial assistance or issuing approval for activities that do not conform to approved plans for achieving National Ambient Air Quality Standards. Requires the U.S. Environmental Protection Agency (or authorized state agencies) to issue a permit before the construction of, or major modification to, any major stationary source of air pollution.

Note. Adapted from *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States*, p. 11-12, by DOE, 2011a.

3 OFFSHORE WIND ENERGY FOR THE U.S. MID- ATLANTIC REGION

3.1 THE U.S. MID-ATLANTIC REGION

Some of the most densely populated centers in the United States are stretched along the Atlantic Seaboard where energy demands are some of the highest in the country (OWC, 2009). These areas offer opportunities for utility-scale offshore wind energy development with minimum human impacts (OWC, 2009).

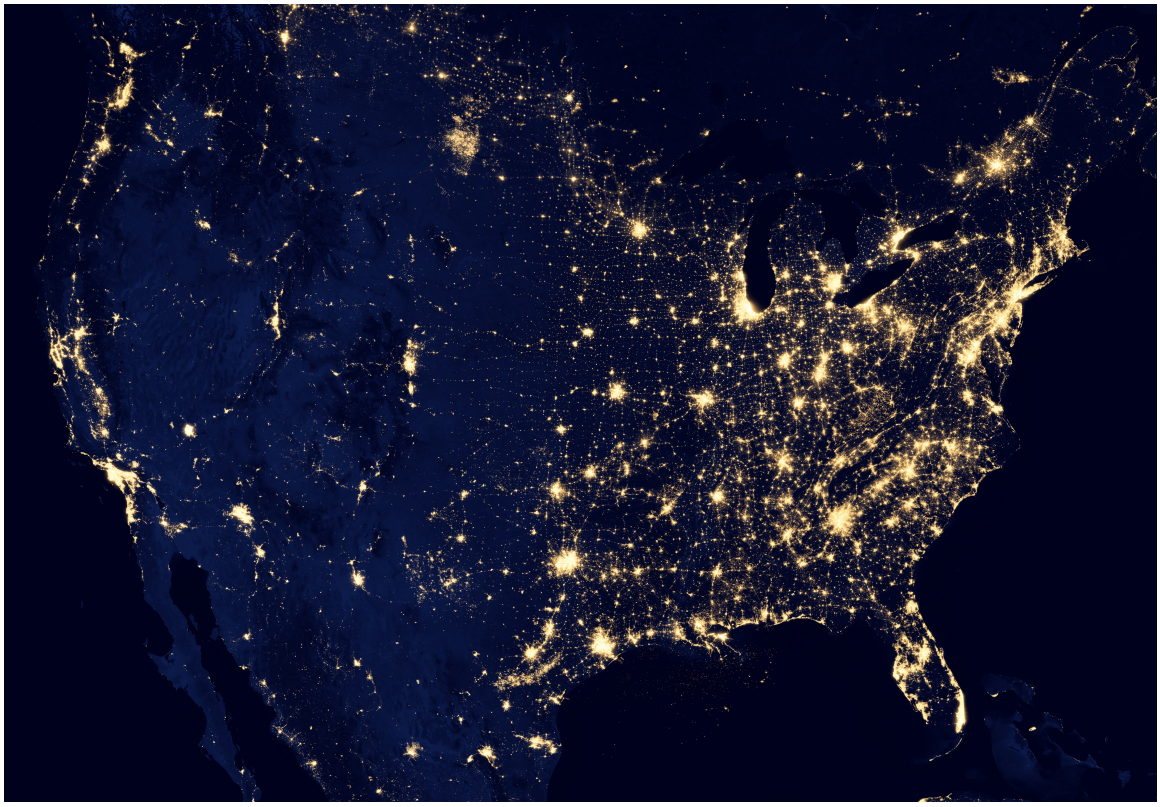


Figure 3.1: City Lights of the United States 2012 (Simmon & NASA Earth Observatory, 2012).

The National Renewable Energy Laboratory estimated that the potential offshore wind energy capacity within 50 nautical miles between the shores of New York and Virginia is around 410 gigawatts (GW) and covers an area of approximately 82,000 km^2 (Environmental Law Institute, 2013; Schwartz et al., 2010). Along with this high energy potential and proximity to urban centers, the Mid-Atlantic Coast exhibits physical features that make it ideal for offshore wind energy development such as a gently sloping, shallow continental shelf and steady offshore winds (Environmental Law Institute, 2013).

Almost one quarter of potential capacity for offshore wind energy is concentrated within three nautical miles offshore, meaning that jurisdiction of this resource falls under the jurisdiction of the adjacent coastal states (Environmental Law Institute, 2013). The U.S. Department of the Interior ultimately oversees management and development of offshore wind energy beyond three nautical miles (Environmental Law Institute, 2013). These characteristics and factors have pushed individual states to take the lead in developing state-level offshore wind policies and regulations (Environmental Law Institute, 2013).

An analysis by the National Renewable Energy Laboratory (NREL) yielded promising numbers for the job and economy sector. First, each megawatt of offshore wind energy produced annually in the United States could create 20.7 direct jobs (Musial & Ram, 2010). Moreover, each cumulative megawatt of offshore wind in operation could create close to 0.8 jobs (Musial & Ram, 2010). Considering the 2008 U.S. Department of Energy's installation of 54 GW offshore wind under a 20% wind scenario by 2030, the job market could benefit from 43,000 permanent jobs in operations and maintenance;

plus, it also estimates that turbine manufacturing and installation would benefit from more than 1.1 million job-years (Musial & Ram, 2010). Ultimately, development of the wind industry at a domestic level can render a means to increase activity of the domestic manufacturing sector, create jobs that are high-paying and stable, and allow the United States to take advantage of twenty-first century advancements in energy technology (Musial & Ram, 2010).

Table 3.1 Offshore wind resource area and potential for the states of Delaware, Maryland, New Jersey, and Virginia within 50 nm of shore

	Total		0-3 nautical miles		3-50 nautical miles	
	Area (km^2)	Potential (GW)	Area (km^2)	Potential (GW)	Area (km^2)	Potential (GW)
Delaware	2,940	14.7	1,087.60	5.5	1,852.50	9.2
Maryland	10,756	53.8	4,291.80	22	6,464.60	32
New Jersey	19,935	99.7	2,270.60	11	17,664	88
Virginia	18,890	94.4	5,647.80	28	13,242	66
TOTAL	81,960	409.8	19,530	98	62,430	312

Note. Adapted from *A Guide To State Management Of Offshore Wind Energy In The Mid-Atlantic Region*, p. 2, by Environmental Law Institute, 2013, and from *Assessment of Offshore Wind Energy Resources for the United States*, p. 3-4, by Schwartz et al., 2010.

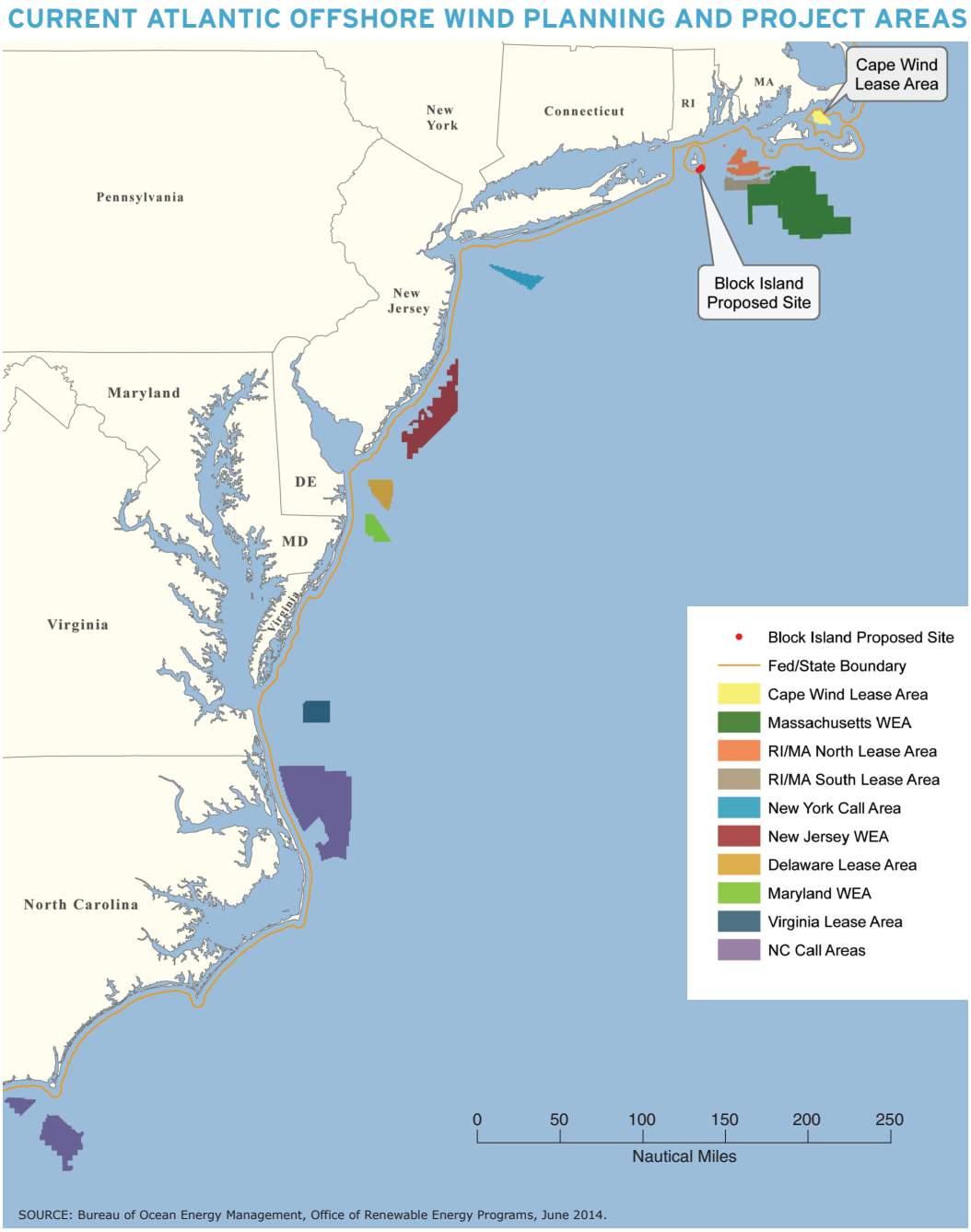


Figure 3.2: Current Atlantic Offshore Wind Planning and Project Areas (National Wildlife Federation, 2014).

As discussed in Chapter 1, a renewable portfolio standard, also referred to as renewable electricity standard, is a policy by which state governments establish firm clean energy targets requiring retailers to provide a minimum amount or percentage of their electricity to be supplied from renewable energy sources (International Economic Development Council, 2013; Cory & Swezey, 2007). Nearly all renewable portfolio standards have been established by means of legislation or ballot initiative, indicating extensive political support as its main driver (Leon, 2013).

One of the most important characteristics of renewable portfolio standards is their adaptability; as flexible policy mechanisms, they are able to adapt to the states' varying policy needs, goals, and renewable energy resources (Leon, 2013). This flexibility allows states to calculate their own renewable portfolio standard ambitions by varying the percentage of renewable portfolio standard targets and compliance dates (Leon, 2013). A state's economic development goals and environmental objectives are used to determine which technologies to support and incentivize for renewable portfolio standard compliance (Leon, 2013). As a result, successful renewable portfolio standard policy implementation will "balance a state's goals for fuel diversity, economic development, price effects, and environmental benefits" (Cory & Swezey, 2007).

This study will focus on offshore renewable energy in four states of the MARCO five-state region: Delaware, Maryland, New Jersey, and Virginia. The following table is a summary of their renewable portfolio standards:

Table 3.2 State Action and Renewable Energy Goals to Advance Offshore Wind Energy

State	Goal	Renewable Energy Policy (RES) / Renewable Portfolio Standard (RPS)	Carbon Policies	Initiatives / Investment
Delaware		RES: 25% by 2025	Regional Greenhouse Gas Initiative (RGGI)	3.5 multiplier for offshore wind energy by May 2017
Maryland	200 MW by 2017 (2013)	RES: 20% by 2022; Offshore Wind Energy Act requiring 2.5% of state's electricity (approximately 200 MW) to be supplied by offshore wind (2013)	RGGI; Greenhouse Gas Reduction Act (state to develop plan for 25% reduction by 2020)	Offshore Wind Development Fund: $700,000 (2012)
New Jersey	1,100 MW (2010)	RPS: 23% by 2021, Offshore Wind Development Act requires 1,100 MW of state's electricity to be supplied by offshore wind (2010): 100% tax credit for $50 million+ capital investments (2010)	Global Warming Response Act (20% Greenhouse gas emissions reduction by 2020, 80% by 2050)	New Jersey Department of Environmental Protection Ocean/Wind Power Ecological Baseline Studies (2010)
Virginia	3,000 MW by 2025 (2011 non-binding legislative resolution)	Voluntary RES: 15% by 2025, with a multiplier credit for offshore wind; Legislation declaring offshore wind planning in the public interest (2014)		Executive Order establishing Virginia Energy Council (2014); Virginia Department of Mines, Minerals and Energy investment in Virginia Offshore Wind Technology Advancement Project (VOWTAP) project and $800,000 - $1 million annually for offshroe wind research; Virginia Offshore Wind Development Authority established (2010)

Note. Adapted from *Catching The Wind: State Actions Needed To Seize The Golden Opportunity Of Atlantic Offshore Wind Power* p. 12, by National Wildlife Federation, 2014.

3.1.1 DELAWARE

Delaware's offshore wind resource potential, as estimated by the 2010 National Renewable Energy Laboratory's Assessment, stands at 14.7 gigawatts within 50 nautical miles of the coast and covers an area of 2,940 km^2 (Schwartz et al., 2010). Delaware's central location makes it an ideal place for offshore wind development as is has a port connected to the Atlantic Ocean, a well-trained labor force, and excellent research capabilities (Clean Energy States Alliance, 2012a). One of its most important assets, the Port of Wilmington, has been managing wind power projects since 2001, benefiting from having easy access to rails and highways (Clean Energy States Alliance, 2012a). Research on offshore wind power takes place at the University of Delaware's College of Earth, Ocean, and Environment (University of Delaware CEOE, 2014). Some of the studies include modeling atmospheric turbulence and wake effects of wind turbines, evaluating public's perceptions on the basis of offshore wind, assessing user conflicts using marine spatial planning tools, and studies on integrated system design, grid integration, and resource assessment (University of Delaware CEOE, 2014).

In 2005, Delaware enacted legislation to establish a renewable portfolio standard that required retail electricity suppliers to purchase 10 percent of the electricity they sold in the state to come from renewable resources by 2019-2020 (DSIRE, 2013a). In 2010, the law was amended to increase Delaware's renewable portfolio standard target to 25 percent by 2025-2026 (DSIRE, 2013a). Utilities that need to comply with the law include investor-owned, municipal, and rural electric cooperatives. However, municipal utilities and rural electric cooperatives were authorized to be exempt from the renewable portfolio standard

requirements as long as they established a program that is comparable to the renewable portfolio standards beginning in 2013 (Delaware Public Service Commission, 2010; (DSIRE, 2013a). However, the amendments of 2010 eliminated this exemption for an option permitting municipal utilities and rural electric cooperatives to create and put into effect a similar renewable portfolio standard beginning in 2013 (Delaware Public Service Commission, 2010; (DSIRE, 2013a).

In 2008, Delaware proved to be an early offshore wind leader when it finalized the first power purchase agreement (PPA) for a U.S. offshore wind energy development between Bluewater Wind and Delmarva Power & Light (National Wildlife Federation, 2014; Clean Energy States Alliance, 2012a). When Bluewater Wind was acquired by NRG, it was forced to give up the power purchase agreement settled with Delmarva Power & Light, as there was no financial security for the 200 MW offshore wind project (Clean Energy States Alliance, 2012a). In 2012, an environmental assessment published by the Bureau of Ocean Energy Management concluded a "Finding of No Significant Impact" for development of offshore wind energy on the coast of Delaware (BOEM, 2010b). Currently, NRG Bluewater holds the lease agreement covering 96,430 acres on federal waters 11 nautical miles off the coast of Delaware, comprised of 11 full Outer Continental Shelf blocks and 16 partial blocks. (DOI, 2012; National Wildlife Federation, 2014).

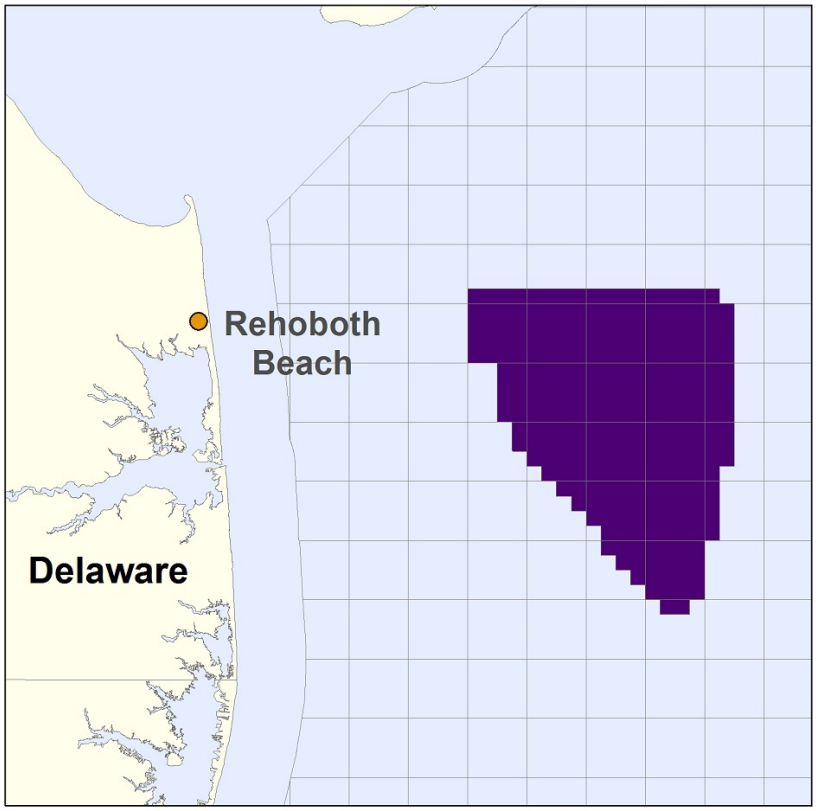


Figure 3.3: Delaware Wind Energy Area (BOEM, 2010b).

3.1.2 MARYLAND

Maryland is also strategically placed for offshore wind energy development (Ridlington, Kerth & Landers, 2012; Clean Energy States Alliance, 2012b). In addition to having offshore wind energy potential as its largest renewable energy resource, the state of Maryland also provides government incentives, support to build energy infrastructure, and grants to help create and increase local wind power related businesses (Clean Energy States Alliance, 2012b).

Identified as an immature industry in the United States, offshore wind can benefit from a well-equipped port terminal to support the supply chain (Guillen, Wetzler & Abstoss, 2011; Clean Energy States Alliance, 2012b). Although Maryland has three commercial deepwater ports, only the Dundalk Marine Terminal located in Baltimore has been identified as a suitable supply terminal (Guillen et al., 2011; Clean Energy States Alliance, 2012b). As most of the offshore wind components will have to be imported, Dundalk can serve the storage, assembly of components, manufacturing, and distribution needs of the offshore wind industry (Guillen et al, 2011).

A large group of higher education institutions and organizations provide expertise related to offshore wind energy in Maryland. Some of these include the Clean Energy Technology Incubator and the Energy Research Center at the University of Maryland, both working in fields related to clean energy technologies including wind and other aspects such as business, policy, and education (University of Maryland CETI, 2012; University of Maryland ERC, 2014). The Maryland Clean Energy Center supports the

growth of Maryland's energy economy through programs that aim at growing businesses, increasing jobs in the green sector, and facilitates affordable, accessible, and easy to implement clean energy technologies (Maryland Clean Energy Center, 2014).

Maryland originally enacted its renewable portfolio standard in 2004 and has gone through several amendments since then (DSIRE, 2013b). Currently, Maryland's renewable portfolio standard requires that 20 percent of the state's electricity is produced by means of renewable sources by 2022 (DSIRE, 2013b). In April 2013, the Maryland Offshore Wind Energy Act of 2013, House Bill 226 was enacted, adding a tangible target for offshore wind energy to the state's renewable portfolio standard by creating a resource carve-out of up to 2.5% of retail electricity sales by 2017 (DSIRE, 2013b; EIA, 2014c). The carve-out requirements will be determined by the Maryland Public Service Commission contingent on the 2.5 percent limitation (DSIRE, 2013b; EIA, 2014c). Offshore wind facilities taken under consideration will need to be within the DOI's designated leasing zone located on the outer continental shelf between 10 and 30 miles off the coast of Maryland, and planned to be connected to PJM Interconnection at a point on the Delmarva Peninsula (DSIRE, 2013b; EIA, 2014c). Finally, these projects will need to follow a process of approval established by the Maryland Public Service Commission along with cost constraints for both residential customers and renewable energy credits for offshore wind (EIA, 2014c).

The National Renewable Energy Laboratory's 2010 Assessment lists Maryland's offshore wind resource potential at 53.8 gigawatts within 50 nautical miles of the coast and

covering an area of 10,756 km^2 (Schwartz et al., 2010). The Bureau of Ocean Energy Management identified an offshore Wind Energy Area for Maryland that covers approximately 324 km^2 (80,000 acres) and located at approximately 10 nautical miles off the coast of Ocean City in Maryland (BOEM, 2014a). The auction for this Wind Energy Area was held on August 19, 2014 as two leases: the North Lease Area comprised of 133 km^2 (32,737 acres) and the South Lease Area with 190 km^2 (46,970 acres) (BOEM, 2014a). According to the National Renewable Energy Laboratory, this area has the capacity to provide between 850 and 1450 megawatts of commercial wind energy generation (DOI, 2014b). No winning bidders have been identified to date (BOEM, 2014a).

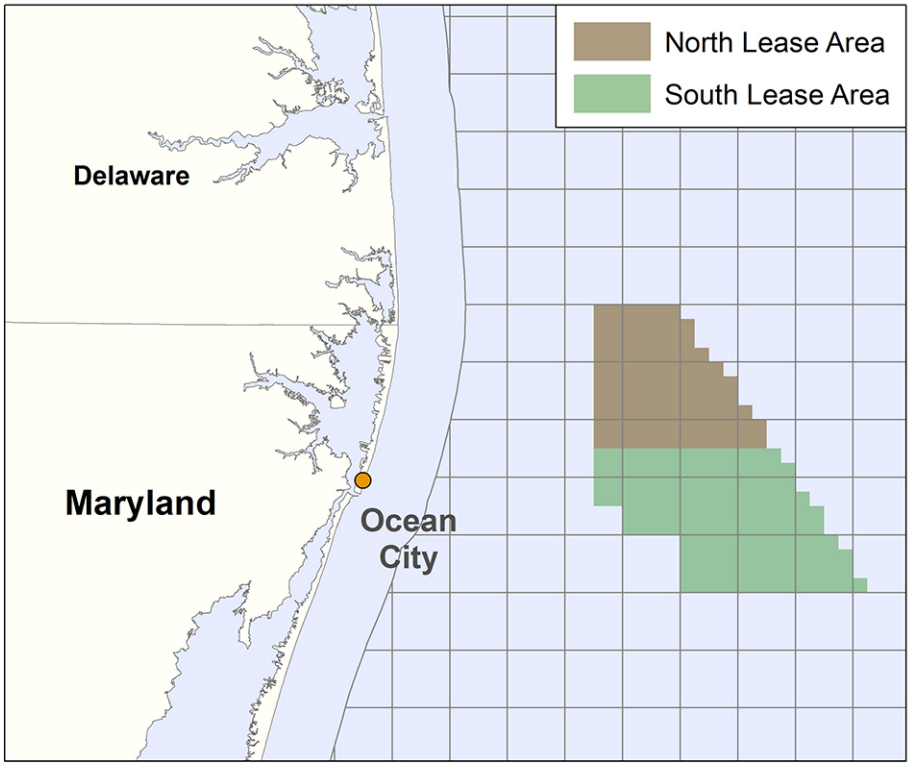


Figure 3.4: Maryland Wind Energy Area (BOEM, 2014a).

3.1.3 NEW JERSEY

New Jersey has become a leader and supporter of the offshore wind energy industry development in the United States. This has been possible by enacting legislation and setting up rules to create an offshore wind renewable energy portfolio while also making financial incentives available for offshore wind project development and manufacturing (Clean Energy States Alliance, 2012c).

The National Renewable Energy Laboratory's 2010 Assessment estimates New Jersey's offshore wind resource potential at 99.7 gigawatts within 50 nautical miles of the coast and covering an area of 19,935 km^2 (Schwartz et al., 2010). Apart from having the highest offshore wind resource potential from the four states considered in this study, New Jersey offers favorable characteristics for offshore wind energy development such as a "strategic central location on the East Coast," "long coastline and shallow outer continental shelf," "steady wind resource," and an "educated, skilled workforce" (Clean Energy States Alliance, 2012c).

In 2004, the New Jersey Board of Public Utilities set into motion a chain reaction for New Jersey's government policies for offshore wind energy development by offering support towards utility-scale offshore wind energy projects (OWC, 2009; Clean Energy States Alliance, 2012c). In May 2006, a blue ribbon panel was created to evaluate offshore wind energy effects on the state's economic, environmental, and regulatory aspects (OWC, 2009; State of New Jersey, 2006). The report issued by this panel resulted in 12 million dollars in funding for grants used for the construction of meteorological towers as well as

state funds directed at consumer surveys and ocean/wind power ecological baseline studies (OWC, 2009; Clean Energy States Alliance, 2012c; Geo- Marine Inc., 2010). A report issued by the New Jersey Department of Environmental Protection in 2010 identified the location of ecological resources in the waters near the coast of New Jersey with the purpose of determining suitable areas for offshore wind energy development (OWC, 2009; Clean Energy States Alliance, 2012c). The study was based on determining potential ecological impacts by performing predictive modeling, mapping, and environmental assessment, which led to establishing the areas for offshore wind facility siting (Clean Energy States Alliance, 2012c).

One of the most significant steps taken by New Jersey in favor of offshore wind energy is the establishment of the Offshore Wind Economic Development Act (OWEDA) signed in 2010 by Governor Chris Christie (Clean Energy States Alliance, 2012c). The Act establishes and provides the following:

- An offshore wind renewable energy certificate (OREC) program consisting of a mechanism based on an open and transparent process for financing offshore wind energy projects. Offshore wind development companies' proposals are accepted or rejected by the Board of Public Utilities using a set of criteria determined by the Act (Clean Energy States Alliance, 2012c).
- Establishes a renewable portfolio standard to guarantee steady demand for the offshore wind energy produced (Clean Energy States Alliance, 2012c).
- Provides tax credits for wind energy facilities in wind development zones (Clean Energy States Alliance, 2012c).

- Grants financial incentives for offshore wind turbine manufacturers (Clean Energy States Alliance, 2012c).
- Requires the construction of a transmission system to deliver the wind-generated energy to New Jersey's grid from the minimum of 1100 MW of offshore wind capacity required (Clean Energy States Alliance, 2012c).

In a 2013 assessment, the National Renewable Energy Laboratory calculated that New Jersey's Wind Energy Area (WEA), delineated by the Bureau of Ocean Energy Management, is able to produce a maximum of 3,400 megawatts of offshore wind energy (Musial et al., 2013). The designated Wind Energy Area, located approximately seven nautical miles off the coast from Atlantic city, ensures that zones exhibiting ecological sensitivity are protected, user conflicts are low, and that the chosen areas are optimal for commercial offshore wind energy development (Musial et al., 2013; DOI, 2014a). The Wind Energy Area comprised of 344,000 acres offshore New Jersey has been proposed by BOEM to be auctioned in two leases: the North Lease Area containing 183,353 acres and the South Lease Area containing 160,480 acres (DOI, 2014a). The auction for the New Jersey Wind Energy Area leases is expected to start in 2014 by the Bureau of Ocean Energy Management (DOI, 2014a).

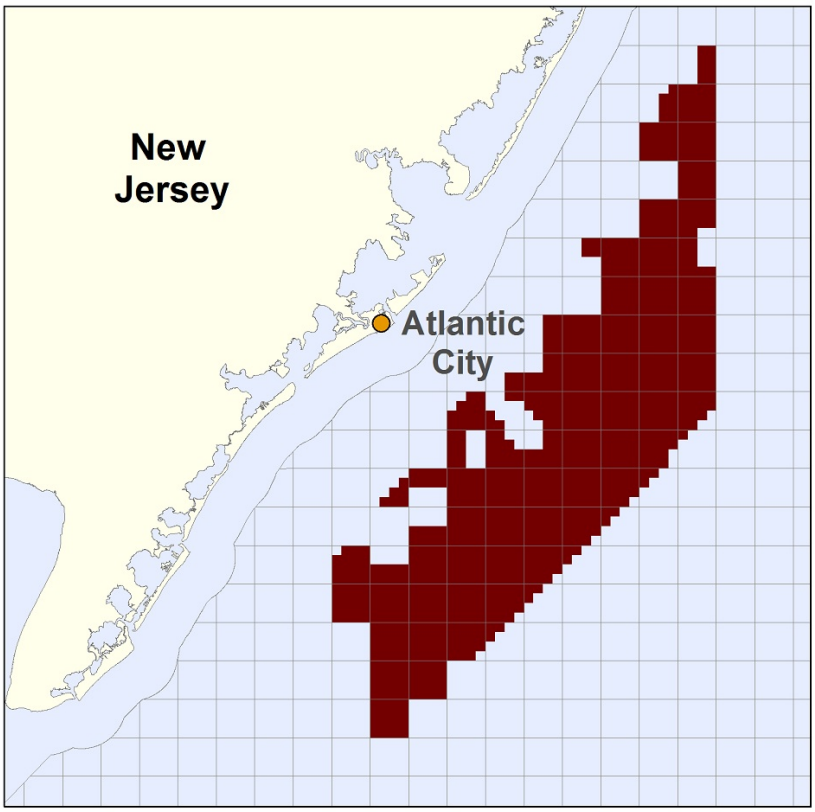


Figure 3.5: New Jersey Wind Energy Area (BOEM, 2014b).

3.1.4 VIRGINIA

The Commonwealth of Virginia has one of the highest potentials for generation of energy by means of offshore wind among the states covered in this study. The 2010 NREL Assessment calculated Virginia's offshore wind resource at 94.4 GW within 50 nautical miles of the coast covering an area of 18,890 km^2 (Schwartz et al., 2010). The combination of wind potential, strategic geographic location, skilled work force, and port facilities featuring manufacturing and shipbuilding makes Virginia a center for the advancement of the offshore wind energy industry and its associated supply chain (Clean Energy States Alliance, 2012d).

In 2007, a voluntary renewable portfolio standard was enacted in Virginia, and in 2009, legislation was passed to expand this target in order to urge investor-owned utilities to acquire a portion of the energy sold in Virginia from qualified renewable energy sources (DSIRE, 2013d). Additional legislation passed in 2012 gave investor-owned utilities an opportunity to reach a maximum of 20 percent of a renewable energy goal by means of investments in research and development associated to renewable and alternative energy sources (DSIRE, 2013d; Clean Energy States Alliance, 2012d). These utilities can also receive performance incentives in the form of an increased rate of return or profit from the Virginia State Corporation Commission for each of the four renewable portfolio standard goals accomplished as long as these are obtained from qualified renewable energy generation facilities (DSIRE, 2013d). Using 2007 as the base year, the goals are scheduled through 2025 to include triple credit towards renewable portfolio standard goals if purchases of energy are done from offshore wind technology (DSIRE, 2013d).

In 2007, the Virginia legislature created the Virginia Coastal Energy Research Consortium (VCERC) whose mission is "to identify and develop new coastal energy resources through multidisciplinary research collaborations and environmentally responsible strategies" in order to assist in meeting the targets established by the Virginia Energy Plan (VCERC, 2009a). VCERC efforts were developed based on Virginia General Assembly energy policy and included the development of clean energy technologies to accomplish the following priorities:

- minimize pollution,
- promote research for market place competitive alternative energy sources,
- develop energy sources and facilities that are affordable to all social economic levels,
- ensure that the locations of energy facilities are close enough to compatible development to minimize impacts of natural habitats,
- and to increase the reliance on biofuels from local sources (VCERC, 2009a).

VCERC is currently composed of nine university institutions, six government agencies, and three industry partners (VCERC, 2009a). Offshore wind related work done by VCERC focuses on radar; data acquisition for atmospheric, oceanic, and subsea variables; turbine reliability; grid infrastructure; studies for cost of energy comparison between energy generated by fossil fuel and offshore wind; and feasibility and economic baseline studies (VCERC, 2009b; VCERC, 2009c).

In 2010, the Virginia Offshore Wind Development Authority (VOWDA) was created by legislation with the mission to facilitate, coordinate, and support three important aspects of offshore wind energy: development of the industry, projects, and supply chain vendors (VOWDA, 2014). A more detailed list of VOWDA's assignments include the collection of environmental and metocean data; identification of regulatory and administrative barriers; improvement and modernization of port and logistic facilities through joint work with local, state, and federal government agencies; ensuring consistency between development and ocean/wildlife uses, and advising on methods targeted at promoting and accelerating the development of the offshore wind industry (VOWDA, 2014).

The 2013 VOWDA annual report compiles recommendations as a result of activities and accomplishment in 2013. Recommendations are prioritized as follows: supplement state funding with private and federal funding in order to increase the interest of the offshore wind industry, support the completion of the demonstration project aimed at advancing technology, assist in the federal process for development of Virginia's offshore commercial wind energy area, and avoid conflict for ocean uses and wildlife habitats (VOWDA, 2014). Some additional recommendations include (1) continued collaboration with the Virginia Ship Repair Association, Virginia Offshore Wind Coalition, the maritime industry, and other stakeholders, (2) support the extension of federal Investment Tax Credits and Production Tax Credits, (3) perform data collection to demonstrate the economic benefits if Virginia becomes the center of the Mid- Atlantic offshore wind industry and supply chain, (4) collect data that helps calculate the costs ratepayers are willing to spend in order to enable the development of an offshore wind project in

Virginia, and (5) stand behind legislative and administrative efforts to bring economic development for the offshore wind energy industry of Virginia (VOWDA, 2014).

The Bureau for Ocean Energy Management determined Virginia's Wind Energy Area to be comprised of approximately 112,799 acres made up of 19 whole OCS blocks and 13 sub-blocks (Federal Register, 2012). The area located 23.5 nautical miles form the Virginia Beach coastline was auctioned in September 4, 2013 as a single slot, representing the second competitive lease sale for renewable energy on the OCS (Federal Register, 2012; BOEM, 2013). The auction resulted in leases being awarded to Dominion Virginia Power (BOEM, 2013).

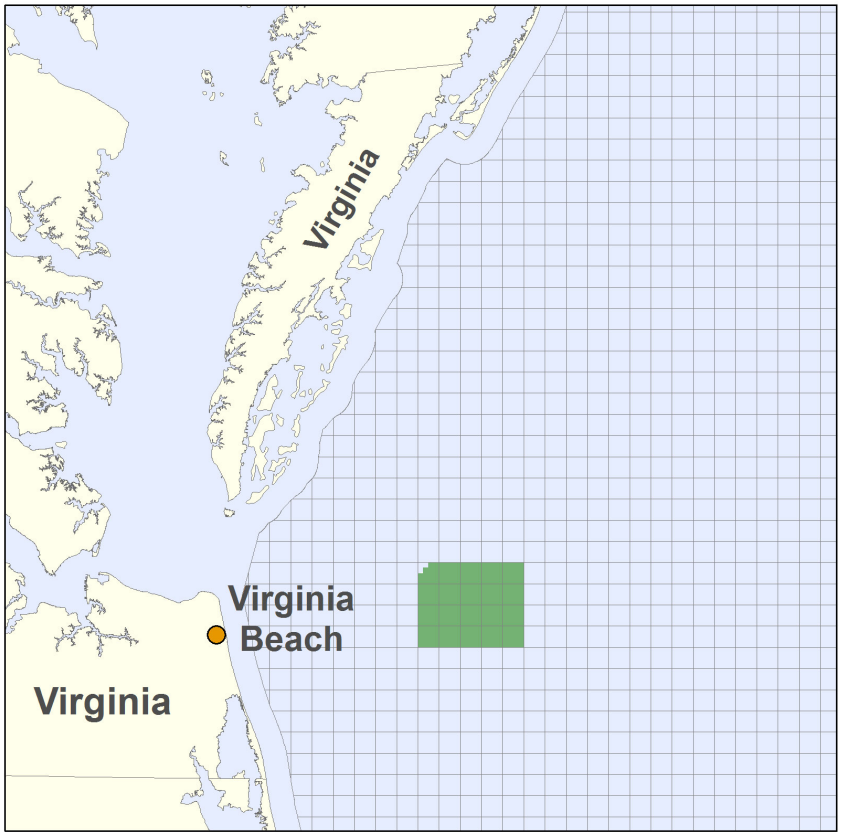


Figure 3.6: Virginia Wind Energy Area (BOEM, 2014c).

In May 2014, the U.S. Department of Energy selected Dominion Virginia Power as one of a group of three projects selected for offshore wind advancement technology demonstration (DOE, 2014c; DOE, 2014d). The project consists of the installation of two 6 MW wind turbines at 26 miles off the coast of Virginia Beach, VA (DOE, 2014c; DOE, 2014d). Along with the Virginia Offshore Wind Technology Advancement Project (VOWTAP), a research and development project supporting offshore wind generation and composed of a team of various organizations, Dominion will develop appropriate methods for the installation, operation, and maintenance of offshore wind turbines in the Mid-Atlantic (Dominion Virginia Power, 2013, 2014). Some of the features these turbines will have are twisted jacket foundations produced locally with hurricane-resilient design characteristics making these a more reliable, safe, and cost-effective product that could be used in hurricane-prone waters (DOE, 2014c; DOE, 2014d). Upon approval by the Virginia State Corporation Commission, these turbines are expected to become operational by 2017 (DOE, 2014c; DOE, 2014d).

4 METHODOLOGY

4.1 GENERAL INTRODUCTION

Global emissions of carbon dioxide from the energy sector increased 1.4 percent in 2012, accounting for a total of 31.6 gigatonnes of CO_2 (IEA, 2013). According to the International Energy Agency (IEA), energy use represents the largest source of greenhouse gas emissions with carbon dioxide constituting the principal contributor (IEA, 2013). The IEA's 2013 World Energy Outlook calculates that under its New Policies Scenarios, where global energy demand rises by one-third, global CO_2 emissions produced by fuel combustion could reach 37.2 gigatonnes by the year 2035, a twenty percent rise from 2013 emissions (IEA, 2013). The calculation for this projection, performed by the IEA, is obtained by taking into account "the broad policy commitments and plans that have been announced by countries around the world, including national pledges to reduce GHG emissions and plans to phase out fossil-energy subsidies" (IEA, 2013).

As part of the efforts to address global climate change and prepare for its impacts in the United States, the Obama Administration announced in June 2013 a series of executive actions aimed at reducing carbon pollution (Office of the Press Secretary, 2013). A Presidential Memorandum within this Climate Action Plan directs the EPA to calculate a set of carbon pollution standards for the power sector (Office of the Press Secretary, 2013).

On June 2nd, 2014, the EPA released the Clean Power Plan Proposed Rule, under the authority of Section 111(d) of the Clean Air Act (EPA, 2014e). The plan proposes guidelines for carbon pollution emissions generated by existing fossil fuel-fired EGUs, also known as power plants (EPA, 2014e). By implementing the rule as proposed, EPA projects achieving a reduction of 30 percent in carbon emissions from the power sector from 2005 levels by 2030 (EPA, 2014e).

The emission goals proposed in the rule are state-specific and not requirements on individual EGUs (EPA, 2014e). Recognizing the unique sets of policies, power sources and mixes of emissions a state possesses, the rule gives each state broad flexibility to meet the calculated rates by 2030 (EPA, 2014e). The EPA basic formula calculates a state's specific goal by using state and regional information as a rate of "CO_2 emissions from fossil fuel-fired power plants in pounds (lbs) divided by state electricity generation from fossil-fuel fired power plants and certain low- or zero-emitting power sources in megawatt hours (MWh)" (EPA, 2014e).

The purpose of this study is to demonstrate that, while the EPA Clean Power Plan Proposed Rule considers renewable energy technologies as an option to achieve the proposed CO_2 emission reduction targets, the offshore wind energy option is being undervalued. By using the Clean Power Plan Proposed Rule as the baseline or "reference" scenario for this dissertation, this study will make a compelling case for how offshore wind energy deployment rates can significantly contribute toward the reduction of carbon dioxide emission levels from existing power plants, with the possibility of bringing about

much greater reductions than originally estimated.

This study projects across different scenarios based on varying rates of offshore wind deployment in the Mid-Atlantic by using cumulative total installed capacity estimates associated with six different scenarios using 2030 as the target year proposed by the EPA.

4.2 PROPOSED SCENARIOS

Given the fast-growing electricity demand of the Mid-Atlantic States; its close proximity to densely populated centers; the differences between national, regional, and state energy policy frameworks for offshore wind; and continuous climate change and energy discussions, it became clear that there is an opportunity in offshore wind energy to contribute to cutting carbon emissions.

The rationale behind the design of the scenarios is illustrated as a flow chart diagram displayed by Figure 4.1. The EPA Clean Power Plan Proposed Rule is preceded by two important initiatives from the U.S. Federal Government: the National Offshore Wind Strategy and the Climate Action Plan. In February 2011, the U.S. Department of Interior and the U.S. Department of Energy announced an interagency plan to help develop the U.S. offshore wind energy industry (DOE, 2011a). The *National Offshore Wind Strategy: Creating an Offshore Wind Industry in the United States* plan acts as a guide to address three important challenges of the industry: the costs of offshore wind energy, technology development challenges, and the absence of site data and practical knowledge in the permitting process (DOE, 2011a). As part of this strategy, the DOE will be pursuing a

scenario for deployment of 54 gigawatts of OSW by 2030 (DOE, 2011a). Along with the National Offshore Wind Strategy, the offshore wind industry received more support through President Obama's Climate Action Plan established in June 2013 (Office of the Press Secretary, 2013). The Climate Action Plan's main goal is to reduce greenhouse gas emissions such as carbon dioxide by 17 percent below 2005 levels by 2020 through strategies that involve cutting carbon pollution from power plants and doubling renewable electricity generation (Office of the Press Secretary, 2013). These two initiatives lead the focus of this study to the EPA Clean Power Plan Proposed Rule. The Clean Power Plan was proposed under the Climate Action Plan to cut carbon pollution from existing power plants with standards issued by the EPA using its authority given by Section 111 of the Clean Air Act. The main goal of the Clean Power Plan is to cut carbon pollution from the power sector by 30 percent below 2005 levels by 2030. The scope of the study focuses in the Mid-Atlantic Region due to the enormous amount of wind energy potential. The region is characterized by strong offshore winds, a gently sloping continental shelf, and most importantly, wind is part of the states' renewable portfolio standards as a target resource. The scenarios chosen for this study include valid OSW deployment potentials ranging from zero deployment in Scenario 1 to the largest deployment calculated for the Mid-Atlantic in Scenario 6. The data used to formulate the scenarios were obtained from four different sources:

- EPA Clean Power Plan Proposed Rule (Scenario 1)
- Bureau of Ocean Energy Management (Scenario 2)
- Virginia Center for Wind Energy at James Madison University (Scenarios 3, 4, 5)
- National Renewable Energy Laboratory (Scenario 6)

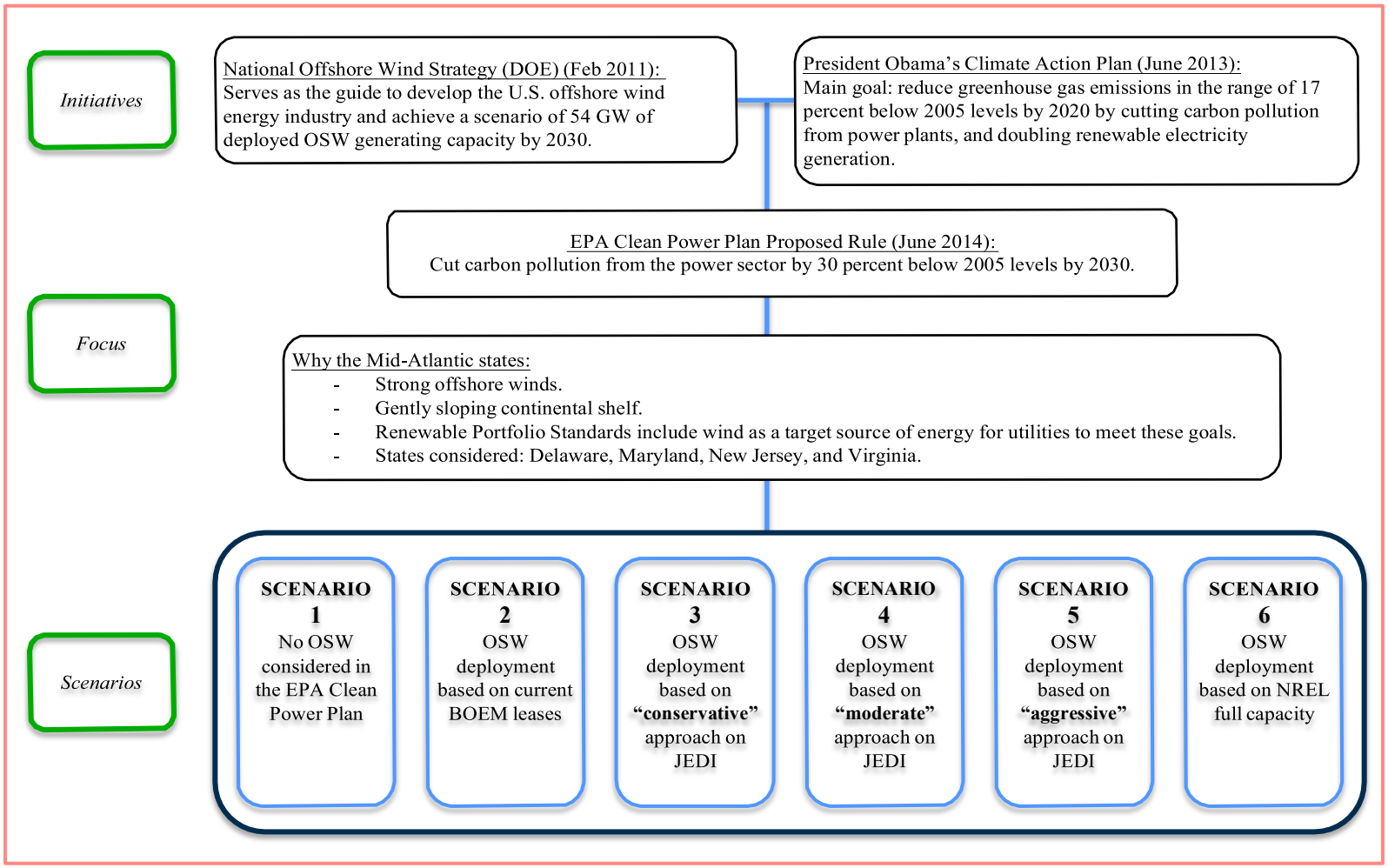


Figure 4.1: Methodology Flow Chart

4.2.1 SCENARIO 1 – NO OFFSHORE WIND CONSIDERED IN THE EPA CLEAN POWER PLAN PROPOSED RULE

The EPA Clean Power Plan Proposed Rule determines state-specific goals by taking into account four categories of potential emission reductions or "building blocks." Building Block 1 looks at "reducing the carbon intensity of generation at individual affected EGUs through heat-rate improvements" (EPA, 2014f). Building Block 2 considers "reducing emissions from the most carbon-intensive affected EGUs in the amount that results from substituting generation at those EGUs with generation from less carbon- intensive affected EGUs, including natural gas combined cycle (NGCC) units that are under construction" (EPA, 2014f). Building Block 3 looks at emissions reductions from affected EGUs by replacing generation with expanded low- or zero-carbon generation (EPA, 2014f). This strategy takes into account increasing electricity generation by means of renewable energy sources (EPA, 2014f). Finally, Building Block 4 looks at "reducing emissions from affected EGUs in the amount that results from the use of demand-side energy efficiency that reduces the amount of generation required" (EPA, 2014f).

When reviewing the methodology used to calculate Building Block 3, the EPA makes it clear that "offshore wind was not considered under this methodology because there are currently no operational offshore wind facilities in the United States from which to calculate a benchmark development rate" (EPA, 2014a). As states are responsible for developing compliance approaches, another aspect of the rule provides the states with flexibility to determine what type of approach will be used to achieve the goal; offshore wind energy provides a carbon-free energy source to reach their emission targets. This

rule could represent an incentive to harness the wind resources available off the Mid-Atlantic shores for the four states considered in this study: Delaware, Maryland, New Jersey, and Virginia. However, as offshore wind is not considered under the plan, Scenario 1 will result in cumulative total installed capacity with a value of zero (see Figure 4.2).

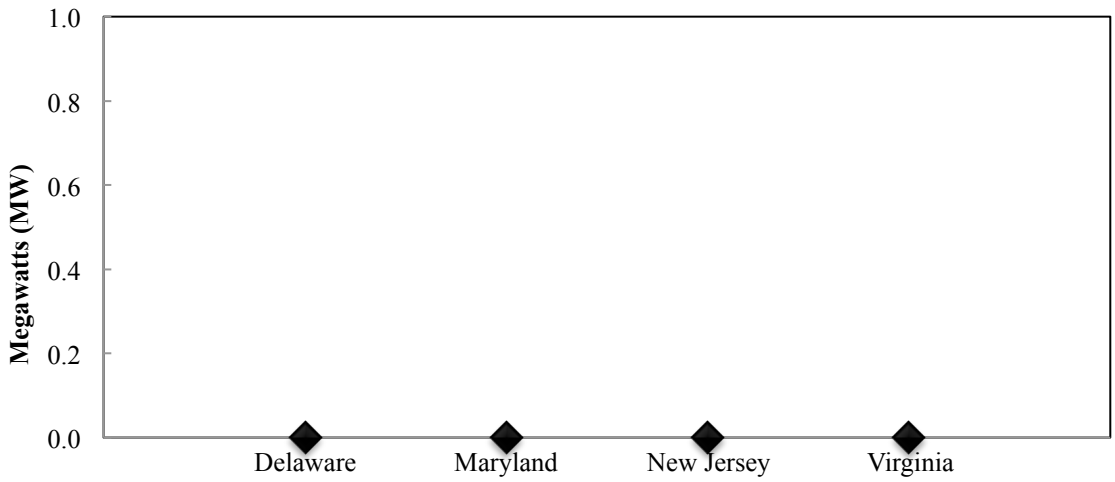


Figure 4.2: **Scenario 1** - Cumulative Total Potential Capacity of OSW Deployment by 2030 based on EPA Clean Power Plan Proposed Rule.

4.2.2 SCENARIO 2 - OFFSHORE WIND DEPLOYMENT BASED ON CURRENT BOEM WIND ENERGY AREA LEASES

The Bureau of Ocean Energy Management is in charge of implementing regulations for the Outer Continental Shelf Renewable Energy Program under authorization by the Energy Policy Act of 2005 (BOEM, n.d.). These regulations establish a framework for BOEM to designate Wind Energy Areas (WEAs) for commercial leasing in order to develop offshore renewable energy (BOEM, n.d.).

The process of selecting WEAs by BOEM consists of four different phases:

1. Planning and Analysis: during this phase BOEM identifies appropriate locations for wind energy development offshore. These areas are known as Wind Energy Areas (BOEM, n.d.). BOEM also prepares environmental assessments for lease issuance, and reviews and consultations of site activities with stakeholders, and government agencies (BOEM, n.d.).
2. Lease Issuance: through this phase BOEM issues commercial wind energy leases either through a competitive or noncompetitive process (BOEM, n.d.). The commercial lease only gives a permit to the lessee to use the area to develop a plan for construction of an offshore wind facility (BOEM, n.d.). Once BOEM approves this plan, then the lessee can continue to the next step of the process (BOEM, n.d.).
3. Site Assessment: during this phase the lessee submits a site assessment plan (SAP) which includes a "detailed proposal for the construction of a meteorological tower and/or the installation of meteorological buoys on the leasehold " (BOEM, n.d.). The SAP is submitted to BOEM for approval, approval with modifications, or disapproval (BOEM, n.d.). In addition to the SAP, the lessee can develop surveys and studies in this phase for site characterization about bird and marine mammal populations, and archeological remains, among others (BOEM, n.d.).
4. Construction and Operations: this phase entails submitting a Construction and Operations Plan (COP) where the lessee delineates a plan for construction and operation of the proposed wind energy project on its lease (BOEM, n.d.). After submitting the COP, BOEM reviews the plan and conducts a process for approval.

Then a plan for the facilities decommissioning is presented when the end of the lease time approaches (BOEM, n.d.).

For purposes of this study, Scenario 2, displayed in Figure 4.3, will consider cumulative total installed capacity for the Wind Energy Area leases awarded to the states of Delaware, Maryland, New Jersey, and Virginia. The timeframe for our analysis is the target year 2030. For this section, the timeframe will be defined as the time it will take to fully complete the projects granted by the leases up to this point.

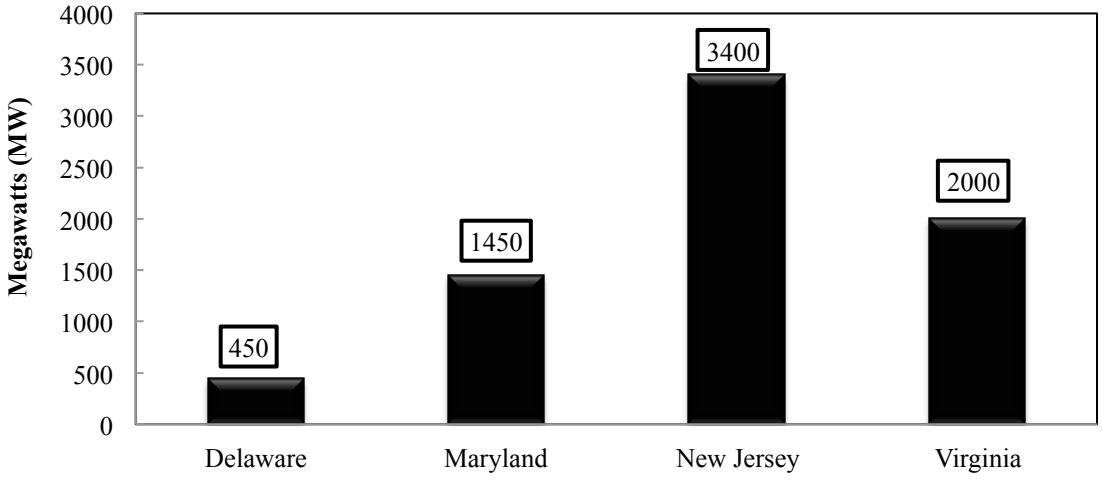


Figure 4.3: **Scenario 2** - Cumulative Total Potential Capacity of OSW Deployment by 2030 based on current BOEM Wind Energy Area Leases.

4.2.3 SCENARIO 3, 4, AND 5 - OFFSHORE WIND DEPLOYMENT BASED ON THREE DISTINCT APPROACHES FROM A JEDI STUDY OF THE MID-ATLANTIC REGION

In order to develop Scenarios 3, 4, and 5, this analysis used part of the methodology and data (see Appendix I) from the Mid-Atlantic JEDI Report developed by the Virginia Center for Wind Energy at James Madison University as a basis. The study titled

"Potential Economic Impacts from Offshore Wind in the United States – The Mid-Atlantic Region" carried out an analysis by applying NREL's Offshore Wind "Jobs and Economic Development Impacts (JEDI) model to estimate the economic impacts associated with offshore wind power developed off the coasts of Virginia, New Jersey, Delaware, Maryland and Pennsylvania" (Kraemer, Zammit, & Miles, 2013).

The JEDI study created three scenarios that span from 2015 to 2030 for offshore wind energy in the Mid-Atlantic, and was run for each year (Kraemer et al., 2013). The study determined that an average of 1.38 GW/year was added in this region between the years 1990 through 2011 by analyzing historical growth rates for electricity capacity additions (Kraemer et al., 2013). By assuming a consistent historical growth rate, this average (1.38 GW/year) was then used to calculate a projection for the region's additional generating capacity estimated at 26 GW between 2012 and 2030 (Kraemer et al., 2013).

The JEDI study developed three scenarios representing three distinct levels of approach (conservative, moderate, and aggressive) to project OSW deployment in the Mid-Atlantic region from 2015 to 2030. These data from Tables 3, 4, and 5 of the Mid-Atlantic JEDI report (see Appendix I) was used in this dissertation to plot the projections in Figures 4.4, 4.5, and 4.6.

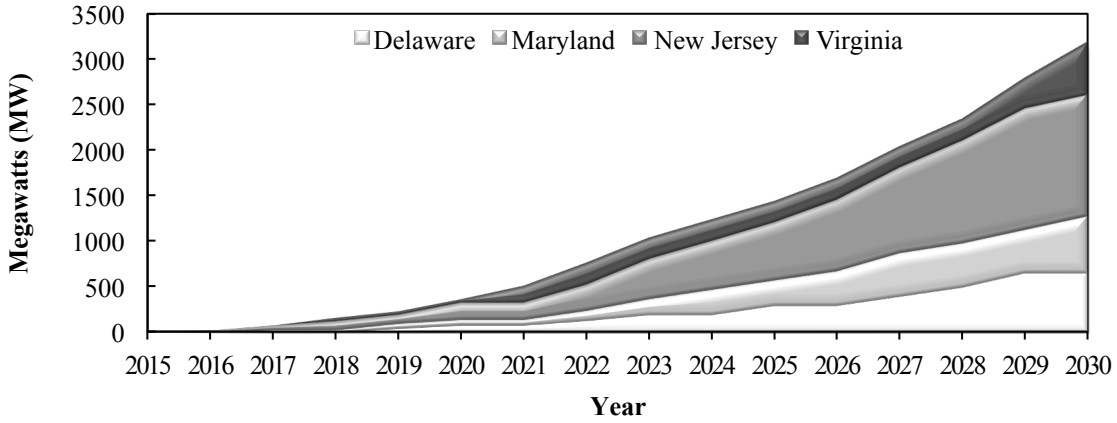


Figure 4.4: **Scenario 3** - Cumulative Total Potential Capacity of OSW Deployment by 2030 based on the JEDI **"conservative"** approach.

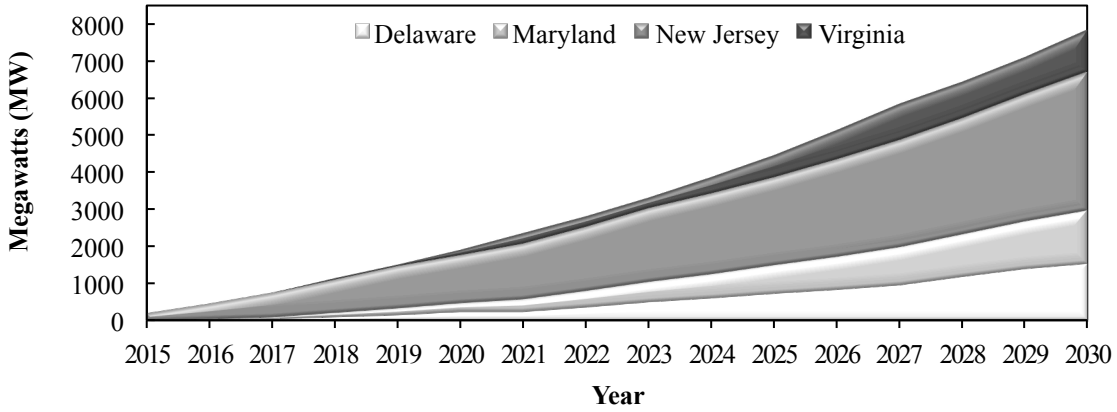


Figure 4.5: **Scenario 4** - Cumulative Total Potential Capacity of OSW Deployment by 2030 based on the JEDI **"moderate"** approach.

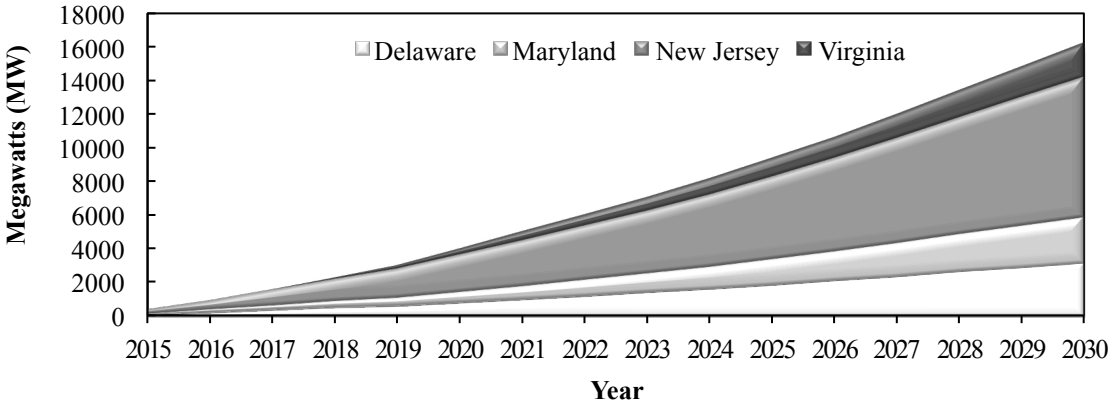


Figure 4.6: **Scenario 5** - Cumulative Total Potential Capacity of OSW Deployment by 2030 based on the JEDI **"aggressive"** approach.

4.2.4 SCENARIO 6 - OFFSHORE WIND DEPLOYMENT BASED ON NREL's FULL OSW CAPACITY

The National Renewable Energy Laboratory prepared a report entitled, "Assessment of Offshore Wind Energy Resources for the United States" to summarize the resource potential of offshore wind using map estimates for the contiguous the United States (Schwartz et al., 2010). By applying Geographic Information System (GIS) techniques, NREL developed a standard and flexible database with offshore wind resource characteristics including wind speed, water depth, and distance from shore (Schwartz et al., 2010).

The data used for Scenario 6 (see Figure 4.7), as described by the report, represents "the offshore wind resource by available km^2 of water and potential installed capacity in gigawatts for annual average wind speeds greater than 7.0 meters per second (m/s) at 90 m above the surface. A uniform factor of 5 megawatts/km^2 was applied to calculate the potential installed capacity" (Schwartz et al., 2010). The states taken into consideration were Delaware, Maryland, New Jersey, and Virginia assuming that full deployment will be achieved by 2030.

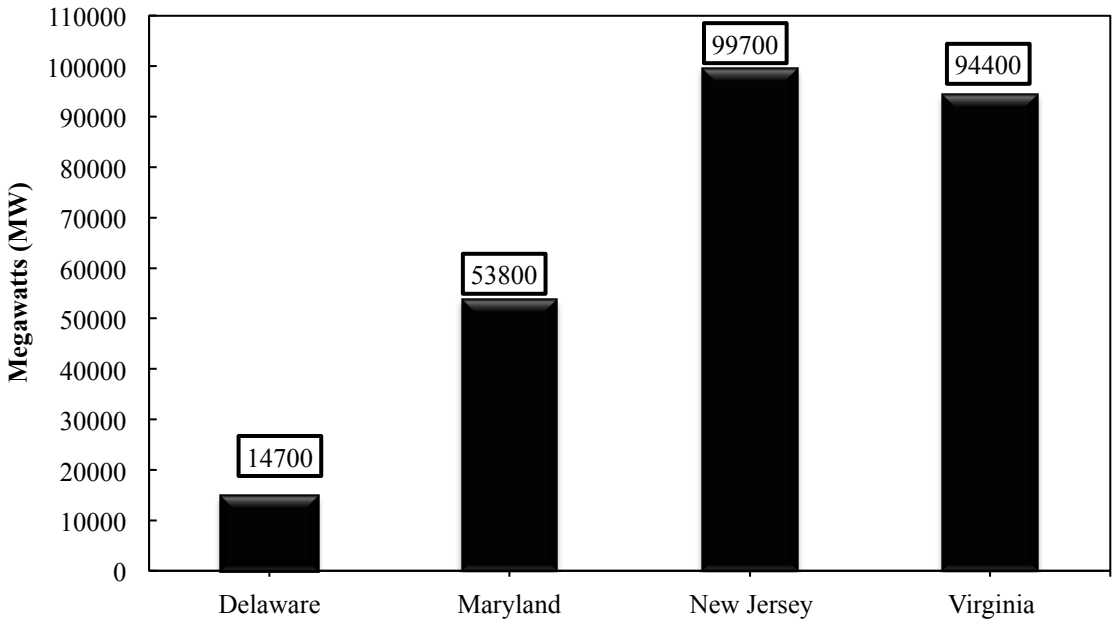


Figure 4.7: **Scenario 6** - Cumulative Total Potential Capacity of OSW Deployment by 2030 based on NREL full-calculated capacity.

4.2.5 EMISSIONS REDUCTIONS BASED ON OFFSHORE WIND AVERAGE CAPACITY FACTOR

The EPA Clean Power Plan Proposed Rule Building Block 3 is aimed at reducing emissions of carbon dioxide from power plants by replacing generation from fossil fuel EGUs with renewable and nuclear energy production (EPA, 2014a). The renewable technologies selected by EPA to calculate the renewable target generation level are based on the 2012 available net generation data which includes solar, onshore wind, geothermal, and select existing biopower capacity types (EPA, 2014f). However, the EPA does not include offshore wind energy as part of this building block's technology because there are no operational offshore wind turbines to use as a benchmark (EPA, 2014a).

The EPA developed emissions goals for each state by employing the building blocks along with each state's 2012 data for fossil fuel emissions and generation (EPA, 2014a). As a general rule, the methodology for all building blocks applies emissions values into the numerator, and generation values into the denominator (EPA, 2014a). The Building Block 3 methodology for the calculation of the state fossil emission rate goal considers three emission reduction opportunities: new renewable energy (excluding hydropower), new nuclear power plants under construction, and nuclear generation "at risk" of being retired (EPA, 2014f). As such, the EPA applied the values for Building Block 3 to adjust the denominator as megawatts per hour (MWh) (EPA, 2014a).

In order to achieve the Final State Goal, the EPA followed a series of steps described in the *"Goal Computation Technical Support Document"* (EPA, 2014c). For the purposes of

this dissertation, only the formulas for the Building Blocks will be described. The values appearing in bold in the equations below reflect the adjustments from their historical level up to the point of the calculation step (EPA, 2014c).

The EPA formula for Building Block 1 "calculates state fossil emission rate goal for covered sources resulting from heat rate improvement (HRI)" (EPA, 2014c):

Equation 1: *State Emission Rate for Building Block 1* = [(coal gen. × **coal emission rate**) + (OG gen. × OG emission rate) + (NGCC gen. × NGCC emission rate) + "Other" Emissions] / [Coal gen. + OG gen. + NGCC gen. + "Other" gen.]

(EPA, 2014c)

The EPA formula for Building Block 1 & 2 combined reflects the "calculation of state fossil emission rate goal resulting from heat rate improvement and redispatch to existing and under construction NGCC capacity" (EPA, 2014c):

Equation 2: *State Emission Rate for Building Blocks 1 & 2* = [**(coal gen.** × coal emission rate) + (**OG gen**. × OG emission rate) + (**NGCC gen**. × NGCC emission rate) + **"Other" emissions] / [Coal gen. + OG gen. + NGCC gen. + "Other" gen.]**

(EPA, 2014c)

The EPA formula to compute Building Blocks 1, 2, & 3 reflects the "calculation of state fossil emission rate goal resulting from heat rate improvement, redispatch to existing and under construction NGCC capacity, new and "at risk" nuclear, and Renewable energy generation (RE)" (EPA, 2014c):

Equation 3: *State Emission Rate for Building Blocks 1, 2 & 3* = [(coal gen. × coal emission rate) + (OG gen. × OG emission rate) + (NGCC gen. × NGCC emission rate) + "Other" emissions] / [Coal gen. + OG gen. + NGCC gen. + "Other" gen. + Nuclear gen. $_{uc+ar}$ **+ RE gen.**]

(EPA, 2014c)

The calculation for the Final State Goal is a combination of the values from all four building blocks. The EPA formula to compute Building Blocks 1, 2, 3, & 4 reflects the "calculation of state fossil emission rate goal resulting from heat rate improvement, redispatch to existing NGCC, "under construction" NGCC, under construction and at risk nuclear, RE, and demand-side EE" (EPA, 2014c). This final calculation applies demand-side energy efficiency measures (EE gen.).

Equation 4: *State Emission Rate for Building Blocks 1, 2, 3 & 4* = [(coal gen. × coal emission rate) + (OG gen. × OG emission rate) + (NGCC gen. × NGCC emission rate) + "Other" emissions] / [Coal gen. + OG gen. + NGCC gen. + "Other" gen. + Nuclear gen. $_{uc+ar}$ + RE gen. **+ EE gen.]**

(EPA, 2014c)

A schematic diagram for Equation 4, i.e. the computed goal for each state, can be summarized as follows:

$$\frac{\text{Total adjusted } CO_2 \text{ emissions from affected EGUs following application of Building Blocks 1 \& 2}}{\text{Total net generation from affected EGUs + Annual net generation from Nuclear and Renewable (Building Block 3) + Annual savings from Energy efficiency measures (Building Block 4)}}$$

The methodology for this study aims at exploring the contributions of the potential deployment of offshore wind energy in the Final State Goal. In order to obtain **OSW gen.**, which is expressed in MWh, the cumulative total installed capacity (MW) for potential offshore wind energy deployment has to be converted to MWh by multiplying it by the amount of hours in one year (8760 hours) and then by a capacity factor. Capacity factor is defined as "the ratio of the actual output of a generating unit over a period of time (typically a year) to the theoretical output that would be produced if the unit were operating uninterruptedly at its nameplate capacity during the same period of time" (IPCC, 2011). Also known as rated capacity or nominal capacity, nameplate capacity is the maximum potential output under ideal conditions if that system is operating at 100 percent capacity. For offshore wind, the capacity factor refers to the proportion or capacity of nameplate capacity electricity a wind turbine produces in comparison to the amount it is designed to generate if the turbine operates at full nameplate capacity 100 percent of the time.

A capacity factor value for wind power depends on several aspects including wind speed and availability, geographical location of the wind farm, turbine design, maintenance schedules, equipment failures, and safety, among others. The rights to develop proposed offshore wind power plant projects in the Mid-Atlantic region have been awarded by BOEM to several different companies whose turbine models might not be the same for all projects resulting in differentiating capacity factors. As a result, this study will be applying an average capacity factor calculated by the National Renewable Energy Laboratory and the Open Energy Information (OpenEI) Database (see Appendix II). By compiling data from several studies, NREL and OpenEI had calculated an average of 45 percent for OSW capacity factor (see Figure 4.8). This value will be applied to the offshore wind "Cumulative Total Potential Capacity" already determined in Scenarios 2, 3, 4, 5, and 6 in order to obtain an **OSW gen.** value (see Equation 5) to apply in Equation 6.

The following equation was used to calculate the offshore wind generation (OSW gen.) with a Capacity Factor of 45 percent (see Table 4.1):

Equation 5: ***OSW gen.* (MWh)** = (Cumulative Total Potential Capacity in MW × 8760 hours × Average Capacity Factor)

As such, a **new** Final State Goal for emissions' rates (lb/MWh) was calculated for each state and Scenario by applying offshore wind generation (OSW gen.) as part of the equation's denominator in Equation 4 (State Emission Rate for Building Blocks 1, 2, 3 & 4). The new equation is the following:

Equation 6: *State Emission Rate for Building Blocks 1, 2, 3 & 4* ***w/OSW gen.*** =

[(coal gen. × coal emission rate) + (OG gen. × OG emission rate) + (NGCC gen. × NGCC emission rate) + "Other" emissions] / [Coal gen. + OG gen. + NGCC gen. + "Other" gen. + Nuclear gen. $_{uc+ar}$ + RE gen. + EE gen. **+ OSW gen.**]

(EPA, 2014a)

The EPA Clean Power Plan Proposed Rule computation values are obtained from technical documents for State Goal Data for Emissions Reduction Computation; see Appendix III for values corresponding to Delaware, Maryland, New Jersey, and Virginia. In summary, a "new" Final State Goal emission rate (lbs/MWh) was calculated for Scenarios 2, 3, 4, 5, and 6 by applying the newly calculated ***OSW gen.*** value (see Table 4.2) into the EPA Clean Power Plan Final State Goal calculations described in Equation 4.

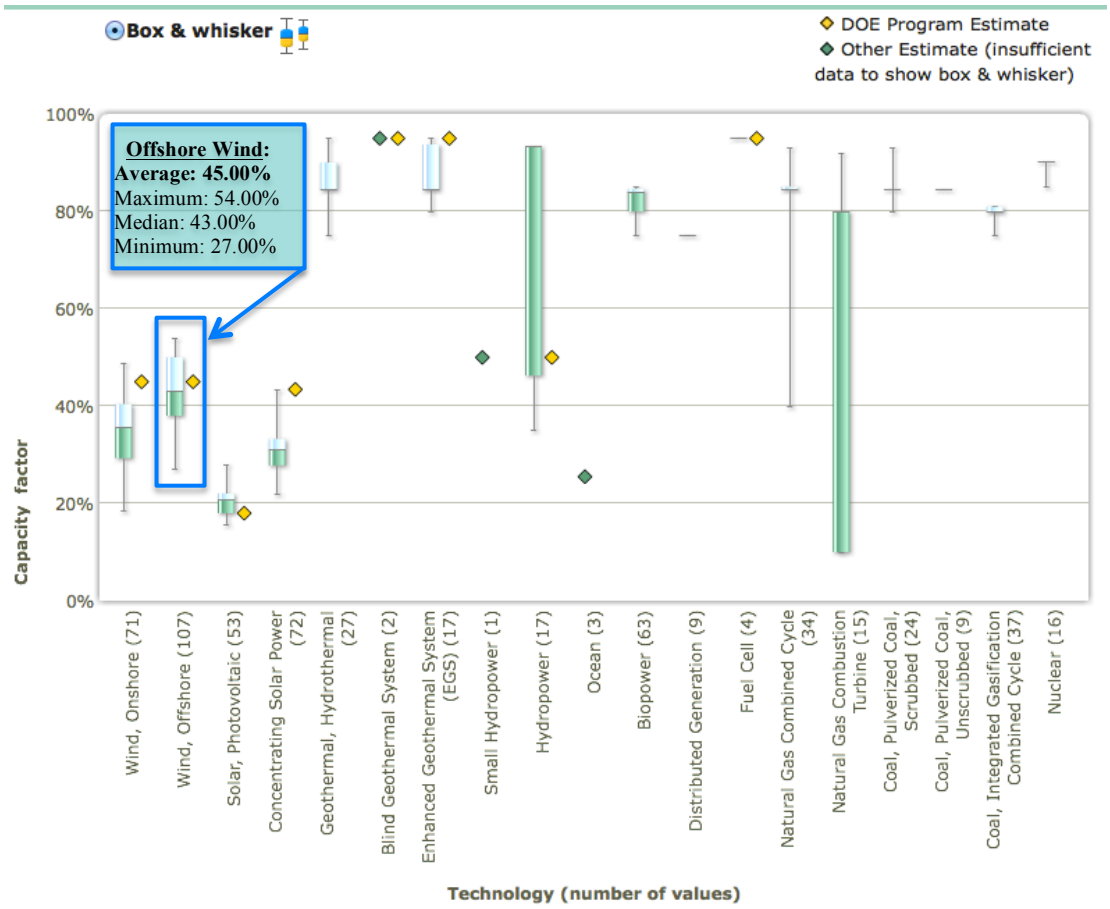


Figure 4.8: Utility-Scale Energy Technology Capacity Factors.

"This chart indicates the range of recent capacity factor estimates for utility-scale renewable energy technologies. The dots indicate the average, and the vertical lines represent the range: Average +1 standard deviation and average -1 standard deviation" (NREL, 2013). *Note.* Adapted from *NREL and Open Energy Information's Transparent Cost Database.* Retrieved 10/29, 2014, from http://en.openei.org/apps/TCDB/, by (NREL, 2013; Open Energy Information, 2013). Offshore wind data values can be found in Appendix II.

Table 4.1: Cumulative Total Potential Capacity (MW) & Offshore Wind Generation with Capacity Factor of 45% (MWh).

State	Cumulative Total Potential Capacity (MW)					Offshore Wind Generation with Capacity Factor of 45%				
	Scenario **2**	Scenario **3**	Scenario **4**	Scenario **5**	Scenario **6**	Scenario **2**	Scenario **3**	Scenario **4**	Scenario **5**	Scenario **6**
Delaware	450	640	1,520	3,080	14,700	1,773,900	2,522,880	5,991,840	12,141,360	57,947,400
Maryland	1,450	630	1,450	2,800	53,800	5,715,900	2,483,460	5,715,900	11,037,600	212,079,600
New Jersey	3,400	1,340	3,730	8,350	99,700	13,402,800	5,282,280	14,703,660	32,915,700	393,017,400
Virginia	2,000	586	1,132	2,000	94,400	7,884,000	2,310,012	4,462,344	7,884,000	372,124,800
Total	7,300	3,196	7,832	16,230	262,600	28,776,600	11,278,062	30,873,744	63,978,660	1,035,169,200

5 RESULTS & ANALYSIS

In the Clean Power Plan Proposed Rule, the EPA offers four categories to achieve potential emissions reductions known as "building blocks," which together form the Best System of Emission Reduction (BSER) (EPA, 2014c). Building Block 3 applies the use of low- or zero- carbon generation, which is achievable by increasing energy generation through new nuclear and new renewable energy, and maintaining "at risk" of being retired nuclear generation (EPA, 2014c). However, the agency's proposed state goals involving renewable energy do not take into account the potential of offshore wind energy, reflected in Scenario 1 (see Figure 4.2), resulting in zero contributions for GHG abatement.

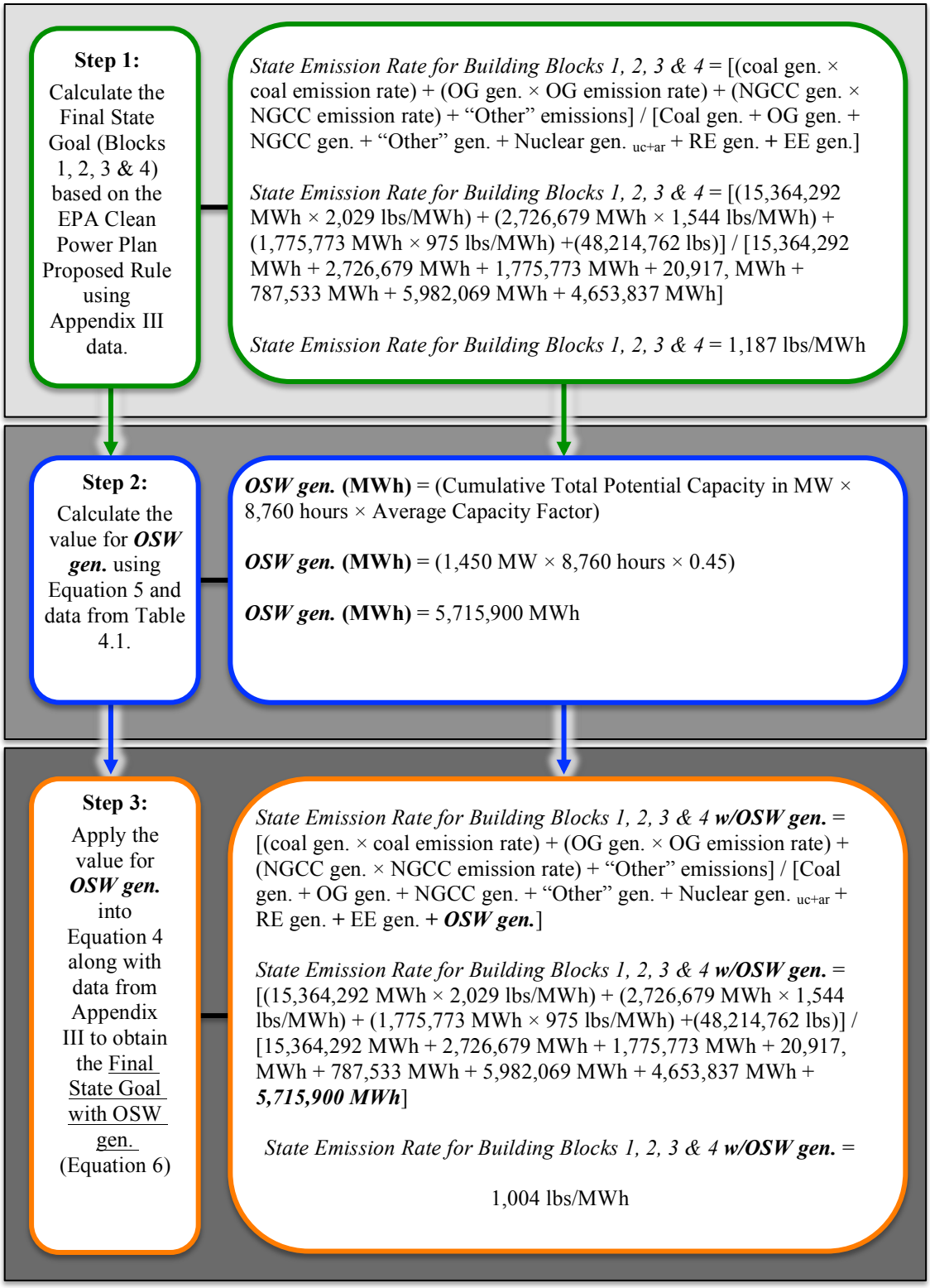
This study calculated values for Offshore Wind Generation (OSW gen.) (see Table 4.1) by using data for Cumulative Total Potential Capacity (see Table 4.1) and an average Capacity Factor of 45 percent. These values were incorporated into the Final State Goal computation formula (Equation 4) to obtain a new emission reduction target taking Offshore Wind Energy Generation into account (Equation 6); see Figure 5.1 for the calculation steps. The "new" Final State Goals calculated with the OSW gen. values and Equation 6 are contained in Table 4.2.

Table 4.2: Proposed Final State Goals (2030) proposed in the EPA Clean Power Plan Proposed Rule, and Proposed Final State Goals (2030) with Offshore Wind Energy Generation Application for Scenarios 2, 3, 4, 5, and 6.

State	**Final State Goal (lbs/MWh)**					
	EPA Blocks 1, 2, 3, & 4	Scenario **2**	Scenario **3**	Scenario **4**	Scenario **5**	Scenario **6**
Delaware	841	705	660	510	363	116
Maryland	1,187	1,004	1,100	1,004	877	153
New Jersey	531	404	473	395	300	52
Virginia	810	724	783	759	724	123
Total	3,368	2,837	3,015	2,667	2,265	443

Note: Values under column "EPA Blocks 1, 2, 3, & 4" were obtained from Appendix III (EPA, 2014c).

Figure 5.1: Flow Chart for calculation of Final State Goal with OSW gen. for the state of Maryland under Scenario 2.



The Clean Power Plan Final State Goals were calculated by the EPA taking into account Building Blocks 1, 2, 3, and 4. The values reflect the following emission targets to be accomplished by 2030 (see Table 4.2): 841 lbs/MWh for Delaware, 1,187 lbs/MWh for Maryland, 531 lbs/MWh for New Jersey, and 810 lbs/MWh for Virginia.

Scenario 2 shows a more realistic view of the contributions from renewable energy towards emissions reductions. All four states contemplated in this study, Delaware, Maryland, New Jersey, and Virginia, have been assigned WEAs for commercial leases by the Bureau of Ocean Management. Only two of these states, Delaware and Virginia, have been awarded commercial leases to develop offshore wind energy. The largest potential capacity for OSW deployment has been identified for the state of New Jersey (3,400 MW) followed by Virginia (2,000 MW), Maryland (1,450 MW), and Delaware (450 MW). A new set of emission targets was calculated for Scenario 2 by incorporating OSW gen. values based on the Cumulative Total Potential Capacity from the WEAs. Scenario 2 new Final State Goals were: 705 lbs/MWh for Delaware, 1,004 lbs/MWh for Maryland, 404 lbs/MWh for New Jersey, and 724 lbs/MWh for Virginia.

Scenario 3 represents an approach of conservative development in terms of the OSW industry, manufacturing, and services. As such, small contributions and changes are achieved regarding policy and government support. Scenario 3 Final State Goals calculated reflect the following emission reduction targets: 660 lbs/MWh for Delaware, 1,100 lbs/MWh for Maryland, 473 lbs/MWh for New Jersey, and 783 lbs/MWh for Virginia. All States reflect a lower emission target than the ones proposed by the EPA.

For Scenario 4, OSW deployment reflects a moderate approach supported by a growing OSW industry. In this case, manufacturing and services get established in these regions resulting in development of the OSW industry. As expected, emission targets from Scenario 4 are even lower than the proposed in Scenario 3, which reflects a conservative development of the offshore wind industry. Scenario 4 new Final State Goals were: 510 lbs/MWh for Delaware, 1,004 lbs/MWh for Maryland, 395 lbs/MWh for New Jersey, and 759 lbs/MWh for Virginia. Its worth noting that Scenario 4 contains values closest to Scenario 2 which is consider the most realistic of all six scenarios since WEAs have already been identified.

In the "aggressive" approach, Scenario 5, the OSW industry is assumed to experience an accelerated development stemming from substantial regional investments allowing sourcing of materials and services at a local level. As such, a more reduced emission target was obtained for the Final State Goals: 363 lbs/MWh for Delaware, 877 lbs/MWh for Maryland, 300 lbs/MWh for New Jersey, and 724 lbs/MWh for Virginia.

The Mid-Atlantic JEDI report data show that for Scenario 3, the "conservative approach" a total of 3,196 MW of OSW deployment could be reached by 2030 followed by 7,832 MW in Scenario 4 or the "moderate" approach, and 16,230 MW in Scenario 5 or the "aggressive" approach. In addition, OSW deployment for Scenario 2 totals 7,300 MW, and for Scenario 6 adds up to 262,600 MW.

The most ambitious scenario is reflected by OSW deployment covering the maximum

WEA calculated by the NREL. The largest deployment is calculated for New Jersey (99,700 MW) followed by Virginia (94,400 MW), Maryland (53,800 MW), and Delaware (14,700 MW). For the new Final States Goals considering OSW gen., the emission targets are the most stringent of all scenarios: 116 lbs/MWh for Delaware, 153 lbs/MWh for Maryland, 52 lbs/MWh for New Jersey, and 123 lbs/MWh for Virginia.

When comparing all the emission targets' totals, excluding Scenario 1, it can be noted that the moderate approach (Scenario 4) target with 2,667 lbs/MWh closely resembles the Scenario 2 with a total target of 2,837 lbs/MWh. In contrast, the EPA Clean Power Plan target of 3,368 lbs/MWh is closer to the conservative approach (Scenario 3) target of 3,015 lbs/MWh. As a result of representing the most aggressive approach of the six scenarios, Scenario 6 emission target is the strictest goal with 443 lbs/MWh.

The analysis of the EPA Clean Power Plan State Goals formula for Building Block 3 reflected the absence of offshore wind deployment generation as part of the measures to cut carbon pollution from fossil fuel-fired power plants. As a result, this study determined that these goals are not reasonable and consistent with offshore wind energy development projection calculations for the United States through 2030. The EPA should reconsider renewable energy contributions to state targets by including offshore wind energy generation as part of its methodology since leases for commercial-scale wind energy proposed projects have already been awarded by the Bureau of Ocean Energy Management specifically for the Mid-Atlantic states of Delaware, Maryland, New Jersey, and Virginia.

6 CONCLUSIONS

Overall, this study revealed that EPA targeted reductions of power plant carbon emissions could be even greater if offshore wind energy generation were included as part of Building Block 3. Further, OWS carve-outs have been specifically identified for the states of Maryland and New Jersey as part of their RPS policies, although all four states have assigned RPS requirements with Virginia being a volunteer RPS. Under the EPA approach, the OSW carve-outs, constituting a legal obligation, should have been included as part of the state targets for new renewable energy generation.

Not only can offshore wind energy contribute to carbon dioxide reductions, it also forms an important role in diversifying the nation's energy portfolio. One of the most significant benefits of OSW energy is that it minimizes energy security and economic risks associated with the nation's considerable dependence on fossil fuels such as coal, petroleum, and gas (Bolinger, 2013).

Globally, offshore wind energy has experienced remarkable growth, mainly driven by European countries taking advantage of technology advancements (Wiser & Bolinger, 2014). At the end of 2013, the world's total cumulative offshore wind power capacity was approximately 6,800 MW (Navigant, 2014; Wiser & Bolinger, 2014). Installations of new offshore wind capacity in 2014 are expected to reach close to 2,300 MW, surpassing

commissions from 2012 (1,131 MW) and 2013 (1,721 MW) (Navigant, 2014; Wiser & Bolinger, 2014).

The calculations for the "new Final State Goals" applying OSW generation suggest that there are enough documented progress, action, and policy efforts to demonstrate quantitatively the impact of offshore wind in lowering carbon dioxide emissions. The JEDI study's various levels of approach, covered by Scenarios 3, 4, and 5, clearly show how dependent emission rates are on the levels of progress of the offshore wind energy industry. However, a more robust Clean Power Plan benefiting from OSW generation could bolster a strategic policy that will help accelerate deployment of offshore wind energy and achieve progress in development of renewable energies already established. As a result, firm and effective courses of action will be required in order to successfully attain significant emissions reductions.

7 RECOMMENDATIONS FOR FURTHER RESEARCH

Given the current efforts and collaborations by the U.S Department of Energy, U.S. Department of Interior, and the Bureau of Ocean Management in identifying wind energy areas and awarding commercial leases, the EPA Clean Power Plan should have created an option within Building Block 3 to factor in offshore wind as part of the renewable energy generation. A realistic emissions target could apply the cumulative total potential capacity from Scenario 2.

Another meaningful opportunity for further research related to this study is the design of a systems thinking model in which to analyze how are carbon emissions impacted by offshore wind energy. This tool could serve to understand the interactions and responses to addressing climate change and how policy such as the EPA Clean Power Plan can affect the system and peoples behaviors.

8 APPENDIX I

Appendix I: OSW Deployment for Scenarios 3, 4 & 5.*Note.* Adapted from *Mid-Atlantic JEDI report.* Retrieved 07/03, 2014, from http://wind.jmu.edu/research/jobseconomic.html, by (Kraemer, Zammit, & Miles, 2013). *These values were slightly adjusted to correct for typographical errors in the draft manuscript in consultation with author Miles, J. J.

Scenario 3: *Conservative* approach data for OSW deployment										
Year	**Delaware**		**Maryland**		**New Jersey**		**Virginia**		**Total**	
	Market	Total	Market	Total	Market	Total	Market	Total	Market	Total
2015	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	25	25	0	0	25	25
2017	0	0	30	30	25	50	0	0	55	80
2018	40	40	0	30	50	100	36	36	126	206
2019	40	80	30	60	0	100	0	36	70	276
2020	0	80	0	60	90	190	0	36	90	366
2021	50	130	0	60	0	190	150	186	200	566
2022	60	190	50	110	100	290	50	236	260	826
2023	0	190	70	180	150	440	0	236	220	1,046
2024	100	290	100	280	100	540	0	236	200	1,246
2025	0	290	0	280	100	640	0	236	200	1,446
2026	100	390	100	380	150	790	0	236	350	1,796
2027	100	490	100	480	150	940	0	236	350	2,146
2028	150	640	0	480	200	1,140	0	236	350	2,496
2029	0	640	0	480	200	1,340	100	336	300	2,796
2030	0	640*	150	630	0	1,340*	250	586	400	3,196

Scenario 4: *Moderate* approach data for OSW deployment										
Year	**Delaware**		**Maryland**		**New Jersey**		**Virginia**		**Total**	
	Market	Total	Market	Total	Market	Total	Market	Total	Market	Total
2015	0	0	0	0	200	200	0	0	200	200
2016	50	50	0	0	200	400	0	0	250	450
2017	0	50	50	50	250	650	0	0	300	750
2018	50	100	60	110	250	900	32	32	392	1,142
2019	50	150	70	180	250	1,150	0	32	370	1,512
2020	80	230	70	250	150	1,300	100	132	400	1,912
2021	0	230	100	350	200	1,500	150	282	450	2,362
2022	120	350	100	450	230	1,730	0	282	450	2,812
2023	150	500	100	550	250	1,980	0	282	500	3,312
2024	100	600	100	650	200	2,180	150	432	550	3,862
2025	120	720	120	770	200	2,380	150	582	590	4,452
2026	100	820	130	900	250	2,630	200	782	680	5,132
2027	130	950	130	1,030	200	2,880	200	982	660	5,792
2028	220	1,170	120	1,150	300	3,130	0	982	640	6,432
2029	200	1,370	150	1,300	300	3,430	0	982	650	7,082
2030	150	1,520	150	1,450	300	3,730	150	1,132	750	7,832

Scenario 5: *Aggressive* approach data for OSW deployment										
Year	**Delaware**		**Maryland**		**New Jersey**		**Virginia**		**Total**	
	Market	Total	Market	Total	Market	Total	Market	Total	Market	Total
2015	50	50	100	100	250	250	0	0	400	400
2016	150	200	100	200	300	550	0	0	550	950
2017	150	350	100	300	400	950	0	0	650	1,600
2018	150	500	100	400	400	1,350	64	64	764	2,364
2019	50	550	150	550	400	1,750	136	200	736	3,100
2020	200	750	150	700	500	2,250	150	350	1,000	4,100
2021	200	950	150	850	500	2,750	150	500	1,000	5,100
2022	200	1,150	150	1,000	500	3,250	150	650	1,000	6,100
2023	200	1,350	200	1,200	500	3,750	150	800	1,050	7,150
2024	200	1,550	200	1,400	550	4,300	150	950	1,100	8,250
2025	250	1,800	200	1,600	600	4,900	150	1,100	1,200	9,450
2026	250	2,050	200	1,800	650	5,550	150	1,250	1,250	10,700
2027	250	2,300	250	2,050	700	6,250	150	1,400	1,350	12,050
2028	280	2,580	250	2,300	700	6,950	200	1,600	1,430	13,480
2029	250	2,830	250	2,550	700	7,650	200	1,800	1,400	14,880
2030	250	3,080	250	2,800	700	8,350	200	2,000	1,400	16,230*

9 APPENDIX II

Appendix II: OSW Utility-Scale Energy Capacity Factors Dataset.
Note. Adapted from *NREL and Open Energy Information's Transparent Cost Database.* Retrieved 10/29, 2014, from http://en.openei.org/apps/TCDB/, by (NREL, 2013; Open Energy Information, 2013).

OSW Utility-Scale Energy Capacity Factors	
The data below was downloaded from the Transparent Cost Database at http://en.openei.org/apps/TCDB/.	
Chart View:	**Capacity Factor**
Date:	**2014-10-29 8:12**
Data Points:	**581**

Legend

Green indicates the data displayed in the chart.

White indicates data from the publication (converted in some cases).

Gold indicates a DOE Program Estimate that is displayed on the chart as a gold diamond.

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g39616	Offshore	2010	45%	DOE 2013	2013	DOE	DOE Program Estimate	
g30149	Offshore	2003	34%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30146	Offshore	2000	34%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30151	Offshore	2005	34%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30148	Offshore	2002	34%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30150	Offshore	2004	34%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g30147	Offshore	2001	34%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30152	Offshore	2006	35%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30153	Offshore	2007	35%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30154	Offshore	2008	36%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30199	Offshore	2002	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30407	Offshore	2006	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30404	Offshore	2003	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30201	Offshore	2004	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30401	Offshore	2000	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30409	Offshore	2008	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30198	Offshore	2001	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30406	Offshore	2005	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30403	Offshore	2002	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30200	Offshore	2003	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g30408	Offshore	2007	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30197	Offshore	2000	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30405	Offshore	2004	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30202	Offshore	2005	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30402	Offshore	2001	38%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30203	Offshore	2006	39%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30204	Offshore	2007	39%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30205	Offshore	2008	40%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30249	Offshore	2001	42%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30251	Offshore	2003	42%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30248	Offshore	2000	42%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30253	Offshore	2005	42%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30250	Offshore	2002	42%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30252	Offshore	2004	42%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g30254	Offshore	2006	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30457	Offshore	2005	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30454	Offshore	2002	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30459	Offshore	2007	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30456	Offshore	2004	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30453	Offshore	2001	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30458	Offshore	2006	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30455	Offshore	2003	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30452	Offshore	2000	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30460	Offshore	2008	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30255	Offshore	2007	43%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30256	Offshore	2008	44%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30507	Offshore	2004	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30299	Offshore	2000	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g30504	Offshore	2001	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30304	Offshore	2005	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30509	Offshore	2006	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30301	Offshore	2002	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30506	Offshore	2003	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30503	Offshore	2000	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30511	Offshore	2008	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30303	Offshore	2004	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30508	Offshore	2005	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30300	Offshore	2001	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30505	Offshore	2002	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30510	Offshore	2007	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30302	Offshore	2003	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30305	Offshore	2006	46%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g30306	Offshore	2007	47%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30307	Offshore	2008	47%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30557	Offshore	2003	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30554	Offshore	2000	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30562	Offshore	2008	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30354	Offshore	2004	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30559	Offshore	2005	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30351	Offshore	2001	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30556	Offshore	2002	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30561	Offshore	2007	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30353	Offshore	2003	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30558	Offshore	2004	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30350	Offshore	2000	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30555	Offshore	2001	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g30355	Offshore	2005	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30560	Offshore	2006	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30352	Offshore	2002	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30356	Offshore	2006	50%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30357	Offshore	2007	51%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30358	Offshore	2008	51%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30607	Offshore	2002	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30612	Offshore	2007	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30609	Offshore	2004	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30606	Offshore	2001	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30611	Offshore	2006	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30608	Offshore	2003	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30605	Offshore	2000	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g30613	Offshore	2008	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g30610	Offshore	2005	54%	Logan et al., 2008	2008	Logan et al	NREL - SEAC (2008). Data from ReEDS model, NREL.	www.nrel.gov/docs/fy09osti/45161.pdf
g26481	Offshore	2008	27%	GPRA 2009	2009	GPRA	GPRA (2009). Data from MARKAL model, IEA and BNL	
g26482	Offshore	2009	32%	GPRA 2009	2009	GPRA	GPRA (2009). Data from MARKAL model, IEA and BNL	
g26532	Offshore	2008	34%	GPRA 2009	2009	GPRA	GPRA (2009). Data from MARKAL model, IEA and BNL	
g26533	Offshore	2009	37%	GPRA 2009	2009	GPRA	GPRA (2009). Data from MARKAL model, IEA and BNL	
g26583	Offshore	2008	40%	GPRA 2009	2009	GPRA	GPRA (2009). Data from MARKAL model, IEA and BNL	
g26584	Offshore	2009	43%	GPRA 2009	2009	GPRA	GPRA (2009). Data from MARKAL model, IEA and BNL	
g38157	Offshore	2009	32%	Lazard 2010	2010	Lazard	Lazard Levelized Cost of Energy Analysis, version 4.0	www.dpuc.state.ct.us/
g38155	Offshore	2009	40%	E3 2010	2010	E3	Capital Cost Recommendations for 2009 TEPPC Study.	www.wecc.biz/
g38159	Offshore	2009	45%	Lazard 2010	2010	Lazard	Lazard Levelized Cost of Energy Analysis, version 4.0	www.dpuc.state.ct.us/

EntityId	Technology	Year	Average Capacity Factor	Reference Name	Publication Year	Report Author(s)	Dataset name	Dataset web source
g38448	Offshore	2011	39%	DOE 2011	2011	DOE	DOE Program Estimate	
g38820	Offshore	2011	40%	IPCC 2011	2011	IPCC	IPCC Annex 3	http://srren.ipcc-wg3.de/report/
g38822	Offshore	2011	40%	IPCC 2011	2011	IPCC	IPCC Annex 3	http://srren.ipcc-wg3.de/report/
g38821	Offshore	2011	40%	IPCC 2011	2011	IPCC	IPCC Annex 3	http://srren.ipcc-wg3.de/report/
g38697	Offshore	2010	39%	Mai et al., 2012	2012	Mai et al	Renewable Electricity Futures	www.nrel.gov/docs/fy12osti/52409-1.pdf
g38848	Offshore	2010	39%	Tegan et al., 2012	2012	Tegan et al	2010 Cost of Wind Energy Review	www.nrel.gov/docs/fy12osti/52920.pdf
g38541	Offshore	2010	39%	Black & Veatch 2012	2012	Black and Veatch	Cost and Performance Data for Power Generation Technologies	http://bv.com/docs/reports-studies/nrel-cost-report.pdf

10 APPENDIX III

Appendix III: State Goal Data for Emissions Reduction Computation adapted from the EPA Clean Power Plan Proposed Rule (EPA, 2014c).

	Step 1 (2012 Data for Fossil Sources)									
State	Coal Rate (lb/MWh)	NGCC Rate (lb/MWh)	O/G rate (lb/MWh)	Other Emissions (lbs)	Hist Coal Gen (MWh)	Hist NGCC Gen. (MWh)	Historic OG steam Gen. (MWh)	Other Gen. (MWh)	NGCC Capacity (MW)	Under Construction NGCC Capacity (MW)
Delaware	2,137	979	1,430	2,008,473	1,406,502	5,179,270	1,076,070	1,432	1,193	0
Maryland	2,158	975	1,544	48,214,762	16,297,835	676,556	2,892,354	20,917	289	0
New Jersey	2,102	889	1,473	2,431,861,784	2,602,990	20,015,730	173,972	2,295,215	5,832	0
Virginia	2,268	903	1,652	2,581,898,592	13,641,552	23,070,350	343,908	1,140,288	4,346	1,928

	Step 2 (HRI)	Step 3a & 3b (Redispatch)						
State	Adj. Coal Rate (lbs/MWh)	Redispatched Coal Gen. (MWh)	Redispatch O/G steam Gen. (MWh)	Redispatched NGCC Gen. (MWh)	Other Emissions (lbs)	Other Gen. (MWh)	2012 NGCC Capacity Factor*	Post Redispatch Assumed NGCC Capacity Factor for Existing Fleet
Delaware	2,009	184,879	141,445	7,335,518	2,008,473	1,432	49%	70%
Maryland	2,029	15,364,292	2,726,679	1,775,773	48,214,762	20,917	27%	70%
New Jersey	1,976	0	0	22,792,692	2,431,861,784	2,295,215	39%	44%
Virginia	2,132	7,600,565	191,613	29,263,632	10,995,356,047	10,454,842	60%	70%

	Step 4a Nuclear	Step 4b Renewable (MWh)									
State	Nuclear Generation Under Construction and "At Risk" (MWh)	2020 Existing and Incremental RE	2021 Existing and Incremental RE	2022 Existing and Incremental RE	2023 Existing and Incremental RE	2024 Existing and Incremental RE	2025 Existing and Incremental RE	2026 Existing and Incremental RE	2027 Existing and Incremental RE	2028 Existing and Incremental RE	2029 Existing and Incremental RE
Delaware		247,757	290,517	340,658	399,452	468,394	549,235	644,028	755,181	885,519	1,038,351
Maryland	787,533	1,697,995	1,991,053	2,334,691	2,737,638	3,210,129	3,764,169	4,413,830	5,175,617	5,982,069	5,982,069
New Jersey	1,616,037	2,421,244	2,839,129	3,329,137	3,903,716	4,577,463	5,367,492	6,293,872	7,380,138	8,653,883	10,147,466
Virginia	1,645,275	4,458,736	5,228,273	6,130,626	7,188,717	8,429,425	9,884,268	11,192,008	11,192,008	11,192,008	11,192,008

	Step 5 (Demand Side EE - % of avoided MWh sales)											
State	2020 EE Potential	2021 EE Potential	2022 EE Potential	2023 EE Potential	2024 EE Potential	2025 EE Potential	2026 EE Potential	2027 EE Potential	2028 EE Potential	2029 EE Potential (%)	State Generation as % of sales	2012 Total MWh (sales x 1.0751)
Delaware	1.14%	1.86%	2.73%	3.72%	4.83%	5.94%	6.96%	7.89%	8.72%	9.47%	45.09%	12,384,433
Maryland	4.21%	5.38%	6.45%	7.44%	8.33%	9.13%	9.85%	10.48%	11.04%	11.51%	60.82%	66,455,750
New Jersey	1.25%	1.99%	2.87%	3.88%	5.00%	6.10%	7.11%	8.02%	8.84%	9.58%	76.19%	80,689,388
Virginia	1.23%	1.96%	2.82%	3.81%	4.91%	5.98%	6.95%	7.83%	8.62%	9.33%	58.01%	115,890,388

	Step 6&7 (State Goal Phase I & II (lbs/MWh))											
State	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	**Interim Goal (2020 - 2029 average)**	**Final Goal (2030 and thereafter)**
Delaware	973	963	951	938	924	908	892	876	859	841	**913**	**841**
Maryland	1,543	1,496	1,450	1,407	1,364	1,321	1,278	1,235	1,194	1,187	**1,347**	**1,187**
New Jersey	759	738	714	688	661	634	607	582	556	531	**647**	**531**
Virginia	991	969	943	916	886	855	830	822	816	810	**884**	**810**

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