UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Atlantic Grid Operations A LLC	
Atlantic Grid Operations B LLC	**Docket Nos. EL11-____-000**
Atlantic Grid Operations C LLC	**ER11-____-000**
Atlantic Grid Operations D LLC	
Atlantic Grid Operations E LLC	

DIRECT TESTIMONY OF

JOHANNES P. PFEIFENBERGER AND

SAMUEL A. NEWELL

ON BEHALF OF

THE AWC COMPANIES

December 20, 2010

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(Exhibit AWC-400)

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**DIRECT TESTIMONY OF
JOHANNES P. PFEIFENBERGER and SAMUEL A. NEWELL**

I. INTRODUCTION

Q. PLEASE STATE YOUR NAMES, EMPLOYER, TITLE, AND BUSINESS ADDRESS.

A. My name is Johannes P. Pfeifenberger and my name is Dr. Samuel A. Newell. We are both Principals of *The Brattle Group*, an economic consulting firm with offices in Cambridge, Massachusetts; Washington, D.C.; San Francisco; London; Brussels; and Madrid. Our business address is 44 Brattle Street, Cambridge, Massachusetts 02138.

Q. ON WHOSE BEHALF ARE YOU TESTIFYING?

A. We are testifying on behalf of The AWC Companies.

Q. MR. PFEIFENBERGER, PLEASE DESCRIBE YOUR BACKGROUND, EDUCATION, AND PROFESSIONAL EXPERIENCE AS IT RELATES TO THIS DIRECT TESTIMONY.

A. I am an economist with a background in power engineering and over 20 years of work experience in the areas of regulated industries, energy policy, and finance. I received a M.A. in Economics and Finance from Brandeis University and a M.S. in Electrical Engineering with a specialization in Power Engineering and Energy Economics from the University of Technology, Vienna, Austria. I lead *The Brattle Group's* utilities practice area and am the author and co-author of numerous articles, reports, and presentations on subject areas related to the economic benefits of transmission investment, planning, market design, and cost allocation.

I have filed testimony before the Federal Energy Regulatory Commission (the "Commission" or "FERC") and numerous state regulatory commissions on a range of subject areas, including the economic benefits of transmission investments. For example, I filed testimony with the Public Service Commission of Wisconsin on behalf of American Transmission Company LLC and ATC Management Inc. in Docket No. 137-CE-149 discussing the economic benefits of the Paddock-Rockdale Transmission Project, which was the first "economic" transmission project evaluated by the Wisconsin commission. On behalf of Southern California Edison Company, I testified before the Arizona Power Plant and Transmission Line Siting Committee in Docket No. L-00000A-06-0295-00130, Case No. 130 regarding the economic impacts of the proposed Devers-Palo Verde No. 2 ("DPV2") transmission line in 2006 and conducted congestion and economic analyses in 2009 to evaluate the project under changed market conditions. On behalf of the Southwest Power Pool ("SPP"), I conducted the analysis of the economic stimulus benefits associated with the construction of proposed SPP transmission and wind generation, which SPP filed in FERC Docket No. ER10-1069 in support of the proposed Highway/Byway transmission cost allocation methodology. I also filed with the Commission (co-authored with colleagues on behalf of ourselves) comments in Docket Nos. AD09-8 and RM10-23 on regional transmission planning and cost allocation, and submitted testimonies on transmission tariff design, the costs and benefits of alternative transmission access charge methodologies, and regional transmission organization ("RTO") scope and configuration issues on behalf of various clients. Exhibit AWC-401 to our testimony contains a more complete description of my qualifications and expert witness experience.

Q. DR. NEWELL, PLEASE DESCRIBE YOUR BACKGROUND, EDUCATION, AND PROFESSIONAL EXPERIENCE AS IT RELATES TO THIS DIRECT TESTIMONY.

A. I am an economist and engineer with 12 years of work experience in the modeling and analysis of electricity markets and their relationship to the transmission system. I received a Ph.D. in technology management and policy from the Massachusetts Institute of Technology, a M.S. in materials science and engineering from Stanford University, and a B.A. in chemistry and physics from Harvard College. Prior to joining *The Brattle Group*, I was Director of Cambridge Energy Research Associates' Transmission Service. I currently lead *The Brattle Group's* use of the locational marginal price ("LMP") market simulation models of PJM and other North American electricity markets. I am the author or co-author of numerous articles, reports, and presentations on a broad range of subject areas related to wholesale electricity markets and transmission.

I have submitted testimony with FERC in RTO-related cases and prepared expert reports for PJM, other RTOs, and transmission clients that have been filed with both state regulatory commissions and the FERC. For example, I was one of the co-authors of a report filed by American Transmission Company LLC with the Public Service Commission of Wisconsin in Docket No. 137-CE-149 discussing the economic benefits of the Paddock-Rockdale Transmission Project. My role was to advise staff at American Transmission Company LLC on its use of PROMOD IV simulations, to compute customer benefits, and to analyze several categories of benefits outside the scope of the model. Recently, I also testified on behalf of Connecticut Light & Power and The United Illuminating Company in their Integrated Resource Planning proceeding before the Connecticut Department of Public Utility Control. My role, as the leader of the *Brattle* team in that assignment, was to analyze customer impacts and policy implications of various resource strategies regarding renewables development and energy efficiency. Exhibit AWC-402 to our testimony contains a more complete description of my qualifications and expert witness experience.

II. PURPOSE AND SUMMARY OF TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. The purpose of our testimony is to describe and quantify some of the public policy, reliability, congestion relief, and other economic benefits associated with the Atlantic Wind Connection Project ("AWC Project" or "Project").

Q. WHAT IS THE AWC PROJECT?

A. The AWC Project is a double-circuit, high-voltage direct current ("HVDC") offshore transmission backbone with twelve offshore AC-DC converter stations capable of integrating at least 6,000 MW of offshore wind generation in geographic locations ranging from northern New Jersey to southern Virginia. The Project will also have onshore DC-AC converter stations at seven locations in New Jersey, Maryland, Delaware, and Virginia, where renewable power can be injected into the existing transmission grid in controlled proportions. The Project, which will be built in five phases, can also be used to transmit up to 2,000 MW of energy and capacity between interconnection points along the coast, providing an offshore reinforcement to the existing onshore grid in the congested Mid-Atlantic power market.

Q. WHAT ARE THE AWC PROJECT'S MAIN BENEFITS?

A. The AWC Project provides a platform on which offshore wind developers can interconnect their wind farms with significantly reduced siting, permitting, and interconnection barriers. This will help meet state renewable energy requirements and other state and federal energy, environmental, and economic policy goals.

Offshore wind generation facilitated by the AWC Project will lower CO_2 emissions by reducing coal, gas, and oil usage, and it will reduce energy prices across the PJM footprint. The Project will also enhance reliability and reduce congestion in what the Department of Energy ("DOE") has designated as one of the most congested National Interest Electric Transmission Corridors. Importantly, this is true of the AWC Project whether viewed without wind build out, full wind build-out, or simply in comparison to a scenario in which offshore wind is interconnected by radial transmission lines.

The Mid-Atlantic region offers the most abundant and most attractive offshore wind resources in the country. The AWC Project can help the Mid-Atlantic and other PJM states take advantage of this resource to achieve their RPS requirements. In doing so, the Project offers significant economic benefits compared to individual radial interconnections for each offshore wind farm. By reducing siting, permitting, and interconnection barriers to wind development, the Project will expedite the installation of offshore wind on a scale that very likely spurs the development of local industry to provide equipment and services, which will substantially lower the cost of offshore wind development.

Of particular importance, the AWC Project's HVDC backbone and AC-DC converters are controllable which, unlike the typical radial transmission interconnections, allows for optimal power transfers and injections of offshore generation in real time. This enhances reliability and relieves transmission congestion, which lowers system-wide electricity production costs. Compared to radially interconnecting individual offshore wind plants, the AWC Project is a more effective solution for developing Mid-Atlantic offshore wind resources. It provides significantly higher economic, reliability, congestion relief, operating, and environmental benefits to the PJM grid and to the region. Our testimony explains these public policy, reliability, congestion relief, and other economic benefits in detail.

Q. PLEASE SUMMARIZE THE EXTENT TO WHICH THE AWC PROJECT WILL ENABLE STATES TO MEET THEIR RPS.

A. The AWC Project helps meet states' RPS policies, which require load serving entities to buy increasing amounts of energy from renewable resources, including offshore wind. PJM projects that meeting these state RPS requirements in its footprint would require up to 25,000 MW of wind by 2015 and 50,000 MW by 2025. Of the states directly interconnected by the AWC Project, New Jersey requires 22.5% renewables by 2020, Delaware 25% by 2025, Maryland 20% by 2022, and Virginia has a goal of 15% by 2025.

Offshore wind power has received an increasing amount of public policy attention as a key resource for the eastern U.S. because it is abundant and located close to load centers. In contrast, other local renewable resources are scarce and remote resources (such as onshore wind in the Midwest) would require major transmission investments without much local economic development benefit to the states.

The AWC Project could deliver 6,000 MW of offshore wind energy, closing approximately 75% of the gap toward the 8,000 MW of new offshore wind that would be sufficient to meet the 2020 RPS requirements of New Jersey, Delaware, Maryland and Virginia, and providing nearly 65% of the requirement by 2025—before considering the potential demand for offshore wind from other states. Moreover, since wind conditions rarely allow entire wind farms to simultaneously generate at their maximum rated capacity, it is more cost effective to install wind capacity in excess of the transmission capacity to maximize the value of the overall investment. In our analysis of benefits, we have assumed that 6,600 MW of nameplate wind generation would be interconnected to the AWC Project, which will result in 10% additional wind energy generated with only 0.2% in curtailments.

Q. PLEASE SUMMARIZE SOME OF THE COSTS AND BENEFITS ASSOCIATED WITH THE SCALE OF OFFSHORE WIND DEVELOPMENT SUPPORTED BY THE AWC PROJECT.

A. Developing this amount of offshore wind generation will require an overall investment of approximately $30 billion. This investment has to be considered in the context of associated benefits. As shown in Table 1, integration of the 6,600 MW of offshore wind generation facilitated by the AWC Project will reduce customer locational marginal prices ("LMPs") by approximately $1.6 billion per year (net of offsetting impacts on capacity market prices). Our analysis shows that this benefit is widespread: load-weighted annual average LMPs decrease by approximately $6/MWh in New Jersey, by $2-4/MWh in Delaware, Maryland and Virginia, by $2-5/MWh in Pennsylvania, and by $0.5-1.6/MWh in western PJM.

In addition, the development of offshore wind will create jobs and economic stimulus for the local economy, as shown in Table 2. There are also other benefits and costs, including the capacity value of wind, wind integration costs, and the AWC Project-specific benefits discussed in Sections IV through VII of our testimony.

Table 1
Electricity Market and Emissions Benefits of Integrating 6,600 MW of Offshore Wind Generation in New Jersey, Delaware, Maryland, and Virginia
(relative to a Base Case without offshore wind)

Type of Benefit	Annual Value (in 2016 $'s)	20-year NPV (in 2010 $'s)
Emission reductions	16 million tons CO_2 25,000 tons SO_2 11,000 tons NOx	
Value of CO_2 emission reductions (assuming $30/ton CO_2)	$500 million	$5.2 billion
Reduction in fossil fuel production costs in Eastern Interconnection	$1.1 billion	$12 billion
Customer value of LMP reductions in PJM (net of $480 million/year offsetting impact on capacity prices)	$1.6 billion	$17 billion

Table 2
Economic Stimulus Benefit of 6,600 MW of Offshore Wind Generation and Related Offshore Transmission
(relative to a Base Case without offshore wind)

Economic Activity	Jobs (FTE-years)	Earnings ($ billions)	Economic Activity ($ billions)
Construction and *low* in-region manufacturing	130,000 to 184,000	$7.6 – 11.4	$16.4 – 30.3
Construction and *high* in-region manufacturing	184,000 to 263,000	$11.4 – 17.4	$30.3 – 51.5

Q. PLEASE EXPLAIN THE DIFFERENCE BETWEEN "LOW IN-REGION" AND "HIGH IN-REGION" MANUFACTURING IN TABLE 2

A. As Table 2 shows, the overall magnitude of the economic stimulus benefits of offshore wind investments to the local economies is significant. However, the magnitude of this economic benefit also strongly depends on the extent to which wind turbines and other plant and equipment are manufactured within the Mid-Atlantic region (rather than being imported) and the extent to which construction services and logistical support are provided by companies and employees within the region. Achieving a high in-region provision of these equipment and services will require a scale of offshore wind power development that justifies the investment in manufacturing and logistical facilities.

Q. DOES YOUR TESTIMONY EVALUATE THE ECONOMICS OF RPS REQUIREMENTS AND OFFSHORE WIND GENERATION RELATIVE TO OTHER POLICY OPTIONS?

A. No. While we recognize the above benefits and costs of offshore wind generation, the focus of our testimony is to identify the public policy, reliability, congestion relief, and other economic benefits of the AWC Project itself. We do so primarily by comparing the Project to more conventional ways to interconnect offshore wind through radial transmission lines. The rest of this summary (and Sections IV though VII of our testimony) focuses on that comparison.

Q. HOW DOES THE AWC PROJECT'S CONFIGURATION AND COST COMPARE TO CONVENTIONAL RADIAL INTERCONNECTION OF OFFSHORE WIND PLANTS?

A. The AWC Project is able to reliably deliver 6,000 MW of offshore wind power and additionally provide a fully controllable 2,000 MW HVDC transmission path between southern Virginia and northern New Jersey at a total construction cost of approximately $5 billion. In comparison, we estimate that delivering 6,000 MW of wind power with radial transmission lines from individual wind plants to shore would incur construction costs of $3.4 billion to $5.3 billion without offering the substantial additional public policy, reliability, congestion relief, and other economic benefits we have identified and partially quantified for the AWC Project. We estimate that interconnecting offshore wind with the AWC Project provides $9-15 billion of benefits over a radial approach (including the avoided costs of radial transmission lines), in addition to reliability and operating benefits we have not quantified.

Q. PLEASE SUMMARIZE HOW THE AWC PROJECT WOULD SUPPORT STATE POLICY OBJECTIVES.

A. The AWC Project will support meeting the states' renewable energy goals by reducing permitting and planning barriers and achieving significant economies of scale for offshore wind development. The Project creates a one-stop process for landing-point selection, state environmental siting, and PJM transmission planning. Compared to a plant-by-plant permitting and transmission planning process, this will reduce development barriers and provide a platform that increases the certainty, ramp-up, and scale of offshore wind development in the Mid-Atlantic region. The AWC Project requires fewer landing points, has a smaller environmental footprint, and allows the development of offshore wind locations independently of these landing points and with a greatly simplified permitting process.

Q. HAVE YOU QUANTIFIED THE VALUE OF SOME OF THESE PUBLIC POLICY BENEFITS THAT THE AWC PROJECT WOULD PROVIDE?

A. Yes. Increased scale and predictability of offshore wind development facilitated by the AWC Project offers the prospect of significant cost savings for almost every aspect of offshore wind development. It will facilitate investments in local manufacturing of wind turbines and related components and the development of more cost-effective construction and logistical infrastructure. We estimate that streamlined permitting and increased scale that allows local manufacturing and sourcing will reduce total offshore costs by approximately 20 percent. Based on $30 billion of offshore wind generation investment supported by the AWC Project, this results in total cost reductions of approximately $6.0 billion. In addition, promoting in-region manufacturing and sourcing results in significantly greater employment and economic development benefits, as indicated by the difference between "low" and "high" in-region manufacturing benefits in Table 2.

Q. PLEASE SUMMARIZE HOW THE AWC PROJECT PROVIDES RELIABILITY AND OPERATIONAL BENEFITS.

A. The AWC Project will provide significant reliability and operational benefits. The AWC Project will likely reduce the long-term need for costly enhancements to the existing onshore transmission system. This is because: (a) the Project can be designed to interconnect at the strongest onshore nodes, which is less likely to be achieved by interconnecting individual wind farms; (b) the Project's

2,000 MW transfer capability between landing points in Virginia, Maryland, Delaware, and New Jersey reinforces the onshore grid in the constrained Mid-Atlantic region, reducing the need for future onshore reinforcements; and (c) the Project's controllable HVDC technology provides PJM with additional flexibility to address reliability challenges whenever they arise.

The capabilities of the Project's advanced HVDC technology also provide operating benefits that enhance reliability and reduce the cost of system operations. These include: (a) the ability to redirect power flows instantaneously to address system contingencies; (b) improved system stability; (c) voltage support and improved reactive performance; and (d) blackstart capability. The Project further provides for more reliable delivery of offshore wind power than individual radial connections by being able to redirect power away from landing points with temporary reliability-related transmission constraints.

We have not quantified the economic value of these reliability and operational benefits, nor have we quantified the value of the Project's specific reliability benefits. However, if the AWC Project avoids the need for even one major onshore transmission project, the savings would likely exceed $1 billion.

Q. HOW DOES THE AWC PROJECT PROVIDE CONGESTION RELIEF?

A. The Project's offshore backbone and controllability allows energy from offshore wind plants or onshore interconnection points to be transmitted to the interconnection points with the highest LMPs, thereby reducing congestion and overall costs compared to a radial system that simply delivers power from individual offshore wind plants irrespective of onshore grid congestion.

We analyzed the economic value of this benefit using Ventyx's PROMOD simulation model. Working with Ventyx staff, we simulated market conditions for 2016 with the addition of 6,600 MW of nameplate offshore wind generation added in two ways: one case with the AWC Project and an alternative case with radial interconnections. These simulations showed that the AWC Project significantly reduces congestion. Instead of simply injecting wind power at the closest onshore location, the AWC Project transfers power to the best locations along the backbone, where the LMP is the highest. It also transfers power from low-priced onshore interconnection points to higher-priced locations. These two benefits reduce system-wide congestion costs by $196 million annually compared to radial interconnections of individual wind plants. Most of the relief occurs on constraints near the wind power injection points and also on constraints from western Pennsylvania into eastern PJM. Compared to the radial interconnection of individual wind plants, the congestion relief provided by the AWC Project helps to reduce system-wide production costs by $33 million per year or by approximately $350 million over the initial 20 years of the Project.

Q. WHAT IMPACT WOULD THE AWC PROJECT HAVE ON LMPS AND CUSTOMER PAYMENTS RELATIVE TO A RADIAL ALTERNATIVE?

A. The LMP benefits from the AWC Project with full wind build-out (compared to a Base Case without AWC Project and without offshore wind) were described above. On average, these benefits are greater than with radially interconnecting the same amount of wind. The AWC Project will reduce LMPs, especially in the "EMAAC" region of PJM, compared to the radial alternative. These price impacts would save PJM customers approximately $126 million per year, or $1.35 billion over 20 years. However, the lower LMPs will increase capacity prices, which offsets $110 million annually ($1.2 billion over 20 years) of these LMP reductions.

Q. ARE THERE ANY SIGNIFICANT FACTORS THAT ARE NOT INCLUDED IN THE ABOVE ESTIMATES OF CONGESTION-RELATED BENEFITS?

A. Yes. The above estimates significantly understate the value that the AWC Project will provide under real-time system operations. This is because a number of operational factors that cause price volatility in the real-time market are not captured in PROMOD simulations, including wind generation uncertainty and forecasting errors, load forecasting errors, sudden outages of generation units, transmission outages, unexpected loop flows from neighboring regions, and ramp-rate limitations on generators.

Analysis of historical hourly day-ahead and real-time LMP differentials among the AWC Project's interconnection points shows that the ability to control power flows in *real time* is **worth approximately twice** as much as in the day-ahead market**.** Since PROMOD simulations are more comparable to the day-ahead market than the real-time market, we estimate that the Project's real-time congestion-relief value will add at least $310 million to the simulation-based production cost savings over the initial 20 years of the Project.

Q. HOW WOULD THE AWC PROJECT AFFECT CONGESTION IF LESS WIND POWER WERE DEVELOPED?

A. We simulated the effects of the AWC Project without any offshore wind generation. Compared to a 2016 Base Case that includes only planned transmission and generation additions, adding the AWC Project reduces onshore congestion by transmitting power from less congested, lower-priced locations to more congested, higher-priced locations. The results of this analysis show that congestion costs would decrease by $147 million and production costs by $51 million per year.

Q. WHAT OTHER CONGESTION-RELATED ECONOMIC BENEFITS DOES THE AWC PROJECT PROVIDE?

A. In addition to transmitting the capacity value of 6,000 MW of offshore wind—which PJM is likely to count as less than 2,000 MW for resource adequacy purposes—the AWC Project will be able to transmit 2,000 MW of capacity from unconstrained southern Virginia northward into the constrained EMAAC region of PJM. The Project also allows transmission of capacity between any constrained subareas within EMAAC if capacity prices were to differ across these subareas again in the future.

We have not forecasted future capacity market conditions and the precise impact of the Project on such future prices. However, using a scenario analysis PJM recently conducted to assess the impact of added transfer capability on 2013/14 capacity prices, and assuming that these price impacts would be realized for only five years over the entire life of the Project, we estimate that the AWC Project would reduce retail customers' capacity payments by approximately $2.1 billion in EMAAC and by approximately $2.7 billion in all of PJM. Even without considering the capacity price benefits to all retail customers, the value of transmitting up to 2,000 MW of capacity from southern Virginia to EMAAC for five years would be worth $180 million.

Q. WHAT EFFECTS DOES THE AWC PROJECT HAVE ON EMISSIONS?

A. By facilitating the development of offshore wind more quickly and at greater scale than if individual wind developers had to plan, permit, and build their own interconnections, the AWC Project will give rise to major emissions reductions. As shown in Table 1, the 6,600 MW of offshore wind interconnected by the AWC Project would eliminate 16 million tons of CO_2 emissions from fossil-fuel-fired generation per year. That is equivalent to taking 3 million cars off the road.

Q. PLEASE SUMMARIZE YOUR MAIN CONCLUSIONS ABOUT THE AWC PROJECT'S BENEFITS.

A. Table 3 summarizes the benefits discussed and quantified in our testimony. As Table 3 shows, the approximately $5 billion construction cost of the AWC Project is more than offset by a number of economic benefits that the Project offers over a plant-by-plant development of offshore wind generation and the interconnection of individual wind power plants through radial HVAC transmission links to the onshore grid. Interconnecting offshore wind with the AWC Project provides $9-15 billion of benefits over a radial approach (including the avoided costs of radial transmission lines), without considering the economic value of reliability and operating benefits we did not quantify.

Table 3
Types and Approximate Magnitude of AWC Project-Related Economic Benefits Over Individual Radial Interconnections of 6,600 MW Offshore Wind Generation

Type of AWC Project Benefit	**Estimate of Economic Value**
• Avoided cost of radial HVAC transmission links to shore • Economic value of ability to access better wind locations	$3.4-5.3 billion *not quantified*
Scale-related benefits (streamlined planning and permitting): • Reduced cost from higher in-region turbine manufacturing • Scale-related savings for other equipment and installation • Reduced planning, permitting, and siting costs/uncertainties • Shoreline siting-related environmental benefits	 $3.2 billion $1.2-3.0 billion $0.6 billion *not quantified*
Reliability benefits: • Avoided cost of on-shore reliability upgrades • Reinforced existing grid through offshore backbone • HVDC operational benefits (voltage support, improved reactive performance, stability, and control of AC power flows, blackstart capability)	 *not quantified* *not quantified* *not quantified*
Congestion relief benefits: • NPV of reduced production costs measured in PROMOD • NPV of additional production cost savings in real-time or, *alternatively*: • NPV of additional reduction in PJM Load LMP • NPV of capacity price offset to LMP decreases Related (locational) capacity market benefit: • Capacity value of 2,000 MW EMAAC import capability: NPV of resource cost savings*—or, *alternatively*: NPV of reduced customer payments due to price impact* * *these are order-of-magnitude estimates that are not included in the low end of total benefits below*	 $350 million $310 million $1.35 billion -$1.2 billion $180 million $2.7 billion
Approximate overall magnitude of AWC Project benefits over radial interconnection of individual wind plants (compared to approximately $5 billion in AWC Project cost)	**> $9-15 billion**

Q. HOW HAVE YOU ORGANIZED THE REMAINDER OF YOUR TESTIMONY?

A. The remainder of our testimony is organized as follows:

- Section III provides an overview of state renewable energy policies, the associated renewable energy requirements, and the economic impact of offshore wind generation facilitated by the AWC Project.
- Section IV analyzes the AWC Project configuration and costs compared with the radial interconnection of individual wind farms.
- Section V evaluates the public policy and scale-related benefits of the AWC Project.
- Section VI discusses and provides preliminary estimates of the reliability and operational benefits associated with the AWC Project.
- And, finally, Section VII discusses the congestion relief and related economic benefits associated with the AWC Project.

III. BACKGROUND: STATE RPS REQUIREMENTS AND ECONOMIC BENEFITS OF OFFSHORE RENEWABLE POWER DEVELOPMENT

1. State Renewable Energy Policy Requirements

Q. WHAT ARE THE RENEWABLE ENERGY REQUIREMENTS OF STATES WITHIN THE PJM FOOTPRINT?

A. Eleven of the fourteen states within the PJM footprint—Delaware, Illinois, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Virginia, West Virginia and the District of Columbia—have renewable portfolio standards or goals ranging from 15% to 25% by 2025. PJM projects that meeting these state RPS requirements in its footprint would require up to 25,000 MW of wind by 2015 and 50,000 MW by 2025.[1]

Q. WHAT ARE THE RENEWABLE ENERGY REQUIREMENTS OF THE FOUR COASTAL MID-ATLANTIC STATES WITH AWC LANDING POINTS?

A. All four coastal Mid-Atlantic states with AWC landing points have passed legislation or regulations establishing renewable energy requirements or goals ranging from 15 to 25 percent of total supply over the next 10 to 15 years.

- New Jersey's RPS requires investor-owned utilities and retail suppliers to procure 22.5% of their electricity sales from qualifying renewable resources by 2020. Qualifying resources include wind, solar, small hydro, resource recovery facilities, biomass, fuel cells, geothermal, landfill gas, and tidal energy. In-state solar generation must provide approximately 2% of the total energy supply, and approved small hydro and resource recovery facilities must provide at least 2.5% of the total energy supply. Legislation enacted in August 2010 also requires offshore wind to provide part of the renewable supply, although the details of this policy are still

[1] 2010 RTEP Sensitivity Analysis Assumptions, PJM Transmission Expansion Advisory Committee, April 14, 2010, slide 8. Available at: http://pjm.com/~/media/committees-groups/committees/teac/20100414/20100414-reliability-analysis-update.ashx

under development. That legislation aims to support the development of at least 1,100 MW of offshore wind.

- Delaware's RPS requires all utility and retail suppliers to procure 25% of their electricity sales from qualifying renewable resources by 2025, with at least 3.5% from solar generation. Solar PV and fuel cell resources sited before December 31, 2014 receive 300% credit (*i.e.,* each MWh generated counts for three MWh). Onshore wind resources sited before December 31, 2012 receive 150% credit, and offshore wind resources sited before December 31, 2017 receive 350% credit toward meeting the state's RPS requirements.
- Maryland's RPS requires all utility and retail suppliers to procure 20% of their electricity sales from qualifying renewable resources by 2022, with at least 2% from solar generation. On November 2010, the Bureau of Ocean Energy Management, Regulation and Enforcement ("BOEMRE") accepted the planning recommendations of the Maryland Offshore Wind Task Force and issued a Request for Interest ("RFI") and also a map of an offshore wind leasing area in federal waters adjacent to Maryland's Atlantic Coast (which made Maryland only the second state in the nation after Delaware to reach this point in the planning process).
- Virginia has not established a mandatory RPS requirement, but the legislature enacted a voluntary renewable energy portfolio goal, with a target of 15% by 2025. RPS targets are defined as a percentage of base

year (2007) electricity sales that are supplied by non-nuclear generation.[2] According to the legislation, the utilities participating in the RPS program are allowed to recover all incremental costs and also given incentives in the form of increased rate of return. In addition, utilities receive 200% credit for the energy derived from onshore wind, and 300% credit for the energy derived from offshore wind. A study by the Virginia Coastal Energy Research Consortium, which was established by the 2006 Virginia Energy Plan legislation, has now identified 25 lease blocks with 3,200 MW of potential offshore wind capacity in shallow waters beyond the visible horizon.[3]

Figure 1 below summarizes the projected demand for renewable energy based on these state RPS requirements and goals. As Figure 1 shows, the total demand is estimated to increase from 11,700 GWh in 2010, to more than 40,000 GWh in 2020, and approximately 54,000 GWh in 2025. Assuming an average capacity factor of 37%, this demand is equivalent to 3,600 MW of renewable power plants in 2010, more than 12,000 MW in 2020, and approximately 16,600 MW in 2025. As discussed below, however, due to RPS credit multipliers, less offshore wind generating capacity would be needed to satisfy the existing requirement.

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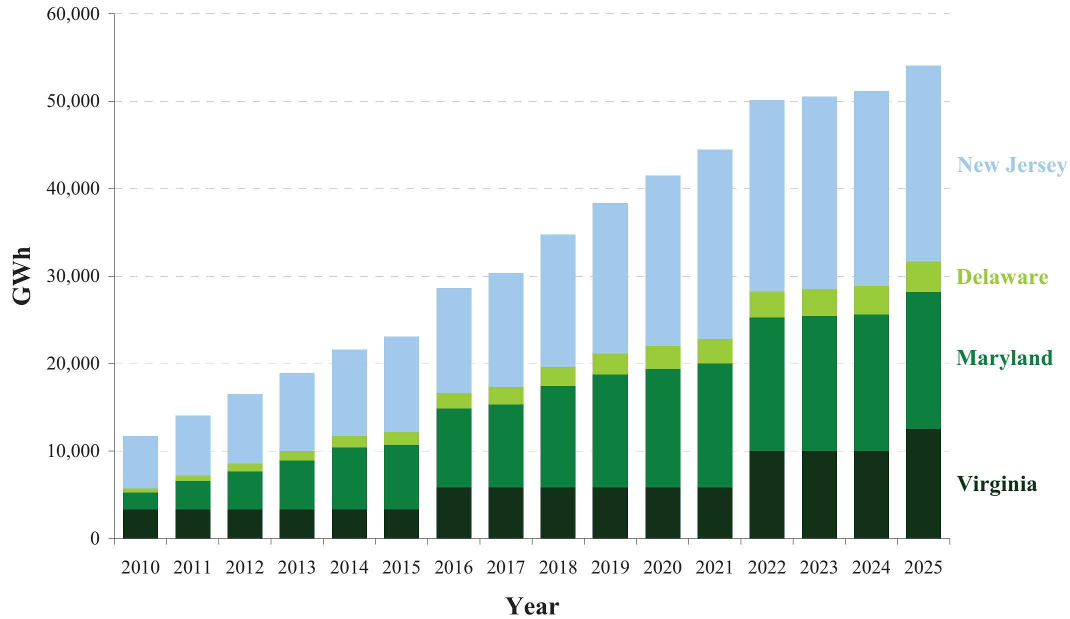
[2] Amount excluded from the base year sales is calculated based on average nuclear generation for calendar years 2004 through 2006.

[3] Virginia Coastal Energy Research Consortium, *Virginia Offshore Wind Studies, July 2007 to March 2010: Final Report*, April 2010, p. ix.

Figure 1
Renewable Demand in Mid-Atlantic Coastal States by Year



Sources and Notes:
[1] RPS targets from DOE's Database of State Incentives for Renewables and Energy Efficiency (DSIRE).
[2] Load forecasts based on EIA 2008 state electricity profiles; applied RTO-wide load growth rates from 2010 PJM Load Forecast.
[3] Virginia RPS goal is defined as a percent of base year (2007) sales minus average nuclear generation between 2004-06.

Q. HOW MUCH RENEWABLE CAPACITY CURRENTLY EXISTS WITHIN THESE STATES?

A. Table 4 below summarizes renewable generation supply in the coastal Mid-Atlantic states based on the unit-level database compiled by Ventyx, *The Energy Velocity Suite*. As the table shows, approximately 1,250 MW of renewable supply already exists, is under construction, or is at least partially permitted within states' boundaries (mostly biomass and landfill gas). Assuming appropriate technology-specific capacity factors, these resources would produce about 7,150 GWh of energy per year.

Table 4
Renewable Supply in Mid-Atlantic Coastal States by Technology

Status	Delaware	Maryland	New Jersey	Virginia	TOTAL CAPACITY	Assumed Capacity Factor	TOTAL GENERATION
	(MW)	*(MW)*	*(MW)*	*(MW)*	*(MW)*	*(%)*	*(GWh)*
Biomass	0	117	150	263	**530**	85%	**3,948**
Landfill Gas	7	26	65	128	**226**	85%	**1,684**
Onshore Wind	2	108	8	188	**306**	32%	**856**
Small Hydro	0	18	4	121	**144**	48%	**609**
Solar	0	4	43	0	**48**	16%	**66**
TOTAL	**9**	**274**	**270**	**700**	**1,253**	**-**	**7,163**

Sources and Notes:
[1] Capacity calculated based on data compiled by Ventyx, The Velocity Suite (downloaded on 10/21/2010).
[2] Generation estimated based on technology-specific capacity factors.
[3] Includes existing units, and units that are under construction or permitted.
[4] "Small Hydro" includes only the units with a nameplate capacity of less than 30 MW.
[5] "Solar" does not include customer-sited generators.
[6] Bluewater's proposed 350 MW project is not included because its status is listed as "Application Pending".

Q. IS THE SUPPLY DESCRIBED ABOVE SUFFICIENT TO MEET THE STATED RENEWABLE REQUIREMENTS OR GOALS OF COASTAL MID-ATLANTIC STATES?

A. No. There is a large gap that will need to be met by additional resources. In addition to the 7,150 GWh from renewable energy plants that already exists, are under construction, or are partially permitted, approximately 47,000 GWh of additional renewable generation will be needed to meet state RPS targets by 2025. Considering that at least 6,600 GWh is required to come from solar resources, this leaves approximately 40,000 GWh in additional demand from other renewable resources. This gap substantially exceeds even the sum of all tentatively "proposed" renewable projects, which add up to about 20,000 GWh, with approximately 16,000 GWh from offshore wind.[4] Taking the states' RPS credit multipliers into account, this number goes up to more than 26,000 GWh, with approximately 22,000 GWh from offshore wind, which is only two thirds of the incremental 40,000 GWh needed for RPS compliance by 2025.

Q. HOW MUCH OFFSHORE WIND POTENTIAL EXISTS IN THE MID-ATLANTIC REGION?

A. The Mid-Atlantic offshore region has been recognized as one of the most fertile locations for offshore wind generation. The National Renewable Energy Laboratory ("NREL") has determined that total Mid-Atlantic offshore wind energy potential is over 480,000 MW, of which 44,000 MW is located in shallow waters between 12 and 50 nautical miles off the shores of PJM's four Mid-Atlantic coastal states.[5]

Q. HOW MUCH ADDITIONAL OFFSHORE WIND CAPACITY WOULD BE NEEDED TO SATISFY ONLY THE REMAINING REQUIREMENTS IN THE FOUR MID-ATLANTIC STATES' RPS TARGETS?

A. If the incremental 40,200 GWh required for RPS compliance of the four states came only from *onshore* wind resources with an average 32% capacity factor, then approximately 12,800 MW of additional onshore wind capacity would be needed (taking into account solar carveouts and the 200% RPS credit multiplier for onshore wind in Virginia). Alternatively, if the renewable energy were to

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[4] As calculated based on data compiled by Ventyx, *The Velocity Suite* (downloaded on 10/21/2010).

[5] National Renewable Energy Laboratory, *Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers*, September 2010, pp. 56-63. The study defines the Mid-Atlantic region as the coasts of New Jersey, Delaware, Maryland, Virginia, and North Carolina. Wind potential cited is based on 8.0 m/s wind speeds or greater. Shallow water is water depth of 30 meters or less. North Carolina's offshore potential in shallow waters between 12 and 50 nautical miles is 52,000 MW.

come only from *offshore* wind resources with an average 40% capacity factor, then approximately 9,200 MW of new capacity would be needed (taking into account solar carveouts and the 300% RPS credit for offshore wind in Virginia and 350% in Delaware). Thus, not even considering any potential demand for offshore wind energy in other PJM and neighboring states, the RPS requirement of the four Mid-Atlantic states with AWC landing points already significantly exceeds the 6,000 MW of offshore wind generation that can be delivered to shore by the Project.

Q. HOW MUCH OF THE FOUR STATES' RENEWABLE REQUIREMENT WOULD LIKELY BE IMPORTED FROM STATES OUTSIDE THE MID-ATLANTIC REGION?

A. That is difficult to assess at this point. Most other states' demand for renewables similarly exceeds their local supply, limiting the potential for onshore wind imports by the coastal Mid-Atlantic states. Only states in the Upper Midwest have significant long-term export potential. While these Upper Midwestern states have a large amount of high-quality onshore wind that could meet some of the coastal states' RPS requirements, development of these resources is also limited by severe transmission constraints. In addition, the east coast states have voiced a strong preference in favor of developing renewable resources within the region, rather than relying on imports from the Midwest.[6]

[6] For example, as stated in a letter from the governors of Massachusetts, Rhode Island, Delaware, Maine, Maryland, New Hampshire, New Jersey, New York, Vermont, and Virginia to members of Congress dated May 4, 2009.

Q. WHAT IS THE MID-ATLANTIC STATES' RATIONALE FOR SUPPORTING OFFSHORE WIND OVER ONSHORE ALTERNATIVES?

A. The coastal states support the development of offshore wind resources for a number of reasons. First, the Mid-Atlantic offers attractive wind speeds and wind capacity factors that are comparable to or exceed those in the Upper Midwest. In addition, the Mid-Atlantic coast has large areas of shallow water that are well suited for deployment of offshore wind generation at lower cost than would be incurred in deep-water locations. As mentioned above, NREL estimates that the Mid-Atlantic has a very large offshore wind potential in shallow waters with attractive wind speeds (almost half of the U.S. total).[7]

Second, offshore wind generation can be located close to the coastal load centers, which avoids the transmission investment costs and losses associated with integrating much more distant onshore renewable resources.[8] Finally, the coastal states have expressed a clear preference for offshore wind development in their efforts to create a clean-tech industry and reach a scale of offshore wind power development that would support local manufacturing of wind turbines and related equipment as well as the development of supporting infrastructure, such as specialized vessels and on-shore staging areas. The availability of such local manufacturing and other infrastructure is seen as a critical factor in reducing the

[7] National Renewable Energy Laboratory, *Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers*, September 2010, p. 59.

[8] Letter from the governors of Massachusetts, Rhode Island, Delaware, Maine, Maryland, New Hampshire, New Jersey, New York, Vermont, and Virginia to members of Congress dated May 4, 2009.

cost of renewable power options, in particular the still evolving offshore wind technologies.[9]

2. ***Production Cost, Energy Price, and Emissions Benefits***

Q. WHAT ARE THE MAIN COSTS AND BENEFITS ASSOCIATED WITH OFFSHORE WIND DEVELOPMENT?

A. While developing this amount of offshore wind resources requires substantial investments—approximately $30 billion for 6,600 MW of installed capacity—these investments have to be considered in the context of associated benefits. Some of these benefits include: (1) environmental benefits through reduced emissions of CO_2 and other pollutants; (2) promotion of a strategic industry and the economic stimulus associated with manufacturing, construction, plant operations, and other economic activities; (3) electricity market benefits in the form of reduced LMPs and production costs from fossil fuel power plants.

Q. HAVE YOU QUANTIFIED THESE BENEFITS?

A. Yes, we have. We have analyzed the electricity market and emissions impacts of injecting 6,600 MW of offshore wind using PROMOD simulations. We have also estimated the employment and economic stimulus impact of this level of wind investment, using the Job and Economic Development Impact ("JEDI") simulation tool that NREL developed to analyze wind plant investment-related benefits.

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[9] See Virginia Coastal Energy Research Consortium, *Virginia Offshore Wind Studies, July 2007 to March 2010: Final Report*, April 20, 2010, p. viii.

Q. PLEASE EXPLAIN HOW YOU SIMULATED THE ELECTRICITY MARKET AND EMISSION IMPACTS OF OFFSHORE WIND POWER DEVELOPMENT.

A. As discussed further in Section VII of our testimony and Exhibit AWC-403, we directed staff of Ventyx, the vendor of the PROMOD simulation model, to simulate market conditions for 2016 with and without the addition of 6,600 MW of nameplate offshore wind generation. These simulations showed that injecting wind via the AWC Project significantly reduces LMPs, as well as the emissions and production costs from fossil fuel generating plants.

Q. WHAT ARE THE EMISSIONS REDUCTIONS ASSOCIATED WITH 6,600 MW OF OFFSHORE WIND?

A. The approximately 23,000 GWh of energy produced by 6,600 MW of wind will displace more than 23,000 GWh of fossil generation (the displacement is more than one-for-one because injecting power closer to the coastal load centers reduces electrical losses by approximately 1,000 GWh, or more than 100 MW on average). Approximately 61% of the displaced generation is gas-fired, 37.5% coal-fired, and 1.5% oil-fired, and all of the associated emissions are eliminated. As previously shown in Table 1, injecting up to 6,000 MW of energy from 6,600 MW of offshore wind capacity will reduce CO_2 emissions from fossil fuel generation by 16 million tons each year. It will also avoid 25 thousand tons of SO_2 emissions and 11 thousand tons of NOx emissions annually. At CO_2 prices of \$30/ton, the wind-generation-related reduction in CO_2 emissions would have an economic value of approximately $500 million per year.[10] The present value of these emissions cost savings over 20 years from 2016 through 2035 would be $5.2 billion (expressed in 2010 dollars).[11] These benefits are additive to production cost benefits, since the production costs in the PROMOD model did not include CO_2 allowance price adders, reflecting the currently poor prospects for near-term climate legislation.

Q. WHAT ARE THE IMPACTS OF 6,600 MW OF WIND GENERATION ON SYSTEM PRODUCTION COSTS?

A. The PROMOD simulations show that injecting up to 6,000 MW of energy from 6,600 MW of offshore wind capacity reduces system-wide production costs by $1.1 billion per year. The present value of the $1.1 billion in annual production cost savings over 20 years from 2016 through 2035 would be at least $12 billion (expressed in 2010 dollars). The savings are primarily derived from replacing fossil fuel-fired generation with zero-variable-cost generation, but also by substantially reducing congestion and losses on the prevailing west-to-east flows on the onshore system. In fact, our simulations show that annual congestion costs decrease by $410 million and losses decrease by more than 115 MW on average.

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[10] This is conservative compared to the recent EIA projections from its analysis of the American Power Act. Depending on the scenarios considered, EIA estimated CO_2 prices to range from $40/ton to $140/ton by 2030 (in 2008 dollars). (*Source*: Energy Information Administration, Energy Market and Economic Impacts of the American Power Act of 2010, July 2010, page 7). In a similar analysis of the American Power Act, EPA estimated CO_2 prices at approximately $38/ton by 2030 and $100/ton in 2050 (in 2005 dollars). (Source: U.S. Environmental Protection Agency, EPA Analysis of the American Power Act in the 111th Congress, June 2010, page 26).

[11] All NPV calculations assume 50% debt, with a 6% debt rate, 11% equity rate, 40% tax rate, and 2% inflation rate.

Q. HOW MUCH WOULD ADDING 6,600 MW OF OFFSHORE WIND CAPACITY SAVE CUSTOMERS BY REDUCING ENERGY PRICES?

A. The PROMOD simulation results also show that this amount of offshore wind energy will reduce energy prices paid by customers by approximately $6/MWh in New Jersey, by $2-4/MWh in Delaware, Maryland and Virginia, by $2-5/MWh in Pennsylvania, and by $0.5-1.6/MWh in western PJM, with effects outside of PJM as well. These price impacts, which are shown in Table 5, would reduce customer payments by $2.2 billion per year in PJM alone, without counting reductions in other regions. Net of reduced loss refunds in the AWC Wind case—because system losses and LMPs are lower, which reduces marginal-loss-related refunds by $79 million—the customer savings are only $2.1 billion, as described in the Technical Appendix report filed as Exhibit AWC-403 with this testimony.

However, lower energy prices can be expected to increase capacity prices. As energy prices decrease, so do the energy margins earned by generators, which will induce them to bid commensurately more in the capacity market. For example, the potential developer of a new combustion turbine in EMAAC would anticipate $9/kW-yr lower energy margins and thus would bid that much higher for capacity in order to be willing to enter the market.

Assuming new combustion turbines set the capacity prices when new supply is needed, we estimate that capacity prices would increase by $9 to $10 per kW-year in EMAAC and SWMAAC, about $2/kW-year in the rest of MAAC, and $0.4/kW-year in the rest of PJM RTO. Such a capacity price increase applied to all demand in PJM areas would increase customer payments by $480 million per year ($5 billion NPV), offsetting some of their savings from reduced LMPs. This yields a $1.6 billion annual _net_ benefit in terms of customer wholesale power purchase costs, calculated as $2.2 billion in annual LMP reductions *net of* reduced marginal loss refunds ($79 million) and capacity price increases ($480 million).

Table 5
Impacts of the AWC Project with Wind on PJM Load LMPs
Compared to the Base Case (without AWC and without Offshore Wind)

Region	State	PJM Area	Annual Load *(GWh)* [1]	Base Case *LMP* *($/MWh)* [2]	AWC Wind *LMP* *($/MWh)* [3]	AWC Wind vs. Base Case *LMP* *($/MWh)* [4]= [3]-[2]	AWC Wind vs. Base Case *Load Payments* *($m/yr)* [5]= [1]×[4]
AWC States	DE	DPLC	20,517	$55.4	$51.7	($3.7)	($76)
AWC States	NJ	AE	13,978	$58.2	$52.2	($6.0)	($84)
AWC States	NJ	JCPL	29,004	$62.5	$56.2	($6.3)	($182)
AWC States	NJ	PSEG	54,250	$60.4	$53.7	($6.8)	($367)
AWC States	NJ	RECO	1,751	$64.6	$61.6	($3.0)	($5)
AWC States	VA	VP	114,406	$53.2	$50.9	($2.2)	($254)
AWC States	MD	BGE	39,503	$54.3	$50.9	($3.4)	($136)
AWC States	MD	PEPCO	36,283	$54.8	$51.2	($3.6)	($132)
Other PJM-E	PA	METED	18,518	$55.8	$51.3	($4.5)	($84)
Other PJM-E	PA	PECO	47,010	$57.7	$52.1	($5.6)	($262)
Other PJM-E	PA	PENN Elec	21,574	$48.0	$46.0	($2.0)	($43)
Other PJM-E	PA	PPL	47,100	$56.1	$51.1	($5.0)	($237)
Other PJM-E	PA	UGI	1,159	$57.6	$52.1	($5.5)	($6)
PJM-W	IL	COMED	125,253	$43.1	$42.5	($0.6)	($73)
PJM-W	OH	AEP	188,533	$44.4	$43.9	($0.5)	($97)
PJM-W	OH	FE OHIO	78,361	$43.9	$43.4	($0.5)	($36)
PJM-W	WV	APS	55,414	$48.7	$47.0	($1.6)	($91)
PJM TOTAL			**892,613**	**$50.2**	**$47.7**	**($2.4)**	**($2,165)**
AWC States			309,692	$56.1	$52.1	($4.0)	($1,236)
Other PJM-E			135,361	$55.3	$50.7	($4.7)	($632)
PJM-W			447,561	$44.5	$43.8	($0.7)	($297)

* Based on PROMOD simulations for 2016.

Employment and Economic Stimulus Benefits

Q. WHAT ARE ECONOMIC STIMULUS BENEFITS?

A. The development of offshore wind and associated transmission infrastructure will provide economic stimulus benefits for the Mid-Atlantic region through growth in employment, earnings by employees, and overall economic activity (*i.e.*, the total revenues associated with sales and re-sales of goods and services stimulated). These employment and economic activity benefits arise as direct, indirect, and induced impacts associated with the investment. "*Direct impacts*" capture the jobs, earnings, and economic activity generated by the direct construction activities and spending on transmission infrastructure and wind generation facilities. "*Indirect impacts*" arise as in-region suppliers to the transmission and wind generation industries, as well as other upstream producers, benefit from the increased investment in infrastructure and generation. Finally, "*induced impacts*" are created when the increased income from jobs supported by the transmission and offshore wind construction is spent on products and services in other industries, generating a ripple effect throughout the regional economy.

Q. HOW DID YOU ESTIMATE THE ECONOMIC STIMULUS BENEFITS PROVIDED BY THE 6,600 MW OF WIND AND ASSOCIATED TRANSMISSION INVESTMENT?

A. The economic stimulus benefits associated with offshore wind development and operations were quantified with the Department of Energy's Job and Economic

Development Impact ("JEDI") Model.[12] The economic stimulus benefits associated with the transmission infrastructure build-out was estimated based on a recent study that quantified transmission investment benefits for the Southwest Power Pool ("SPP") based on analysis conducted using the Minnesota IMPLAN Group Model.[13] JEDI and IMPLAN are widely-used by economists and policy analysts to estimate how specific investments affect a regional economy.

Q. FOR WHAT LEVEL OF WIND AND TRANSMISSION INVESTMENT AMOUNTS HAVE YOU ANALYZED ECONOMIC STIMULUS BENEFITS TO THE MID-ATLANTIC REGION?

A. The investment assumptions we used for this analysis are summarized in Table 6 below. As the table shows, these investments consist of approximately $23 billion of investments in wind turbines and their foundations, approximately $2.8 billion in lower voltage AC transmission cables to connect the turbines to the offshore substations, and $5 billion in HVDC-related transmission expenses (the AWC Project) to interconnect these offshore wind farms to shore.

[12] JEDI Model from July 2009, model number W1.09.04e. Available at: http://www.nrel.gov/analysis/jedi/about_jedi_wind.html

[13] Pfeifenberger, Chang, Hou, and Madjarov, *Job and Economic benefits of Transmission and Wind Generation Investment in the SPP Region*, Report prepared for the Southwest Power Pool, *The Brattle Group*, March 2010.

Table 6
Estimated Wind Plant, AC Collector System, and AWC Project Investment Summary

Components	Total Cost (2010$)	Percentage of Total Investment	Unit Cost (2010$)
	($ Billion)		($/kW)
6,600 MW Wind Plant Investment	23.0	75%	3,485
Offshore AC Collector System Investment	2.8	9%	419
AWC Project Investment	5.0	16%	758
Total	30.8	100%	4,661

Sources & Notes:
Wind Plant Investment includes turbines, blades, towers, foundations, and additional labor and development, and permitting costs.
AWC Project Investment includes HVDC system components: off- and onshore converters and HVDC backbone and lateral cables.

Q. HOW HAVE YOU USED THESE INVESTMENT ASSUMPTIONS IN YOUR ANALYSIS?

A. For the purposes of this analysis, the JEDI model was used with predefined settings for the state of New Jersey (as a proxy for the region), but the cost of turbines, blades, towers, and foundations were adjusted to reflect offshore equipment and construction costs as summarized in Table 6. To derive a preliminary estimate of transmission-related benefits, we simply scaled the benefits per billion dollar of investments derived from the SPP study to the necessary investment in the offshore collector system that connects the various wind turbines to the offshore substation and the cost of the AWC Project, consisting of the offshore converter substations, the offshore grid, and the onshore converter substations.

Q. HAVE YOU ANALYZED TO WHAT EXTENT THE ECONOMIC STIMULUS BENEFITS OF OFFSHORE WIND PLANT AND RELATED TRANSMISSION INVESTMENT DEPENDS ON THE DEGREE TO WHICH THE WIND GENERATION AND TRANSMISSION COMPONENTS ARE MANUFACTURED WITHIN THE MID-ATLANTIC REGION?

A. Yes, we have. To analyze the extent to which economic stimulus benefits depend on the degree of in-region manufacturing of wind plant and transmission components, we analyzed the impact of three cases: *Low, Medium,* and *High* in-region manufacturing. Table 7 summarizes the in-region manufacturing assumptions associated with each of these three cases.

Table 7
Local Manufacturing Share
Assumptions for the Economic Analysis Impact

	Share of In-Region Manufacturing		
Wind Farm	*Low*	*Medium*	*High*
Equipment			
Turbines	0%	0%	100%
Blades	0%	100%	100%
Towers	0%	100%	100%
Transportation	0%	100%	100%
Balance of Plant	82%	93%	93%
Total Wind Farm Local Manufacturing Share	26%	55%	98%
Offshore AC Collector System			
Wires and electrical equipment	0%	50%	100%
AWC Project			
Off- and onshore converters and HVDC backbone and lateral cables	0%	50%	100%
Overall Share	**19%**	**54%**	**98%**

Note: Shares are cost-based.

For the wind farm construction-related analysis, these in-region manufacturing assumptions were analyzed with the JEDI model. For the transmission-related analysis, we relied on the SPP study, which similarly analyzed transmission build-out scenarios for a *Low* in-region manufacturing case (assuming all transmission equipment would be imported from out-of-region suppliers) and a *Medium* case (assuming that 50% of transmission wires and related electrical equipment facilities would be manufactured within the region). These SPP investment levels and economic stimulus results were used to calculate normalized ratios for the amount of jobs, earnings, and overall economic activity stimulated by the transmission investment for both the *Low* and *Medium* in-region manufacturing cases. These ratios were then applied to the transmission investments associated with the AWC Project. The difference between the *Low* and the *Medium* in-region manufacturing case was then applied to derive an estimate of the *High* in-region manufacturing case.

Q. WHAT ARE THE RESULTS FROM THIS ANALYSIS?

A. The results from our preliminary economic stimulus analysis are summarized in Table 8 below. As Table 8 shows, the combination of the offshore wind and associated transmission investment are estimated to support a total of 130,000 to 263,000 full-time equivalent ("FTE") years of employment during the construction period. For example, if construction activities were spread out evenly over 10 years, this level of offshore wind and transmission investment would support 13,000 to 26,000 full-time jobs in each of the ten years. These employment impacts encompass the direct, indirect, and induced economic benefits as described earlier. Of the approximately 120,000 FTE-years in the *Medium* in-region manufacturing case for wind plant construction, approximately 39,000 (33%) are directly supported by on-site construction, engineering, and design work; approximately 62,000 (52%) are supported "indirectly" at suppliers of wind power generation components and construction materials; and around 18,000 (15%) are "induced" by the additional spending (food, housing, services, etc.) of employees supported by the direct and indirect economic activities.

As Table 8 also shows, the total earnings by employees working in construction-period jobs supported by the wind and associated transmission investment range from $7.6 to $17.4 billion, depending on the level of in-region manufacturing. The estimated overall economic activity stimulated by these investments during the construction period ranges from $16.4 to $51.5 billion.

Table 8
Analysis of Jobs, Earnings, and Economic Activity

	Full-Tme Equivalent Years	Total Earnings (2010$)	Total Economic Activity (2010$)
	(FTE-Years)	($ Billion)	($ Billion)
Low In-Region Manufacturing (19% of All Equipment)			
Wind Plant Construction (6,600 MW)	79,000	$5.0	$9.8
Offshore AC Collector System Construction	18,000	$0.9	$2.4
AWC Project Construction	33,000	$1.6	$4.3
Total	**130,000**	**$7.6**	**$16.4**
Medium In-Region Manufacturing (54% of All Equipment)			
Wind Plant Construction (6,600 MW)	120,000	$8.2	$20.6
Offshore AC Collector System Construction	23,000	$1.1	$3.5
AWC Project Construction	41,000	$2.1	$6.3
Total	**184,000**	**$11.4**	**$30.3**
High In-Region Manufacturing (98% of All Equipment)			
Wind Plant Construction (6,600 MW)	184,000	$13.3	$37.2
Offshore AC Collector System Construction	28,000	$1.5	$5.1
AWC Project Construction	51,000	$2.6	$9.2
Total	**263,000**	**$17.4**	**$51.5**
NREL (Musial, 2007)*			
Wind Plant Construction (Scaled to 6,600 MW)	**257,000**	*NA*	*NA*
Wind Farm Operation Over 20 years	**145,000**	*NA*	*NA*
Ontario Offshore Wind Study (2010)**			
Base Case (55% Local Sourcing of Development Costs)			
Wind Plant Construction (Scaled to 6,600 MW)	**166,551**		
High Case (63% Local Sourcing of Development Costs)			
Wind Plant Construction (Scaled to 6,600 MW)	**191,080**		

Sources & Notes:
* "Large-Scale Offshore Wind Power in the United States: Assesment of Opportunities and Barriers," *NREL* , Sepetember 2010.
"Offshore Wind: Viable Option for Coastal Regions of the United States", *Marine Technology Society Journal* , 2007
** "Employment and Economic Impacts of Ontario's Future Offshore Wind Power Industry", The Conference Board of Canada, December 2010

Q. HOW MUCH OF THE ECONOMIC STIMULUS BENEFIT OF THE OFFSHORE WIND INVESTMENT IS DEPENDENT ON THE EXTENT TO WHICH COMPONENTS CAN BE MANUFACTURED WITHIN THE MID-ATLANTIC REGION?

A. As Table 8 documents, the extent to which these investments benefit the Mid-Atlantic region depends to a considerable extent on how much of the plant and equipment can be manufactured within the region. For example, the *Low* in-region manufacturing case (in which only 19% of all equipment is sourced locally) supports only 130,000 FTE-years of employment while the *Medium* case (with 54% of all equipment manufactured sourced locally) supports over 180,000 FTE-years, an increase of almost 50%. As we discuss further in Section V of our testimony, this means developing offshore wind at a pace and scale that can support the creation of local supply-chain industries should be an important public policy goal that provides significantly greater economic benefits for the region.

Q. WHAT ARE THE EMPLOYMENT BENEFITS THAT CONTINUE AFTER THE CONSTRUCTION OF OFFSHORE FACILITIES HAS BEEN COMPLETED?

A. Once construction of the AWC Project and the 6,600 MW of offshore wind plants has been completed, employment and related benefits to the local economy will continue in two ways. First, there will be employment and associated economic benefits related to the operations and maintenance of the equipment. As shown in Table 8, NREL has estimated the operating-period employment benefit for 6,600 MW of offshore wind plants at approximately 145,000 FTE-years spread over a 20-year operation period. Second, the development of 6,600 MW of offshore wind generation in the Mid-Atlantic region will create a manufacturing base and local supply chain for logistical services that can support the further expansion of offshore wind generation beyond the 6,600 MW facilitated by the AWC Project. If additional offshore facilities are added at a steady rate, these employment and associated economic benefits would continue to last. Considering the enormous offshore wind generation potential of the Mid-Atlantic region, this is a plausible outcome.

Q. IS THE MAGNITUDE OF YOUR PRELIMINARY ESTIMATE OF THESE ECONOMIC STIMULUS BENEFITS OF OFFSHORE WIND DEVELOPMENT CONSISTENT WITH THE MAGNITUDE OF THESE BENEFITS FOUND BY OTHER STUDIES?

A. Yes. As shown in Table 8, NREL's research has found employment impacts to be close to the upper bound of the benefits we estimated.[14] The table also shows that results from a recent study for Ontario offshore wind development are very similar to our estimates.[15]

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[14] Musial, W. "Offshore Wind: Viable Option for Coastal Regions of the United States." *Marine Technology Society Journal*. Vol. 41, Number 3, Fall 2007 and National Renewable Energy Laboratory, *Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers*, September 2010.

[15] Conference Board of Canada, *Employment and Economic Impacts of Ontario's Future Offshore Wind Power Industry*, December 2010.

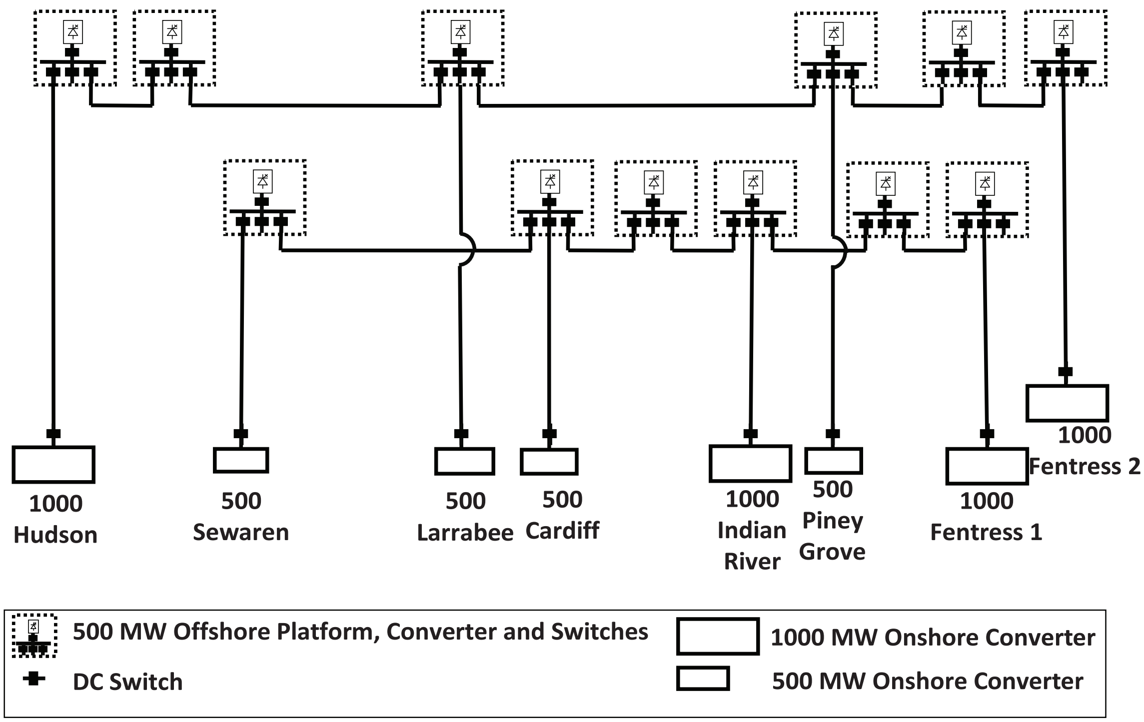
IV. AWC PROJECT CONFIGURATION AND COSTS

Q. PLEASE SUMMARIZE THE CONFIGURATION OF THE AWC PROJECT.

A. As explained in the testimony of Mr. Paul McCoy, the AWC Project is configured as a double-circuit HVDC offshore transmission backbone with twelve offshore AC-DC converter stations interconnected at seven existing substations of the onshore grid. As shown in Figure 2, each circuit will be able to transmit 1,000 MW of energy and capacity between interconnection points along the coast, accommodate six 500 MW offshore AC-DC converter stations to interconnect offshore wind plants, and interconnect a total of 3,000 MW of onshore AC-DC converter stations at four locations.

As also shown in Figure 2, both circuits interconnect with 1,000 MW converter stations at PJM's Fentress substation in southern Virginia. The other interconnection points are: 500 MW at Piney Grove (MD), 500 MW at Larrabee (NJ), and 1,000 MW at Hudson (NJ) for one of the circuits, and 1000 MW at Indian River (DE), 500 MW at Cardiff (NJ), and 500 MW at Sewaren (NJ) for the other circuit. In addition to facilitating the interconnection of offshore wind power plants, this configuration provides an offshore reinforcement to the existing onshore grid in the congested Mid-Atlantic power market. A line diagram showing the configurations of these two circuits is also included in Exhibit AWC-403. As explained in the testimony of Mr. McCoy, the Project will be built in five phases.

Figure 2
Preliminary AWC 2-Circuit Design



Q. WHAT IS THE TOTAL INSTALLED NAMEPLATE CAPACITY OF THE OFFSHORE WIND FARMS FACILITATED BY THE AWC PROJECT?

A. Considering the transmission capability to inject 6,000 MW, we have assumed 6,600 MW of installed offshore nameplate wind generation capacity would be interconnected to the AWC Project. Building slightly more wind capacity lowers the overall cost of renewable power. For example, National Grid, the United Kingdom's regulated transmission company, has estimated that the optimal ratio between installed offshore wind and transmission capacity is 112%.[16]

[16] National Grid, *Round 3 Offshore Wind Farm Connection Study: Version 1.0*, p. 3.

Q. DOES BUILDING WIND CAPACITY IN EXCESS OF THE TRANSMISSION CAPABILITY RESULT IN SIGNIFICANT CURTAILMENT OF WIND GENERATION?

A. No, not if the wind capacity exceeds the transmission capacity by only 10%, as we have assumed. Analyzing the NREL data for the AWC sites, we found that only 0.2% of the potential energy generated from 6,600 MW of offshore wind would have to be curtailed to avoid exceeding the 500 MW output limit on any of the 12 offshore converters. This minimal curtailment was incorporated into our market simulations.

Q. HOW DO THE AWC PROJECT'S COSTS COMPARE TO CONVENTIONAL RADIAL INTERCONNECTION OF INDIVIDUAL OFFSHORE WIND PLANTS?

A. The AWC Project is able to reliably deliver 6,000 MW of offshore wind power and additionally provide a fully controllable 2,000 MW HVDC transmission path between southern Virginia and northern New Jersey at a total cost of approximately $5 billion. In comparison, we estimate that delivering 6,000 MW of wind power with radial high-voltage alternating current ("HVAC") transmission lines from individual wind plants to shore would cost between $3.4 and $5.3 billion without offering the substantial additional public policy, reliability, congestion relief, and other economic benefits we have identified and partially quantified for the AWC Project. A more detailed discussion of the Project configuration and its unique capabilities is presented in the testimonies of Mr. Paul McCoy and Mr. Donald P. Jones.

Q. YOU NOTED THAT IT WOULD COST BETWEEN $3.4 BILLION AND $5.3 BILLION TO INTERCONNECT OFFSHORE WIND FARMS WITH INDIVIDUAL RADIAL HVAC TRANSMISSION LINES. HOW DID YOU ESTIMATE THESE COSTS?

A. We have estimated these costs by analyzing the installed costs of the individual transmission elements needed to interconnect individual offshore wind farms to the onshore grid. These transmission elements include: (1) an offshore substation consisting of switchgear, transformation, and platform; (2) several HVAC cables from the offshore substation to shore; and (3) an onshore substation without transformation (as a conservative assumption). These cost estimates are based on publicly-available information on the costs and project configuration from a variety of sources, including actual project proposals. They do not include the cost of wind turbines, turbine foundations, and the transmission collector system that connects the individual turbines of a wind farm to the offshore substation, because these cost elements will be identical or approximately the same irrespective of whether the individual wind farms are integrated through individual HVAC lines to shore or through the AWC Project.

Q. HOW MANY INDIVIDUAL WIND FARMS DID YOU ASSUME WOULD BE DEVELOPED TO DELIVER 6,000 MW OF OFFSHORE WIND CAPACITY IF THESE PLANTS WERE TO BE INTERCONNECTED INDIVIDUALLY THROUGH RADIAL HVAC TRANSMISSION LINES?

A. We evaluated two scenarios. In the first, we evaluated the costs of twelve radial HVAC transmission lines, each capable of delivering 500 MW of offshore wind.

The second scenario we evaluated consisted of twenty radial HVAC transmission lines with a capacity of 300 MW each. Either of these radial transmission scenarios can thus deliver 6,000 MW of offshore wind generation similar to the capability of the AWC Project.

Q. WHAT VOLTAGE LEVELS AND HOW MANY INDIVIDUAL CABLES WOULD BE NEEDED TO ACHIEVE THESE 500 MW AND 300 MW TRANSFER CAPABILITIES TO INTERCONNECT INDIVIDUAL WIND FARMS TO THE ONSHORE GRID?

A. We evaluated two configurations to achieve 500 MW transfer capability: (1) a 230 kV HVAC submarine cable system consisting of two parallel circuits; and (2) a 138 kV HVAC cable system consisting of three parallel circuits. For the 300 MW transfer scenario, we developed the costs for a 138 kV HVAC cable configuration with two parallel circuits.

Q. WHAT ARE THE OVERALL COSTS AND INDIVIDUAL COST ELEMENTS ASSOCIATED WITH EACH OF THESE THREE HVAC RADIAL OFFSHORE TRANSMISSION CONFIGURATIONS?

A. Our estimates of the overall costs and cost elements of these three HVAC radial transmission configurations are summarized in Table 9.

Table 9
Estimated Costs of Radial HVAC Transmission Lines Interconnecting Individual Wind Power Plants to the Onshore Grid

		Description of Illustrative HVAC Systems		
		Interconnection of 12 offshore wind farms based on two 230 kV cables laid in parallel trenches	Interconnection of 12 offshore wind farms based on three 138 kV cables laid in three parallel trenches	Interconnection of 20 offshore wind farms based on two 138 kV cables laid in parallel trenches
	Category	**(2010$ Billion)**	**(2010$ Billion)**	**(2010$ Billion)**
	[A]	[B]	[C]	[D]
[1]	Offshore substations and platforms	$1.0	$1.0	$1.6
[2]	Offshore radial cables	$1.6	$1.9	$2.5
[3]	Onshore landing and radial cables	$0.5	$0.6	$0.7
[4]	Onshore substations	$0.2	$0.2	$0.4
[5]	**Total HVAC System Cost**	**$3.4**	**$3.8**	**$5.3**

Sources and Notes:

All systems assume 6,600 MW of installed wind generation capacity which is equivalent to a 10% overbuild for 6,000 MW of transfer capability. Each illustrative HVAC system has equally sized wind farms (i.e., 12 wind farms = 550 MW of installed capacity each).

[1A]: Offshore substation costs based on onshore substation (with transformer) costs based on estimates from Electric Reliability Organzation of Texas ("ERCOT"), "CREZ Transmission Optimization Study," April 2, 2008, p. 5. Offshore platforms based on cost estimates from National Grid, "2010 Offshore Development Information Statement: Appendix," September 2010, p. A-69.

[1B]: 12 offshore substations and platforms.

[1C]: 12 offshore substations and platforms.

[1D]: 20 offshore substations and platforms.

[2]: Cable cost estimates based on similar technology from National Grid, "2010 Offshore Development Information Statement: Appendix," September 2010, pp. A-67-68. All cable costs are based on 3-core cross-linked polyethelene (XLPE) technology. Each offshore wind farm is 25 miles from the shoreline. A total of 55 miles of additional cabling was assumed from the shoreline to the onshore substation. Includes cable installation costs based on variable installation costs per mile (excludes materials, ancillary vessels, and surveys) from National Grid, "2010 Offshore Development Information Statement: Appendix," September 2010, p. A-70. Fixed installation costs per radial interconnection for surveys, engineering, mobilization/demobilization based on estimates from Green, J., Bowen, A., Fingerish, L.J., Wan, Y., "Electrical Collection and Transmission Systems for Offshore Wind Power," March 2007, p. 3.

[3]: Landing costs based on horizontal directional drills for submarine cable landing and underground to aerial transition based on separate estimates for HVDC and HVAC technology for the Mid-Atlantic Power Pathway ("MAPP") project as cited in PJM Transmission Expansion Advisory Committee, “2008 RTEP - Reliability Analysis Update," TEAC Meeting, October 15, 2008, p. 7. Cable and installation costs the same as in [2].

[4]: Onshore substation costs without transformation based on estimates from Electric Reliability Organzation of Texas ("ERCOT"), "CREZ Transmission Optimization Study," April 2, 2008, p. 5. Assumed same number of onshore and offshore substations. See [1].

Q. WHICH OF THESE THREE RADIAL HVAC TRANSMISSION CONFIGURATIONS WOULD MOST LIKELY GET BUILT?

A. Assuming 6,600 MW of offshore wind could actually get developed solely through radial interconnections without an offshore backbone, we believe the most likely outcome would be a mix of these three configurations depending on a number of factors, including the availability of onshore interconnection points (*e.g.*, existing 138 kV and 230 kV facilities close to shore), the ability of the onshore grid to accommodate injections of wind generation in the 300 MW to 500 MW range, and the size of wind farms that individual developers are able to finance through individual power purchase agreements. While the actual configurations of radial cable system interconnecting individual wind farms can certainly differ from the three configurations we evaluated, total costs of all such radial cable systems to interconnect individual wind farms with the onshore grid will very likely be within the $3.4 to $5.3 billion range of our cost estimate. These costs of interconnecting individual wind farms with their own radial transmission cables will be avoided if this amount of offshore wind generation is integrated by means of the AWC Project.

Q. HAVE YOU VERIFIED THAT YOUR COST ESTIMATES FOR SUCH RADIAL INTERCONNECTIONS OF INDIVIDUAL WIND FARMS IS CONSISTENT WITH THE ESTIMATED $5 BILLION COST OF THE AWC PROJECT?

A. Yes. We have used the same approach to estimate the cost of the AWC Project. This yielded cost estimates ranging from $4.9 to $5.6 billion, which is very much consistent with the $5 billion estimate from the Project sponsors.

Q. YOU MENTIONED THAT THERE ARE ADDITIONAL BENEFITS THAT THE AWC PROJECT OFFERS OVER RADIAL INTERCONNECTIONS OF INDIVIDUAL WIND PLANTS WITH THE ONSHORE GRID. WHAT ARE THESE BENEFITS?

A. As we discuss in the next three sections of our testimony, the additional benefits offered by the AWC Project over the individual radial interconnection of offshore wind power plants with the onshore grid includes a number of public policy, reliability, and congestion relief-related economic benefits. As the analyses presented in Sections V, VI, and VII show, the modest incremental cost of an offshore transmission backbone over the cost of radial interconnections is more than offset by the cost savings and economic benefits associated with scale economies, reduced siting and permitting uncertainties, and the reliability and congestion relief advantages offered by the AWC Project compared to radial interconnections of individual offshore wind power plants.

V. PUBLIC POLICY BENEFITS ASSOCIATED WITH THE AWC PROJECT

Q. WHAT ARE THE PUBLIC POLICY BENEFITS THAT THE AWC PROJECT PROVIDES COMPARED TO INTERCONNECTING OFFSHORE WIND VIA CONVENTIONAL RADIAL LINES?

A. The AWC Project will facilitate meeting the coastal Mid-Atlantic states' renewable energy policy requirements and goals. It will do so in a way that substantially reduces the barriers, uncertainties and costs of developing offshore wind generation, and that attracts more in-region manufacturing. It will also reduce the environmental shoreline impact of siting the needed transmission.

Q. HOW DOES THE AWC PROJECT REDUCE THE UNCERTAINTIES AND OVERALL COSTS OF DEVELOPING OFFSHORE WIND GENERATION?

A. The AWC Projected reduced the uncertainties and overall costs of developing offshore wind generation in several important ways. First, it significantly reduces environmental permitting barriers and associated uncertainties with offshore wind developments. Second, it greatly streamlines the PJM transmission planning and interconnection process for developing significant amounts of offshore wind generation in the region. Third, the Project allows for a decoupling of the selection and optimization of the locations for onshore landing points and offshore wind power plants. This combination of factors reduces investment risk and project development costs and allows a faster ramp-up and larger scale of offshore wind developments, leading to reduced costs and increased local supply of wind turbines, plant components, and logistics services.

Q. PLEASE EXPLAIN HOW THE AWC PROJECT REDUCES ENVIRONMENTAL PERMITTING BARRIERS AND UNCERTAINTIES ASSOCIATED WITH OFFSHORE WIND DEVELOPMENT.

A. Environmental permitting of any transmission project, large or small, is costly, time consuming, and uncertain. The Department of Energy's Electricity Advisory Committee, for example, noted that the fragmented nature of transmission permitting and siting is exacerbated by a lack of coordination which may "further delay the already lengthy siting process, add to the cost of transmission projects, and increase the financial risk to a transmission developer." As the decade-old Cape Wind permitting process has shown, permitting constraints and environmental sensitivities create costly barriers and significant delays in the siting process.

A major advantage of the AWC Project is that it provides both coordination and economies of scale for the permitting process: it replaces the many individual offshore-to-shore permitting efforts with a single onshore permitting process for all 6,600 MW of offshore plants supported by the Project.

The value of a coordinated and streamlined single shoreline permitting process for 6,600 MW of wind power plants is likely to be accentuated by the plethora of competing uses and jurisdictions along the Mid-Atlantic coast. The Mid-Atlantic coast has environmentally sensitive and otherwise restricted areas, including environmentally protected shorelines, military installations, radar usage, tourist and residential areas, aviation routes, fishing zones, and shipping lanes.[17] These constraints will limit the number of viable sites for both offshore wind farms and associated onshore landing points. In fact, because of such overlapping shoreline and offshore constraints, the Maryland Offshore Wind Development study found that there may be only a few locations where wind farms could be interconnected.[18]

In short, in addition to offering a smaller environmental footprint, the single streamlined permitting process of the AWC Project will greatly reduce the uncertainties and costs of offshore wind development.

Q. PLEASE EXPLAIN HOW THE PROJECT STREAMLINES THE PJM TRANSMISSION PLANNING AND INTERCONNECTION PROCESS.

A. Similar to streamlined environmental permitting, the AWC Project also offers a substantially streamlined PJM transmission planning process compared to the interconnection of individual wind power projects. The AWC Project can be evaluated in the PJM interconnection and transmission planning effort as a single project for injecting up to 6,000 MW from 6,600 MW of offshore wind nameplate capacity into the onshore grid. Evaluating the interconnection of this amount of offshore wind generation as a single transmission project and interconnection

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[17] See, for example: Center for Integrative Environmental Research ("CIER"), University of Maryland, *Maryland Offshore Wind Development: Regulatory Environment, Potential Interconnection Points, Investment Model, and Select Conflict Areas*, October 2010; and Virginia Coastal Energy Research Consortium, *Virginia Offshore Wind Studies, July 2007 to March 2010: Final Report*, April 20, 2010.

[18] The Study estimates that there may be as few as four optimal points of interconnection along the Delmarva Peninsula coastline given the limited landing points without environmental conflicts *and* close proximity to an onshore substation. See Center for Integrative Environmental Research ("CIER"), University of Maryland, *Maryland Offshore Wind Development: Regulatory Environment, Potential Interconnection Points, Investment Model, and Select Conflict Areas*, October 2010, p. 31.

request avoids a lengthy iterative transmission planning and interconnection process for many individual projects. Given that individual wind power proposals may be delayed or withdrawn, PJM would constantly have to re-evaluate different combinations of wind plant and on-shore locations in its interconnection queue. For the AWC Project, a single planning effort can identify the best landing points for all 6,000 MW of potential injections from the offshore wind plants. Not only will this single planning step save time and effort, it will also result in a more optimal configuration for both onshore and offshore transmission.

Q. YOU NOTED THAT THE AWC PROJECT ALLOWS FOR A DECOUPLING OF THE SELECTION AND OPTIMIZATION OF LOCATIONS FOR ONSHORE LANDING POINTS AND OFFSHORE WIND PLANTS. HOW DOES THE PROJECT ACHIEVE THAT?

A. Unlike individual radial transmission interconnections from offshore wind farms to shore, the AWC Project is able to "decouple" the landing point and wind plant locations so that each can be separately optimized. In the case of transmission, the AWC Project does not require a straight radial interconnection from the offshore wind farm to shore. Instead, the Project allows for the selection of the best locations for submarine cables to come on shore and interconnect with the onshore grid, while offshore wind plant locations can be developed along the 250 mile offshore HVDC transmission backbone at locations that can be largely independent of the onshore landing points. In other words, the Project allows the developers of wind farms to select their offshore plant locations along the entire

HVDC backbone stretching from northern New Jersey to southern Virginia almost independently from the selected landing points.

Q. DOES THIS DECOUPLING ALSO SIMPLIFY THE PERMITTING PROCESS FOR WIND DEVELOPERS?

A. Yes, very much so. The fact that onshore permitting and PJM interconnection processes are resolved through the AWC Project greatly simplifies the remaining permitting requirements for wind plant developers by limiting the additional permitting needs to federal waters at locations that are mostly beyond the visible horizon from shore. Once these offshore permits are obtained, the project developers can simply interconnect their plants with the AWC Project at the various offshore locations. This expedited and simplified siting process is what the Dutch grid operator, TenneT, referred to as a "plug and play" solution in a 2009 position paper evaluating a proposed offshore transmission grid. The paper further noted that:

> [The] availability of offshore cables, grids and connections enables wind farm operators to 'plug in' directly in order to supply electricity to the grid. This provides developers and financial backers with more assurances in advance, allowing national and international objectives to be achieved more quickly.[19]

Q. ARE OFFSHORE GRIDS SIMILAR TO THE AWC PROJECT UNDER DEVELOPMENT ELSEWHERE?

A. Yes. Several offshore grid development efforts are taking place in Europe including: Kriegers Flak (connecting Sweden, Germany, and Denmark and up to

[19] TenneT, *Position Paper: Offshore Wind Energy*, Reference CDV 09-076, February 17, 2009, p. 2.

1,600 MW of offshore wind);[20] TenneT's North Sea analysis to interconnect 6,000 MW of offshore wind capacity;[21] and the Irish Scottish Links on Energy Study (connecting Scotland, Ireland, and Northern Ireland).[22] Moreover, ten European countries recently signed a memorandum of understanding to study offshore grid networks in the North Sea to interconnect 150,000 MW of wind capacity by 2030.[23]

With over 2,000 MW of installed offshore wind capacity and much more under construction and planned, Europe currently has the most offshore wind development experience. This has evolved from embracing the idea of offshore grids as an "infrastructure priority" to help meet renewable energy targets in the most cost effective and efficient manner.[24] The AWC Project would allow the nascent U.S. offshore wind experience leapfrog past individually interconnecting single offshore wind farms and bring offshore wind power development in the U.S. more on par with that in Europe.

Q. HAVE YOU QUANTIFIED THE POTENTIAL ECONOMIC VALUE OF THE AWC PROJECT'S ABILITY TO INCREASE THE CERTAINTY, RAMP-UP, AND SCALE OF OFFSHORE WIND DEVELOPMENT IN THE MID-ATLANTIC REGION?

[20] Energinet.dk, Svenska Kraftnät, and Vattenfall Europe Transmission, *An Analysis of Offshore Grid Connection at Kriegers Flak in the Baltic Sea: Joint Pre-feasibility Study*, May 2009, p. 3.
[21] TenneT, *Position Paper: Offshore Wind Energy*, Reference CDV 09-076, February 17, 2009, p. 1.
[22] Irish-Scottish Links on Energy Study ("ISLES") announcement available at: http://www.islesproject.eu
[23] "Paul Magnette: 10 States sign the North Seas Counties Offshore Grid Initiative," Belgian Presidency of the Council of the European Union, December 3, 2010.
[24] Klein, Markus, "Europe signs historic MOU for North Sea offshore grid," *GlobalEnergy Magazine*, December 9, 2010.

A. Yes, we have. By increasing scale and promoting faster industry ramp-up times, the AWC Project can reduce procurement and construction costs, in part by making it economic to develop a *local* supply chain. According to a study by the Virginia Coastal Energy Research Consortium ("VCERC"), "*[t]he greatest upside opportunity for reducing the cost of offshore wind energy... is to attract major elements of a Mid-Atlantic offshore wind supply chain to the state.*"[25] VCERC estimates that local manufacturing of offshore wind components rather than importing (primarily from Europe) would decrease the capital cost of an offshore wind project: "[i]f the turbine and tower package were manufactured in Virginia, we estimate the project capital cost would decrease by $480 per kilowatt."[26] The VCERC study shows that these savings from local manufacturing of turbines and towers reduce costs by 22% below the costs of importing the equipment from Europe.[27] Saving $480/kW in wind turbine and tower costs on 6,600 MW of installed wind turbines would save almost $3.2 billion in total offshore wind plant costs.

In addition to lowering equipment costs, the AWC Project would help achieve economies of scale in the construction of support structures as well as logistics and installation. Based on data compiled by the National Renewable Energy Laboratory ("NREL"), 20% to 50% of the total cost of offshore wind is

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[25] Virginia Coastal Energy Research Consortium, *Virginia Offshore Wind Studies, July 2007 to March 2010: Final Report*, April 20, 2010, p. viii.

[26] *Id*.

[27] *Id*., p. 18, noting that domestically manufactured offshore wind turbines are estimated to cost $1,680/kW while the cost of turbines imported from Denmark or Germany is estimated at $2,160/kW. The VCERC study also points out that "[d]omestic turbine manufacturing reduces costs associated with dollar devaluation relative to the euro, and minimized shipping costs and delays."

attributed to a combination of support structures (20% to 30%) and logistics and installation (as high as 20%). If we assume that the reduced uncertainty, faster ramp-up, larger scale and local supply facilitated by the AWC Project will help save 20% on that portion of total offshore wind generation costs, these savings will reduce the overall costs of developing 6,600 MW of offshore wind plants by between $1.2 billion to $3.0 billion.[28]

Finally, the streamlined environmental permitting and PJM transmission planning and interconnection process will reduce the costs and time of project development efforts. If we assume a coordinated effort in streamlined permitting, development, and transmission planning and interconnection process will save 20% of the total project development and permitting costs, the associated savings for 6,600 MW of wind development would be approximately $600 million based on estimates by NREL that approximately 10% of total installed offshore wind generation costs are attributable to project development and permitting efforts.[29]

The combination of these scale-related cost savings on offshore wind development—$3.2 billion lower wind turbine costs, $1.2 to 3.0 billion in lower construction, logistics, and installation costs, and $0.6 billion in project development and permitting costs—amounts to $5.0 billion to $6.8 billion or

[28] As noted earlier, a total of 6,600 MW of installed offshore wind generation, including transmission, would cost approximately $30 billion, of which 20% to 50%, or $6 to $15 billion, would be for support structures, logistics, and installation. A 20% savings on these costs would be worth $1.2 billion to $3.0 billion.

[29] National Renewable Energy Laboratory, *Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers*, September 2010, p. 110. At approximately $30 billion in total project costs for 6,600 MW of installed offshore wind generation, if total project development and siting costs account for 10% of the total cost, or $3.0 billion, a 20% reduction in such costs would save approximately $600 million.

approximately 20% of a total $30 billion investment need. These cost savings alone have the potential to offset the entire cost of the AWC Project, even before considering that the Project offers substantial reliability and energy market benefits and avoids between $3.4 billion and $5.3 billion in transmission costs that would be associated with radial interconnections of individual wind farms.

Q. IS THE ESTIMATED 20% SCALE AND COORDINATION-RELATED REDUCTION IN OFFSHORE WIND PLANT COSTS CONSISTENT WITH THE SAVINGS ESTIMATED BY OTHERS?

A. Yes. For example, Steve Holliday, the Chief Executive Officer of the United Kingdom's National Grid (the country's regulated transmission company), recently noted in the context of planning an offshore grid to interconnect offshore wind plants that "[u]nless we get coordination between offshore and onshore right, the investment overall will be much higher than it needs to be."[30] He further stressed that "[a]n uncoordinated approach may cost *25 percent more* overall, past the end of the 2020s. And [we] will have to pay in our electricity bills more for unnecessary investments."[31] Similarly, and as already noted earlier, the Virginia Coastal Energy Research Consortium has estimated that local manufacturing of wind turbines and towers would reduce the costs by approximately 22%.

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[30] Steve Holliday as quoted in Williams, Selina, "UK Offshore Wind-Grid Coordination Would Save Billions-National Grid," Dow Jones Newswires, November 2, 2010.

[31] Steve Holliday as quoted in Reuters, "UK Power Market Reforms Needed by End of 2011-Nat Grid," November 2, 2010 (emphasis added).

Q. SOME OF THE ESTIMATED COST REDUCTIONS ARE ASSOCIATED WITH LOCAL MANUFACTURING AND LOGISTICS SERVICES. HOW WOULD THE AWC PROJECT HELP DEVELOP SUCH A LOCAL SUPPLY CHAIN?

A. Attracting local manufacturing and logistics services requires that offshore wind development has sufficient predictability and annual scale so that suppliers can justify the upfront investments needed for building up the local industry for manufacturing and investing in the necessary supporting infrastructure. For local manufacturing of wind farm components, VCERC notes that:

> [The] one-time investment to build a turbine manufacturing plant (including a foundry for large castings, and separate facilities for blade fabrication, tower fabrication, and nacelle assembly) is estimated to be at least $500 million. Review of trade publications and conversations with turbine manufacturers suggest that a demand of 100 to 150 turbines per year (or 500 to 800 MW per year) for a minimum of 5 years is required to justify such an investment."[32]

Similarly, investments will be needed in supporting infrastructure such as harbor facilities and specialized vessels to erect offshore wind turbines, install offshore platforms, and lay submarine cables. NREL estimates that the initial capital outlay for vessels alone would be more than $100 million and therefore "construction of the initial dedicated offshore wind vessel might require either a large-scale wind project with sufficient capital investment to offset the upfront costs for a specialized vessel or evidence of a large, probable U.S. development

[32] Virginia Coastal Energy Research Consortium, *Virginia Offshore Wind Studies, July 2007 to March 2010: Final Report*, April 20, 2010, p. 28.

pipeline."[33] Without such supporting local infrastructure, offshore wind projects will be more expensive and may also be delayed by the limited availability. As a recent Ontario study of offshore wind development noted:

> The [local] supply potential for offshore wind will depend critically on the pace at which specialized construction, manufacturing, assembly and staging facilities can be developed. These factors will be far more important than the availability of suitable sites in determining how fast the industry can be established and the extent to which it can grow… As a result, the industry must address a critical mass issue.[34]

The AWC Project can spur local manufacturing by creating the predictability, ramp-up, and scale needed to overcome these initial investment hurdles to achieve cost reductions and facilitate timely project completion and avoid supply bottlenecks.

Q. WHAT IS THE ADDITIONAL EMPLOYMENT AND ECONOMIC DEVELOPMENT BENEFIT OF INCREASED LOCAL MANUFACTURING AND SUPPLY OF LOGISTICS SERVICES?

A. As discussed in Section III of our testimony, an increase of local manufacturing, local construction, and other services substantially magnify the employment and economic stimulus benefits of the offshore wind investment to the Mid-Atlantic region. As we estimated in Section III of our testimony, increased local manufacturing and supply of logistics services can easily increase employment benefits by 50%. Our analysis shows that the *low* in-region manufacturing case

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[33] National Renewable Energy Laboratory, *Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers*, September 2010, pp. 42-43.

[34] The Conference Board of Canada, *Employment and Economic Impacts of Ontario's Future Offshore Wind Power Industry*, December 2010, p. 8.

(in which only 19% of all equipment is sourced locally) supports only 130,000 full-time-equivalent years of employment while the *medium* case (with 54% of all equipment manufactured or sourced locally) supports over 180,000 FTE-years, an increase of almost 50%. As our analysis showed, the increase would be even larger if more than 54% of all equipment would be manufactured or sources locally. This means that developing offshore wind at a pace and scale supported by the AWC Project not only reduces overall costs but also provides significantly greater economic benefits for the region.

Q. YOU MENTIONED THAT THE AWC PROJECT WILL REDUCE THE ENVIRONMENTAL IMPACTS OF SITING OFFSHORE WIND GENERATION. PLEASE EXPLAIN.

A. The AWC Project allows for a single, coordinated environmental permitting effort focusing on the best onshore interconnection points that avoid nature preserves and other sensitive coastal areas. The Project makes this possible by dint of its high capacity and the offshore backbone, which enables the selection of landing points to be largely independent of the wind farms' offshore locations. This coordinated landing point selection benefit has also been recognized in Europe, where several offshore grids are under development. For example, the Dutch grid operator TenneT noted that: "[c]ompared with separate private connections to the landside grid, a centralised approach … yields significant advantages in terms of spatial planning. For instance, there is less disruption to sea and coastal locations because transsections of dykes and dunes are kept to a minimum."[35]

In addition, the Project's HVDC technology allows for the transmission of 6,000 MW of offshore power with fewer cables than AC technology and, therefore, narrower right-of-ways. This smaller environmental footprint of HVDC technology has also been recognized by PJM in its analysis of the Mid-Atlantic Power Pathway ("MAPP") project, where it found that the HVDC option requires less space for the same power transfer, reducing the disturbed area by 40% compared to an HVAC solution.[36]

Finally, the environmental impact of offshore wind is reduced further by the fact that the AWC Project's offshore interconnection points for wind farms are located approximately 20 miles from shore beyond the horizon, which means that the wind turbines will not be visible from the shore.

VI. <u>RELIABILITY AND OPERATIONAL BENEFITS</u>

Q. PLEASE SUMMARIZE HOW THE AWC PROJECT PROVIDES RELIABILITY AND OPERATIONAL BENEFITS.

A. The AWC Project will provide significant reliability and operational benefits. Compared to radial interconnections of individual plants, the AWC Project will (1) likely reduce the need for future upgrades to the existing onshore transmission

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[35] TenneT, *Position Paper: Offshore Wind Energy*, Reference CDV 09-076, February 17, 2009, p. 2.
[36] PJM, 2008 RTEP - Reliability Analysis Update, TEAC Meeting, October 15, 2008.

system and (2) provide system operational benefits that enhance reliability and reduce the cost of grid operations.

Q. PLEASE EXPLAIN HOW THE AWC PROJECT WILL LIKELY REDUCE THE NEED FOR ONSHORE ENHANCEMENTS?

A. The AWC Project will likely reduce the need for upgrades to the onshore transmission system compared to a system based on radial interconnections of individual offshore wind power plants. This is achieved in three ways. First, the Project can be designed to interconnect at the strongest onshore nodes, which is less likely to be achieved by interconnecting individual offshore wind farms with radial transmission lines. In fact, four of the seven proposed interconnection points are the same nodes that PJM has chosen in its preliminary simulations to be capable of interconnecting 10,000 MW to 30,000 MW of offshore wind plants.[37]

Second, the Project's 2,000 MW transfer capability between landing points in Virginia, Maryland, Delaware and New Jersey reinforces the onshore grid in the constrained Mid-Atlantic region, thereby providing the existing system with an additional transmission path that will reduce the long-term need for future onshore reinforcements in eastern PJM as load grows and many of the aging existing power plants retire.

And finally, as broadly recognized in the industry, including by both the American and European Wind Energy Associations ("AWEA" and "EWEA"), the HVDC technology used by the AWC Project allows the independent control of

[37] "Off-Shore Wind Conceptual Study Initial Results" in Transmission Expansion Advisory Committee presentation, October 6, 2010, pp.43-59.

real and reactive power flows, which allows the HVDC system to interconnect with the onshore grid at both electrically strong and weak points.[38] Thus, even if the AWC Project's interconnection points are strong initially, that part of the system may become stressed in the future as more offshore wind is added beyond the 6,600 MW connected to AWC. As a result, AWC's controllability will likely become increasingly valuable for maintaining system reliability.

Q. HAVE YOU QUANTIFIED THE LIKELY ONSHORE UPGRADE COSTS THAT THE AWC PROJECT WOULD HELP AVOID?

A. No, we have not studied the extent to which the AWC Project would reduce the number and costs of onshore grid upgrades compared to the radial interconnection of individual offshore wind power plants. However, because the AWC Project also provides a fully controllable 2,000 MW transmission path from Virginia to Maryland, Delaware, and New Jersey, the Project will likely be able to avoid major future onshore transmission investments that might become necessary to address load growth, plant retirements, or the interconnection of additional offshore wind generation. Considering that the cost of individual recent upgrades has been in the order of $1 billion each,[39] it is likely that the AWC Project would

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[38] As noted in several sources including: (1) Center for Integrative Environmental Research ("CIER"), University of Maryland, *Maryland Offshore Wind Development: Regulatory Environment, Potential Interconnection Points, Investment Model, and Select Conflict Areas*, October 2010, p. 51; (2) European Wind Energy Association, *Oceans of Opportunity: Harnessing Europe's Largest Domestic Energy Resource*, September 2009, p. 27; (3) Siemens, "HVDC PLUS (VSC Technology): Benefits." Available from: http://www.energy.siemens.com/us/en/power-transmission/hvdc/hvdc-plus/#content=Benefits. Accessed November 24, 2010; and (4) Wright, S.D., Rogers, A.L., Manwell, J.F., Ellis, A., "Transmission Options for Offshore Wind Farms in the United States," American Wind Energy Association, 2002.

[39] Of the seven major backbone projects approved by PJM, five are in the $1 billion range: (1) Branchburg-Roseland-Hudson at $700 million; (2) Mid-Atlantic Power Pathway at $1.1 billion; (3) Potomac-Appalachian Transmission Highline at $2.1 billion; (4) Susquehanna – Roseland at $1.2 billion; and (5) Trans Allegheny Line at $1.0 billion. Branchburg-Roseland-Hudson cost reflects revised 230 kV buildout

be able to avoid at least one onshore transmission project with costs of that order of magnitude. In addition to these potentially significant cost savings associated with avoided onshore upgrades, the offshore solution also avoids the many barriers, uncertainties, and perhaps unavoidable delays associated with permitting and siting major onshore upgrades.

Q. HOW DOES THE AWC PROJECT PROVIDE SYSTEM OPERATIONAL BENEFITS?

A. As explained in the testimony of Robert Burton, the advanced HVDC technology of the AWC Project can provide a number of reliability benefits related to system operations, including operational flexibility, blackstart capability, faster load restoration, and a host of HVDC-technology-specific benefits such as voltage control and improved dynamic system stability.[40] These operational benefits, which in large part stem from the Project's voltage source converters ("VSC") technology, are also broadly recognized in the industry. For example, various authors note that the technology can be used to (1) provide dynamic voltage support to the AC system, thereby increasing its transfer capability;[41] (2) supply voltage and frequency support;[42] (3) improve transient stability[43] and reactive

based on costs reported by PJM's Transmission Expansion Advisory Committed, presented September 8, 2010, page 34. All other costs based on PJM's Backbone Project Construction Status Database. Available at: http://pjm.com/planning/rtep-upgrades-status/backbone-status.aspx. Accessed December 2, 2010.

[40] Testimony of Robert S. Burton, Exhibit AWC-200, pp.13-17.

[41] Bahrman, M.P., "VDC Transmission Overview," 2008, p. 5.

[42] Wang, S., Zhu, J., Trinh, L., and Pan, J., "Economic Assessment of HVDC Project in Deregulated Energy Markets," April 2008, p. 19.

[43] Trans Bay Cable presentation, March 16, 2005, p. 75.

performance;[44] (4) provide AC system damping;[45] (5) serve as a "firewall" to limit the spread of system disturbances;[46] (6) "decouple" the interconnected system so that faults and frequency variations between the wind farms and the AC network or between different parts of the AC network do not affect each other;[47] and (7) provide blackstart capability to re-energize a 100% blacked-out portion of the network.[48]

By being able to control flows on the HVDC lines, the AWC Project can also be used to control real power flow on the AC grid similar to phase angle regulators, but at a much faster response rate. In fact, during AC system contingencies, the HVDC VSC technology can be used to redirect power flows

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[44] As noted in several sources including: (1) Center for Integrative Environmental Research ("CIER"), University of Maryland, *Maryland Offshore Wind Development: Regulatory Environment, Potential Interconnection Points, Investment Model, and Select Conflict Areas*, October 2010, p. 51; (2) European Wind Energy Association, *Oceans of Opportunity: Harnessing Europe's Largest Domestic Energy Resource*, September 2009, p. 27; (3) Siemens, "HVDC PLUS (VSC Technology): Benefits." Available from: http://www.energy.siemens.com/us/en/power-transmission/hvdc/hvdc-plus/#content=Benefits. Accessed November 24, 2010; and (4) Wright, S.D., Rogers, A.L., Manwell, J.F., Ellis, A., "Transmission Options for Offshore Wind Farms in the United States," American Wind Energy Association, 2002, p. 5.

[45] Trans Bay Cable presentation, March 16, 2005, p. 75.

[46] Siemens, "HVDC PLUS (VSC Technology): Benefits." Available from: http://www.energy.siemens.com/us/en/power-transmission/hvdc/hvdc-plus/#content=Benefits. Accessed November 24, 2010.

[47] Lazaridis, L.P., *Economic Comparison of HVAC and HVDC Solutions for Large Offshore Wind Farms under Special Consideration of Reliability*, 2005, p. 34.

[48] As noted in several sources including: (1) European Wind Energy Association, *Oceans of Opportunity: Harnessing Europe's Largest Domestic Energy Resource*, September 2009, p. 27; (2) Siemens, "HVDC PLUS (VSC Technology): Benefits." Available from: http://www.energy.siemens.com/us/en/power-transmission/hvdc/hvdc-plus/#content=Benefits. Accessed November 24, 2010; (3) Lazaridis, L.P., *Economic Comparison of HVAC and HVDC Solutions for Large Offshore Wind Farms under Special Consideration of Reliability*, 2005, p. 34; and (4) Wright, S.D., Rogers, A.L., Manwell, J.F., Ellis, A., "Transmission Options for Offshore Wind Farms in the United States," American Wind Energy Association, 2002, p. 5.

[48] Trans Bay Cable presentation, March 16, 2005, p. 75.

[48] Siemens, "HVDC PLUS (VSC Technology): Benefits." Available from: http://www.energy.siemens.com/us/en/power-transmission/hvdc/hvdc-plus/#content=Benefits. Accessed November 24, 2010.

instantaneously to avoid overloading transmission facilities and to quickly restore the system to reliable N-1 operation.

Q. HAS PJM RECOGNIZED ANY OF THESE OPERATIONAL BENEFITS OF HVDC TECHNOLOGY?

A. Yes. PJM explicitly noted the improved reliability, reactive performance, system stability, and control of real power flows as benefits of HVDC technology in its recommendation to pursue the HVDC option for the Mid-Atlantic Power Pathway ("MAPP") project, despite the higher cost of the HVDC option.[49]

VII. CONGESTION RELIEF AND OTHER ECONOMIC BENEFITS OF THE AWC PROJECT RELATIVE TO A RADIAL ALTERNATIVE

Q. WHAT ARE THE OTHER CATEGORIES OF ECONOMIC BENEFITS RELATED TO THE AWC PROJECT?

A. As we will describe in greater detail below, the AWC Project will relieve congestion and thereby reduce production costs and energy market prices (in some locations) compared to a radial approach to interconnecting offshore wind. The Project will also provide capacity value to eastern PJM and help reduce the system operations costs of integrating wind.

[49] PJM Transmission Expansion Advisory Committee, "2008 RTEP - Reliability Analysis Update," TEAC Meeting, October 15, 2008, pp. 8-10.

1. ***Congestion Relief and Related Benefits***

Q. HOW DOES THE AWC PROJECT PROVIDE CONGESTION RELIEF?

A. If offshore wind generation were interconnected to shore solely via radial lines, the power would be delivered to each corresponding onshore landing point as the individual wind power plants generate electricity. This power could be injected during time periods when the injections exacerbate transmission congestion on the onshore transmission system, which would require potentially costly re-dispatching of onshore generation or curtailing some of the wind power. In contrast, the AWC Project diversifies on its offshore backbone the wind generation from all interconnected plants and enables optimal control of where this power is injected onshore. The AWC Project can be operated to transmit offshore wind generation from anywhere on the backbone to wherever it is most valuable (*i.e.*, where the LMP is highest), not only avoiding adding flows to congested onshore transmission facilities but also actively relieving congestion into the receiving area around each landing point. Moreover, the line can move economic but "constrained-off" onshore power from interconnection points with low LMPs to interconnection points with higher LMPs, further relieving congestion. The controllability of the line adds substantial operational flexibility to the PJM system and helps manage congestion and minimize system-wide costs.

Q. HAVE YOU SIMULATED THE AWC PROJECT'S ABILITY TO RELIEVE CONGESTION AND INTEGRATE OFFSHORE WIND GENERATION?

A. Yes. We used Ventyx's PROMOD simulation model, with Ventyx professionals conducting the actual model runs at our direction. PROMOD is a widely used model for analyzing electricity markets and transmission benefits. It is also used by PJM in its transmission planning studies. The version we used spans PJM and the rest of the Eastern Interconnection. PROMOD simulates the electric system operation and energy market by emulating how the RTOs dispatch generation to serve load at least cost, subject to transmission constraints and operating constraints. It reports hourly nodal LMPs, the generation output and emissions of each generating unit, the flows on each transmission line, and the costs of transmission congestion. The model is most useful for estimating how these attributes change as new generation or transmission is added.

Q. HOW DID YOU DESIGN YOUR PROMOD SIMULATIONS TO ESTIMATE CONGESTION IMPACTS OF THE AWC PROJECT?

A. We simulated market conditions for 2016 with the addition of 6,600 MW of nameplate offshore wind generation interconnected in two alternative ways: A case with the AWC Project and a conservative hypothetical case in which the 6,600 MW of wind plants are only interconnected to shore with radial transmission lines. Both cases include the same load forecast, the same planned transmission and generation additions, the same wind generation, and the same onshore transmission topology. The two cases differ only in that the "Radial

Wind" case delivers wind generation to the onshore interconnection point individually from each wind farm, whereas the "AWC Wind" case explicitly models the HVDC technology and optimizes deliveries and transfers along the line to manage congestion and minimize system-wide costs.

Q. WHAT DATA SOURCES AND KEY ASSUMPTIONS DID YOU RELY ON FOR YOUR MODELING ASSUMPTIONS?

A. The transmission topology is based on a 2015 load flow case that the Multi-Regional Modeling Working Group (MMWG) assembled from the various RTOs' and utilities' FERC Form 715 filings, with minor modifications by Ventyx to fully reflect transmission projects planned for 2016 consistent with PJM's 2010 Regional Transmission Expansion Plan (RTEP). Planned projects include the major PATH, TrAIL, MAPP, and Susquehanna-Roseland projects.

We also refined definitions of transmission constraints in eastern PJM by applying flow limits on vulnerable transmission facilities, interfaces, and contingencies. The list of key constraints is derived from various sources, including prior studies conducted by Ventyx, a contingency analysis conducted by Ventyx specifically for this study, the list of historically-congested constraints from PJM's website, and input from PJM based on its recent analysis of offshore wind power. The flow limits on the monitored facilities are defined primarily by the thermal ratings of the lines under N-1 contingency conditions as contained in the load flow data.

The load forecast was taken from each of the eastern RTOs' official ten-year forecast for peak load and annual energy, with an hourly profile that Ventyx derived based on several past years of data.

The list of generating units and their characteristics includes every existing facility and new generation that is under construction or permitted (from Ventyx's database). Planned renewable generation is not sufficient to meet the Mid-Atlantic states' 2016 RPS standards, as described in Section III of our testimony.

Gas and oil prices are consistent with forward curves available from NYMEX. Coal prices and gas basis differentials were provided by Ventyx.

The modeling assumptions and data sources are documented in the Technical Appendix report filed as Exhibit AWC-403 with this testimony.

Q. WHY DID YOU USE 2016 AS YOUR STUDY YEAR?

A. 2016 is the first year in which part of the AWC Project would be operational. Although the full set of line segments is not scheduled to be completed until 2020, we limited our study to 2016 to avoid having to make speculative assumptions about market conditions further in the future.

Q. WHY DID YOU SAY THE RADIAL WIND CASE WAS A "CONSERVATIVE HYPOTHETICAL" CASE?

A. The AC Radial case is not based on specific proposed offshore wind power projects. We constructed it assuming that exactly the same size wind farms would be built at the same locations as in the AWC Wind case and that these wind farms would be interconnected radially to exactly the AWC Project's onshore interconnection points. Imposing these assumptions allowed us to isolate more clearly the benefits of AWC Project's backbone and controllability. However, these assumptions for the Radial Wind case are very conservative (*i.e.*, understating the comparative value of the AWC Project) because it is unrealistic to assume that independent developers could agree to design and coordinate radially-interconnected wind power projects that are developed within the same time frame, utilize the same 500 MW to 1,000 MW scale, and choose the same optimally-selected onshore interconnection points as is possible with the AWC Project. No such projects have been announced or are under development, not even from the developers of currently-proposed offshore wind generation projects. Absent a coordinated offshore wind development effort like that facilitated by the AWC Project, the more likely outcome of a "radial" scenario would be a more delayed development of smaller scale wind farms that are interconnected using smaller radial interconnections that are less optimally selected with respect to their impacts on the onshore grid. AWC will also facilitate a faster ramp-up and lower-cost scale of offshore wind power development, and thus likely deliver more quickly the benefits of integrating offshore wind as discussed in Sections III and V of our testimony.

Q. WHAT DID YOUR MARKET SIMULATIONS SHOW ABOUT THE AWC PROJECT'S CONGESTION RELIEF BENEFITS RELATIVE TO THE RADIAL ALTERNATIVE?

A. Our simulations showed that the AWC Project significantly reduces transmission congestion relative to a radial alternative. Congestion relief occurs on transmission constraints in and into eastern PJM, including constraints near the selected interconnection points. The largest congestion reductions occur on the following constraints (listed in descending order of impact):

- a constraint on eastward flows on a 500 kV line from Keystone and Conemaugh (in western Pennsylvania) to the Juniata substation in central Pennsylvania for the loss of a parallel 500 kV line;
- a constraint on a 230 kV line emanating from the Fentress interconnection point in Virginia for the loss of a parallel 230 kV line;
- a constraint on a 230 kV line emanating from the Larrabee interconnection point (just south of Atlantic City) for the loss of a parallel 230 kV line;
- a constraint on a 230 kV line near the Hudson interconnection point for the loss of another 230 kV line; and
- a constraint on a 500 kV line from the Branchburg to Jefferson substations in northern New Jersey for the loss of a nearly parallel 500 kV line.

It is possible that these particular facilities might not exactly be the ones that are congested in the future if market conditions are different from those modeled or if there are transmission upgrades associated with the interconnection of offshore wind. However, relieving one constraint often causes another constraint in parallel or series to bind, so our findings will reasonably represent likely congestion patterns with and without the AWC Project.

Q. HOW DOES THE CONGESTION RELIEF PROVIDED BY THE AWC PROJECT REDUCE THE COST OF ELECTRICITY RELATIVE TO THE RADIAL ALTERNATIVE?

A. There are three alternative metrics that are frequently used to express the costs of congestion, and we have estimated the AWC Project's impact on all three: (1) congestion costs; (2) effects of congestion on production costs; and (3) effects of congestion on LMPs paid by load. Congestion costs are often used to describe actual markets, as in PJM's Annual State of the Market reports. Congestion costs express the amount of congestion charges loads pay into PJM's congestion fund. It is also equal to the total LMP payments less the LMP payments to generation, net of marginal-loss-related charges and payments. Technically, congestion costs also reflect the product of the shadow price and flow on each binding transmission constraints, summed over all constraints and all hours. Our simulations show that the AWC Project would reduce total annual PJM congestion costs by $196 million compared to the Radial Wind case.

Q. WHAT IS THE IMPACT OF AWC'S CONGESTION REDUCTIONS ON SYSTEM-WIDE PRODUCTION COSTS RELATIVE TO THE RADIAL ALTERNATIVE?

A. Reducing congestion allows lower-cost, more efficient generating units to be dispatched instead of higher cost units, resulting in lower overall production costs. The AWC Project reduces annual production costs by $33 million relative to the Radial Wind case. If such savings continued for 20 years, the net present value of future savings would be $350 million (expressed in 2010 dollars). However, because of inherent limitations of these types of market simulations, these estimates understate the congestion and production cost savings that the Project would provide under real-world system conditions as discussed further below.

Q. WHY DO THESE CONGESTION AND PRODUCTION COST ESTIMATES UNDERSTATE THE VALUE THE PROJECT WOULD PROVIDE UNDER REAL-WORLD SYSTEM CONDITIONS?

A. The PROMOD simulations do not capture a number of factors that cause real-time prices to be significantly more volatile than day-ahead prices. Such factors include wind generation uncertainty and forecasting errors, load forecasting errors, sudden outages of generation units, and all types of transmission outages. For example, PROMOD simulations assume actual wind generation and load are exactly as forecasted during the day-ahead generation commitment process, that all generation outages are known in advance, that wind generation and load do not vary within each hour, and that all transmission facilities are 100% available during all hours of the year. Because PROMOD does not model these factors, it is more representative of day-ahead market conditions than real-time. Thus, PROMOD understates real-time price volatility and the congestion and production cost implications of that volatility.

Q. HOW DOES ACCOUNTING FOR HIGHER REAL-TIME VOLATILITY AFFECT THE ECONOMIC BENEFIT OF THE PROJECT?

A. Volatility affects the value of all assets that provide flexibility, such as the AWC Project. To estimate the difference between day-ahead and real-time value of the Project, we analyzed the value that the AWC Project would have been able to realize in 2008, 2009, and 2010 by transferring power between the various onshore interconnection points. The transfer value is calculated on an hourly basis using the price differential between the lowest and highest LMP points, net of converter and DC line losses, assuming that the Project would have been able to transmit up to 2,000 MW (if the price differential exceeds the losses). As shown in Table 10, we found that the annual value of the AWC Project based on *hourly real-time* locational price differentials would have been 160% to 212% of the value under the less volatile *hourly day-ahead* price differentials. As the table shows, on average, the value of the Project in the hourly real-time market is 88% *higher* than the Project's value in the less volatile day-ahead market.

Table 10
Value of 2,000 MW Transfer Capability Based on Real-Time Prices in Comparison to Value based on Day-Ahead Prices

Year	Energy Transfer Value Ratio
2008	192.8%
2009	160.2%
2010	212.0%
2008-2010 Avg	188.3%

Assessing Project value based on hourly real time prices *still* understates the Project's total value, because the AWC Project will be able to respond to *5-minute real-time prices*, thereby providing additional benefits. In addition, this real-time market benefit is likely to increase over time as real-time volatility increases with the addition of more intermittent resources to the system. We have not yet quantified this additional real-time value due to limitations and inconsistencies in the available 5-minute historical real-time price data compared to hourly real-time price data and the challenge of simulating real-time markets factoring in wind uncertainty. Nevertheless, the analysis of historical real-time and day-ahead hourly price data shows that the total value of the AWC Project's congestion relief benefit under real-time market condition will likely be at least $660 million in terms of production cost savings, or approximately *twice* the congestion relief and production cost benefits captured in PROMOD.

Q. HOW WILL THE AWC PROJECT AFFECT THE POWER PRICES PAID BY CUSTOMERS?

A. Our simulations show that, by reducing congestion, the AWC Project lowers energy prices (*i.e.*, LMPs), especially in Eastern PJM. The results of this analysis are shown in Table 11 below. This LMP reduction is *in addition* to the LMP reduction realized by injecting energy from 6,600 MW of offshore wind plants with radial transmission interconnections. (We have already presented the overall LMP impacts of the AWC Project including the effects of wind generation in Section III of our testimony). Thus, the customer price impacts quantified here only reflect the AWC Project's incremental load LMP benefits relative to the Radial Wind case.

As shown in Table 11, this AWC-related decrease in load-weighted annual average LMPs is approximately \$1.4 to \$2.5/MWh in northern New Jersey, and \$0.80 to \$1.30/MWh in eastern Pennsylvania. Compared to the Radial Wind case, LMPs increase slightly: by \$0.50/MWh in Virginia and by \$0.20 to \$0.30/MWh in western PJM.

<u>Table 11</u>
Impacts of AWC Project on PJM Load LMPs
Compared to Radial Interconnections of Individual Wind Farms

Region	**State**	**PJM Area**	**Annual Load** *(GWh)* [1]	**Radial Wind** *LMP* *($/MWh)* [2]	**AWC Wind** *LMP* *($/MWh)* [3]	**AWC Wind vs. Radial Wind** *LMP* *($/MWh)* [4]= [3]-[2]	**AWC Wind vs. Radial Wind** *Load Payments* *($m/yr)* [5]= [1]×[4]
AWC States	DE	DPLC	20,517	$51.2	$51.7	$0.5	$10
AWC States	NJ	AE	13,978	$52.1	$52.2	$0.2	$2
AWC States	NJ	JCPL	29,004	$58.0	$56.2	($1.8)	($53)
AWC States	NJ	PSEG	54,250	$56.1	$53.7	($2.5)	($135)
AWC States	NJ	RECO	1,751	$63.0	$61.6	($1.4)	($2)
AWC States	VA	VP	114,406	$50.5	$50.9	$0.5	$53
AWC States	MD	BGE	39,503	$50.8	$50.9	$0.1	$3
AWC States	MD	PEPCO	36,283	$50.9	$51.2	$0.3	$9
Other PJM-E	PA	METED	18,518	$52.1	$51.3	($0.8)	($15)
Other PJM-E	PA	PECO	47,010	$53.0	$52.1	($0.9)	($44)
Other PJM-E	PA	PENN Elec	21,574	$46.1	$46.0	($0.1)	($2)
Other PJM-E	PA	PPL	47,100	$52.1	$51.1	($1.1)	($50)
Other PJM-E	PA	UGI	1,159	$53.4	$52.1	($1.3)	($2)
PJM-W	IL	COMED	125,253	$42.3	$42.5	$0.2	$22
PJM-W	OH	AEP	188,533	$43.7	$43.9	$0.2	$47
PJM-W	OH	FE OHIO	78,361	$43.3	$43.4	$0.2	$15
PJM-W	WV	APS	55,414	$46.8	$47.0	$0.3	$14
PJM TOTAL			**892,613**	**$47.9**	**$47.7**	**($0.1)**	**($126)**
AWC States			309,692	$52.5	$52.1	($0.4)	($113)
Other PJM-E			135,361	$51.5	$50.7	($0.8)	($112)
PJM-W			447,561	$43.6	$43.8	$0.2	$99

* Based on PROMOD simulations for 2016.

Q. HOW MUCH ARE THE ESTIMATED CUSTOMER SAVINGS ASSOCIATED WITH THESE CHANGES IN LOAD LMPS?

A. Compared to the Radial Case, the net effect of the AWC Project's congestion relief benefit would save customers in PJM approximately $126 million per year. If such savings continued for 20 years, the net present value of customer savings would be $1.3 billion (expressed in 2010 dollars). This does not count partially offsetting effects of FTRs, but it similarly does not count the amplifying effect of being to operate in the more volatile real-time market, as discussed above.

Q. DID YOU ESTIMATE HOW REDUCED ENERGY PRICES COULD INCREASE CAPACITY PRICES, AS YOU DID IN SECTION III?

A. Yes. The AWC Project would significantly reduce energy prices in EMAAC relative to a radial alternative. This would also reduce the energy margins earned by capacity resources in EMAAC, which would increase the market price for capacity. For example, a potential developer of a new combustion turbine would anticipate $3/kW-yr lower energy margins and thus need to obtain that much higher a price for capacity in order to be able to finance the project. Assuming new combustion turbines in EMAAC eventually set the clearing price for capacity, we estimate that the decrease in LMPs would increase capacity prices by $3.0/kW-yr. Similarly, the capacity prices would increase by $1.3/kW-yr in SWMAAC, $0.5/kW-yr in the rest of MAAC (and it would decrease slightly in the rest of PJM RTO). Such a capacity price increase applied to all demand in PJM areas would increase customer payments by $115 million per year ($1.2 billion NPV).

It should be noted that these capacity price adjustments are uncertain and would depend on the extent to which transmission constraints bind in PJM's capacity market, particularly between areas with differential changes in energy prices.

Q. DID YOU ANALYZE HOW THE PROJECT WOULD AFFECT CONGESTION IF LESS WIND POWER WERE DEVELOPED?

A. Yes, we have simulated a case without any offshore wind generation. Although it is unlikely that the Project would be constructed without the accompanying development of offshore wind generation, simulating the effects of the AWC Project without offshore wind provides a useful "bookend" case that allows us to better understand the value of the offshore backbone itself. Compared to a 2016 Base Case that includes only planned transmission and generation additions (*i.e.*, without the 6,600 MW of offshore wind), adding the AWC Project reduced onshore congestion by transmitting power from less congested, lower-LMP locations to more congested, higher-LMP locations. This relieves transmission constraints heading into northeastern PJM, especially on a 500 kV line from Keystone and Conemaugh (in western Pennsylvania) to the Juniata substation in central Pennsylvania for the loss of a parallel 500 kV line and a constraint on a 500 kV line from the Branchburg to Jefferson substations in northern New Jersey for the loss of a nearly parallel 500 kV line. Total annual congestion costs with the AWC Project without wind are $147 million lower than in the Base Case without wind—or about 75% of the congestion cost benefit of the AWC Project with 6,600 MW of offshore wind generation (relative to the Radial Wind case).

Q. HOW DOES THE AWC PROJECT AFFECT SIMULATED PRODUCTION COSTS AND LOAD LMPS IN THE CASES WITHOUT WIND?

A. The congestion relief provided by the AWC Project would reduce production costs even without wind. Including effects on losses, annual production costs in the AWC Without Wind case would be $51 million lower than in the Base Case without wind, with an NPV benefit of $540 million over 20 years (expressed in 2010 dollars). Compared to the Base Case, the AWC Without Wind case decreases load-weighted annual average LMPs by approximately $1.50 to $2.70/MWh in New Jersey and $1.00 to $1.70/MWh in eastern Pennsylvania. Compared to the Radial Case, LMPs increase slightly: by $0.90/MWh in Virginia and by $0.2 to $0.50/MWh in western PJM.

2. ***Capacity Value***

Q. HOW DOES THE AWC PROJECT PROVIDE CAPACITY VALUE?

A. The Project's ability to control the injection of wind generation and transfer power across the constrained Mid-Atlantic region also provides capacity value that is not captured in production cost simulations. First, the AWC Project can transmit the capacity value of wind to the landing points with highest capacity value. In addition, the AWC Project allows transmission of 2,000 MW from southern Virginia, where PJM capacity prices are lower and unconstrained, to New Jersey and the Delmarva Peninsula, which are part of the higher-cost, capacity-import-constrained "EMAAC" region of PJM. The Project also allows transmitting capacity between subareas within EMAAC if capacity prices were to differ across these subareas again in the future.

Q. DID YOU ESTIMATE THE VALUE OF THE AWC PROJECT'S ABILITY TO TRANSFER CAPACITY?

A. Yes. We estimated the order-of-magnitude capacity value of transmitting 2,000 MW into EMAAC based on a scenario analysis PJM recently conducted using data from its 2013-14 forward capacity auction.[50] As a rough proxy for the capacity market benefits of the AWC Project, we used analyzed the difference in capacity prices between (1) PJM's scenario that already includes the PATH and Susquehanna-Roseland transmission projects; and (2) the PJM scenario that additionally includes the MAPP transmission project. This addition of the MAPP transmission project increases the import capability into EMAAC by 1,576 MW, which is comparable to 2,000 MW the incremental EMAAC import capability provided by the AWC Project.

These scenarios show a $36/MW-day capacity price decrease in MAAC and EMAAC relative to the rest of PJM (relative its corresponding scenario without MAPP) and a remaining $62/MW-day capacity price differential between EMAAC and the rest of PJM. Assuming the $62/MW-day capacity price differential existed for only five years over the entire life of the Project (and ignoring the possibility that capacity price differentials may reappear within EMAAC), the Project's ability to transfer 2,000 MW of capacity would be worth $180 million. Similarly, if AWC were able to achieve the same $36/MW-day capacity price reduction in MAAC and EMAAC that MAPP achieves in PJM's scenario analysis, the resulting price impact would reduce customer capacity payments by $524 million per year in EMAAC and $666 million in PJM overall, or $2.1 and $2.7 billion, respectively, over five years.

[50] http://pjm.com/markets-and-operations/rpm/~/media/markets-ops/rpm/rpm-auction-info/scenario-analysis-results.ashx

We believe these estimates conservatively capture the approximate magnitude of the capacity market benefits provided by the AWC Project. A more precise estimate would require forecasting future locational capacity market conditions, which we have not undertaken at this point.

Q. HOW MIGHT FUTURE MARKET CONDITIONS AFFECT THE CAPACITY VALUE OF THE AWC PROJECT?

A. The price differentials we assumed already account for the addition of the PATH, Susquehanna-Roseland, and MAPP transmission projects, which PJM's scenario analysis shows to reduce the EMAAC-to-RTO price differential from $217/MW-day in 2013/14 to just $62/MW-day. However, the price impact we assumed EMAAC, could be overstated if the additional 2,000 MW of import capability provided by the AWC Project creates less price impact than the 1,576 MW of increased transfer capability into MAAC (as PJM estimated MAPP would provide). However, load growth and planned and likely future retirements of existing generating plants will tend to increase capacity prices in MAAC and EMAAC, and thus increase the capacity value of the AWC Project. (For example, the 645 MW Oyster Creek nuclear plant in New Jersey recently announced an agreement to retire by 2019.) At the same time, however, load growth and the retirement of existing supply in the rest of PJM could similarly increase prices there, thus diminishing the capacity value of the AWC Project.

3. __Reduced System Operating Costs__

Q. WHAT EFFECTS WILL THE AWC PROJECT HAVE ON WIND INTEGRATION COSTS?

A. The AWC Project will reduce the system operating costs associated with wind integration compared to a scenario in which individual resources that are interconnected to shore via radial transmission lines. The Project will do so by aggregating wind resources across hundreds of miles of offshore sites, and injecting into the onshore grid a more diversified wind energy portfolio with greater predictability and less variability. This will reduce the system operating costs of maintaining supply-demand balance at every point in time.

Q. WHY DOES INTEGRATING WIND USUALLY IMPOSE ADDITIONAL COSTS ON SYSTEM OPERATIONS?

A. Integrating significant amounts of wind imposes costs on system operations due to the *variability* and *unpredictability* of wind generation across all timeframes. Day-ahead unpredictability of wind output requires the commitment of extra resources to ensure there will always be enough generators turned on to be able to ramp up and provide adequate supply in the event that wind generation is less than expected. Closer to real-time, instantaneous and short-term fluctuations must be accommodated by procuring more *regulation* and *load-following* services.

Wind output also often exhibits patterns of steep increases and drops over the course of several hours, known as "ramps." Such ramping excursions could occur during morning and evening peak hours, thus magnifying load-related ramping needs and exerting additional pressure on system resources. Steeper ramps require generation equipment that can respond more quickly to increase (ramp up) or decrease (ramp down) output. Such resources are costlier to build, maintain, and operate.

Q. HOW LARGE ARE THE OPERATIONAL COSTS OF INTEGRATING WIND?

A number of studies have examined the operational costs of integrating various levels of wind generation. Effects on system costs depend on the penetration and characteristics of the wind generation portfolio as well the other characteristics of the particular electric system. A recent study by the National Renewable Energy Laboratory (NREL) concluded that, with 20% to 30% wind energy penetration levels for the Eastern Interconnection—and assuming substantial transmission expansions and balancing-area consolidation—total system operational costs caused by wind variability and uncertainty range from \$5.77/MWh to \$8.00/MWh of wind energy injected.[51] The day-ahead wind forecast error contributes between \$2.26/MWh and \$2.84/MWh, while within-day variability accounts for \$2.93/MWh to \$5.74/MWh of wind energy injected.[52]

Q. PLEASE DESCRIBE HOW THE AWC PROJECT WILL REDUCE THE COST OF INTEGRATING WIND.

A. The AWC Project can aggregate a diverse set of wind generation profiles thus reducing renewable generation volatility and unpredictability. The Project will

[51] NREL, "Eastern Wind Integration and Transmission Study," January 2010.
[52] \$/MWh of wind energy in US\$2024.

provide such aggregation before the profile is delivered to the onshore grid, thus decreasing the need for balancing services such as regulation and load-following in a transmission constrained grid. In addition, forecasting a composite wind generation profile for the entire AWC system, will result in lower forecast errors across all time-frames. The aggregation of diverse wind resources will also reduce the occurrence and severity of unexpected ramps (up- and down-excursions) in wind output, thus decreasing the need for ramping resources.

Of course, even with radial lines, some of the same diversification benefits can be realized, but only by imposing additional flows and thus transmission constraints on the onshore grid. In the presence of these transmission constraints, the AWC Project's ability to diversify wind generation through its offshore backbone reduces system-wide ramping, load following, and regulation needs.

Q. HAVE YOU QUANTIFIED THE WIND INTEGRATION COST SAVINGS PROVIDED BY THE AWC PROJECT ?

A. No, we have not. Such quantification would require detailed within-hour simulations taking into consideration both wind uncertainty and onshore grid constraints. However, the following analysis demonstrates that the savings of diversification could be quite significant. If total wind integration costs for 6,600 MW are $6/MWh (corresponding to the low end of NREL estimates because wind penetration will remain below 20% for many years), integration costs would amount to $140 million per year. Diversification and, by extension, any *improved* diversification that AWC would provide over radial alternatives, could save a significant portion of that.

Q. HOW MUCH DIVERSIFICATION CAN THE AWC PROJECT ACTUALLY ACHIEVE?

A. The significance of diversification along the sites on the AWC backbone can be demonstrated by several key statistics for the five wind locations we have analyzed in our market simulations. In contrast to the near-100% correlation within each site, the correlations among sites decrease quickly with distance. As shown in Table 12, the correlations between wind locations in northern, central and southern New Jersey (NJ Sites 1, 2 and 3) are in the 77% to 88% range. In contrast, the correlations between New Jersey and southern Virginia wind locations range only from 49% to 61%.

Table 12
Ten-Minute Correlations for Project Wind Sites

	NJ Site 1	NJ Site 2	NJ Site 3	DE Site	MD Site
NJ Site 2	88%				
NJ Site 3	77%	87%			
DE Site	68%	75%	82%		
MD Site	62%	70%	78%	87%	
VA Site	49%	54%	61%	70%	74%

Source: NREL Eastern Wind Dataset

Thus, integrating wind locations across the entire AWC Project significantly reduces variability. We find that the standard deviation of 10-minute output fluctuations of wind power of the diversified system is *less than half* the standard deviation of 10-minute output deviations for individual sites.

Ramp rates of the diversified wind profile are lower as well. For example, we find that for every 1,000 MW of individual wind locations, the 10-minute period-to-period volatility exceeds 100 MW during 2% of all periods with fluctuations as high as 800-900 MW (up and down). In contrast, the AWC-system-wide wind fluctuations (also for 1,000 MW of wind) exceed only 50 MW during 2% of all periods with maximal swings only in the -245 MW (down) to 245 MW (up) range. Together, these factors indicate that the aggregated wind profile AWC injects at its interconnection points with the onshore grid will be less volatile and will impose lower ramp rates, which will reduce the amount of regulation and load-following that would be needed. The ability to forecast injections more accurately will also reduce day-ahead unit commitment costs.

4. Emission Reduction Benefits

Q. WHAT EFFECTS DOES THE AWC PROJECT HAVE ON EMISSIONS?

A. By facilitating the development of offshore wind more quickly and at greater scale than if individual wind developers had to arrange their own interconnections, the AWC Project will give rise to major emissions reductions. As explained in Section III, the 6,600 MW of offshore wind interconnected by the AWC Project would eliminate 16 million tons of CO_2 emissions from fossil-fuel-fired generation per year. That is equivalent to taking 3 million cars off the road.[53] At a value of $30 per ton of CO_2 (as discussed in Section III), the reductions are worth approximately $500 million per year, or $5.2 billion over 20 years.

[53] Based on average passenger and light truck vehicle emissions of 5.5 metric tons of CO_2 per vehicle per year, as estimated by the Environmental Protection Agency, "Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle," EPA420-F-05-004, February 2005.

Q. HOW DO YOU RESPOND TO THE CONCERN THAT THE AWC PROJECT MIGHT BE USED TO MOVE COAL FROM VIRGINIA TO NEW JERSEY AND INCREASE CARBON EMISSIONS?

A. The possibility that the AWC Project might be used to move coal from Virginia to New Jersey and thereby increase carbon emissions is not is a very realistic concern. It takes less than 200 MW of additional wind capacity facilitated by the AWC Project (*i.e.*, less than 3 percent of what the Project can accommodate) to reduce CO_2 emissions throughout the Eastern Interconnection. We expect the Project to promote the development of much more additional wind generation than 200 MW, resulting in major reductions in coal generation and CO_2 emissions.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.