The Brattle Group

An Assessment of the Public Policy, Reliability, Congestion Relief, and Economic Benefits of the Atlantic Wind Connection Project

Executive Summary

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AN ASSESSMENT OF THE PUBLIC POLICY, RELIABILITY, CONGESTION RELIEF, AND ECONOMIC BENFITS OF THE ATLANTIC WIND CONNECTION PROJECT

*** * * EXECUTIVE SUMMARY * * ***

The AWC Companies have asked *The Brattle Group*[1] to analyze 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").

The AWC Project is a high-voltage direct-current ("HVDC") offshore transmission backbone spanning approximately 250 miles from northern New Jersey to southern Virginia. It can integrate 6,000 MW of offshore wind generation into PJM's onshore grid with significant benefits over the radial interconnection of individual wind farms. The AWC 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.

The offshore wind generation interconnected through the AWC Project will reduce system wide production costs from fossil-fuel fired generation by $1.1 billion per year with a 20-year present value of $12 billion. It will also reduce customer locational marginal prices ("LMPs") by approximately $1.6 billion per year (net of offsetting impacts on capacity market prices), with a present value of $17 billion. In addition, the development of the AWC Project and associated offshore wind generation will reduce CO_2 emissions by 16 million tons annually, the equivalent of taking 3 million cars off the road. Depending on the degree of in-region manufacturing and supply of equipment and logistical support, these wind and transmission investments will support between 130,000 and 260,000 full-time-equivalent years of employment and provide significant associated economic stimulus benefits for the local economy.

The AWC Project will enable these wind-related benefits more quickly and with major economic advantages over relying on wind developers to interconnect their own wind farms via radial AC lines. Through its scale and HVDC technology, the AWC Project provides the following comparative benefits:

- It enables states to meet their **renewable energy policy requirements** and goals through streamlined permitting, greater scale, and lower costs;
- It maintains and improves the **reliability and operation** of the transmission grid; and
- It provides **congestion relief and other economic benefits** in the congested Mid-Atlantic power market

Compared to the radial interconnection of individual wind plants, the AWC Project offers total benefits of $9-$15 billion, including the avoided costs of radial transmission lines. These total benefits far exceed the approximately $5 billion cost of constructing the Project.

[1] This Executive Summary is based on the direct testimony of Johannes Pfeifenberger and Samuel Newell on behalf of The AWC Companies in Federal Energy Regulatory Commission Docket No. EL11-13-000 filed December 20, 2010. The analysis and views contained in this Executive Summary are solely those of the authors and do not necessarily reflect the views of *The Brattle Group, Inc*. or its clients.

I. STATE RPS REQUIREMENTS AND ECONOMIC BENEFITS OF OFFSHORE RENEWABLE POWER DEVELOPMENT

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 radial interconnections of individual offshore wind farms. 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.

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.

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 using the PROMOD simulation model 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.

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 reduction 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

In addition, the development of offshore wind will create jobs and economic stimulus for the local economy, as shown in Table 2 above. As Table 2 shows, the overall magnitude of the economic stimulus benefits of the 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. The AWC Project facilitates achieving the necessary scale, as discussed below.

There are also other benefits and costs, including the capacity value of wind, wind integration costs, and the AWC Project-specific benefits discussed below.

While we recognize the above benefits and costs of offshore wind generation, the focus of our analysis was 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.

II. AWC Project Costs

We compared both the costs and benefits of the AWC Project versus radial alternatives. 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.

III. Public Policy Benefits Associated with the AWC Project

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. In addition, 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.

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.

IV. Reliability and Operational Benefits of the AWC Project

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.

V. Congestion Relief and Other Economic Benefits of the AWC Project Relative to a Radial Alternative

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 congestion relief 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 interconnected 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 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 production costs by $33 million per year or by approximately $350 million over the initial 20 years of the Project.

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 relative to radial interconnections will increase capacity prices, which offsets $110 million annually ($1.2 billion over 20 years) of the AWC Project's incremental LMP benefit.[2]

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.

The AWC Project would also provide capacity value that radial interconnections would not. In addition to transmitting the capacity value of 6,000 MW of offshore wind—which PJM is likely to count 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.

Finally, the AWC Project will also decrease emissions. 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 6,600 MW of offshore wind interconnected via the AWC Project would eliminate 16 million tons of CO_2 emissions from fossil-fuel-fired generation per year, as shown in Table 1.

VI. SUMMARY

Table 3 summarizes the benefits discussed and quantified in our comparison of the AWC Project to radially interconnected individual wind farms. 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

[2] We also 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.

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**