MARYLAND PUBLIC SERVICE COMMISSION
OFFSHORE WIND ANALYSIS 3.2.1

Generation Interconnection

System Impact Study Report

Prepared for

The Maryland Public Service Commission

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I. Preface

On April 23, 2014, the Maryland Public Service Commission ("Commission") issued a Request for Proposal ("RFP") for (A) estimating the need for transmission upgrades and associated costs (Section 3.2.1); and (B) evaluating potential applications for proposed offshore wind projects (Section 3.2.2), in compliance with the Offshore Wind Energy Act of 2013.[1] Section 3.2.1 stated that a Qualified Offshore Wind Project[2] will be required to secure capacity resource status, and will be located on the outer continental shelf of the Atlantic Ocean in the area designated for lease by the United States Department of Interior after coordination and consultation with the State. The area designated is between ten (10) to thirty (30) miles offshore and is located off the coast of Maryland.[3] The Qualified Offshore Wind Project must be interconnected to the PJM Interconnection system at a point located on the Delmarva Peninsula.

This report addresses the scope of Section 3.2.1 of the RFP. Specifically, a system impact study was conducted for interconnecting 250 MW to 400 MW (nameplate capacity) of

[1] 2013 Md. Laws, ch. 003. The Act, subsequently codified in the Public Utilities Article ("PUA"), directed the Commission to contract for the services of independent consultants and experts. PUA § 7-704.1(D)(2).

[2] "Qualified Offshore Wind Project" is defined by the authorizing statute, PUA § 7-701 (k), as follows: "Qualified offshore wind project" means a wind turbine electricity generation facility, including the associated transmission-related interconnection facilities and equipment, that: (1) is located on the outer continental shelf of the Atlantic Ocean in an area that: (i) the United States Department of the Interior designates for leasing after coordination and consultation with the State in accordance with § 388(a) of the Energy Policy Act of 2005; and (ii) is between 10 and 30 miles off the coast of the State; (2) interconnects to the PJM Interconnection grid at a point located on the Delmarva Peninsula; and (3) the Commission approves under § 7-704.1 of this subtitle.

[3] *See* Attachment 3.

potential offshore wind generation connecting at a point on the Delmarva Peninsula. The estimated costs associated with any network upgrades are made available herein on behalf of the Commission for use by potential applicants in the submission of a proposed offshore wind project application.

The Maryland offshore wind ("OSW") system impact study process mirrored the PJM generation interconnection study procedures as described in PJM Manuals, specifically:

- Manual 14A - Generation and Transmission Interconnection Process; and
- Manual 14B - PJM Region Transmission Planning Process.

In addition, the study utilized the most current PJM base case (2018 Queue Z2 – Generation Base Case) for generation interconnection. Power flow analysis was performed using Siemens PTI PSS/E program and short circuit analysis was performed using ASPEN One-Liner program. Stemming from these analyses, this study identifies the network impacts and upgrades, along with associated estimated costs, to connect potential offshore wind projects at a point on the Delmarva Peninsula. The planning level estimates of network upgrade costs included in this report are based on PJM and other industry information available at the time of the study.

In accordance with PJM requirements, an interconnection requester will have the responsibility of the connection costs including rights-of-way costs and network upgrade costs. The network upgrades costs are "but for" costs for facility additions or upgrades to existing facilities that are needed to maintain the reliability of the PJM system. Cost responsibility for the various network upgrades discussed in this report was determined in accordance with the PJM Manual 14A.

This system impact study report represents the Commission's estimated cost of transmission upgrades associated with two increments of capacity for a potential MD OSW project. In accordance with Commission regulations, an application shall include a proposed offshore wind renewable energy credit ("OREC") price schedule for the proposed offshore wind

project that consists of either a one-part OREC price or a two-part OREC price.[4] In submitting a two-part OREC price, the first component is expressed as a firm price while the second price component is subject to a true-up based upon any change between the Commission's estimated cost of transmission upgrades and PJM's actual upgrade costs as specified in the executed Interconnection Service Agreement,[5] for a total OREC price up to and not exceeding $190 per megawatt hour (levelized in 2012 dollars).[6]

[4] *See* COMAR 20.61.06.02(M)(1).

[5] The network upgrade estimates represented in this report are point in time estimates. A future study, most importantly, a PJM Queue Process study for a proposed or qualified MD OSW project expected to be conducted at a future date could produce different results due to changes in generation retirement and/or changes in the status of prior queue projects (e.g., project withdrawals).

[6] The true-up is also subject to the projected net rate impact caps for residential and nonresidential customers, as described in PUA § 7-704.1(e)(1)(ii) and (iii).

II. General

The location of the MD OSW project(s) is expected to be approximately thirteen (13) miles offshore in the Atlantic Ocean within the Maryland Offshore Wind Energy lease area. Two increments of Offshore Wind MW sizes were analyzed for interconnection to the PJM System: at 250MW of full output and at 400MW of full output.

A 30% capacity factor was applied to calculate the resulting capacity values: 75MWC and 120MWC, respectively. Note that currently, the effective class average capacity factor for both offshore and onshore wind resources is 13%.[7] The capacity factor for mature resources, defined by PJM as resources with three or more years of historical operational data, is determined by calculating the mean of the single year capacity factors for the three years prior to the delivery year. Owners/developers of immature intermittent resources are permitted to substitute an alternate class average capacity factor with suitable documentation and approval by PJM. Suitable documentation is likely to include actual wind speed data provided by an adjacent mature intermittent resource, meteorological tower or from temporary wind towers. In addition, documentation for justifying an alternative capacity factor could also include manufacturer specifications, resource diagnostics, and engineering analysis supporting the ability to reach increased production levels.

While there are currently no offshore wind resources operating within the PJM footprint, empirical data analyzed from other locations demonstrates that higher capacity factors (at or above 30%) are potentially achievable for offshore wind resources. Therefore, evidence may exist to support a capacity factor above the class average for offshore wind resources.[8]

[7] *See* PJM Manual 21Rules and Procedures for Determination of Generating Capability, page 17.

[8] *See, e.g.* http://www.nrel.gov/docs/fy13osti/56266.pdf; http://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-and-Environmental-Markets/RPS/RPS-Documents/wind-integration-report.pdf; http://www1.eere.energy.gov/wind/pdfs/offshore_wind_market_and_economic_analysis_10_2013.pdf; http://pjm.com/~/media/committees-groups/committees/elc/postings/capacity-performance-action-item-presentation.ashx; http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2014/2014q3-som-pjm-sec8.pdf.

However, in addition to the referenced documents that indicate that other comparable wind projects have achieved elevated capacity factors, PJM will likely require investment in offshore data towers to assess actual wind resource and verify the likelihood of power generation during peak periods. Offshore wind developer(s) would have to meet PJM regulations if it plans to undertake the alternative class average capacity factor process, including but not limited to those discussed above.[9]

For purposes of this analysis, the assumed commercial operation date of MD OSW project(s) located on the Maryland lease sites is 2019.

III. Point of Interconnection

A number of potential interconnection sites/substations, that is, Delmarva Power & Light Company ("DPL") substations in the Lower Peninsula, were considered as a potential point of interconnection for the MD OSW project. These substations were selected for review due to their location relative to the Maryland North and South lease sites off of the Outer Continental Shelf of the Atlantic Ocean. The analysis used a high-level qualitative comparison of the options based on electrical, constructability and economic factors. A number of these substations along the Atlantic Coast were deemed unacceptable for the proposed level of generation injection.[10] The DPL Indian River 230kV Substation offered the best option for a point of interconnection.[11]

[9] The study assumes that considerations of alternative capacity factor would include an evaluation of expected benefits (i.e., revenues) versus expected costs (i.e., costs/penalties).

[10] The primary reasons for this finding include physical space limitation to accommodate a 138 kV or a 230kV interconnection, expected level of local reinforcements and limited power transfer capability for the proposed level of generation injection.

[11] The interconnection customer entering the PJM Queue process at a future date may designate an alternative point of interconnection after consultation with the MD PSC for the qualified MD OSW project. Per the Commission's regulations, any material change to the qualified offshore wind project shall be reported to the Commission within 30 days of the date of that decision.

While about 12 miles inland to connect the MD OSW to Indian River, the new 230kV line would be built over an existing 138kV right-of-way that has sufficient width to support both the existing 138kV line and a new 230kV line.

IV. Connection Requirements

A. Interconnection Facilities – Transmission Side

1. Transmission:

Establish approximately 12.2 miles of new 230kV transmission line from a new switching station located near DPL's Bethany 138kV Substation to Indian River 230kV Substation. The new 230kV facility could be built within an existing 150-foot wide right-of-way. This will require rebuilding the existing H-Frame 138kV line using a monopole structure to accommodate the 230kV line within the existing right-of-way. Design and construction must meet Delmarva Applicable Standards. Estimated cost is $24,000,000.[12]

2. Substation:

At Indian River:

Establish a 230kV line terminal with associated equipment to accommodate the new 230kV line. Estimated cost is $2,300,000.

At a New Switching Station:

(*Adjacent to MD OSW on-shore switching station*)

[12] This system impact study assumes the use of existing DPL rights-of-way to establish the interconnection facilities from Bethany to Indian River. Consistent with PJM Impact Study Report language, the Interconnection Customer (IC) is responsible for all design and construction related activities on its side of the Point of Interconnection. Site preparation, including grading and access roads, as necessary, is assumed to be by the IC. Route selection, line design and rights-of-way acquisition will be conducted during a Facility Study stage as part of the PJM study process after the qualified MD OSW project enters the PJM Queue process.

Establish a 230kV switching station, 230kV breaker, disconnect switches, metering, relaying and associated equipment. Estimated cost is $2,600,000.

See Attachment 1 for a simplified one-line diagram of the Interconnection Facilities.

B. Customer Interconnection Facilities – Generation Side

Generator will be responsible for the construction of all generating station facilities on the Generator's side of the Point of Interconnection ("POI"). Protective relaying and metering design and installation must comply with Delmarva's Applicable Standards. Interconnection generator is also required to provide revenue metering and real-time telemetering data to PJM in conformance with the requirements contained in PJM Manuals M-01 and M-14 and the PJM Tariff.

V. Network Impacts

The analysis used a 2018 PJM Base Case. For the generation deliverability analysis the case included all active PJM queue projects up to Z2 queue. The analysis was initially conducted with all of these queue projects using the 2018 PJM Base Case, including Queue project X2-066 (309 MW), which was later withdrawn from the PJM queue process on or about January 15, 2015. The analysis was updated to reflect X2-066's withdrawal. This update eliminated the need for two new upgrades identified in the first iteration of the analysis; it also caused an overload condition that was a previously-identified facility overload in the first iteration of the analysis to now be triggered instead by the MD OSW project.

The following summarize the results of the updated analysis (without PJM Queue X2-066).

A. Generator Deliverability

Single Contingency results for the capacity portion of the interconnection:

Any generator requesting interconnection to the PJM system must be deliverable in order to be a PJM capacity resource. The generation deliverability test determines the ability of an electrical area to export generation sources to the remainder of the PJM system. This test is applied to ensure that generation is not bottled from a reliability perspective or that there is sufficient transmission capability from the generation resources to deliver energy to the load. The method tests the project at the MW capacity level for single contingency conditions and at the full output MW level for common mode outages. These common mode outages include double circuit tower line, line with failed breaker and bus fault contingencies. If violations are determined under the single or common mode contingencies, the interconnection generator is responsible for the costs associated with the enhancement. This section provides the results of the single contingencies. Common mode outage results are discussed under the multiple facility contingency section.

There were no single contingency violations for the capacity portion (75 MW & 120 MW) of the MD OSW project.[13]

B. Multiple Facility Contingency

Double circuit tower line, line with failed breaker and bus fault contingencies for the full output of the interconnection:

The Edgemoor5 – Linwood 230kV line loads from 97.03% to 100.96% of its emergency rating of 805 MVA for MD OSW at 250 MW and to 103.33% of its

[13] Note that there were no reliability violations for the capacity portion of the analysis at the assumed 30% capacity factor.

emergency rating of 805 MVA for MD OSW at 400 MW for the line fault with failed breaker contingency outage. This is a new (i.e., not previously identified) reliability violation caused by the MD OSW project at 250 MW and at 400 MW.

C. Contributions to Previously Identified Overloads

The MD OSW project contributes to the following contingency overload, i.e. "Network Impacts," identified for earlier generation or transmission interconnection projects in the PJM Queue:

1. The Chichester – Eddystone 230kV circuit loads from 104.78% to 105.78% of its emergency rating of 863 MVA for MD OSW at 250 MW and to 106.38% of its emergency rating of 863 MVA for MD OSW at 400 MW for the single contingency of DELCO $220-04. The upgrade needed for this facility was identified in the PJM RTEP process and as a result is designated as a Baseline upgrade for which no cost responsibility is assigned to the MD OSW project.

2. The DELCO TAP – Mickleton 230kV circuit loads from 100.67% to 103.62% of its emergency rating of 725 MVA for MD OSW at 250 MW and at 105.37% of its emergency rating of 725 MVA for MD OSW at 400 MW for the bus fault outage (CHI230B1) and line fault with breaker outage (CHICH045). The estimated cost to mitigate the overload is approximately $200,000. Since PJM uses single queue allocation for upgrades that are less than $5,000,000, the MD OSW project is not allocated any cost responsibility.

3. The Claymont – Linwood 230kV circuit loads from 106.81% to 111.40% of its emergency rating of 805 MVA for MD OSW at 250 MW and at 114.31% of its emergency rating of 805 MVA for MD OSW at 400 MW for the line fault with failed breaker outage (LINWO225). The estimated cost to mitigate the overload is approximately $3,030,000. Since PJM uses single queue allocation for

upgrades that are less than $5,000,000, the MD OSW project is not allocated any cost responsibility.

4. The Edgemoor5 – Claymont 230kV circuit loads from 110.85% to 115.04% of its emergency rating of 805 MVA for MD OSW at 250 MW and at 117.65% of its emergency rating of 805 MVA for MD OSW at 400 MW for the line fault with failed breaker outage (LINWO225). The cost to mitigate the overload is estimated to be approximately $10,295,000. Since this project is over $5,000,000, the MD OSW project will have a cost allocation towards this network upgrade cost.

D. Short Circuit

The short circuit analysis is a critical component of the evaluation of the electrical system. Interconnection of new generation into the existing power system will increase the available short circuit current. The purpose of the study was to determine if the short circuit ratings of the existing breakers that are near and at Indian River Substation are exceeded with the addition of a 400 MW OSW project. No overstressed breakers were identified.[14]

VI. System Reinforcements and Estimated Costs

A. New System Reinforcements

[Network upgrades required to mitigate reliability criteria violations, i.e. "Network Impacts" initially caused by the addition of this project's generation.]

[14] Because no overstressed breakers were identified at the 400 MW capacity level, an additional study at the 250 MW increment was unnecessary in order to similarly conclude that no overstressed breakers exist at the 250 MW level.

The Edgemoor – Linwood 230kV overload is a new violation caused by the addition of MD OSW project and as result MD OSW project will be 100% responsible for the costs to mitigate the overload. Reinforcements to mitigate the Edgemoor – Linwood 230kV circuit overload will include reconductoring the existing circuit along with pole replacements. The estimated total cost to perform this work is approximately $12,325,000.

B. Contribution to Previously Identified System Reinforcements

[Contribution to network upgrades for previously identified system reinforcements]

To mitigate the Edgemoor – Claymont 230kV circuit overload will require reconductoring the circuit, including some pole replacements. The cost to mitigate the overload is estimated to be approximately $10,295,000. Since this project is over $5,000,000, the MD OSW project will have cost allocation towards this upgrade cost. This circuit was initially overloaded by PJM queue X2-066 (309 MW project), which was recently withdrawn. As a result of this withdrawal, PJM queue X2-067 (also a 309 MW project) now overloads this facility. Also, PJM queue Y3-033 (100 MW project) contributes to the overload of Edgemoor – Claymont 230kV circuit. The addition of the MD OSW projects contributes to the overload of this facility, therefore the MD OSW project, along with the other two active PJM Queue projects, will have cost allocation towards the network upgrade cost. The following tables show the estimated cost allocated to each project at both capacity increments studied for the MD OSW project:

Table 1 – Allocated Costs at 400 MW

MD OSW at 400 MW			
Queue/Project	MW Contribution	% of MW Contribution	Allocated Cost ($M)
Queue X2-067	13.93	15.10%	$1.554
Queue Y3-033	16.45	17.83%	$1.836
MD OSW	61.88	67.07%	$6.905
Total	92.26	100.00%	$10.295

Note: MW Contribution is based on DFAX consistent with PJM methodology.

Table 2 – Allocated Costs at 250 MW

MD OSW at 250 MW			
Queue/Project	MW Contribution	% of MW Contribution	Allocated Cost ($M)
Queue X2-067	13.93	20.17%	$2.077
Queue Y3-033	16.45	23.82%	$2.453
MD OSW	38.67	56.01%	$5.765
Total	69.05	100.00%	$10.295

Note: MW Contribution is based on DFAX consistent with PJM methodology.

C. Estimated Costs

The estimated capital expenditures were derived from:

1. Planning-level estimates based on unit cost data and recent estimates.

2. Economic analysis to translate the planning-level estimates[15] into constant 2012 dollars[16] and to reflect additional cost escalation – in excess of actual and expected general inflation – (or real escalation) through the assumed completion date of construction.[17]

See Attachment 2 for a summary of estimated costs.

[15] Planning-level costs reflect mid-2014 current dollar estimates.

[16] The estimated costs are provided in constant 2012 dollars to mirror the statutory specifications regarding a potential Commission order on Offshore Wind Renewable Energy Credits. The statutory language states, for example: "the price set in the proposed OREC price schedule does not exceed $ 190 per megawatt-hour in 2012 dollars." PUA § 7-704.1.

[17] Estimated real escalation was derived from the previous five year history of nominal escalation using Mid-Atlantic region data in the *Handy-Whitman Index of Public Utility Construction Costs*, Bulletin No. 180. As a measure of inflation, the Gross Domestic Price Implicit Price Deflators ("GDP-IPD") was used. A compound average annual growth rate ("CAGR") was developed to estimate the annual rate of real escalation. The real escalation CAGR was applied to the planning-level estimates to calculate real escalation as of the in-service date for each facility. To restate the in-service date estimate into 2012 dollars, the escalated amounts were deflated using a cumulative deflation factor.

VII. Summary and Conclusion

A Qualified Offshore Wind Project will be required to secure capacity resource status located on the outer continental shelf of the Atlantic Ocean in the area designated for lease by the United States Department of Interior after coordination and consultation with the State. The area designated is between ten (10) to thirty (30) miles offshore and is located off the coast of Maryland. The offshore wind project is to be interconnected to the PJM Interconnection Grid at a point located on the Delmarva Peninsula.

This report summarizes the results of a system impact study for interconnecting 250 MW to 400 MW nameplate capacity of potential offshore wind generation connecting to the Indian River 230kV substation. The purpose of the study was to identify potential interconnection facilities,[18] network upgrades and associated cost estimates. The cost estimates may be used as a proxy by applicants when submitting an application for a proposed offshore wind project with the Maryland Commission. Designing, constructing, and operating the offshore wind farm and the interconnection of the project to the existing grid operated by the PJM Interconnection is the responsibility of the applicant(s).

A 30% capacity factor was applied to calculate the resulting capacity values: 75MWC and 120MWC, respectively. Evidence likely exists to support a capacity factor above PJM's currently effective class average rate of 13% for offshore wind resources. Per PJM regulations, owners/developers of immature intermittent resources are permitted to substitute an alternate class average capacity factor with suitable documentation and approval by PJM.

For purposes of the study, the assumed commercial date of operation of MD OSW on the Maryland lease sites is 2019. The analysis utilized the most current PJM base case (2018

[18] The cost estimates for the Interconnection Facilities assume the use of DPL's existing rights-of-way for the line section from Bethany area to Indian River Substation. Therefore, these estimates did not include estimated costs of new rights-of-way from Bethany area to Indian River Substation.

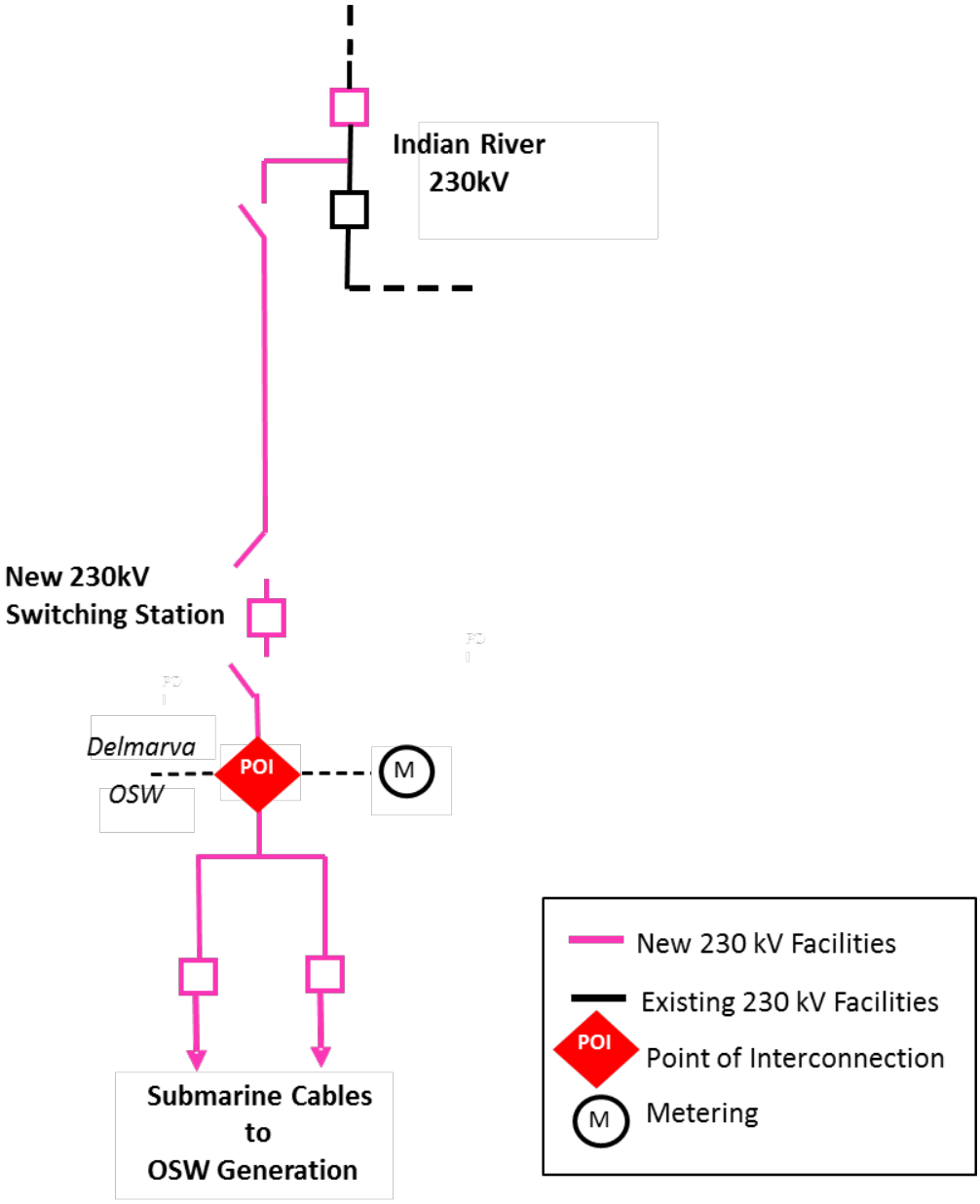
Queue Z2 – Generation Base Case) for generation interconnection. For the generation deliverability analysis the case included all PJM queue projects with a signed Interconnection Service Agreement and/or Facility Service Agreement. The analysis was initially conducted with all queue projects, including Queue project X2-066 (309 MW), which was later withdrawn from the PJM queue process. The analysis was updated to reflect Queue X2-066's withdrawal.

The results show that MD OSW at 250 MW and at 400 MW will trigger a new facility overload (Edgemoor – Linwood 230kV). The MD OSW project will have 100% allocation towards any upgrade costs stemming from the newly triggered facility overload. The MD OSW project will also contribute to four (4) previously identified facility overloads. However, MD OSW will have cost allocation for only one network upgrade (Edgemoor - Claymont 230kV) stemming from previously identified facility overloads due to the application of the PJM cost allocation formula.

Estimated costs are summarized in Attachment 2. This report provides planning-level estimates of network upgrade costs based on PJM and industry information available at the time of the study. The estimated costs are provided in constant 2012 dollars to mirror the statutory specification regarding a potential Commission order on Offshore Wind Renewable Energy Credits.

ATTACHMENT 1

MD OSW PROJECT INTERCONNECTION FACILITIES



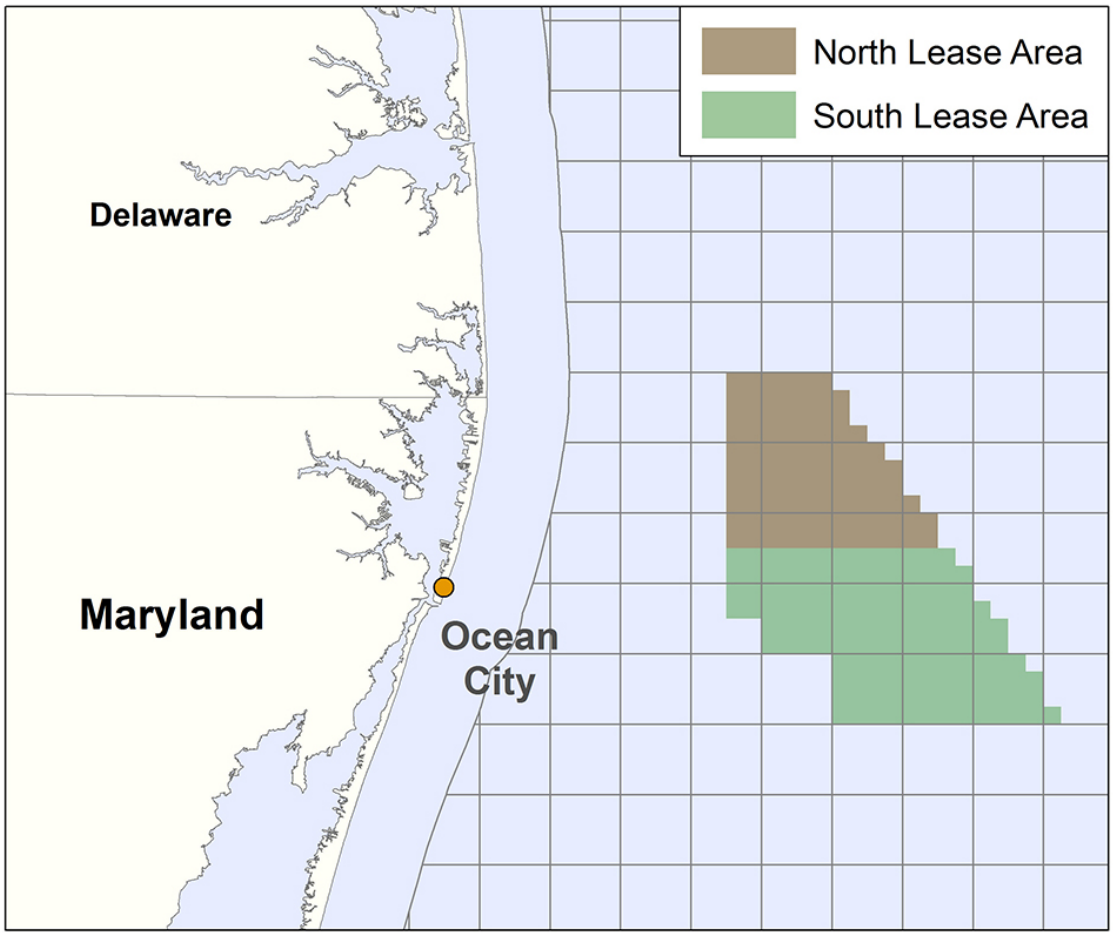
Note: This system impact study assumes the use of DPL's existing rights-of-way for the interconnection facilities from the new switching station (near Bethany Substation) to Indian River Substation. Furthermore, the report assumes that this portion of the interconnection facility which includes the 230kV line, terminal and new switching station will be Transmission Owner Interconnection Facility to be designed, constructed, owned and operated by DPL. This assumption is subject to change as part of the PJM study process conducted after the qualified MD OSW project enters the PJM Queue.

ATTACHMENT 2
ESTIMATED COSTS

	MD OSW at 250 MW	MD OSW at 400 MW
	Estimated Costs ($ x 1,000)*	Estimated Costs ($ x 1,000)*
1. Interconnection Facilities – Transmission Side		
• 230kV Transmission Line	$24,997	$24,997
• Substation Work: New 230kV line Terminal at IR	$ 2,399	$2,399
• Substation Work: New Switching Station with a 230kV Line Terminal, DS, Metering	$ 2,713	$2,713
Interconnection Facilities - TOTAL	**$30,109**	**$30,109**
2. New System Reinforcements		
• Edgemoor – Linwood 230kV	$12,770	$12,770
SUBTOTAL	$12,770	$12,770
3. Contribution to Previously Identified System Reinforcements		
• Edgemoor – Claymont 230kV	$ 5,698	$6,825
SUBTOTAL	**$ 5,698**	**$6,825**
Network Upgrades - TOTAL	**$18,468**	**$19,595**
TOTAL	**$48,577**	**$49,704**

* The estimated costs are provided in constant 2012 dollars to mirror the statutory specifications regarding a potential Commission order on Offshore Wind Renewable Energy Credits. The statutory language states, for example: "the price set in the proposed OREC price schedule does not exceed $ 190 per megawatt-hour in 2012 dollars." PUA § 7-704.1.

ATTACHMENT 3
MARYLAND LEASE AREAS



Source: Bureau of Ocean Energy Management