December 2022

Maryland Offshore Wind:

Estimating the Costs and Benefits of Offshore Wind Energy Development

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This Report was commissioned by the Chesapeake Climate Action Network and made possible through the generous support of The Clayton Baker Foundation and The Abell Foundation. The authors gratefully acknowledge external reviewers, internal reviewers, colleagues, and sponsors who supported this report. External review and support do not imply affiliation or endorsement.

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EXECUTIVE SUMMARY

Gabel Associates, Inc ("Gabel") was engaged by the Chesapeake Climate Action Network ("CCAN") to conduct an independent study focused on the impacts of offshore wind development to meet the goals of the Climate Solutions Now Act. Specifically, this Report analyzes the expected costs and benefits of offshore wind development that could be utilized to reach the 60% target by 2031 and provides a potential range of outcomes that offer stakeholders and policy-makers guidance on the next steps to realize the benefits of offshore wind.

Background and Context

Maryland has a long history of valuing its residents' health and the environment through legislation. A major component of this policy has been the planned development of offshore wind energy projects. In 2017, the Maryland Public Service Commission ("PSC") announced the approval of two proposed offshore wind projects, Skipjack and US Wind, totaling 368 megawatts ("MW").[1] In 2021, the PSC approved two additional projects, Skipjack Phase 2 and Momentum Wind, totaling 1,654 MW.[2] In total, the PSC has already approved over 2 GW of new offshore wind generation, which is expected to be in service by 2026.

Offshore wind provides many benefits as a generation resource, including its zero emissions profile from generation, promise of substantial economic development benefits, and fuel diversification value. As states continue to transition generation supply to renewable and low/no emissions sources, offshore wind provides a unique alternative to traditional generation sources by providing coastal states with a previously unavailable option to meet and exceed state-level decarbonization goals.

With the passage of the Climate Solutions Now Act in 2022,[3] Maryland established an ambitious target to reduce statewide greenhouse gas emissions by 60% from 2006 levels by 2031 and achieve net-zero emissions by 2045. While the Act does not specifically require offshore wind to meet emissions reduction targets, the development of in-state carbon-free

[1] In The Matter of the Applications of U.S. Wind, Inc. and Skipjack Offshore Energy, LLC for a Proposed Offshore Wind Projects Pursuant to the Maryland Offshore Wind Energy Act Of 2013. Maryland Public Service Commission. Order No. 88192 in Case No. 9431. psc.state.md.us/wp-content/uploads/Order-No.-88192-Case-No.-9431-Offshore-Wind.pdf.

[2] Skipjack Offshore Energy, LLC and US Wind, Inc.'s Offshore Wind Applications under the Clean Energy Jobs Act of 2019. Maryland Public Service Commission. Order No. 90011 in Case No. 9666. psc.state.md.us/wp-content/uploads/Order-No.-90011-Case-No.-9666-Order-Granting-Offshore-Wind-Renewable-Energy-Credits.pdf.

[3] Climate Solutions Now Act of 2022. Maryland General Assembly. mgaleg.maryland.gov/mgawebsite/Legislation/Details/sb0528.

resources will be critical to meeting its targets. Other states in the region (e.g., New York and Massachusetts) have concluded that they cannot achieve such levels of GHG reductions without large-scale offshore wind development.

To help guide Maryland in its consideration of developing additional offshore wind projects, this Report analyzes the expected costs and benefits of Maryland adding an additional 6,000 MW of offshore wind generation beginning in 2028 to meet the carbon reduction goals outlined in the Climate Solutions Now Act.

Costs of Offshore Wind

While Offshore wind has a longer history of development in Europe, it is a relatively new energy resource to the United States. The first commercial offshore wind project, the 30 MW Block Island Wind Farm off the coast of Rhode Island, went into operation in late 2016. Since that time, several other projects have been approved by state regulators, or have come online, such as two turbines off the coast of Virginia which began operation in 2020. Therefore, publicly available cost data for offshore wind projects in the United States is limited. The available cost data is constantly changing due to macroeconomic drivers like inflation and supply chain issues. Additionally, costs have generally been declining because of advances in technology, engineering design, and manufacturing processes.

Given these evolving factors, this Report uses a conservative approach to estimate the cost of offshore wind using a range of sources, while considering the uncertainties. This is not intended to be a "bottom-up" cost estimate for a specific project but is instead intended to provide a reasonable estimate for calculating costs and benefits of additional offshore wind energy development.

Cost estimates for new offshore wind in Maryland in 2028 are based on publicly available cost projections. The cost projections vary because of different assumptions. We relied on a range of potential estimates to forecast the cost in Maryland. The data sources utilized in this analysis for cost projections include the National Renewable Energy Laboratory ("NREL"),[4] the Energy Information Agency ("EIA"),[5] Lazard,[6] the University of Delaware Special

[4] United States National Renewable Energy Laboratory. 2022 Annual Technology Baseline. Accessed September 2022. atb.nrel.gov/.

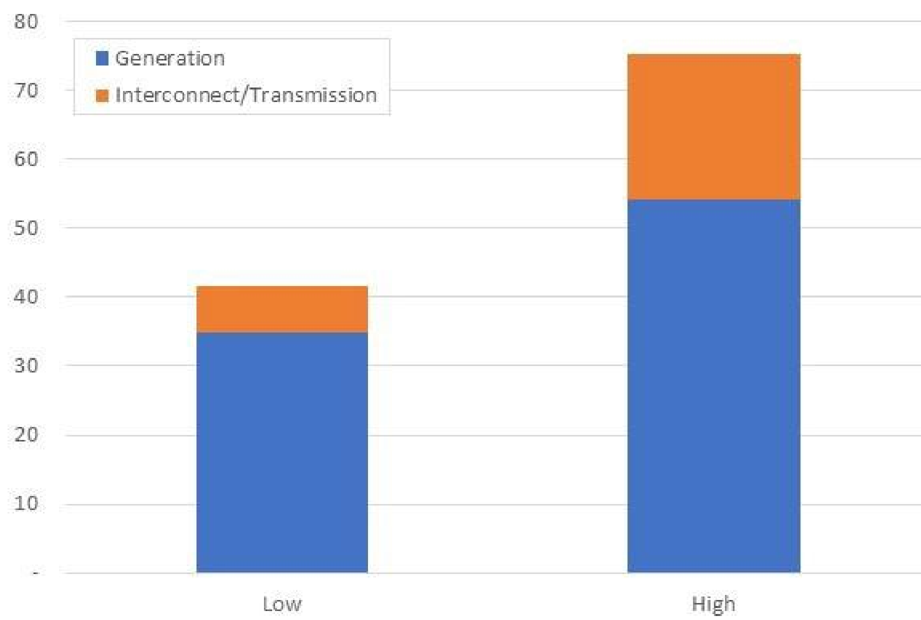
[5] United States Energy Information Administration. Annual Energy Outlook 2022. March 3, 2022. eia.gov/outlooks/aeo/.

[6] Lazard. Levelized Cost of Energy, Levelized Cost of Storage, and Levelized Cost of Hydrogen. October 28, 2021. lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/.

Initiative on Offshore Wind ("SIOW"),[7] and the ISO-NE Offer Review Trigger Price ("ISO-NE ORTP") Offshore Wind Analysis.[8] Cost projections include estimates for construction, operations, and decommissioning. We also considered the effect of the Inflation Reduction Act ("IRA") on the cost projections.[9]

Based on our review of the cost estimate sources, we developed a high and low-cost estimate for Maryland to procure 6,000 MW of offshore wind. The high and low values are intended to provide a range of potential costs and provide a band of potential uncertainty. The costs are shown on a levelized basis, meaning all the projected project costs are spread across all assumed production of the asset over its lifetime. Levelized costs are typically used to provide an "apples to apples" comparison of costs over the lifetime of a project. Our levelized cost of offshore wind incorporates many inputs, including but not limited to project costs, the cost of capital, the impact of depreciation and incentives on taxes, interest during construction, and other factors. The analysis is predicated on an assumed 30-year project life for offshore wind. Figure 1 shows the range of costs developed.

Figure 1. Weighted 2028-2031 Offshore Wind Levelized Cost of Energy (2021$/MWh)



[7]Kempton, W., L. Peterson, A. Bosteels, and K. Ohleth. 2022. Offshore Wind Procurement Options for Delaware. Special Initiative on Offshore Wind at the University of Delaware. cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/e/10028/files/2022/04/DE-OSWProcurement-SIOW-27Feb2022-3.pdf.

[8]New England ISO. Summary of 2026-2027 Offer Review Trigger Price Review. March 3, 2022. iso-ne.com/static-assets/documents/2022/03/2026-2027-ccp-forward-capacity-auction-17-iso-offer-review-trigger-price.xlsm.

[9] Inflation Reduction Act of 2022. H.R. 5376. 17th United States Congress. congress.gov/bill/117th-congress/house-bill/5376.

The levelized cost of offshore wind generation is expected to range between $35 and $55 per MWh, not inclusive of interconnection and transmission. Including interconnection and transmission, the total levelized cost is expected to be between $40 and $75 per MWh. The transmission and interconnection costs are significant, estimated at 15% of the total levelized cost for the low case and 30% for the high case.

Benefits of Offshore Wind

Energy and environmental benefits to ratepayers are quantified in this analysis. Ratepayer energy benefits provide direct revenues or savings that can offset some or all of the total costs of offshore wind projects. Environmental benefits are estimated based on displaced fossil fuel air pollution damages. We quantified the following benefits for this analysis:

1. Energy revenues – As offshore wind projects deliver energy into wholesale power markets, the revenues from the sale of this energy will flow back to customers as a reduction in costs. This credit is consistent with how Maryland has arranged previous offshore wind procurement requirements.

2. Capacity revenues – Offshore wind projects earn revenue from the wholesale capacity market, which will flow back to customers as a reduction in costs. This credit is consistent with how Maryland has arranged previous offshore wind procurement requirements.

3. Energy merit order – Offshore wind projects increase the available energy supply in the wholesale power market. The increase in supply will result in decreased prices to customers because energy from offshore wind, which has no fuel cost, goes into the bottom of the supply stack and reduces the market price for energy. This benefit will flow back to customers through reduced wholesale power prices. This impact is recognized by Maryland regulators as a value of new resources.

4. Capacity merit order – Offshore wind projects increase the amount of generation capacity participating in the wholesale capacity market auction. The increase in supply will result in a decreased price for customers. This benefit will flow back to customers in the form of reduced wholesale capacity prices. This impact is recognized by Maryland regulators as a value of new resources.

5. Avoided renewable energy credit purchases – This benefit reflects the value of avoiding additional costs associated with complying with the Maryland Renewable Portfolio Standard ("RPS"). Energy from offshore wind is a renewable resource and qualifies in many jurisdictions for renewable energy certificates, thereby reducing the need to purchase renewable energy certificates from other technologies. This

impact is recognized by Maryland regulators as a value of renewable supply resources.

We also quantified the environmental benefits associated with reductions in air pollution. Traditional fossil fuel generation produces harmful air pollution, including carbon dioxide ("CO_2"), sulfur dioxide ("SO_2"), and nitrogen dioxide ("NO_X"). These pollutants are avoided when offshore wind energy production displaces fossil fuel generation. For these benefits, using nationally and internationally accepted valuations of emissions reductions, we estimated the displaced air emissions for the life of the projects and quantified the economic value associated with the avoided damages from harmful air emissions.

The table below shows the present value of lifetime benefits for each benefit category in millions of real 2021 dollars and levelized real 2021 dollars per MWh.

Table 1. NPV of Lifetime Benefits of Adding 6,000 MW of Offshore Wind (2021$ millions and 2021$/MWh)

Benefit	$millions	$/MWh
Energy	17,287	43.12
Capacity	596	1.49
Avoided RPS	337	0.84
Energy Merit Order	2,880	7.18
Capacity Merit Order	365	0.91
Avoided CO_2 Damages	15,861	39.57
Avoided SO_2 Damages	7,257	18.10
Avoided NO_X Damages	632	1.58
Total	**45,215**	**112.79**

An additional benefit of offshore wind development is the local and regional economic development that occurs during the development, construction, operations, and decommissioning of offshore projects. These benefits are primarily driven by spending associated with construction and operations in the local economy across all phases of the project. While we do not provide detailed modeling or quantify macro-economic benefits impacts in this Report, we expect that adding 6,000 MW of offshore wind generation would stimulate significant economic growth in the region. Maryland's most recently approved offshore wind projects promised to generate significant benefits. The Skipjack 2 and Momentum Wind projects are expected to generate over 10,000 job-years and increase Maryland's GDP by over $1 billion over the life of the projects.[10] In New Jersey, the Board of

[10] Skipjack Offshore Energy, LLC and US Wind, Inc.'s Offshore Wind Applications under the Clean Energy Jobs Act of 2019. Order No. 90011 in Case No. 9666. Maryland Public Service Commission. December 17, 2021.webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/Casenum/9600-9699/9666/102.pdf.

Public Utilities announced two offshore wind projects totaling 2,658 MW, which are expected to generate $3.5 billion in economic benefits, while creating approximately 7,000 job-years over the life of the new plants.[11] The 6,000 MW contemplated in this analysis is 3.5 times the size of previously approved Skipjack and US Wind projects in Maryland and therefore the jobs and benefits created from investment in 6,000 MWs of offshore wind could significantly exceed those delivered from the previous projects.

This Report focuses on the primary costs and benefits associated with offshore wind deployment. This approach provides policymakers with the tools to make an informed decision on the potential range of net-benefits that could accrue from offshore wind. It provides a tool for policymakers to decide whether continued offshore wind development off the coast of Maryland is cost-effective. When the time comes to evaluate actual offshore wind project proposals, decision-makers may choose to consider additional benefits and costs that are outside of the scope of this analysis.[12]

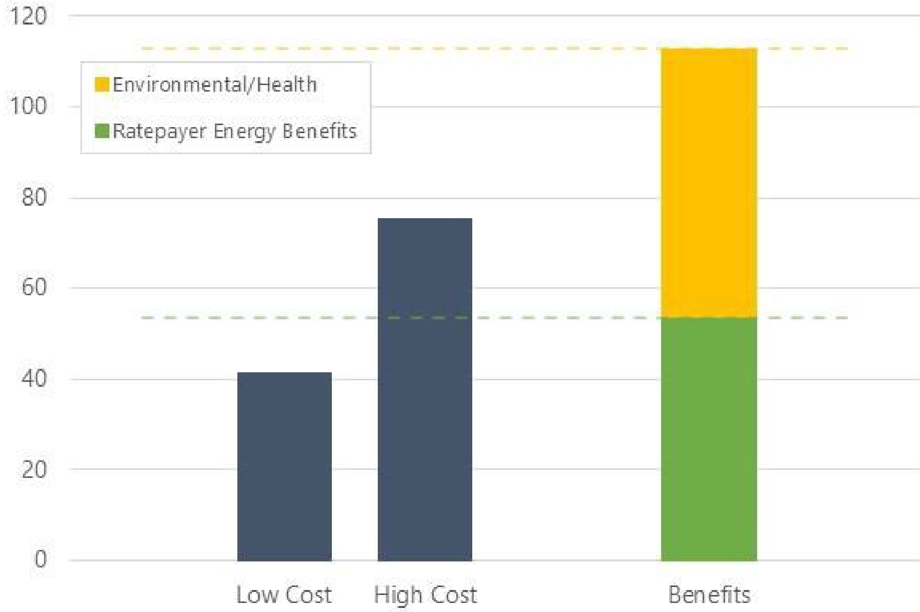
Findings and Conclusion

This Report analyzes a range of potential costs and provides a 'low' and 'high' case cost estimate. Comparing the cost estimates against projected benefits provides an evaluation of the level of net-benefits which are associated with offshore wind capacity of 6,000 MW could provide to Maryland. The figure below illustrates the low and high levelized cost estimates compared against the expected benefits from offshore wind. Costs are provided on the left-hand side of the figure. Benefits are shown to the right of the cost estimates, with ratepayer benefits in green and environmental and health benefits in yellow. All values are provided in real 2021 dollars per MWh.

[11] New Jersey Board of Public Utilities. "NJBPU Announces Nationals' Largest Combined Offshore Wind Award to Atlantic Shores and Ocean Wind II." June 30, 2021. nj.gov/bpu/bpu/newsroom/2021/approved/20210630.html.

[12] These included items such as benefits related to impacts on the State's Gross Domestic Product, job creation, water savings, gas demand reduction induced price effects, other avoided emissions and pollutants, and many more; as well as costs such as in-state manufacturing incentives, economic development costs, or other costs outside of the direct project costs. Impacts related to fishing, wildlife, recreation, vessel routing, and other effects from offshore wind, both positive and negative, may also be considered during the procurement and award process.

Figure 2. Levelized Offshore Wind Cost and Benefit Comparison (2021$/MWh)

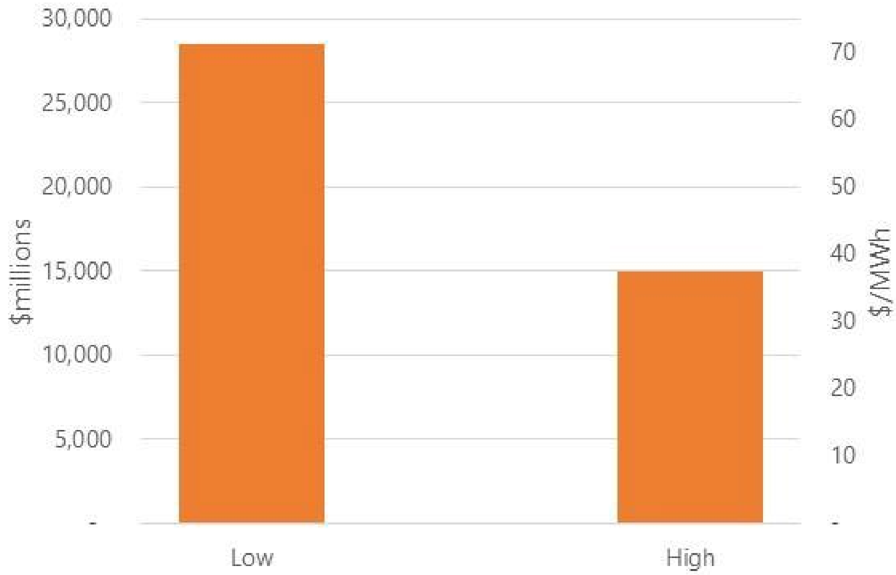


Under the low-cost scenario, we expect ratepayer energy benefits, including energy revenues, capacity revenues, avoided RPS costs, energy merit order, and capacity merit order, to exceed costs. That means that deployment of offshore wind will return ratepayer energy benefits greater than its costs. When accounting for environmental and health benefits, the net benefits greatly exceed costs. Lifetime impacts range between $4.7 billion and $28.5 billion in present value terms for net ratepayer energy benefits and total benefits including ratepayer energy benefits and environmental health benefits, respectively.

Under the high-cost scenario, costs are expected to exceed ratepayer energy benefits, meaning that ratepayer energy benefits would not completely offset costs. However, when accounting for environmental and health benefits, total benefits would exceed even the “high” levelized cost estimate. Environmental benefits are especially critical to consider because Maryland is relying on additional renewable energy generation to meet climate emissions reduction goals. Lifetime impacts range between a cost of $8.7 billion and a benefit of $15.0 billion in present value terms for net ratepayer energy benefits and total benefits including ratepayer energy benefits and environmental health benefits, respectively.

The figure below provides an illustration of the total net-benefits for the low- and high- cost scenarios. All values are provided in present valued millions of real 2021 dollars and real 2021 dollars per MWh.

Figure 3. Net Benefits (ratepayer + environmental benefits) of Offshore Wind (2021$ millions and 2021$ per MWh)



The analysis presented in this Report can provide clarity and guidance as Maryland evaluates the economic costs and benefits of additional offshore wind development and considers setting offshore wind energy development goals to meet the state's climate commitments.

1 INTRODUCTION

In 2013, Maryland passed the Maryland Offshore Wind Energy Act. The law revised Maryland's existing renewable energy portfolio standard ("RPS") and created a carveout requirement for offshore wind. In 2017, the Maryland Public Service Commission ("PSC") announced approval of two proposed offshore wind projects, Skipjack and US Wind, totaling 368 megawatts ("MW").[13] Maryland's RPS was updated again after the passage of the 2019 Clean Energy Jobs Act, which required an additional 1,200 MW of offshore wind through additional rounds of new procurement through the PSC.[14] In 2021, the PSC approved two additional projects, Skipjack Phase 2 and Momentum Wind, totaling 1,654 MW.[15] In total, the PSC has already approved over 2 GW of new offshore wind generation, which is expected to be in service by 2026.

In 2022 Maryland passed the Climate Solutions Now Act,[16] which established an ambitious target to reduce statewide greenhouse gas emissions by 60% from 2006 levels by 2031 and achieve net-zero emissions by 2045. The law directs the Maryland Department of the Environment to develop an action plan to meet the targets by June 2023. While the Act does not specifically require offshore wind to meet emissions reduction targets, the development of in-state carbon-free resources will be critical to meeting its targets.

Offshore wind is a key zero-emission resource that can be developed in-state to meet the targets passed in the Climate Solutions Now Act. Offshore wind energy production produces many economic and environmental benefits. Local and regional economies are stimulated through development, construction, operations, and decommissioning activities. Because the offshore wind industry is still relatively new in the United States, new projects are driving the development of several new industries on the Eastern Seaboard. Environmental benefits are created through the displacement of fossil fueled generation sources that currently serve Maryland's electric demand to reduce greenhouse gas emissions, as well as other pollutants.

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[13] In The Matter of the Applications of U.S. Wind, Inc. and Skipjack Offshore Energy, LLC for a Proposed Offshore Wind Projects Pursuant to the Maryland Offshore Wind Energy Act Of 2013. Maryland Public Service Commission. Order No. 88192 in Case No. 9431. psc.state.md.us/wp-content/uploads/Order-No.-88192-Case-No.-9431-Offshore-Wind.pdf.

[14] Clean Energy Jobs Act of 2019. Maryland General Assembly. mgaleg.maryland.gov/mgawebsite/Legislation/Details/SB0516?ys=2019rs.

[15] Skipjack Offshore Energy, LLC and US Wind, Inc.'s Offshore Wind Applications under the Clean Energy Jobs Act of 2019. Maryland Public Service Commission. Order No. 90011 in Case No. 9666. psc.state.md.us/wp-content/uploads/Order-No.-90011-Case-No.-9666-Order-Granting-Offshore-Wind-Renewable-Energy-Credits.pdf.

[16] Climate Solutions Now Act of 2022. Maryland General Assembly. mgaleg.maryland.gov/mgawebsite/Legislation/Details/sb0528.

Gabel Associates, Inc ("Gabel") was engaged by the Chesapeake Climate Action Network ("CCAN") to conduct an independent study focused on the impacts of offshore wind development to meet the goals of the Climate Solutions Now Act. Specifically, this Report analyzes the expected costs and benefits of offshore wind development that could be utilized to reach the 60% target by 2031 and provides a potential range of outcomes that offer stakeholders and policy-makers guidance on the next steps to realize the benefits of offshore wind.

This analysis is built through the following steps:

1. We describe an identified development schedule for Maryland to procure additional offshore wind projects;
2. We provide an overview of offshore wind energy costs, with an emphasis on forecasting and understanding specific categories of project costs;
3. We describe our methodology and provide the results for estimating future benefits and project revenues for the assumed offshore wind projects; and
4. We provide an overview of our forecast, providing the results of the projected net benefits.

1.1 About Gabel Associates

Gabel Associates is an energy, environmental and public utility consulting firm that has provided highly focused and specialized energy consulting services and strategic insight to its clients for nearly 30 years. Gabel Associates has applied its expertise to drive success for hundreds of clients involved in virtually every sector of the energy industry. The firm has built its reputation on its extensive knowledge and rigorous analysis of wholesale and energy markets. We have successfully assisted public and private sector clients implement energy projects and programs that reduce costs and enhance environmental quality. The firm possesses strong economic, financial, project development, technical, and regulatory knowledge.

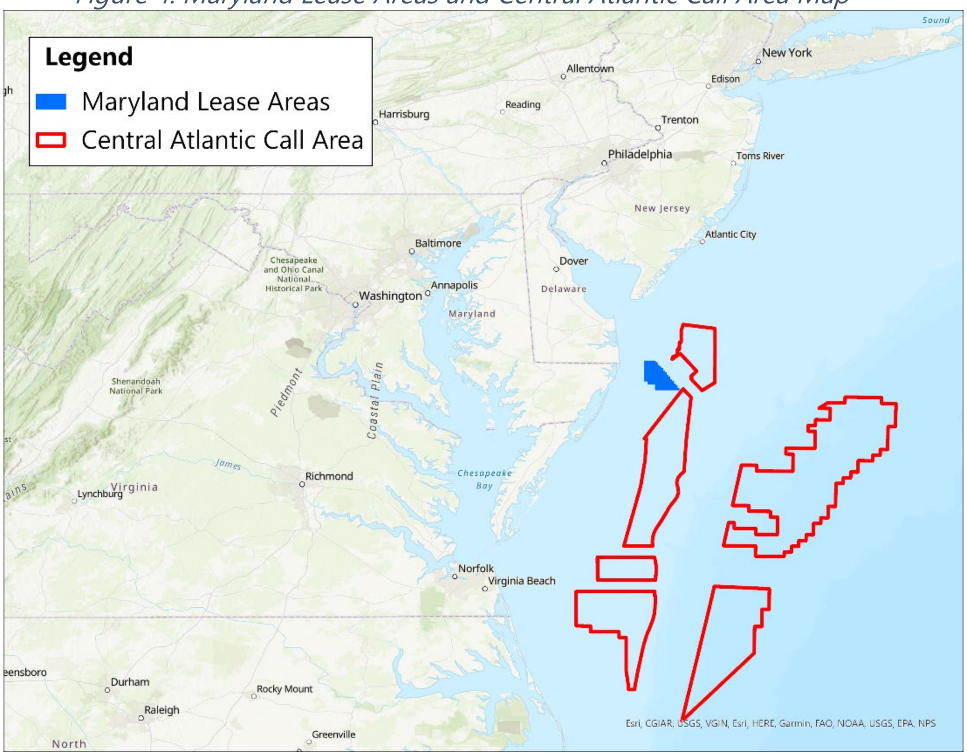
Gabel Associates has analyzed actual offshore wind projects in the United States and been a part of project teams that have been successfully awarded projects. Our work on these projects has focused on economic, net-benefit, and ratepayer analysis.

The firm has extensive experience analyzing Maryland energy issues. Gabel Associates supported the State of Maryland Public Service Commission ("PSC") with the evaluation of interconnection issues for offshore wind transmission development. Our role included estimating the need for transmission upgrades and helping the Maryland PSC understand the PJM interconnection process and its associated costs as it relates to offshore wind development. The firm authored a report evaluating the benefits of energy-efficiency programs for low-income customers in Maryland. We provided strategic planning, modeling and analysis, offer design and implementation support, tariff design development, forecasting and benchmarking, benefit/cost analysis, expert testimony, and general subject matter expertise on a range of electric vehicle topics to DPL, PEPCO, BG&E, and Potomac Edison in Maryland. The firm also provided expert testimony before the Maryland PSC regarding the Exelon/Pepco merger.

2 SCENARIO AND METHODOLOGY OVERVIEW

This Report evaluates the potential costs and benefits of expanding offshore wind generation in Maryland. The analysis is predicated on a policy scenario from CCAN, which assumes 6,000 MW of new offshore wind, with commercial deployment beginning in 2028. This incremental offshore wind capacity will likely be located in the Central Atlantic Call Area, which is located off the coasts of Delaware, Maryland, Virginia, and North Carolina. The figure below shows the existing Maryland Lease Area and the Central Atlantic Call Area.

Figure 4. Maryland Lease Areas and Central Atlantic Call Area Map[17, 18]



The 6,000 MW by 2031 policy scenario is ambitious but achievable and aligns with the target of 60% reduction in greenhouse gases by 2031 contained in the Climate Solutions Now Act. We assume 1,500 MW of new offshore wind generation will be installed per year beginning in 2028 and ending in 2031.

Both cost and production assumptions in this analysis are sourced from various peer-reviewed, established, and industry standard studies and resources. This includes the National

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17 United States Bureau of Ocean Energy Management Maryland Lease Area. boem.gov/renewable-energy/state-activities/maryland-activities.

18 United States Bureau of Ocean Energy Management Central Atlantic Call Area. boem.gov/renewable-energy/state-activities/central-atlantic.

Renewable Energy Laboratory ("NREL"),[19] the Energy Information Agency ("EIA"),[20] Lazard,[21] the University of Delaware Special Initiative on Offshore Wind ("SIOW"),[22] and the ISO-NE Offer Review Trigger Price ("ISO-NE ORTP") Offshore Wind Analysis.[23] Costs projections include estimates for construction, operations, maintenance, and decommissioning. According to these sources, future offshore wind projects are expected to produce energy with a capacity factor between 45% and 58%. This analysis assumes a capacity factor of 50%, consistent with the low-end estimate used by EIA in the 2022 Annual Energy Outlook.[24] While we do not evaluate specific interconnection pathways or transmission upgrades, it is likely the offshore wind projects will connect through the Delmarva peninsula and also be deliverable into Baltimore Gas and Electric ("BGE") service territory.

These studies range in assumptions and outcomes but are similarly focused on future time periods. For example, NREL produces a 'conservative', a 'moderate', and an 'advanced' technology innovation scenario when developing forward-looking estimates of costs for the period 2028 through 2031. The conservative technology innovation scenario assumes the continued use of 12 MW turbines installed by existing and announced installation vessels. The advanced technology innovation scenario assumes next-generation drivetrain and blade materials that enable 18 MW turbines, growth in the supply chain with accelerated standardization, large economies of scale, and increased competition.

The SIOW study incorporates a two-part review to determine the potential costs of offshore wind. The first approach is a trend-based analysis that adjusts past offshore wind contract prices based on expected price trends derived from a survey of market participants. The second approach utilized by SIOW leverages a bottom-up financial analysis for actual cost estimates for specific project configurations off the coast of Delaware. The combination of these approaches provides the SIOW report with a range of outcomes for consideration.

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[19] United States National Renewable Energy Laboratory. Annual Technology Baseline. Accessed September 2022. atb.nrel.gov/.

[20] United States Energy Information Administration. Annual Energy Outlook 2022. March 3, 2022. eia.gov/outlooks/aeo/.

[21] Lazard. Levelized Cost of Energy, Levelized Cost of Storage, and Levelized Cost of Hydrogen. October 28, 2021. lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/.

[22] Kempton, W., L. Peterson, A. Bosteels, and K. Ohleth. 2022. Offshore Wind Procurement Options for Delaware. Special Initiative on Offshore Wind at the University of Delaware. cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/e/10028/files/2022/04/DE-OSWProcurement-SIOW-27Feb2022-3.pdf.

[23] New England ISO. Summary of 2026-2027 Offer Review Trigger Price Review. March 3, 2022. iso-ne.com/static-assets/documents/2022/03/2026-2027-ccp-forward-capacity-auction-17-iso-offer-review-trigger-price.xlsm.

[24] United States Energy Information Administration. Renewable Fuel Module. March 2022. eia.gov/outlooks/aeo/assumptions/pdf/renewable.pdf.

The analytical approach to estimating offshore wind costs is intended to provide a reasonable range of potential costs. As evidenced by the varied assumptions contained in the source documents, expectations differ across the industry on the types of available technologies, development of supply chains, and availability of expert workforce to construct and maintain offshore wind projects. By drawing from the results of many expert analyses, this Report provides a projection of possible outcomes for offshore wind costs from 2028 through 2031. This reasonable bandwidth of outcomes can be used by stakeholders, policymakers, and interested parties to understand cost implications and begin to plan for the next stage of offshore wind projects in Maryland.

The cost estimates in this Report are compared with potential project revenues and benefits to provide a complete evaluation of the cost impacts of offshore wind to Maryland electricity customers. Because this Report intends to evaluate a policy aiming to help Maryland reach climate-related goals, we also quantify environmental and health-related benefits. This cost-benefit approach is consistent with that used in the evaluation of offshore wind projects throughout the country and provides a fair and balanced assessment of the quantifiable costs and benefits of offshore wind. It also aligns with the offshore wind funding mechanisms for Maryland's currently approved offshore wind projects,[25] which states that offshore wind projects must sell all energy, capacity, and ancillary services associated with the creation of ORECs and distribute the proceeds received from those sales to be refunded or credited to customers in the State of Maryland.[26]

This Report focuses on the primary costs and benefits associated with offshore wind deployment. This approach provides policymakers with the tools to make an informed decision on the potential range of net-benefits that could accrue from offshore wind. It provides a tool for policymakers to decide whether continued offshore wind development off the coast of Maryland is cost-effective. When the time comes to evaluate actual offshore wind project proposals, decision-makers may choose to consider additional benefits and costs that are outside of the scope of this analysis. These included items such as benefits related to impacts on the State's Gross Domestic Product, job creation, water savings, gas demand reduction induced price effects, other avoided emissions and pollutants, and many more; as well as costs such as in-state manufacturing incentives, economic development costs, or other costs outside of the direct project costs. Impacts related to fishing, wildlife, recreation, vessel routing, and other effects from offshore wind, both positive and negative, may also be considered during the procurement and award process.

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[25] As expressed in Article II, Section 17(c) of the Maryland Constitution - Chapter 578 that contains the Maryland Renewable Energy Portfolio Standard and Renewable Energy Credits – Offshore Wind Act, passed in May of 2022

[26] Renewable Energy Portfolio Standard and Renewable Energy Credits. Maryland General Assembly. mgaleg.maryland.gov/mgawebsite/Legislation/Details/sb0526.

3 COSTS OF OFFSHORE WIND

While offshore wind projects have been developed globally for approximately 30 years, in the United States their development has been underway for about a decade. In the context of electricity-generating resources, especially within the United States, this means offshore wind technology is still developing. Because of this and other reasons, offshore wind has to date not been price competitive. However, with advancements in technology and the development of the offshore wind supply chain, offshore wind may be competitive with other resources over the time frame analyzed here.

Determining how offshore wind compares to other technologies is a two-step process. The first step is to evaluate the total cost of offshore wind. This section explores that topic and provides an estimated cost range for offshore wind in the expected implementation period of 2028 through 2031.

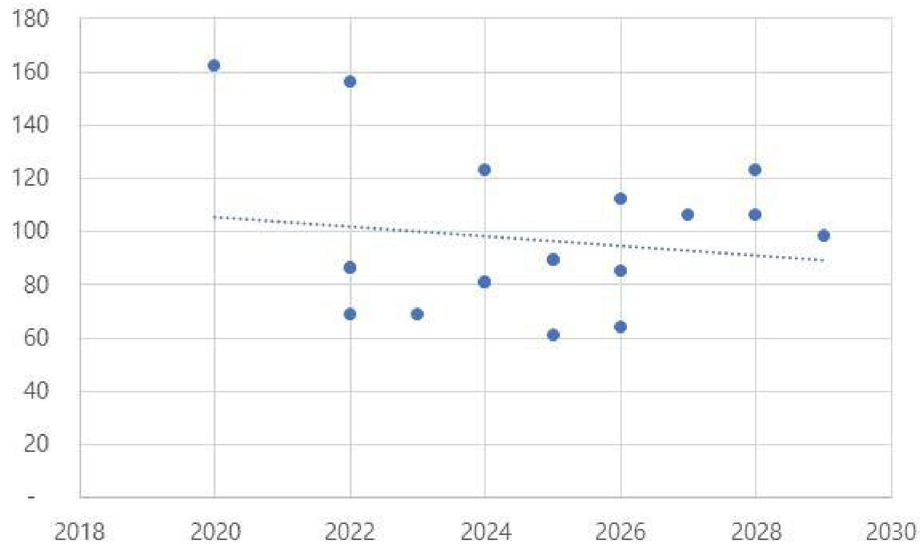
The first portion of this section reviews the history of offshore wind contracts and discusses why these may not be applicable in estimating future project costs. The second portion of this section reviews cost estimates for the implementation period that are sourced from commercially available and established industry resources. These estimates are predominantly for the period of 2028 through 2031, meaning that they incorporate expectations related to component costs, technological advancements, evolving supply chains, and other factors. We have also considered a range of estimates to provide a reasonable range of potential costs.

3.1 Historical Costs in the United States

Several offshore wind projects have been approved for construction in the United States; however, very few have entered commercial operation. The currently approved projects have come through competitive state procurement efforts which require the purchase of offshore wind energy through the state's electric utilities. This has been done through power purchase agreements ("PPA") or an obligation to purchase offshore wind renewable energy certificates ("OREC"). Under both mechanisms, states (or utilities) are effectively required to purchase energy and capacity from approved offshore wind projects. The PPA or OREC price of prior projects reveals historical offshore wind project prices, and thus are an indicator of costs. However, significant differences exist among the state procurement efforts which limit the usefulness of direct comparisons between the price results.

The figure below illustrates the approved levelized PPA/OREC for approved offshore wind projects in the United States.[27] Values are provided in real 2021 dollars per MWh.

Figure 5. Levelized PPA/OREC Prices of Approved U.S. Offshore Wind Projects (2021$/MWh)



The figure shows the price results for the approved projects in the United States through June 2020. The results show a wide range of prices, which are explained by several factors. Earlier and smaller projects generally have higher prices. These price results should only be used as a qualitative information source due to other factors affecting price. Some of these factors include:

1. Inclusion of Transmission Costs: The installation of offshore wind projects typically requires offshore or onshore transmission upgrades to facilitate the new and increased injection of electricity into the existing transmission grid. Some approved projects include transmission costs in the price, while others did not. It is also unclear the extent of upgrades that were forecasted for each project, and so the extent of the effects of the inclusion of transmission costs on price may vary across the projects.

2. Local Content: Many states required (or strongly encouraged) bidders to include additional economic investments such as factory development, local hiring, and/or sourcing local manufacturing content in offshore wind proposals. The level of investment varies by proposal, thus making comparisons between them challenging.

[27] PPA and OREC prices were sourced from jurisdictional approval documents and orders. Prices were converted to a 2021$ basis using a price deflator developed from GDP data sourced from the U.S. Bureau of Economic Analysis.

3. Other Limitations: In addition to the mentioned limitations, prices may vary due to differences in methods of project cost calculations, project subsidies, access to capital, access to manufacturing materials, risk tolerance, amount of energy risk absorbed by the developer, and other unforeseen circumstances.

Given these differences, as well as changes in cost and technology over time, we do not recommend using historic PPA or OREC costs as an indicator of future costs of offshore wind development in Maryland.

3.2 Levelized Cost Analysis and Approach

Levelized cost of energy ("LCOE") is a metric used by economists and policymakers to evaluate alternative technologies and sources of energy on a common basis. LCOE unitizes total project costs on a per megawatt hour ("MWh") basis so that if multiplied against the total lifetime production of the resource, it would equal the total costs on a present value basis. LCOE is also useful because it provides a single, understandable price estimate that is easily comparable to the cost of energy from other sources.

We utilize a fixed cost rate approach which incorporates project costs, the cost of capital, the impact of depreciation and incentives on taxes, interest during construction, and other factors to calculate the levelized cost that would be required to pay for all offshore wind costs over its assumed lifetime. The analysis is predicated on an assumed 30-year project life for offshore wind. From an LCOE perspective, that means that the costs occur over a 30-year period. To the extent cost recovery were to occur over a shorter period (such as the 20-year period contained in Maryland's previous offshore wind procurements) the calculated LCOE would differ.

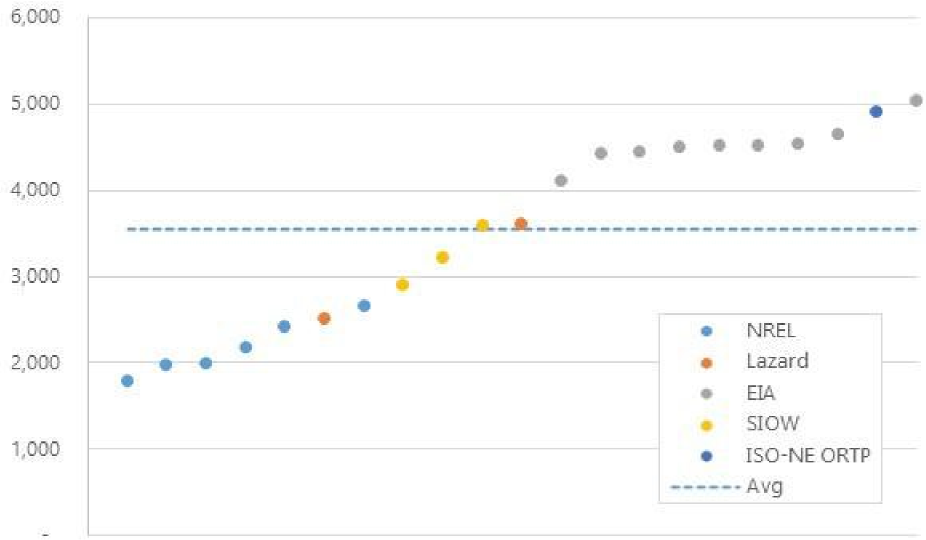
Offshore wind costs are broken into three separate categories: (1) overnight capital construction costs; (2) interconnection and transmission costs; and (3) fixed operating costs. As stated previously, cost estimates were sourced from numerous publicly available estimates, including from NREL, Lazard, EIA, SIOW, and the ISO-NE ORTP.

3.2.1 Overnight Generation Capital Construction Cost

Offshore wind overnight generation capital construction costs represent the cost to construct an offshore wind facility without accounting for interest during construction. Overnight costs are a useful metric to compare costs across different types of resources. Our overnight capital construction costs include most offshore wind cost components, including items such as turbines, nacelles, foundations, monopiles, the balance of plant equipment, and decommissioning. The overnight capital construction costs do not include interconnection and transmission-related costs, which were removed from the estimates and evaluated separately. Sources are publicly available and peer reviewed.

Cost estimates are assembled from five separate sources representing a range of 21 different overnight cost estimates for the evaluated period between 2028 and 2031. These sources provide forecasted cost estimates that take into consideration expected advancements in technologies and changes to component costs. The graphic below illustrates the array of benchmarked data for overnight construction cost estimates for offshore wind in 2028. All values are provided in real 2021 dollars per kW installed.

Figure 6. 2028 Offshore Wind Overnight Generation Construction Cost Estimates (2021$/kW)



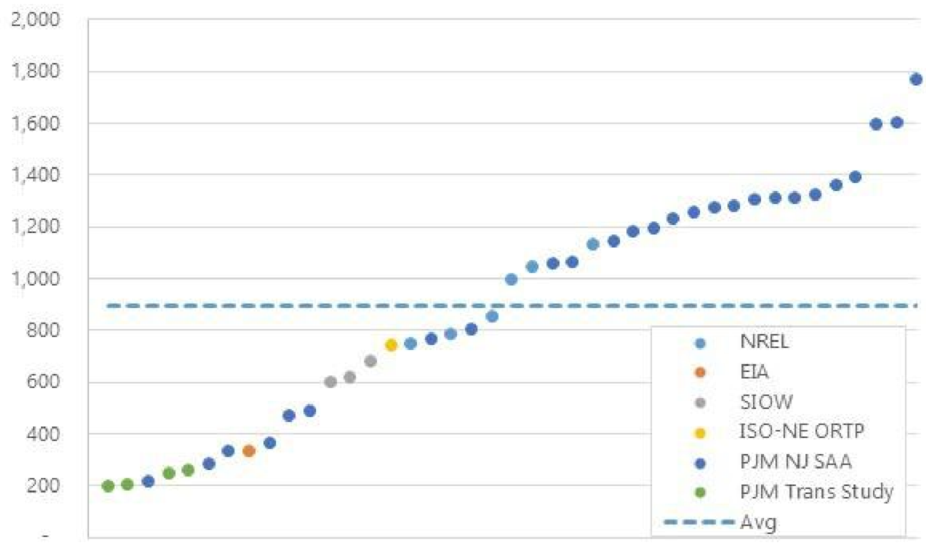
Overnight cost estimates range from below $2,000 per kW to above $5,000 per kW in real 2021 dollars. The average overnight cost for offshore wind in 2028 is approximately $3,500 per kW.

3.2.2 Interconnection and Transmission Cost

Interconnection and transmission costs are separated in this analysis from the offshore wind overnight capital costs to isolate these costs. Injecting power from a new source has ripple effects across the transmission system which may necessitate significant grid upgrades. The interconnection upgrades can be costly and time-consuming to implement. Transmission upgrade costs are unique to each project due to varied electricity system topology, interconnection points, peak loads, existing and planned infrastructure, and many other factors. Because of this, we do not model specific transmission options or scenarios to interconnect 6,000 MW to Maryland's existing transmission system. Our analysis evaluates interconnection and transmission costs that have been included or proposed in other jurisdictions or in other studies to provide a range of potential outcomes. In addition to the sources listed above, we also included estimates from PJM on potential interconnection and transmission costs.[28,29] Actual costs will need to be determined through extensive analysis and modeling of specific offshore wind projects, their exact interconnection points, and the impact of injecting new generation at those electric nodes. The approach we use in this analysis allows policymakers to understand the potential range of outcomes prior to conducting an in-depth analysis of specific project proposals.[30]

Cost estimates are assembled from six separate sources representing 41 different offshore wind interconnection and transmission cost estimates. The graphic below illustrates the array of benchmarked data for interconnection and transmission costs of offshore wind in 2028. All values are provided in real 2021 dollars per kW installed.

Figure 7. 2028 Offshore Wind Interconnection and Transmission Cost Estimates (2021$/kW)



Interconnection and transmission cost estimates range from below $200 per kW to above $1,700 per kW in real 2021 dollars. The average interconnection and transmission cost for offshore wind is approximately $900 per kW.

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[28] PJM Interconnection LLC. 2021 SAA Proposal Window to Support NJ OSW - Transmission Expansion Advisory Committee. July 18, 2022. pjm.com/-/media/committees-groups/committees/teac/2022/20220718-special/item-01---nj-osw-saa.ashx

[29] PJM Interconnection LLC. Offshore Wind Transmission Study: Phase 1 Results. October 19, 2021. pjm.com/-/media/library/reports-notices/special-reports/2021/20211019-offshore-wind-transmission-study-phase-1-results.ashx

[30] An example of the time and effort needed to determine these costs is demonstrated by New Jersey's State Agreement Approach process, which began in November of 2020 and recently awarded projects in October of 2022.

3.2.3 Fixed Operating Cost

Unlike fossil-fueled electric generating resources, offshore wind has no variable operating or fuel costs. However, these facilities require ongoing maintenance to ensure they function properly. These operating costs are required regardless of the amount of generation an offshore wind facility produces (i.e. they must be maintained whether the wind is blowing fast or slow), which is why we refer to these costs as "fixed".

Cost estimates are assembled from five separate sources representing 13 different fixed operating cost estimates. The graphic below illustrates the array of benchmarked data for fixed operating costs of offshore wind in 2028. All values are provided in real 2021 dollars per kW installed per year.

Figure 8. 2028 Offshore Wind Fixed Operating Cost Estimates (2021$/kW-yr)

Fixed operating cost estimates range from below $60 per kW-year to above $115 per kW-year in real 2021 dollars. The average fixed operating cost for offshore wind is estimated to be approximately $85 per kW-year.

3.2.4 Inflation Reduction Act

The Inflation Reduction Act ("IRA") provides significant new and extended incentives for renewable energy and reducing carbon emissions, including for the development of offshore wind and related interconnection and transmission costs.[31]

[31] Inflation Reduction Act of 2022. congress.gov/bill/117th-congress/house-bill/5376/text.

The IRA extends and expands both the production tax credit ("PTC") and the investment tax credit ("ITC") for relevant renewable energy projects that are placed in service before 2024. Following 2024, both credits will transition to a technology-neutral credit through 2033.

The updated ITC (beginning after 2024) provides developers with a tax credit of 6% of total project costs. The credit can be increased based on four bonus or "adder" categories. Offshore wind projects can qualify for two of these adders:

1. Prevailing wage and apprenticeship adder:[32] Projects that meet prevailing wage and apprenticeship requirements will be eligible for an increased base credit from 6% to 30% of eligible construction costs. These requirements include maintaining prevailing wage for construction, alteration, or repair services for a duration of five years after the project is placed in service and ensuring that the applicable percentage of the total labor hours dedicated to these tasks are performed by qualified apprentices. The applicable percentage ranges between 10% and 15% depending on the date on which construction begins.

2. Domestic Content Adder:[33] Offshore wind projects that use 100% of steel and iron and 20% of manufactured products that are produced in the United States are eligible for a bonus adder of 10% if the prevailing wage and apprenticeship requirements have been met, and 2% if they have not. This will increase the credit from 30% to 40% for projects that meet the prevailing wage and apprenticeship requirements, and from 6% to 8% for projects that do not.

The updated PTC (beginning after 2024) provides a base tax credit of $3.00 per MWh produced by the project.[34] Projects are eligible to receive the tax credit for ten years after commercial operation begins. The base tax credit value per MWh may be increased if specific conditions are met. Offshore wind projects can qualify for two of these adders:

1. Prevailing wage and apprenticeship adder:[35] Projects that meet prevailing wage and apprenticeship requirements will be eligible for five times the base credit, increasing it from $3.00 per MWh to $15.00 per MWh. These requirements include offering the prevailing wage for construction, alteration, or repair services for the duration of the ten-year tax credit and ensuring that the

[32] Ibid, page 102.

[33] Ibid, page 103.

[34] The credit is established in real 1992 dollars; however, the law provides for adjustment for inflation. At present, it is expected that the base credit would be equal to approximately $5.30 per MWh.

[35] Inflation Reduction Act of 2022, page 90. congress.gov/bill/117th-congress/house-bill/5376/text.

applicable percentage of the total labor hours dedicated to these tasks are performed by qualified apprentices. The applicable percentage ranges between 10% and 15% depending on the date on which construction begins[36].

2. Domestic Content Adder:[37] Offshore wind projects that use 100% of steel and iron and 20% of manufactured products that are produced in the United States are eligible for a bonus adder of 10% (only if the prevailing wage and apprenticeship requirements have been met).[38] This will increase the credit for projects that meet the prevailing wage and apprenticeship requirements.

The table below summarizes the ITC incentives made available in the IRA.

Table 2. Summary of ITC Incentives Available for Offshore Wind Projects

Base Credit	**6%**
Prevailing Wage and Apprenticeship Adder	**+24% (30%)**
Domestic Content Adder	**+10% if Prevailing Wage and Apprenticeship requirements are met (40%)** **+2% if Prevailing Wage and Apprenticeship requirements are not met (8%)**

Costs related to interconnection and transmission for offshore wind are not eligible for the ITC. However, the IRA does contain other incentives designed for interconnection and transmission costs.[39]

The IRA dedicates approximately $2.76 billion in grant and direct loan funding to finance transmission facility development as well as accompanying administrative and development costs. Of this, $2 billion is dedicated to transmission facility financing, to be made available through September 30, 2030. It is expected to fund direct loans and loan guarantees to non-Federal borrowers for the construction or modification of electric transmission facilities. In addition, the IRA provides $760 million in grants to facilitate the siting of inter-state electricity transmission lines.

[36] Ibid, page 249.

[37] Ibid, page 93.

[38] There are exceptions allowed in the IRA for these provisions.

[39] The IRA allows projects that are less than 5 MW to include interconnection costs as part of the costs eligible under the ITC. However, because offshore wind projects are significantly larger than 5 MW, their interconnection and transmission costs do not qualify for the ITC.

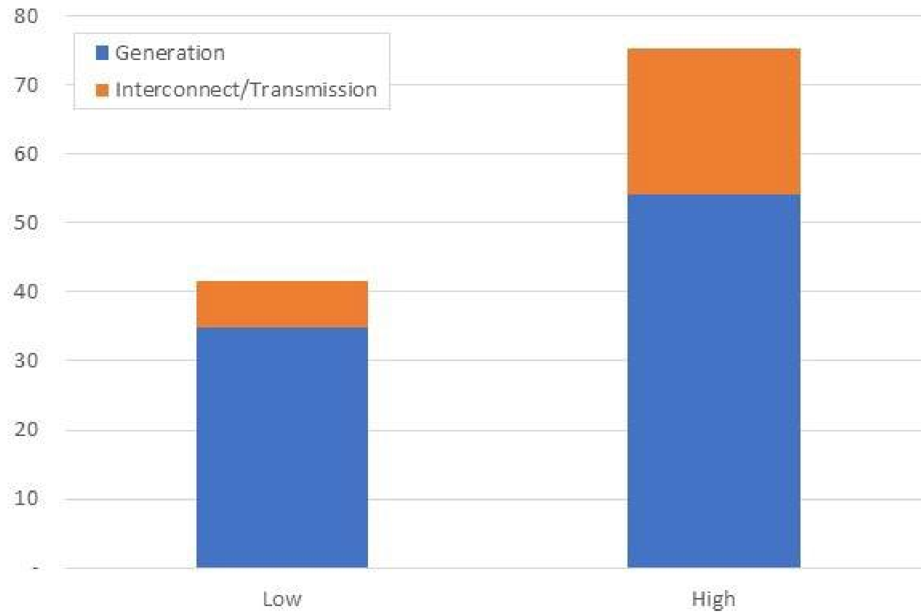
The analysis in this Report incorporates the ITC for offshore wind development. Specifically, it assumes satisfaction of the prevailing wage and apprenticeship requirements as well as the domestic content bonus, which provides for a total tax credit equal to 40% of eligible capital costs. To the extent the domestic content bonus cannot be achieved, it would likely increase the levelized cost of offshore wind by between $5 to $10 per MWh. We also reviewed the impact of selecting the PTC; however, it was determined that the ITC would be more advantageous for offshore wind projects.

There are several components of the IRA that will further impact the costs and development of offshore wind in the United States that were not explicitly included in the analysis. These include funding for the offshore wind supply chain, funding for clean energy permitting, loans for transmission projects, and grants for evaluating and studying interconnection and transmission issues. While these additional incentives were not included in the analysis, they stand to increase the viability of offshore wind development and buttress the conservative nature of this analysis.

3.2.5 Calculated Offshore Wind Levelized Cost of Energy

The benchmark cost data summarized above illustrates the varied nature of offshore wind capital costs, interconnection and transmission costs, and fixed operating costs. There are several factors that may change the future costs of offshore wind in Maryland. These factors include actual changes in technology, the development of offshore wind supply chains in the United States, economic conditions such as inflation and the cost of capital, and transmission constraints. Because of these factors, our analysis focuses on a range of potential levelized costs that capture the potential uncertainty of future outcomes. The table below compares a 'low' case and 'high' case levelized cost for offshore wind, broken out between offshore wind-related levelized cost and interconnection and transmission-related levelized costs for 2028 through 2031. The offshore wind-related levelized cost includes overnight capital costs and fixed operating costs discussed in sections 3.2.1 and 3.2.3 of this report, adjusted for impacts of the IRA. The Interconnection and transmission-related costs include the interconnection and transmission costs discussed in section 3.2.2 of this report. All values are provided in 2021 dollars per MWh.

Figure 9. Weighted 2028-2031 Offshore Wind Levelized Cost of Energy (2021$/MWh)



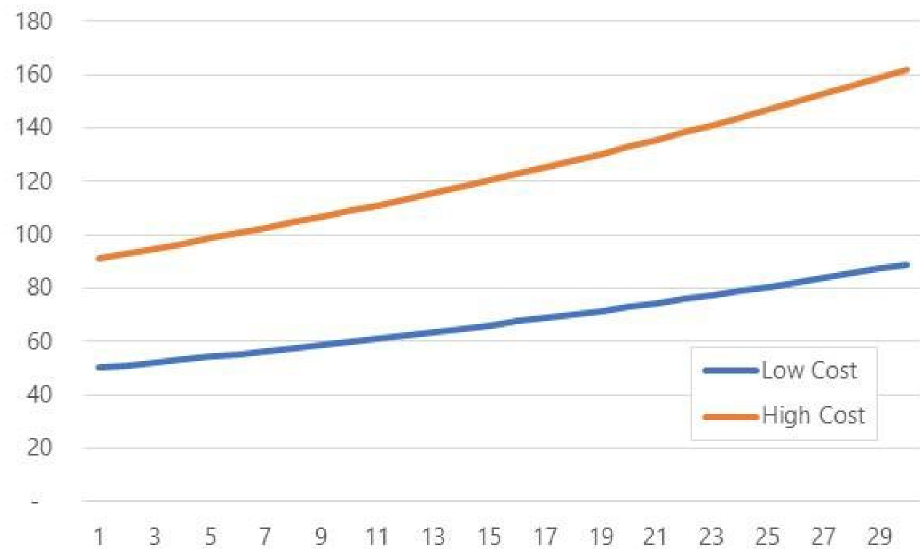
The levelized cost of offshore wind generation is expected to range between $35 and $55 per MWh, not inclusive of interconnection and transmission. Including interconnection and transmission, the total levelized cost is expected to be between $40 and $75 per MWh. The transmission and interconnection costs are significant, estimated at 15% of the total levelized cost for the low case and 30% for the high case.

The assumed levelization period used in determining the levelized cost also has a significant impact on the calculation. This analysis assumed a levelization period of 30 years, equal to the expected useful life of the projects. However, states such as Maryland and New Jersey have recently awarded OREC contracts over a twenty-year period. This means that offshore wind developers will look to recover costs over a twenty-year period rather than the entire thirty-year life. If costs are recovered over a period that is ten years shorter, more costs will have to be recovered each year, resulting in a higher OREC price. In this analysis, the total levelized cost would increase from a range of $40 to $75 per MWh over thirty years to $50 to $95 per MWh over twenty years in real 2021 dollars. Depending on the terms of the arrangement with the offshore wind developer, benefits could also be reduced if energy and capacity revenues do not flow back, either directly or indirectly, to customers following the twenty-year contract period. This is further discussed in Appendix B.

While levelized costs are useful for comparing alternatives on a common basis, a PPA or OREC mechanism, such as the OREC approach previously utilized in Maryland, typically transacts in nominal dollars. These arrangements also often incorporate an annual price escalation. Therefore, we also calculate the equivalent PPA or OREC price that would deliver the same present value returns to an offshore wind developer. This provides an estimate of what the actual offshore wind PPA or OREC contract cost in the year it occurs could be. On a non-levelized basis, assuming a 2.0% annual price escalator, it is expected that these projects would have a first-year nominal price of between $50 and $95 per MWh in 2028.[40] By year 20 (2047 for projects beginning in 2028), the nominal price ranges between $70 and $135 per MWh. The year 30 (2057 for projects beginning in 2028) nominal price with escalation ranges between $90 and $165 per MWh. Importantly, these nominal price estimates do not include the ratepayer energy benefits that accrue to customers, which directly offset these costs on electricity bills.

The figure below illustrates the comparison between the low- and high-cost scenario non-levelized price assuming a price escalator of 1.5% per year. Prices are provided in nominal dollars per MWh.

Figure 10. Offshore Wind Nominal Escalated PPA/OREC Cost Estimate ($/MWh)



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[40] The real levelized price calculated in this analysis was converted to nominal terms assuming 2% annual inflation.

4 BENEFITS OF OFFSHORE WIND

Offshore wind projects produce many benefits. Some benefits provide direct reductions in electricity costs to customers while others are societal in nature but do not directly reduce electricity costs. A primary benefit of offshore wind when compared to other forms of generation is significantly reduced air pollution. Traditional fossil fuel generation produces harmful air pollution, including carbon dioxide ("CO_2"), sulfur dioxide ("SO_2"), nitrogen dioxide ("NO_X"), particulate matter, and mercury. These pollutants are avoided when offshore wind energy production displaces fossil fuel generation. An additional primary benefit is the local and regional economic development that occurs during the development, construction, operations, and decommissioning of offshore projects.

For this analysis, we examine ratepayer energy and environmental benefits. Ratepayer energy benefits provide direct electricity cost reductions against the cost recovery for offshore wind projects by customers. In Maryland, under the current OREC mechanism, the cost to ratepayers of purchasing offshore wind energy is offset by energy, capacity, and ancillary service market revenues realized by a project, as well as the reduction in the need to purchase renewable energy certificates ("REC") from other resource types in order to meet Maryland's Renewable Portfolio Standard ("RPS"). Additionally, the energy and capacity from offshore wind projects place downward pressure on market prices, reducing costs for all market participants and ultimately retail customers.

Environmental benefits are estimated based on the displaced fossil fuel air pollution benefits. Reduced emissions from fossil fueled generation avoid health and social costs related to both ground-level air pollutants as well as greenhouse gas emissions driving climate change.

All these benefits are estimates for the year they are expected to occur. This ensures that projected costs in the 2028 through 2031 period align with benefits that are forecast to occur when the offshore wind is operating and would actually deliver benefits to customers.

In addition, Appendix C provides an overview of an alternate approach that compares Maryland Standard Offer Service ("SOS") to the expected benefits calculated in this section.

4.1 Ratepayer Energy Benefits

Ratepayer energy benefits of offshore wind are those that directly impact and reduce customers' electricity bills, either through revenues from offshore wind projects or savings created by offshore wind's participation in markets. This analysis quantifies five ratepayer energy benefits:

1. Energy Revenues
2. Capacity Revenues
3. Avoided Renewable Portfolio Standard Costs
4. Energy Merit Order Price Reduction
5. Capacity Merit Order Price Reduction

Each of these benefits was evaluated separately and is described in greater detail below.

4.1.1 Electric Energy Revenues

Offshore wind facilities in Maryland are expected to be interconnected to and receive revenues by selling power into wholesale electricity markets. The revenues are established based on wholesale energy prices, which are set based on several factors. In PJM, the presiding regional transmission organization ("RTO") that oversees the wholesale markets in Maryland, this cost is known as the locational marginal price ("LMP").

For this analysis, we use AURORA, an industry-leading, fundamental North American market-driven forecast model, to calculate expected future energy revenues of offshore wind projects. AURORA relies on cost and operations data for every generator in North America to simulate the hourly commitment and dispatch of the units to serve load. As a fundamentals-based model, AURORA employs multi-area, transmission-constrained dispatch logic to simulate real market conditions. The model's economic dispatch logic captures the dynamics and economics of electricity markets and how electric power plants perform to produce wholesale prices.

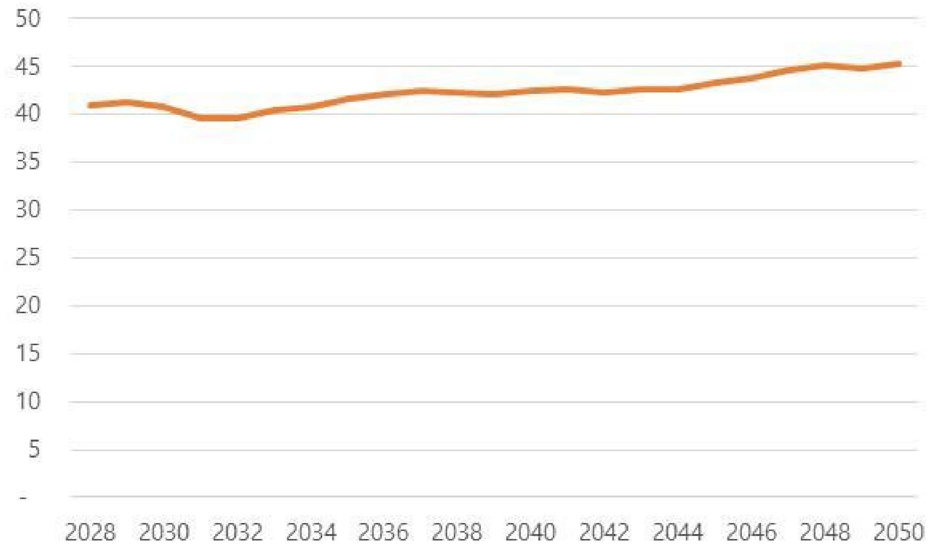
In addition to AURORA's general data maintenance, the simulation contains a forecast of resource fuel prices. For natural gas prices, it utilizes Henry Hub natural gas NYMEX futures[41] blended into the EIA 2022 Annual Energy Outlook reference case forecast of Henry Hub prices. Monthly city gate basis differential, transportation, and final retail delivery costs are embedded on top of Henry Hub commodity costs by AURORA to produce generator-specific burner-tip natural gas costs that capture regional and seasonal variations. The analysis also incorporates Regional Greenhouse Gas Initiative ("RGGI") CO_2 allowance costs. We use an average of the Cost Containment Reserve ("CCR") and Emissions Containment Reserve ("ECR") price thresholds for the RGGI allowance price forecast. The AURORA model and the assumptions used to forecast energy revenues is detailed further in Appendix D.

The figure below illustrates the expected realized energy revenue rate of the 6,000 MW of offshore wind projects. This accounts for not only the expected production profile of

[41] As of August 18, 2022.

offshore wind but also all the market factors summarized above. All values are provided in real 2021 dollars per MWh.

Figure 11. Energy Forecast – Maryland Offshore Wind Weighted LMP (2021$/MWh)



Fluctuations in the revenues received by offshore wind can occur for numerous reasons, including changes to the natural gas forecast (a primary driver of LMP), changes to load, availability of new resources, and retirements of existing resources.

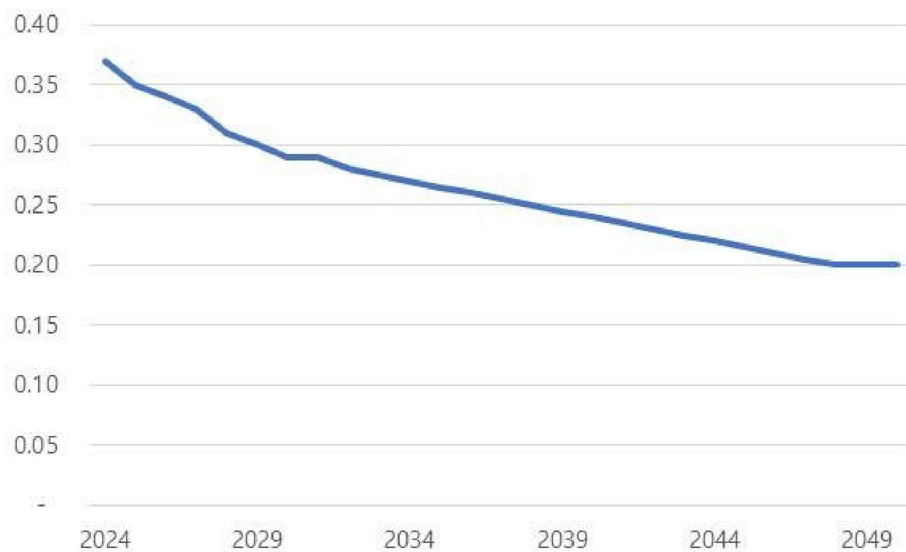
4.1.2 Electric Capacity Revenues

PJM also administers a capacity market that is aimed at ensuring generation is available in future periods for resource adequacy. The capacity market in PJM, known as the Reliability Pricing Model ("RPM"), is in a constant state of change that has had significant impacts on the market clearing prices. These changes result in extreme variability in capacity revenues for generators and costs for load.

One recently implemented change at PJM is the inclusion of effective load carrying capability ("ELCC"). ELCC is a method to evaluate the capacity a resource can provide based on its ability to serve peak load compared to all other resources in the market. As more offshore wind is interconnected to the grid, the calculation of its ELCC value declines. This occurs because resources such as offshore wind generate electricity intermittently and cannot produce on demand. As the percentage of grid capacity supplied from intermittent resources increases, so too does the risk that supply cannot meet demand during peak periods. As such, ELCC for renewable resources decreases as the total generating capacity of those resources increases. PJM has analyzed the expected changes to the resource mix of the grid and published estimated ELCC values by resource type through 2032. ELCC effectively derates the quantity of capacity with which a resource can participate in PJM's RPM capacity market. For example, a 1,000 MW resource with an ELCC of 20% is only eligible to offer and clear 200 MW in PJM's capacity market.

The figure below illustrates the expected ELCC value by year for offshore wind resources, consistent with PJM's *December 2021 Effective Load Carrying Capability (ELCC) Report*.[42] After 2032, our analysis assumes the ELCC continues to decline to a minimum of 20%. This value is a ratio of how much capacity a resource will be eligible to offer in the capacity market. Values are provided as a percentage of total generating capacity.

Figure 12. Effective Load Carrying Capability of Offshore Wind



The capacity market is administered as a single price clearing auction, with allowance for specific zones to produce different prices based upon import and export limitations. The market design has also undergone significant alterations that result in extreme uncertainty related to likely market clearing prices. Some of these changes, such as the implementation of a Market Seller Offer Cap ("MSOC") stand to reduce prices. Lower capacity market clearing prices mean lower costs for customers; however, it also means lower revenues for capacity producing resources, such as offshore wind.

Because of the uncertainty attendant with PJM's capacity market, as well as the unknown interconnection point of future offshore wind projects, our analysis assumes a capacity market price based upon the PJM RTO clearing price in the three most recently conducted base residual auctions, equal to $74.71 per MW-day, un-escalated in real terms for the entirety of the useful life of the projects.

[42] PJM Interconnection LLC. December 2021 Effective Load Carrying Capability (ELCC) Report. December 31, 2021. pjm.com/-/media/planning/res-adeq/elcc/elcc-report-december-2021.ashx

4.1.3 Avoided Renewable Portfolio Standard Costs

Maryland's RPS sets an ascending percentage, up to 50% by 2030, of state load to be sourced with renewable energy. Functionally, the RPS is implemented by energy suppliers that purchase Maryland Tier I RECs to match the annual required proportion of the customer load they serve. When a new resource, such as offshore wind, satisfies these requirements, fewer RECs are purchased from other resource types. These savings are realized by all customers because suppliers are required to purchase fewer Tier I RECs from other sources to meet their load obligations in the State, meaning the costs they pass on to customers are reduced. This results in greater RPS affordability by satisfying RPS targets while decreasing costs.

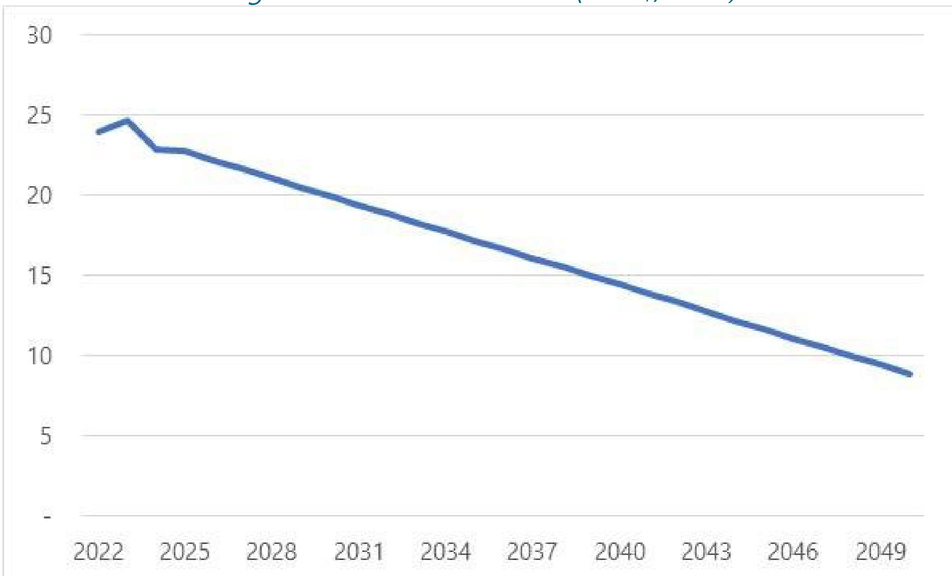
The renewable percentages in the RPS were established in the Clean Energy Jobs Act of 2019.[43] A portion of the requirement is carved out for in-state solar resources. The Clean Energy Jobs Act also provides for a 2.5% carve-out for offshore wind projects through 2020. Following 2020, the offshore wind carve-out is based upon "an amount set by the Commission under § 7–704.2(a) of this subtitle derived from offshore wind energy."

The 6,000 MWs of offshore wind contemplated in this analysis would fully satisfy the requirements of Maryland's current RPS. It is unknown what level of carve-out the Commission will set for these projects. As such, we conservatively assume these projects would contribute only an additional 2.5% reduction to Maryland's RPS requirements. To the extent the commission allows offshore wind to offset a larger proportion of the RPS, the benefits generated from avoiding Tier I RECs would be increased.

The price of Tier I RECs is forecast based on the average of actual reported bid and ask prices for calendar years 2022 through 2024. After 2024, prices are de-escalated using a regression of the price trend in 2022 through 2024. The figure below illustrates the Maryland Tier I REC forecast used in the analysis to determine the avoided cost of RPS requirements. All values are provided in real 2021 dollars per MWh.

[43] Clean Energy Jobs. Maryland General Assembly. mgaleg.maryland.gov/mgawebsite/Legislation/Details/SB0516?ys=2019rs.

Figure 13. Tier I REC Forecast (2021$/MWh)



Maryland Tier I RECs are currently trading just below $25 per MWh. Prior to mid-2020, Maryland Tier I RECs typically traded below $10 per MWh. In the long-run, we expect Maryland Tier I RECs to decrease in price due to supply-demand dynamics in the regional market where Tier I RECs are traded. Demand is likely to decline because of the increase in offshore wind production in Maryland, New Jersey, and Virginia. Supply of other Tier I RECs will be increasing due to the growth of wind projects in Pennsylvania and other states in western PJM.

Assuming the 2.5% additional carve out, the 6,000 MW of offshore wind would avoid the need to purchase more than $330 million in Tier I RECs over their lifetime. This is a conservative estimate because it limits the impact of offshore wind in avoiding REC purchases. If the 6,000 MWs were to fully subscribe to the RPS, the value of avoided REC purchases could exceed $5.3 billion over the 30-year production life.[44]

4.1.4 Merit Order Price Reduction Impacts (Energy and Capacity)

Offshore wind resources participate in wholesale energy markets administered by PJM. These markets not only determine the revenues of generating resources, but also the costs paid by customers to those resources. As previously discussed, offshore wind has no variable costs and therefore is a low-cost resource in PJM's dispatch logic to match supply and demand. As new low-cost resources are inserted into the generation supply curve, it necessarily displaces more expensive resources at the top of the resource stack. Because prices are set based on the cost of the marginal unit of energy, displacing a more expensive resource, reduces wholesale market prices thereby reducing costs for all customers (and

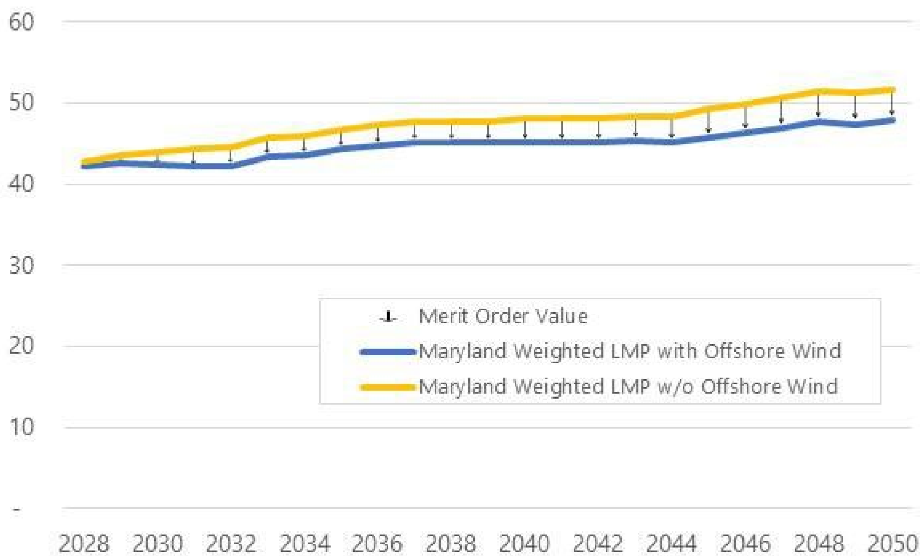
[44] All monetary values provided in net-present value terms in 2021 dollars.

revenues for all resources). Similarly, PJM's capacity market is also a single clearing price auction – meaning that displacing more expensive capacity units will have a similar impact by reducing costs to all customers (and lowering revenues for all generators). In short, resources with low energy and capacity offers reduce market prices, which benefits all customers. Merit order price reductions occur based upon disruptions to the supply stack; when changes to demand occur, it is known as demand reduction induced price effects ("DRIPE"). This benefit has been accepted by the Maryland PSC.

We also calculated merit order using AURORA to determine the differential between energy prices with and without offshore wind. To calculate this value, the analysis compares two Aurora market simulations; the only difference between the two is that one scenario included 6,000 MW of offshore wind interconnected in Maryland between 2028 and 2031, and the other included no additional offshore wind interconnected to Maryland. The differential between these simulations represents the price differential experienced from the participation of offshore wind in the wholesale electricity market. Simply, the addition of offshore wind energy and capacity reduces clearing prices to the benefit of all customers.

The figure below illustrates the calculated merit order impact on energy prices in Maryland from offshore wind. Values are provided in real 2021 dollars per MWh.

Figure 14. Energy Merit Order Impact from Offshore Wind in Maryland (2021$/MWh)



Capacity merit order is estimated using a price regression based upon data provided by PJM in its scenario analysis of the delivery year 2022-2023 base residual auction. This impact was determined to be $0.0035 per MW-day for each new low-cost MW offered into the capacity auction from offshore wind. In 2031 (when all 6,000 MWs are expected to be in service) this equates to a reduction of $6.04 per MW-day in capacity prices.

4.2 Environmental and Health Benefits

A primary reason that states across the country are mandating procurement of offshore wind is because of its value as a highly productive renewable resource that produces no greenhouse gases or other emissions. Because the power is generated emission-free, it displaces generation from fossil-fueled generation that emit harmful pollutants. All these emissions produce harmful effects on human health and the natural environment. This analysis estimates the displaced CO_2, SO_2, and NO_X emissions and quantifies the value of the avoided health harms, also known as damages. These benefits inure to the public at large but do not directly impact electricity costs to customers. This study utilizes estimation methods that are widely accepted among policymakers, the federal government, and many state governments.

4.2.1 Avoided Air Emissions

The quantity of avoided air emissions from electric generation was estimated using the same AURORA analysis that forecast the electric energy revenues and merit order impact on energy markets. AURORA contains plant-specific emissions factors and calculates estimated emissions based on the assumed production of all resources in the simulation. The same comparison between a simulation with and without offshore wind was used to establish the difference in emissions spurred by offshore wind. This approach captures the expected actual emissions reductions during periods when offshore wind is anticipated to generate power. In addition, it accounts for the changing resource mix on the grid, so as fewer inefficient fossil-fueled units are available in the future, the avoided emissions decreases.

The table below summarizes the avoided emissions over the lifetime of the projects. Values are provided in short tons.

Table 3. Avoided Lifetime Air Emissions by Pollutant (tons)

Pollutant	Avoided emissions (tons)
CO_2	361,445,105
SO_2	120,508
NO_X	128,931

4.2.2 Avoided Emissions Damages

Air pollution causes significant health harms resulting in lost workdays, hospital visits, asthma, respiratory disease, and increased morbidity for adults and children. CO_2 emissions are a significant contributor to human-induced climate change, which causes increased wildfires, droughts, hurricanes, and other costly weather events. Climate change is also contributing to rising sea levels, which presents significant costs to coastal communities. The negative social costs driven by power plant pollution are substantial and avoiding these costs is a critical benefit of offshore wind generation. Quantifying the monetary avoided damages associated with reduced emissions is based on social cost estimates of human and environmental health harms.

This analysis uses generally accepted estimates of environmental benefits. The avoided damages for CO_2 were estimated using the *Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990* produced by the Interagency Working Group on Social Cost of Greenhouse Gases, United States Government released in February 2021.[45] The avoided damages from SO_2 and NO_X were estimated using the January 2022 *Technical Support Document Estimating the Benefit per Ton of Reducing Directly-Emitted PM2.5, PM2.5 Precursors and Ozone Precursors from 21 Sectors* produced by the U.S. Environmental Protection Agency Office of Air and Radiation and Office of Air Quality Planning and Standards.[46]

These sources quantify the social costs or damages to human health and the environment per unit of pollution. To estimate the potential benefit, the per unit damage value is multiplied by the avoided air emissions. The table below presents the avoided emissions damages that result from offshore wind over its useful life. The values are presented in millions of real 2021 dollars as well as levelized real 2021 dollars per MWh.

Table 4. Avoided Emissions Damages (2021$ millions and 2021$/MWh)

Pollutant	$ millions	$/MWh
CO_2	15,861	39.57
SO_2	7,257	18.10
NO_X	632	1.58
Total	**23,750**	**59.25**

4.3 Economic Development Benefits

Offshore wind projects also produce economic benefits to local and regional economies. The economic benefits are primarily driven by construction and associated

[45] Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. February 2021. whitehouse.gov/wp-.content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

[46] United States Environmental Protection Agency. Technical Support Document Estimating the Benefit per Ton of Reducing Directly Emitted PM2.5, PM2.5 Precursors and Ozone Precursors from 21 Sectors. January 2022. epa.gov/system/files/documents/2021-10/source-apportionment-tsd-oct-2021_0.pdf.

spending in the local economy across all phases of the project. The economic impacts can be categorized as direct, indirect, and induced impacts. Direct impacts are those from immediate expenditures such as project labor and materials. Indirect impacts are those generated in the supply chain and supporting industries of an industry that is directly impacted by the expenditure. Induced impacts are those generated by the re-spending of received income resulting from direct and indirect effects in the affected region. The impacts can be measured across all phases of the project including development, construction, operations, and decommissioning.

Development impacts are generated as a result of local spending on project development related efforts for offshore wind projects. This includes items such as bid preparation, economic modeling, surveys and studies, permitting, legal fees, and other costs. Construction impacts occur as a result of local spending on the construction of the offshore wind facility and associated direct supply chain operations in Maryland. This includes items such as manufacturing, fabrication, assembly, ocean-going vessels, electrical equipment and interconnection, labor, and other costs. The current Skipjack and US Wind projects have already resulted in supply chain investments, including the Sparrows Point Steel manufacturing plant. Operations and maintenance impacts are a result of ongoing spending to keep the offshore wind facility in working condition over its lifetime. This includes items such as parts and materials, technicians' salaries, inspections, and other costs. Decommissioning impacts are a result of future spending to retire and decommission the offshore wind facility once it has reached the end of its useful life. This includes items such as teardown, recycling, ocean-going vessels, labor, and other costs.

While the scope of this Report does not include a full analysis and quantification of macro-economic impacts, we expect that adding 6,000 MW of offshore wind generation would stimulate significant economic growth in the region. Other recently announced offshore wind projects have been accompanied by substantial economic development benefits. Maryland's most recently approved offshore wind projects were estimated to generate significant economic development benefits. The Skipjack 2 and Momentum Wind projects are expected to generate over 10,000 jobs and increase Maryland's GDP by over $1 billion over the life of the projects.[47] In New Jersey, the Board of Public Utilities announced two offshore wind projects totaling 2,658 MW, which are expected to generate $3.5 billion in economic benefits, while creating approximately 7,000 jobs over the life of the new projects.[48] The 6,000 MW contemplated in this analysis is 3.5 times the size of previously approved

[47] Skipjack Offshore Energy, LLC and US Wind, Inc.'s Offshore Wind Applications under the Clean Energy Jobs Act of 2019. Order No. 90011 in Case No. 9666. Maryland Public Service Commission. December 17, 2021.webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/Casenum/9600-9699/9666/102.pdf.

[48] New Jersey Board of Public Utilities. "NJBPU Announces Nationals' Largest Combined Offshore Wind Award to Atlantic Shores and Ocean Wind II." June 30, 2021. nj.gov/bpu/bpu/newsroom/2021/approved/20210630.html.

Skipjack and US Wind projects in Maryland and therefore the jobs and benefits created by 6,000 MWs could significantly exceed those delivered from those projects. However, all projects differ, and a full in-depth analysis of economic impacts should be conducted during the review of individual project proposals to determine their estimated economic and job creation impact.

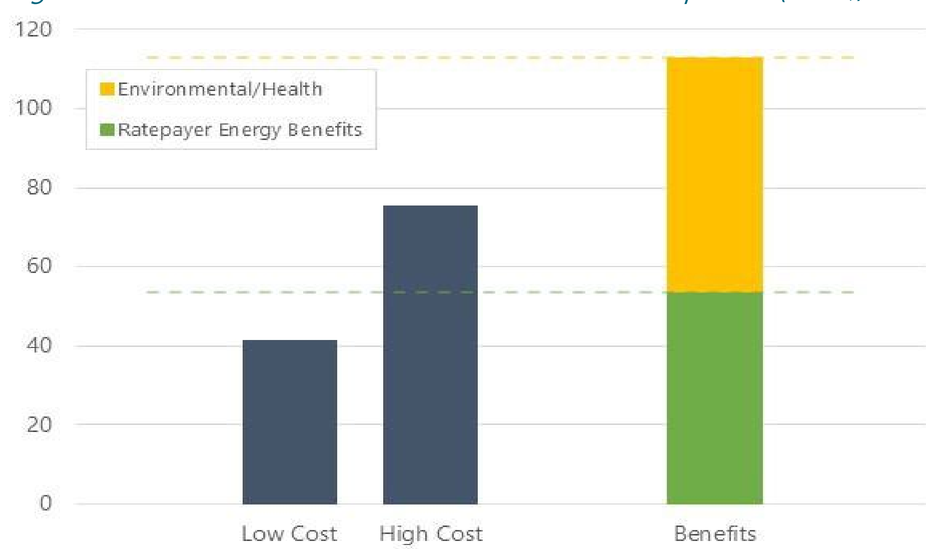
5 FINDINGS AND CONCLUSIONS

Offshore wind represents an integral investment for the State of Maryland in meeting the targets outlined in the Climate Solutions Now Act. A key to understanding where and how offshore wind can help meet these goals is to assess whether procuring offshore wind will result in benefits to the State and its associated electric rate impacts.

Because there are many factors impacting the potential costs of offshore wind in the future, this Report analyzes a range of potential costs and provides a 'low' and 'high' case cost estimate. Comparing the cost estimates against projected benefits provides an evaluation of the level of net-benefits that 6,000 MW of offshore wind capacity could provide to Maryland. We evaluated two types of benefits: direct ratepayer and environmental/health. Ratepayer energy benefits result in direct electricity savings (either from revenues to the projects or market-related savings to Maryland customers). Environmental and health benefits occur based on the reduction of greenhouse gases and other pollutants from fossil-fueled power plants. Because the Climate Solutions Now Act is focused on reducing emissions, quantifying and including the value associated with these reductions is vital to evaluating the cost-effectiveness of offshore wind in Maryland for achieving the requirements of the Climate Solutions Now Act.

The figure below illustrates the low and high levelized cost estimates compared against the expected benefits from offshore wind. Costs are provided on the lefthand side of the figure as levelized costs, with blue including both generator, interconnection, and transmission costs together for both the 'low' and 'high' cost cases. Benefits are shown in the bar to the right of the figure, with ratepayer benefits in green and environmental and health benefits in yellow. All values are provided in real 2021 dollars per MWh.

Figure 15. Levelized Offshore Wind Cost and Benefit Comparison (2021$/MWh)



Under the low-cost scenario, the figure shows ratepayer energy benefits (green), including energy revenues, capacity revenues, energy merit order, and capacity merit order, to exceed ratepayer costs (low blue bar). That means that implementation of offshore wind will return ratepayer energy benefits greater than its ratepayer costs. This is without considering environmental and health benefits. If they are included, the benefits greatly exceed the costs. Under the high-cost scenario, ratepayer costs are expected to exceed ratepayer energy benefits, meaning that ratepayer energy benefits do not completely offset costs. However, when accounting for environmental and health benefits, total benefits exceed the high levelized cost estimate. These benefits are important to consider because Maryland is unlikely to meet climate emissions reduction goals without deploying more offshore wind. The table below illustrates the numerical values illustrated in the figure above, and also provides the net-impacts of both the ratepayer energy benefits and avoided environmental and health damages. Values are provided in real 2021 dollars per MWh.

Table 5. Levelized Offshore Wind Cost and Benefit Comparison (2021$/MWh)

Offshore Wind Costs	**Low**	**High**
Generation Costs	(34.90)	(54.06)
Interconnect/Transmission Costs	(6.75)	(21.24)
Total Costs	**(41.65)**	**(75.29)**
Ratepayer Energy Benefits	53.55	
Net Benefits	**11.90**	**(21.75)**
Avoided Environmental/Health Damages	59.25	
Net Benefits w Environmental/Health	**71.14**	**37.50**

Many factors impact the cost of offshore wind. The range provided in this Report attempts to capture this uncertainty. However, it should be recognized that actual development and procurement costs could change. In addition, the unknown cost for lease areas to site offshore wind off the coast of Maryland are not all known and could further impact the levelized costs summarized herein.

Additionally, this Report does not examine all potential benefits in detail. For example, we have not conducted an economic impact assessment on the 6,000 MW. Previous analyses (including those in Maryland) have found that offshore wind generation development produces significant benefits for local and regional economies including the creation of thousands of jobs and boosting of state gross domestic product. These benefits are largely driven by the in-state spending related to the projects and the use or development of in-state supply chains for offshore wind components.

The analysis presented in this report can provide guidance and clarity as Maryland lawmakers consider ways to achieve the 60% reduction of greenhouse gases by 2030 and evaluate the impacts of expanding its offshore wind energy procurement goals.

APPENDIX A: Annual Cost and Benefit Comparison

Table 6. Low-Cost – Annual Cost and Benefit Comparison (2021$ millions)

Year	Gross Cost	Energy Revenue	Capacity Revenue	Avoided RPS	Energy Merit Order	Capacity Merit Order	CO2 Avoided Damages	SO2 Avoided Damages	NOx Avoided Damages	Ratepayer Energy Net Benefits	Total Net Benefits
2028	(281)	269	13	30	30	8	223	187	11	69	490
2029	(559)	543	25	29	62	16	448	268	20	116	853
2030	(827)	802	36	29	92	23	685	454	36	153	1,328
2031	(1,094)	1,041	47	28	130	30	923	691	48	183	1,844
2032	(1,094)	1,042	46	27	136	29	929	660	45	186	1,820
2033	(1,094)	1,065	45	26	135	28	932	599	45	206	1,782
2034	(1,094)	1,072	44	26	138	28	937	672	45	213	1,868
2035	(1,094)	1,095	43	25	139	27	946	672	43	236	1,897
2036	(1,094)	1,108	43	24	141	26	967	658	44	248	1,918
2037	(1,094)	1,115	42	23	149	26	970	560	41	262	1,832
2038	(1,094)	1,109	41	23	151	25	987	505	44	256	1,792
2039	(1,094)	1,106	40	22	152	25	991	601	43	251	1,886
2040	(1,094)	1,115	39	21	162	24	996	520	44	268	1,827
2041	(1,094)	1,119	38	20	165	24	992	490	42	273	1,797
2042	(1,094)	1,112	38	20	172	23	988	517	43	271	1,819
2043	(1,094)	1,120	37	19	178	22	999	466	39	282	1,786
2044	(1,094)	1,120	36	18	182	22	1,016	301	37	284	1,638
2045	(1,094)	1,135	35	17	205	21	1,032	350	38	321	1,740
2046	(1,094)	1,153	34	17	209	21	1,042	448	40	340	1,871
2047	(1,094)	1,174	34	16	219	20	1,037	323	37	369	1,765
2048	(1,094)	1,187	33	15	232	20	1,046	268	36	393	1,741
2049	(1,094)	1,177	33	14	233	20	1,058	314	35	383	1,791
2050	(1,094)	1,190	33	13	227	19	1,074	335	37	389	1,835
2051	(1,094)	1,200	33	13	232	19	1,082	311	36	403	1,832

Year	Gross Cost	Energy Revenue	Capacity Revenue	Avoided RPS	Energy Merit Order	Capacity Merit Order	CO2 Avoided Damages	SO2 Avoided Damages	NOx Avoided Damages	Ratepayer Energy Net Benefits	Total Net Benefits
2052	(1,094)	1,210	33	12	236	19	1,090	289	36	416	1,831
2053	(1,094)	1,219	33	11	241	19	1,097	269	35	430	1,831
2054	(1,094)	1,229	33	10	246	19	1,105	250	34	444	1,833
2055	(1,094)	1,239	33	9	251	19	1,113	232	34	458	1,837
2056	(1,094)	1,249	33	9	257	19	1,121	216	33	472	1,843
2057	(1,094)	1,259	33	8	262	19	1,129	201	32	487	1,849
2058	(813)	952	25	7	267	14	1,138	187	32	452	1,808
2059	(535)	640	16	6	273	9	1,146	173	31	409	1,760
2060	(266)	322	8	5	278	5	1,154	161	30	353	1,698
Total	(32,812)	34,490	1,131	592	6,184	688	32,394	13,147	1,226	10,275	57,041
NPV	(16,695)	17,287	596	337	2,880	365	15,861	7,257	632	4,770	28,520

Table 7. High-Cost – Annual Cost and Benefit Comparison (2021$ millions)

Year	Gross Cost	Energy Revenue	Capacity Revenue	Avoided RPS	Energy Merit Order	Capacity Merit Order	CO2 Avoided Damages	SO2 Avoided Damages	NOx Avoided Damages	Ratepayer Energy Net Benefits	Total Net Benefits
2028	(511)	269	13	30	30	8	223	187	11	(162)	259
2029	(1,017)	543	25	29	62	16	448	268	20	(343)	394
2030	(1,498)	802	36	29	92	23	685	454	36	(518)	657
2031	(1,977)	1,041	47	28	130	30	923	691	48	(700)	961
2032	(1,977)	1,042	46	27	136	29	929	660	45	(697)	937
2033	(1,977)	1,065	45	26	135	28	932	599	45	(677)	899
2034	(1,977)	1,072	44	26	138	28	937	672	45	(670)	984
2035	(1,977)	1,095	43	25	139	27	946	672	43	(647)	1,014
2036	(1,977)	1,108	43	24	141	26	967	658	44	(635)	1,035
2037	(1,977)	1,115	42	23	149	26	970	560	41	(621)	949
2038	(1,977)	1,109	41	23	151	25	987	505	44	(628)	909
2039	(1,977)	1,106	40	22	152	25	991	601	43	(632)	1,003
2040	(1,977)	1,115	39	21	162	24	996	520	44	(615)	944
2041	(1,977)	1,119	38	20	165	24	992	490	42	(610)	914
2042	(1,977)	1,112	38	20	172	23	988	517	43	(612)	936
2043	(1,977)	1,120	37	19	178	22	999	466	39	(601)	903
2044	(1,977)	1,120	36	18	182	22	1,016	301	37	(599)	755
2045	(1,977)	1,135	35	17	205	21	1,032	350	38	(562)	857
2046	(1,977)	1,153	34	17	209	21	1,042	448	40	(543)	988
2047	(1,977)	1,174	34	16	219	20	1,037	323	37	(515)	882
2048	(1,977)	1,187	33	15	232	20	1,046	268	36	(491)	858
2049	(1,977)	1,177	33	14	233	20	1,058	314	35	(500)	908
2050	(1,977)	1,190	33	13	227	19	1,074	335	37	(494)	952
2051	(1,977)	1,200	33	13	232	19	1,082	311	36	(480)	949
2052	(1,977)	1,210	33	12	236	19	1,090	289	36	(467)	948
2053	(1,977)	1,219	33	11	241	19	1,097	269	35	(453)	948

Year	Gross Cost	Energy Revenue	Capacity Revenue	Avoided RPS	Energy Merit Order	Capacity Merit Order	CO2 Avoided Damages	SO2 Avoided Damages	NOx Avoided Damages	Ratepayer Energy Net Benefits	Total Net Benefits
2054	(1,977)	1,229	33	10	246	19	1,105	250	34	(439)	950
2055	(1,977)	1,239	33	9	251	19	1,113	232	34	(425)	954
2056	(1,977)	1,249	33	9	257	19	1,121	216	33	(411)	959
2057	(1,977)	1,259	33	8	262	19	1,129	201	32	(396)	966
2058	(1,466)	952	25	7	267	14	1,138	187	32	(201)	1,155
2059	(959)	640	16	6	273	9	1,146	173	31	(15)	1,335
2060	(478)	322	8	5	278	5	1,154	161	30	141	1,486
Total	(59,304)	34,490	1,131	592	6,184	688	32,394	13,147	1,226	(16,218)	30,549
NPV	(30,182)	17,287	596	337	2,880	365	15,861	7,257	632	(8,717)	15,033

APPENDIX B: OREC Period Duration Sensitivity

The analysis presented in this Report uses a levelization period equal to the expected useful life of offshore wind resources, assumed to be 30 years. However, we recognize that in procuring offshore wind energy, states may ask developers to price PPA/ORECs over a shorter period of time. In Maryland's previous procurements, ORECs were provided to developers over a 20-year period. The shorter period means that developers may need to increase the annual OREC price to recover their full costs over 20 years rather than 30 years. However, developers will also have the opportunity to realize revenues as a merchant generator following the expiration of the OREC period. These revenues can allow for continued capital recovery and serve to reduce the 20-year OREC price provided by developers.

To provide additional insight into the potential equivalent 20-year OREC price, we conducted an additional analysis to determine the 20-year levelized price, inclusive of revenues to the offshore wind developer in years 21 through 30.

As discussed in Section 3.2.5 and Section 5 of this Report, the 30-yr levelized OREC price is expected to range between $40 per MWh and $75 per MWh. To recover the same amount of costs over 20 years, without accounting for revenues in years 21 through 30, would increase the expected levelized OREC price range to $50 per MWh to $95 per MWh. However, including the additional revenues which would be realized by developers over years 21 to 30 decreases this cost to a range similar to that of the 30-year levelization period. Because developers are taking on market risk by reducing their OREC price to account for these revenues, it is likely they will discount the value of market revenues realized in years 21 to 30 in their OREC price calculations. The chart below summarizes the 'low' and 'high' cost estimates of 20-year levelized OREC prices based upon a range of discounting scenarios for revenues in years 21 through 30. All values are provided in real 2021 dollars per MWh.

Table 8. 20-Yr OREC Price Sensitivity (2021$ per MWh)

	Low	High
30-Yr Levelized Cost	41.65	75.29
20-Yr Levelized Cost	49.82	91.94
w/100% Revenues Yrs 20-30	34.60	76.72
w/75% Revenues Yrs 20-30	38.40	80.52
w/50% Revenues Yrs 20-30	42.21	84.33
w/25% Revenues Yrs 20-30	46.01	88.13

The chart above does not contain the benefits realized by ratepayers up through year 20, it only provides the levelized cost to ratepayers to pay directly for the cost of OSW. This is meant to illustrate the gross OREC cost paid to developers. In addition, several benefits, such as merit order impact and emissions reductions occur regardless of the levelization period. That means that customers will enjoy reductions in wholesale prices and reduced health damages from displaced emissions even if the offshore wind projects operate on a merchant basis in years 21 through 30.

APPENDIX C: Maryland Standard Offer Service Comparison

The majority of Maryland residential customers receive electric service from one of four major distribution companies. These companies own and operate the electric distribution system that delivers power to customers; however, they do not own or operate any generation that supplies that power. In order to procure energy supply, these distribution companies hold periodic auctions[49] to purchase default electricity supply on behalf of their customers. This default supply is known as Standard Offer Service ("SOS") in Maryland. SOS service is designed to provide electricity supply for a short period of time.[50] The SOS product contains multiple products, including load-following energy supply, capacity, ancillary services, renewable energy obligations, losses, and a supplier margin. The benefits of offshore wind include energy revenues (non-load following), capacity (at the offshore wind ELCC), avoided RPS costs, price reductions as a result of merit order, and avoided emissions damages.

As discussed in the benefits section of this report, offshore wind does not produce the same products as are bundled into SOS. Instead of including capacity and ancillary services in the price, offshore wind projects are required by current Maryland law[51] to refund those revenues from PJM to Maryland ratepayers. This contractual balancing arrangement means that customers only pay the net cost (or enjoy the net benefit) of offshore wind.

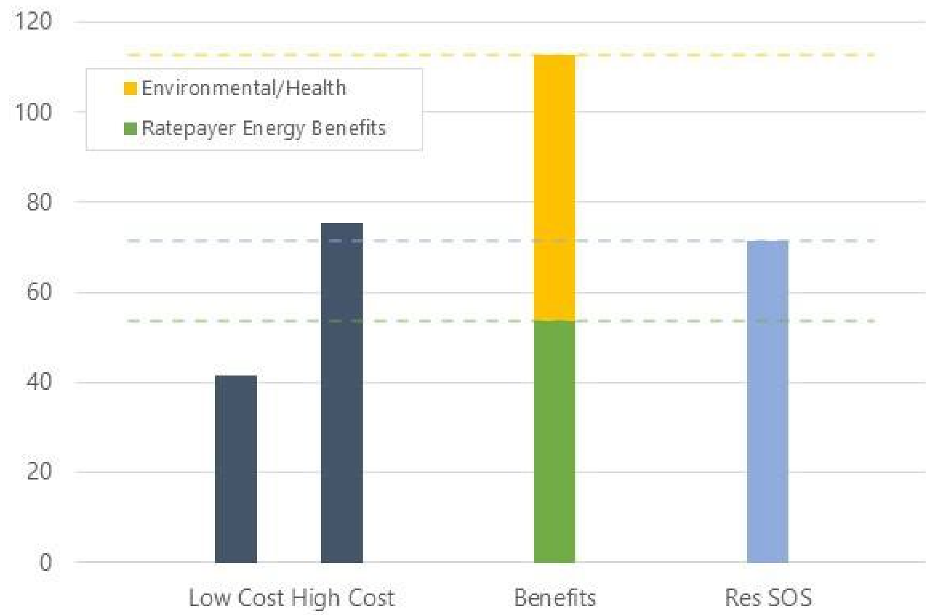
The figure below illustrates the calculated benefits of offshore wind using the current SOS Kilowatt Hour Charge for residential customers in Delmarva's service territory. The dark blue columns on the left of the figure represent the levelized ratepayer costs inclusive of generator, interconnection, and transmission costs for both the high cost and low cost scenario. The green and orange columns in the middle represent the ratepayer energy and environmental benefits respectively. All these values are the same as those provided in the figures contained in the conclusion of this Report. The light blue column on the right of the figure represents the SOS costs in Delmarva's service territory. Values are provided in real 2021 dollars per MWh.

[49] Residential and small commercial SOS bids occur twice a year, and contracts are awarded to the lowest bidders. Large commercial bids are received quarterly on the same bases.

[50] Delmarva Power is currently administering two procurements for up to a 24-month contract period.

[51] And provided for in Article II, Section 17(c) of the Maryland Constitution - Chapter 578 which contains the provisions of the Maryland Renewable Energy Portfolio Standard and Renewable Energy Credits – Offshore Wind Act

Figure 16. Levelized Offshore Wind Cost and Benefit Comparison w/SOS (2021$/MWh)



SOS has a value much greater than the expected ratepayer energy benefits generated by offshore wind. There are some considerations to keep in mind with this comparison, including (1) SOS is priced for a period in 2022 through 2023, while offshore wind incurs costs and creates benefits beginning in 2028 through 2060; (2) SOS is load following based upon customer load. Customer load peaks during higher priced hours. Offshore wind does not produce in coincidence with customer load and is largely weighted toward off-peak and winter hours; (3) SOS contains products that are not offset or realized by offshore wind; and (4) Because offshore wind produces for a thirty-year period not beginning until 2028, the values are discounted into present terms while SOS is provided in current terms.

APPENDIX D: AURORA Model and Assumptions

AURORA, developed and supported by EPIS, Inc., is an industry-leading, fundamental market-driven North American electric market forecast model that simulates the hourly commitment, dispatch, and operation of generators to serve utility load. It simulates the North American power grid to forecast wholesale energy prices, generation output, and other key variables.

As a fundamentals-based model, AURORA employs multi-area, transmission-constrained dispatch logic to simulate real market conditions. Its true economic dispatch captures the dynamics and economics of electricity markets and how electric power plants perform to produce wholesale prices.

In order to be as accurate as possible, EPIS maintains the model's database with regular updates to fundamental market drivers, such as:

- Hourly utility load data;
- Inter-zonal transmission capacity;
- Existing generator characteristics, operational dates, and retirements;
- Future generator capabilities including technology improvements;
- Generator-specific delivered fuel prices; and,
- Regional and seasonal emissions prices.

Additionally, the AURORA database is continuously maintained with market information from a variety of data sources, including:

- US Energy Information Administration;
- Federal Energy Regulatory Commission;
- US Environmental Protection Agency;
- Utility Integrated Resource Plans; and
- Regional ISOs and RTOs.

AURORA has been adopted and used by numerous market participants to make critical investment decisions, including regulated and unregulated utilities (investor-owned), publicly-owned utilities, independent power producers and developers, energy consultants, traders, and regulators, and academic institutions.

AURORA uses sophisticated linear programming dispatch logic to simulate the operation of the North American power grid. The general sequence of events is that AURORA:

- Determines generator availability (based on location, maintenance outages, fuel limits, etc.);
- Builds a resource stack, sorted by cost; and
- Dispatches the lowest cost, next available unit to serve hourly load (e.g. renewables first, then nuclear, coal, intermediate gas units and eventually peaking gas and oil units and demand response resources), subject to the operational constraints of the generation units.

In the commitment, dispatch, and operation of generation assets, the model considers all constraining details such as ramp rates, regional operating reserves, locational transmission limits, fuel limits, minimum/maximum capacity, minimum up and down times, heat rate curves, start costs, variable operating expenses, and other costs and operational constraints.

Once a unit is operating, it receives energy market revenue based on its hourly generation and the corresponding energy prices generated by the AURORA model. As loads increase and higher-priced units are dispatched, wholesale energy costs and prices increase and units that are already operating receive increasing gross margin revenue. Conversely, as loads decline, prices also decline along with generators' gross margins.

When gross margins for an operating unit decline to zero, the AURORA model generally shuts down that unit. Prior to shutting down an operating unit, the model will consider future prices, minimum up and down time, start costs, shut down costs, etc. to make the best overall economic decision for the market.

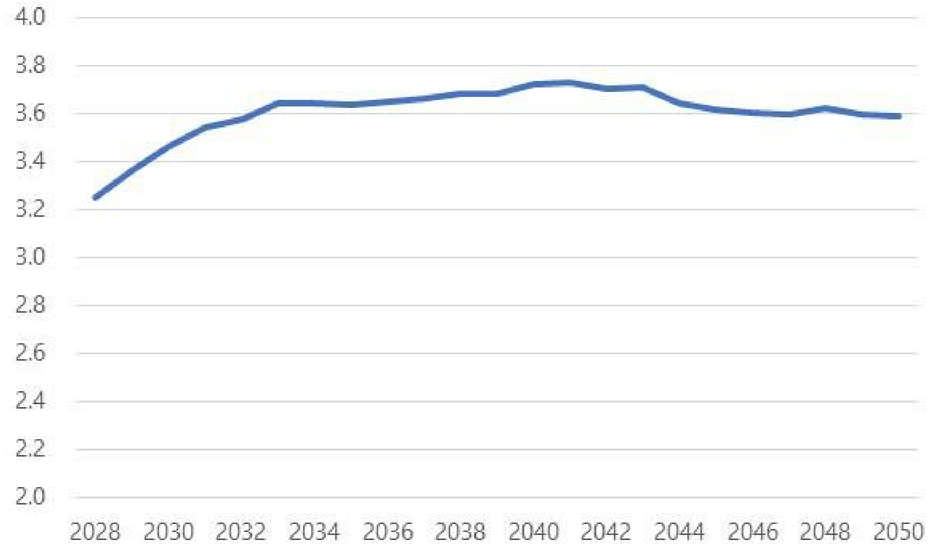
Assumptions used in the Aurora modeling

Energy market forecasts results are largely dependent on the assumptions and inputs used in the simulation. While there are many inputs and assumptions, there are a few primary drivers that have an outsize impact on the results of any forecast. These consist of fuel prices (mainly natural gas), carbon price assumptions, load growth, and renewable generation assumptions.

For natural gas, we utilize Henry Hub natural gas NYMEX futures[52] blended into the EIA 2022 Annual Energy Outlook reference case forecast of Henry Hub prices. Monthly city gate basis differential, transportation and final retail delivery costs are embedded on top of Henry Hub commodity costs by AURORA to produce generator-specific burner-tip natural gas costs that capture regional and seasonal variations. The figure below illustrates the henry hub commodity natural gas forecast we use in the forecast. The values are presented in real 2021 dollars per dekatherm.

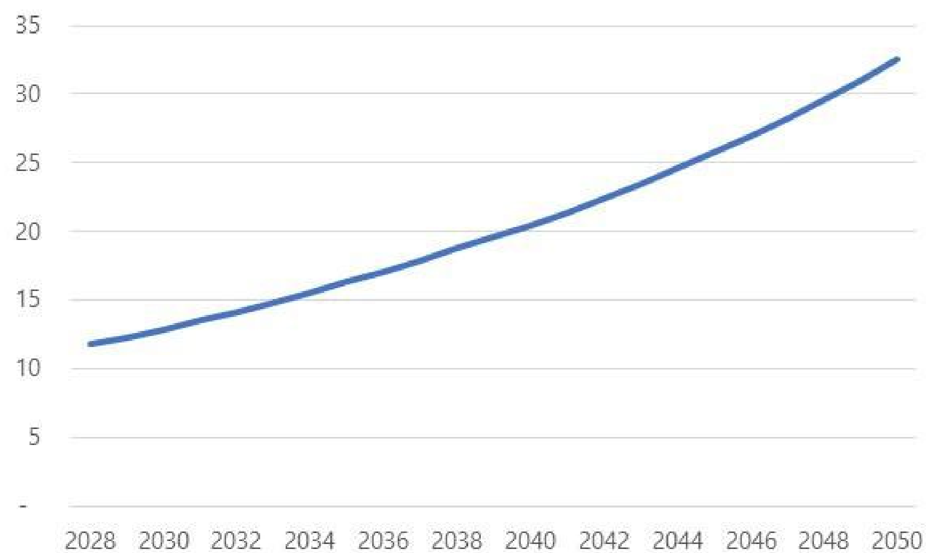
[52] As of August 18, 2022.

Figure 17. Henry Hub Natural Gas Forecast (2021$ per dekatherm)



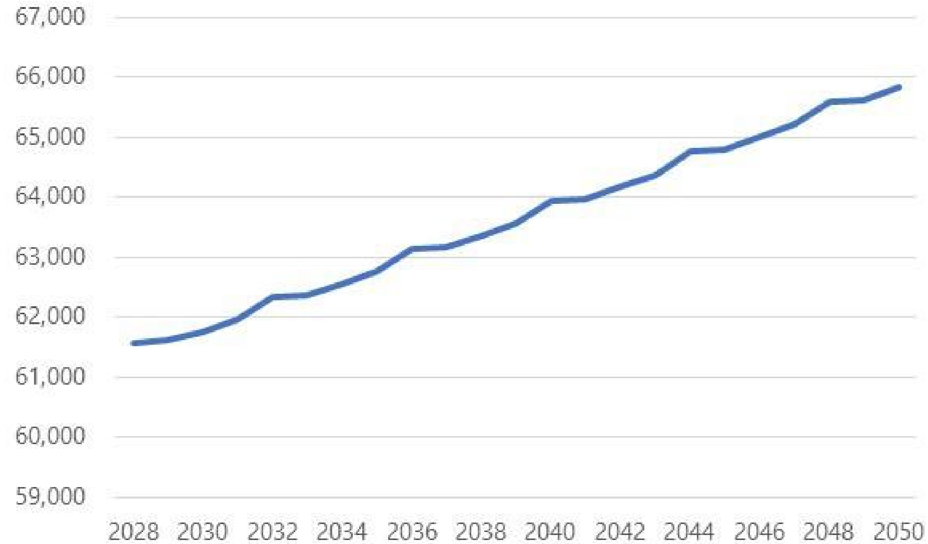
For carbon price, we incorporate Regional Greenhouse Gas Initiative ("RGGI") CO_2 allowance costs. We use an average of the Cost Containment Reserve ("CCR") and Emissions Containment Reserve ("ECR") price thresholds for the RGGI allowance price forecast. The figure below illustrates the RGGI carbon price forecast we use in the forecast. The values are presented in real 2021 dollars per ton.

Figure 18. RGGI Carbon Price (2021$ per ton)



For Maryland load, we utilize PJM's load forecast by load zone.[53] The figure below illustrates the growth in Maryland's load through 2050. The values are present in gigawatt hours per year.

Figure 19. Maryland Load Growth (GWh)



For renewable development throughout the region, we assumed that all future state RPS requirements will be satisfied. Solar, offshore wind, and other RPS carve-outs are satisfied with in-state resources as required. Long-term RPS buildout assumes that onshore wind generation will be the primary Class I compliance technology and that wind turbines will continue to be built in regions that have had historical development.

53 PJM Interconnection LLC. PJM Load Forecast Report. January 2022. pjm.com/-/media/library/reports-notices/load-forecast/2022-load-report.ashx