MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

PPRP

100% Renewable Portfolio Standard (RPS) and 100% Clean Energy Standard (CES) by 2040 Study

July 2024

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Maryland Department of Natural Resources
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MARYLAND POWER PLANT
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ACP	Alternative Compliance Payment
ATB	NREL Annual Technology Baseline
BAU	Business as usual
BECCS	Bioenergy with carbon capture and storage
BOS	Balance of system
BPT	Benefit per ton
Btu	British thermal unit
C&I	Commercial and industrial
CARES	Maryland Clean and Renewable Energy Standard
CC	Combined cycle
CCS	Carbon capture and storage
CEJA	Maryland Clean Energy Jobs Act
CERC	Clean Energy Resource Credit
CES	Clean Energy Standard
CH_4	Methane
CHP	Combined heat and power
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CONE	Cost of new entry
CPCN	Certificate of Public Convenience and Necessity
CSNA	Maryland Climate Solutions Now Act
CT	Combustion turbine
DES	Distributed energy storage
DGS	Maryland Department of General Services
DNR	Maryland Department of Natural Resources
DPV	Distributed solar photovoltaics
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FTE	Full-time equivalent
GATS	PJM Generation Attribute Tracking System
GHG	Greenhouse gas
GMI	Guaranteed minimum income
GSHP	Ground source heat pump
GW	Gigawatt
GWh	Gigawatt-hour
HAA	Maryland Healthy Air Act
HB	House Bill
HVAC	Heating, ventilation and air conditioning
I-O	Input-output
IMPLAN	IMpact analysis for PLANning
IOU	Investor-owned utility
IPL	Industrial Process Load
JEDI	NREL Jobs and Economic Development Impact model
kW	Kilowatt
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LFG	Landfill gas
LMI	Low- and moderate-income
LMP	Locational Marginal Price
LSE	Load-serving entity
MDE	Maryland Department of the Environment
MDOL	Maryland Department of Labor
MEA	Maryland Energy Administration
MMT	Million metric tons
MSW	Municipal solid waste
MW	Megawatt
MWh	Megawatt-hour
N_2O	Nitrous oxide
NG	Natural gas
NOx	Nitrogen oxides
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
O&M	Operations and maintenance
OBG	Other biomass gas
OCC	Overnight capital cost
OREC	Offshore Renewable Energy Credit
OSW	Offshore wind
PILOT	Payment in Lieu of Taxes
PJM	PJM Interconnection, LLC
PM	Particulate matter
PPA	Power Purchase Agreement
PPRP	Maryland Power Plant Research Program
PSC	Maryland Public Service Commission
PV	Photovoltaic
REC	Renewable Energy Credit
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable Portfolio Standard
S&P	Standard & Poor's
SB	Senate Bill
SC-GHG	Social Cost of Greenhouse Gas
SCED	Security constrained economic dispatch
SO_2	Sulfur dioxide
SREC	Solar Renewable Energy Credit
T&D	Transmission and distribution
TIS	Transitional income support
TWh	Terawatt-hour
UES	Utility-scale energy storage
UPV	Utility-scale solar photovoltaics
VCE	Vibrant Clean Energy, LLC
VOC	Volatile organic compound
WIS:dom®-P	Weather-Informed energy Systems: for design, operations and markets
ZEC	Zero Emission Credit

EXECUTIVE SUMMARY

In 2019, the Maryland General Assembly enacted the Clean Energy Jobs Act (CEJA) that, in addition to raising the Maryland Renewable Portfolio Standard (RPS) target to 50% by 2030, also required the Maryland Power Plant Research Program (PPRP) to prepare a study assessing the cost, benefits, and feasibility of increasing the RPS to 100% by 2040 (100% Study). The study was eventually expanded to also assess a 100% Clean Energy Standard (CES).

This 100% Study was prepared by Exeter Associates, Inc. (Exeter), under contract with PPRP. The modeling work was conducted by Vibrant Clean Energy, LLC (VCE) (since purchased by the Pattern Energy Group) under subcontract to Exeter. This study builds on a retrospective assessment of Maryland's RPS published in 2019 (2019 RPS Report), also prepared by Exeter on behalf of PPRP, with new prospective analysis.[1]

Modeling efforts for the 100% Study were conducted in two phases. Exeter developed the initial assumptions for Phase 1 models between February 2021 and March 2022 in consultation with members of the 100% Study Working Group (see Appendix A). Key assumptions included treating the Climate Solutions Now Act (CSNA) as a target rather than a binding requirement, allowing the Calvert Cliffs Nuclear Power Plant (Calvert Cliffs) to retire due to economic reasons, assuming EmPOWER Maryland ends in 2023, and assuming participation by both Pennsylvania and Virginia in the Regional Greenhouse Gas Initiative (RGGI). Results for four Phase 1 scenarios were shared with the 100% Study Working Group in May 2023.

Due to modeling issues, approximately a year elapsed between the preparation of the Phase 1 scenarios and the completion of additional modeling. During the interim period, some policy and market conditions changed. Exeter also received feedback on the initial model assumptions, which included changes to the "base case" (e.g., reversing the decision to treat certain targets as goals rather than requirements). As a result, the Phase 2 models were based on revised inputs and assumptions. Additionally, VCE adopted an alternative modeling approach to address technical constraints that impeded the model from solving.

Key model changes for Phase 2 included updating load forecasts, incorporating consequential new federal policies (e.g., the 2023 Inflation Reduction Act), assuming Maryland retained Calvert Cliffs with economic support (as needed), treating CSNA targets as mandates, re-incorporating EmPOWER Maryland requirements, assuming Maryland achieved its 8.5 gigawatt (GW) offshore wind and 3 GW storage targets, and assuming only Virginia joined RGGI, among other differences. Phase 2 assumptions reflect state and federal statutory provisions as of mid-2023. The Phase 2 model results are also more limited than Phase 1 in so far as they lack county-specific findings and use more geographically expansive PJM boundary assumptions.

This study comes with several important caveats. First, modeling results took some time to emerge due to modeling difficulties as well as a desire to incorporate new and consequential federal and state policies that entered law midway through the assessment. As a result, the two modeling phases relied on different foundational assumptions. These differences preclude direct comparison of Phase 1 and Phase 2 model results. However, Phase 2 model results build on Phase 1, and both phases remain critical for understanding the key findings of the 100% Study, e.g., understanding the impact of Calvert Cliffs.

Second, modeling took place during particularly volatile macroeconomic conditions. Data and forecasts used in the model rely on information from 2022 or earlier and do not directly reflect more recent changes. Third, it should be recognized that models, by design, pursue optimal solutions. This form of perfect foresight does not reflect real-world conditions. For these and other reasons, the model results should be viewed as directionally indicative rather than as precise predictions of the future.

Key Findings

Capacity, Generation and Transmission

- Substantial amounts of renewables, both in Maryland and elsewhere in the PJM Interconnection (PJM), are added in all scenarios. Most fossil fuel-based combustion resources, meanwhile, experience capacity retirements and reductions in capacity factors. This includes the retirement of virtually all coal generation by the early 2030s in all scenarios except those that limit new natural gas capacity in PJM. Additionally, much of the traditional nuclear capacity in PJM retires at the end of its licensed life, primarily between 2030-2040. These resources are replaced by new renewable energy capacity, energy storage capacity, and natural gas combined cycle (CC) capacity, as well as through increased access to existing capacity as a result of transmission upgrades. **Figure 1** shows forecast Maryland capacity under 100% RPS assumptions.

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[1] CEJA required PPRP to update several elements of the 2019 RPS Report. These updates are provided in the appendices to the 100% Study.

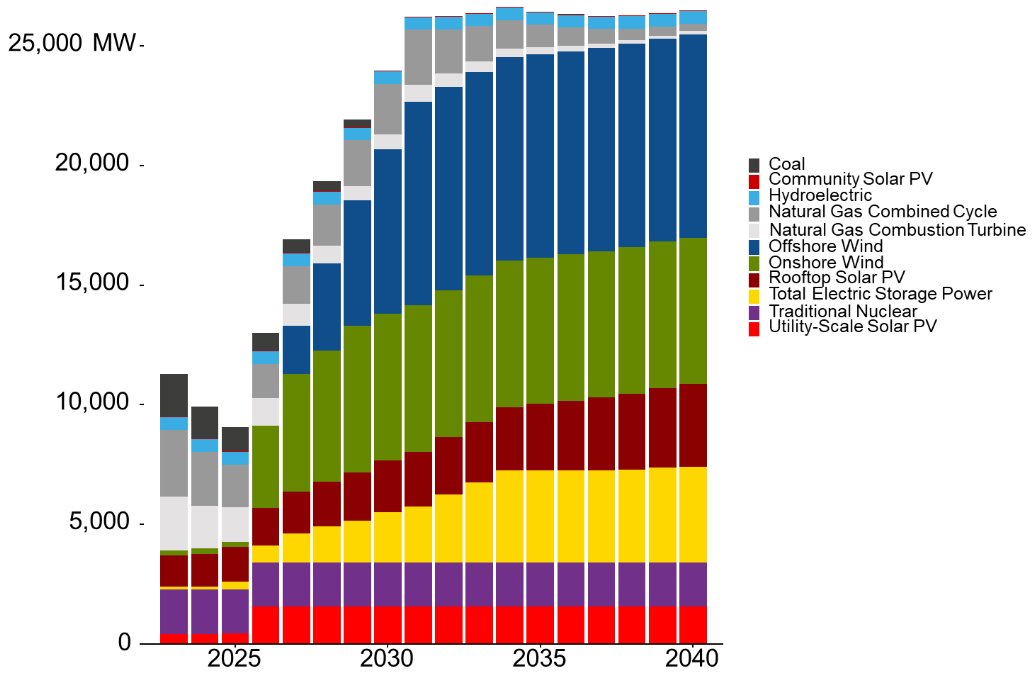

Figure 1. Maryland Capacity, 100% RPS-2 Scenario

- Most scenarios add new natural gas CC capacity, especially in place of retiring coal and less efficient natural gas CC or combustion turbine (CT) capacity. This reflects a consolidation of baseload resources with similar characteristics. The model will also add carbon capture and storage (CCS) when allowed to do so as part of 100% CES scenarios. Other possible options policymakers may promote, if they wish to avoid or minimize natural gas capacity additions, include accelerated transmission expansion, additional energy storage deployment, or expanded demand-side resources.
- Traditional nuclear capacity, when retired, is replaced with nearly three times as much new installed capacity. The replacement resources are mostly wind and solar, but also some new natural gas CC or CT plants. Keeping Calvert Cliffs online results in slightly less natural gas capacity in Maryland but a more significant reduction of natural gas capacity in PJM.
- The model results suggest that, in an optimized world (e.g., no interconnection queue issues or siting problems), a 100% RPS scenario is the same as business as usual, or BAU.
- Scenarios that allow advanced energy technologies (e.g., small modular reactors or molten salt reactors) result in the addition of these resources towards the end of the review period. Considerable uncertainty exists regarding the development of these resources, including permitting, commercialization, and development timelines.
- Maryland becomes a net exporter in all scenarios. This shift occurs sooner, and Maryland exports more power, in the scenarios that assume a 100% CES as compared to a 100% RPS. This reflects the projected deployment of CCS technologies, starting around 2031. Maryland is in position to become an energy exporter in part because of the state’s access to gas transportation and high-voltage transmission, and proximity to major loads. This does not mean, however, that Maryland will not need power imports at times to maintain reliability or to access economic power sources.
- The model almost exclusively upgrades existing transmission (e.g., reconductoring and grid-enhancing technologies) in place of building new, greenfield transmission.
- Short-term deficits in the availability of Renewable Energy Credits (RECs) may result in Alternative Compliance Payments (ACPs) under scenarios assuming a 100% RPS by 2035 or 2040, likely from solar REC (SREC) deficiencies. These payments persist until 2026. Maryland can address these shortfalls by increasing the ACP or the compliance value of certain RECs. Alternatively, the ACP can continue to support compliance as a stop value to prevent excessive costs.

Costs and Rates

- After falling initially, estimates of total resource costs for Maryland begin to increase by 2026 for most of the scenarios modeled, and then more sharply increase toward the end of the forecasted period (see **Figure 2**). Conditions that make Maryland more favorable to add new natural gas capacity led to a front-loading of costs. Conditions that result in higher levels of load growth cause a greater increase in costs in the 2030s.
- Most costs (e.g., capacity and distribution) increase for Maryland and remain flat in other states within the high electrification scenarios. This suggests that the model meets increased load requirements through in-state resource expenditures. At the same time, high electrification scenarios assume the adoption of more efficient heat pumps and flexible load. As a result, wholesale marginal costs slightly fall.
- For most scenarios, retail rates stay relatively flat until the end of the forecast period. These results are sensitive to the assumptions used. For example, the model results reflect use of the National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) from 2020 that depicted declining cost trends for offshore wind (OSW) that have been reversed in recent years due to inflation, supply-chain disruptions, interest rate increases, labor shortages, and other challenging market conditions.
- Additionally, the actual prices that customers pay can vary due to contractual arrangements, hedging strategies, regulatory requirements, and more.
- For the Phase 2 models, RPS and CES costs are relatively similar when comparing equivalent models. CES costs are slightly higher in most cases for reasons attributable to higher levels of in-state capacity, especially CCS and advanced energy technologies.

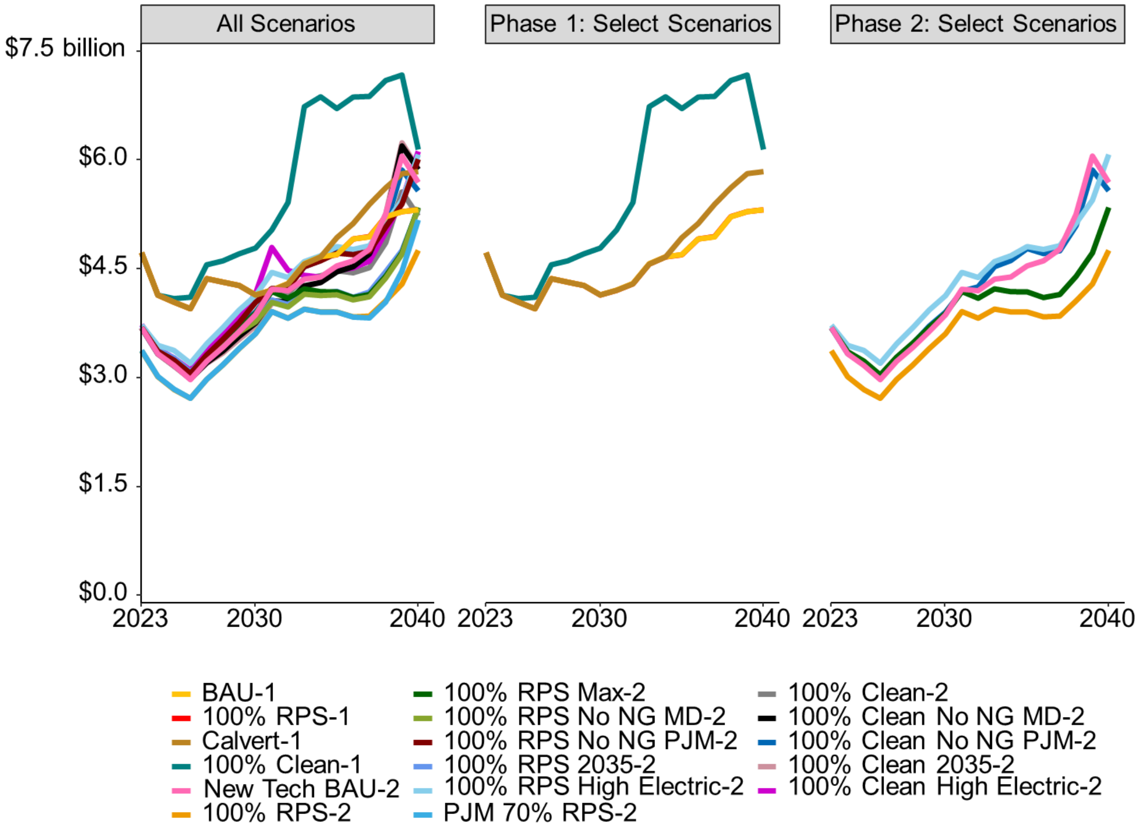

Figure 2. Total Resource Cost in Maryland, by Scenario

Emissions

- Air emissions in Maryland fall to near zero with either a 100% RPS (see **Figure 3**) or CES if the targets in the CSNA are met and Calvert Cliffs is relicensed. If both assumptions are reversed, then some air emissions (e.g., methane and nitrogen oxides) begin increasing in the 2030s.
- Removing the option for new natural gas in Maryland has limited greenhouse gas (GHG) emissions impact regionally insofar as prospective natural gas plants in Maryland shift to other states. More aggressive limitations on natural gas additions in PJM, however, have an unintended consequence of causing existing coal and less efficient natural gas plants to delay retirement. This is suggestive of a potential need for non-emitting generation capacity (e.g., advanced energy technologies, storage) to replace the functions served by natural gas additions, including flexible dispatch.
- In-state generation used for complying with the Maryland RPS, serving Maryland load, and exporting to PJM does not experience proportional emission reductions as compared to the PJM grid mix. This is because many fossil fuel generation sources in Maryland, especially coal plants, have already retired. Additionally, state policies like an RPS or CES, by accepting RECs or Clean Energy Resource Credits (CERCs) from elsewhere in PJM, promote the development of renewable or clean resources in all PJM states. Marylanders accrue some benefit from these resources through reductions in GHGs and other cross-state pollutants.

Jobs

- For all scenarios, the aggregate job losses associated with coal and natural gas plant retirements are offset by substantial additions in other energy sector jobs. Exeter did not assess differences in the types of jobs or durability of associated employment resulting from this shift.
- The in-state job impacts of utility-scale solar photovoltaics (UPV), distributed solar photovoltaics (DPV), OSW, energy storage, and ground source heat pumps (GSHP) all correspond with the presence of in-state targets or mandates, illustrating the importance of in-state requirements as a way for RPS or CES policies to create Maryland employment opportunities. The magnitude of the job impact of an in-state target or mandate depends on the size of the requirement. **Figure 4** shows average annual direct, indirect, and induced job creation in Maryland, measured in full-time equivalents (FTEs), for the select scenarios and technologies modeled.
- The identified economic benefits of the Maryland RPS are concentrated in the construction and service industries.
- Most near-term manufacturing opportunities for OSW are limited to upstream materials and subcomponents that can be easily transported, such as scaffolding, coatings, ladders, fastenings, hydraulics, concrete, and electrical components. Nevertheless, opportunities to expand economic development in Maryland are primarily associated with OSW due to the state's legislative targets to place OSW component manufacturing facilities in Maryland. Besides prospective OSW opportunities, the Maryland RPS is currently of little benefit to the state's manufacturing sector because most solar, wind, and energy storage components are manufactured out of state or abroad.

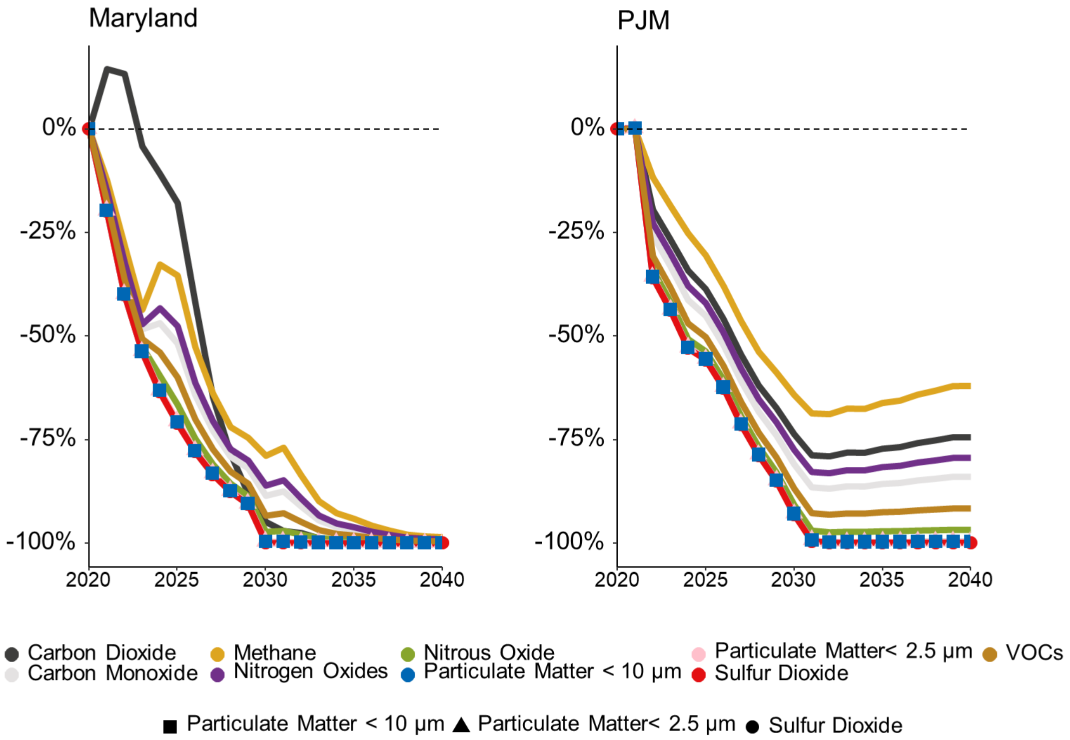

Figure 3. Percent Change in Maryland and PJM Emissions Relative to 2020, 100% RPS-2 Scenario

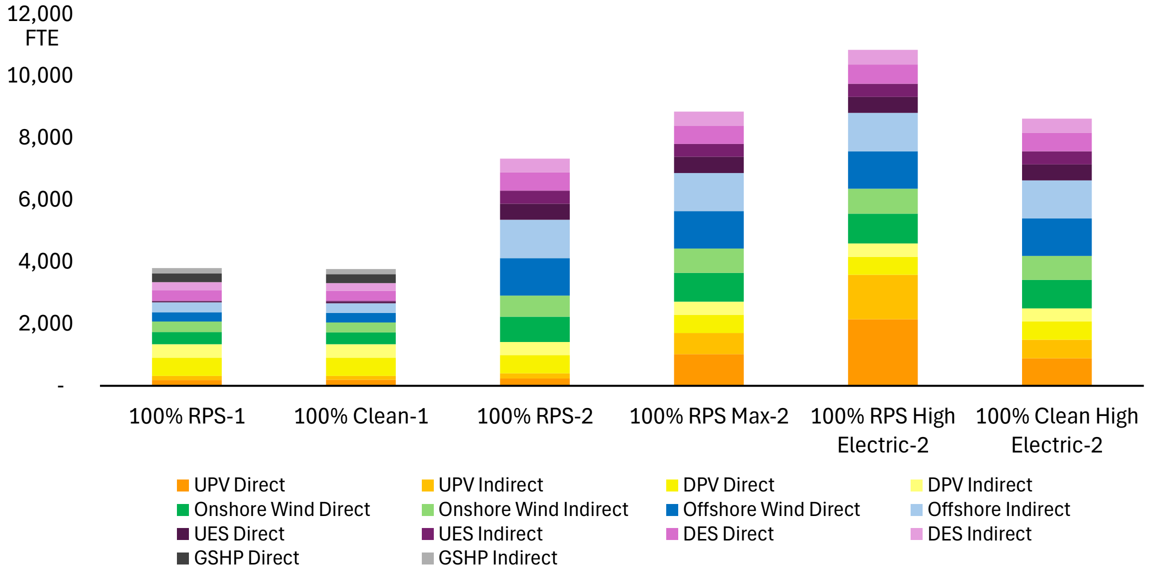

Figure 4. Maryland Average Annual Direct or Indirect and Induced Full-Time Equivalent Job Creation, by Technology and Select Scenarios

Other Industry Impacts

- Some dislocation of the existing natural gas workforce occurs in all modeling scenarios because of the retirement of existing natural gas capacity. Scenarios that treat Maryland Climate Solutions Now Act (CSNA) emission reduction targets as mandatory, independent of whether Maryland pursues a 100% RPS or CES, cause the greatest displacement. These workers will require transition support for new employment.
- The impacts of 100% RPS or CES policies on employment and economic output as a result of higher retail power prices are expected to be small, both because (1) model results show relatively small changes; and (2) the sectors most likely to be adversely affected, such as energy-intensive manufacturing, are relatively small in Maryland.

Feasibility of a 100% RPS or CES

CEJA, in addition to initiating the 100% Study, also required that PPRP "use the findings of the [100% Study] to publish recommendations regarding the feasibility of implementing a renewable energy portfolio standard [or clean energy standard] of 100% by 2040." Before addressing this question, it is important to remember that an RPS or CES is not only a driver of renewable **energy** development, but also serves as a tool for combating climate change and improving local air quality; a source of jobs and economic development; a support for technological innovation; an impetus and sustainer of in-state businesses; and more. As documented in the 2019 RPS Report, the success of the existing Maryland RPS in serving all these functions simultaneously is mixed, especially since some of these objectives are in tension (e.g., spurring in-state jobs and minimizing retail costs). Ultimately, Maryland policymakers must decide to prioritize what they want the Maryland RPS or CES to accomplish, and then adjust current law to best meet those priorities.

Regarding technical feasibility, **modeling confirms that Maryland can technically meet the requirements of a 100% RPS or CES in a variety of circumstances**, including scenarios with high electrification expectations, compliance target dates of 2035 (versus 2040), limits on new natural gas development, and more.[2] Notably, Maryland's ability to satisfy these requirements by 2040 is not contingent on Maryland meeting its 8.5-GW OSW mandate, 3-GW energy storage target, or the requirements of CSNA. These conditions do, however, significantly increase the amount of in-state renewable energy generation available to satisfy Maryland RPS or CES requirements. The one exception to technical feasibility is a 100% RPS using generation solely within Maryland, which the model was unable to solve.

Regarding economic feasibility, **implementation of a 100% RPS or CES does not substantially alter aggregate costs or benefits as compared to business as usual** within the cost-benefit categories assessed. Exeter calculated benefits from either a 100% RPS or CES in terms of decreased emissions, decreased natural gas consumption, and increased economic output and jobs. Exeter also calculated costs in terms of total resource expenditure and retail rates. There is uncertainty involved in each of these calculations (e.g., appropriate discount rate or valuation methodologies) stemming from unquantified costs and benefits. There are also trade-offs between the different cost and benefit categories that, as discussed above, preclude direct comparison.

Several model scenarios suggest that Maryland will require ACPs to meet RPS requirements in the near term (i.e., through 2026). Because ACPs represent a price ceiling, the application of ACPs suggests that compliance costs exceed desired levels. There are several paths Maryland might take to address these near-term deficiencies or the associated costs, including maintaining the status quo and using ACPs to support new resource development,[3] increasing the ACP, or increasing the compliance factor of eligible resources. Maryland might also expand the number of eligible resources or alter the percentage requirements. Again, each of these approaches introduces policy trade-offs.

Finally, it is important to emphasize once again that models have perfect foresight and are not affected by real-world constraints such as financing or interconnection challenges. Achieving these results will depend critically on resolving constraints such as generation interconnection or upgrading existing or developing new transmission projects. Some, if not many, constraints extend beyond Maryland's border, including regional load growth and PJM market reforms. Should Maryland policymakers choose to adopt a 100% RPS or CES, careful attention will be needed through implementation and launch in case any corrective policies are needed.

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[2] Further consideration is required to understand the implications of these scenarios on actual grid operations, including instantaneous balancing, market clearing, and more. These forms of technical feasibility are beyond the scope of this assessment.

[3] Note that ACPs can only be used for developing new generating resources that benefit low- and moderate-income customers.

PREFACE

In 2019, the Maryland General Assembly enacted the Clean Energy Jobs Act (CEJA)[4] which, among other requirements, directed the Maryland Department of Natural Resources' (DNR's) Power Plant Research Program (PPRP) to prepare a study assessing the cost, benefits, and feasibility of increasing the Maryland Renewable Energy Portfolio Standard (RPS) to 100% by 2040 (100% Study).[5] Additionally, the General Assembly required PPRP to update a preceding PPRP study evaluating the past and future impacts of the Maryland RPS (2019 RPS Report), published in December 2019.[6] PPRP was also required to assess as part of the 100% Study whether any in-state industries could be displaced or negatively economically impacted by a 100% RPS, and propose approaches to support affected workers and communities. Additionally, Senate Bill (SB) 516 required PPRP to address the findings and recommendations of a previously published PPRP study on nuclear power and its role as a renewable or clean energy resource.[7] SB 516 established an initial deadline for the 100% Study of January 1, 2024.

In February 2021, following consultation between the DNR and individual members of the Maryland General Assembly, the 100% Study was re-scoped to also include assessment of a 100% clean energy requirement by 2040 and to narrow the number of topics addressed in the new study.[8,9] These changes were intended to minimize costs by avoiding the duplication of work conducted as part of the 2019 RPS Report. Portions of the 2019 RPS Report set apart for update included:

- The impact of alterations that have been made in the component of each tier of the standard, the implementation of different specific goals for particular sources, and the effect of different percentages and alternative compliance payments (ACPs) for energy in the tiers;
- Whether the RPS is able to meet current and potential future targets without the inclusion of certain technologies (namely, black liquor and waste-to-energy);[10]
- Which industries are projected to grow, and to what extent, as a result of incentives associated with the RPS;
- Whether the state is likely to meet its existing goals under the RPS and, if the state were to increase those goals, whether electricity suppliers should expect to find an adequate supply to meet the additional demand for credits;
- Availability of all clean energy sources at reasonable and affordable rates, including in-state and out-of-state renewable energy options; and
- Additional opportunities to promote local job creation within the industries that are projected to grow as a result of the standard.

The 100% Study was led by PPRP's socioeconomic integrator, Exeter Associates, Inc. (Exeter), which also previously led the 2019 RPS Report. For this study, Exeter teamed with Vibrant Clean Energy, LLC (VCE) to conduct modeling analysis. To support the study, PPRP reconstituted the Maryland RPS Work Group, consisting of representatives from the renewable energy industry, electric utilities, environmental and consumer organizations, county and state government, and consultants, as the 100 Percent Study Working Group. The 100 Percent Study Working Group met three times during report development through online webinars. The full list of RPS Work Group members is provided in Appendix A.

Exeter commenced work for the 100% Study in February 2021. Preparatory work for the 100% Study, including deriving assumptions and collecting model inputs, continued through spring 2022. This initial delay was intended to allow time for market, regulatory, and environmental conditions to evolve from the 2019 RPS Report. Although VCE began its modeling exercise in spring 2022, several obstacles delayed subsequent completion of the report.

First, VCE experienced significant problems with programming the 100% Study models. These issues, also compounded by staffing shortages, delayed completion of initial model results until May 2023.

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[4] Senate Bill (SB) 516 (Ch. 757).

[5] Clean and Energy Jobs Act of 2019 (PUA, Section 7-714).

[6] In 2017, the Maryland General Assembly enacted House Bill (HB) 1414 directing PPRP to conduct a study of the Maryland RPS and the impacts of increasing the standard to 50%. HB 1414 identified 17 general and specific requirements of the study, including assessment of: the effectiveness of the RPS along several economic and environmental dimensions, the availability and cost of renewable energy resources, the impact of alterations to the Maryland RPS, and the potential to meet future Maryland RPS standards. SB 516 ultimately altered the Maryland RPS to a 50% standard by 2030.

[7] PPRP, *Nuclear Power in Maryland: Status and Prospects*, January 2020. dnr.maryland.gov/pprp/Documents/NuclearPowerinMaryland_Status-and-Prospects.pdf.

[8] Letter between DNR and Senator Feldman (2/3/21).

[9] For additional definitions of 100% RPS and 100% Clean energy, see Chapter 1.

[10] HB 1362, enacted in 2021, explicitly calls for the removal of black liquor from the Maryland RPS as an eligible technology after existing contracts expire.

Second, VCE was acquired by Pattern Energy in March 2023. This resulted in a further reduction in staff availability to support the 100% Study. Additionally, continued technical challenges resulted in VCE adopting a new modeling approach. Modeling did not conclude until March 2024. As a result of the above issues, targeted completion of the 100% Study was delayed until July 1, 2024.

1. INTRODUCTION AND APPROACH

The main goal of this study is to understand the economic feasibility of either a 100% Renewable Portfolio Standard (RPS) or 100% Clean Energy Standard (CES) in Maryland. The following sections provide additional introductory information regarding RPS and CES policies in general and Maryland's RPS specifically, both as they currently exist and going forward. This includes reviewing potential 100% RPS and 100% CES policies in Maryland. This introduction is followed by a review of the report approach, including the methods used and scenarios assessed.

The subsequent study is broken out into five parts: (1) an initial overview of the capacity, generation, and transmission resulting from each modeled scenario; (2) a review and cost-benefit assessment of total expenditure (fixed and variable) and rate (wholesale and retail) impacts; (3) a review and cost-benefit assessment of the global emission and local pollutant impacts; (4) a review and cost-benefit assessment of job and economic output impacts; and (5) a discussion of the industries and communities negatively impacted by RPS or CES requirements, as well as mechanisms to potentially alleviate negative impacts for affected workers and communities.

The main report is also followed by several technical appendices, including an overview of VCE's production cost and capacity expansion modeling approach and assumptions (Appendix D); an overview of Exeter's IMpact analysis for PLANning (IMPLAN) modeling approach and assumptions (Appendix E); discussion of the potential impact of excluding certain technologies from the Maryland RPS (Appendix F); discussion of projected Renewable Energy Credit (REC) availability compared to future RPS requirements (Appendix G); and a summary of the findings and recommendations of PPRP's "Nuclear Power in Maryland: Status and Prospects" study as they pertain to RPS and CES policies (Appendix H).

1.1. RPS and CES Policies

The Maryland RPS requires that a designated percentage of the electricity sold by load-serving entities (LSEs) in the state come from eligible renewable energy sources or technologies.[11] Maryland is one of 29 states (and the District of Columbia) with an RPS requirement. Fifteen of these states also maintain a CES, which functions similarly but includes additional non-emitting energy technologies like nuclear power.[12]

The primary way that LSEs comply with RPS or CES policies is through the retirement of RECs or Clean Energy Resource Credits (CERCs). A REC or CERC is a certificate demonstrating 1 megawatt-hour (MWh) of energy output from a certified renewable or clean energy generator that can be used to meet RPS or CES compliance requirements. CERCs or RECs can usually be traded, sold, or purchased multiple times until they are retired.

Although RECs and CERCs can only be retired for RPS or CES compliance in a single state, they can be procured from the pool of energy resources that can encompass sources located in multiple states. The Maryland RPS can be met by RECs from resources supplying power in, or transmitted into, the PJM Interconnection (PJM). PJM is the regional transmission organization (RTO) serving portions or all of 13 states (and the District of Columbia), including Maryland.[13] An LSE can also opt instead to pay an Alternative Compliance Payment (ACP) during a given compliance period in lieu of supplying the minimum percentage of RECs or CERCs required. The ACP operates as a *de facto* ceiling for REC prices.

1.2. Maryland RPS

The Maryland RPS was first enacted in 2004 when the Maryland General Assembly passed Senate Bill (SB) 869, the Renewable Energy Portfolio Standard and Credit Trading Act (Maryland RPS Act). Since the law first took effect in 2006, the Maryland RPS has been amended 15 times, including as recently as the enactment of SB 526 in October 2022, as codified in Chapter 678 of the Acts of the Maryland General Assembly of 2022. As a result of these revisions, the Maryland RPS has changed in significant ways since first enacted. For a deeper understanding of the history of the Maryland RPS in general, please see the 2019 RPS Report.[14] Additionally, see Appendix B for an overview of policy changes made to the Maryland RPS since the 2019 RPS Report and their impact.

What follows is an abbreviated overview of Maryland's RPS policy.

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[11] In Maryland, various entities can serve customers as an LSE, such as a third-party retail supplier providing competitive electricity service. See PUA §1–101 for additional information.

[12] "Renewables Portfolio Standards Resources." Lawrence Berkeley National Laboratory. emp.lbl.gov/projects/renewables-portfolio/. Last updated June 2023. Nebraska is the only state to have a CES and not an RPS policy.

[13] Participating jurisdictions include Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia.

[14] PPRP, *Final Report Concerning the Maryland Renewable Portfolio Standard as Required by Chapter 393 of the Acts of the Maryland General Assembly of 2017*, December 2019, dnr.maryland.gov/pprp/Documents/FinalRPSReportDecember2019.pdf.

1.2.1. Target

The percentage requirements of the Maryland RPS, after accounting for recent legislative changes, are shown in **Table 1**. Note that the requirements listed in the years after 2023 are projected based on existing legislative requirements, assumed offshore wind (OSW) online dates and resource characteristics, and recent energy sales forecasts from the Maryland Public Service Commission (PSC).[15] See Appendix D for further discussion of these assumptions. Special requirements with regard to carve-outs, municipal utilities, rural cooperative utilities, and OSW are noted in the **Table 1** footnotes. See Appendix C for additional information regarding compliance with the Maryland RPS to date.

The Maryland RPS is currently set to increase to 52.5% by 2030. For scenarios evaluating an 100% RPS requirement, the total percentage requirement is assumed to incrementally increase by 5% each year beginning in 2031 through 2039, and then by an additional 2.5% in 2040, bringing the combined requirement to 100%. The Tier 2, Tier 1 Offshore Wind, Tier 1 Solar, and Tier 1 Geothermal heat pump requirements are not adjusted between the 52.5% and 100% RPS scenarios. Thus, the incremental increases accrue to the Tier 1 non-carve-out requirement.[16]

1.2.2. Qualified Resources

The resources that currently qualify for the Maryland RPS are listed in **Table 2**.

Table 1. Maryland RPS – Percentage of Renewable Energy Required

	TIER 1[1]						
Year	Non-Carve-out	Solar	Offshore Wind [2]	Geothermal	TIER 1 TOTAL	TIER 2 TOTAL	TOTAL RPS
2022	24.6	5.5	0.0	0.0	**30.1**	**2.5**	**32.6**
2023	25.85	6.0	0.0	0.05	**31.9**	**2.5**	**34.4**
2024	27.05	6.5	0.0	0.15	**33.7**	**2.5**	**36.2**
2025	28.25	7.0	0.0	0.25	**35.5**	**2.5**	**38**
2026	29.5	8.0	0.0	0.5	**38.0**	**2.5**	**40.5**
2027	~22.02	9.5	~9.23	0.75	**41.5**	**2.5**	**44**
2028	~21.78	11.0	~9.22	1.0	**43.0**	**2.5**	**45.5**
2029	~26.76	12.5	~9.24	1.0	**49.5**	**2.5**	**52**
2030	~25.27	14.5	~9.23	1.0	**50**	**2.5**	**52.5**

Source: Annotated Code of Maryland, PUA § 7-703.

[1] The geothermal requirement began in 2023. The Annotated Code of Maryland, PUA § 7-703, requires electric cooperatives to obtain 2.5% of energy from solar carve-out resources "in 2020 and later." The reduced share of solar is replaced with a higher share of non-carve-out resources. Municipal utilities are required to obtain 20.4% of total energy from Tier 1 resources, including 1.95% from solar carve-out resources and an amount of OSW energy capped at a maximum of 2.5%, in 2021 and later. The Tier 2 requirement does not apply to municipal utilities after 2021. The geothermal carve-out does not apply to municipal utilities.

[2] The percentage of future RECs provided by OSW will fluctuate on an annual basis depending on total MWh output and retail energy sales. Offshore REC (OREC) estimates assume that all Phase 1 (see Maryland PSC Order No. 88192) and Phase 2 (see Maryland PSC Order No. 88192) projects are fully operational in 2027. All projects are assumed to have a capacity factor of 43.3%. Total OREC generation is relative to projected aggregate energy sales, net demand-side management, from the Maryland PSC's *Ten-Year Plan (2023-2032) of Electric Companies in Maryland*. Estimates do not reflect OSW associated with the non-binding targets established by SB 526 (i.e., 8.5 GW by 2031).

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[15] Recent changes to the expected online data of the Skipjack and US Wind OSW facilities are not reflected in this study.

[16] The Tier 1 non-carve-out requirement also changes in certain models on account of setting the Maryland OSW target to approximately 8.5 GW.

Table 2. Maryland RPS – Eligible Facilities as of April 2024

TIER 1
▪ Solar PV and solar water-heating systems within Maryland
▪ Onshore wind
▪ Offshore wind within designated areas near Maryland
▪ Qualifying biomass[1]
▪ Methane from the anaerobic decomposition of organic materials in a landfill or a wastewater treatment plant
▪ Geothermal, including energy generated through geothermal exchange with or thermal energy avoided by groundwater or a shallow ground source, within Maryland
▪ Ocean, including energy from waves, tides, currents, and thermal differences
▪ Fuel cells powered by a Tier 1 resource
▪ Hydroelectric plants under 30 MW licensed by FERC or exempt from licensing
▪ Poultry litter-to-energy within Maryland
▪ Waste-to-energy within Maryland
▪ Refuse-derived fuel within Maryland
▪ Thermal biomass
▪ Raw or untreated wastewater within Maryland used as a heat source or sink for a heating or cooling system
TIER 2
▪ Hydroelectric power other than pumped storage

Source: Annotated Code of Maryland, PUA § 7-703. FERC = Federal Energy Regulatory Commission.

[1] Qualifying biomass is a non-hazardous, organic material that is available on a renewable or recurring basis; waste material that is segregated from inorganic waste material; and is derived from any of the following sources:

1. Excluding old-growth timber, any of the following forest-related resources:
   a. Mill residue, except sawdust and wood shavings;
   b. Pre-commercial soft wood thinning;
   c. Slash, brush, or yard waste; and
   d. Pallets, crates, or dunnage.
2. Agricultural and silvicultural sources, including tree crops, vineyard materials, grains, legumes, sugar, and other crop byproducts or residues.
3. Gas produced from the anaerobic decomposition of animal waste or poultry waste.
4. A plant that is cultivated exclusively to be used as a Tier 1 or Tier 2 renewable energy resource to produce electricity.

Qualifying biomass does not include unsegregated solid waste or postconsumer wastepaper; black liquor, or any product derived from black liquor; or invasive exotic plant species.

1.3. Maryland CES

In 2020 and 2021, legislation was introduced (but not enacted) to require a 100% CES in Maryland by 2040. The bill (House Bill [HB] 1362, proposed March 2021), known as the Clean and Renewable Energy Standard (CARES), proposed to create a new clean energy resource tier to complement the existing Maryland RPS (as of early 2021).[17] Although not enacted into law, the proposed parameters of CARES (as updated to reflect Maryland RPS legislation through 2022) provided the basis for Exeter's assessment of a potential CES.

1.3.1. Target

The proposed percentage requirements of the Maryland CES, after adjusting for recent legislative changes, are shown in **Table 3**. Existing nuclear generation is not eligible for CARES. Instead, the quotient of the three-year average of nuclear power generation and retail electricity sales in Maryland counts toward the non-carve-out level in CARES. That is, existing in-state nuclear generation from Calvert Cliffs offsets the total CES requirement. Besides a new Clean Energy Tier (see **Table 4**), the remaining CES requirements mirror the existing RPS with the exception that the CES excludes a Tier 2 component beyond 2020.

1.3.2. Qualified Resources

CARES identifies several resources as eligible to create CERCs to meet the CES requirements beginning in 2031. **Table 4** outlines these resources as well as CERC eligibility requirements. Recent combined heat and power (CHP) generation installed in Maryland averaged 77% efficiency, according to the Maryland Department of the Environment (MDE). Although CARES builds upon the existing Maryland RPS requirements, it also removes black liquor and municipal solid waste (MSW) from eligibility as Tier 1 resources.

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[17] CARES 2021 Presentation to MCCC Mitigation Working Group (June 22, 2021). mde.maryland.gov/programs/Air/ClimateChange/MCCC/MWG/CARES%20presentation%20by%20MDE.pdf.

Table 3. Proposed Maryland CES – Percentage of Renewable and Clean Energy Required

	RPS[1]							
Year	Non-Carve-out	Solar	Offshore Wind	Geothermal	RPS TOTAL	Clean Energy Tier	Existing Nuclear Offset[2]	TOTAL CES
2022	~23.4	5.5	0.0	0.0	~28.9	3.3	~25.9	**58.1**
2023	~24.3	6.0	0.0	0.05	~30.3	4.2	~25.9	**60.4**
2024	~25.2	6.5	0.0	0.15	~31.8	5	~25.9	**62.7**
2025	~26	7.0	0.0	0.25	~33.3	5.8	~25.9	**65**
2026	~26.3	8.0	0.0	0.5	~34.8	6.7	~26.0	**67.5**
2027	~17.8	9.5	~9.23	0.75	~37.1	7.5	~25.9	**70.5**
2028	~17.3	11.0	~9.22	1.0	~38.3	8.3	~25.9	**72.5**
2029	~17	12.5	~9.24	1.0	~39.5	9.2	~25.8	**74.5**
2030	~14.8	14.5	~9.23	1.0	~39.3	10	~25.7	**75**
2031	~15.3	14.5	~9.24	1.0	~39.8	12	~25.7	**77.5**
2032	~15.9	14.5	~9.24	1.0	~40.4	14	~25.6	**80**
2033	~16.5	14.5	~9.24	1.0	~41	16	~25.5	**82.5**
2034	~17	14.5	~9.24	1.0	~41.5	18	~25.5	**85**
2035	~17.6	14.5	~9.24	1.0	~42.1	20	~25.4	**87.5**
2036	~18.2	14.5	~9.24	1.0	~42.7	22	~25.3	**90**
2037	~18.7	14.5	~9.24	1.0	~43.2	24	~25.3	**92.5**
2038	~19.3	14.5	~9.24	1.0	~43.8	26	~25.2	**95**
2039	~19.9	14.5	~9.24	1.0	~44.4	28	~25.1	**97.5**
2040	~20.5	14.5	~9.24	1.0	~45	30	~25.0	**100**

[1] The same rural cooperatives, municipal utilities, and OSW assumptions identified in **Table 1** also apply to the 100% CES.
[2] Estimated based on the average Calvert Cliffs net generation listed in EIA Form 923 for the years 2019-2021 relative to projected aggregate energy sales, net demand-side management, from the Maryland PSC's *Ten-Year Plan (2023-2032) of Electric Companies in Maryland*.

Table 4. Proposed Maryland CES – Eligible Facilities and CERC Eligibility

- New nuclear power in Maryland[1]
- New efficient combined heat and power (CHP) in Maryland, defined as follows:[1]
  - >90% efficiency gets full credit (1 CERC per MWh)
  - 75% to <90% efficiency gets ¾ credit (0.75 CERC per MWh)
  - 60% to <75% efficiency gets half credit (0.5 CERC per MWh)
  - <60% efficiency gets no credit
- Natural gas or qualifying biomass with carbon capture, utilization and storage (CCUS) that results in the indefinite sequestration of captured carbon dioxide (CO_2)
- Qualifying biomass with CCUS would get double credit
  - One REC for using qualifying biomass and 1 CERC for capturing carbon
  - Credited in proportion to the share of carbon captured (e.g., capturing 50% emissions gets 50% credit)
- Large hydroelectric of at least 30 MW[2]
- Any Tier 1 resources eligible under the Maryland RPS that are connected to the distribution grid in Maryland
- Other emerging net-zero technologies recognized by the Maryland PSC

[1] New resources defined as being installed in 2022 or later. All fuel types allowed (e.g., natural gas, hydrogen, etc.) subject to efficiency requirements.
[2] Credits accrue to the state, rather than the generation owner, for purposes of funding remediation projects.

1.4. Approach

To address the assessment requirements, this report uses several methods, including assessment of existing research, analysis of both public and proprietary data, production cost and capacity expansion modeling both at a state and regional level, and input-output (I-O) modeling at a state level. An overview of each method is provided below. VCE's model, model setup, data inputs, and assumptions are described in greater detail in Appendix D. Similarly, Appendix E includes additional documentation related to Exeter's IMPLAN models. The Report also uses data from a variety of technical sources, such as the PJM Generation Attribute Tracking System (GATS), the U.S. Energy Information Administration (EIA), and the Maryland PSC, as referenced throughout the report.

Significant effort was applied to make sure the policies of interest, in Maryland in particular, are accurately represented. The model also incorporates certain policies for other PJM states and PJM as a whole. This section (and the companion appendices) provides details on how the model represents these policies and other characteristics of the PJM market. Additionally, to help understand dependencies in the modeling process, Exeter and VCE evaluated alternative pathways and inputs. These alternative approaches, referred to as scenarios, help isolate the impact of certain policies and show the effect of altered assumptions.

1.4.1. Modeling

Vibrant Clean Energy's WIS:dom-P: Capacity Expansion and Production Cost Modeling

Exeter worked with VCE to model various pathways for the State of Maryland to meet a 100% RPS or 100% CES in various fashions and explore the economic feasibility of these various pathways. For this exercise, VCE employed its WIS:dom®-P (Weather-Informed energy Systems: for design, operations and markets) optimization planning model. WIS:dom-P simultaneously co-optimizes the capacity expansion requirements (generation, transmission, and storage) and the dispatch requirements (production cost, power flow, reserves, ramping, and reliability) for the entire electric (energy) grid of interest (see **Figure 5**) while co-optimizing utility-scale generation, storage, transmission, and distributed energy resources. The model utilizes high-resolution (spatially and temporally) weather data to determine resource properties over vast spatial-temporal horizons.

WIS:dom-P relies on publicly available data where possible, and contains default values for generators, transmission, storage, production cost, and resource siting. The model can also incorporate custom datasets required for detailed modeling of specific questions. Exeter worked with VCE extensively to develop the inputs and assumptions for the 100% Study. **Table 5** summarizes some (but not all) of the input changes and adjustments made for this study. In several cases, the assumptions vary between the first four model scenarios (i.e., Phase 1) and subsequent models (i.e., Phase 2). Additional discussions of how WIS:dom-P works and the model assumptions are included in Appendix D.

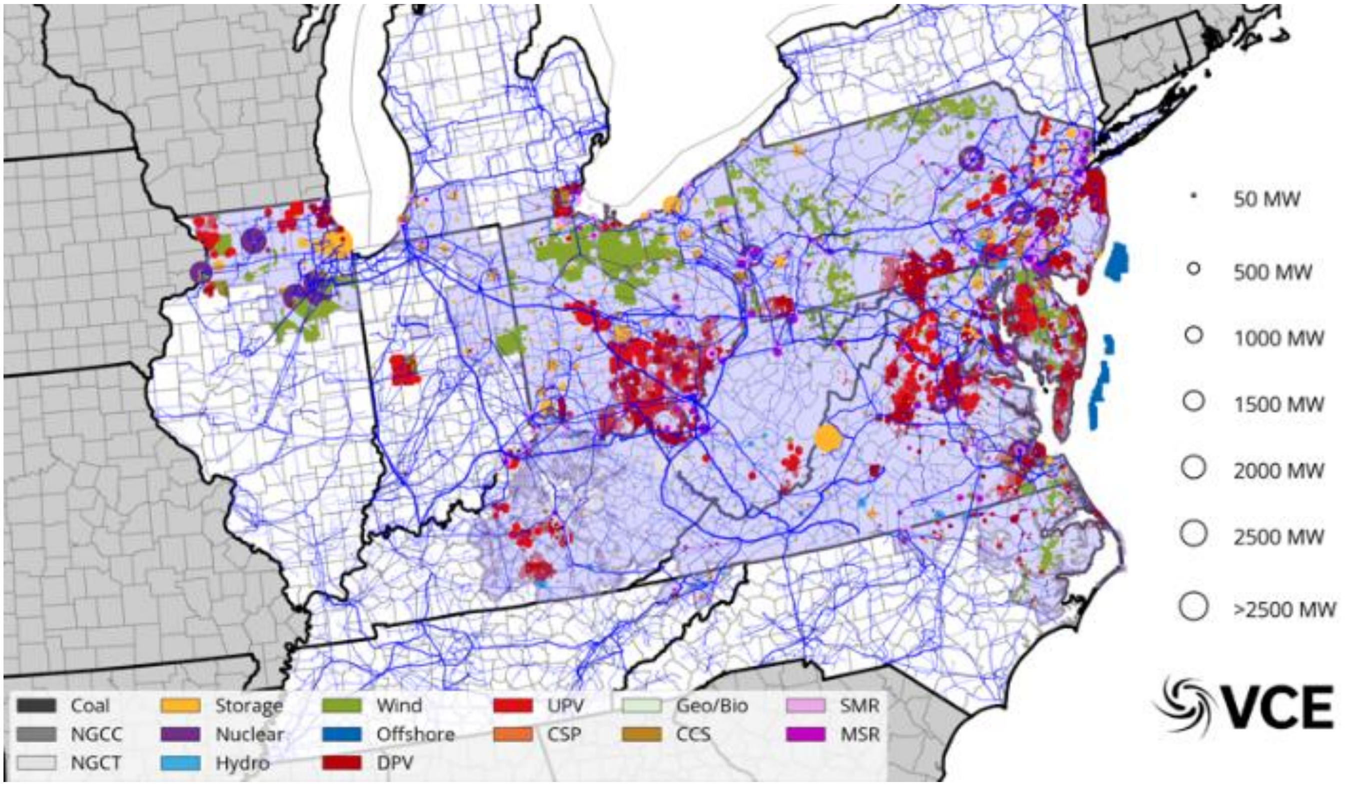

Figure 5. Approximate Region That Would Be Modeled with WIS:dom®-P.

Note: Dark blue area represents the PJM region, comprised of portions or all of 13 states and the District of Columbia. This area, plus the entirety of the State of Illinois, was assessed in the Phase 1 models. The entirety of each PJM jurisdiction was assessed in the Phase 2 models. See below for further description of each Phase.

Table 5. Partial List of WIS:dom-P Inputs and Assumptions Specific to the 100% Study	
Topic	Data Input/Assumptions
Model Resolution	Phase 1: County-level in Maryland, statewide elsewhere. All of PJM modeled, plus the entire State of Illinois. Phase 2: Statewide modeling for all PJM states.
Energy and Peak Demand Forecast	Phase 1: VCE's Business-As-Usual (BAU) forecasts were used. These differed by less than 2% from PJM's forecast. Phase 2: Updated VCE BAU forecasts or high electrification forecasts developed by VCE, depending on the scenario.
Fuel Costs	Fuel costs are based on the EIA *Annual Energy Outlook* (AEO) 2022 High Oil and Gas Supply scenario. Spatial cost multipliers for natural gas were applied to reflect varying fuel costs among states. Additionally, hourly multipliers were applied to coal and natural gas to reflect seasonal variation in fuel prices
Capital Costs	Except as noted, all capital costs are based on NREL's Annual Technology Baseline (ATB) 2021 moderate cost assumptions.
Fixed and Variable O&M Costs	Except as noted, all fixed and variable O&M costs are based on NREL's ATB 2021 moderate cost assumptions.
Excluded Technologies	Carbon capture systems, small modular nuclear reactors, and molten salt reactors were only modeled for select scenarios.
Energy Storage	Fixed and variable costs for energy storage are sourced from VCE.
EmPOWER MD	Phase 1: EmPOWER MD assumed to end in 2023. Phase 2: EmPOWER MD continues at levels as of year-end 2021.
Maryland RPS/CARES	It is assumed that Maryland will meet the requirements of the Maryland RPS or CARES, including carve-outs, through the retirement of RECs or ORECs, as opposed to ACPs.
Federal Environmental Requirements	Existing EPA regulations as of the end of 2020 are incorporated, such as the Cross-State Air Pollution Rule, the Mercury and Air Toxics Standard, and New Source Performance Standards.
Advanced Energy Technologies	Includes molten salt reactors, small modular reactors, and advanced CHP systems. Earliest allowable addition date specified as 2030 in applicable scenarios.
Regional Greenhouse Gas Initiative (RGGI)	RGGI is included. Phase 1: Pennsylvania and Virginia are assumed to be a part of RGGI beginning in 2023. Phase 2: Only Virginia is assumed to be a part of RGGI.
Maryland Climate Solutions Now Act (CSNA)	Phase 1: The CSNA was not incorporated. Phase 2: CSNA targets assumed to be mandatory.
Plant Retirements	Model includes all planned retirements and plants in operation as of December 2021.
Existing Nuclear Power Plants	Except in Illinois, existing nuclear power plants can economically retire after 2026. Nuclear plants can operate through 2027 in Illinois, thanks to supportive state incentives.
Calvert Cliffs	Whether Calvert Cliffs is assumed to retire when the NRC license for Unit 1 expires in 2034 and Unit 2 in 2037 varied by scenario.
New Generation Capacity	Generation plants under construction as of December 2021 were incorporated.
Transmission	All transmission in PJM at 69 kV and above is included.
New Transmission	All new transmission is built with double-circuited lines, with substations every 100 miles. Retired plants opened new transmission capacity on existing lines at the retired generation node.
Transmission Upgrades	Existing lines can be upgraded one voltage class (e.g., 138 kV to 230 kV).
Geothermal	Model will not build utility-scale geothermal plants. Geothermal heat pumps limited to a maximum of 10,000 per year in Maryland to represent manufacturing limitations.

Table 5 (continued)

Topic	Data Input/Assumptions
Offshore Wind	Phase 1: The 2,200 MW of OSW approved by the Maryland PSC is assumed to all come online at the beginning of 2027. Phase 2: the 8,500-MW target enacted by the Maryland General Assembly in 2023 is incorporated between 2027 and 2031 using a glide path.
Combined Heat and Power (CHP)	Modeled as an average of reciprocating engines and gas turbine technologies. Assumes 65-75% efficiency and that CERCs from CHP would only get partial credit under CARES.
Natural Gas Plants with CCS (new and retrofit)	For retrofits of existing natural gas plants, costs sourced from the National Energy Technology Laboratory. Assumes 95% efficiency for new natural gas + CCS and 90% for a CCS retrofit.
Biomass Carbon Capture and Storage (new and retrofit)	Cost data from the Massachusetts Institute of Technology. Retrofit costs estimated by subtracting the cost of a new biomass plant with CCS. Double-credit allowed for CARES. Assumes 90% efficiency for new biomass + CCS and 90% for a CCS retrofit.
Hybrid Resources	Hybrid resources are not modeled explicitly. Generation plants can be located at any node and are co-optimized with each other.
Solar Inverter Loading Ratio	1.25, as sourced by VCE from industry sources.
Discount Rate	5.87%, as sourced by VCE from industry sources.

IMPLAN: Input-Output Modeling

Exeter used the IMPLAN I-O model to project industry growth and local job creation associated with the development of certain technologies used to meet a 100% RPS or 100% CES. In IMPLAN, an initial change in spending is referred to as a change in "final demand." It is considered a direct effect, which then creates indirect and induced effects.

Exeter relied upon the original bill-of-goods approach developed for the 2019 RPS Report and expanded upon it to incorporate the additional renewable technologies included in this 100% Study. Overnight capital costs (OCC) and operations and maintenance (O&M) costs were sourced from the National Renewable Energy Laboratory's (NREL's) Annual Technology Baseline (ATB) (2023 edition) and applied to forecasted capacity additions by year to develop annual OCC and O&M costs. These annual costs were then apportioned into industries as changes to final demand using various resources such as NREL's benchmark reports and Jobs and Economic Development Impact (JEDI) model. Lastly, a Maryland-based proportion of final demand for each industry was derived from various resources including NREL, EIA, and IMPLAN data. This in-state final demand was modeled in IMPLAN as industry output events resulting in estimated economic impacts per technology and scenario.

Exeter's IMPLAN modeling focused on the following in-state technologies: Geothermal Heat Pumps, Onshore Wind, Offshore Wind, Utility-scale Batteries, Utility-scale Solar PV, and Distributed Solar PV. Additional discussion of how IMPLAN works and the model assumptions are included in Appendix E.

1.4.2. Scenarios

Exeter and VCE analyzed a host of pathways and inputs as part of the modeling process. **Table 6** provides a brief description of the scenarios addressed in this report alongside the nomenclature used to refer to each scenario in the subsequent chapters. The initial model runs (i.e., Phase 1 models) focused on a "base case" set of a reference case (i.e., Business-As-Usual, or BAU), 100% RPS by 2040, and 100% CES by 2040. These first three scenarios assumed the Calvert Cliffs nuclear plant (Calvert Cliffs) would retire in 2034 (Unit 1) and 2037 (Unit 2) when the plant's operating license from the Nuclear Regulatory Commission (NRC) expires. A fourth scenario was added assuming a 100% RPS and that Calvert Cliffs would not retire. Specifically, this scenario assumes that Constellation Energy Corporation, the owner and operator of Calvert Cliffs, would apply for and receive approval from the NRC to extend the operating license.

Due to the modeling issues identified in the Preface, approximately a year passed before Exeter and VCE could complete additional modeling. During the interim period, some policy and market conditions changed (e.g., Maryland established new OSW targets). Additionally, Exeter received feedback on the initial model assumptions, including changes to the "base case" (e.g., reversing the previous decision to treat certain targets as goals, rather than requirements). Consequently, Exeter and VCE adopted several significant revisions to the model inputs and assumptions. Additionally, VCE adopted an alternative model approach that relieved technical constraints that impeded the model from solving. As a result, the subsequent set of modeled scenarios (i.e., Phase 2) present a narrower technical analysis (e.g., excluding county-level results for Maryland).

The second set of models includes alternative versions of the BAU, 100% RPS, and 100% CES scenarios. Additionally, Exeter and VCE implemented scenarios assessing high electrification and increased Maryland electricity demand; updated 100% requirement target date set at 2035; and limitations on new natural gas development, separately for Maryland and PJM-wide.[18] Each of these scenarios was conducted for a prospective 100% RPS and 100% CES. Exeter and VCE also modeled a PJM-wide 70% RPS requirement, meaning increased (and competing) REC demand across the PJM footprint;[19] and a scenario where the model maximizes in-state renewable energy generation, such that a higher proportion of a 100% RPS is met by in-state resources. **Table 7** provides a summary of the key differences between each of the Phase 1 and Phase 2 models.

Table 6. Overview of Model Scenarios

Report Nomenclature	Description
BAU-1	Initial Business-As-Usual scenario (i.e., does not reflect recent changes in MD laws, load growth, RGGI, etc.). Strict PJM boundaries plus all of Illinois.
100% RPS-1	Initial BAU scenario adjusted to reflect 100% RPS policy in MD.
Calvert-1	Initial 100% RPS scenario adjusted to assume Calvert Cliffs relicensing and retention.
100% Clean-1	Initial BAU scenario adjusted to reflect 100% CES policy (CARES proposal) in MD.
New Tech BAU-2	Revised BAU scenario incorporating load, policy, and model boundary changes. Assumes Calvert Cliffs relicensing and CSNA targets are met, among other adjustments. Allows CCS/bioenergy with CCS (BECCS) and advanced technologies.
100% RPS-2	Revised BAU scenario adjusted to reflect 100% RPS policy in MD. Excludes CCS/BECCS and advanced technologies.
100% RPS Max-2	Revised 100% RPS scenario adjusted to maximize in-state renewable generation.
100% RPS No NG MD-2	Revised 100% RPS scenario adjusted to not allow new natural gas capacity in MD.
100% RPS No NG PJM-2	Revised 100% RPS scenario adjusted to not allow new natural gas capacity in PJM.
100% RPS 2035-2	Revised 100% RPS scenario adjusted to meet target by 2035.
100% RPS High Electric-2	Revised 100% RPS scenario adjusted to assume high electrification.
PJM 70% RPS-2	Revised BAU scenario adjusted to reflect 70% RPS policy for all states in PJM.
100% Clean-2	Revised BAU scenario adjusted to reflect 100% CES policy (CARES proposal) in MD.
100% Clean No NG MD-2	Revised 100% CES scenario adjusted to not allow new natural gas capacity in MD.
100% Clean No NG PJM-2	Revised 100% CES scenario adjusted to not allow new natural gas capacity in PJM.
100% Clean 2035-2	Revised 100% CES scenario adjusted to meet target by 2035.
100% Clean High Electric-2	Revised 100% CES scenario adjusted to assume high electrification. Excludes CCS/BECCs.

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[18] The scenarios limiting the development of new natural gas in Maryland and PJM reflect suggestions from the Maryland 100% RPS and CES Study Working Group that Exeter and VCE evaluate the impacts of additional constraints on natural gas development, having observed significant natural gas capacity additions under the Phase 1 model assumptions.

[19] A 70% PJM-wide RPS requirement implies that, in aggregate, 70% of total PJM load is attached to an RPS requirement. The 70% target roughly aligns with the assumptions of the "Accelerated" scenario (i.e., 70% clean energy generation in 2035 and beyond) studied by PJM in the second phase of an ongoing study series: pjm.com/-/media/library/reports-notices/special-reports/2022/20220517-energy-transition-in-pjm-emerging-characteristics-of-a-decarbonizing-grid-white-paper-final.ashx.

Table 7. Comparison of Model Scenarios

	MARYLAND												
Report Nomenclature	RPS/ Clean Require-ment	Calvert Cliffs Re-tained	8.5-GW OSW	3-GW Energy Storage	GSHP	Em-POWER	CSNA Targets	Load Growth	Natural Gas Limi-tations	CCS/ BECCS Allowed[1]	Advanced Tech. Allowed[1]	Bound-aries	PA & VA in RGGI
BAU-1	Current RPS	No	No	No	Yes	No	No	Low	None	No	No	PJM + Entirety of IL	Yes
100% RPS-1	100% RPS	No	No	No	Yes	No	No	Low	None	No	No	PJM + Entirety of IL	Yes
Calvert-1	100% RPS	Yes	No	No	Yes	No	No	Low	None	No	No	PJM + Entirety of IL	Yes
100% Clean-1	100% CES	No	No	No	Yes	No	No	Low	None	Yes [17.8 GW]	Yes [4.0 GW]	PJM + Entirety of IL	Yes
New Tech BAU-2	Current RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	Yes [4.2 GW]	Yes [1.6 GW]	Entirety of PJM States	VA only
100% RPS-2	100% RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	No	No	Entirety of PJM States	VA only
100% RPS Max-2	100% RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	No	No	Entirety of PJM States	VA only
100% RPS No NG MD-2	100% RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	No new NG in MD	No	No	Entirety of PJM States	VA only
100% RPS No NG PJM-2	100% RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	No new NG in PJM	No	No	Entirety of PJM States	VA only
100% RPS 2035-2	100% RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	No	No	Entirety of PJM States	VA only
100% RPS High Electric-2	100% RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	No	No	Entirety of PJM States	VA only
PJM 70% RPS-2	70% RPS	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	No	No	Entirety of PJM States	VA only
100% Clean-2	100% CES	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	Yes [39.0 GW]	Yes [7.4 GW]	Entirety of PJM States	VA only
100% Clean No NG MD-2	100% CES	Yes	Yes	Yes	No	Yes	Yes	Mod.	No new NG in MD	Yes [4.2 GW]	Yes [3.0 GW]	Entirety of PJM States	VA only
100% Clean No NG PJM-2	100% CES	Yes	Yes	Yes	No	Yes	Yes	Mod.	No new NG in PJM	Yes [38.8 GW]	Yes [12.5 GW]	Entirety of PJM States	VA only
100% Clean 2035-2	100% CES	Yes	Yes	Yes	No	Yes	Yes	Mod.	None	Yes [4.2 GW]	Yes [3.0 GW]	Entirety of PJM States	VA only
100% Clean High Electric-2	100% CES	Yes	Yes	Yes	No	Yes	Yes	High	None	No	Yes [2.1 GW]	Entirety of PJM States	VA only

Key: BAU = business as usual; BECCS = bioenergy with carbon capture and storage; CCS = carbon capture and storage; CES = Clean Energy Standard; CSNA = Climate Solutions Now Act; GSHP = ground source heat pumps; GW = gigawatts; Mod = moderate; NG = natural gas; OSW = offshore wind; PJM = PJM Interconnection; RGGI = Regional Greenhouse Gas Initiative; RPS = Renewable Portfolio Standard.

[1] Bracketed numbers are the maximum annual capacity observed in the modeled years.

Maryland Policy Assumptions

From Phase 1 to Phase 2, Exeter and VCE adopted new assumptions that incorporate the following targets, each of which was legislatively established between 2022 and 2023, as model requirements:

- In April 2023, the Maryland General Assembly approved SB 781 (Ch. 95), the Promoting Offshore Wind Energy Resources Act, which adopted a new OSW target of approximately 8.5 GW by 2031. Exeter and VCE incorporated this requirement through a linear interpolation of the additions required to get from 2,022 megawatts (MW) in 2027 to 8.5 GW by 2031.
- In May 2023, the General Assembly approved HB 910 (Ch. 570), creating a new energy storage program for Maryland. Exeter and VCE incorporated this legislation by adding in-state storage requirements of 750 MW by end of 2027; 1,500 MW by end of 2030, and 3,000 MW by end of 2033.
- In March 2022, the General Assembly approved SB 528 (Ch. 38), the Climate Solutions Now Act of 2022, which set a new target for Maryland to reduce its greenhouse gas (GHG) emissions by 60% from 2006 levels by 2031, and to achieve net-zero emissions by 2045. Exeter and VCE incorporated this requirement by calculating the level of reductions already achieved as the model initialization year (2020) and deriving two separate linear glide paths; one based on the slope of reductions to get from 2020 emissions to the 2031 requirement, and another based on the slope to get from 2031 to the 2045 target.

Electrification / Demand Assumptions

Exeter and VCE began the project in 2021, at which time the best available utility and PJM forecasts suggested relatively low demand growth in Maryland.

The trajectory adopted in this study for the Phase 1 models also aligned with electricity load estimates published by other Maryland agencies.[20] In subsequent years, many entities have revised upwards their estimates in response to macroeconomic conditions and broader trends in electrification. Consequently, Exeter and VCE implemented revised demand growth estimates for the Phase 2 models that reflect a modest growth trajectory.[21] Additionally, Exeter utilized VCE's modeled load conditions under "high electrification" conditions, including increased demand for water heating, air conditioning, and personal transportation, for select scenarios. These three sets of demand assumptions are visualized in **Figure 6**.

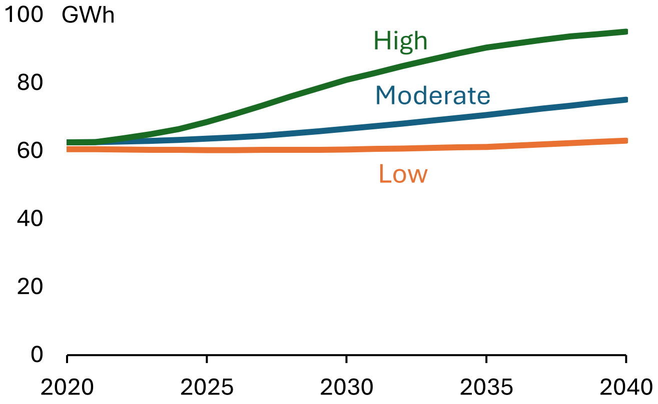

Figure 6. Maryland Electricity Demand Assumptions Used in 100% Study Models

Boundaries

For the Phase 1 models, VCE subdivided the State of Maryland into 23 counties in order to gain higher resolution on the load and bulk transmission within the state. VCE modeled the rest of the PJM footprint as well as Illinois at a state-level.[22] For states with partial PJM coverage (e.g., Kentucky), VCE only included in the model the portion of the state within PJM. Due to model intractability issues, Exeter and VCE adopted alternative boundaries for the Phase 2 models that no longer differentiated county-level Maryland results and incorporated the entirety of all PJM states. The PJM portion of Illinois in the Phase 1 model and all states in the Phase 2 model were differentiated through apportionment.

1.5. How to Use This Report

This report does not aim to answer all questions about the implementation and impact of a 100% RPS or 100% CES. Instead, it responds to the specific requirements of the Maryland General Assembly as defined in Ch. 757, which directed the DNR to conduct a comprehensive study focusing on the economic, socioeconomic, environmental, and reliability impacts of the Maryland RPS. The study findings identified in each of the subsequent chapters address elements of Ch. 757. For the purposes of comparison, findings are converted into dollar figures where applicable and

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[20] For example, Exeter and VCE compared the Phase 1 Maryland load estimates to E3's power sector load estimates developed for MDE's 2030 GGRA Plan. For additional information, see: mde.maryland.gov/programs/air/ClimateChange/Pages/Greenhouse-Gas-Emissions-Reduction-Act-(GGRA)-Plan.aspx.

[21] The development of Exeter and VCE's demand growth estimates preceded the release of the Maryland PSC's electrification study, released December 2023. The PSC's study is available online here: psc.state.md.us/wp-content/uploads/Corrected-MDPSC-Electrification-Study-Report-2.pdf.

[22] The decision to include the entirety of Illinois reflected Maryland's historical reliance on Illinois-wide wind as a source of RECs as well as important changes in PJM's resource mix stemming from Illinois state law. This assumption is discussed further in Appendix D.

presented as part of a broader cost-benefit assessment.

The modeling that undergirds much of the report's analysis assumes perfect foresight and operates in an idealized setting. Unsurprisingly, model results often diverge from real-world conditions that involve competition and imperfect decision-making. Recognizing this, readers should focus on comparative differences between scenarios and model result trends rather than the specific numbers shown in the results. Additionally, "odd" model results, such as the retirement of newly constructed capacity, should not be interpreted as predictive. Rather, these results illustrate challenging conditions and constraints that require additional attention in real life.

2. CAPACITY, GENERATION AND TRANSMISSION

It is well established that demand created by state RPS and CES policies has played an important role in stimulating growth in non-hydroelectric power (hydro) renewable energy generation in the U.S. A recent assessment of RPS and CES policies by the Lawrence Berkeley National Laboratory (LBNL) estimates that state RPS and CES requirements were responsible for, in aggregate, roughly 44% of non-hydro renewable energy generation from 2000-2023 in the U.S.[23,24]

The Maryland RPS itself has also played a pivotal role in the growth of renewable energy in the state. Between 2008-2023, non-hydro, utility-scale (>1 MW) renewable energy capacity in Maryland rose from 155 MW to 924 MW, and generation from these resources nearly tripled from approximately 612,000 MWh to 1,779,000 MWh, according to EIA.[25] More recently, distributed solar generation grew by 455% from 2014-2023.[26] This chapter discusses potential future capacity and generation changes resulting from RPS and CES requirements, among other constraints.[27] The chapter also evaluates related changes in transmission import and export capacity.

2.1. Results

Unsurprisingly, all modeled scenarios show significant additions of renewable energy capacity both in Maryland and within the broader PJM region.[28] These additions correspond with other shifts in market conditions and operations, such as the retirement of existing fossil fuel capacity, increases in generation from renewable resources, and demand for enhancements to existing transmission capacity.

Given the number of models, and for ease of exposition, the subsequent discussion focuses on two scenarios: 100% RPS-1 and 100% RPS-2. These scenarios are then compared to other scenarios within the same Phase. Results are presented both at a PJM-wide and Maryland-specific level. Note that the Phase 1 and Phase 2 models are not directly compared due to differences in the PJM boundaries assumptions.

2.2. Capacity

2.2.1. Phase 1 Model Results

Figure 7 shows PJM-wide capacity for the 100% RPS-1 scenario.[29] Several broader trends are apparent in this data. Notably, virtually all coal capacity across PJM retires by 2031. In its place, several renewable energy resources add significant amounts of capacity. Onshore wind capacity increases the most, to approximately 54.4 GW by 2035, and ultimately comprises 19% of all capacity in 2040—the most for any single resource. UPV (10%), DPV (13%), OSW (6%), and total energy storage power (7%) also become significant sources of PJM-wide capacity by 2040.

From 2023-2040, traditional nuclear capacity declines from 35.6 GW to 20.9 GW. This 41% drop causes traditional nuclear's share of total capacity to halve, from 15% in 2023 to just 7% in 2040. Natural gas combined cycle (CC) capacity fluctuates, with an initial fall from 59.1 GW in 2023 to 46.7 GW in 2026, a subsequent increase to 60.1 GW in 2031, and then a gradual decline to 50.5 GW in 2040. From start to finish, natural gas CC's share of PJM capacity decreases from a quarter of PJM-wide capacity in 2023 to just 18% in 2040. Natural gas combustion turbine's (CT) share of capacity remains approximately the same (15%) over this same time frame.

Maryland-specific capacity levels, as depicted in **Figure 8**, follow comparable patterns as those applicable to PJM, suggesting that the results are driven by similar macro conditions. While renewable capacity gradually increases at a PJM level, it levels off in Maryland by 2030, after the retirement of virtually all coal and some natural gas CT and CC capacity. New natural gas CC installations increase from 2029-2036, especially after Calvert Cliffs retires. The addition of OSW capacity, assumed to come online in 2027, increases total in-state capacity rather than displaces other resources.

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[23] LBNL, *U.S. State Renewables Portfolio & Clean Electricity Standards: 2023 Status Update*. emp.lbl.gov/publications/us-state-renewables-portfolio-clean.

[24] This estimate assumes that all state-level renewable energy growth that coincides with an RPS or CES policy is attributable to the RPS requirement up until the requirement is fulfilled. In reality, some generation used to meet an RPS or CES requirement might have been developed anyway; for instance, if this generation was also economical relative to other types of generation. Additionally, many other factors contributed to the growth of renewable energy over the last two decades, including tax credits, cost declines, and other incentives. Thus, this figure should be interpreted as an upper bound.

[25] *Source:* U.S. Energy Information Administration, "Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860)".

[26] *Source:* U.S. Energy Information Administration, "Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)".

[27] Note that VCE's model results are constrained by the conditions applicable at the time VCE and Exeter developed each model. See Chapter 1 and Appendix D for additional discussion of these assumptions.

[28] For additional information regarding where these resources are sited in Maryland and PJM (subject to assumed constraints), see Appendix D.

[29] For Phase 1 models, "PJM-wide" represents capacity and generation within PJM boundaries or the State of Illinois.

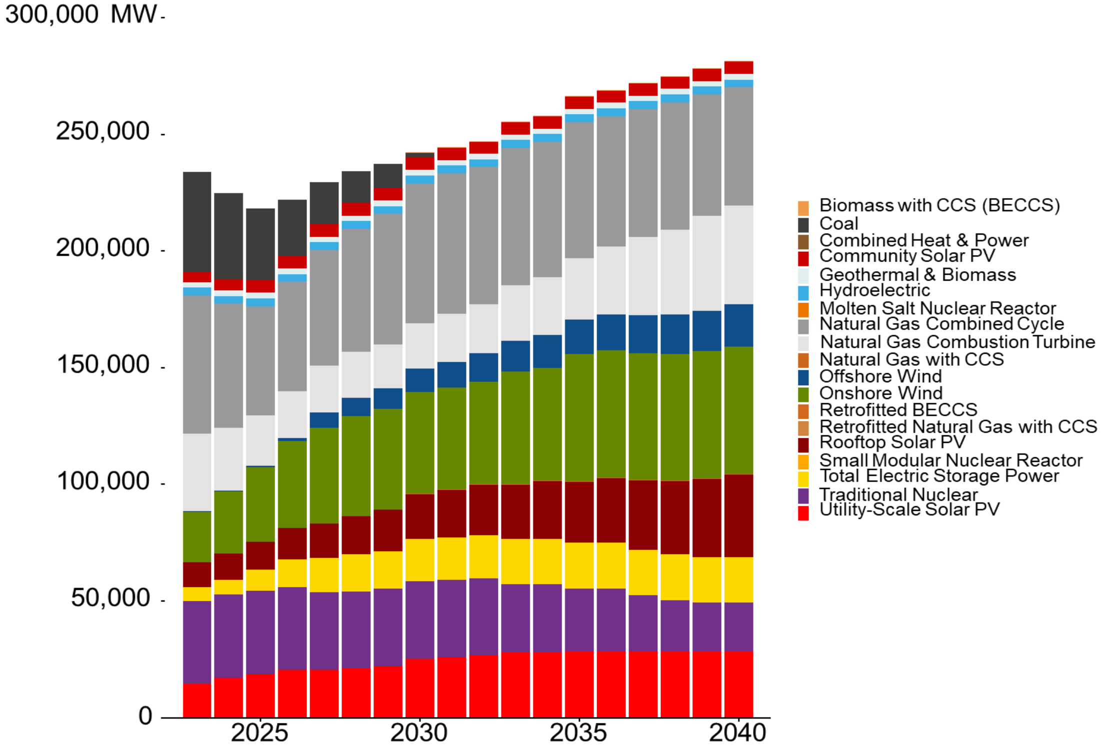

Figure 7. PJM-wide Capacity, 100% RPS-1 Scenario

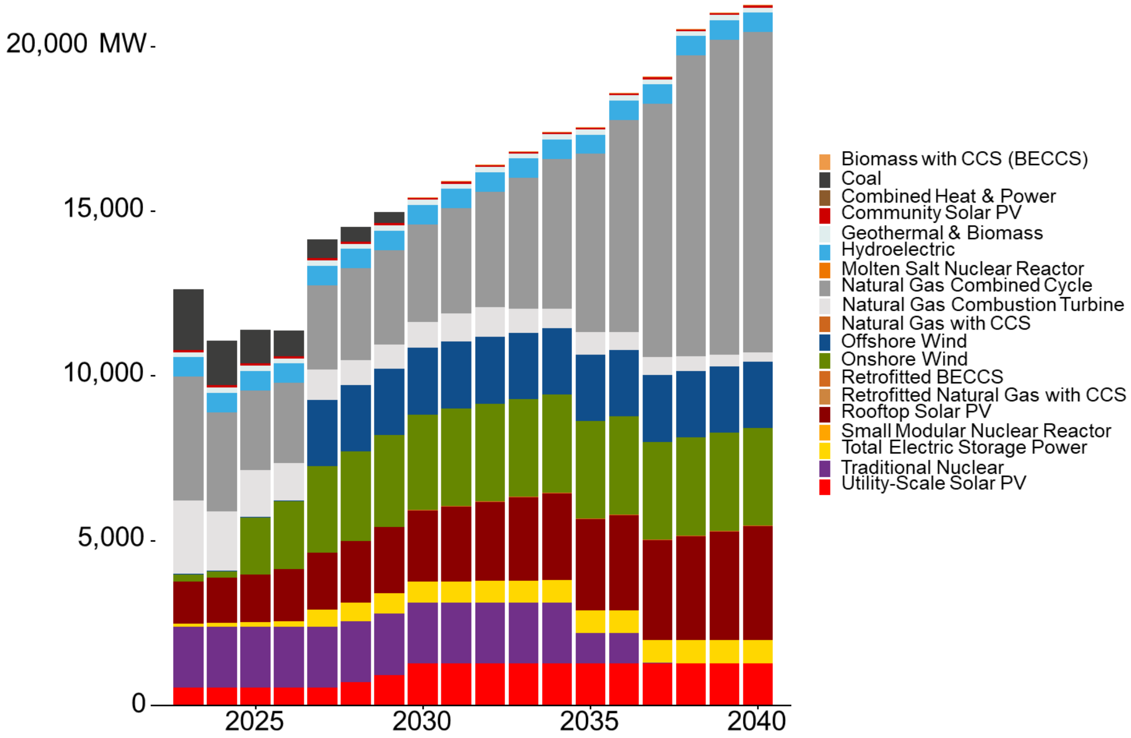

Figure 8. Maryland Capacity, 100% RPS-1 Scenario

Figure 9 and **Figure 10** compare the 100% RPS-1 scenario results to the other Phase 1 scenarios using PJM-wide and Maryland results, respectively. Compared to the 100% RPS-1 scenario, PJM-wide and Maryland capacity are almost identical in the BAU-1 scenario. The results for the Calvert-1 scenario are also similar aside from Calvert Cliffs staying online in 2034 and beyond. After 2023, Calvert Cliffs capacity displaces approximately 500 MW and 1.5 GW of natural gas CC capacity in Maryland and PJM-wide, respectively.

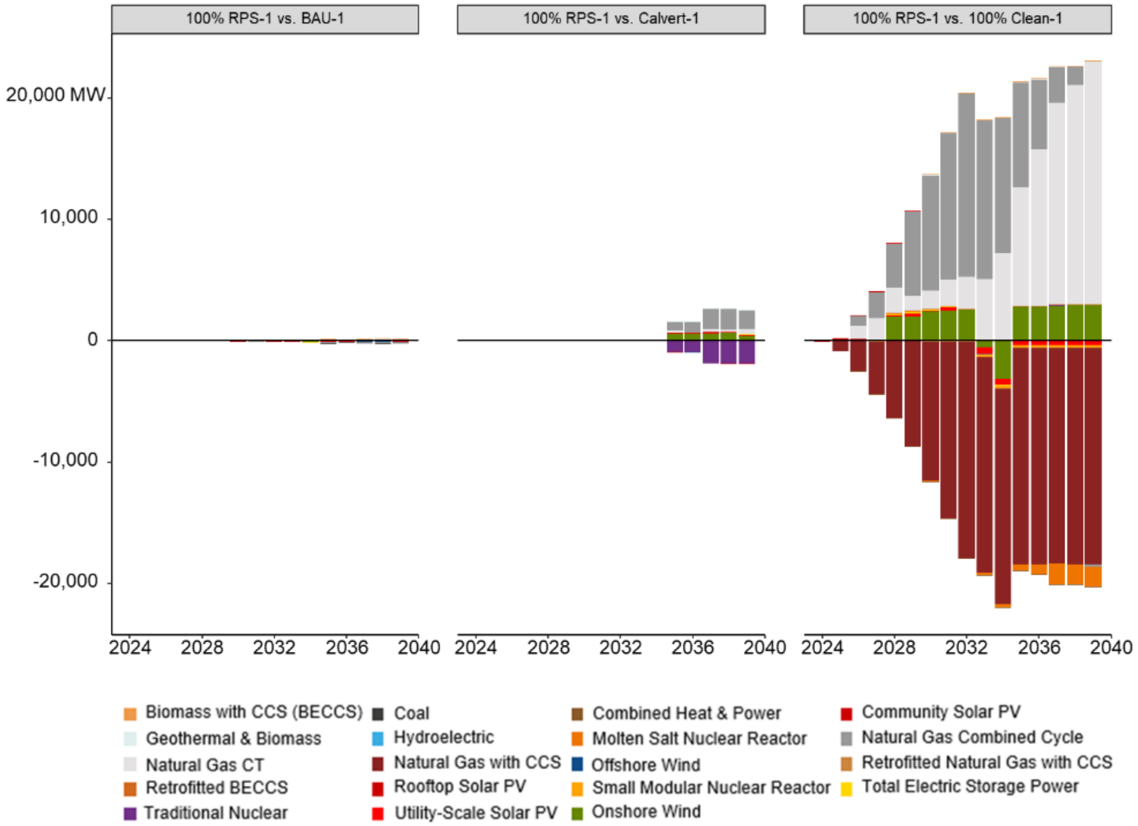

Figure 9. PJM-wide Capacity, Comparison of Phase 1 Scenarios to 100% RPS-1 Scenario

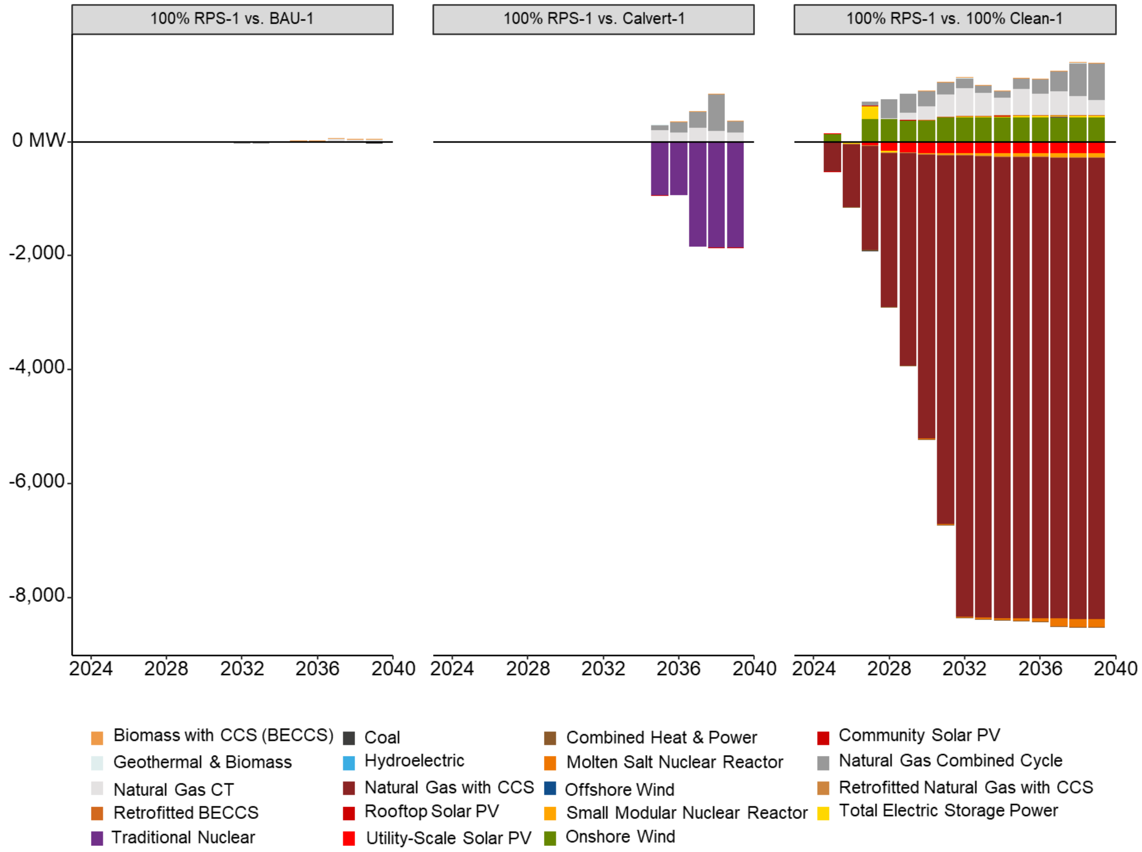

Figure 10. Maryland Capacity, Comparison of Phase 1 Scenarios to 100% RPS-1 Scenario

The chief difference between the 100% Clean-1 scenario and the other three Phase 1 scenarios is the addition of nearly 17.8 GW of new and retrofitted natural gas carbon capture and storage (CCS) capacity PJM-wide, including 8.1 GW in Maryland. The CCS capacity added in Maryland offsets some onshore wind, natural gas CT, and natural gas CC capacity in the state. Over four times as much natural gas CC is displaced outside of Maryland as is displaced in-state. After 2035, the 100% Clean-1 scenario also adds small amounts of capacity from advanced energy technologies both in Maryland and PJM-wide.

2.2.2. Phase 2 Model Results

Figure 11 shows PJM-wide capacity for the 100% RPS-2 scenario.[30] Most of the observed trends are similar to those discussed above for Phase 1: coal capacity decreases to nearly zero by 2031; traditional nuclear capacity declines by approximately a third, bringing its share of capacity down from 13% in 2023 to 6% in 2040; wind becomes the single largest source of capacity, growing from 20.6 GW (9% share of total capacity) in 2023 to over 79.8 GW in 2040 (24% share); and utility-scale solar, rooftop solar, OSW, and total energy storage power all reach an 8-13% share of 2040 capacity. In contrast to Phase 1 results, natural gas CT capacity falls by approximately half, and its share of total capacity declines from 16% in 2023 to 5% in 2040. Natural gas CC capacity initially declines before gradually rising each year after 2026, eventually reaching 70.1 GW in 2040.

The results at a Maryland level, as shown in **Figure 12**, reflect the influence of several changes in assumptions compared to Phase 1. This includes the addition of 8.5 GW of OSW by 2031, 3 GW of electric storage by 2033, and the retention of Calvert Cliffs. Additionally, the assumption that Maryland meets its CSNA targets corresponds with the elimination of coal capacity by 2030 and steep reductions in both natural gas CC (310 MW in 2040) and CT (131 MW in 2040) capacity. After several years of declining capacity, the model shows Maryland beginning to add capacity in 2026. By 2040, renewable energy capacity, including UPV (30%), OSW (23%), onshore wind (20%), and rooftop solar (9%), comprise most of the capacity in Maryland.

Figure 13 and **Figure 14** compare the 100% RPS-2 scenario results to the Phase 2 scenarios with RPS or Clean assumptions, respectively, at a PJM-wide level. Besides the 100% Clean-2 and 100% Clean 2035-2 scenarios, all other scenarios result in additional utility-scale solar capacity, generally in place of smaller quantities of natural gas CC capacity.

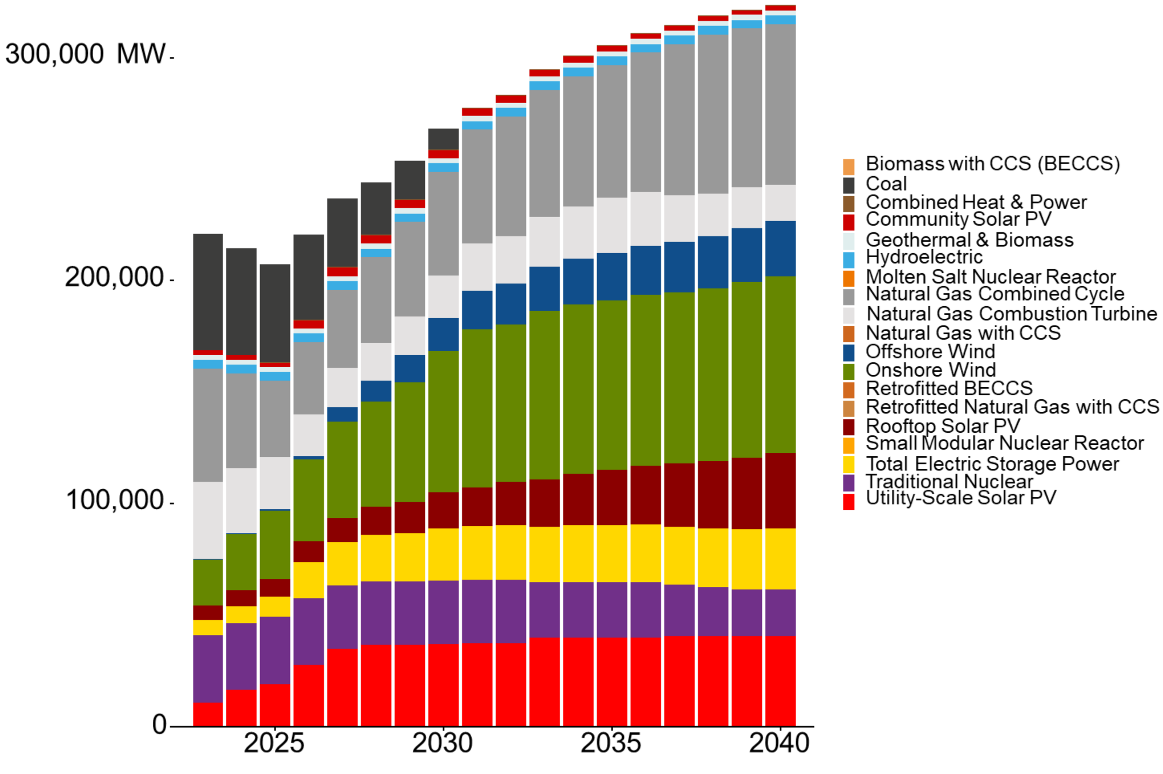

Figure 11. PJM-wide Capacity, 100% RPS-2 Scenario

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[30] For Phase 1 models, “PJM-wide” represents capacity or generation within the entirety of each PJM state.

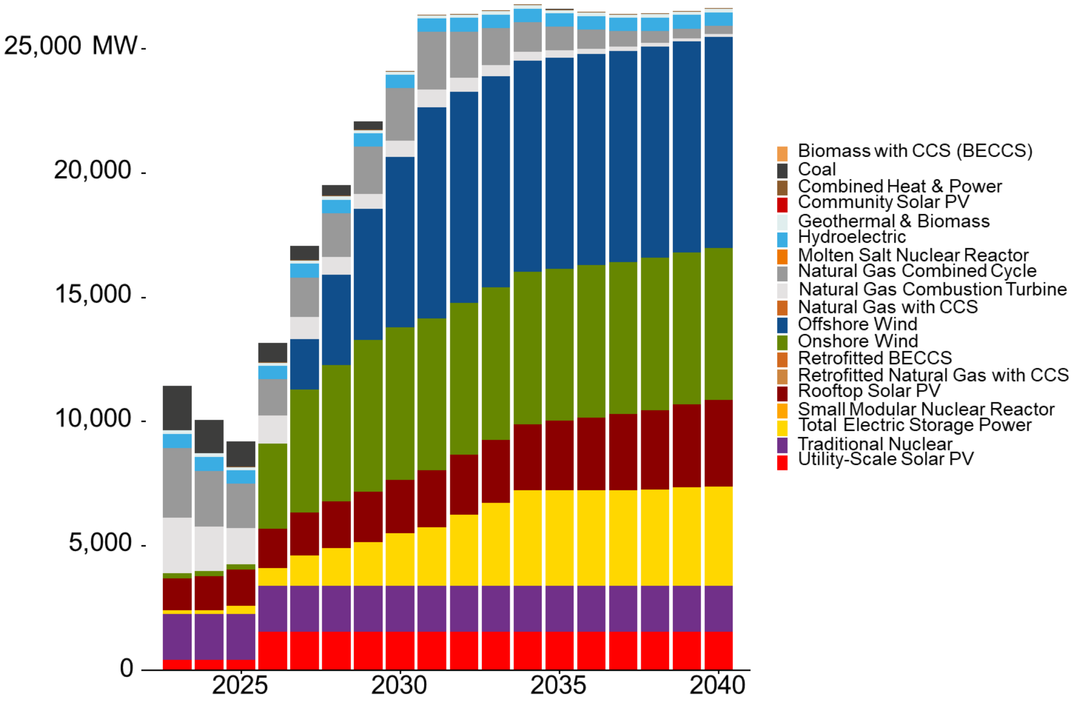

Figure 12. Maryland Capacity, 100% RPS-2 Scenario

Figure 13. PJM-wide Capacity, Comparison of Phase 2 RPS Scenarios to 100% RPS-2 Scenario

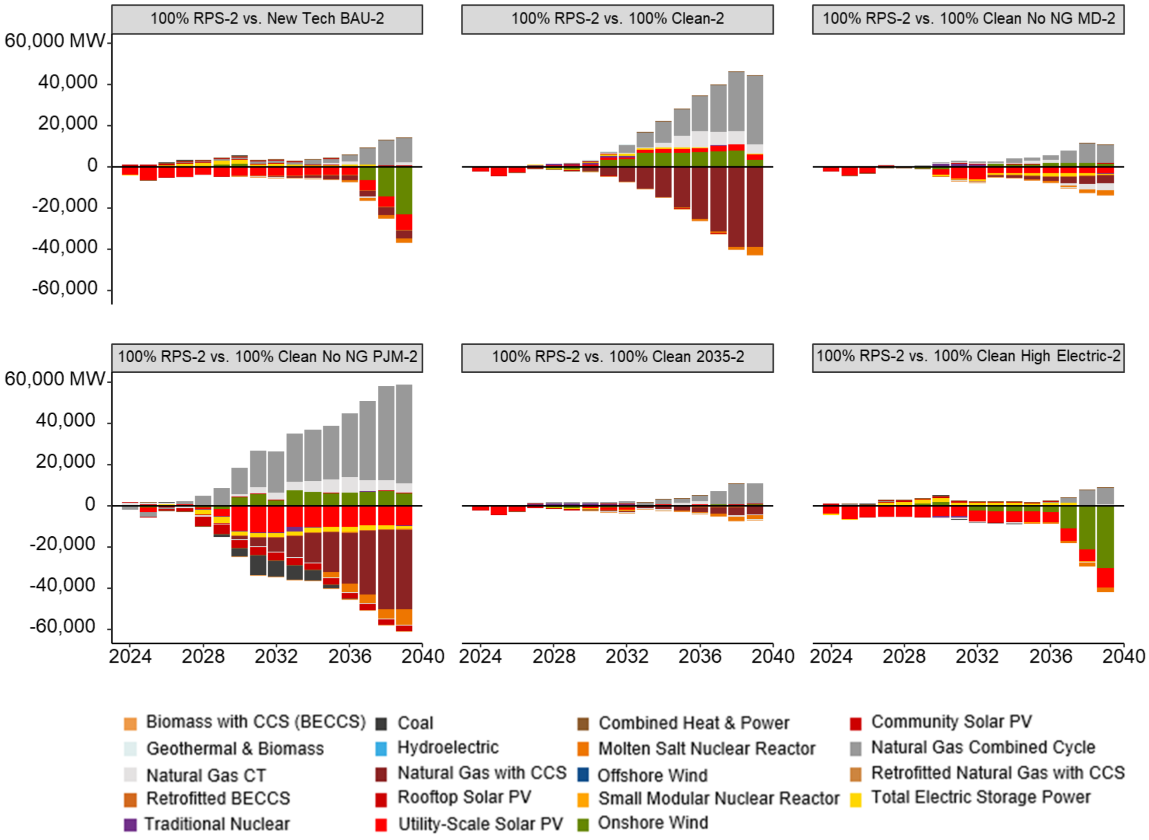

Figure 14. PJM-wide Capacity, Comparison of Phase 2 Clean Scenarios to 100% RPS-2 Scenario

In the 100% RPS No NG PJM-2 scenario, approximately 36.6 GW of natural gas CC from the 100% RPS-2 scenario is replaced with coal (12.0 GW), natural gas CT (1 GW), energy storage (7.5 GW), traditional nuclear (7 GW), utility-scale solar (34.0 GW), and wind (4.6 GW) capacity in 2040. The relative difference in the quantity of capacity between scenarios reflects the lower capacity factor of the resources used as substitutes for natural gas CC.

The differences in capacity between the 100% RPS-2 and 100% RPS 2035-2 scenarios, as shown above, are relatively small, with changes stemming from when each model adds certain resources. The differences between the 100% RPS-2 and PJM 70% RPS-2 scenarios are also small through 2034. In 2035 and beyond, the PJM-wide 70% RPS scenario leads to large increases in wind capacity (34.3 GW by 2040) and lesser but still significant additions of storage (0.8 GW), utility-scale solar (7.1 GW), and natural gas CT (1.1 GW) capacity. Similar differences in wind capacity also apply to the 100% RPS High Electric-2, New Tech BAU-2, and 100% Clean High Electric-2 scenarios.

Compared to 100% RPS-2, the Clean scenarios substitute natural gas CCS and/or advanced energy technologies for natural gas CC and small amounts of renewable capacity, with notable differences beginning to appear in 2030 and then increasing gradually through 2038. Due to model configuration, higher levels of CCS capacity appear in several scenarios that allow CCS (100% Cean No NG PJM-2 and 100% Clean-2) than in others (100% Clean No NG MD-2, 100% Clean 2035-2, New Tech BAU-2). The 100% Clean-2 scenario, in aggregate, results in 42.7 GW of capacity from CCS or advanced energy technology resources by 2040.

The capacity results for each Clean scenario follow patterns that are similar to those applicable to RPS scenarios with equivalent assumptions. For example, excluding natural gas in PJM in the 100% Clean No NG PJM-2 scenario results in additional capacity from almost all types of resources. The chief difference from the 100% RPS No NG PJM-2 scenario is the inclusion of natural gas CCS and then advanced energy technologies in place of utility-scale solar, coal, battery, and nuclear capacity. The 100% Clean High Electric-2 scenario does not allow CCS. Compared to the 100% RPS High Electric-2 scenario, the differences are relatively small.

Looking only at Maryland capacity, as shown in **Figure 15** and **Figure 16**, the chief difference between 100% RPS-2 and other scenarios is the amount of utility-scale solar. Besides the PJM 70% RPS-2 scenario, all other scenarios add at least 5.8 GW more utility-scale solar in all model years. Utility-scale solar capacity levels are the highest in the 100% RPS No NG PJM-2 and 100% RPS High Electric-2 scenarios, and max out at 17.9 GW and 20.3 GW in 2040, respectively.

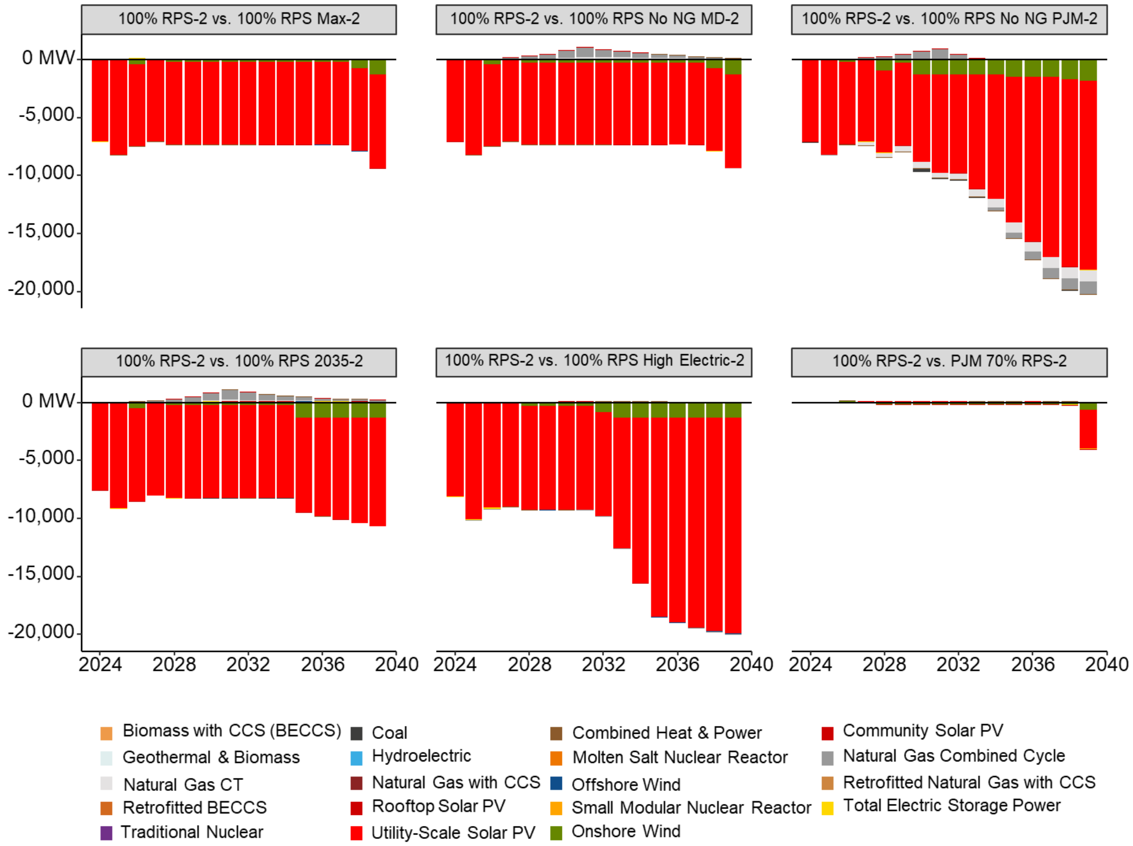

Figure 15. Maryland Capacity, Comparison of Phase 2 RPS Scenarios to 100% RPS-2 Scenario

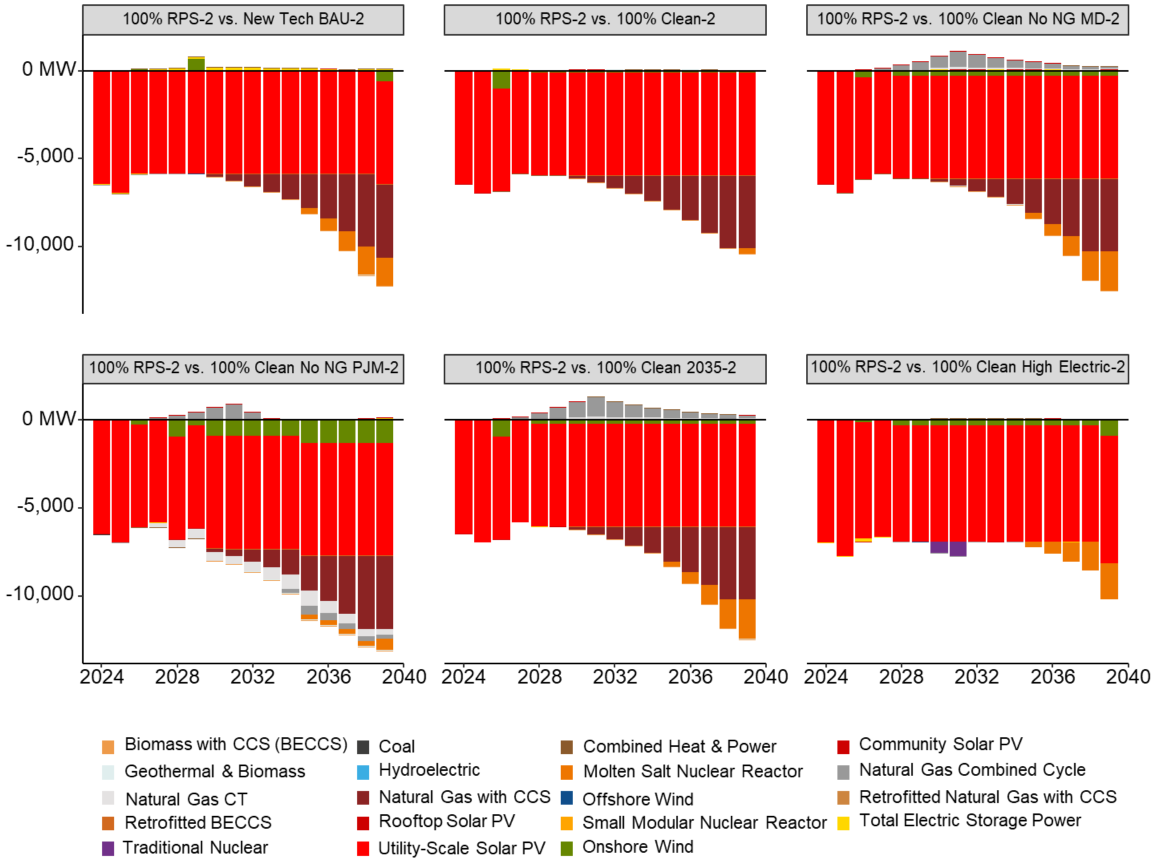

Figure 16. Maryland Capacity, Comparison of Phase 2 Clean Scenarios to 100% RPS-2 Scenario

For the RPS scenarios, the model adds approximately 1.3 GW more onshore wind capacity. The timing of these additions, however, ranges from as soon as 2030 (100% RPS No NG PJM-2) to as late as 2039 or 2040 (100% RPS No NG MD-2, PJM 70% RPS-2, and 100% RPS Max-2). The 100% RPS No NG PJM-2 scenario also results in the retention of higher levels of natural gas CT and CC capacity in the state, albeit not as high as the quantities retained PJM-wide.

Besides differences in utility-scale solar capacity, the results of the 100% Clean-2 model reflect the addition of as much as 4.2 GW of natural gas CCS by 2038 and 672 MW of advanced energy technologies by 2040. These additions change the relative share of each type of capacity, including decreasing the share of utility-scale solar (20%) and onshore wind (17%) and increasing the share of energy storage (11%) capacity as of 2039. Across all Clean scenarios that allow CCS, the quantity of CCS capacity increases through 2040. These CCS additions hasten the retirement of small amounts (<1 GW) of natural gas CC capacity, particularly in the 100% Clean No NG MD-2, 100% Clean No NG PJM-2, and 100% Clean 2035-2 scenarios.

2.2.3. Natural Gas Additions / Retirements

Several scenarios result in concurrent natural gas CC and CT additions and retirements. This turnover can be understood as the process of replacing less efficient natural gas capacity with more efficient (i.e., higher heat rate) units in the absence of viable alternatives. The amount of concurrence and the magnitude of additions or subtractions varies by scenario.

Figure 17 represents the applicable patterns in Maryland for the 100% RPS-1, 100% Clean-1, 100% RPS-2, and 100% Clean-2 scenarios. Across all four scenarios, additions and subtractions in any given year do not exceed 2,000 MW. The scenarios show substantial (>1,000 MW) gross natural gas capacity reductions in the mid-2020s, the pace of which gradually declines thereafter. In the Phase 1 scenarios, the model suggests new natural gas CT additions beginning as soon as 2026 and increasing in most subsequent years. In the Phase 2 scenarios, the model suggests a pause in the retirement of existing natural gas capacity in the late 2020s and early 2030s. During this period, the model instead added small amounts of new natural gas CT units in Maryland. By 2032, the Phase 2 models continue retiring existing natural gas capacity.

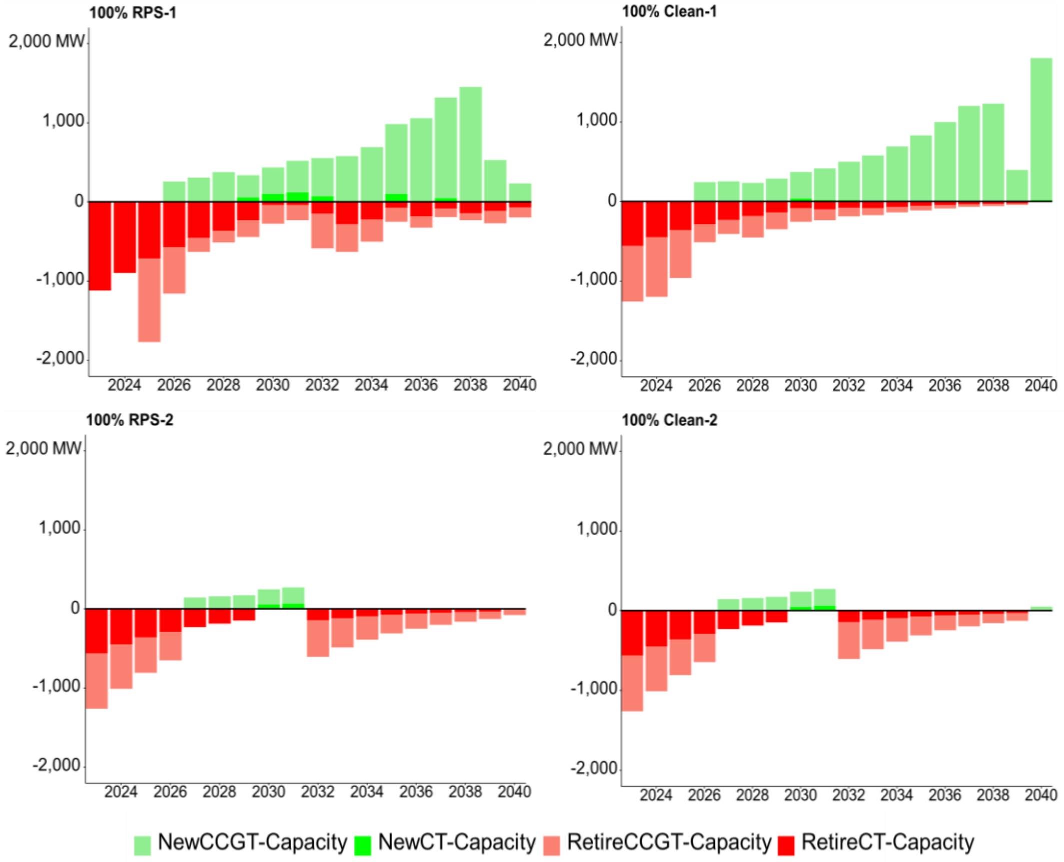

Figure 17. New and Retired Natural Gas Capacity in Maryland, by Type and Year for Select Scenarios

2.2.4. Location

For the Phase 1 models, Exeter examined Maryland capacity additions at a county-level. The results for the 100% RPS-1, BAU-1, and Calvert-1 scenarios were virtually the same. For these scenarios, half of wind capacity additions (as opposed to existing capacity) were placed in Caroline County or Garrett County. Another third of the total additional onshore wind capacity was built in the southern, coastal counties of Dorchester, Somerset, and Wicomico. By comparison, under 100% Clean-1 scenario assumptions, the model places more wind in Cecil County and Kent County (22% of total additions).

The portion of Maryland that has the best solar resource quality (i.e., higher potential generation per square meter, per day for an indicative unit) is in the southeast portion of the state, especially in counties adjacent to the Chesapeake Bay. In the 100% RPS-1 scenario, approximately 13% of utility-scale solar resource additions were in St. Mary's County. The remaining portion was largely placed in Washington County (69%) and Harford County (10%). In the 100% Clean-1 scenario, utility-scale solar additions are far more concentrated, with most additions (91%) located in Washington County.

Only Cecil County observes increases in natural gas CC capacity in all four examined scenarios. Additionally, natural gas CC retirements in Charles County are minimal. The model appears to expand the large plants in these counties with newer equipment as a means to leverage existing infrastructure. For example, the Transcontinental Gas Pipeline, a large interstate natural gas transportation pipeline, runs almost directly between Cecil and Charles counties. Additionally, the two counties are interconnected with a 500-kV circuit that crosses the state into Delaware, New Jersey, Virginia, and West Virginia. These resources ensure the availability of relatively lower-cost natural gas supply and the facilities to readily transmit power.

For distributed resources, in all four examined scenarios, distributed solar, storage, and ground source heat pump (GSHP) resources were concentrated in higher-density areas like Baltimore City and Montgomery, Prince Georges, Howard, and Anne Arundel counties. For example, the 100% RPS-1 scenario placed 74% of distributed solar resources in these regions.

2.3. Generation

2.3.1. Phase 1 Model Results

Figure 18 shows PJM-wide generation for the 100% RPS-1 scenario. Several broader trends are apparent in this data, many of which mirror the patterns discussed above in the context of capacity. Notably, coal generation across PJM rapidly decreases toward zero by 2031. Onshore wind, by contrast, increases to approximately 175 terawatt-hours (TWh) of annual generation by 2035, and ultimately comprises 18% of all generation in 2040—second only to natural gas CC generation. UPV, DPV, and OSW similarly climb over the review period, and each comprises 5-8% of total generation by 2040.

From 2023-2040, traditional nuclear generation declines from over 360 TWh to 231 TWh of annual production. This 41% drop decreases traditional nuclear's share of total generation from 31% in 2023 to just 18% in 2040. Natural gas CC generation reflects a "U" shape insofar as generation falls from 411 TWh in 2023 to 326 TWh in 2029, but then increases again to 466 TWh by 2040. Despite the slight increase in natural gas CC generation, its share drops from 38% in 2023 to 32% in 2040. Natural gas CT generation, by comparison, grows from 1% in 2023 to 7% of total generation by 2040.

Maryland-specific generation levels, as depicted in **Figure 19**, follow comparable patterns as those applicable to PJM. The most notable difference relates to the retirement of Calvert Cliffs in the 100% RPS-1 scenario. As each Calvert Cliffs unit retires, the 100% RPS-1 scenario shows increased levels of additional in-state natural gas CC generation in its place. In 2023, modeled traditional nuclear power made up 32% of Maryland generation and natural gas CC made up 44%. By 2040, traditional nuclear's share falls to zero and natural gas CC's share increases to 66%.

Figure 20 and **Figure 21** compare the 100% RPS-1 scenario results to the other Phase 1 scenarios using PJM-wide and Maryland results, respectively. Compared to the 100% RPS-1 scenario, PJM-wide and Maryland generation are almost identical in the BAU-1 scenario. Calvert-1 scenario results are also similar, aside from additional nuclear generation from Calvert Cliffs in 2034 and beyond. Calvert Cliffs generation primarily displaces natural gas CC generation, as well as some onshore wind and natural gas CT generation, from out-of-state resources.

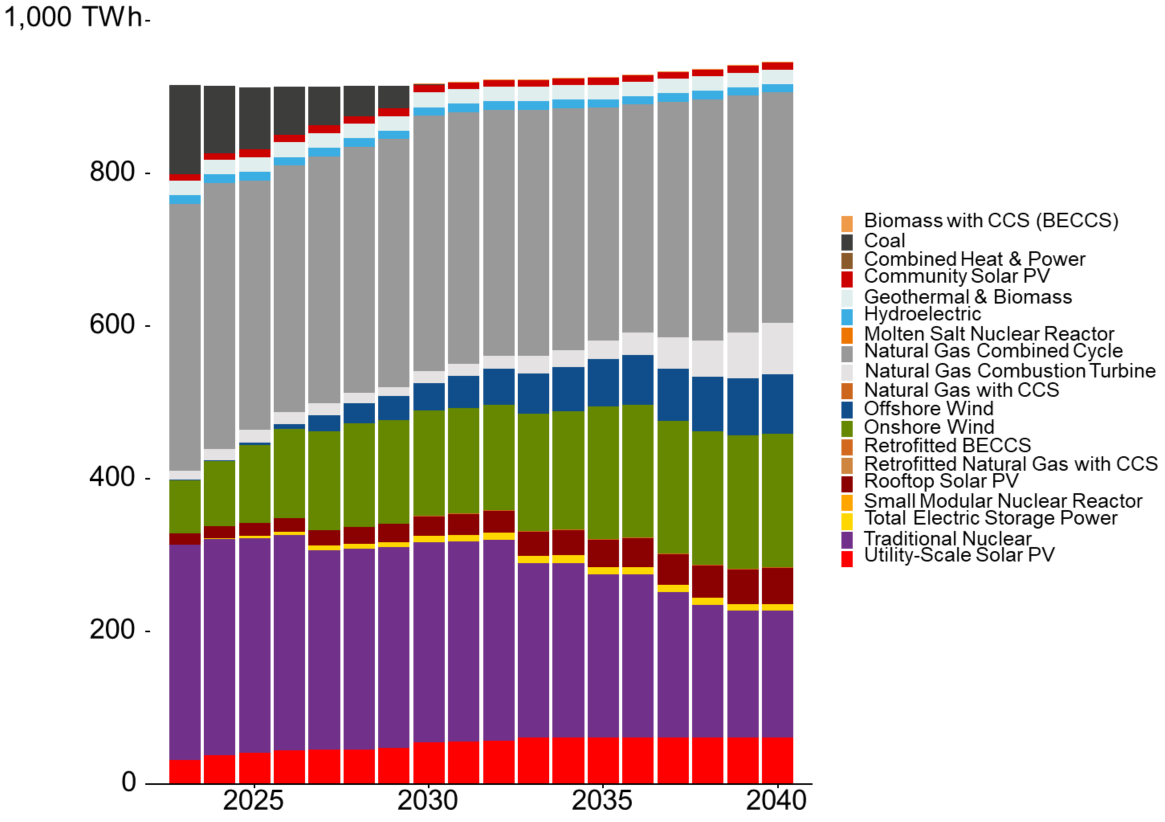

Figure 18. PJM-wide Generation, 100% RPS-1 Scenario

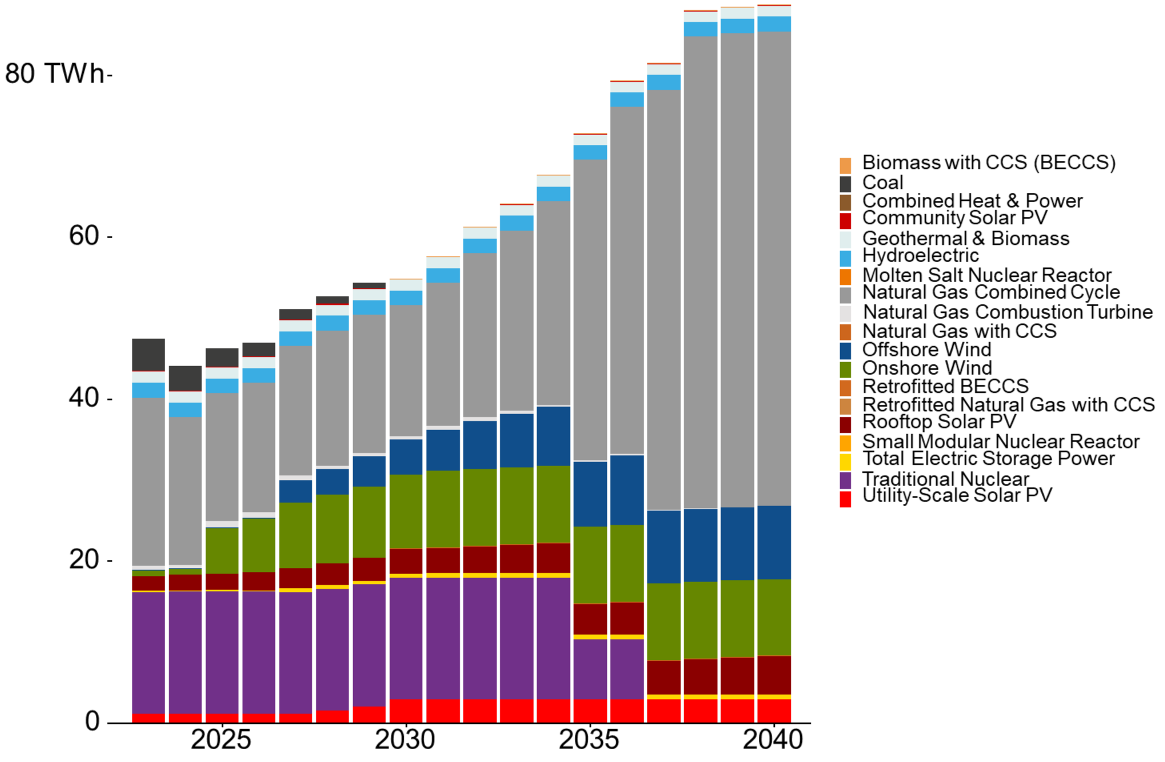

Figure 19. Maryland Generation, 100% RPS-1 Scenario

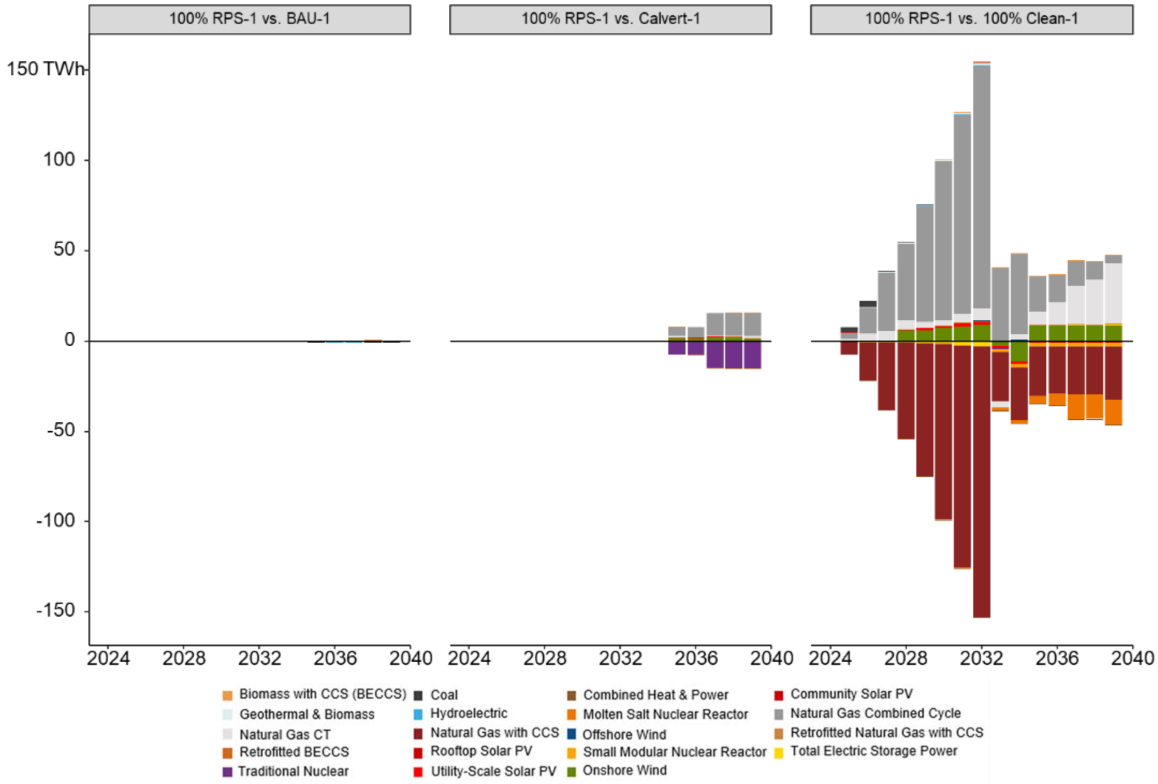

Figure 20. PJM-wide Generation, Comparison of Phase 1 Scenarios to 100% RPS-1 Scenario

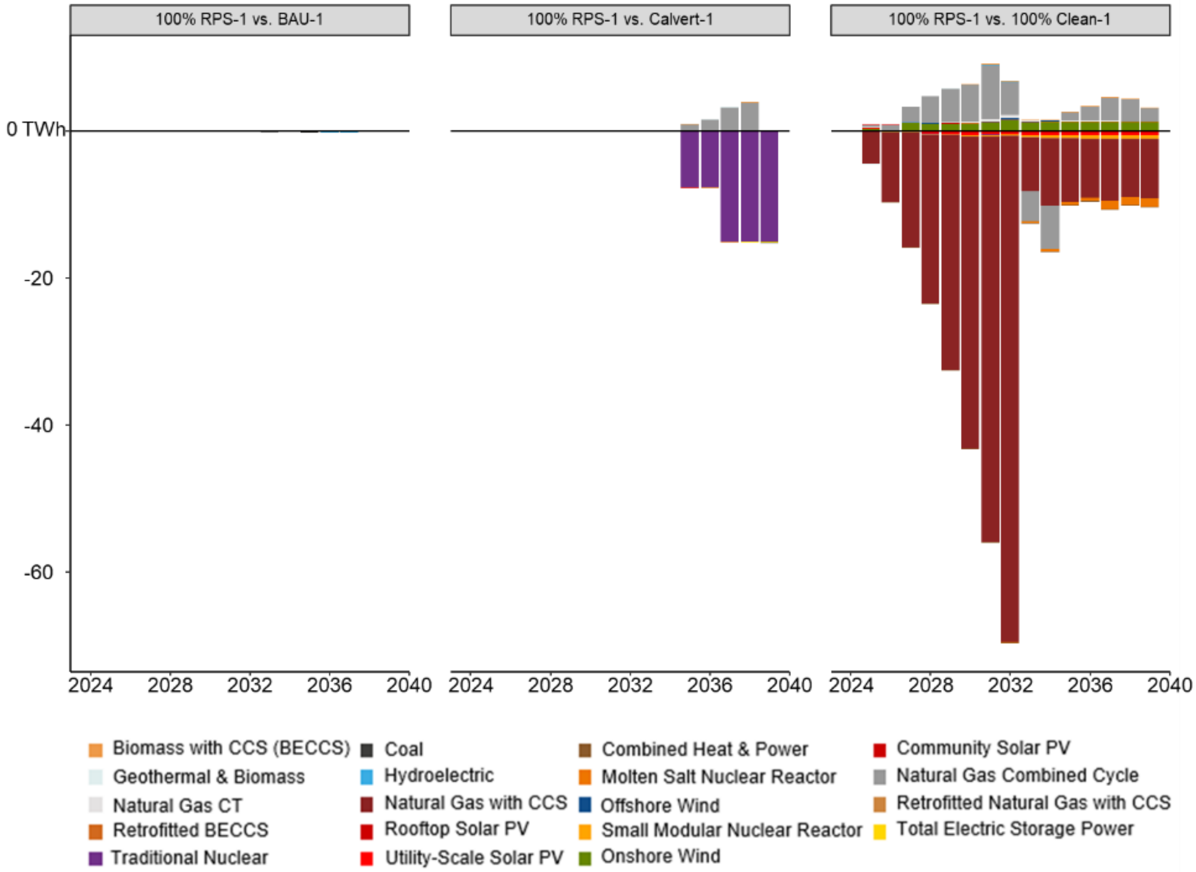

Figure 21. Maryland Generation, Comparison of Phase 1 Scenarios to 100% RPS-1 Scenario

More substantial differences appear in the 100% Clean-1 scenario results. The natural gas CCS capacity added in Maryland offsets some onshore wind (35 TWh) and natural gas CT (33 TWh) generation through 2032, but primarily displaces natural gas CC generation (492 TWh). The Maryland-specific results show that over three times as much natural gas CC is displaced outside of Maryland as is displaced in-state. Maryland CCS generation comprises almost half of PJM-wide CCS generation in this model.

After 2032, the 100% Clean-1 scenario continues to utilize generation from CCS and BECCs and, by the end of the review period, generation from advanced energy technologies. This generation initially displaces natural gas CC generation (136 TWh displaced from 2033-2040), but eventually replaces some wind generation (33 TWh from 2033-2040) and natural gas CT generation (147 TWh from 2033-2040).

2.3.2. Phase 2 Model Results

Figure 22 shows PJM-wide generation for the 100% RPS-2 scenario. The observed trends are similar to those discussed above for Phase 1. Notably, coal generation again decreases to virtually zero by 2031 and traditional nuclear generation declines from over a quarter of total generation (26% in 2023) to under a seventh (14% in 2040). In place of these resources, wind generation increases from 115 TWh in 2023 to over 400 TWh in 2040 (26% share of 2040 total generation), and utility-scale solar generation climbs from 66 TWh to 213 TWh (13% share). Offshore wind, rooftop solar, and storage grow from negligible portions of the generation mix to somewhat more meaningful contributors (2-6%). Natural gas CC generation increases by 14% from 2023-2040 but remains just under one-third of the total resource mix.

The results at a Maryland level, as shown in **Figure 23**, are more pronounced for several resource types. The assumption of 8.5 GW of offshore wind results in 35 TWh of OSW generation in Maryland by 2031. By 2040, OSW represents 42% of the total amount of Maryland generation. Nuclear generation from Calvert Cliffs does not decrease, although the capacity factor is slightly lower in the 2030s. Almost all onshore wind and utility-scale solar capacity additions in Maryland occur in the mid-2020s and, as a result, generation from both resources asymptotes by the late 2020s. In-state natural gas CC generation fluctuates during the review period, including both increases and decreases, until beginning a gradual fall after 2030 to nearly zero by the end of the period. Natural gas CT generation in Maryland also approaches zero as energy storage power increases.

The results of the 100% Clean-2 model are similar in terms of change in generation by resource type and total share of generation. Natural gas CC generation, however, falls from 29% in 2023 to 12% in 2040 within this scenario. In its place, natural gas CCS (11%) and advanced energy technology generation grow as a share of total generation in 2040.

Figure 24 and **Figure 25** compare the 100% RPS-2 scenario results to the Phase 2 scenarios with RPS or Clean assumptions, respectively, at a PJM-wide level. As compared to the 100% RPS-2 scenario, the 100% RPS No NG MD-2 scenario relies on more utility-scale solar (23 TWh) and less natural gas CC generation (32 TWh) from 2023-2040. Coal-fired generation remains online through the forecast period for the 100% RPS No NG MD-2, presumably for resource adequacy reasons.

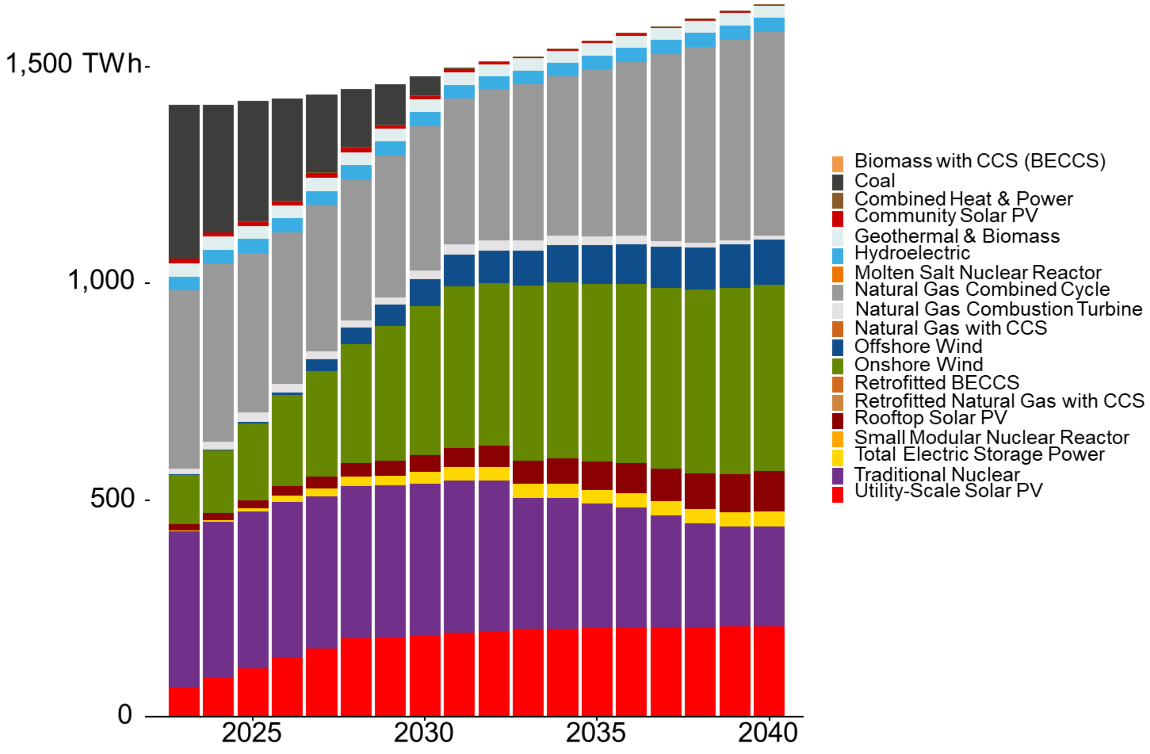

Figure 22. PJM-wide Generation, 100% RPS-2 Scenario

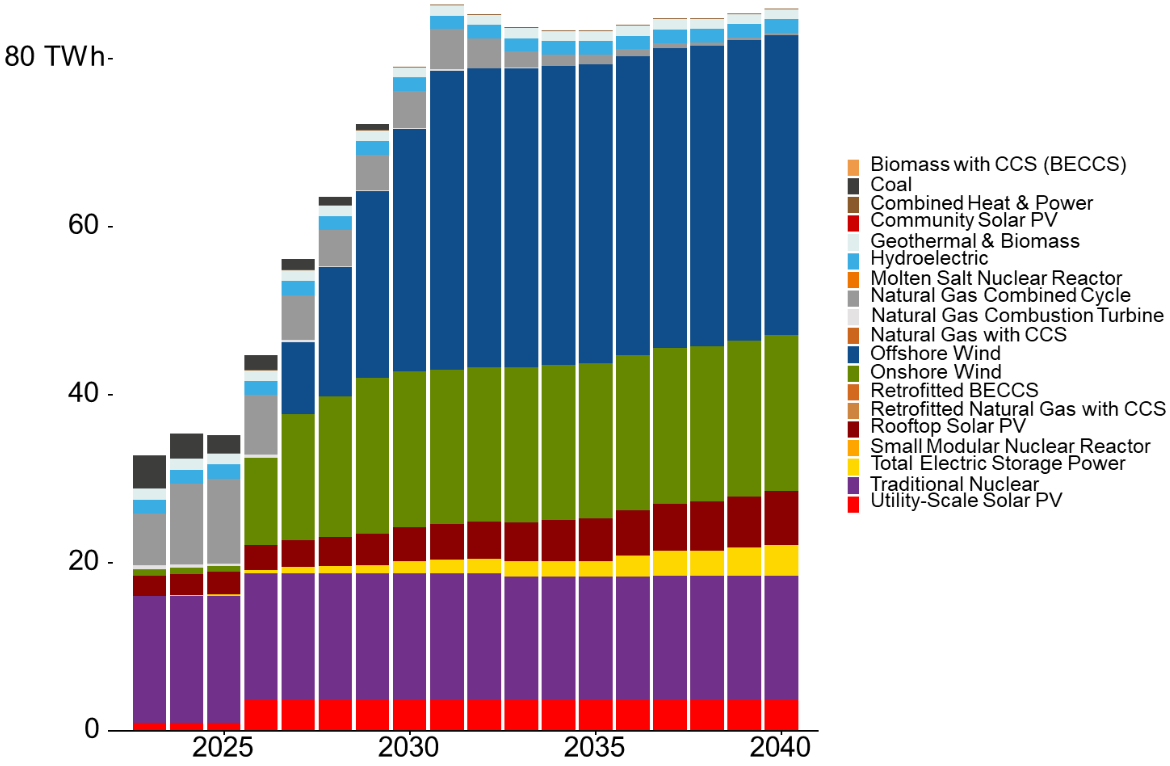

Figure 23. Maryland Generation, 100% RPS-2 Scenario

Figure 24. PJM-wide Generation, Comparison of Phase 2 RPS Scenarios to 100% RPS-2 Scenario

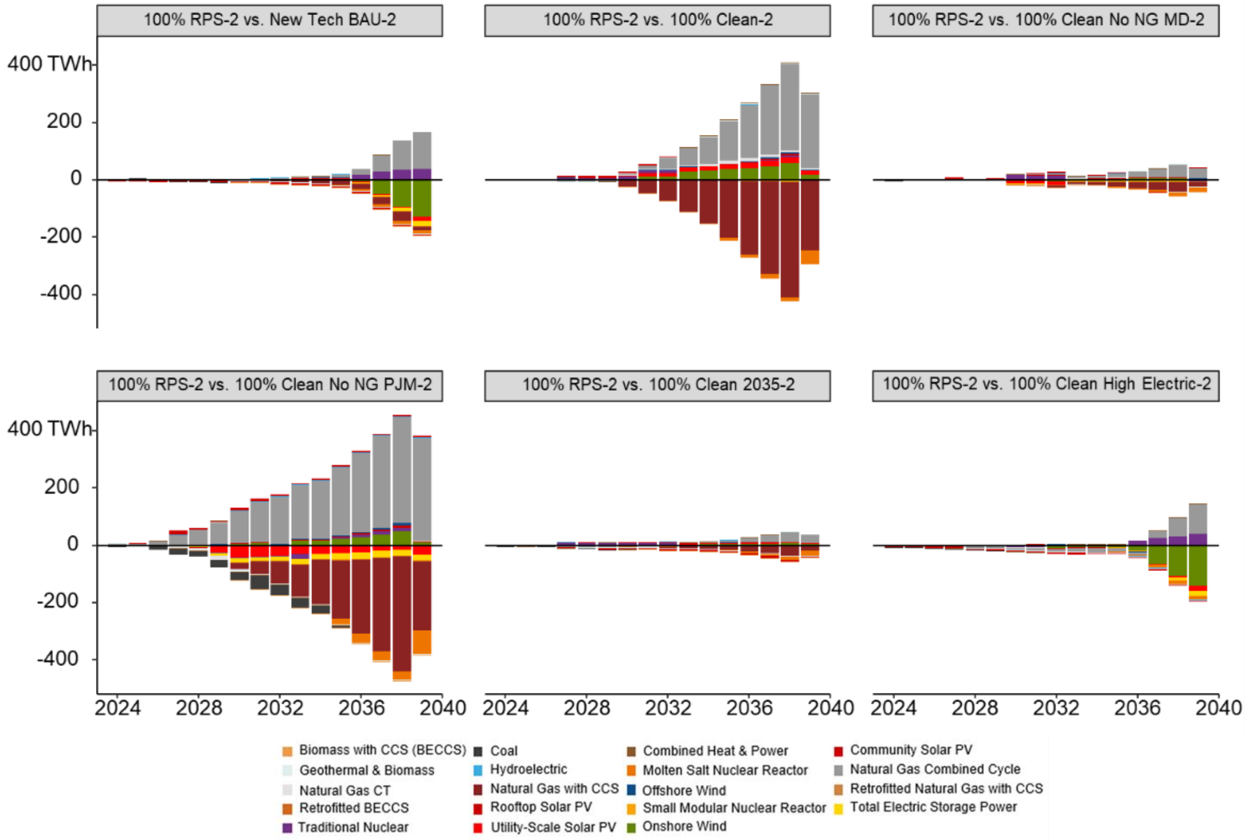

Figure 25. PJM-wide Generation, Comparison of Phase 2 Clean Scenarios to 100% RPS-2 Scenario

The 100% RPS-2 scenario's differences from 100% RPS No NG MD-2 are magnified when compared to 100% RPS No NG PJM-2. In 100% RPS No NG PJM-2, approximately 2,511 TWh of natural gas CC is replaced by additional coal (736 TWh), natural gas CT (107 TWh), energy storage (343 TWh), traditional nuclear (428 TWh), utility-scale solar (761 TWh), and wind (346 TWh) total generation from 2023-2040. The quantity of generation from each of these resources increases over time, consistent with gradual decisions to retain traditional resources or add new resources as a substitute for the natural gas precluded due to modeling assumptions.

The differences in generation in the 100% RPS 2035-2 scenario are relatively small, with changes stemming from when each model adds certain resources. The differences between the 100% RPS-2 and PJM 70% RPS-2 scenarios are also small through 2034. In 2035 and beyond, the PJM-wide 70% RPS scenario leads to large increases in wind generation (443 TWh total from 2035-2040) and lesser but still significant additions in storage (55 TWh) and utility-scale solar (67 TWh) generation. Results similar to the PJM 70% RPS-2 scenario both in terms of timing and magnitude also apply to the 100% High Electric-2 and 100% Clean-2 scenario, except that 100% Clean-2 includes additional CCS and advanced energy technology generation in the late 2030s.

Many of the clean scenarios show a similar result of substituting natural gas CCS and advanced energy technologies for natural gas CC and some renewable generation, with notable differences beginning to appear in 2030 and then increasing gradually through 2038. The 100% Clean-2 scenario, in aggregate, results in 2,188 TWh of generation from CCS or advanced energy technology resources between 2030-2040.

Other Clean scenario patterns are similar to those for RPS scenarios with equivalent assumptions. For example, excluding natural gas in PJM in the 100% Clean No NG PJM-2 scenario results in additional generation from almost all types of resources. The chief difference from the 100% RPS No NG PJM-2 scenario is the inclusion of CCS and then advanced energy technologies.

The 100% Clean High Electric-2 scenario does not allow CCS by assumption. Compared to the 100% RPS High Electric-2 scenario, the differences are relatively small. Notably, the 100% Clean High Electric-2 scenario observes more traditional nuclear (46 TWh) and wind generation (57 TWh) and less utility-scale solar (117 TWh), natural gas CC (28 TWh), and energy storage (18 TWh) between 2023-2040 as compared to 100% RPS High Electric-2. There is also more advanced energy technology generation towards the end of the period, totaling 52 TWh from 2035-2040.

Looking only at Maryland generation, as shown in **Figure 26** and **Figure 27**, the chief difference between 100% RPS-2 and other scenarios is the amount of utility-scale solar. Besides the PJM 70% RPS-2 scenario, all other scenarios result in approximately 20 TWh of additional utility-scale generation in every year. In the 100% RPS No NG PJM-2 and 100% RPS High Electric-2 scenarios, there is more than 40 TWh of additional utility-scale solar generation in the late 2030s. These scenarios also result in some additional in-state wind, energy storage, and natural gas CC generation. The Clean scenarios, by comparison, result in more CCS and advanced energy technology generation during the 2030s, with the amount exceeding 35 TWh per year in 2038.

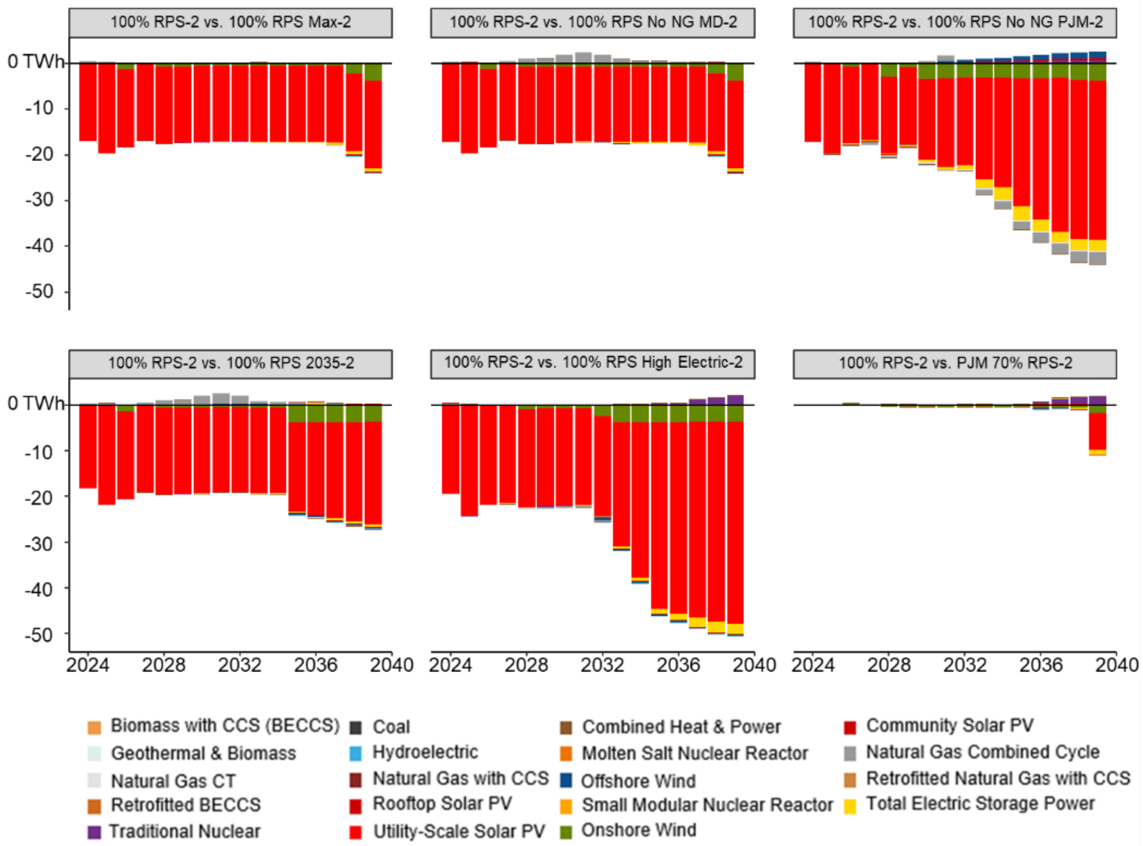

Figure 26. Maryland Generation, Comparison of Phase 2 RPS Scenarios to 100% RPS-2 Scenario

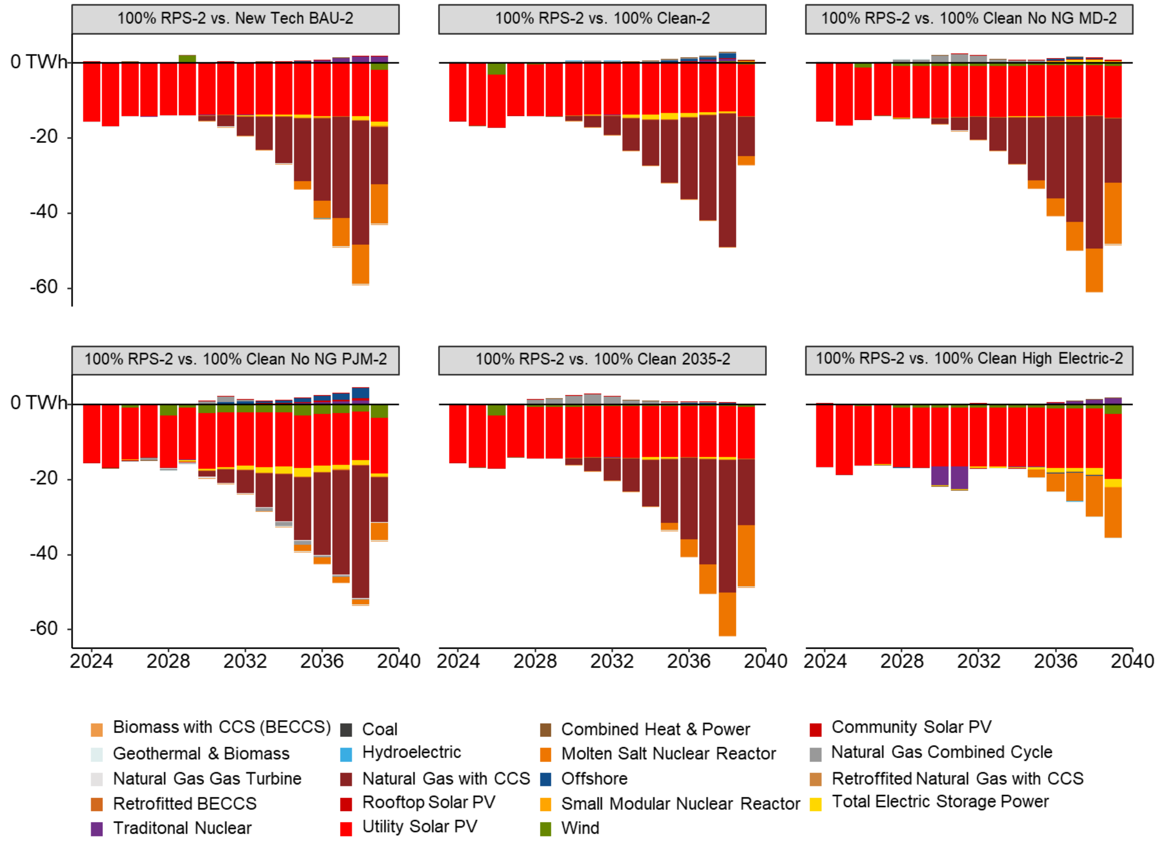

Figure 27. Maryland Generation, Comparison of Phase 2 Clean Scenarios to 100% RPS-2 Scenario

2.3.3. Curtailment

Curtailment refers to intentional reductions in electricity generation from what could otherwise be produced. Grid operators can request curtailment to ensure that the supply and demand for electricity are balanced in real-time. This process is distinct from economic decisions to reduce generation, such as the choice of some generation owners to decrease output due to lower prices.[31]

Hourly curtailment data for all scenarios shows an increase in curtailment, especially during the spring but also in the fall, beginning in 2027. By the late 2030s, hourly curtailments routinely surpass 50 GWh and reach more than 100 GWh on several occasions. **Figure 28** shows annual, cumulative hours of PJM-wide curtailment for each of the Phase 2 scenarios. All else equal, curtailment is higher in the scenarios with more variable generation.

The highest level of curtailment occurs in the 100% RPS No NG PJM-2 and 100% Clean No NG PJM-2 scenarios. Curtailment is relatively higher in the 100% RPS Max-2 scenario, which maximizes in-state renewable generation in Maryland, and both high electrification scenarios. In the case of 100% RPS High Electric-2 and 100% Clean High Electric-2, curtailment increases towards the end of the review period as load increases.

Although the amount of output (TWh) being curtailed is large, this generation as a share of load is relatively small. Excluding the two scenarios that assume no new natural gas in PJM, the average Phase 2 scenario curtails 23.1 TWh per year from 2031-2040. By comparison, the average PJM-wide load during this same time frame and for these same scenarios is 1,365 TWh.

2.3.4. Net Exchange

Net exchange is a measure of the quantity of power generation flowing into or out of a state. This exchange is distinct from the alignment (i.e., coincidence) of in-state generation and load.[32] In recent history, Maryland has generally been a net power importer on an annual basis, meaning the state sources more power from other PJM states than it produces itself. Over time, all modeled scenarios show reductions in imports such that Maryland eventually becomes a net exporter.

The timing of this switch and the magnitude of imports and exports in any given year varies by scenario. For most Phase 1 models (BAU-1, 100% RPS-1, Calvert-1), imports gradually decline from 2024-2034, at which point Maryland becomes a net exporter. **Figure 29** represents this trend using data from the 100% RPS-1 scenario. Exports are shown as negative numbers.

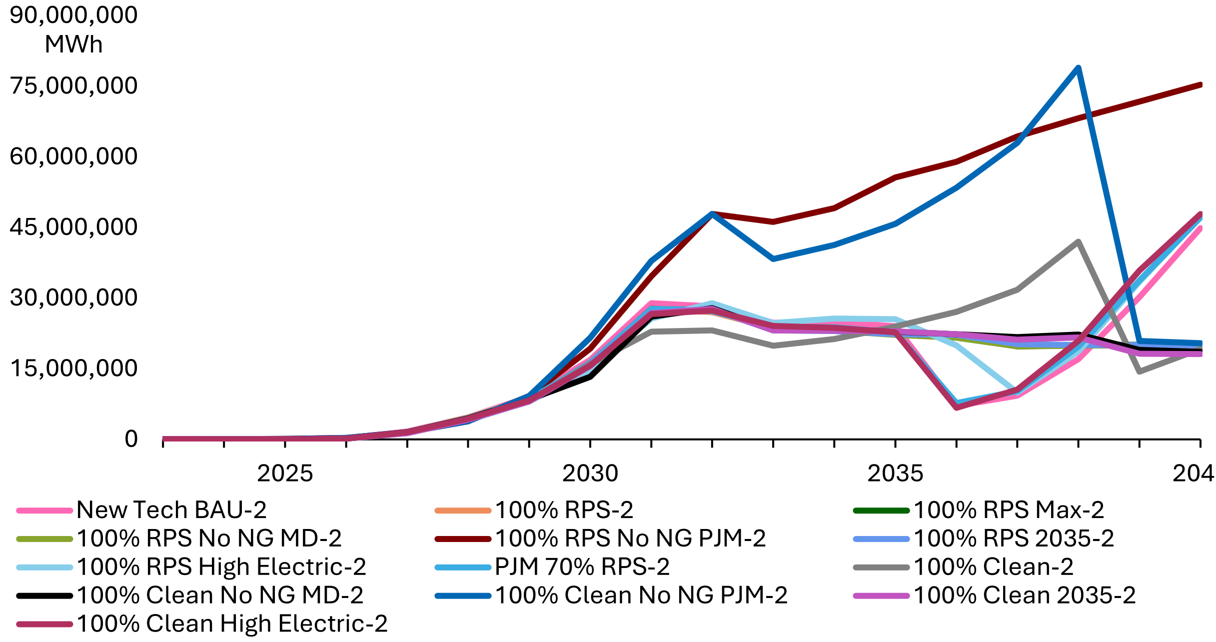

Figure 28. PJM-wide Annual Generation Curtailment, by Scenario

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[31] For example, in a modeling context, curtailment occurs when reductions in generation result in lower total production costs than developing energy storage to capture the curtailed production.

[32] For example, a state with considerable solar resources may, on net, export more power than it imports over the course of a year while also relying on imported power to meet demand. This can occur due to a misalignment of power generation, especially from intermittent renewable generation sources, and load. Additionally, a state may continue to import a high share of power generation for reasons related to comparative advantage. For example, importing low-cost power from neighboring states can facilitate economic activity just as higher retail power prices can displace it, as discussed in Chapter 6.

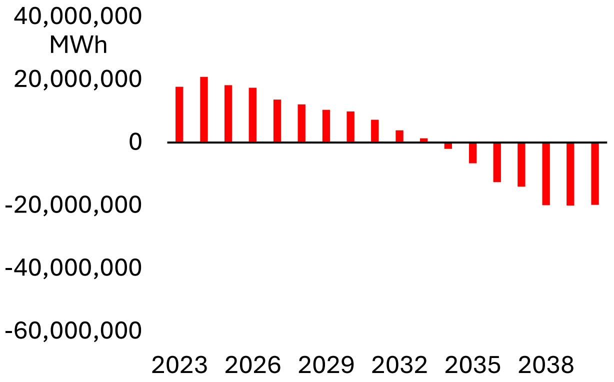

Figure 29. Maryland Net Exchange, 100% RPS-1 Scenario

In the Calvert-1 scenario, the retention and relicensing of Calvert Cliffs result in higher levels of energy exports between 2035-2040 compared to the BAU-1 and 100% RPS-1 scenarios. In the 100% Clean-1 scenario (see **Figure 30**), Maryland transitions to net energy export status in 2028 and sustains significant energy exports through 2032, consistent with high levels of CCS utilization during this period. The level and slope of the export trend is similar across all four Phase 1 scenarios from 2035 onward.

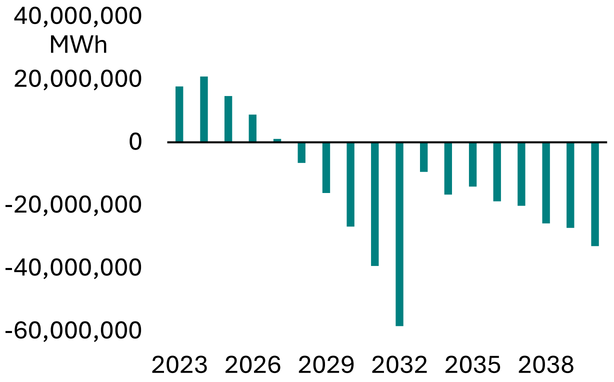

Figure 30. Maryland Net Exchange, 100% Clean-1 Scenario

For most Phase 2 models, Maryland's transition to net export status occurs as soon as 2027 or 2028.[33] The exception to this trend is the 100% RPS-2 and PJM 70% RPS-2 scenarios, which do not reach net export status until 2030. Additionally, in the 100% RPS-2 scenario (see **Figure 31**), Maryland export levels peak at 11 TWh in 2031 before gradually declining. Unlike the other scenarios, Maryland again becomes a net power importer under 100% RPS-2 assumptions, with the switch occurring in 2040.

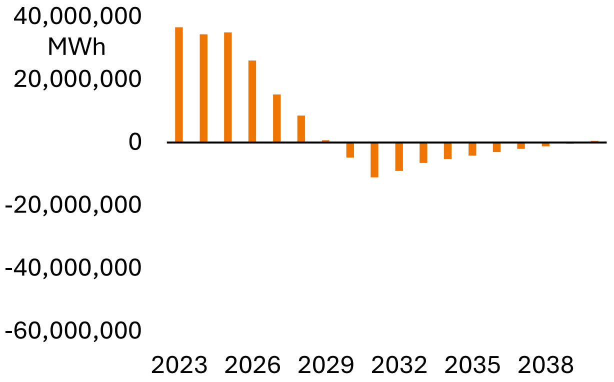

Figure 31. Maryland Net Exchange, 100% RPS-2 Scenario

Scenarios that allow CCS and BECCS additions (New Tech BAU-2, Clean-2, Clean 2035-2, Clean No NG PJM-2, and Clean No NG MD-2) achieve the largest net export exchange values, ranging from -45 TWh to -60 TWh. **Figure 32** represents this trend using 100% Clean-2 scenario data. Among the Clean models, Maryland energy exports are highest in the Clean 2035-2 and Clean No NG MD-2 scenarios.

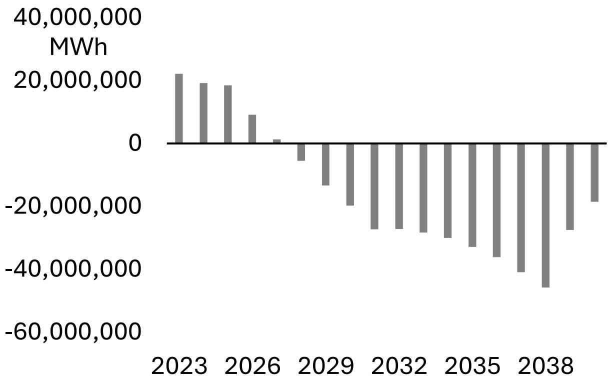

Figure 32. Maryland Net Exchange, 100% Clean-2 Scenario

The other RPS scenarios (100% RPS High Electric-2, 100% RPS 2035-2, 100% RPS No NG PJM-2, 100% RPS No NG MD-2, and 100% RPS Max-2) exhibit peak export levels between 2030-2035 that range from 17-35 TWh. Among these scenarios, the 100% RPS No NG PJM-2 has the highest net export levels (see **Figure 33**).

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[33] This result, like the capacity and generation results discussed above, is sensitive to model assumption about the speed at which Maryland can develop new in-state resources and when other grid resources retire.

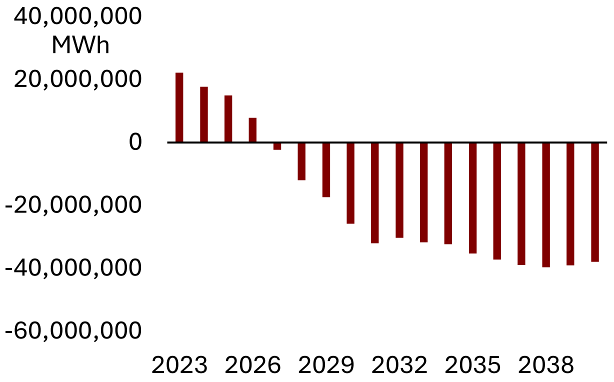

Figure 33. Maryland Net Exchange, 100% RPS No NG PJM-2 Scenario

The export trend declines from 2031-2037 for the 100% RPS Max-2 (see **Figure 34**) and 100% RPS No NG MD-2 scenarios before again increasing. By contrast, the export trend increases during this time frame for most Clean scenarios before again decreasing.

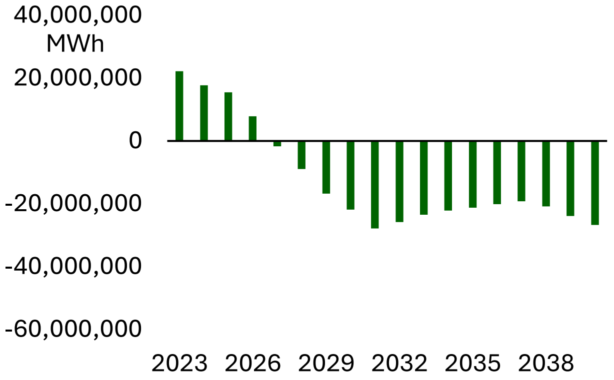

Figure 34. Maryland Net Exchange, 100% RPS Max-2 Scenario

2.3.5. Meeting Maryland RPS Requirements

VCE's model does not include a separately cleared REC market. It does, however, capture the additional payment (i.e., REC price) required to ensure sufficient economic RPS-eligible capacity to meet PJM-wide RPS requirements. All Phase 1 and Phase 2 scenarios result in sufficient renewable capacity to meet the existing 52.5% RPS requirement.[34] Several Phase 2 model results, however, suggest potential near-term shortfalls during which time Maryland suppliers may choose to pay the ACP instead of paying market price for RECs.

For the 100% RPS-2 scenario, the model suggests generic (i.e., not distinguished by carve-out or non-carve-out requirement) REC prices close to or in excess of Maryland's Tier 1 non-carve-out ACP through 2026. Similar results appear in the 100% RPS 2035-2 and 100% CES 2035-2 scenarios due to the expedited compliance time frame (i.e., 100% requirement by 2035 versus 2040), as well as the PJM 70% RPS-2 scenario due to higher RPS demand across PJM. These results are consistent with recent increases in ACPs in place of solar RECs (SRECs), and rising Tier 1 non-carveout REC prices, as shown in Appendix C. By comparison, modeled REC prices do not rise to the level of the Tier 1 non-carve-out ACPs in any other Phase 2 scenarios, including the 100% Clean-2 scenario.

For the Phase 1 models, Exeter and VCE evaluated the proportion of Maryland REC demand met by in-state generation versus REC purchases.[35] **Figure 35** shows these proportions for the 100% RPS-1 scenario. Similar trends apply to the other Phase 1 scenarios as well. Although the amount varies by year, Maryland RPS compliance under the 100% RPS-1 scenario has more REC purchases than in-state generation during all modeled years. Despite an increase in in-state Maryland RECs, the model suggests that Maryland will continue to rely on out-of-state RECs for its own RPS. The availability of RECs in excess of Maryland's RPS requirement, in a modeling context, suggests that some in-state resources are used to support other states' RPS targets instead of Maryland's RPS.[36]

The generation output from VCE's model can also be compared to Maryland's RPS requirements to assess solar carve-out compliance over time. All four Phase 1 models project roughly the same amount of in-state distributed and utility-scale solar generation, with levels reaching the quantities required by Maryland's existing RPS (i.e., 14.5%) and then remaining at that level. A similar result occurs for the 100% RPS-2 and PJM 70% RPS-2 scenarios. By contrast, all other Phase 2 scenarios show solar levels in excess of the requirement. This represents solar resources (most especially utility-scale solar) coming online because the model views the resource as economic. **Figure 36** shows indicative results based on the 100% RPS Max-2 scenario. In this graph, "Solar Requirement" represents the Maryland 100% RPS percentage requirements for each year multiplied by projected Maryland load after adjusting for differences in requirements for municipal, cooperative, and industrial process load customers. The "Utility-Scale Solar" and "Distributed Solar" area charts are stacked, with each section representing the total quantity of generation (MWh) from each resource. The amount of area above the Solar Requirement line represents production in excess of the RPS Tier 1 solar carve-out requirement.

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[34] See Appendix G for discussion of an alternative approach to estimating the availability of sufficient RECs.

[35] This data was not available for the Phase 2 model runs.

[36] The model does not estimate or account for other sources of REC demand, such as corporate renewable energy procurement targets. The decision to sell Maryland RECs in other states reflects a market-clearing process where RECs first serve requirements in the jurisdictions that maximize their return (i.e., off the highest REC price).

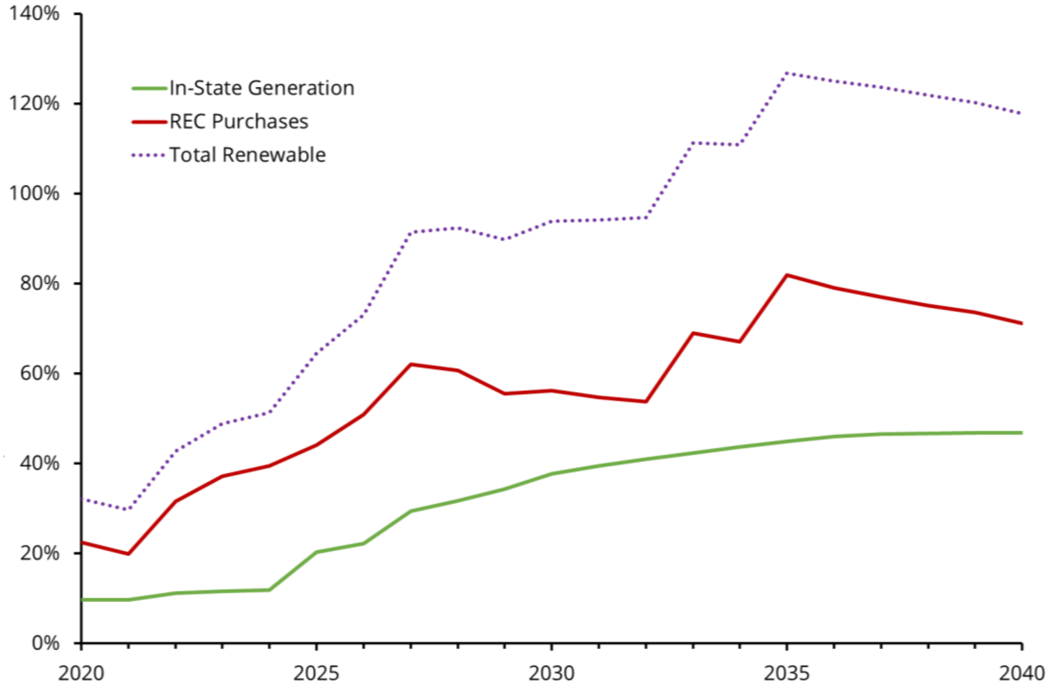

Figure 35. Proportion of Maryland Demand Met by REC Purchases Versus In-state Generation, 100% RPS-1 Scenario

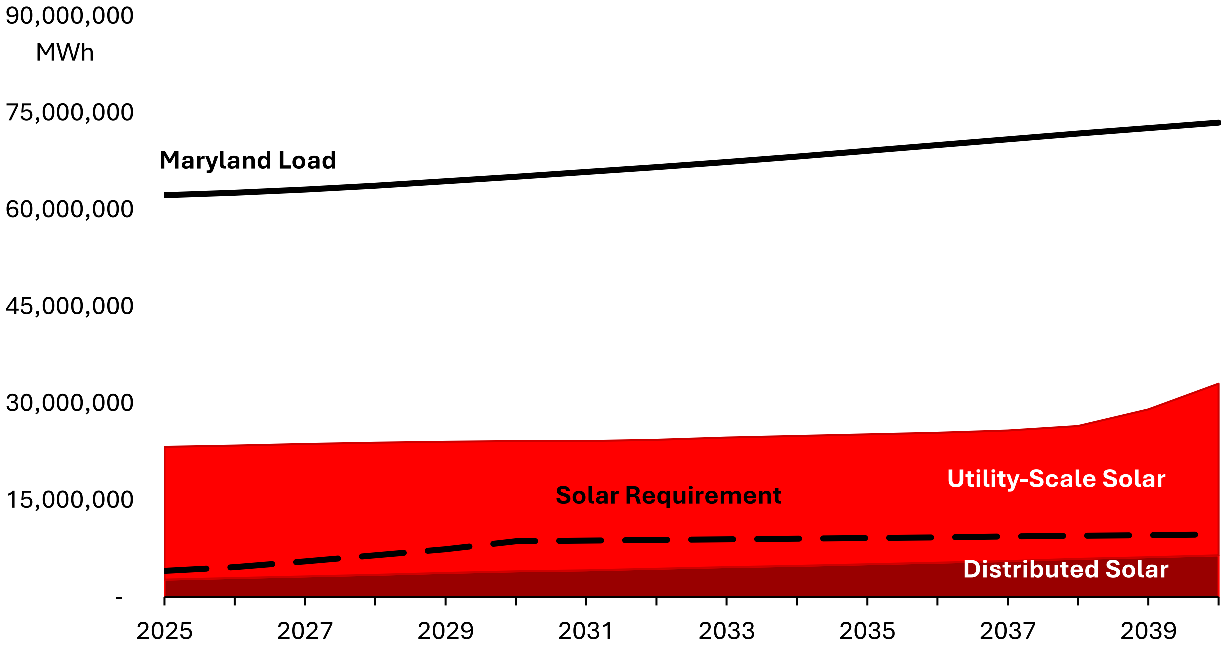

Figure 36. Maryland In-state Solar Generation Compared to Solar Carve-out Requirement, 100% RPS Max-2 Scenario

2.3.6. Capacity Factor

Capacity factor is a measure of how often an electricity generator runs at its maximum power output over a specific period. **Figure 37** shows the PJM-wide capacity factor for each of the major technologies included in VCE's model, expressed in annual percentage terms, for the 100% RPS-2 scenario.[37] These results are indicative of the patterns exhibited for other models and scenarios. The capacity factor of most combustion-based generation is flat or slightly increasing at the beginning of the review period, before falling. The capacity factor of natural gas CC plants falls before stabilizing at approximately 50% by the early 2030s. The traditional nuclear capacity factor also slightly falls. The capacity factor of these resources does not fall further, in part because the model retires less utilized resources, thereby allowing the remaining fleet to continue operating at higher levels.[38] Variability in the capacity factor of intermittent renewable resources reflects small shifts in curtailment and weather variability.

2.3.7. Fuel Burned

Scenarios that include more natural gas capacity (including natural gas CCS), all else equal, result in more natural gas fuel burned for power generation than other scenarios. **Figure 38** and **Figure 39** show annual estimates of the amount of natural gas fuel burned in Maryland for electricity generation purposes in the Phase 1 and Phase 2 scenarios, respectively. Note that these figures are presented on different scales due to differences in magnitudes.

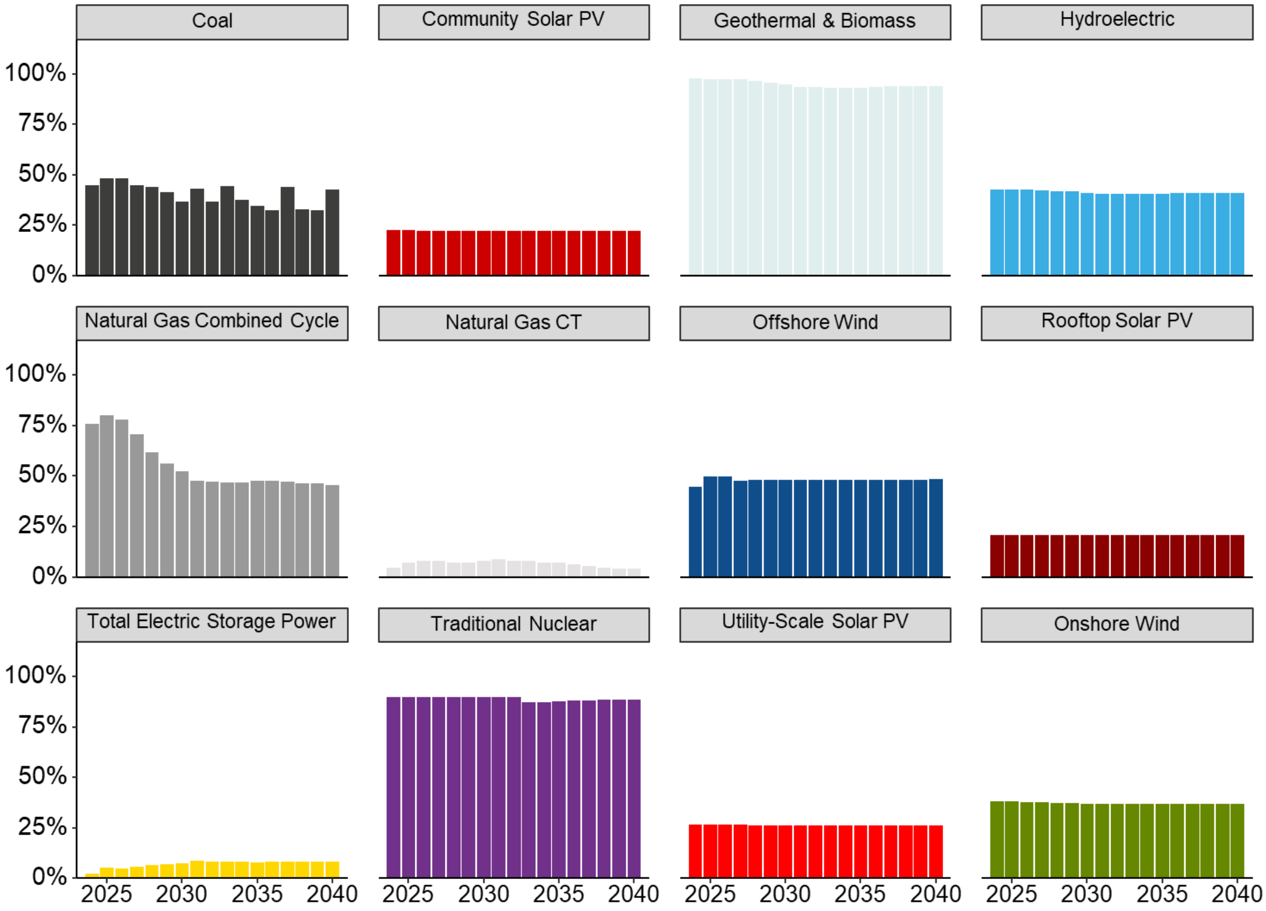

Figure 37. PJM-wide Capacity Factors by Fuel Type, 100% RPS-2 Scenario

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[37] Note that the process PJM uses to determine the amount of capacity that any resource provides for resource adequacy purposes incorporates additional factors, such as forced outage rate, intermittency, and/or limited output duration capability. PJM uses an Effective Load Carrying Capability (ELCC) analysis to calculate the Accredited Unforced Capacity value for Variable Resources (e.g., wind and solar), Limited-Duration Resources (e.g., storage), and Combination Resources (e.g., solar/storage hybrids) (collectively, ELCC Resources).

[38] In the case of coal, the capacity factor numbers reflect products from a very small (near-zero) quantity of coal capacity. For all intents and purposes, the coal capacity factor can be understood as falling to zero after the virtual elimination of coal capacity.

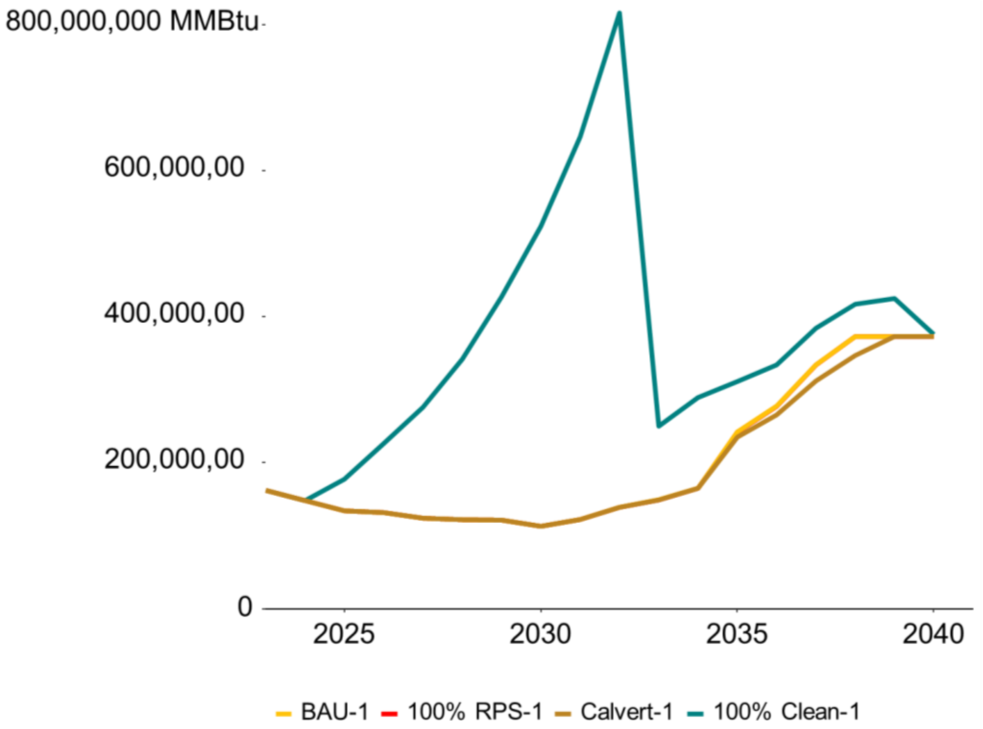

Figure 38. Power Sector Natural Gas Consumption in Maryland, Phase 1 Scenarios

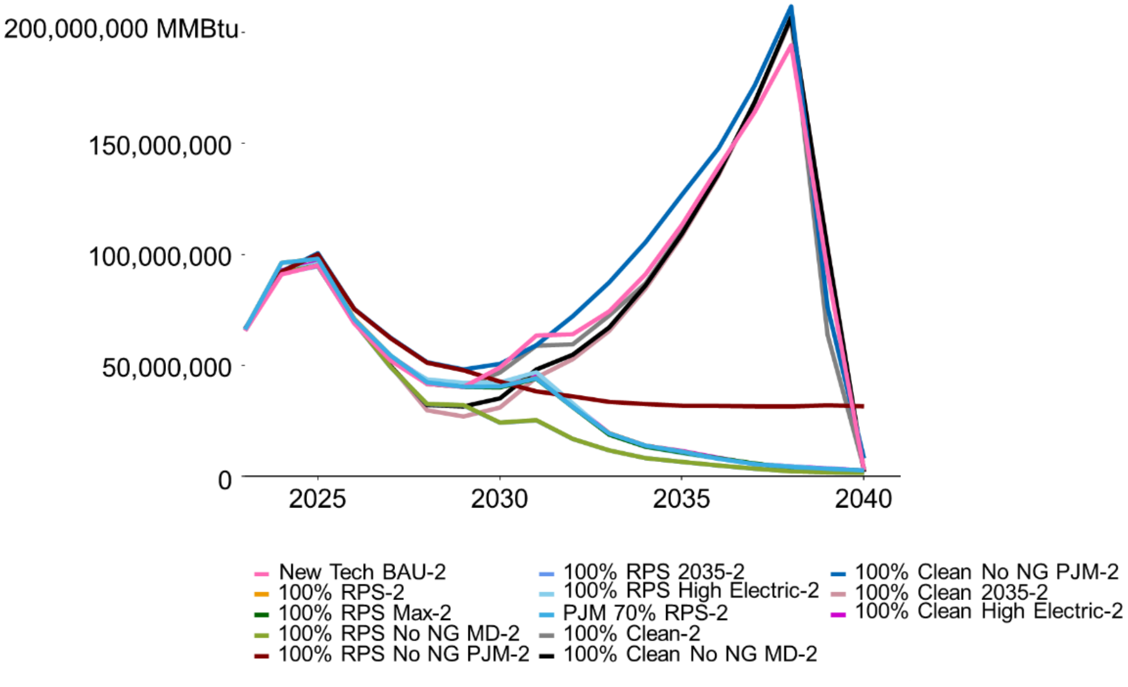

Figure 39. Power Sector Natural Gas Consumption in Maryland, Phase 2 Scenarios

Fuel burned in all Phase 1 models is higher than all Phase 2 models due to differences in natural gas capacity additions, discussed above. The retention of Calvert Cliffs, as highlighted through the Calvert-1 results, displaces additional natural gas generation and, therefore, gas consumption. The 100% Clean-1 scenario is an outlier insofar as gas consumption increases substantially before collapsing. These shifts track changes in the utilization of natural gas CCS capacity in Maryland.

For the Phase 2 models, natural gas consumption fluctuates through 2026, and then begins to decline as natural gas CC and CT capacity in the state retires. This trend continues until 2030, at which time the scenarios cleave. The scenarios that assume a CES policy result in additional natural gas consumption that increases until it peaks in 2038. Consumption then falls as the model replaces natural gas capacity with advanced energy technologies and additional renewable and battery capacity.

Scenarios that assume RPS policies, by comparison, continue their downward trend in terms of Maryland natural gas consumption. Gas consumption decreases fastest in the 100% RPS No NG MD-2 scenario. VCE's model incorporated two options for transmission: upgrade existing lines or build new lines (i.e., greenfield expansion). Maryland-specific transmission results are similar across all five of the scenarios that Exeter examined in detail: 100% RPS-2, 100% RPS 2035-2, New Tech BAU-2, 100% RPS High Electric-2, and 100% Clean-2. All five of these models build minimal amounts of new, greenfield import or export capacity.[39] The only exception is new import capacity from Virginia, ranging from 68-331 MW of capacity. Several scenarios also add some (approximately 100 MW or less) new export capacity to West Virginia, Delaware, or Virginia.

In contrast, the model suggested substantial upgrades to existing lines. **Figure 40**, based on findings from the 100% RPS-2 scenario, represents both import and export upgrades as well as highlights relative differences by state. Although the exact timing of

Maryland gas consumption approaches zero for all Phase 2 models except 100% RPS No NG PJM-2. This scenario levels off at a higher annual amount as the model retains certain natural gas generation because it cannot build substitute capacity elsewhere in PJM.

2.4. Transmission

upgrades differs by scenario, these differences largely accrue in the late 2030s, and do not substantially alter the ultimate level of upgraded capacity.

In terms of import capacity upgrades, the examined models incorporate additional capacity from Pennsylvania (1,927-1,956 MW), Delaware (1,420 MW), Virginia (1,250-1,271 MW), and the District of Columbia (469-482 MW). No scenario results in additional import capacity from West Virginia, in part because of the high quantity of existing import capacity. In terms of export capacity upgrades, the examined models incorporate additional export capacity to Pennsylvania (1,787-1,803 MW), Virginia (1,287-1,303 MW), and the District of Columbia (490-504 MW). Smaller amounts of additional export capacity come online from upgrades to lines connected to Delaware (246-253 MW) and West Virginia (40-189 MW).

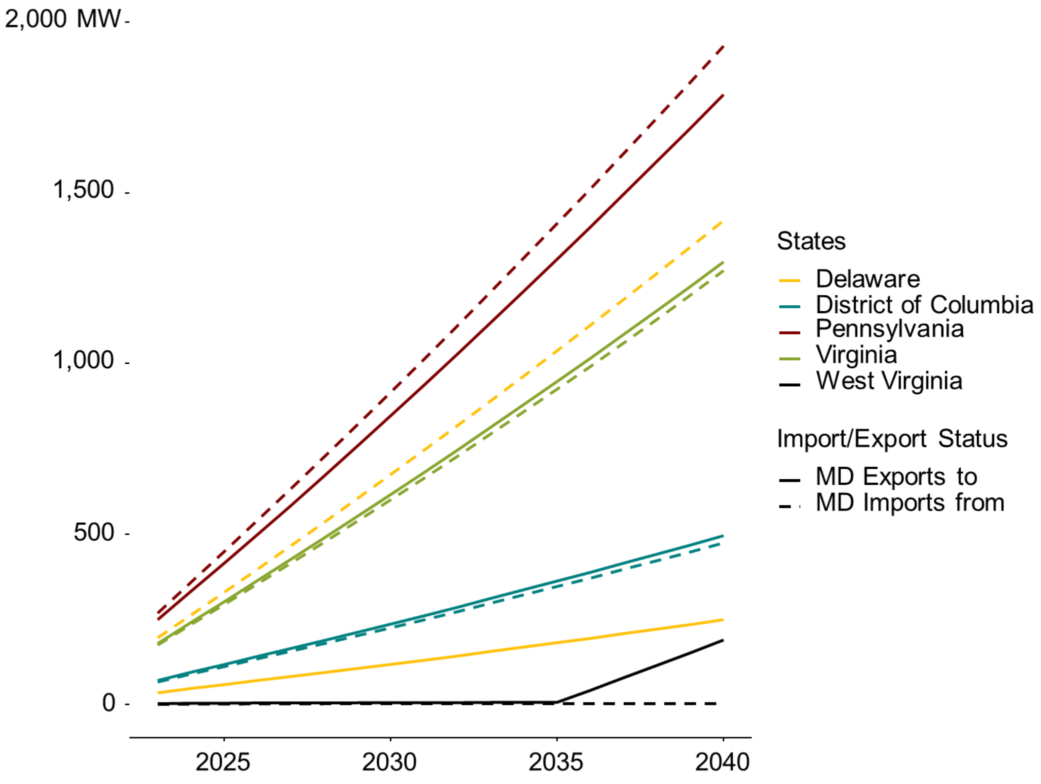

Figure 40. Maryland Transmission Capacity Upgrades Connected to Adjoining States, 100% RPS-2 Scenario

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[39] Import or export capacity does not necessarily represent a state's coincident ability to import or export; rather, it is merely the summation of the capacity for all transmission lines into or out of a state.

2.5. Key Findings

- Substantial amounts of renewables, both in Maryland and elsewhere in PJM, are added in all scenarios.
- Most fossil fuel-based combustion resources experience capacity retirements and reductions in capacity factors in all scenarios. This includes the retirement of virtually all coal generation in all scenarios besides 100% RPS No NG PJM-2. Additionally, much of the traditional nuclear capacity in PJM retires at the end of its licensed life. These resources are replaced by new renewable energy capacity, energy storage capacity, transmission capacity, and natural gas CC capacity.
- Most scenarios add new natural gas CC capacity after retiring coal and less efficient natural gas CC or CT capacity. This reflects a consolidation of baseload resources with similar characteristics. In the near term, new natural gas CC or, when allowed, CCS resources are preferred by the model. Natural gas capacity is replaced by advanced energy resources or storage, depending on the scenario, late in the forecast period.
- Scenarios that limit new PJM natural gas capacity result in the retention of existing natural gas, coal, and traditional nuclear for longer periods of time, including in Maryland. Scenarios that limit new Maryland natural gas capacity, by comparison, result in additional natural gas capacity in surrounding states. This can be understood as a form of “leakage,” meaning policies that preclude new natural gas capacity in Maryland contribute to these resources being located out of state.
- In the 100% RPS-1 and BAU-1 scenarios, the model replaces traditional nuclear capacity with nearly three times as much new installed capacity. The replacement resources are mostly wind and solar, but also some new natural gas CC or CT plants.
- Keeping Calvert Cliffs online results in slightly less natural gas capacity in Maryland but a more significant reduction of natural gas capacity in PJM.
- The BAU-1 and 100% RPS-1 scenarios result in minimal differences in terms of modeled capacity or generation in Maryland or PJM. This suggests that, in an optimized world (e.g., no interconnection queue issues or siting problems), a 100% RPS scenario is the same as business as usual.
- The model consistently adds natural gas capacity in the 2030s to replace retiring generation such as coal and nuclear power. Other possible options policymakers may consider, if they wish to avoid natural gas capacity additions, include accelerated transmission expansion, additional energy storage deployment, or accelerated demand-side resources.
- Scenarios that allow advanced energy technologies (e.g., small modular reactors or molten salt reactors) result in the addition of these resources towards the end of the review period. Considerable uncertainty exists regarding the development of these resources, including permitting, commercialization, and development timelines.
- Scenarios that allow CCS development result in substantial quantities of these resources, thanks at least in part to the federal 45Q tax incentives. The model’s reliance on this incentive, however, also results in sharp CCS capacity reductions after the incentives expire.
- All scenarios, regardless of the policy assumptions, develop similar levels of DPV capacity. The quantity of UPV, meanwhile, varies by scenario. Scenarios that assume a 100% RPS policy generally build more UPV than those that assume a 100% CES policy. Additionally, the quantity of UPV developed in Maryland increases in scenarios that assume Maryland meets its 3-GW storage target.
- Maryland becomes a net exporter in all scenarios. This shift occurs sooner, and Maryland exports more power, in the 100% Clean-1 and 100% Clean-2 scenarios as compared to the 100% RPS-1 and 100% RPS-2 scenarios. The deployment of CCS technologies, starting around 2031, further increases energy exports. Maryland is in a position to become an energy exporter in part because of its access to gas transportation, high-voltage transmission, and proximity to major loads.
- The model upgrades existing transmission far more than building new transmission. Additionally, the model result shows a higher need for import capacity than export capacity. This occurs even as the models suggest that Maryland exports more generation on net. While Maryland is projected to be a net exporter, that does not mean Maryland will not need power imports at times to maintain reliability or to access economic power sources.
- Short-term deficits in the availability of RECs may result in ACP payments under scenarios assuming a 100% RPS by 2035 or 2040. These payments persist until 2026. Maryland can address these shortfalls by increasing the ACP. Alternatively, the ACP can continue to support compliance as a stop value to prevent excessive costs.
- Maryland’s continued and future compliance with RPS or CES policies is sensitive to a variety of conditions, including that states in PJM will not change their existing RPS or CES policies, that states in PJM without RPS or CES policies will remain so,

and that projected load growth and projected growth in solar, onshore wind, and OSW capacity do not vary from what the models estimate or assume.

- CES scenarios result in higher natural gas consumption than RPS scenarios. This may result in broader changes in the cost and availability of natural gas. By the end of the review period, however, almost all modeled Phase 2 scenarios suggest that there are substitutes available that allow Maryland to substantially reduce power sector natural gas consumption.

2.6. Cost-Benefit

A 100% RPS or CES policy can reduce power sector demand for natural gas by displacing natural gas-fired generation, either by inducing the retirement of natural gas power capacity or by spurring reductions in the capacity factor of natural gas power plants. This reduction in demand, in turn, can lead to reductions in wholesale and, to a lesser extent, retail natural gas prices. These effects occur in the short run, until supply re-equilibrates. Over longer time frames, a structural decline in electricity market demand for natural gas can also cause reductions in capital availability for natural gas projects, impacting exploration, production, and infrastructure development.

The above dynamics can be interpreted as a transfer rather than a benefit or cost. That is, from a broader economic perspective, shifts in energy demand and investment signify a reallocation of resources within the economy. A reduction in natural gas prices, while detrimental to producers, benefits consumers and industries that still rely on natural gas for heating, processes, or as a transitional energy source. Note that a similar interpretation also applies to costs and benefits discussed in subsequent chapters; benefits that accrue in one industry can come at the expense of another, at least in the short run.

Table 8, **Figure 41** and **Figure 42** identify, by scenario, modeled power sector natural gas consumption in Maryland from 2025-2040, measured in quads.[40] These values align with the visual differences discussed above and shown in **Figure 38** and **Figure 39**. Additional evaluation of natural gas sector impacts, both in the short and long run, is beyond the scope of this study.

Table 8. Power Sector Natural Gas Consumption in Maryland, by Scenario (Quads)

Scenario	Power Sector Natural Gas Consumption, 2025-2040	Compared to 100% RPS-1	Compared to 100% RPS-2
BAU-1	3.305	0.002	
100% RPS-1	3.303	0.000	
Calvert-1	3.236	(0.066)	
100% Clean-1	6.230	2.928	
New Tech BAU-2	1.351		0.858
100% RPS-2	0.493		0.000
100% RPS Max-2	0.484		(0.009)
100% RPS No NG MD-2	0.389		(0.104)
100% RPS No NG PJM-2	0.715		0.221
100% RPS 2035-2	0.497		0.004
100% RPS High Electric-2	0.498		0.005
PJM 70% RPS-2	0.493		0.000
100% Clean-2	1.317		0.823
100% Clean No NG MD-2	1.298		0.805
100% Clean No NG PJM-2	1.461		0.968
100% Clean 2035-2	1.276		0.783
100% Clean High Electric-2	1.276		0.783

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[40] 1 quad = 1 billion MMBtu (million British thermal units).

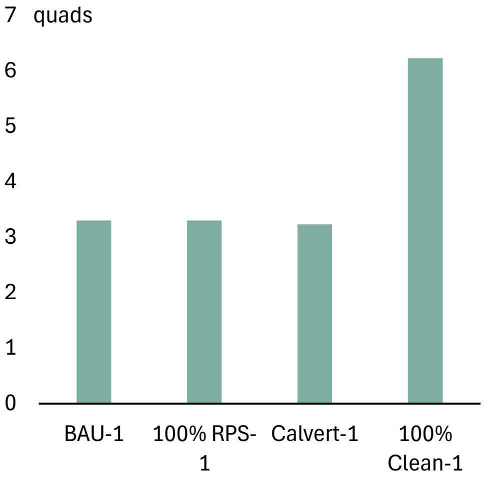

Figure 41. Power Sector Natural Gas Consumption in Maryland from 2025-2040, Phase 1 Scenarios

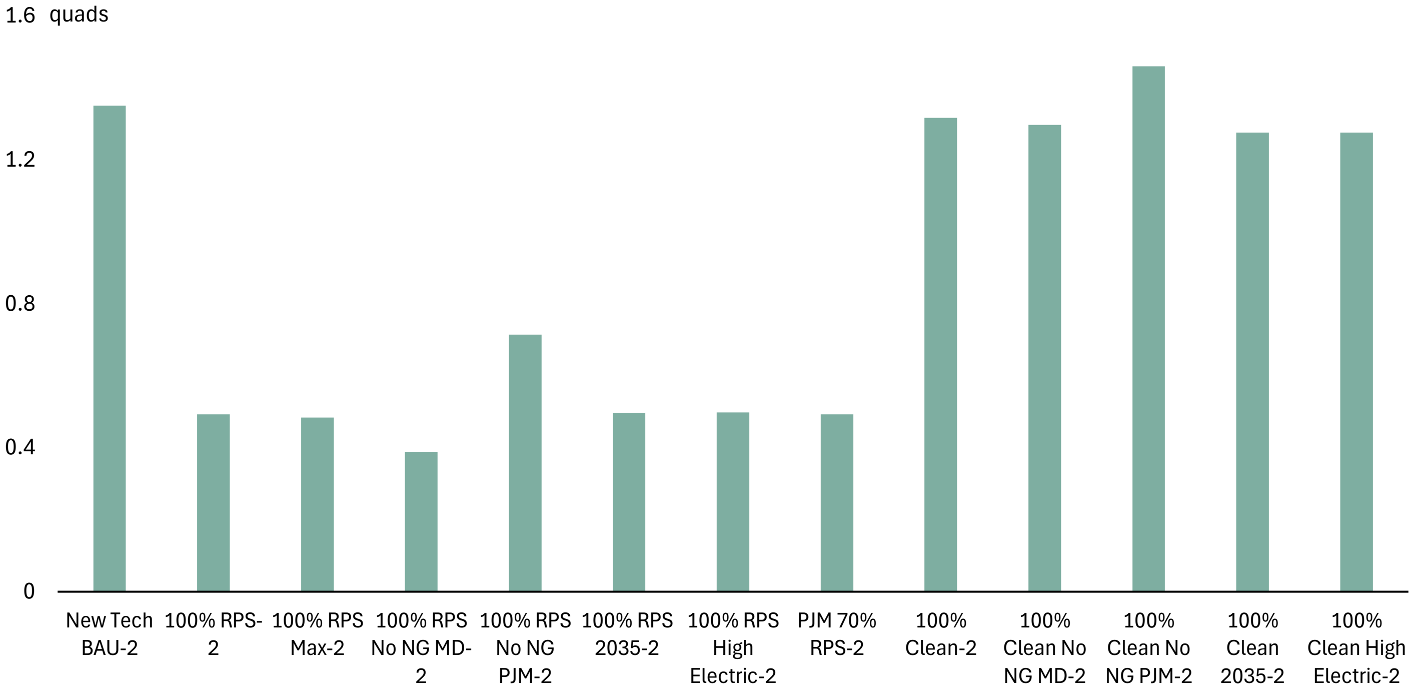

Figure 42. Power Sector Natural Gas Consumption in Maryland from 2025-2040, Phase 2 Scenarios

3. COSTS AND RATES

This section of the report reviews the role of a 100% Maryland RPS or CES requirement in causing changes in various energy sector costs and, subsequently, retail rates. RPS or CES policies incentivize the addition, retention, or retirement of certain electricity generation resources. Because Maryland participates in the PJM competitive wholesale market, shifts in the resource mix manifest as both local and PJM-wide changes in cost. For example, increased renewable energy development spurred by a 100% RPS, in the short run, may reduce electricity prices due to price suppression effects.[41] This occurs because PJM employs security constrained economic dispatch (SCED) and sets prices based on merit order; as lower marginal cost resources displace more expensive resources (i.e., shifting the supply curve to the right), dispatch occurs at a lower clearing price and energy costs fall across all of PJM.[42]

Whether all areas of PJM, including Maryland, observe the above changes in wholesale costs depends on PJM's ability to transmit power across a broader regional grid. Transmission constraints create congestion that causes variation in local prices.[43] Other localized cost impacts also apply. For example, increased capacity development often corresponds with additional transmission or system integration costs. PJM's wholesale electricity prices also have an inverse relationship with the market's capacity prices.[44] Further, investments in transmission projects to reduce congestion can increase local transmission costs.

Additionally, the Maryland PSC oversees a regulatory process through which regulated Maryland utilities receive approval to recover from consumers (and earn a rate of return on) certain regulated transmission and distribution (T&D) service costs. Further, competitive retail or default service suppliers purchase electricity from the PJM wholesale market and pass on these costs to consumers on a contractual basis. In these ways, the costs of generating, transmitting, and distributing electricity, along with regulatory fees, capacity charges, and ancillary services, are incorporated into retail rates. Consequently, retail electricity rates reflect both the competitive market conditions of PJM and the operational costs of maintaining a reliable electricity system, either of which can be influenced by 100% RPS and CES policies. This section discusses how the modeled RPS and CES scenarios influence both the total system costs applicable to Maryland and the retail costs faced by consumers.

3.1. Results

Total resource costs encompass a wide variety of expenditures that encompass the full value-chain of electricity supply.[45] In all scenarios, the model projects cost adjustments that reflect the scenario-specific capacity, generation, and transmission changes discussed in Chapter 2. Generally, total resource costs fall as the model retires inefficient resources in the 2020s before climbing again in the 2030s as the model adds new capacity to serve growing load and meet resource adequacy balancing needs.

Over the review period, resource-specific costs are largely proportionate to the amount of installed capacity and generation for each generation type. For example, fixed and variable costs attributable to coal decrease to almost zero as the model retires most coal generation across all of PJM. Natural gas CT variable costs, as another example, decrease into the 2030s before increasing again toward the end of the review period. Incentives like production tax credits appear in the model as reductions to variable costs.[46] As a result, some high fixed-cost resources are buoyed by lower, subsidized variable costs (e.g., CCS supported by

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[41] PJM's Market Monitor reported that, in 2023, 54.7% of the marginal wind units had negative offer prices and 44.2% had zero offer prices. Monitoring Analytics, LLC, *2023 State of the Market Report for PJM*. monitoringanalytics.com/reports/PJM_State_of_the_Market/2023/2023-som-pjm-vol2.pdf.

[42] SCED is an optimization process used in power system operations to determine the most cost-effective way to allocate generation resources while ensuring the reliability and stability of the power grid. For additional information, see: ferc.gov/sites/default/files/2020-05/final-cong-rpt.pdf.

[43] Congestion refers to situations where there is insufficient transmission capacity to deliver least-cost electricity between two points without violating network operating limits. In these situations, power may be sourced from more expensive generation or routed across longer transmission paths (causing more losses), either of which can increase relative costs. Locational differences in cost are reflected through nodal LMPs.

[44] Capacity market prices are determined by competitive auctions that compensate power plants for their capacity to provide electricity in the future. For general discussion of the trade-off between capacity and energy prices, see Pechman, C. "Whither the FERC? Overcoming the Existential Threat to Its Magic Pricing Formula through Prudent Regulation" National Regulation Research Institute. January 2021.

[45] VCE's technical documentation notes that total resource cost includes, among other details, "amortized generator capital expenditures, fuel costs, start-up and shutdown costs, amortized transmission capital expenditures, amortized storage capital expenditures, variable O&M expenditures, fixed O&M expenditures, amortized natural gas transport expenditures, transmission wheeling charges, transmission access charges, interconnection expenditures, demand-side management and demand response expenditures, distribution costs and access charges, curtailment charges, reserve costs, retirement costs, and international trading costs." See: vibrantcleanenergy.com/wp-content/uploads/2020/08/WISdomP-Model_Description(August2020).pdf.

[46] This treatment reflects the fact that incentivized resources may choose to enter and participate in the wholesale market due to the availability of incentive payments that offset market losses that would otherwise occur. An example of this behavior is the decision of some renewable energy generators to continue operating even when wholesale energy prices approach zero or go negative.

Section 45Q production tax credits). Across all scenarios, the model builds more utility-scale PV and storage as each resource's fixed costs decline. Conversely, the model does not choose to build resources like traditional nuclear or hydropower in part due to high fixed costs.

Estimated retail rates generally follow the same changes observed for total resource costs. Again, scenario specific results reflect the changes discussed in Chapter 2.

3.2. Total Resource Costs

Figure 43 shows Maryland's estimated total resource costs by investment period and scenario.[47] All of the scenarios are shown in the first graph, select Phase 1 scenarios are shown in the second graph, and select Phase 2 scenarios are shown in the third graph. Most scenarios follow a similar trajectory from beginning to the end of the review period: resource costs fall in the early 2020s, begin to increase in 2026, and more steeply rise between 2035-2040. The initial decreases reflect the retirement of inefficient coal and natural gas capacity, while subsequent increases are tied to the addition of new renewable energy and natural gas capacity. All models estimate between approximately $4.5 and $6 billion in total annual resource costs in 2040.

The Phase 1 models were configured using earlier resource mix data than the Phase 2 models and, as a result, begin at a higher starting cost.[48] Additionally, as discussed in Chapter 2, the Phase 1 model assumptions result in the retention of certain in-state generation resources that otherwise retire in the Phase 2 models. As a result, Phase 1 costs fall less steeply through 2026 and subsequently increase on a more gradual basis than costs under Phase 2 model assumptions. An exception to this result is the 100% Clean-1 model, which exhibits a substantial increase in costs after the model retires the in-state natural gas CCS resources built to capture 45Q credits. Total resource costs in the 100% Clean-1 scenario subsequently fall in 2040, bringing them into closer alignment with the other Phase 1 scenarios. Total resource costs are higher in the Calvert-1 scenario due to the assumed availability of out-of-market subsidies to support continued Calvert Cliffs operations.

For the Phase 2 models, most cost estimates move in parallel, at slightly different levels, until 2033. Scenarios that assume policies that incentivize faster addition of renewables in Maryland (e.g., 100% RPS Max-2 and 100% RPS 2035-2) have slightly higher costs in the early 2030s. Costs uniformly spike in the late 2030s for all scenarios that assume CES policies, reflecting anticipated capital investments in CCS and advanced technologies. Scenarios that exclude new natural gas in PJM (100% Clean No NG PJM-2 and 100% RPS No NG PJM-2) or assume high electrification (100% Clean High Electric-2 and 100% RPS High Electric-2) exhibit the highest year-over-year costs.

Total resource costs for other PJM states follow a similar pattern as Maryland insofar as cost reductions and increases primarily correspond with capacity retirements and additions, respectively. **Figure 44** shows these changes for select PJM states based on the 100% RPS-2 scenario results. Compared to 2023, Ohio is the only state to experience large increases in total resource costs. This change reflects the suitability of Ohio to develop a variety of generation resources as well as its centrality. Smaller resource cost increases appear in Maryland, New Jersey, and Virginia, especially from 2025 onward. Conversely, total resource costs fall in Illinois, Pennsylvania, and West Virginia as coal and less efficient natural gas units retire. PJM-wide total resource costs for the 100% RPS-2 scenario fall from approximately $60 billion per year in the early 2020s to as low as $38 billion in the early 2030s, before rebounding to $52 billion at the end of the review period.[49] This same shape applies to other scenarios.

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[47] Unless stated otherwise, all dollar figures are presented in 2020 nominal dollar terms.

[48] As noted above, this reflects higher levels of less efficient and more expensive natural gas and coal capacity.

[49] Excludes costs attributable to the PJM portions of Indiana, Kentucky, Michigan, North Carolina, and Tennessee.

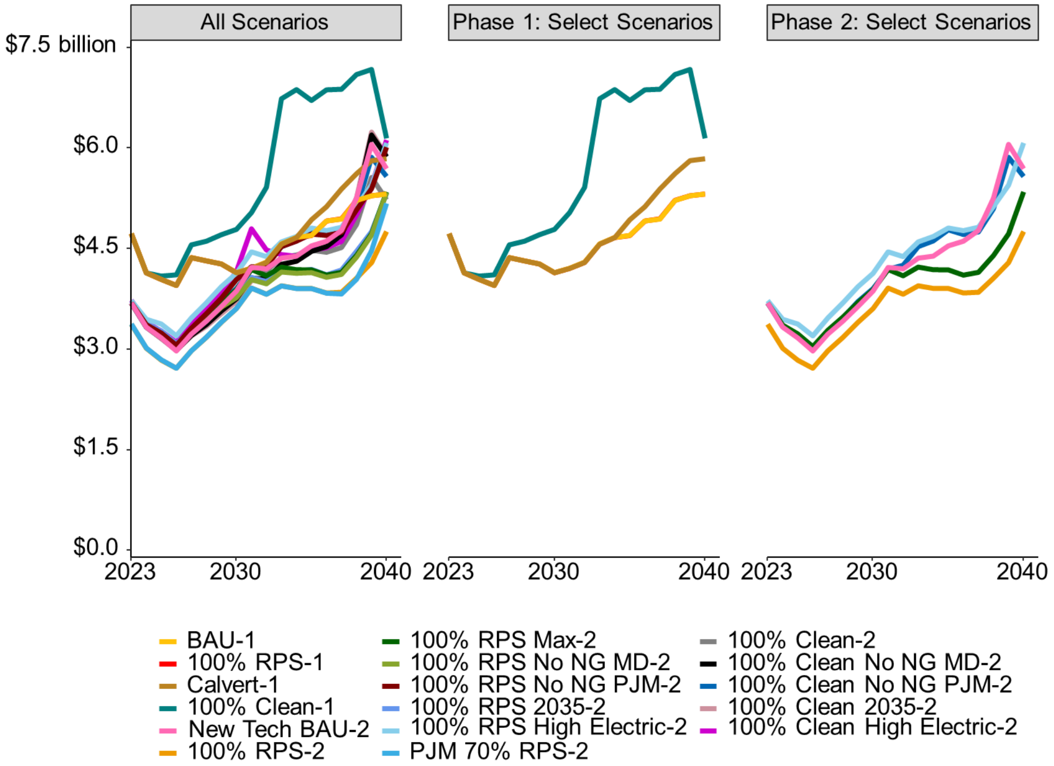

Figure 43. Total Resource Costs in Maryland, by Scenario

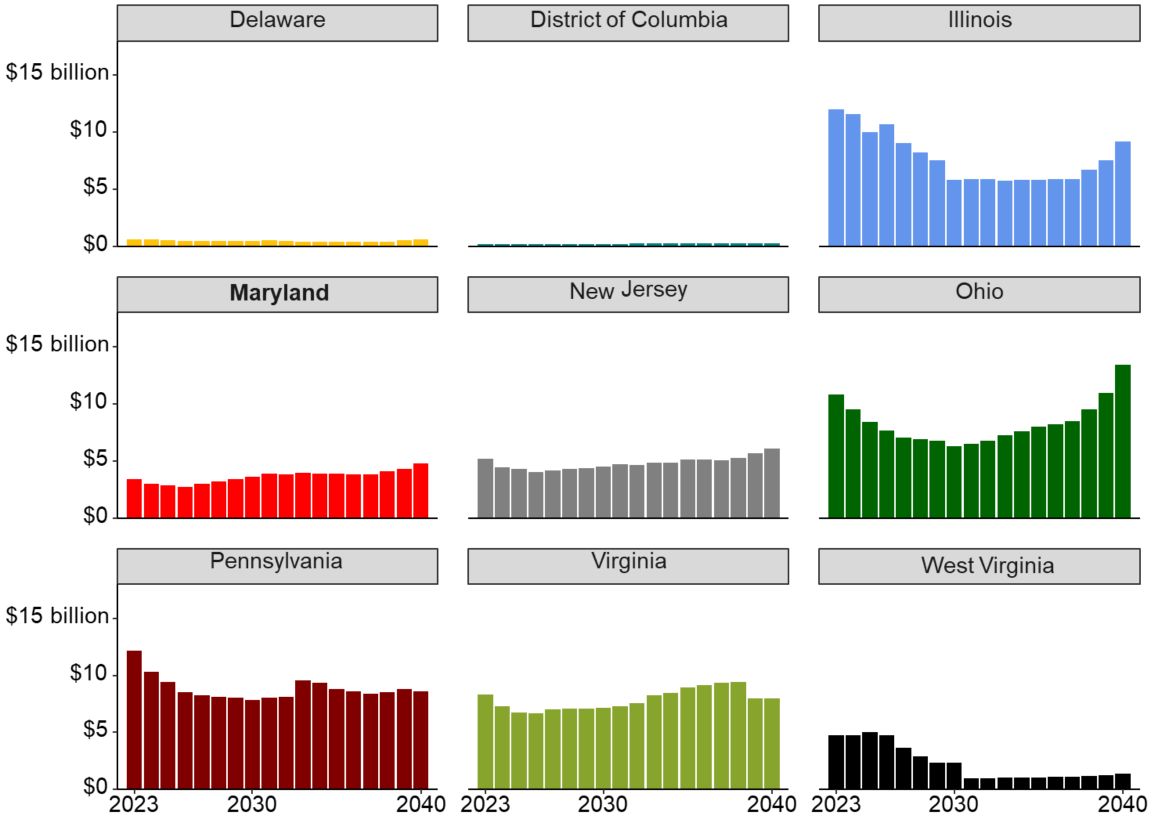

Figure 44. Total Resource Costs for Select PJM States, 100 RPS-2 Scenario

Note: Figure includes resource costs attributable to some non-PJM portions of represented states.

3.2.1. Transmission and Distribution Costs

In all scenarios, PJM-wide T&D costs initially spike as the model builds out transmission because it is economic to do so for reasons including access to new renewable energy capacity in geographic areas with higher wind and solar resource potential. The magnitude of the T&D cost increase is highest in Ohio, Pennsylvania, Virginia, and Illinois, all of which are also geographically large states. Costs subsequently flatten and fall as fossil fuel-based resources retire and existing transmission assets are utilized to support new resources.

Distribution costs, as distinct from transmission costs, are relatively flat in all scenarios and for all states. **Figure 45** shows Maryland distribution costs for the 100% RPS-2 and 100% Clean-2 scenarios, both of which are similar to other scenarios. Changes include a slight decrease in distribution costs through the 2030s and a rise thereafter as load growth increases and additional distributed energy resources come online. Maryland-specific distribution costs and trends are largely the same across all scenarios except for the high electrification scenarios, under which distribution costs increase to approximately $1.1 billion.

3.2.2. Marginal Energy Prices and Capacity Prices

In PJM, the marginal energy price, also referred to as the Locational Marginal Price (LMP), represents the cost of supplying the next increment of electricity demand at a specific location on the grid. This price is calculated by VCE based on the costs of generating units that are incrementally dispatched to meet additional demand. Factors influencing LMP include fuel costs, generator efficiency, transmission constraints, and demand.

Capacity costs are represented in VCE's model as the outcome of a make-whole market. Prices increase when the model identifies capacity deficits, and rise to the level necessary to cover the net cost of new entry (CONE) for the resources needed to overcome the identified deficits. Capacity deficits can occur during specific hours of the year even when there is sufficient aggregate capacity to meet all loads in other hours. Net CONE represents the revenues that a new resource would need to earn in the capacity market, after netting out energy and ancillary service revenues, in order to make entry or continued operation economic for the hours when a capacity deficit exists.

Figure 46 and **Figure 47** show average annual marginal prices and capacity prices, respectively, in Maryland for the 100% RPS-2 and 100% Clean-2 scenarios. These scenarios are representative of all models insofar as, for most model scenarios, Maryland average annual marginal costs approximately halve from 2020 to 2040 while the capacity price more than quadruples. Additionally, the number of PJM-wide hours at a marginal energy price of $0/MWh significantly increases over this time frame, as shown in **Figure 48**. Notably, by 2040, marginal costs regularly reach zero except during the winter and summer peak demand seasons. These changes reflect the cumulative effect of gradual increases in the amount of low- or no-variable cost renewable generation serving all PJM states.

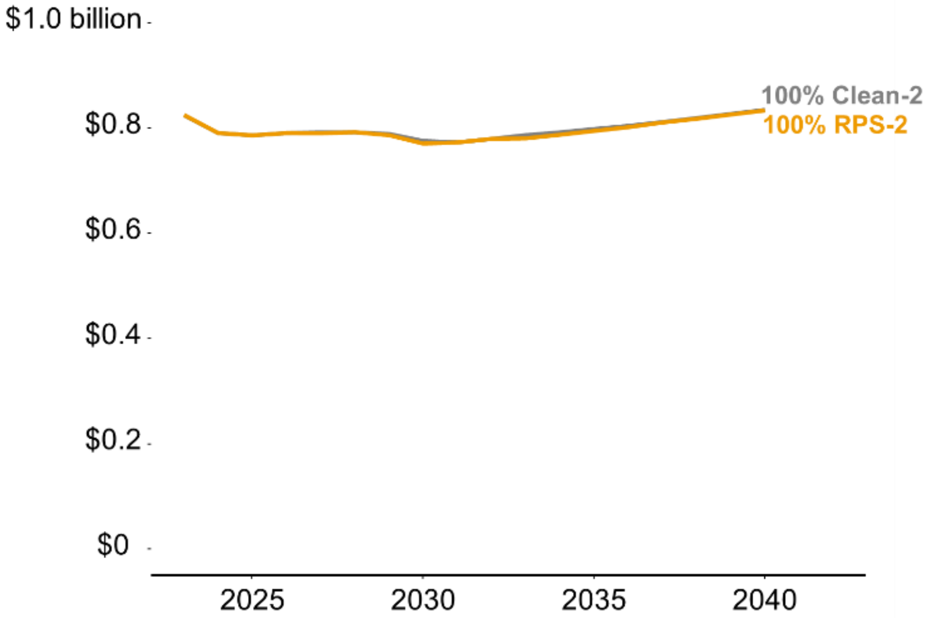

Figure 45. Maryland Distribution Costs, 100% RPS-2 and 100% Clean-2 Scenarios

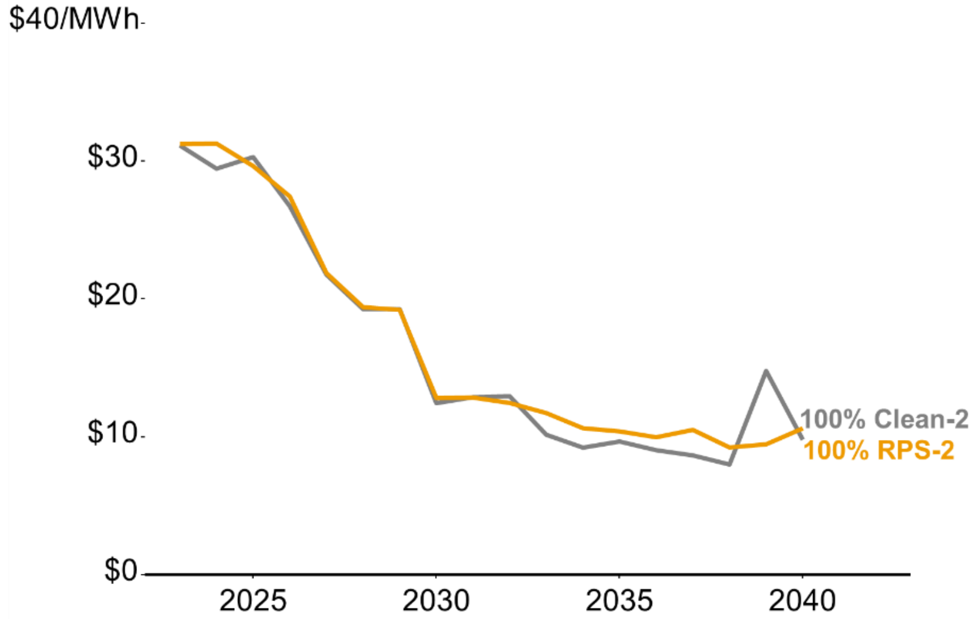

Figure 46. Average Annual Marginal Prices in Maryland, 100% RPS-2 and 100% Clean-2 Scenarios

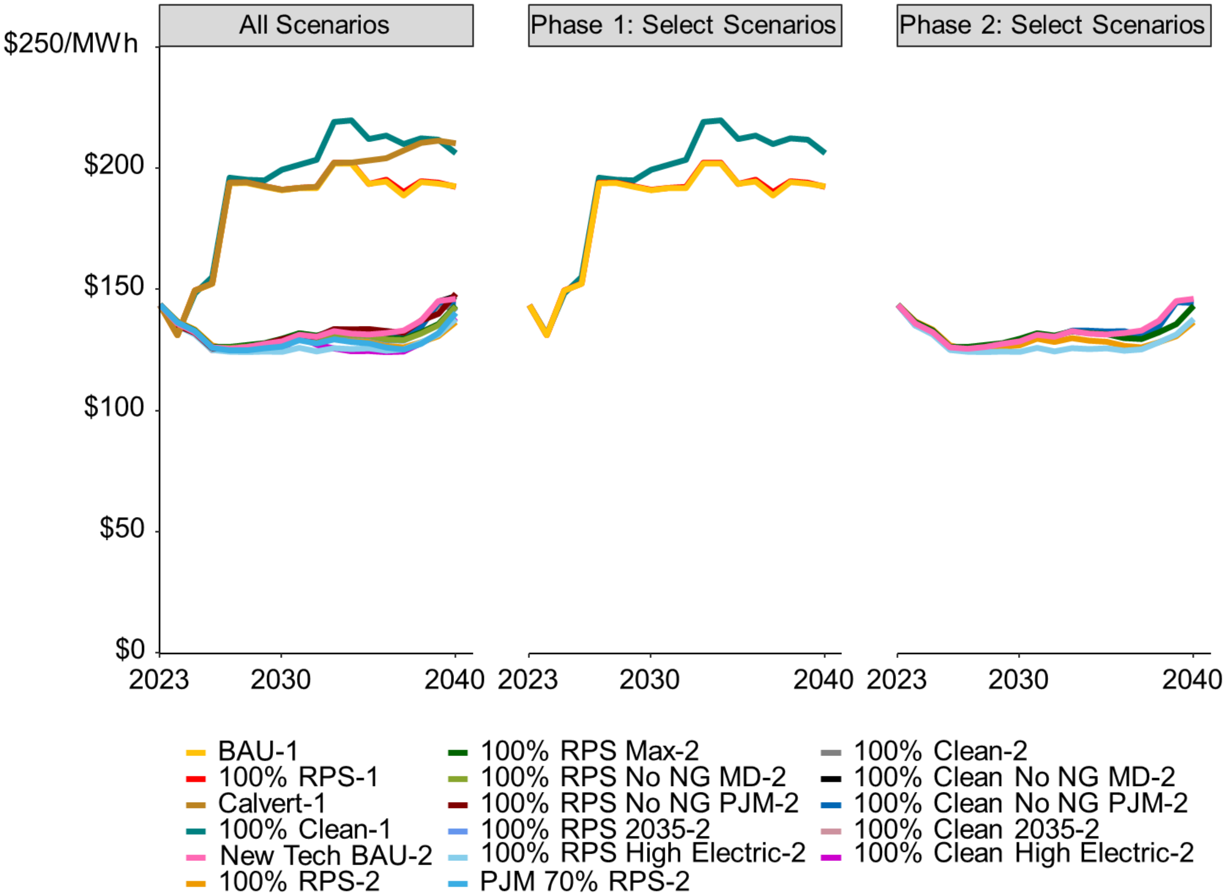

Figure 47. Average Annual Capacity Prices in Maryland, 100% RPS-2 and 100% Clean-2 Scenarios

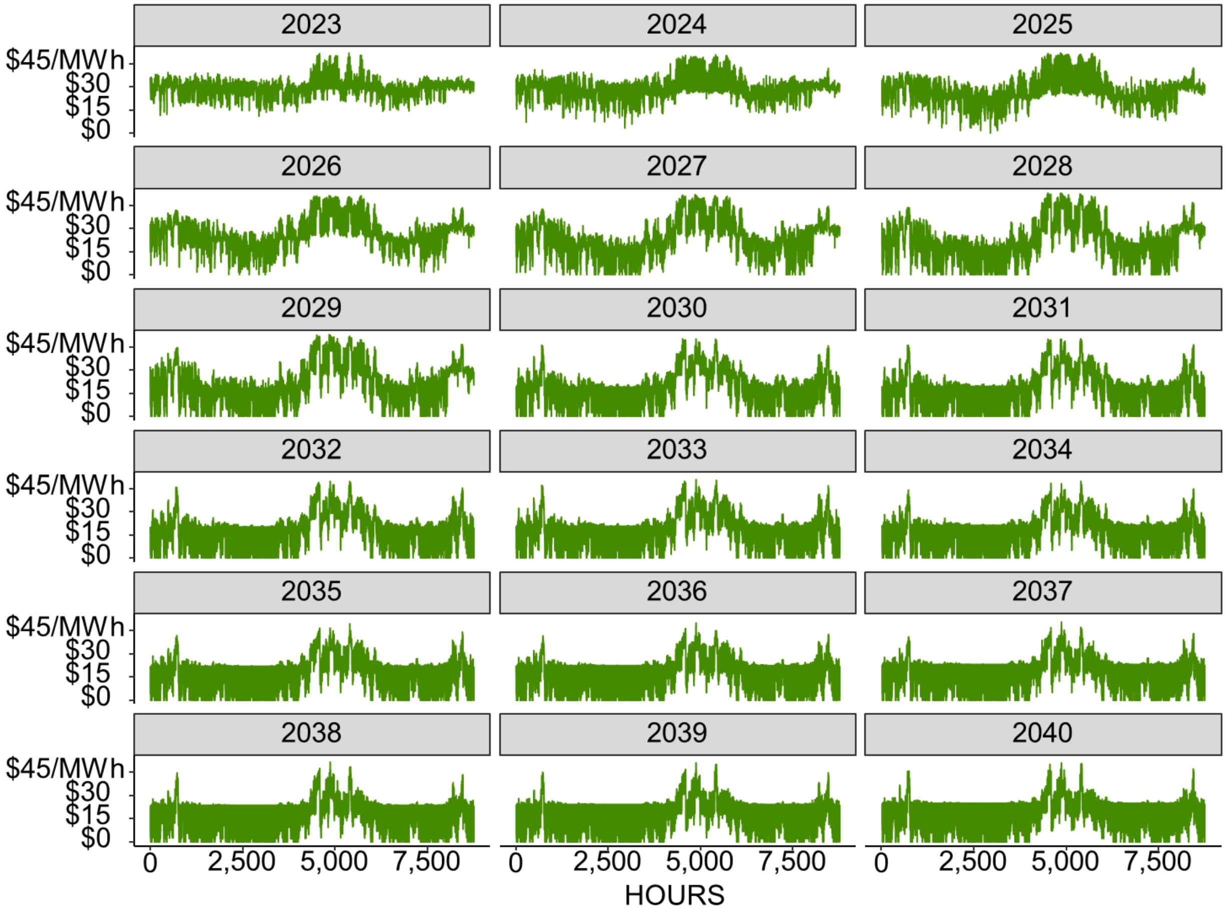

Figure 48. Average Hourly Marginal Prices in PJM by Year, 100% RPS-2 Scenario

VCE's marginal energy and capacity price estimates are best understood as illustrations of market forces and directional trends rather than exact price projections. In theory, wholesale prices should align closely with the marginal costs of energy. However, in practice, they can diverge due to various factors such as fixed contract prices, hedging strategies, and regulatory interventions. Similar interventions also influence capacity prices. For example, PJM applies a market seller offer cap that can vary depending on the type of resource and other market conditions. It is designed to balance the need for fair compensation to generation operators while protecting consumers from excessively high prices. Thus, changes in actual capacity and wholesale energy costs may be more moderate (i.e., lower capacity and higher marginal energy prices) than portrayed above.

3.2.3. Out-of-Market Nuclear Costs

PJM's traditional nuclear generation fleet faces a variety of economic and regulatory challenges that are discussed in Appendix H. Given these challenges, several states, including Ohio, Illinois, and New Jersey, have made out-of-market incentives available to traditional nuclear resources in order to support their continued operation through at least the duration of their existing licensed life.

In all models, Exeter assumes the availability of nuclear incentive payments for all non-Maryland PJM states through the licensed life of existing traditional nuclear assets. For the Calvert-1 and all Phase 2 models, Exeter also assumes the availability of these payments in Maryland (i.e., applicable to Calvert Cliffs) in all years. For the other Phase 1 models besides Calvert-1, Exeter only assumes the availability of payments to Calvert Cliffs *prior* to its license expiration. At this point, Calvert Cliffs retires for economic reasons. The out-of-market nuclear cost estimates derived from the model can be interpreted as either short-term losses to the in-question nuclear power plants or subsidy payments in the form of Zero Emission Credits (ZECs) or equivalent.

Notably, in all models, minimal out-of-market payments are required for Calvert Cliffs through the early 2030s, suggesting that the unit is economic in most years. By contrast, out-of-market support requirements manifest for nuclear resources in Illinois, Michigan, New Jersey, Pennsylvania, Ohio, and Virginia. The size of these support payments consistently increases for all states, including Maryland, beginning in the early 2030s.

In Maryland, a potential gap between Calvert Cliffs' market revenues and continued operating costs emerges in 2028. Estimated out-of-market subsidy prices are similar in most scenarios except for certain clean scenarios (e.g., 100% Clean-2) that build less renewable energy capacity. In these scenarios, the annual ZEC prices are lower.

3.3. Retail Rates

VCE's retail rate estimates are derived from total resource costs with adjustments to account for competitive retail market and regulatory factors not reflected in WIS:dom-P.[50] **Figure 49** shows estimated Maryland retail rates by year and scenario, with several scenarios separately shown to highlight relative differences. Despite starting at a similar rate, the Phase 1 and Phase 2 model results diverge significantly in the 2020s. Phase 1 rates significantly increase due to model assumptions specific to the Phase 1 scenarios and substantial additions of new natural gas capacity, as discussed in Chapter 2. Phase 2 retail rates, by comparison, remain relatively flat until the end of the review period, at which time Phase 2 retail prices increase in part due to higher load.

The four Phase 1 model results diverge post-2025 depending on the scenario. Retail rates are higher for the Calvert-1 scenario due to the estimated cost of out-of-market policy support after the relicensing of Calvert Cliffs. Retail rates are also higher for the 100% Clean-1 scenario because of the costs of emerging technologies, including substantial natural gas CCS additions. The 100% RPS-1 and BAU-1 scenario results are virtually identical, consistent with their similar capacity, generation, and transmission changes.

Phase 2 model results differ for reasons largely attributable to resource mix. Higher retail rates are estimated for models that build out more in-state resources, e.g., more renewables in 100% RPS Max-2, or more CCS in 100% Clean-2. High electrification scenarios result in lower estimated retail rates than other scenarios because of the assumed widespread adoption of more efficient heat pumps and greater demand flexibility. Scenarios with no new natural gas in Maryland or PJM result in higher retail rate impacts.

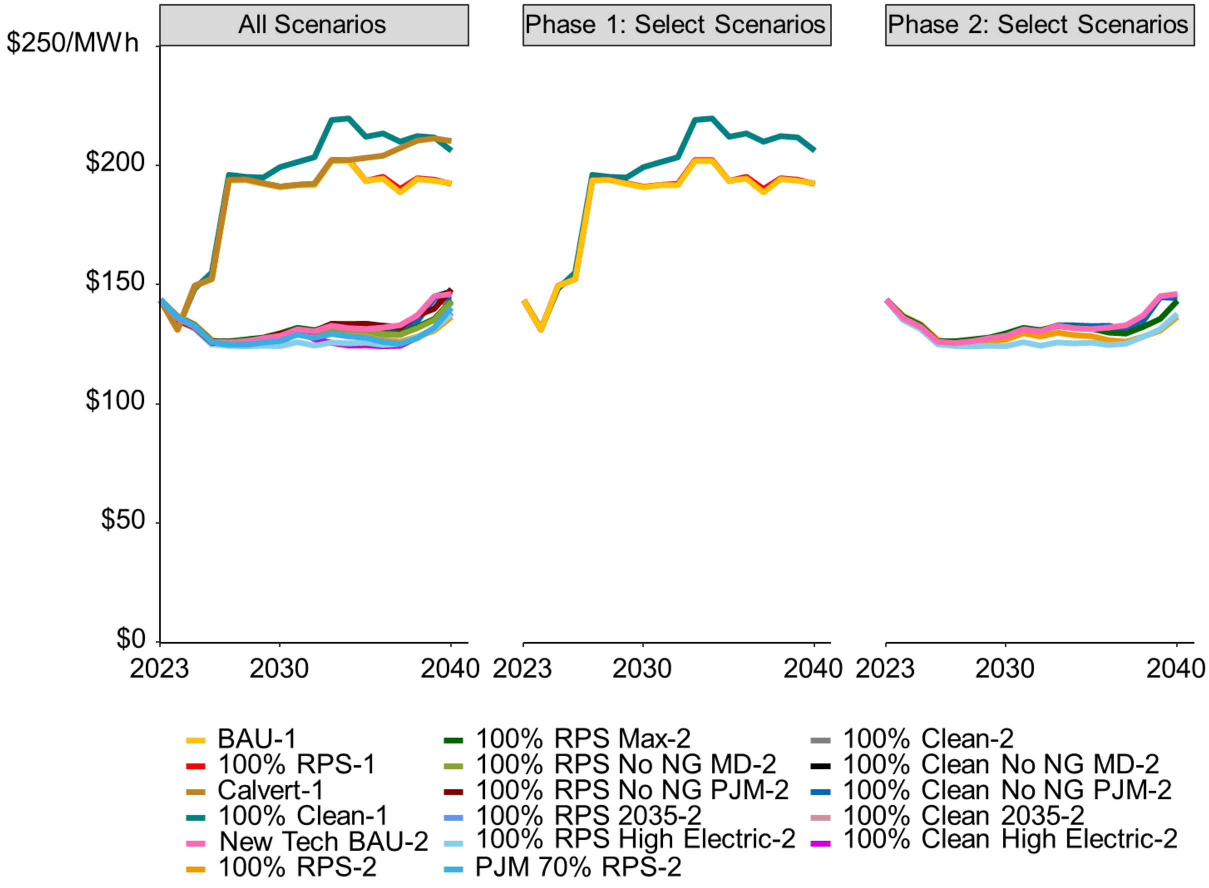

Figure 49. Retail Rates in Maryland by Scenario, Adjusted

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[50] VCE initially compared its model results to actual 2020 retail rates (using EIA-861 data) to derive the adjustment factor. Exeter subsequently made additional adjustments to bring the rates in line with actual 2023 retail rates. These results are still presented in 2020 nominal dollars.

3.4. Key Findings

- After falling initially, estimates of total resource costs in the Phase 2 models begin to increase by 2026 for most of the scenarios modeled, and then more sharply increase toward the end of the forecasted period. By contrast, total resource costs for the Phase 1 models increase early on before flattening. This divergence reflects differences in the expected load growth and the types and timing of capacity additions between Phase 1 and Phase 2. Conditions that make Maryland more favorable to add new natural gas capacity, as applicable in the Phase 1 scenarios, led to a front-loading of costs. Conditions that result in higher levels of load growth, as applicable in all the Phase 2 scenarios, cause a greater increase in costs in the 2030s.
- Changes in T&D costs reflect the model accessing more economic generation in other states and the addition of new renewable generation. Across PJM, T&D costs comprise almost 70% of total resource costs in 2040, illustrating the importance of accounting for these costs when considering RPS or CES policies.
- Marginal energy costs fall sharply with the increasing penetration of low- and zero-cost variable generation resources. In contrast, capacity costs increase for the entire forecast period.
- Natural gas CCS additions in the 100% Clean-1 scenario forestall, but do not eliminate, renewable energy and natural gas capacity additions that eventually occur after these systems retire. As a result, resource costs spike during the mid-2030s in this scenario due to significant capacity additions that occur in a concentrated window of time, before beginning to fall in 2040. This outcome creates price volatility that potentially undermines rate stability objectives.
- Most costs (e.g., capacity and distribution) increase for Maryland and remain flat in other states within the high electrification scenarios. This suggests that the model meets increased load requirements through in-state resource expenditures. At the same time, high electrification scenarios assume the adoption of more efficient heat pumps and flexible load. As a result, wholesale marginal costs slightly fall.
- For the Phase 2 models, retail rates stay relatively flat until the end of the forecast period. For the Phase 1 models, retail rates substantially increase in the first half of the forecast period. This reflects differences in model assumptions, including those discussed above in the context of total resource costs.
- For the Phase 2 models, RPS and CES costs are relatively similar when comparing equivalent models. CES costs are slightly higher in most cases for reasons attributable to higher levels of in-state capacity, especially CCS and advanced energy technologies.
- Scenarios which assume policies that limit the development of new natural gas in Maryland lead to higher retail rates than those that do not. This outcome may reflect the retention of inefficient existing natural gas and coal units for longer periods of time.
- These results are sensitive to the assumptions used. For example, the model results reflect use of NREL's ATB from 2020 that depicted declining cost trends for OSW that have been interrupted in recent history due to inflation, supply-chain disruptions, labor shortages, and other challenging market conditions. Additionally, modeled price projections, especially for retail rates, are best understood as illustrations of market forces and directional trends rather than exact price projections. In practice, the actual prices that customers pay can vary due to contract arrangements, hedging strategies, regulatory requirements, and more.

3.5. Cost-Benefit

The cost and rate impacts of an RPS or CES depend on how they impact both the Maryland and PJM-wide resource mix. Capacity retirement, retention, and additional decisions all incur costs, ranging from upfront capital investment to ongoing operations and maintenance expenses, to the opportunity cost of a more expensive resource operating in place of a less expensive one. The types of resources also influence T&D expenditures as well as marginal energy, capacity, and out-of-market subsidy prices. Ultimately, these costs are translated into retail rates after accounting for additional regulatory and market factors, such as ratemaking and retail contracts.

To assess the cost and benefit of the above total resource cost and retail rate impacts, Exeter derived discounted estimates of the cumulative stream of costs for the period 2025-2040. For this exercise (and similar calculations in other chapters), all results are listed in terms of the purchasing power of 2023 dollars, with conversions made using a GDP implicit price deflator from the Federal Reserve. Exeter discounted the monetized values back to present value terms using a 3% discount factor and assuming 2025 as the first discounted year. Note that modeled costs and benefits for the Phase 1 and Phase 2 scenarios are not directly comparable due to changes in assumptions. However, examining the relative differences between scenarios within each phase can still be useful.

Table 9, **Figure 50** and **Figure 51** represent discounted aggregate total resource costs by scenario both at a PJM and a Maryland level, as well as a comparison of Maryland costs for select scenarios. The 100% Clean-1 scenario is the most expensive scenario with regards to Maryland total resource cost ($81.6 billion), which is $15.7 billion more than the discounted 100% RPS 1 scenario costs ($65.9 billion). Maryland also comprises the largest share of the total costs for PJM (10.1%) in the 100% Clean-1 scenario, as compared to the Phase 1 scenarios. By contrast, for the 100% RPS-1 and BAU-1 scenarios, Maryland total resource costs make up 8.2% of total PJM costs.

For Phase 2, the 100% RPS-2 scenario reflects the lowest discounted total resource cost of the scenarios evaluated. The two high electrification scenarios (100% RPS High Electric-2 and 100% Clean High Electric-2), meanwhile, reflect the greatest total resource cost, and both incur over $9 billion more in cumulative, discounted total cost. On average, the CES scenarios reflect higher total resource costs compared to the RPS scenarios.

Table 10, **Figure 52** and **Figure 53** represent the load-weighted average retail cost in Maryland for each of the scenarios. It also presents a discounted total retail rate impact, calculated by multiplying annual retail rates by estimated retail electricity sales for each scenario, and a comparison of this cost for select scenarios. Similar to the total resource cost estimates above, retail rate impacts are expected to be highest for the 100% Clean-1 scenario among the Phase 1 model results. For the Phase 2 results, both high electrification scenarios have significantly higher total retail costs compared to all other scenarios. Retail cost impacts are also generally higher for the CES scenarios than the RPS scenarios.

Table 9. Discounted Total Resource Costs in PJM and Maryland, by Scenario

Scenario	Discounted Total Resource Costs for PJM, 2025-2040 (billions) (2023$)	Discounted Total Resource Costs for MD, 2025-2040 (billions) (2023$)	MD Discounted Total Costs Compared to 100% RPS-1 (billions)	MD Discounted Total Costs Compared to 100% RPS-2 (billions)
BAU-1	$808.41	$65.94	$0.00	
100% RPS-1	$808.40	$65.94	$0.00	
Calvert-1	$808.58	$67.75	$1.81	
100% Clean-1	$805.48	$81.66	$15.72	
New Tech BAU-2	$623.89	$60.63		$7.82
100% RPS-2	$625.22	$52.81		$0.00
100% RPS Max-2	$624.80	$57.47		$4.66
100% RPS No NG MD-2	$624.50	$56.71		$3.90
100% RPS No NG PJM-2	$648.18	$61.50		$8.69
100% RPS 2035-2	$624.39	$57.31		$4.50
100% RPS High Electric-2	$633.74	$63.28		$10.46
PJM 70% RPS-2	$624.21	$53.18		$0.37
100% Clean-2	$621.88	$59.26		$6.44
100% Clean No NG MD-2	$624.11	$59.97		$7.16
100% Clean No NG PJM-2	$636.31	$61.21		$8.40
100% Clean 2035-2	$623.69	$60.01		$7.20
100% Clean High Electric-2	$633.09	$62.00		$9.18

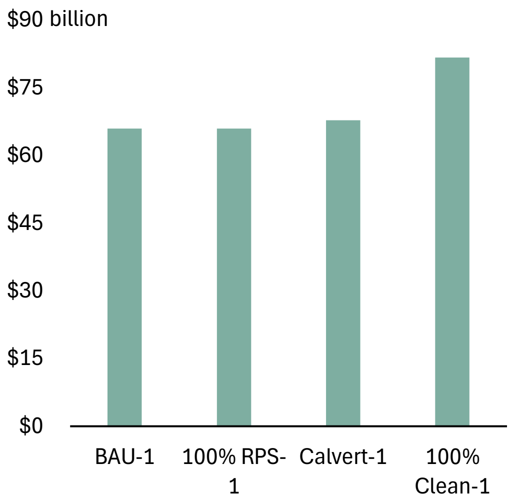

Figure 50. Discounted Total Resource Costs for Maryland from 2025-2040, Phase 1 Scenarios

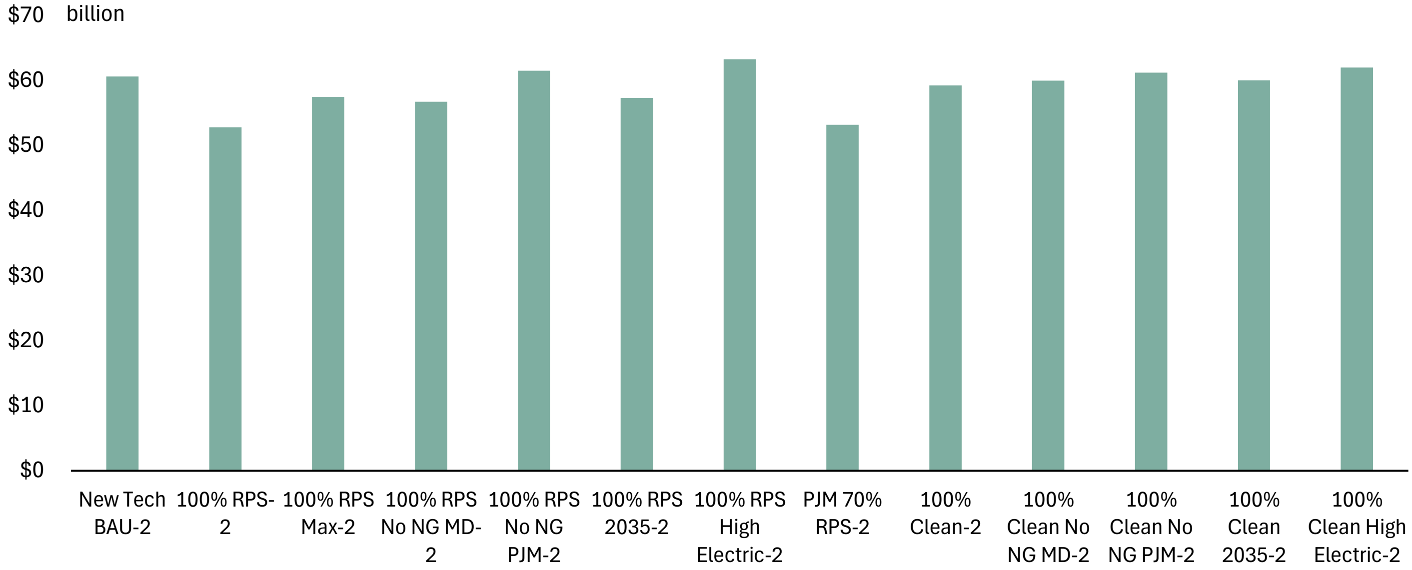

Figure 51. Discounted Total Resource Costs for Maryland from 2025-2040, Phase 2 Scenarios

Table 10. Load-Weighted Average and Discounted Total Retail Costs in Maryland, by Scenario

Scenario	Load-weighted Average Retail Costs, 2025-2040 (2023$) ($/kWh)	Discounted Total Retail Costs, 2025-2040 (2023$) (billions)	Discounted Total Costs Compared to 100% RPS-1	Discounted Total Costs Compared to 100% RPS-2
BAU-1	$0.189	$143.97	($0.08)	
100% RPS-1	$0.189	$144.05	--	
Calvert-1	$0.195	$147.62	$3.58	
100% Clean-1	$0.200	$152.02	$7.98	
New Tech BAU-2	$0.133	$113.35		$2.93
100% RPS-2	$0.129	$110.42		--
100% RPS Max-2	$0.131	$112.54		$2.12
100% RPS No NG MD-2	$0.131	$112.00		$1.58
100% RPS No NG PJM-2	$0.133	$113.51		$3.09
100% RPS 2035-2	$0.131	$111.89		$1.47
100% RPS High Electric-2	$0.127	$132.46		$22.04
PJM 70% RPS-2	$0.129	$110.23		($0.19)
100% Clean-2	$0.132	$113.19		$2.77
100% Clean No NG MD-2	$0.132	$112.86		$2.45
100% Clean No NG PJM-2	$0.132	$113.13		$2.71
100% Clean 2035-2	$0.132	$112.86		$2.44
100% Clean High Electric-2	$0.128	$133.16		$22.75

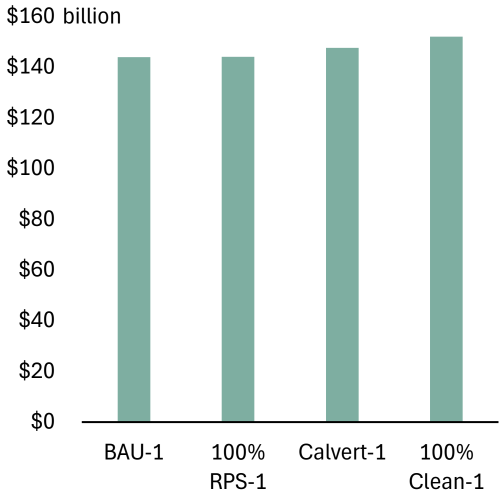

Figure 52. Discounted Total Retail Costs in Maryland from 2025-2040, Phase 1 Scenarios

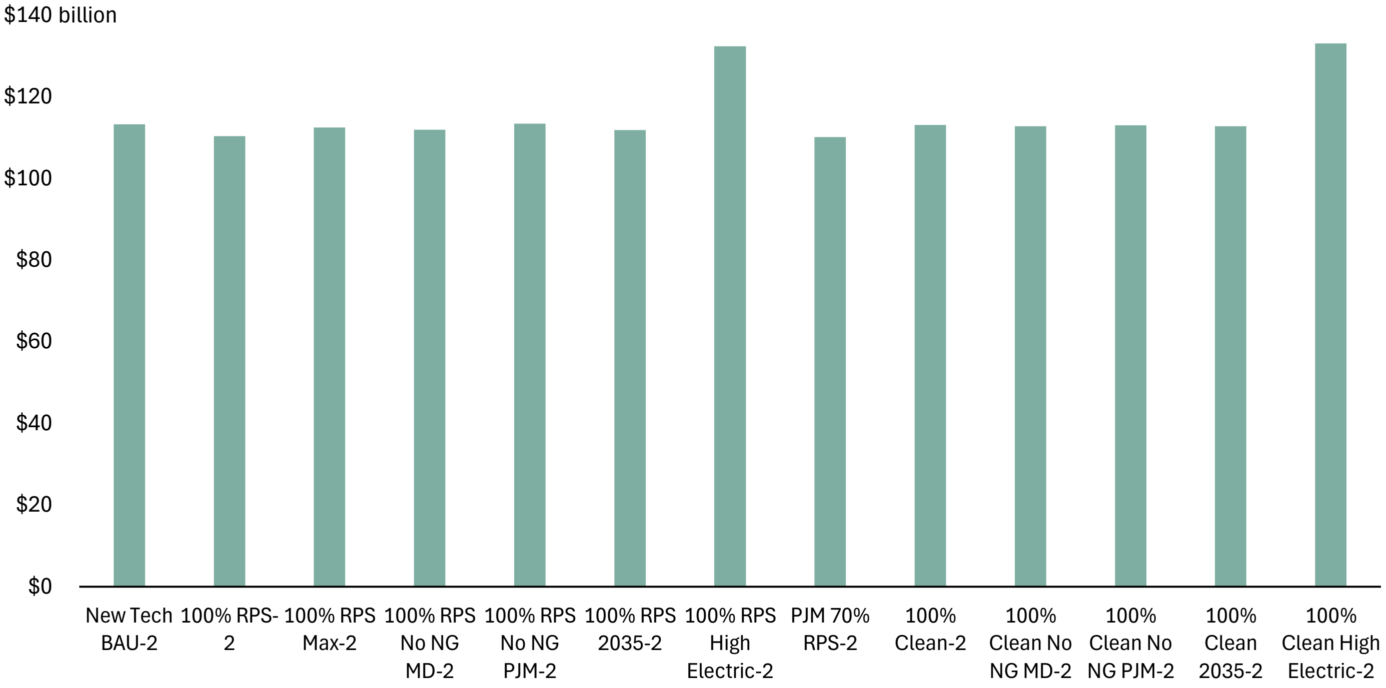

Figure 53. Discounted Total Retail Costs in Maryland from 2025-2040, Phase 2 Scenarios

4. EMISSIONS

This section of the report reviews the role of a 100% Maryland RPS or CES in reducing air emissions from power plants. The emissions content of electricity is a measure of the metric tons of emissions released per unit of generation. In an electricity grid, the emission content of power depends on a variety of factors, including the fuel source and heat rate of contributing electric generators, the load factor and capacity of those generators, and the chemical content of the fuels used. All else equal, switching to a fuel source with a lower- or zero-emission profile (e.g., replacing coal with natural gas or solar), reducing the heat rate, or reducing the load factor or capacity of fossil fuel generators will reduce emissions. Policies that promote renewable energy resources, including an RPS, can help reduce emissions by supporting generation from resources that have low or no emissions.

As discussed in preceding sections, power generation throughout the PJM service area is commingled, with power imported and exported from any given PJM state based on economic dispatch. While PJM can track how much power is generated by individual power plants, once the electric power is on transmission lines, there is no way of knowing the fuel source, and thus the emissions, of the resources that serve customers in specific areas. In other words, the electricity consumed by Maryland ratepayers is sourced from a broader pool of resources. Therefore, the emission reduction contributions of existing and potential Maryland RPS policies are evaluated by looking at the emissions of resources both in-state and within PJM, depending on the type of pollutant. For the purposes of this report, the authors focus exclusively on direct air emissions and therefore do not consider the life-cycle emissions impacts of specific resources.[51] Emission profiles are assumed based on technology type and age.[52]

4.1. Results

In all scenarios, annual emissions drop considerably through 2030 as compared to 2020 levels.[53] **Figure 54** and Figure 55 show these reductions for Maryland and PJM states (combined) based on 100% RPS-2 scenario assumptions. After 2030, PJM-wide emissions flatline or slightly increase, depending on the emission type. In Maryland, all emissions reach or approach zero. These changes, more broadly, reflect turnover in the capacity mix of PJM and Maryland. Because emissions from the power system are primarily produced due to the combustion of fossil fuels (e.g., coal, oil, and natural gas), forces driving the retirement of resources that use these fuels also drive reductions in emissions. The pace and stability of reductions can vary based on model assumptions, as discussed below.

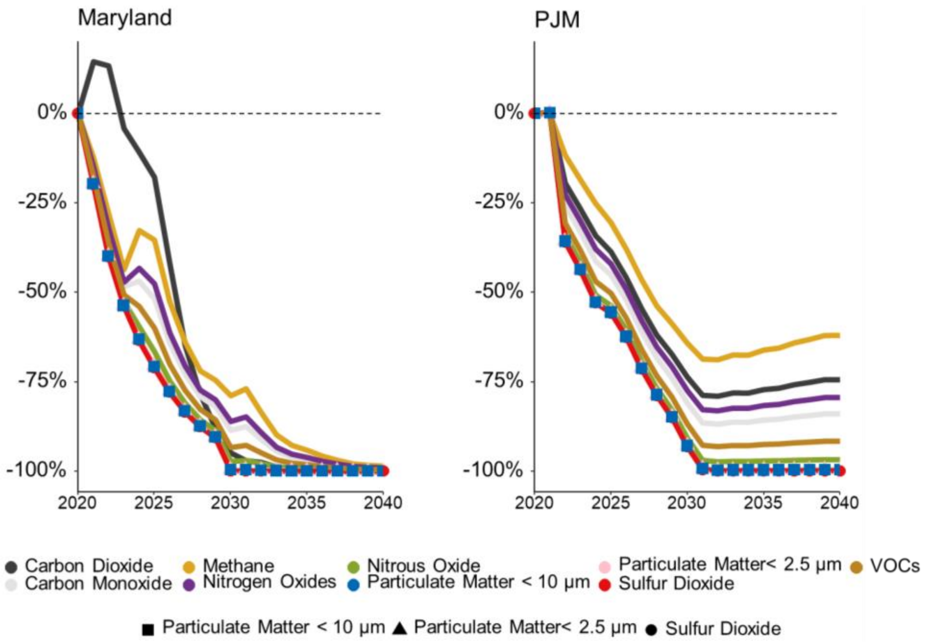

Figure 54. Percent Change in Maryland and PJM Annual Emissions Relative to 2020, 100% RPS-2 Scenario

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[51] For example, the estimates do not address or account for the emission avoidance benefits from combusting some biomass resources, such as MSW and LFG, as compared to landfilling.

[52] Emissions content numbers reflect national average emission factors attributable to different technologies. For new plants, improved heat rate assumptions capture the improvement in technology in terms of emission content.

[53] Note that cumulative emissions and lifetime impact are addressed in Section 4.5.

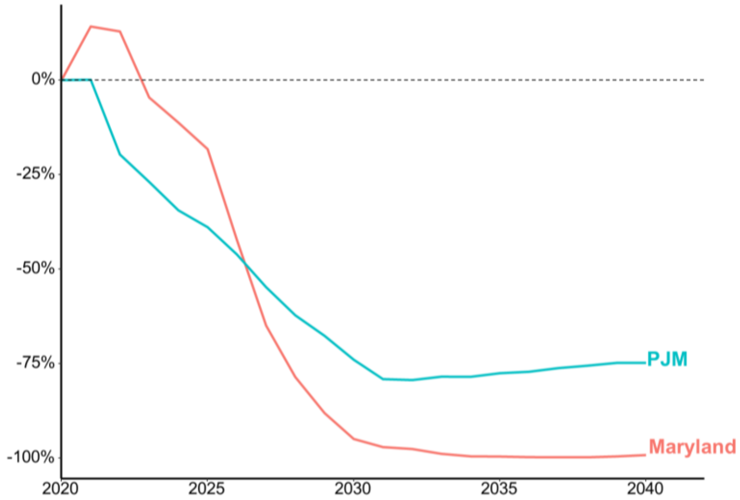

Figure 55. Percent Change in Maryland and PJM Annual CO2e Emissions Relative to 2020, 100% RPS-2 Scenario

Note: Calculated by converting CH_4 and N_2O emissions into carbon dioxide equivalent (CO_2e) (i.e., each unit of the original emission is multiplied by a factor that represents the equivalent number of metric tons of CO_2 emissions in terms of global warming potential) and then summing each input (i.e., CO_2, CH4, and N_2O) together. Conversion based on EPA's Greenhouse Gas Equivalencies Calculator: epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references. (Accessed March 2024).

4.2. Greenhouse Gas Emissions

GHGs, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), are global pollutants that accumulate in the atmosphere and contribute to global warming. The State of Maryland maintains Maryland-specific GHG reduction targets, most notably those outlined in Maryland's Climate Pollution Reduction Plan as a consequence of the Climate Solutions Now Act,[54] in addition to participating in the RGGI cap-and-trade program.[55] The full climate impact of Maryland's environmental strategies, however, are most clear when assessing not only Maryland-specific targets or requirements, but also GHG emissions emanating from the wider PJM territory. Thus, the subsequent discussion and figures look at PJM-wide emissions, by GHG.

4.2.1. Carbon Dioxide

CO_2 emissions are widely considered the primary driver of climate change due to their abundance and persistence in the atmosphere. **Figure 56** shows the range of annual PJM-wide CO_2 emission outcomes across all scenarios. Several scenarios are also separately shown to highlight relative differences; select Phase 1 scenarios are shown in the second graph, and select Phase 2 scenarios are shown in the third graph. A similar layout is used for subsequent emission graphs.

The BAU-1 and 100% RPS-1 scenario results are nearly identical; emissions steeply fall through 2030, flatline, and then begin to rise in the late 2030s. As compared to BAU-1, CO_2 emissions remain slightly lower in the late 2030s in Calvert-1 because of the assumed retention of Calvert Cliffs. The decline in CO_2 emissions is steepest under the 100% Clean-1 assumptions largely due to the presence of natural gas with CCS. The end of 45Q incentives, however, leads to a rebound in CO_2 emissions in the early 2030s under this scenario.

The Phase 1 set of models (BAU-1, Calvert-1, 100% RPS-1, and 100% Clean-1) diverge from the Phase 2 models (i.e., all other scenarios) from 2030-2040 due to changes in applicable assumptions, including a larger modeling footprint that facilitates integration of additional low- and zero-carbon resources. As a result of assumptions changes, CO_2 emissions fall further and faster through 2030, reaching 75% reductions from 2020 levels for all Phase 2 scenarios. The biggest CO_2 emission declines occur in scenarios that allow the development of CCS and BECCS (retrofitted or new) or advanced energy technologies (e.g., 100% Clean-2), limit natural gas capacity expansion in PJM (e.g., 100% RPS No NG PJM-2), or do both (e.g., 100% Clean No NG PJM-2). The New Tech BAU-2 and 100% RPS-2 results

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[54] Current targets established as part of the Climate Solutions Now Act of 2022. See below discussion for additional information about Maryland's Climate Pollution Reduction Plan.

[55] RGGI is a regional carbon trading system comprised of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia.

match closely until the mid-2030s, at which point New Tech BAU-2 emissions decline due to the replacement of natural gas capacity with new CCS, advanced energy technologies, wind, and solar.

Emission reductions are not distributed uniformly by season or time of day. **Figure 57** shows, via heat map, how reductions in CO_2 emissions, most especially from 2020-2030, affect the PJM grid's hourly CO_2 emission content based on the 100% RPS-2 scenario. The emissions that persist through 2030 and 2040 are concentrated in the summer season during non-daytime hours, although at decreased levels as compared to 2020. These periods coincide with increased electricity demand as well as diminished renewable energy generation. Emissions also remain elevated during the coldest winter months, again as demand increases and renewable generation decreases. Total emission levels, however, are lower in 2030 and 2040 as compared to 2020 even during elevated emission hours. **Figure 57** is illustrative of the pattern applicable for all scenarios.

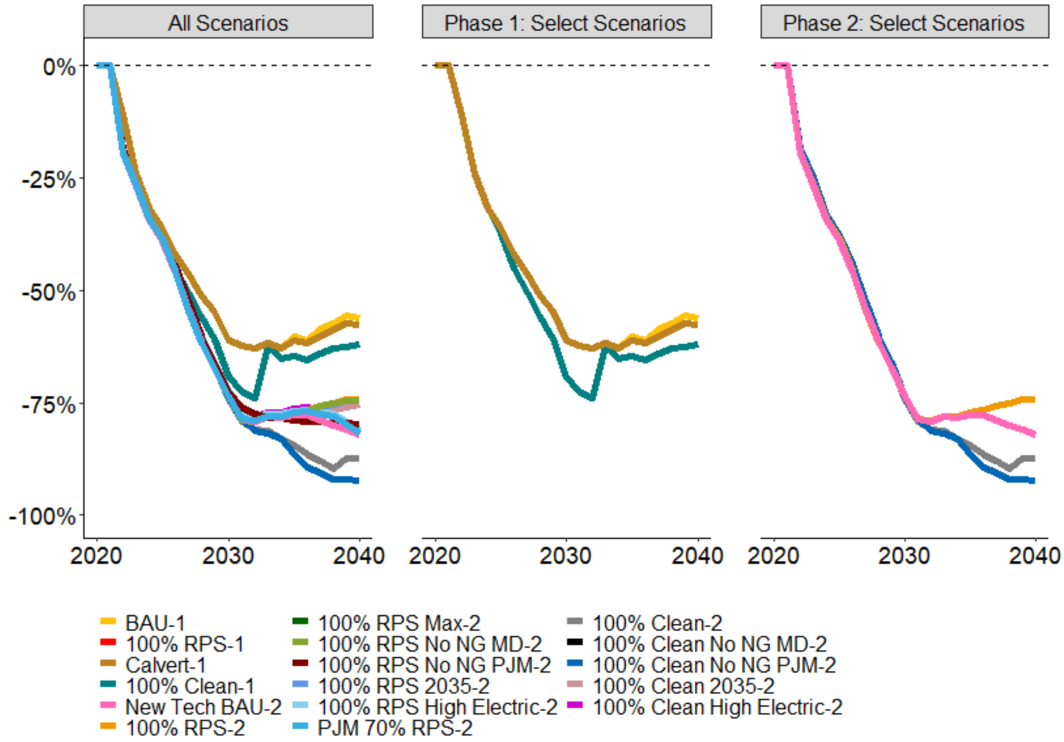

Figure 56. Percent Change in Annual PJM Carbon Dioxide Emissions Relative to 2020, by Scenario

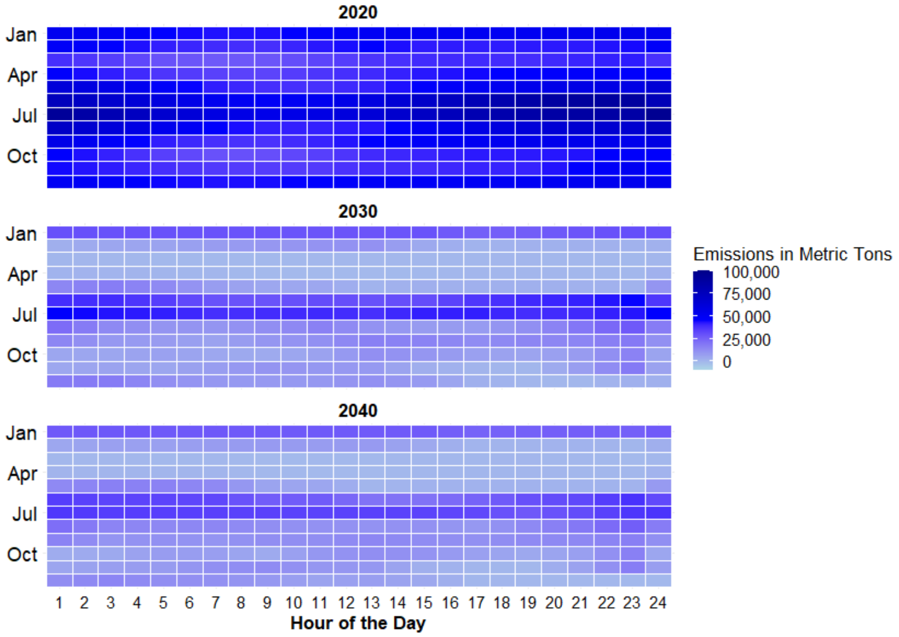

Figure 57. Heatmap of PJM Carbon Dioxide Emissions, 100% RPS-2 Scenario

4.2.2. Methane

CH_4 emissions are less abundant in the atmosphere than CO_2, but are far more potent as a contributor to global warming. **Figure 58** shows the wide, divergent range of annual PJM-wide CH_4 emission outcomes across all scenarios. Similar to the CO_2 results presented above, the presence or absence of fossil-fuel based generation drives which scenarios experience greater declines in CH_4 emissions. For CH_4 specifically, scenarios that explicitly limit natural gas capacity or encourage clean substitutes (e.g., 100% Clean-2, 100% RPS No NG PJM-2, and 100% Clean No NG PJM-2) observe the largest reductions. New Tech BAU-2 and 100% RPS-2 again diverge in the mid-2030s as a result of the differences in assumptions regarding CCS, BECCS, and advanced energy resources.

4.2.3. Nitrous Oxide

N_2O is another potent contributor to climate change, both due to its atmospheric warming effect and contributions to ozone layer depletion. **Figure 59** shows the relatively consistent array of annual PJM-wide N_2O emission outcomes across all scenarios. In most cases, emissions fall dramatically and then level off at or near zero (i.e., a 100% reduction from 2020 levels). The only scenarios where N_2O levels do not flatline at or near zero are the models where some fossil-fuel powered plants persist as a source of baseload, including the Phase 1 models, 100% RPS No NG-PJM-2, and 100% Clean No NG-PJM-2.

4.2.4. Maryland Greenhouse Gas Reduction and RGGI Targets

The 2022 CSNA, among other provisions, sets a target for Maryland to reduce its GHG emissions by 60% before 2031, and achieve net-zero GHG emissions by 2045. The MDE released its latest Climate Pollution Reduction Plan to meet the 2031 goal in December 2023.[56] This Plan, which is based on the Pathway Report by the Center for Global Sustainability at the University of Maryland and on Marylanders' input, shows steep reductions in power sector emissions throughout the 2020s. **Figure 60** shows Maryland emission totals for two indicative scenarios as they compare to the "Current Policies" and "Current plus Planned Policies" trajectories used by MDE.[57] Rapid reductions in GHG emissions in most scenarios allow Maryland to exceed its Climate Pollution Reduction Plan targets by the late 2020s and remain below them in subsequent years. Further, the model estimates negative emissions beginning in the early 2030s for scenarios that include CCS technologies (e.g., 100% Clean-2).

Similar emission reduction trajectories also apply to just CO_2 on its own, as is relevant to Maryland's ongoing participation in RGGI.[58] In the 2021-2023 control period, there were 13 power plants in Maryland with compliance obligations under RGGI. In 2023, the total allowance budget was 87.0 million metric tons (MMT) of CO_2, of which 15.8 MMT (18%) were budgeted to Maryland. VCE modeling shows Maryland meeting its RGGI obligations even when assuming continued reductions in the state's RGGI cap of 0.5 MMT per year through 2040.[59]

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[56] For additional information, see mde.maryland.gov/programs/air/ClimateChange/Pages/Maryland%27s-Climate-Pollution-Reduction-Plan.aspx.

[57] Note that differences in the starting point of the 100% RPS-2 and 100% Clean-2 scenarios reflect variation in underlying model setup assumptions.

[58] Maryland, as required by the state's Healthy Air Act (HAA) of 2006, joined RGGI in 2007. Under the RGGI program, total CO_2 emissions from fossil fuel-fired electricity generating units with nameplate capacities of 25 MW or greater are capped.

[59] If CO_2 emissions exceed the state's RGGI, Maryland generation facilities will be required to purchase RGGI emissions allowances from other RGGI states and/or purchase offsets. The evaluated reduction trajectory reflects feedback provided by stakeholders during the assessment process.

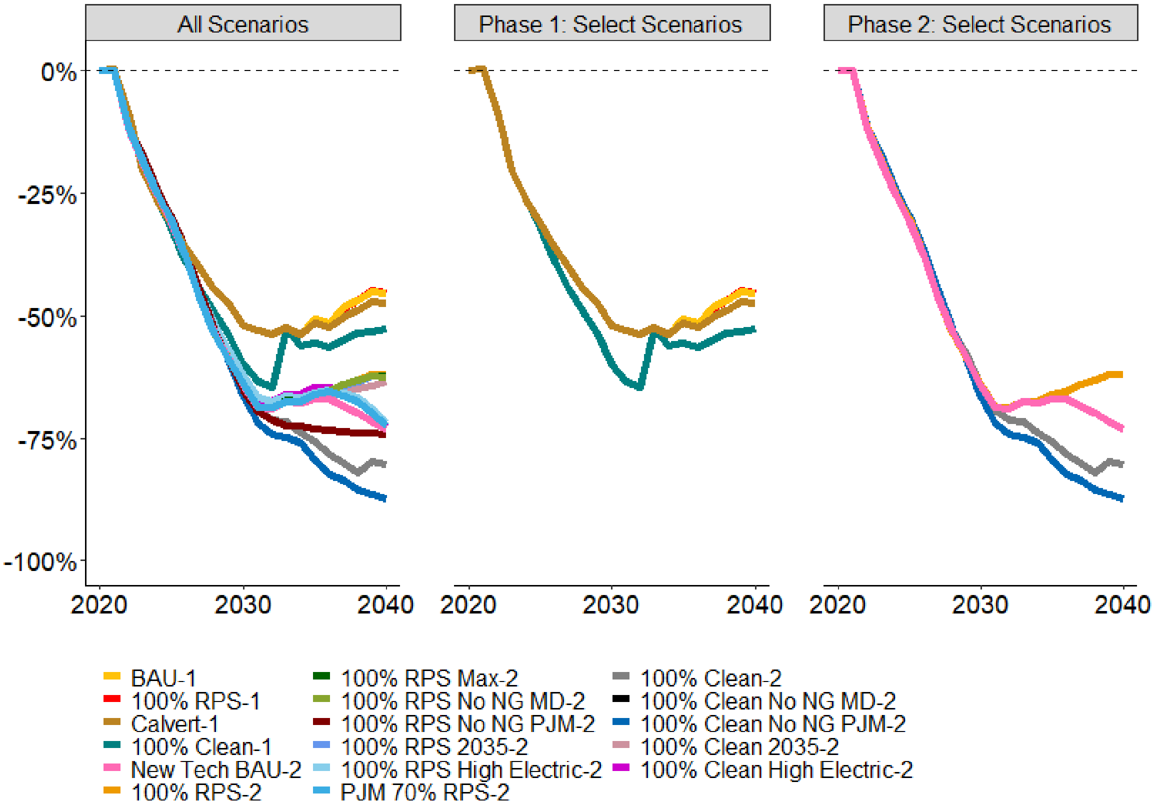

Figure 58. Percent Change in Annual PJM Methane Emissions Relative to 2020, by Scenario

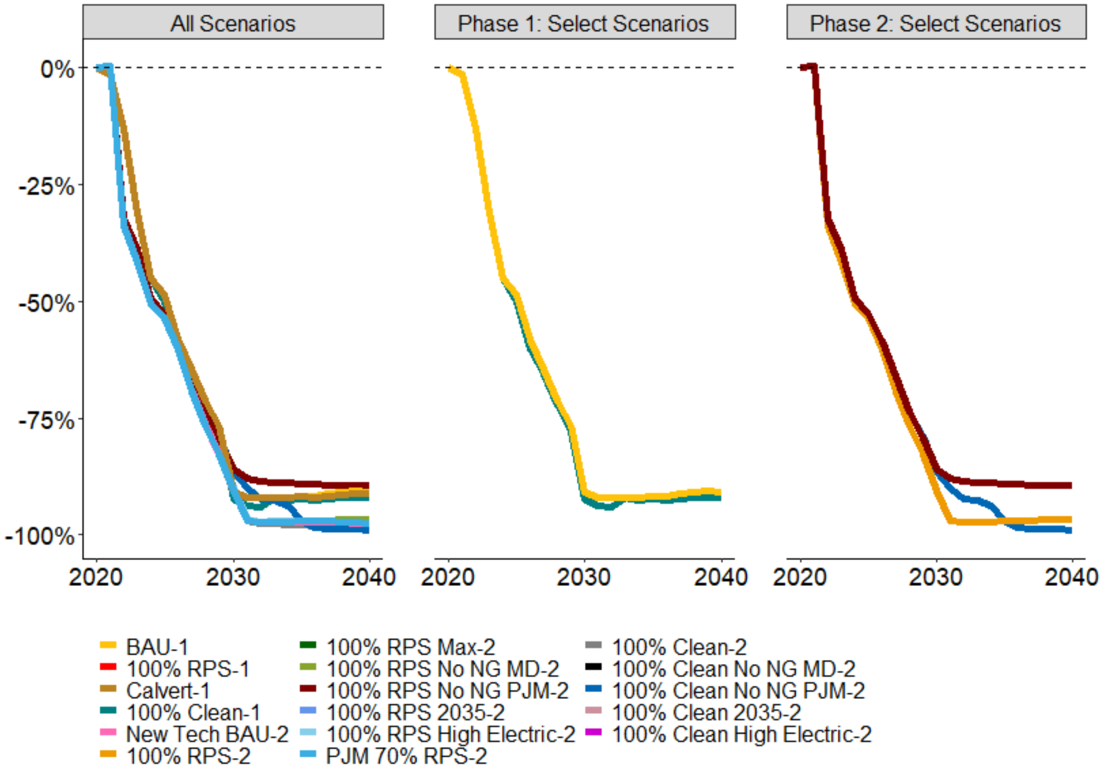

Figure 59. Percent Change in Annual PJM Nitrous Oxide Emissions Relative to 2020, by Scenario

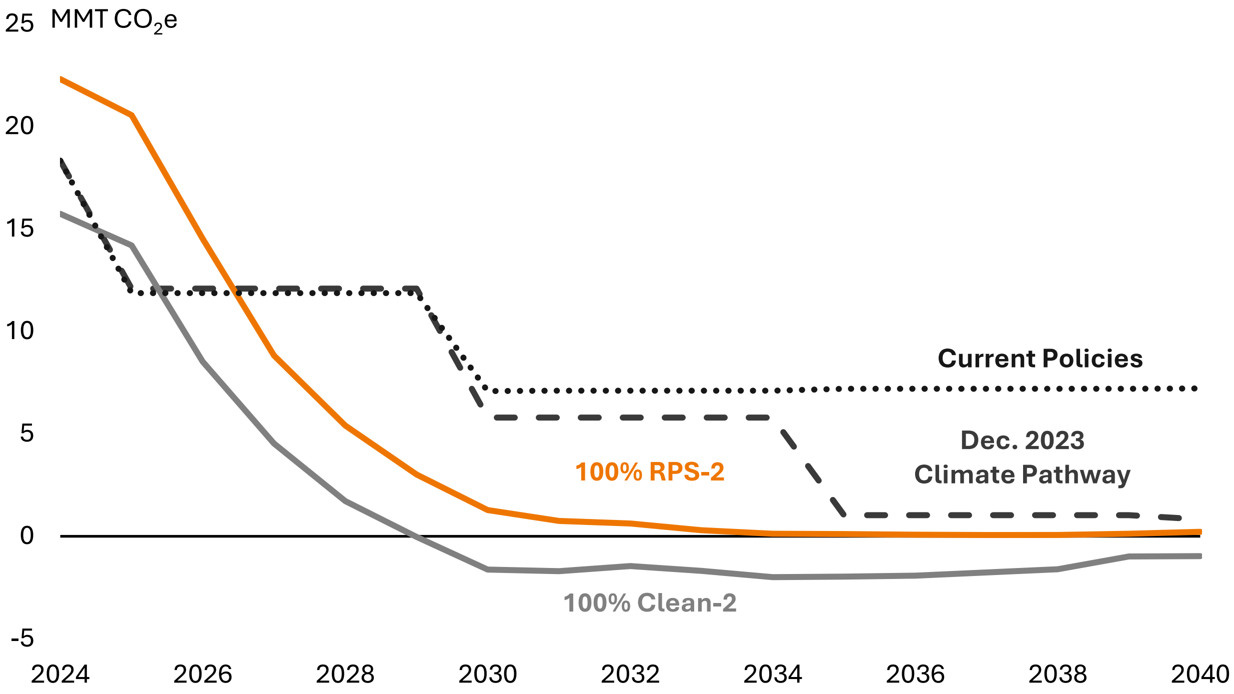

Figure 60. Modeled Maryland GHG Emissions Compared to Maryland's December 2023 Climate Pathway, 100% RPS-2 and 100% Clean-2 Scenarios

Note: The 100% RPS-2 and 100% Clean-2 scenario lines only reflect CO_2, CH_4, and N_2O emissions from the power sector. As defined by the University of Maryland Center for Global Sustainability, the "Current Policies" line in the above graph includes the modeled trajectory under existing Maryland (e.g., Advanced Clean Cars II, Advanced Clean Trucks, Building Energy Performance Standards, EmPOWER, Renewable Portfolio Standard) and federal (e.g., Inflation Reduction Act) policies. The December 2023 Climate Pathway reflects the trajectory of current policies plus new sectoral policies (e.g., Advanced Clean Fleets, a 100% clean power standard by 2035, Zero-Emission Heating Equipment Standard) and economywide policies (e.g., cap-and-invest program). Both the Current Policies and December 2023 Climate Pathway lines reflect only the power sector portion of statewide emissions.

4.3. Other Pollutants

Greenhouse gases are primarily tracked on a regional or global scale. By comparison, other power sector emissions, including sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), small particulate matter (PM), and volatile organic compounds (VOCs), are primarily recognized for their localized air, land, and water impacts.[60] Thus, the subsequent discussion and figures look at Maryland-specific emissions by pollutant. In Maryland, the Healthy Air Act (HAA) requires various controls intended to reduce these emissions as well as ensure that Maryland power generation complies with federal standards, such as National Ambient Air Quality Standards (NAAQS).[61] In response to HAA and other socioeconomic drivers, Maryland is well below its HAA limits for atmospheric deposition of various emissions and in compliance with federal requirements.[62]

4.3.1. Sulfur Dioxide

The largest source of SO_2 in the atmosphere is the burning of fossil fuels. When combined with water vapor, SO_2 forms sulfuric acid, leading to acid rain, which harms ecosystems and infrastructure, and contributes to fine particulate matter, worsening air quality and causing respiratory and cardiovascular issues. **Figure 61** shows that annual Maryland SO_2 emissions are virtually eliminated after 2030 across all scenarios. Emissions fall dramatically due to the elimination of coal and then level off at or near zero (i.e., a 100% reduction from 2020 levels).

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[60] Although some of these emissions are nominally GHGs, their direct impact on warming and climate change is more limited. They do, however, have well documented effects on environmental and health issues including asthma, heart disease, lung cancer, smog, acid rain, and more.

[61] Annotated Code of Maryland, Environment Title 2 Ambient Air Quality Control Subtitle 10 Health Air Act Sections 2-1001 - 2-1005.

[62] The Maryland Healthy Air Act, Accessed May 2023. mde.maryland.gov/programs/air/pages/md_haa.aspx.

4.3.2. Nitrogen Oxides

NOx is primarily produced from the combustion of fossil fuels at high temperatures. NOx reacts with VOCs to form ground-level ozone, a key component of smog, as well as contributes to acid rain and the creation of fine PM. All of these effects harm air quality, vegetation, and pose health risks. As shown in **Figure 62**, in the Phase 1 models, annual Maryland NOx levels decrease, rebound, and eventually surpass 2020 levels by the end of the period. This rebound reflects the replacement of retired in-state natural gas generators in the second half of the model period. The 100% Clean-1 scenario, specifically, also exhibits an additional NOx spike and reduction in the 2030s that coincides with the addition and retirement of high levels of CCS in Maryland.[63] The retired CCS plants are replaced by new natural gas generation, causing a "W" shape to NOx emissions.

In all other scenarios, emissions significantly decrease from 2020-2030 and approach 100% reduction of NOx emissions by 2040. This difference from the Phase 1 models reflects the assumption that CSNA targets are met for all Phase 2 scenarios, leading to natural gas capacity being replaced by renewables and other alternatives. In the revised scenarios, the only instance where NOx levels fail to reach near zero by 2040 is in the 100% RPS No NG PJM-2 scenario. This is because, without new natural gas capacity allowed in this model, some natural gas plants remain in operation in Maryland for longer to support certain PJM balancing needs.

4.3.3. Particulate Matter

Particulate matter is a catch-all term for the tiny particles of solid or liquid matter that can be emitted during the combustion of fossil fuels. PM can include a variety of substances, including metals, soot, and dust. PM is usually classified and measured using the quantity of particles with a diameter of 2.5 micrometers or smaller ($PM_{2.5}$) and 10 micrometers or smaller (PM_{10}). As shown in **Figure 63**, annual Maryland PM is almost eliminated after 2030 in the revised models for reasons like those applicable to the reductions observed for SO_2. Note that the percent change in PM_{10} emissions is not separately visualized since the graph is virtually identical to that for $PM_{2.5}$.

4.3.4. Carbon Monoxide

CO is a byproduct of the incomplete combustion of fossil fuels and has adverse public health effects. Annual Maryland CO emissions decrease but then return to just below 2020 levels in the Phase 1 models for reasons similar to those discussed above for NOx. In the revised models, CO levels fall dramatically by almost 100%. These changes are visualized in **Figure 64**.

4.3.5. Volatile Organic Compounds

VOCs include a variety of chemicals that easily vaporize, affecting air, water, and ground conditions. They contribute to the formation of ground-level ozone and smog when they react with other emissions and have adverse health effects. Annual Maryland VOC emissions decline but then rebound to around 40% of 2020 levels in the Phase 1 models for reasons similar to those discussed above for NOx. In the revised models, VOC levels experience a dramatic drop to near zero. These changes are visualized in **Figure 65**.

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[63] Despite CCS, the model still estimates NOx emissions because of leakage during the natural gas transportation and storage processes.

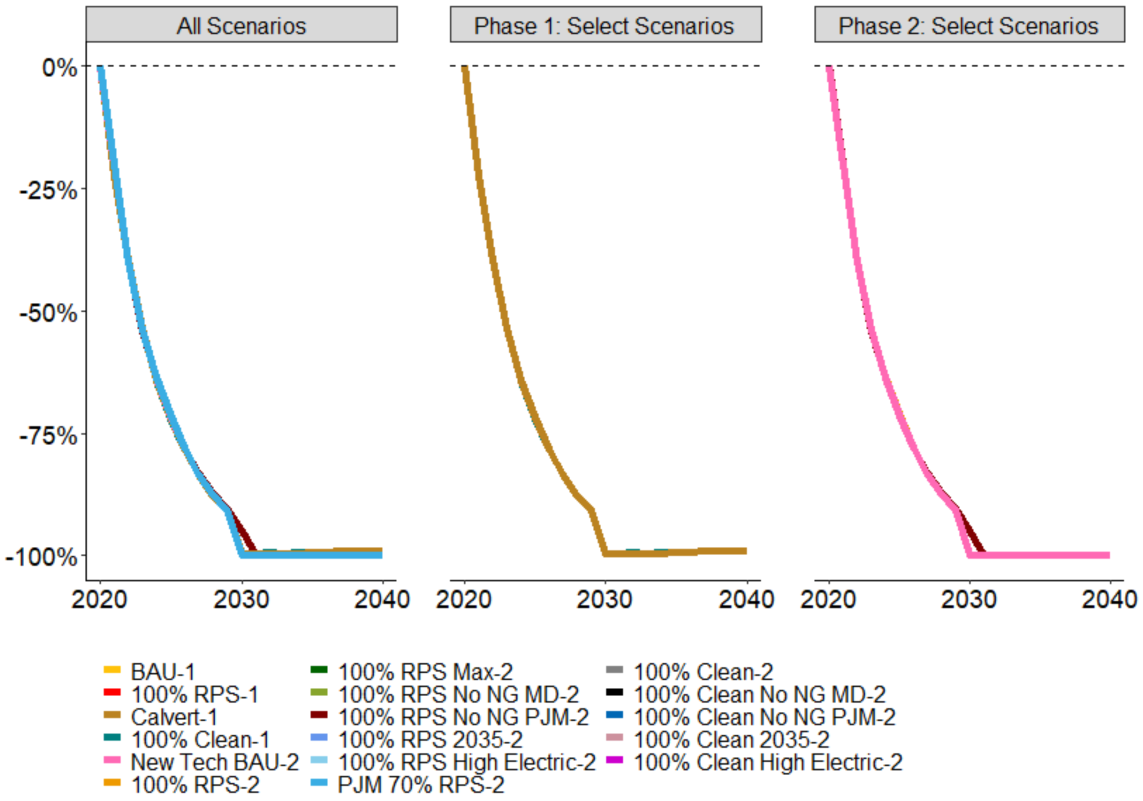

Figure 61. Percent Change in Annual Maryland Sulfur Dioxide Emissions Relative to 2020, by Scenario

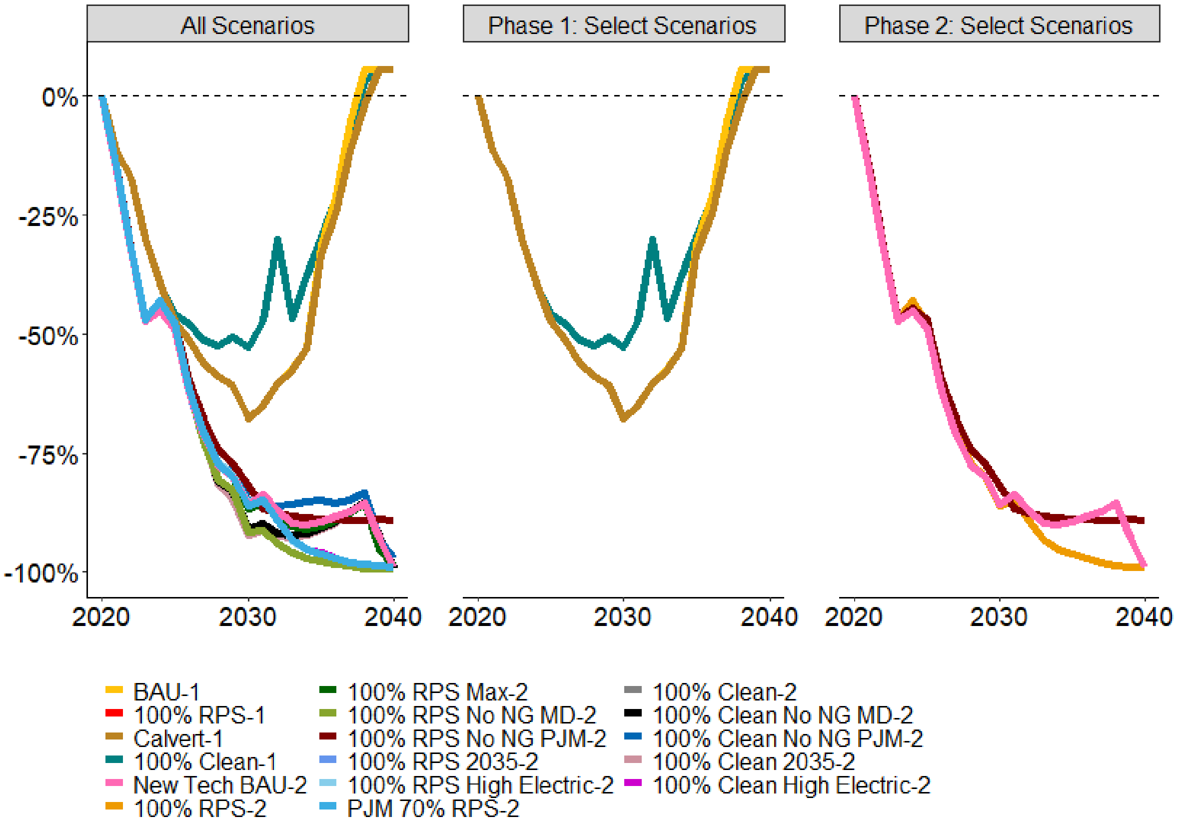

Figure 62. Percent Change in Annual Maryland Nitrogen Oxides Emissions Relative to 2020, by Scenario

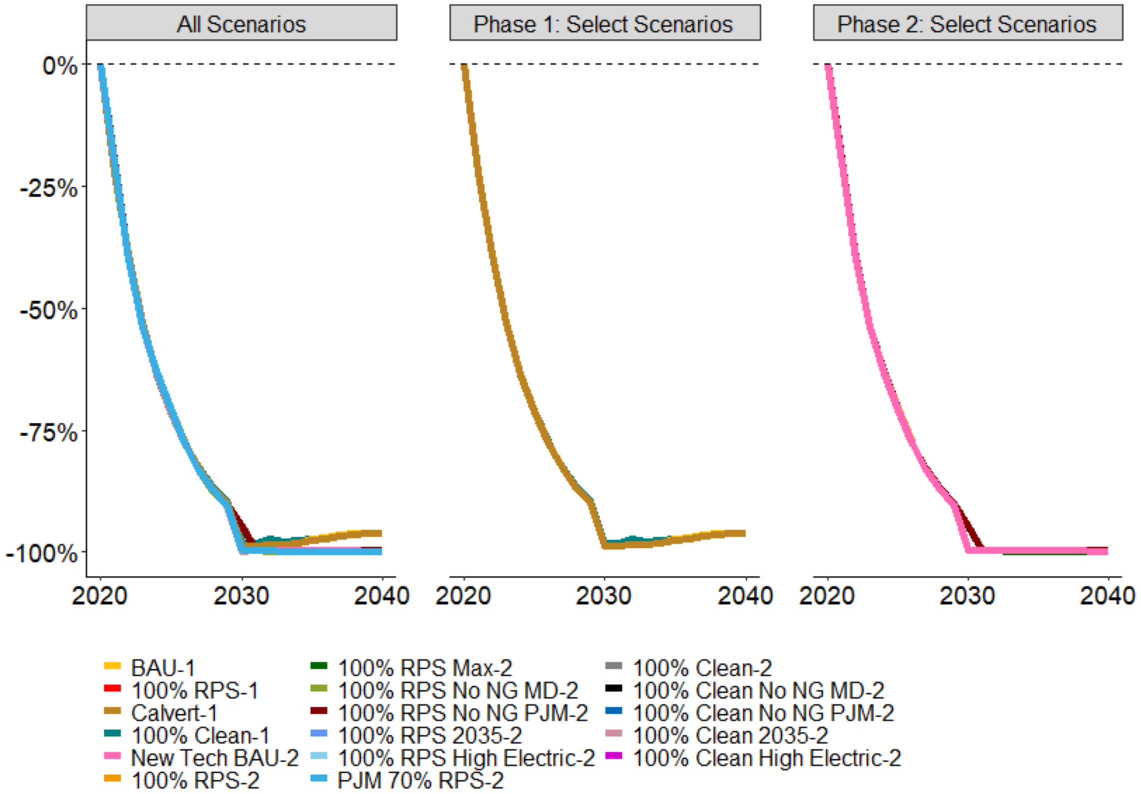

Figure 63. Percent Change in Annual Maryland Particulate Matter Less Than 2.5 μm Emissions Relative to 2020, by Scenario

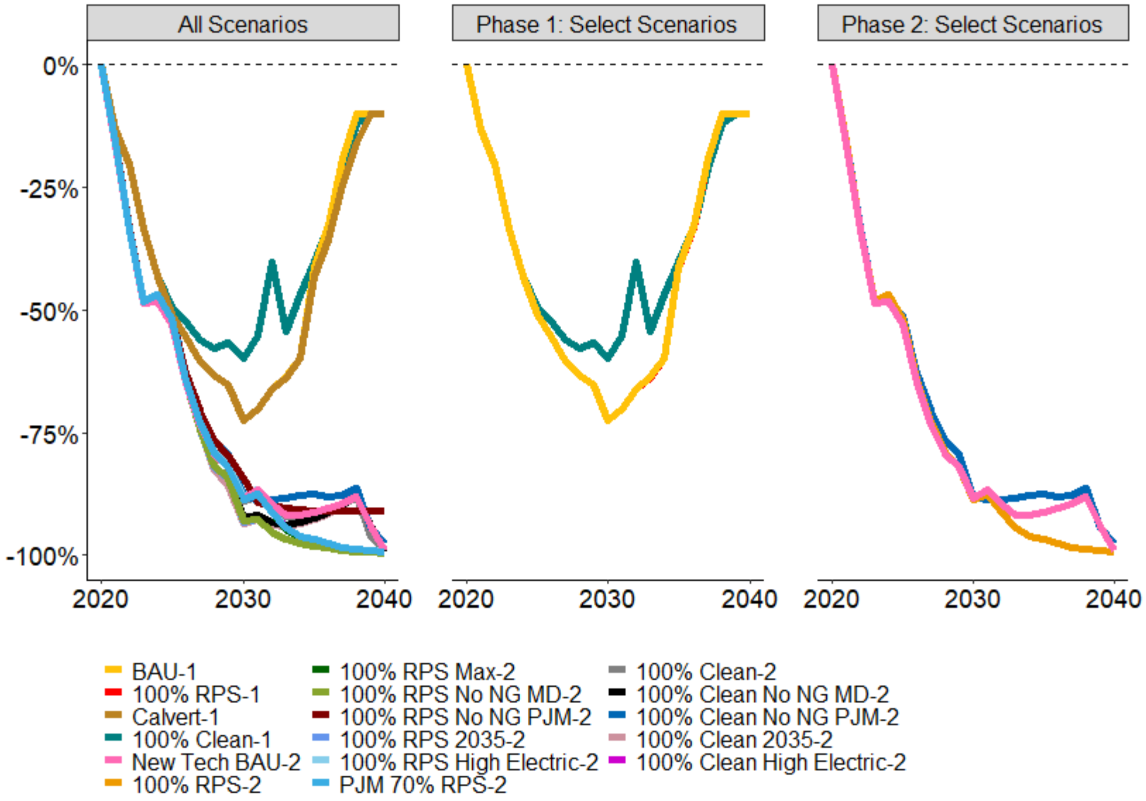

Figure 64. Percent Change in Annual Maryland Carbon Monoxide Emissions Relative to 2020, by Scenario

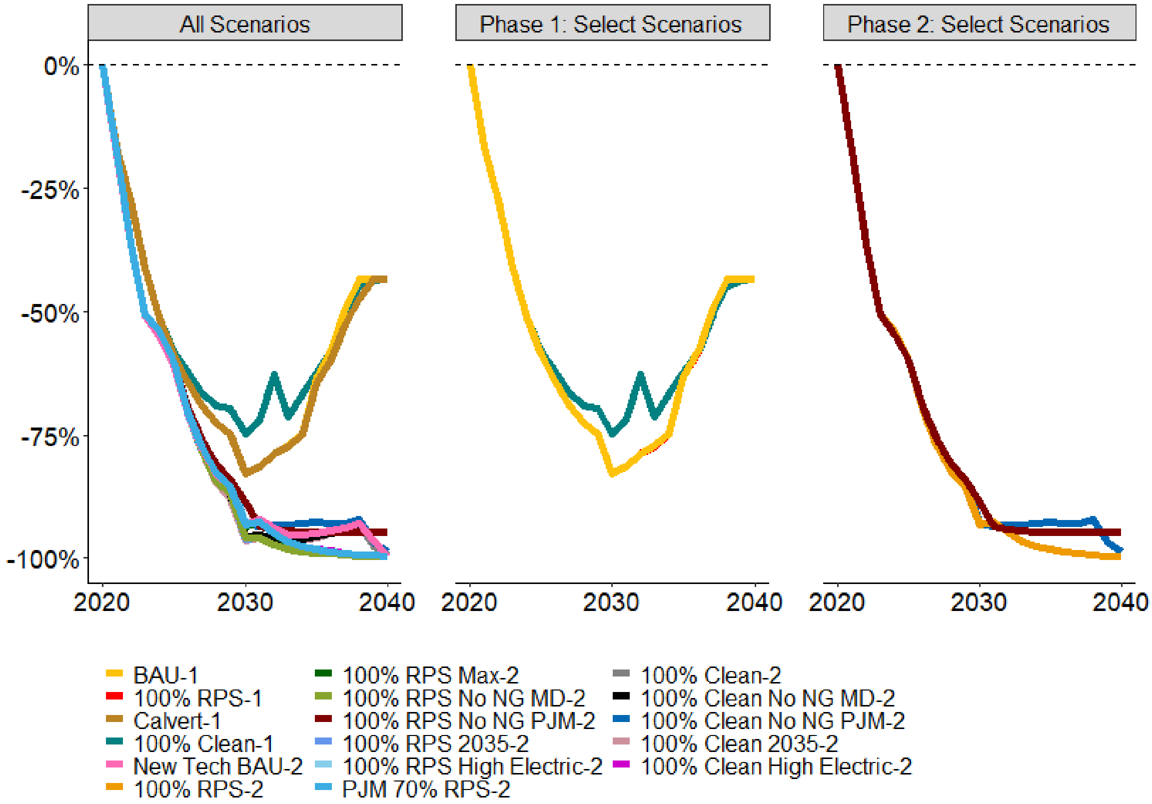

Figure 65. Percent Change in Annual Maryland Volatile Organic Compounds Emissions Relative to 2020, by Scenario

4.4. Key Findings

- Current policies, both federal and state, such as the U.S. Environmental Protection Agency's (EPA's) Acid Rain Program, the Mercury and Air Toxics Standard (MATS), and the Maryland HAA, are already helping to reduce emissions in Maryland under BAU conditions. However, under some circumstances, as discussed above, emissions begin to rise after 2030.
- Adopting a 100% requirement, in combination with mechanisms to keep existing nuclear plants in operation and mandatory GHG reduction requirements, can drive emissions of many pollutants to zero, or near zero, and prevent the rebounding of emissions after 2030.
- In-state generation used for complying with the Maryland RPS, serving Maryland load, and exporting to PJM does not experience proportional emission reductions as compared to the PJM grid mix as a whole. This is because many fossil fuel sources in Maryland, especially coal, have already retired. Additionally, state policies like an RPS and CES, by accepting RECs or CERCs from elsewhere in PJM, promote the development of renewable or clean resources in all PJM states.
- Certain emissions (e.g., methane) begin to increase in the 2030s in some scenarios as a result of some new natural gas being brought online. This is especially true in the Phase 1 scenarios as natural gas combustion cycle turbines replace traditional nuclear generation located throughout PJM in the outyears of the model.
- Treating Maryland's CSNA requirements as a mandate, rather than a goal, causes the model to shift some natural gas power plants to other states. This leads to significant reductions in local pollutants in Maryland. PJM-wide emissions also decrease as a result of the CSNA provisions as the model substitutes some natural gas for renewable energy.
- Policies that keep existing nuclear power plants (e.g., Calvert Cliffs) online longer delay the rebound effect in emissions after 2030 observed in some scenarios. Likewise, policies that support CCS and advanced energy technologies increase the likelihood of its uptake and enable corresponding emission benefits from these resources replacing natural gas capacity.
- The characteristics that make Maryland attractive for natural gas additions in the Phase 1 scenarios

(see Chapter 2) potentially result in a Maryland-grid mix that has higher emissions along several categories, most especially methane. This is suggestive of a potential need for non-emitting generation capacity (e.g., advanced nuclear, storage) to replace the functions served by natural gas additions, including flexible dispatch.

- There is some evidence that the Maryland RPS is driving down emissions throughout PJM by encouraging additional REC-eligible renewable resources elsewhere. Marylanders accrue some benefit from these resources through reductions in GHGs and other cross-state pollutants.
- Removing the option for new natural gas in Maryland has minimal GHG emissions impact regionally insofar as prospective natural gas plants in Maryland shift to other states. More aggressive limitations on natural gas additions in PJM, however, have an unintended consequence of causing existing coal and less efficient natural gas plants to delay retirement. As a consequence, through the 2030s, emissions are slightly higher for CH_4, CO_2, NOx, SO_2, and other pollutants in the models that restrict new natural gas additions in PJM.

4.5. Cost-Benefit

The emission benefits of renewable or clean energy supported by an RPS and CES stem from a combination of factors. First, many renewable and clean energy resources have a lower emission profile than fossil fuel-powered thermal energy generation, such as natural gas and coal-powered generators. Second, renewable energy generators, especially wind and solar, often have low operating costs and are dispatched over existing fossil-fuel powered thermal energy generation. That is, once renewable energy projects are developed, they reduce the share of hours during which conventional thermal energy generators produce power. Third, a combination of public policy support and increasing cost competitiveness creates conditions that incentivize the addition of renewable or clean capacity in place of new or existing fossil fuel capacity.

At the same time, some characteristics of either the existing or a prospective Maryland RPS or CES may be interpreted as limiting its emission reduction potential. For example, MSW, biomass, black liquor, and landfill gas (LFG) are all eligible for Tier 1 of the RPS and emit GHGs or other air pollutants. Thus, variation in emissions output between the modeled scenarios illustrates how different energy policies or assumptions regarding energy systems can influence health and environmental outcomes. These impacts are conditioned by which resources the model builds and dispatches over time.

For purposes of cost-benefit analysis, Exeter converted the annual emissions from each of the above scenarios into dollar costs. This conversion begins with estimates of the social cost of various emissions. Each social cost represents the monetary value of the net harm to society incurred from emitting a unit of pollution in a given year. Although just a single value, social cost is intended to capture the monetized future health, agriculture, productivity, property damage, and other related impacts of emissions, all discounted back to a particular emission year. The estimated social cost varies by pollutant due to differences in each pollutant's damage function over time.

Exeter referenced EPA's December 2023 Final Rulemaking, titled "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," for estimates of the Social Cost of Greenhouse Gas (SC-GHG) emissions.[64] These SC-GHG estimates specifically account for future climate change impacts including changes in agricultural productivity, human health effects, property damage from increased flood risks, natural disasters, disruption of energy systems, risk of conflict, environmental migration, and ecosystem services. However, due to data and modeling limitations, the SC-GHG estimates cannot include all impacts of climate change and implicitly assigns a value of zero to omitted damages. Thus, these values should be understood as underestimating the marginal benefits of abatement or marginal costs of pollution.

For purposes of estimating the social cost of local pollutants (SO_2, NOx and $PM_{2.5}$), Exeter utilized the benefit per ton (BPT) estimates from EPA's "Technical Support Document: Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5}$, $PM_{2.5}$ Precursors, and Ozone Precursors from 21 Sectors" for electricity generating units in 2025.[65] These BPT values account for the economic benefits derived from reducing adverse health impacts such as premature mortality, hospital admissions, and other morbidity effects. The benefits from SO_2 and NOx emissions reductions specifically address health improvements and ozone formation due to reductions in sulfate $PM_{2.5}$ and nitrate $PM_{2.5}$, but do not encompass the full social cost of each pollutant, which would also include environmental and

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[64] U.S. Environmental Protection Agency, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," December 2023. Additional information regarding the methodology underlying the SC-GHG estimates is detailed in the technical report, "Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances," EPA SC-GHG. The specific SC-GHG estimates used by Exeter reflect the social cost of carbon, methane, and nitrous oxide from 2025-2040 based on a 2.5% near-term Ramsey discount. These estimates were subsequently adjusted following the same constant discounting approach used in other chapters.

[65] Given the relatively short time horizon being examined, Exeter assumed constant discounting based on near-term target rates.

ecological damages such as acid rain, visibility degradation, and damage to vegetation and ecosystems. Similar to the SC-GHG estimates, these costs likely underestimate abatement and pollution benefits and costs, respectively.

The social costs of emissions over multiple emission years can be combined for purposes of comparison. The differences in total present value across scenarios represent the benefit (or cost) of policy action. **Table 11** and **Figure 66** through **Figure 69** represent the aggregate emissions by scenario and emission type alongside a calculated dollar impact and a comparison of select scenarios. Given differences in boundary assumptions, Phase 1 and Phase 2 GHG results are not directly comparable. The below estimates are sensitive to the assumptions and discount rates applied both to calculate the social cost and to put aggregate social costs into present value terms.

Notably, scenarios featuring a 100% CES policy in Maryland (or other Maryland policies that support CCS, BECCS, and other advanced energy technologies) generally exhibit substantially lower aggregate emission costs. This benefit primarily accrues at a PJM-level as a result of reductions in CO_2 emissions at assumed SC-GHG values. This is despite the 100% CES scenarios having higher local emission impacts in Maryland due to higher aggregate NOx levels. Additionally, scenarios with limitations on new natural gas capacity generally have lower aggregate emission cost impacts.

Table 11. Cumulative Emissions and Discounted Emissions Cost Impact, by Scenario

	Cumulative Emissions of GHGs in PJM from 2025-2040 (MMT)			Cumulative Emissions of Local Pollutants in Maryland from 2025-2040 (MMT)			Discounted GHG Impact from 2025-2040 (PJM) (billions, 2023$)	Discounted Local Pollutant Impact from 2025-2040 (MD) (billions, 2023$)	Comparison to BAU-1 (billions, 2023$)	Comparison to 100% RPS-2 (billions, 2023$)
Scenario	CO_2	CH_4	N_2O	SO_2	NOx	$PM_{2.5}$				
BAU-1	3,879.593	0.310	0.098	0.049	0.160	0.019	$341.98	$15.19	$0	
100% RPS-1	3,879.432	0.310	0.098	0.049	0.160	0.019	$341.96	$15.18	($0.03)	
Calvert-1	3,852.328	0.307	0.097	0.049	0.158	0.019	$338.37	$14.91	($3.89)	
100% Clean-1	3,591.675	0.288	0.095	0.050	0.173	0.019	$301.56	$16.79	($38.81)	
New Tech BAU-2	6,189.745	0.440	0.274	0.051	0.062	0.019	$470.55	$4.55		($22.27)
100% RPS-2	6,369.146	0.455	0.276	0.051	0.057	0.019	$493.46	$3.90		$0
100% RPS Max-2	6,364.906	0.455	0.276	0.051	0.061	0.019	$492.81	$4.43		($0.13)
100% RPS No NG MD-2	6,362.072	0.455	0.276	0.051	0.053	0.019	$492.42	$3.48		($1.47)
100% RPS No NG PJM-2	6,311.498	0.427	0.325	0.052	0.064	0.019	$485.75	$4.96		($6.65)
100% RPS 2035-2	6,359.044	0.454	0.276	0.051	0.053	0.019	$492.01	$3.47		($1.89)
100% RPS High Electric-2	6,334.095	0.452	0.278	0.051	0.056	0.019	$490.04	$3.92		($3.41)
PJM 70% RPS-2	6,244.134	0.445	0.275	0.051	0.057	0.019	$477.08	$3.90		($16.39)
100% Clean-2	5,811.193	0.412	0.272	0.051	0.061	0.019	$418.95	$4.44		($73.97)
100% Clean No NG MD-2	5,740.149	0.396	0.291	0.051	0.059	0.019	$407.82	$4.20		($85.35)
100% Clean No NG PJM-2	5,740.149	0.396	0.291	0.051	0.065	0.019	$407.82	$4.96		($84.58)
100% Clean 2035-2	6,337.833	0.453	0.276	0.051	0.058	0.019	$489.49	$4.11		($3.77)
100% Clean High Electric-2	6,315.517	0.450	0.277	0.051	0.057	0.019	$487.43	$3.92		($6.02)

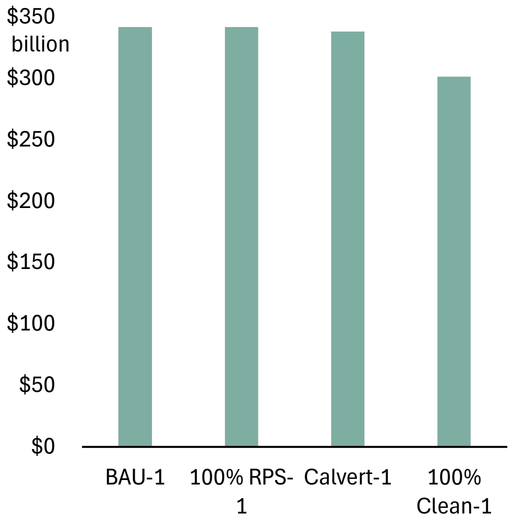

Figure 66. Discounted PJM-wide GHG Impact from 2025-2040, Phase 1 Scenarios

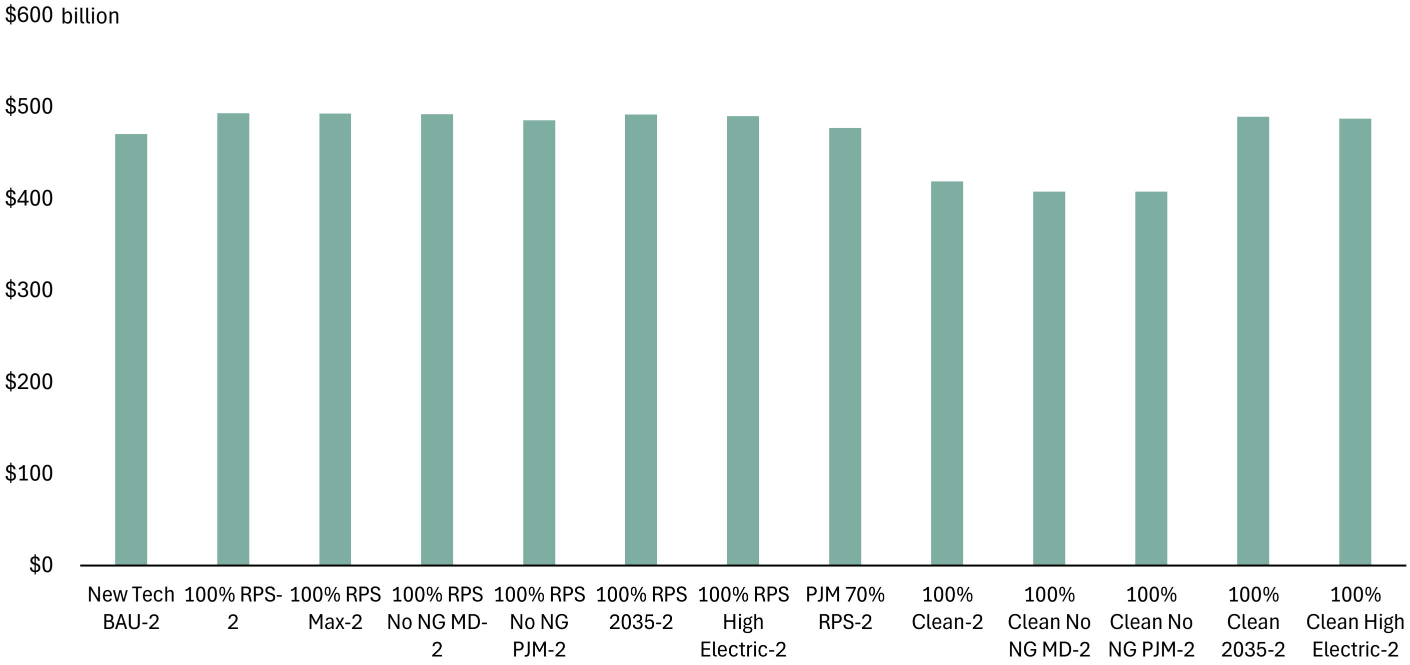

Figure 67. Discounted PJM-wide GHG Impact from 2025-2040, Phase 2 Scenarios

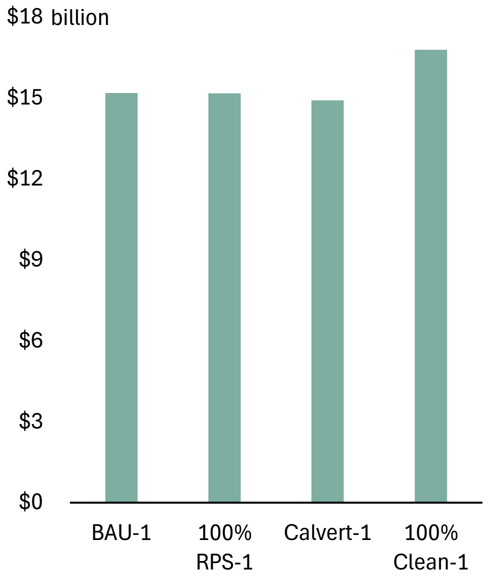

Figure 68. Discounted Maryland Local Pollutant Impact from 2025-2040, Phase 1 Scenarios

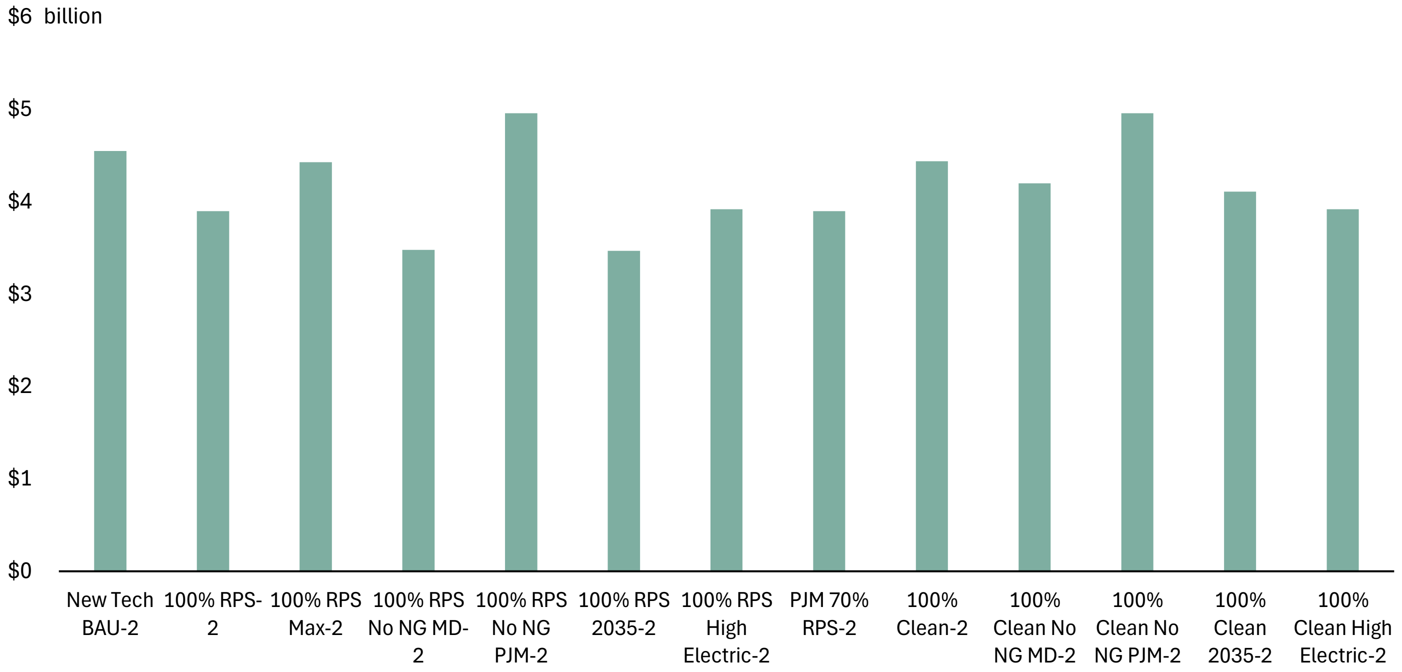

Figure 69. Discounted Maryland Local Pollutant Impact from 2025-2040, Phase 2 Scenarios

5. JOBS

This section of the report reviews the role of a 100% Maryland RPS or CES in creating direct and indirect jobs in Maryland. Although Maryland has relatively fewer energy sector jobs as compared to other PJM states, clean energy jobs make up a significant and growing share of the state's energy employment. In 2022, Maryland had an estimated 15,187 direct jobs in the electric power generation sector, an increase of 712 jobs (4.9%) from 2021. Solar generation encompassed 6,865 (45%) of these direct jobs. Maryland's transmission, distribution, and storage sector represented an additional 14,854 direct jobs.[66] As observed in the 2019 RPS Report, states with higher RPS requirements, such as Maryland, New Jersey, and the District of Columbia, tend to have a greater share of renewable energy jobs as a portion of total energy employment.

RPS or CES policies can impact employment and associated economic output by spurring activities like the construction of new renewable energy capacity or upgrades to T&D systems. Jobs associated with these activities are also complemented by broader, economy-wide economic activity that is spurred by the initial investment. The subsequent discussion reviews job and economic output estimates derived from VCE's WIS:dom-P model and separate, more detailed modeling conducted by Exeter.

5.1. Results: VCE

VCE's job estimates include both direct and indirect (but not induced) jobs as measured in terms of full-time equivalents (FTEs).[67,68] These estimates are constrained in several ways. First, VCE's job estimates are only available in an aggregate form. Second, VCE's estimated employment impacts rely on parameters last updated in 2022. Third, VCE does not separately output economic investment estimates. For these reasons, Exeter also developed more detailed and updated IMPLAN estimates (see below). Exeter's IMPLAN models, however, do not exhaustively examine all technologies and scenarios included in this study. Therefore, VCE's job estimates remain useful as a preliminary indication of both the direction and magnitude of Maryland job impacts of 100% RPS and CES policies. **Figure 70** visualizes Maryland jobs by resource for all scenarios. Note that VCE estimates differ from the above DOE census totals insofar as they incorporate indirect jobs and are future-oriented.

Transmission jobs, which include both interconnection and network transmission work, are the single largest employment category in all modeled scenarios. The second largest job category is solar, especially in scenarios that assume an RPS policy (versus a CES policy). Whether DPV or UPV jobs predominate depends on the model; more UPV jobs appear in the high electrification and no-natural gas models, while more DPV jobs appear in most other scenarios.

Other major categories in terms of associated Maryland employment include wind (onshore and offshore), distribution, and storage (utility-scale and distributed), with the size of each depending on the scenario. In general, the Phase 2 models incorporate assumptions (e.g., 3 GW of energy storage and 8.5 GW of OSW based on the POWER Act of 2023) that result in higher job estimates in the affected categories. Increases in distribution jobs correspond with an increase in DPV capacity.

Despite comprising a large portion of Maryland capacity in many scenarios, natural gas jobs remain relatively low. Likewise, traditional nuclear jobs remain flat except in scenarios that allow Calvert Cliffs to retire, in which case nuclear jobs fall to zero. Employment associated with "baseload" generation (nuclear, coal, natural gas, and hydro) comprises less than 5% of total energy sector jobs in all scenarios in all years. VCE's estimates do not separately reflect employment impacts from CCS or advanced technologies.

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[66] Estimates sourced from DOE's 2023 United States Energy and Employment Report: energy.gov/sites/default/files/2023-06/2023%20USEER%20States%20Complete.pdf.

[67] Jobs are estimated using per-MW multipliers. The multipliers were derived by VCE using multiple sources, including IMPLAN, JEDI, and US Jobs Reports, to ensure robust estimates.

[68] See below for additional definition of direct, indirect, and induced jobs in the context of IMPLAN. FTE employment is the number of full-time equivalent jobs, defined as total hours worked divided by average annual hours worked in full-time jobs. This metric allows integration of full-time and part-time jobs across industries.

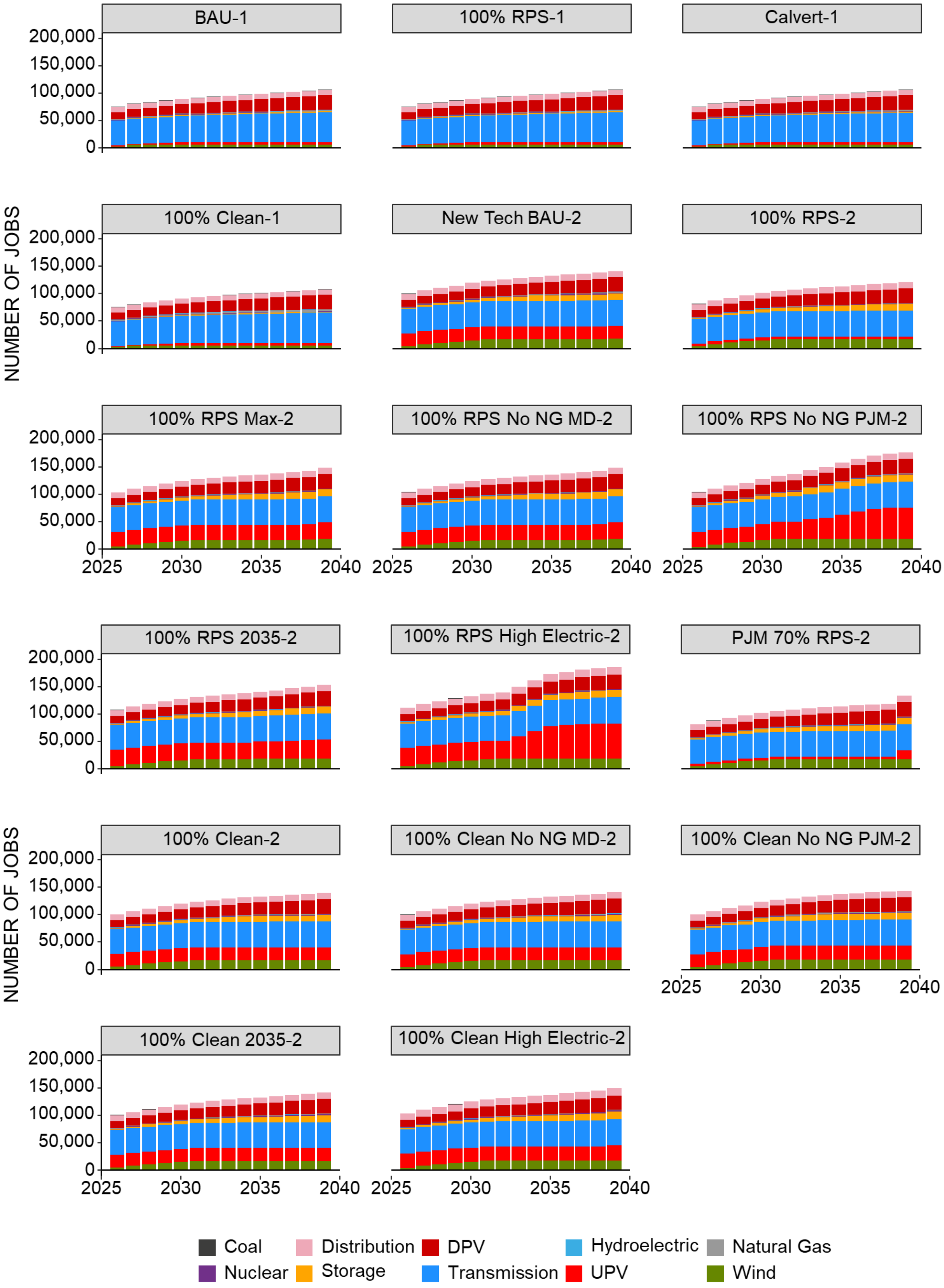

Figure 70. Maryland Jobs, by Scenario and Technology

5.2. Results: IMPLAN

In addition to the above model outputs, this study uses the input-out model known as IMPLAN (IMpact analysis for PLANning) to estimate regional job creation and spending associated with the Maryland RPS from 2025-2040. In IMPLAN, an initial change in spending is referred to as a change in "final demand." It is considered a direct effect, which then creates indirect and induced effects.[69] Indirect effects stem from local industries' purchases of inputs (i.e., goods and services) from other local industries. Induced effects reflect the spending of wages from residents involved in providing the goods and services being modeled.

IMPLAN has important limitations. IMPLAN multipliers, upon which these results depend, reflect industry linkages in a local economy at a given time; the multipliers do not account for price elasticities. IMPLAN also does not estimate economy-wide net impacts or leakages (i.e., impacts arising from or to out-of-state industries). For example, increases in jobs and spending for renewable energy projects may be offset by contractions in other parts of a regional or national economy, such as fossil fuel power production. Therefore, the results discussed in this chapter are strictly related to Maryland industries. Additionally, IMPLAN does not reflect job reductions as a result of increased electricity prices. Some of these topics are separately addressed in Chapter 6 alongside a broader discussion of comparable transition considerations.

5.2.1. Modeling Process Overview

Exeter's IMPLAN modeling process builds upon the original bill-of-goods approach developed for the 2019 RPS Report to incorporate additional renewable energy technologies and the model scenarios of this project. The OCC and O&M costs for this study were sourced from NREL's ATB (2023 edition) and applied to annualized capacity additions by year from VCE's models. These annual costs were then apportioned into various industries as changes to final demand using resources such as NREL's technology-specific benchmark reports and the NREL JEDI model.

Lastly, Exeter derived a Maryland-based proportion of final demand for each industry from various resources including NREL, EIA, and IMPLAN data.[70] This in-state final demand was modeled in IMPLAN as Industry Output events resulting in estimated economic impacts per technology and scenario. **Figure 71** shows these steps sequentially as they were used to derive the economic impact estimates below. See Appendix E for additional description of IMPLAN and the modeling process undergirding Exeter's analysis.

Exeter's IMPLAN analysis examined several technologies for select, indicative scenarios during the years 2025-2040. The technologies included in this analysis were DPV, UPV, onshore wind, OSW, utility-scale energy storage (UES), distributed energy storage (DES), and GSHP. Final demand inputs were derived for each technology and scenario from the forecasted incremental installed capacity for the construction phase as well as the forecasted cumulative installed capacity representative of the O&M phase. For modeling purposes, projects were assumed to become commercially operational in the year in which they are forecasted to be installed. O&M expenditures were assumed to apply to the entire fleet of installed capacity, including the capacity coming online, for each year.[71]

Since the final demand inputs are reliant upon forecasted capacities, scenarios with higher forecasted capacities generally result in higher employment and output values, whereas the opposite is true for scenarios with lower forecasted capacities.[72] Average employment and output values reflect a similar relationship as moderated by the year of capacity addition. Scenarios with backloaded capacity additions (e.g., more additions after 2035) have a lower average, all else equal, than the nominal amount of capacity might suggest on its own. Lower employment due to backloading is consistent with higher levels of uncertainty about model results in later periods.

Note that the absence of model estimates for certain technologies, such as CCS or advanced energy technologies, may artificially suppress aggregate job estimates for the Clean scenarios.

Figure 72 illustrates these relationships using onshore wind as an example. The Phase 2 models result in significantly more in-state onshore wind capacity and, as a result, higher FTE estimates. This capacity is more backloaded in scenarios like 100% RPS-2; however, resulting in fewer average FTEs than scenarios like 100% RPS Max-2 despite higher aggregate capacity between 2025-2040.

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[69] Final demand is the demand for goods that is not used to produce other goods.

[70] Note that Exeter based the final demand for offshore wind technology on prior in-state manufacturing commitments (also used in the 2019 RPS Report) weighted by the amount of capacity for known projects. This may result in a conservative estimation of job and sales impacts to the extent that the Phase 2 (or prospective Phase 3) projects include additional in-state employment, investment, or related economic commitments.

[71] In reality, utility-scale projects—especially offshore wind, which does not have any viable manufacturing industries or supply chains in Maryland—can take multiple years to reach commercial operations.

[72] Scenarios with very similar capacity results (e.g., BAU-1 and 100% RPS-1) are not separately assessed due to the absence of notable differences in terms of job and output.

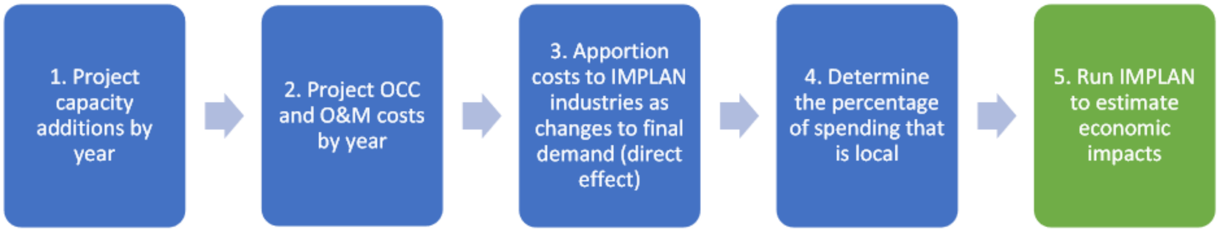


Figure 71. Basic Steps to Developing IMPLAN Spending Projections

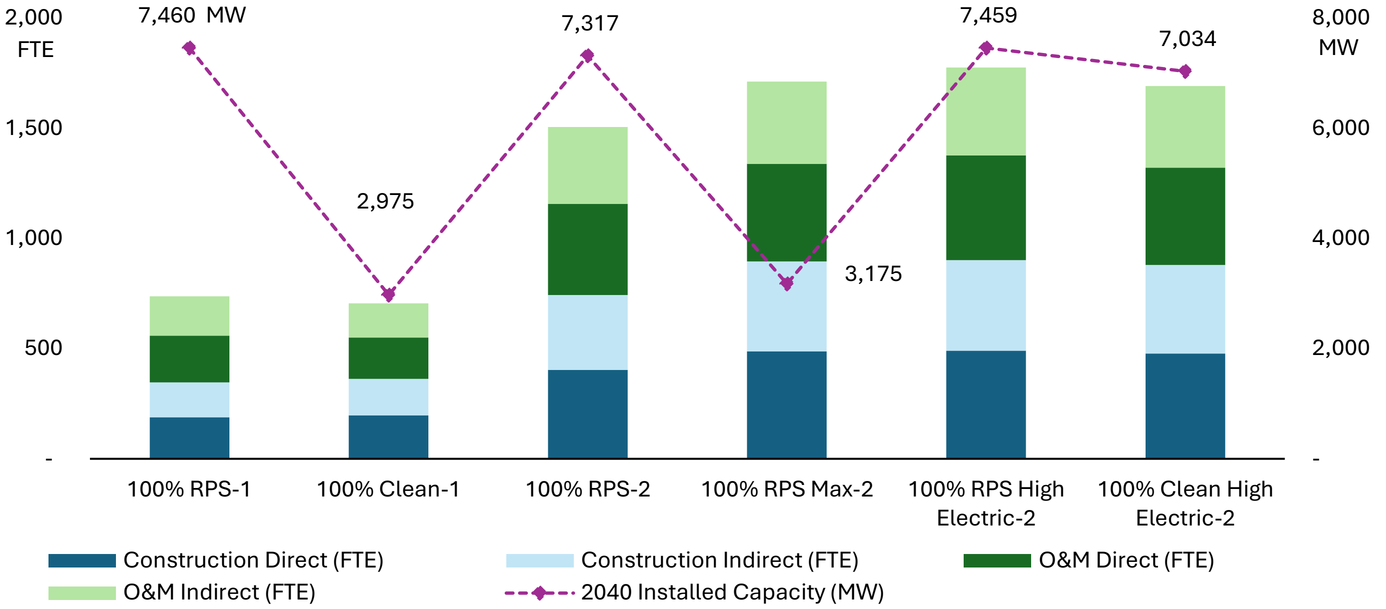


Figure 72. Maryland Average Annual Full-Time Equivalent Employment Created from Onshore Wind

5.2.2. Average Full-time Equivalent Jobs

Figure 73 illustrates the estimated average employment impacts from 2025-2040 resulting from several indicative RPS and CES scenarios. Across most technologies and scenarios, direct average annual FTE job creation surpasses indirect job creation. In the solar sector, direct jobs are, on average, 49% higher than indirect jobs. Onshore wind direct jobs are 19% higher on average. However, for OSW, direct job creation is slightly lower than indirect jobs, by 3% in the Phase 2 scenarios and 5% in the Phase 1 scenarios.

The relative number of FTEs added within a technology corresponds with the amount of capacity added in the model. For example, the 100% RPS-2 scenario results in lower UPV-related job creation compared to other Phase 2 scenarios with higher levels of in-state UPV capacity. Likewise, there is a 292% increase in FTE employment related to OSW construction and operations from the scenarios that assume 2,022 MW to those assuming 8,500 MW. Solar and energy storage contribute the highest average share of total FTE employment (53%) through 2040 based on the scenarios and technologies modeled.

The 100% Clean-1 scenario exhibits 4.9% fewer DES and 4.1% fewer onshore wind FTEs compared to the 100% RPS-1 scenario. However, it offsets this with approximately 50% more UES-related FTEs. The average annual FTE job creation in the 100% RPS High Electric-2 scenario is markedly higher than in the 100% Clean High Electric-2 scenario. This disparity is primarily attributed to the significantly greater UPV-related job creation in the former.

Job creation in FTE for GSHP technologies is approximately 65% lower than for solar technologies. 100% Clean-1 has marginally higher GSHP FTE jobs than 100% RPS-1. Clean-1 has approximately 48% more FTE jobs than RPS-1 in UES and approximately 5% fewer FTE jobs than RPS-1 in DES.

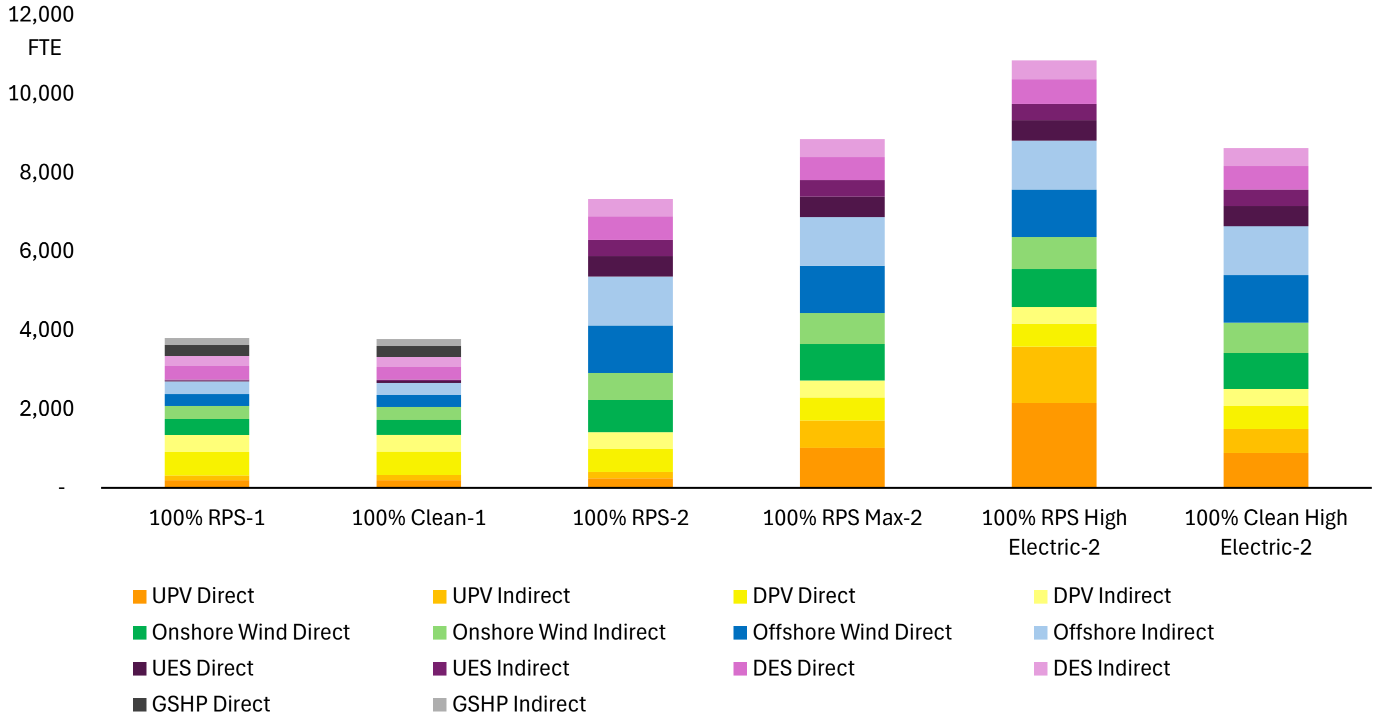


Figure 73. Maryland Average Annual Direct or Indirect and Induced Full-Time Equivalent Job Creation, by Technology and Scenario

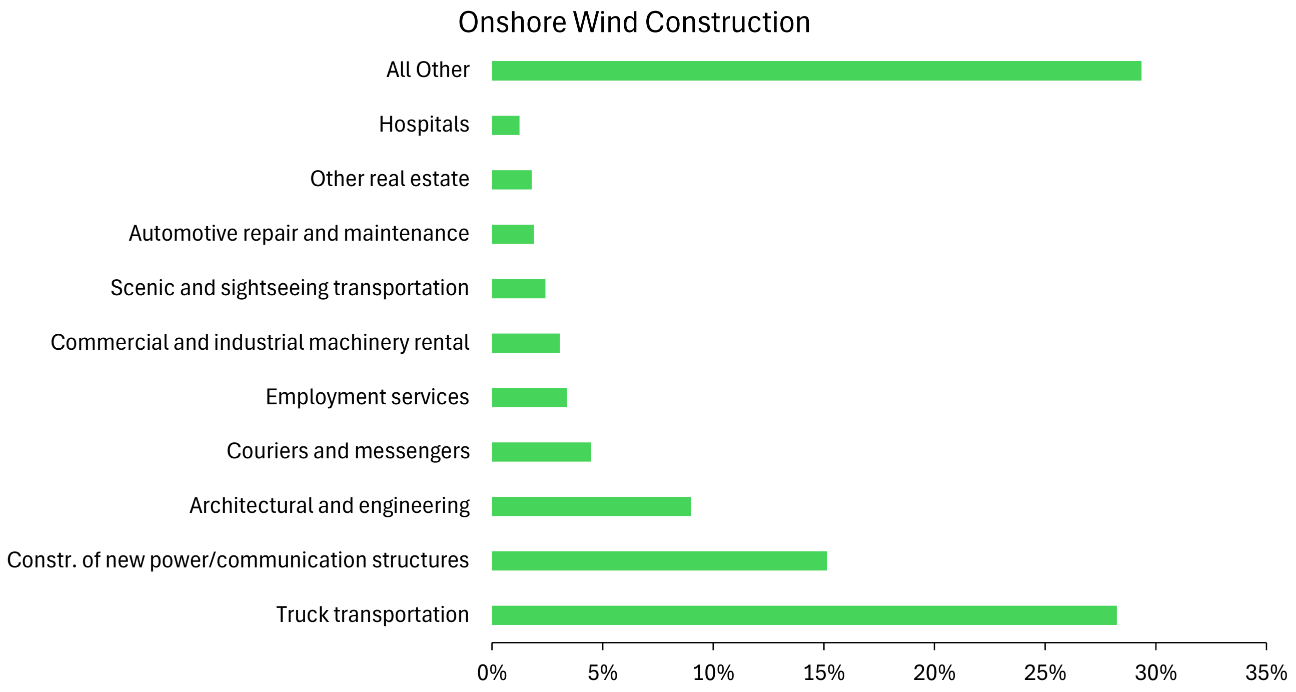
Note: Construction Indirect and O&M Indirect include induced effects.

5.2.3. Types of Jobs

Different industries are impacted from the construction and operation of each of the modeled renewable energy technologies based on technology-specific characteristics. For example, the construction of OSW turbines requires the utilization of specialized water transportation to deliver manufactured components and workers to the sites offshore, construction of onshore wind requires utilization of heavy truck transportation, and adoption of GSHPs utilizes heating, ventilation and air conditioning (HVAC) technicians and landscapers to install the specialized piping necessary to transfer heat to and from the ground surrounding a residence or business.

Again, since IMPLAN does not consider out-of-state contributions to construction or O&M, several manufacturing-related industries are not impacted due to the fact that Maryland does not have a robust renewable energy manufacturing sector. On the other hand, most O&M expenditures are assumed to be captured almost entirely by in-state industries.

Importantly, impacts associated with construction and O&M of all technologies considered are distributed throughout the economy from consumption expenditures (induced impacts) and, to a lesser extent, supply chain transactions (indirect impacts), creating jobs across the occupational spectrum. The ranking of the top 10 industries in terms of FTE job creation is presented in **Figure 74** for onshore wind technologies, as an indicative example. The “All Other” category includes smaller job impacts across hundreds of industries, summed together.



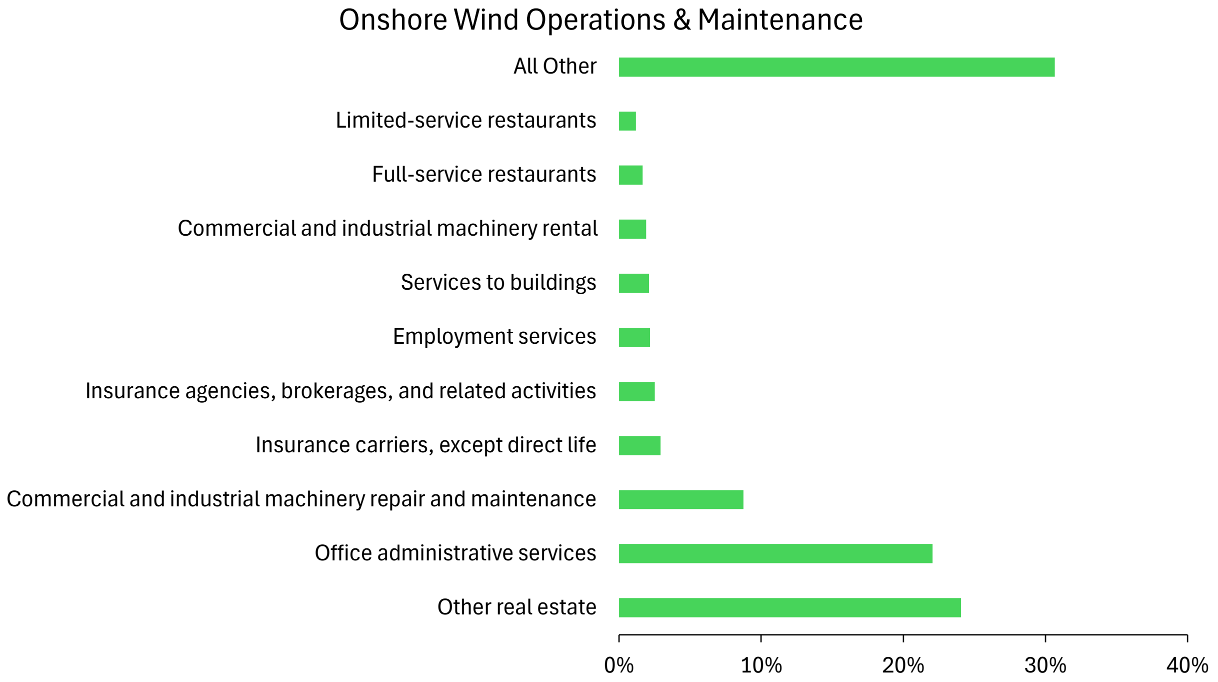


Figure 74. Top 10 Maryland-Based Industries Benefiting from Onshore Wind Construction and O&M (Percent of Total FTE Creation), 100% RPS High Electric-2 Scenario

Several occupational categories consistently contribute to FTEs across all renewable energy technologies. These include the construction of new power and communication structures, architectural and engineering services, employment services, and sectors like restaurants, real estate, and hospitals. Additionally, most technologies create significant numbers of FTE jobs in legal services (particularly solar and OSW), management consulting services (particularly battery storage and solar), and insurance (particularly wind and battery storage). The industries benefiting the most from consumption expenditures (induced impacts) or supply-chain transactions (indirect impacts) across all technologies and scenarios are full and limited-service restaurants, hospitals, employment services, insurance carriers, and consulting services.

Exeter's IMPLAN modeling found that truck transportation is the leading job category for onshore wind. Fabricated structural metal manufacturing and water transportation are two of the unique job categories for OSW, perhaps reflecting the complex supply chain and specialized logistics needed for OSW installations. Another important job category for both onshore and offshore wind is insurance.

For both utility-scale and distributed solar, job creation is observed in landscape and horticultural services, as well as services to buildings and real estate. Landscape and horticultural services and household goods repair and maintenance are the main job categories for GSHPs. These jobs are complemented by additional employment created in building material and garden equipment and supply stores and air conditioning, refrigeration, and warm air heating equipment manufacturing industries. For utility-scale batteries, architectural, engineering, and related services are the top job types, perhaps reflecting the specialized design, planning, and ongoing technical support required for the installation and maintenance of battery energy storage systems.

5.2.4. Cumulative Economic Output

Figure 75 illustrates the estimated cumulative sales impacts for in-state businesses over the years 2025-2040. Across all scenarios and technologies, the sales impact from direct jobs is consistently greater than that of indirect jobs. This difference ranges from around 13% to 15% higher for UES to 63% higher for GSHP.

Both the 100% Clean-1 and 100% RPS-1 scenarios have a total sales impact of approximately $13 billion. The 100% Clean-1 scenario has a cumulative sales impact that is 4% higher from direct UPV, 51% higher from UES, and 1% higher from GSHP relative to the 100% RPS-1 scenario. However, 100% Clean-1 has a 4% lower sales impact from onshore wind and 5% lower sales impact from DES, leading to its total sales impact being lower than 100% RPS-1 by around $73.6 million.

Solar accounts for 38% of the total sales impact in the 100% RPS High Electric-2 scenario, which has the highest overall sales impact due to substantial contributions from UPV (both direct and indirect / induced sales). Conversely, the 100% RPS-2 scenario has the lowest total sales impact among the revised scenarios, with solar contributing only 17% to its total sales impact. Notably, 59% of the total sales impact in the 100% RPS-2 scenario comes from wind energy.

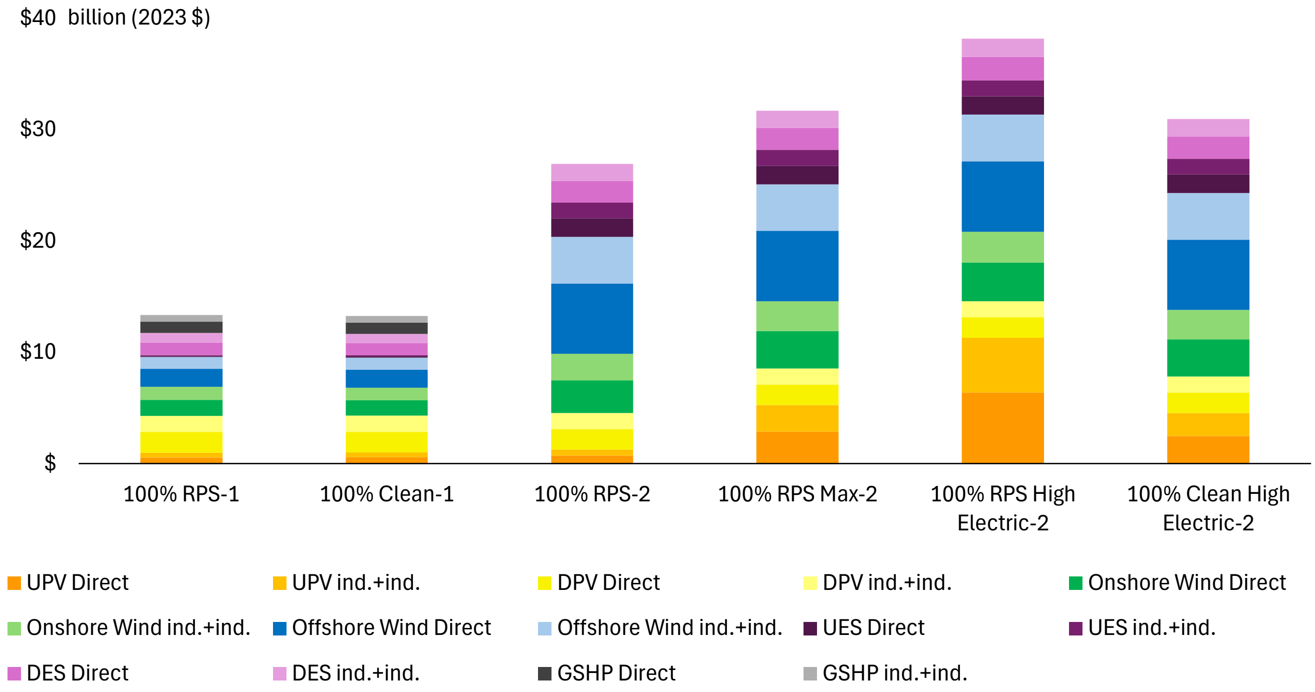


Figure 75. Maryland Total Cumulative Direct, Indirect, and Induced Output, by Technology and Scenario

5.3. Key Findings

- Based on the modeled technologies and scenarios, RPS policy scenarios generally result in higher numbers of FTE jobs than CES policy scenarios. This result largely stems from RPS policies encouraging higher levels of distributed resources. A complete comparison of relative job impacts, however, would require additional analysis of the job and output impacts of additional energy technologies, especially advanced energy technologies and CCS.
- For all scenarios, the aggregate job losses associated with coal and natural gas plant retirements are offset by substantial additions in other energy sector jobs in the VCE modeling. The types of jobs or durability of associated employment, however, may not be comparable. Chapter 6 discusses related considerations in the context of ensuring a "comparable" transition for workers affected by energy transition policies.
- The in-state job impacts of UPV, DPV, OSW, energy storage, and GSHP all correspond with the presence of in-state targets or mandates, illustrating the importance of in-state requirements as a way for RPS or CES policies to create Maryland employment opportunities.
- The magnitude of the job impact of an in-state target or mandate depends on the size of the requirement. GSHP adoption, for example, has relatively low job impacts compared to other modeled renewable energy technologies in part due to the low level of the geothermal carveout.
- Predicted changes in Maryland OSW employment are highly sensitive to the schedule of OSW development and the in-state employment commitments made by OSW developers. For example, Maryland's water transportation and scenic sightseeing transportation and support industries are estimated to receive around 15% of the job benefits from O&M of OSW facilities through 2040. Delays in OSW development would reduce or eliminate these jobs.
- The identified economic benefits of the Maryland RPS are concentrated in the construction and service industries. However, across scenarios, the average contribution of construction activities to FTE employment is only 56%, suggesting that O&M of projects also contributes to employment in Maryland. This is especially true considering most O&M activities are expected to be sourced in-state.
- Similar to the key findings of the 2019 RPS Report, OSW installations require many specialized components that are not currently produced in the United States. Most near-term manufacturing opportunities for OSW are limited to upstream materials and subcomponents that can be easily transported, such as scaffolding, coatings, ladders, fastenings, hydraulics, concrete, and electrical components. Nevertheless, opportunities to expand economic development in Maryland are primarily associated with OSW due to the state's legislative targets to place OSW component manufacturing facilities in Maryland.
- While GSHPs require somewhat specialized components, Maryland can rely on existing in-state HVAC manufacturers and various HVAC businesses to supply the materials and install GSHPs. As such, nearly 70% of FTE jobs created for O&M of GSHP systems are concentrated in the personal and household goods repair sector.
- Advertising, public relations, and related services are among the leading job types created in FTE for DES and, to a lesser extent, distributed solar. This is likely because effective marketing and public engagement are essential for promoting the adoption of distributed energy technologies, especially among consumers and businesses.
- Besides prospective OSW opportunities, the Maryland RPS is currently of little benefit to the state's manufacturing sector because most solar, wind, and energy storage components are manufactured out-of-state or abroad. Further, opportunities for manufacturing growth in Maryland from continuing deployment of these resources are probably limited to the structural and electrical balance of system (BOS) supply chains.

5.4. Cost-Benefit

The job creation and economic output benefits of an RPS or CES primarily stem from its impact on resource investment; adding any new resource to the grid requires labor and capital. Differences in results by scenario, therefore, reflect differences in expected resource outlays.

As noted above, IMPLAN does not model the potential costs incurred as a result of a 100% RPS or CES. The estimated total economic output for the technologies and scenarios assessed, however, helps illustrate trade-offs between certain policy and market condition assumptions in terms of benefit. **Table 12**, **Figure 76** and **Figure 77** show these results as they compare across scenarios.

After accounting for dollar discounting (see Section 3.5.), the total output for the 100% RPS-1 scenario is approximately $80 million higher than the 100% Clean-1 scenario. Similarly, the total output for the 100% RPS High Electric-2 scenario is higher than the 100% Clean High Electric-2 scenario, although by a significantly higher margin ($5.5 billion). Again, note that Exeter did not assess certain clean energy technologies. Amongst

RPS scenarios, scenarios that maximize in-state RPS-eligible energy generation (100% RPS Max-2) or assume high electrification (100% RPS High Electric-2) increases total output benefits above the 100% RPS on its own (100% RPS-2) by $3.5 and $8.4 billion, respectively. These changes correspond with the addition of high levels of in-state renewable capacity either due to hypothetical policy conditions or in response to increased demand.

Table 12. Cumulative and Discounted Total Output in Maryland, by Scenario

Scenario	Total Output, 2025-2040 in 2023$ (billions)	Discounted Total Output 2025-2040, in 2023$ (billions)	Models Compared to 100% RPS-1 (billions)	Models Compared to 100% RPS-2 (billions)
100% RPS-1	$13.34	$11.00	$0.00	
100% Clean-1	$13.27	$10.86	($0.15)	
100% RPS-2	$26.94	$22.10		$0.00
100% RPS Max-2	$31.69	$25.60		$3.50
100% RPS High Electric-2	$38.18	$30.64		$8.54
100% Clean High Electric-2	$30.95	$25.06		$2.96

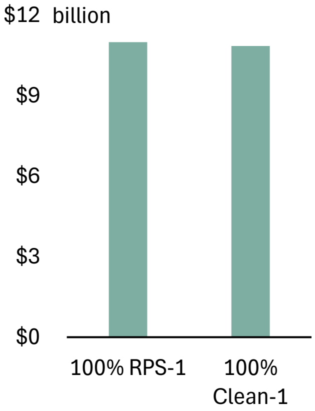


Figure 76. Discounted Total Output in Maryland from 2025-2040, Phase 1 Scenarios

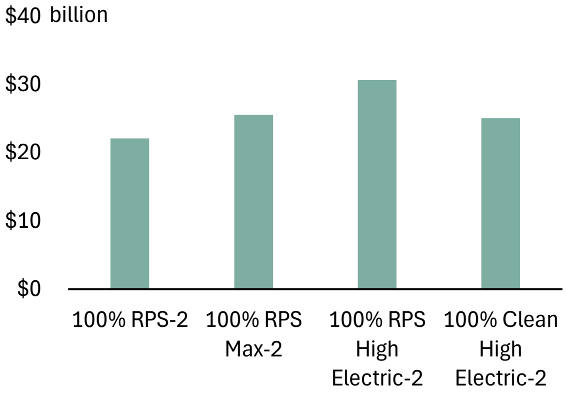


Figure 77. Discounted Total Output in Maryland from 2025-2040, Phase 2 Scenarios

6. OTHER INDUSTRY IMPACTS

This section addresses additional industry impacts of a 100% Maryland RPS or CES, including potential job and economic output reductions due to increased retail electricity prices or the closure of displaced fossil fuel power plant capacity. Additionally, this section addresses statutory language outlined in CEJA which requires an assessment of in-state industries potentially affected by a 100% requirement and recommendations for a comparable transition for impacted workers and their communities.

The increased deployment of renewable and clean energy resources in Maryland and PJM coincides with the closure of certain non-renewable energy resources in Maryland. These changes can occur even in the absence of a 100% RPS or CES policy in Maryland, especially as resources reach the end of their expected useful life. However, policy assumptions can influence the speed of retirements and whether shuttered facilities are replaced with new facilities that require a similar workforce. Likewise, policy assumptions impact the magnitude and rate of change of certain energy sector costs that are partially or fully passed on to consumers in the form of higher or lower retail electricity rates. Customer segments that are most sensitive to energy costs, including energy-reliant and energy-intensive industries, respond to these changes by altering employment and output, among other variables.

To the extent that a 100% RPS or CES policy negatively impacts certain industries or areas, Maryland can address associated dislocations through a variety of policy mechanisms. The appropriate design of “comparable transition” or “just transition” (used interchangeably) policies depends on how Maryland prioritizes various policy objectives, discussed below.

6.1. Impacts of Power Plant Closures in Maryland

As noted in preceding chapters, Maryland’s coal power fleet will retire during the review period for economic and environmental justifications that are independent of Maryland’s RPS. Thus, subsequent discussion of power plant closure impacts focuses on the potential early retirement of natural gas and nuclear power plants. In practice, the decision to retire a plant depends on a variety of factors, including age, expected retirement date, technology/efficiency updates, the number of units and capacity, and wholesale market conditions. Absent relicensing, both units of the Calvert Cliffs Nuclear Power Plant (Calvert Cliffs) will reach the end of their license by 2037. Likewise, about 2.1 GW (or 41%) of Maryland’s natural gas-fired capacity is expected to reach the end of its expected useful life before 2040.[73] Therefore, the impact of an 100% RPS or CES is most manifest in the ways it alters the expected retirement trajectory of existing plants’ nuclear or natural gas (e.g., causes existing plants to retire or relicense faster or slower) or results in the development of “replacement” capacity.

For workers, especially those directly employed at these facilities, power plant retirement decisions can translate to sudden job losses with accompanying disruption of livelihoods. Affected workers may also experience challenges in finding comparable employment opportunities. Many of these workers possess specialized skills and expertise tailored to the energy sector and/or specific types of energy capacity, and retraining programs may be necessary to transition them into new roles. Additionally, the economic stability of communities reliant on these plants may be compromised, as they often serve as major employers and contributors to state and local tax revenue.[74] The closure of these plants could lead to a decline in property values, loss of businesses that rely on plant employees, and a general downturn in the local economy.

6.1.1. Nuclear Retirements

Maryland hosts a single nuclear power facility, the Calvert Cliffs Clean Energy Center (Calvert Cliffs), situated in Calvert County and operated by Constellation Energy. This plant comprises two nuclear reactors, Unit 1 and Unit 2, with a total nameplate capacity of approximately 1,850 MW.[75] Calvert Cliffs plays a significant role in both the state and Calvert County, contributing substantially to tax revenues and employment. As of the end of 2023, the plant maintains

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[73] For the purposes of this report, Exeter only considered utility-scale natural gas-fired units that utilize CT or CC. Exeter defines utility-scale as being more than 2 MW and producing more power for sale on the grid than for on-site consumption. Natural gas power plant data retrieved from EIA-860 accessed May 15, 2023.

[74] Local tax revenue is primarily related to property tax. Though technically not a tax, local governments often consider revenue from Payment in Lieu of Taxes (PILOT) programs in their annual tax revenues. PILOT programs involve agreements between local governments and property tax-exempt entities to make payments to the local government in lieu of traditional property taxes. Some local jurisdictions in Maryland impose utility license taxes for providing utility services within their boundaries and franchise tax for use of infrastructure within the jurisdiction. State tax revenue from power plants typically involve state corporate income tax, sale and use tax (on the purchase of goods and equipment used in plant operations), public service company tax, and income tax paid by direct employees. A portion of the tax revenue received by the state from the public service company tax may be distributed to local governments.

[75] Unit 1 has a nameplate capacity of 918 MW and Unit 2 has a nameplate capacity of 932 MW. U.S. Energy Information Administration. Form 860. Accessed May 2024. eia.gov/electricity/data/eia860/.

747 direct jobs and pays approximately $23 million in annual taxes to Calvert County.[76]

Typically, nuclear power plants operate for decades, often spanning 40-60 years, subject to regulatory approval and maintenance. Calvert Cliffs commenced operations with Unit 1 in 1975 and Unit 2 in 1977, with the initial operational life set to conclude in 2014 and 2016, respectively.[77] However, the plant has undergone various upgrades and modifications to comply with evolving regulatory standards and, in 2000, became the first nuclear power plant in the U.S. to earn extended licenses from the NRC. The license extensions allow Unit 1 to run through 2034 and Unit 2 through 2036.[78]

Several other nuclear plants in PJM have recently retired or are slated to retire for economic reasons, and some states have taken steps to provide support to avoid these retirements (see Appendix H for related discussion). In addition, the Bipartisan Infrastructure Law authorizes up to $6 billion to keep existing nuclear plants online on a case-by-case basis, while the Inflation Reduction Act has a production tax credit of $15/MWh for existing nuclear plants. VCE's Phase 1 modeling, as discussed in Chapter 2, indicates that Calvert Cliffs will retire for economic reasons. This decision takes place except in scenarios that incentivize the retention of in-state nuclear, such as the Calvert-1 or various Phase 2 scenarios, via the availability of clean energy resource credits. Thus, the jobs and economic output associated with Calvert Cliffs are sensitive to future conditions, including Maryland RPS and CES policy.

6.1.2. Natural Gas Retirements

Maryland has begun to shift away from developing new in-state natural gas resources in favor of alternative resources and energy imports. The most recent natural gas CC project to receive licensing and commence operations in Maryland was the 831-MW Keys Energy Center, located in Prince George's County, which began operations in 2018. As of 2024, there are 32 natural gas-fired units from nine utility-scale natural-gas fired plants operating in Maryland, representing approximately 4.8 GW of capacity.[79] As shown in **Table 13**, the majority of the state's natural gas capacity is produced in Cecil County (~1.9 GW) and Prince George's County (~1.6 GW), with the remaining capacity spread between Charles, Harford, and Montgomery counties.

Many of the plants listed in **Table 13** have been in operation for more than three decades. While the life cycle of a natural gas plant is expected to be around 30-40 years, many have been updated over their lifespan such that they can continue operating past the initial expected life. **Table 13** includes the estimated retirement date for each natural gas plant, assuming no further interventions to extend the plant's useful life.

VCE's model results estimate natural gas capacity reductions (i.e., retirements) and additions (i.e., new builds) for each of the modeled 100% RPS and CES scenarios. However, these results aggregate capacity for all of Maryland and do not distinguish which specific units or plants are being retired, or where new capacity potentially replaces retired plants. Therefore, the focus of Exeter's assessment is the relative timing of net capacity reductions (retirements less additions) in relation to net changes in capacity. These details indicate which scenarios create more dislocation for workers. Specifically, **Figure 78** through **Figure 81** plot estimated retirements (light blue lines), additions (yellow lines), net retired natural gas (green lines), and overall capacity (dark blue lines) for select scenarios that are indicative of Maryland natural gas capacity trends across all other scenarios.[80,81]

In all scenarios, the pace of retirements is faster than the expected capacity retirements based solely on remaining useful life. The net impact of natural gas capacity, however, varies, as does the slope of retirements and the size of the gap between retirements and additions.

In the scenarios that introduce additional natural gas capacity (**Figure 78** and **Figure 79**), the level of additions is insufficient to make up for the retirements, particularly during the initial model years (2024-2026) when annual net retirements are highest and little to no new capacity has been built. This lag in capacity additions relative to retirements in the first three years corresponds with a less seamless transition for affected workers from one plant to another as workers

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[76] The PILOT agreement between Calvert County and Calvert Cliffs expired at the end of fiscal year 2023. The county is in the process of completing updated valuations of the property to use for property tax liability assessment. The assessment could also be used to develop a payment schedule if Calvert County were to reestablish a PILOT agreement with Calvert Cliffs. Local tax revenue and direct jobs data were retrieved from Constellation Energy's 2024 Calvert Nuclear Fact Sheet. constellationenergy.com/content/dam/constellationenergy/pdfs/2024-nuclear-fact-sheets/2024_Calvert_Nuclear_Fact_Sheet.pdf.

[77] U.S. Nuclear Regulatory Commission. "Calvert Cliffs Nuclear Power Plant, Units 1 and 2, License Renewal Application." nrc.gov/reactors/operating/licensing/renewal/applications/calvert-cliffs.html.

[78] Ibid.

[79] Natural gas power plant data retrieved from EIA-860 accessed May 15, 2023. These totals exclude cogeneration and other non-traditional gas power plants (e.g., LFG facilities).

[80] Natural gas data incorporated into VCE's model represents natural gas capacity in Maryland as of 2022, including cogeneration and non-utility-scale natural gas. As a result, graphs may represent some natural gas capacity not addressed in **Table 13**. Additionally, the graphs may not accurately encompass some natural gas power plant retirements after 2022.

[81] Note that this analysis does not account for potential employment opportunities at new natural gas CCS plants, which may mitigate some natural gas worker dislocation.

would have to wait more than a year to be reemployed by a natural gas plant. Additionally, potential reemployment would require some degree of geographic alignment between retired and new natural gas plants.

In the scenarios where no new natural gas is added, (**Figure 80** and **Figure 81**), there is no mitigation to displacement, meaning workers that lose their jobs have no means of maintaining comparable employment by transitioning to a new natural gas plant.

Table 13. Maryland's Natural Gas Units – Size, Direct Employees and Useful Life

Plant Name (Owner/Operator)	County	Units (Total Nameplate Capacity)	Direct Employees	Expected End of Useful Life
Rock Springs Generation Facility (Essential Power Rock Springs)	Cecil	4 Units (773 MW)	39	2033
Wildcat Point Generation Facility (Old Dominion Electric Coop)	Cecil	3 Units (1,114 MW)	50	2048
CPV St. Charles Energy Center (CPV Maryland LLC)	Charles	3 Units (775 MW)	38	2057
Perryman Generating Station (Constellation Power Source Gen)	Harford	2 Units (333 MW)	20	2035
Central Utility Plant at White Oak (GSA Metropolitan Service Center)	Montgomery	8 Units (42 MW)	3	2043-2054
Dickerson Power (Lanyard Power Holdings, LLC)	Montgomery	2 Units (326 MW)	17	2032
Brandywine Power Facility (KMC Thermo, LLC)	Prince George's	3 Units (289 MW)	15	2036
Chalk Point Power (Lanyard Power Holdings, LLC; NRG)	Prince George's	5 Units (550 MW)	23	2031
Keys Energy Center (PSEG Keys Energy Center, LLC)	Prince George's	3 Units (831 MW)	38	2058

Note: Direct jobs were estimated using NREL's JEDI model for natural gas. Model inputs were retrieved from utility financial data from publicly available financial reports by the plant's owner/operator and Maryland PSC regulatory filings, including Certificate of Public Convenience and Necessity (CPCN) filings for each plant/unit.

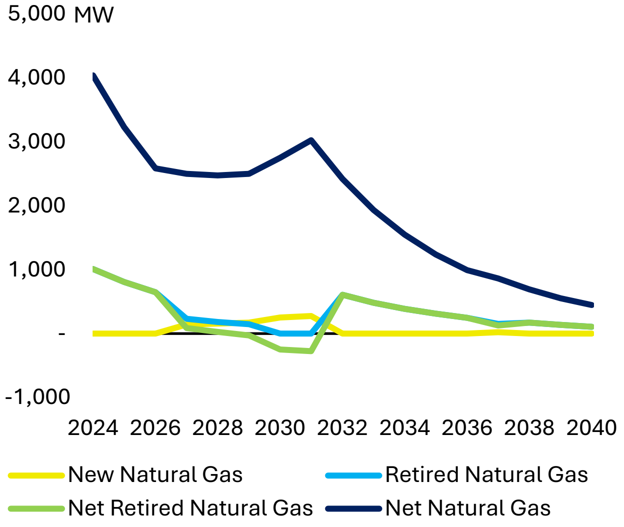

Figure 78. Maryland Natural Gas Additions and Retirements, 100% RPS-2 Scenario

Note: The natural gas retirement trends in the 100% RPS-2 scenario are similar to trends in the 100% Clean-2, 100% RPS-Max-2, 100% Clean High Electric-2, 100% RPS High Electric-2, and PJM 70% RPS-2 scenarios.

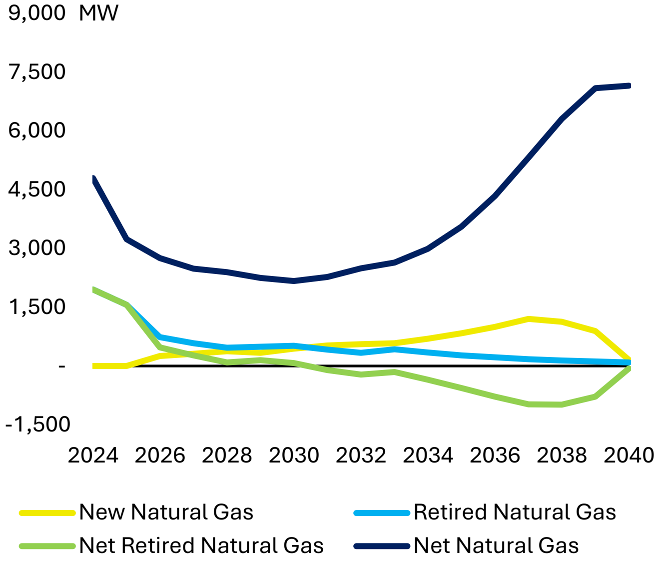

Figure 79. Maryland Natural Gas Additions and Retirements, Calvert-1 Scenario

Note: The Calvert-1 scenario shows trends that are similar to the other Phase 1 models.

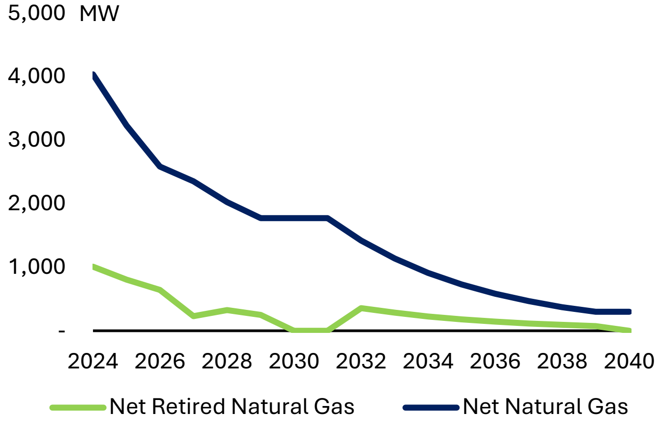

Figure 80. Maryland Natural Gas Additions and Retirements, 100% RPS No NG MD-2 Scenario

Note: The 100% RPS No NG MD-2 Scenario was indicative of trends in the 100% Clean No NG MD-2, 100% RPS 2035-2, 100% Clean 2035-2, and 100% RPS-1 scenarios.

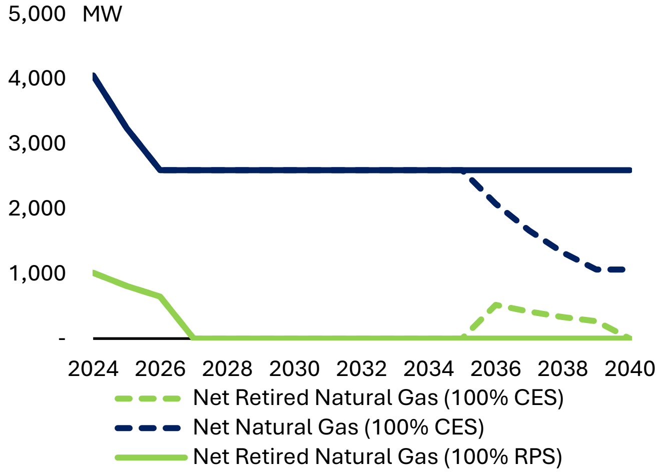

Figure 81. Maryland Natural Gas Additions and Retirements, 100% RPS No NG PJM-2 and 100% Clean No NG PJM-2 Scenario

Note: The remaining scenarios, 100% RPS No NG PJM-2 and 100% Clean No NG PJM-2, are both included due to nearly identical trends that diverged only from 2036 and 2039.

6.2. Non-Energy Industry Impacts

Nominal (or relative) increases in retail electricity prices can increase costs for downstream industries and consumers, with potential ripple effects in terms of job losses or reductions in productivity. These types of price responses are usually assessed by calculating cross-price elasticities, meaning measures of the expected percentage change in a certain economic outcome relative to a percentage change in retail electricity price. A consensus exists among economists in the United States that the elasticity coefficients for electricity prices in relation to employment are negative.[82,83,84] This observation is echoed in international research as well, with studies also reporting negative correlations between rising electricity prices and key economic growth indicators.[85] However, the size of this negative correlation is fairly small in most economic sectors (meaning lower changes when retail prices increase, all else equal). The notable exception is energy-intensive (or energy-reliant) industries.

6.2.1. Most Affected Industries in Maryland

Energy-intensive industries, including metal, paper, wood, chemical, textile, and mineral production or manufacturing, consume large amounts of energy to support essential business functions, such as heating, cooling, or chemical reaction. In Maryland, these sectors employed approximately 112,000 people, contributed $55 billion in production outputs, and sustained roughly $29.5 billion in Gross Domestic Product in 2022, according to data obtained from IMPLAN, EIA, and Maryland Manual On-Line.[86] According to EIA, the "industrial" sector comprised 6% of Maryland electricity consumption in 2022.[87]

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[82] Ann Wolverton, Ronald Shadbegian, and Wayne B. Gray, in their 2022 paper "The U.S. Manufacturing Sector's Response to Higher Electricity Prices: Evidence from State-Level Renewable Portfolio Standards," examine how U.S. RPS policies impact electricity prices and, consequently, the manufacturing sector using data from 1992 to 2015. The authors find that higher electricity prices led to a modest reduction in electricity usage by manufacturing plants. Energy-intensive plants showed a more significant decrease in usage, roughly 1.8%, compared to a general decrease of 1.2%.

[83] Olivier Deschenes, in the 2010 paper "Climate Policy and Labor Markets," examines the impact of various policies on U.S. labor using the variation in electricity prices across states from 1976-2007. Deschenes finds that employment rates are slightly responsive to changes in electricity prices, with an estimated decrease in full-time employment of 0.6% for a 4% increase in electricity prices.

[84] Aron Patrick, Adam Blandford, and Leonard K. Peters, in their 2013 paper "The Vulnerability of the United States Economy to Electricity Price Increases," explore the impact of rising electricity prices on the U.S. economy, particularly focusing on employment and economic growth across different sectors. The study estimates that a 10% increase in national electricity prices could lead to a loss of over one million jobs and reduce the annual Gross Domestic Product (GDP) by $142 billion.

[85] See, for example, the research of Cox, *et al.* (2014); Bölük and Koç (2010); He, *et al.* (2010); and Sterner (1989) that find negative elasticities in their studies of Germany, Turkey, China, and Mexico, respectively. Complete citations for these and other research referenced by Exeter available upon request.

[86] U.S. Energy Information Administration. (n.d.). Maryland State Profile and Energy Estimates. Retrieved June 14, 2024, from eia.gov/state/print.php?sid=MD and Maryland State Archives. (n.d.). Contact Information. Retrieved June 14, 2024, from msa.maryland.gov/msa/mdmanual/html/contact.html.

[87] Defined by utility rate classification. eia.gov/state/analysis.php?sid=MD#:~:text=10,12%2C13%2C14.

6.2.2. Production and Employment Impact Estimates

Exeter synthesized elasticities from various studies to develop a framework for estimating changes in employment and production outputs in Maryland's energy-intensive manufacturing sectors in response to specific changes in electricity prices. The identified elasticities were derived from regression analyses of U.S.-specific historical data measuring the responsiveness of employment and production outputs to changes in electricity prices. Categories assessed include:

- Production Outputs: Exeter identified a range of elasticities from -0.081 to -1.185, with an average elasticity of -0.409. The average suggests that an increase in electricity prices of 1% would lead, all else equal, to a 0.41% decrease in production outputs.
- Employment: Exeter identified a range of elasticities from -0.067 to -1.17, with an average elasticity of -0.300. The average suggests that an increase in electricity prices of 1% would lead, all else equal, to a 0.30% decrease in manufacturing jobs.

With a hypothetical 10% rise in the real retail electricity price, all else equal, this analysis suggests that Maryland could experience the loss, or absence of creation, of around 3,400 jobs and a $2 billion decrease in annual production output from its manufacturing sectors. Areas with a concentration of energy-intensive industries could face disproportionate economic setbacks due to electricity price increases. As discussed in Chapter 3, however, expected retail electric price increases attributable to a 100% RPS or CES are relatively small and, for most scenarios, occur near the end of the forecast period.

6.3. Just Transition Policy

The concept of a "comparable" or "just" transition emerged from environmental and labor movements over four decades ago in response to the harms caused by traditional energy systems (e.g., local pollution) and the disruptions caused by transitioning to sustainable, low-carbon alternatives (e.g., job displacement).[88] More recently, just transition policies have gained prominence as a way to mitigate the impacts on workers and communities dependent on polluting energy industries for local employment and tax base. The basic principle underlying just transition policy is to fairly compensate workers and communities for losses associated with the transition to clean energy.[89] How best to design and implement just transition policies depends on the needs of the displaced workers and communities for whom the policies are designed to assist.

Maryland's Just Transition Working Group (see sidebar) identified the following principles for just transition policies:

- Quality clean job creation;
- Occupational training and education;
- Promoting investment in clean jobs and impacted communities;
- Identifying and eliminating structural barriers to employment;
- Hiring and retaining underrepresented workers; and
- Collaborating with stakeholders, especially emphasizing workers.

These principles were developed by the Working Group following consideration of various state, federal, international, and non-profit resources.[90]

Maryland's Just Transition Working Group

Maryland's Climate Solutions Now Act of 2022 established a Just Transition Working Group focusing on transitioning workers in fossil fuel industries to employment opportunities in a clean energy economy. Specifically, the working group focuses on developing strategies to support workers and communities impacted by the shift away from fossil fuels and toward renewable energy resources. Key functions of the Just Transition Working Group include workforce development, job creation, labor rights and protections, community engagement, and policy recommendations, among other areas of focus.

The Maryland Just Transition Working Group conducted its first meeting on April 26, 2024, and is anticipated to continue meeting through November 2025. This report, which addresses a statutory requirement of the Maryland Clean Energy Jobs Act, is not intended to supplant the ongoing efforts of the Working Group. Rather, this standalone chapter of the 100% Study is intended to complement the Working Group's efforts and introduce related topics at a high level. For additional information on Just Transition topics in Maryland or the Working Group, please visit: mde.maryland.gov/programs/air/ClimateChange/MCCC/Pages/JTWG.aspx.

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[88] For a more complete history of just transition and related environmental and energy justice concepts, or further explanation of some of the programs and approaches discussed below, see Appendix I for a list of works referenced when compiling this Chapter.

[89] The just transition movement is closely tied to the energy justice movement as it seeks to address the social and economic impacts of transitioning to cleaner energy systems, particularly for marginalized communities disproportionately affected by fossil fuel extraction and pollution.

[90] See Appendix I for relevant references identified by the Working Group.

6.3.1. Policy Considerations

Exeter reviewed the existing just transition policy landscape and has determined that most governments/entities incorporate provisions that fall into one or more of the following categories:

- Job support for workers
- Wage replacement
- Community investment

The subsequent sections discuss these provisions in more detail and highlight some policy approaches for each category. As part of this discussion, Exeter provides initial recommendations for initiatives that could be implemented in Maryland and identifies the state agency/entity (or multiple agencies and entities) that would be best suited to oversee each policy. Beyond the above review, Exeter also discusses the benefits of stakeholder engagement in the decision-making processes as a way to support effective policy design and implementation. Finally, this section concludes with a review of potential funding options available to support just transition policies.

Job Support for Workers

Job support for the labor force affected by the energy transition (i.e., "just transition workers"), is commonly addressed through retraining or reskilling programs and job placement assistance. These programs are intended to enable workers to acquire the new skills necessary for transitioning to jobs in the renewable or clean energy sector or other growing industries, while also removing barriers to this transition. Retraining or reskilling programs can be initiated by the state to meet the employment needs of the state, or by employers as part of their onboarding process. In the latter case, employers can collaborate with the state to identify potential candidates among the pool of workers who are best suited for the required retraining or reskilling. States can also offer incentives to employers, such as subsidies to cover the costs of training new hires (see the discussion of "Employer Subsidies" in the Wage Replacement section). Additionally, these programs may allow workers to earn a related degree or certification from a qualifying academic institution in lieu of participating in state- or employer-created retraining or reskilling programs.

Job placement programs are designed to assist individuals in finding suitable employment opportunities. Typically, they offer a range of resources and support to help job seekers secure employment that aligns with their skills, qualifications, and career goals. These programs can be designed to complement retraining or reskilling initiatives by offering support like skill assessment and career counseling before workers enroll in a specific retraining or reskilling program. This approach allows workers to identify which retraining or reskilling path to pursue by evaluating their existing career goals, skill strengths, and areas for skill improvement. Upon completion of training, job placement programs can offer further assistance, including additional career counseling, resume writing support, job search support, networking opportunities, and interview preparation support.

The Maryland Department of Labor (MDOL) already supports initiatives like retraining and reskilling through its Maryland Apprenticeship and Training Program, which partners with employers to provide on-the-job training and classroom instruction. MDOL also oversees the Employment Advancement Right Now (EARN) program, which funds industry-led partnerships to address workforce needs, demonstrating its capability to manage comprehensive job support initiatives. MDOL could potentially oversee any new initiatives aimed at supporting just transition workers using this established infrastructure and drawing from broader experience in workforce development.

Wage Replacement

Wage replacement programs involve the transfer of state-administered funds to individual employees as a substitute for lost wages from an employer. In practice, "wage replacement programs" include a variety of programs that aim to compensate workers for the loss of income during their job transition, such as unemployment insurance, guaranteed minimum income programs, and transitional income support. The objective of income and wage replacement programs is to give affected workers economic stability during periods of job transition or retraining.

MDOL currently oversees the provision of unemployment benefits in Maryland through the state's unemployment insurance program, which provides temporary financial assistance to eligible workers who have lost their jobs through no fault of their own.[91] Workers must meet certain requirements to qualify for these benefits, and the amount and duration of benefits vary based on individual circumstances. Maryland's unemployment insurance program can already be leveraged to provide support to qualified workers. Changes such as removing access or eligibility barriers, increasing benefits received, or extending the duration of benefits would allow Maryland to expand support to eligible just transition workers.

Transitional income support (TIS) programs incorporate several forms of wage replacement assistance, such as

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[91] Maryland Department of Labor. Division of Unemployment Insurance. Accessed May 2023. dllr.state.md.us/employment/unemployment.shtml.

subsidies, reemployment incentives, and benefit coverage, to aid workers transitioning from one job to another. Training subsidies provide workers with financial security through grants, stipends, or cash payments only while they are engaged in retraining/reskilling programs. Other TIS programs offer one-time bonuses or incentives to workers who secure employment in specific industries that align with clean energy goals. Entrepreneurship support can also be provided through subsidies to help workers overcome the initial financial barriers to start their own businesses in sustainable sectors. Finally, TIS programs can offer subsidies or other financial assistance to workers who need to relocate for new job opportunities. These types of support can be provided to workers directly or via the employer.

Another form of wage replacement is a guaranteed minimum income (GMI) program, also known as universal basic income. The most common example of this type of program is Social Security benefits. A GMI program, in the context of a just transition policy, would provide regular payments regardless of employment status, ensuring a baseline level of financial security during transitions. Some GMI programs subject payments to income taxation and implement "clawback mechanisms" to reduce payments as income exceeds thresholds. A program of this nature necessitates a robust administrative infrastructure for payment distribution, eligibility verification, and compliance. This may require the creation of a new agency to oversee the program or expansion of an existing agency. Maryland's Department of Human Services, for example, has existing frameworks in place to distribute welfare payments that could be expanded.

Several recent wage replacement initiatives in other states suggest potential approaches for Maryland. Washington State Initiative 1631 in 2018 proposed full wage replacement for every just transition worker within five years of retirement, wage replacement for every worker for each year of service up to five years, and wage insurance for up to five years for workers reemployed who have more than five years of service.[92] Although the initiative did not pass, it illustrates a comprehensive approach. Colorado's 2019 Just Transition law, another example, will cover part or all of the difference between a worker's wage from their previous employment in the fossil-fuel industry and the wage from new employment, as well as supplemental income during job retraining.[93] This initiative is in effect.

Community Investment

Communities that are heavily reliant on non-renewable energy industries can be supported through policies establishing funds for economic diversification, infrastructure development, and job creation in renewable energy and other sustainable sectors.

This support mirrors income and wage replacement policies for workers and replaces revenue streams derived from production, such as tax revenues. The Maryland Department of Budget and Management currently provides information and guidance to communities as they develop tax revenue replacement strategies. Community Investment Funds, which support things like sustainable development, small business growth, and workforce training, are traditionally the domain of the Maryland Department of Commerce.

Investment in a community can also take the form of environmental remediation and site restoration. Once power plants have retired, policies that support investment in environmental cleanup and restoration efforts can create opportunities for new economic development in the areas that previously hosted the retired plants. This includes new industrial activity on brownfield sites as well as employment tied to the clean-up itself. Further, these efforts can also improve local health and ecosystems in ways that attract new residents and promote development. Remediation and restoration policies are typically implemented by environmental or energy regulatory agencies and enforced through legal frameworks that hold former site occupants accountable for restoring land to a condition suitable for reuse. Decommissioning policies can require companies to post financial surety mechanisms such as bonds to compensate other parties, such as the county or state, to perform the cleanup and restoration.

In Maryland, fossil fuel-based power plant decommissioning, environmental remediation, and site restoration is overseen by the MDE to ensure that decommissioning activities are in accordance with all relevant regulatory requirements and are conducted safely, minimize environmental impacts, and protect public health.[94] MDE may work in conjunction with other state agencies and local authorities to address various aspects of power plant decommissioning, such as land use planning and community engagement. There are currently no statutory requirements for natural gas plants in Maryland to have a decommissioning plan in place during operation. Calvert Cliffs, on the other hand, is subject to an

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[92] Ballotpedia. Washington Initiative 1631, Carbon Emissions Fee Measure (2018). Retrieved June 14, 2024, from ballotpedia.org/Washington_Initiative_1631,_Carbon_Emissions_Fee_Measure_(2018).

[93] Colorado Department of Labor and Employment. Colorado Just Transition Action Plan. Retrieved June 14, 2024, from cdle.colorado.gov/offices/the-office-of-just-transition/colorado-just-transition-action-plan.

[94] All fossil fuel-fired power plants operating in the U.S. must be decommissioned in accordance with the EPA's Clean Air Act.

extensive decommissioning process regulated by the NRC that requires the power plant to have an up-to-date decommissioning plan.[95]

Separately, remediation planning is addressed for utility-scale solar projects as part of obtaining a Certificate of Public Convenience and Necessity (CPCN) from the Maryland PSC.[96] MDE and the PSC both have some capabilities to support new decommissioning initiatives tailored to address just transition concerns. Additionally, Maryland can tap into resources available as part of federal initiatives. For example, the EPA's Brownfield Program offers funding opportunities, including grants, loans, and technical assistance, to support the assessment, cleanup, and redevelopment of contaminated properties, known as brownfields, with the goal of revitalizing communities, promoting economic development, and safeguarding public health and the environment. [97]

6.3.2. Stakeholder Consultation and Participation

Active stakeholder engagement has several key advantages in terms of promoting an effective just transition policy.[98] First, consultation ensures that the voices of workers, unions, and communities are heard, and their concerns addressed. Second, engagement fosters trust, transparency, and collaboration which, in turn, enhances stakeholder support and participation in the transition process. Third, involving diverse stakeholders enables policymakers to understand the impacts of their decisions and develop equitable solutions. Finally, these efforts cultivate a sense of ownership of the proposed policies among all involved parties. One prominent stakeholder consultation strategy for just transition is to create a community advisory group that involves just transition workers and meets regularly with state officials to dialogue regarding just transition issues. The Maryland Energy Administration (MEA), MDE, and PPRP all have experience convening groups of stakeholders to discuss energy sector matters.

6.3.3. Funding Options

In Maryland, various funding options are available to support just transition policies and programs across different sectors. For policy initiatives that are implemented through existing state agencies, funding may be secured through increases to the funding mechanisms already in place. This may involve reallocating the state budget, increasing tax rates and/or fees, or establishing new funding mechanisms such as a tax on generation and/or transmission assets. Policy initiatives that involve direct (e.g., grants) or indirect (e.g., tax exemptions) financial contributions to employees, employers, or communities may require the state to access or create new sources of funding. **Table 14** provides a list of additional funding sources that can be leveraged for just transition policy initiatives.

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[95] Though Calvert Cliffs' decommissioning process is regulated by the federal government, MDE would still oversee certain aspects of the process, in conjunction with the NRC.

[96] Under Code of Maryland Regulations (COMAR) Chapter 27.01.14.04, local governments must require a decommissioning plan for solar projects that are less than 2 MW and do not require a CPCN from the Maryland PSC.

[97] Environmental Protection Agency. "Brownfields Program." Accessed May 2023. epa.gov/brownfields.

[98] Just transition stakeholders include displaced workers, displaced communities, labor unions, community organizations, environmental advocates, and more.

Table 14. Summary of Potential Funding Mechanisms for Just Transition Programs

Funding Source	Description	Examples
Grants	Maryland offers grants and loans through state agencies that can be adopted as is or adapted to specifically support just transition. Maryland agencies can also access funding from federal agencies to support a wide range of activities. This funding can be used to complement existing state initiatives related to just transition or create new ones.	Economic Development ▪ Maryland Economic Development Assistance Authority and Fund (MEDAAF)[1] Affordable Housing ▪ Maryland Department of Housing and Community Development (DHCD) Grants[2] Energy Efficiency ▪ EmPOWER Maryland Energy Efficiency Programs[3] Renewable Energy Projects ▪ Maryland Strategic Energy Investment Fund (SEIF) Grants[4] Workforce Training ▪ MDOL Workforce Development and Adult Learning[5] Environmental Justice ▪ Environmental Justice Small Grants (EJSG) Program (EPA)[6] Environmental Remediation ▪ Brownfields Program (EPA)[7]
Tax Credits/ Incentives	Various federal and Maryland tax credits and incentives are available to businesses, homeowners, and developers to encourage investment in certain areas or activities. These initiatives can be tailored to support just transition.	Energy Community Projects ▪ Inflation Reduction Act – Energy Community Tax Credit Bonus[8] Renewable Energy Projects ▪ Sales Tax Exemption for Renewable Energy Equipment[9] ▪ Maryland Property Tax Exemption for Renewable Energy Systems[10] ▪ Maryland Clean Energy Production Tax Credit[11] ▪ Residential Renewable Energy Tax Credit[12]
Foundations	Local and national philanthropic foundations can provide funding for just transition programs initiated by nonprofit organizations and community groups. Each foundation has specific priorities, application processes, and eligibility criteria.	Community Development ▪ The Middendorf Foundation[13] ▪ The Harry and Jeanette Weinberg Foundation[14] Training and Workforce Development ▪ The Living Classrooms Foundation[15] Environmental Remediation ▪ The Chesapeake Bay Trust[16] ▪ The Town Creek Foundation[17]

[1] commerce.maryland.gov/fund/programs-for-businesses/medaaf.
[2] onestop.md.gov/tags/5f1747f832745e0101b1b35f
[3] energy.maryland.gov/pages/facts/empower.aspx
[4] energy.maryland.gov/Pages/Strategic-Energy-Investment-Fund-(SEIF)-.aspx
[5] labor.maryland.gov/earn/
[6] labor.maryland.gov/employment/mpi/
[7] epa.gov/brownfields/types-funding
[8] energycommunities.gov/energy-community-tax-credit-bonus/.
[9] marylandtaxes.gov/business/sales-use/tax-exemptions/index.php
[10] dat.maryland.gov/Pages/default.aspx
[11] energy.maryland.gov/business/pages/incentives/cleanenergytaxcredit.aspx
[12] energy.maryland.gov/residential/Pages/incentives/CleanEnergyGrants.aspx
[13] middendorffoundation.org/
[14] hjweinbergfoundation.org/
[15] livingclassrooms.org/
[16] cbtrust.org/grants/
[17] towncreekfdn.org/

6.4. Key Findings

- Both the jobs and economic output associated with Calvert Cliffs can be understood to be sensitive to the future policy conditions due to the economic pressures facing traditional nuclear generation. The only model scenarios that retain Calvert Cliffs beyond license expiration dates incorporate explicit assumptions allowing subsidy payments. Policymakers should weigh the costs of these payments against employment and tax revenue impacts, among other factors.
- Some dislocation of the existing natural gas workforce occurs in all modeling scenarios because of the retirement of existing natural gas capacity. These workers will require transition support to new employment.
- In both the Phase 1 and Phase 2 100% RPS and 100% Clean scenarios, natural gas capacity additions are able to slow the reduction in net capacity between the years 2027 and 2031, which would allow some affected workers to transition to new natural gas plants without much delay. Whether or not Maryland pursues a 100% RPS or CES does not influence these results.
- Post 2031, natural gas retirements for most Phase 2 scenarios spike and capacity additions fall to almost zero through 2040. In the Phase 1 scenarios, by comparison, natural gas additions exceed retirements after 2031. A major contributor to this divergence is the presence or absence of an assumption that Maryland meets its CSNA emission reduction targets. Emissions policy, therefore, has an outsized impact on transition requirements that is independent of whether Maryland pursues a 100% RPS or CES.
- A variety of Maryland agencies support job training, wage replacement, and community investment initiatives that can be adapted to specifically address just transition issues.
- The impacts of 100% RPS or CES policies on employment and economic output as a result of higher retail power prices are expected to be small both because (1) model results show relatively small changes for reasons discussed in Chapter 2, and (2) the sectors most likely to be adversely affected, such as energy-intensive manufacturing, are relatively small in Maryland.
- With wage replacement programs it is important to consider provision duration and thresholds for eligibility cutoff as a way to keep program costs manageable.
- Federal programs can provide resources and funding to support certain just transition initiatives, especially those involving the transition of workers and communities away from fossil-fuel generation.

APPENDIX A. Working Group Members, Maryland 100% Study

Table A-1. Working Group Members, Maryland 100% Study

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Table A-1. Working Group Members, Maryland 100% Study

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APPENDIX B. Impact of Recent Changes to the Maryland RPS

As with most states with an RPS or CES policy, Maryland has changed its RPS multiple times. A discussion of these changes through 2018 is provided in the 2019 RPS Report. The purpose of this section is to review changes made since the 2019 RPS Report and provide an update on the impacts of previous changes. As was also the case in the 2019 RPS Report, this discussion assesses the impact of recent changes in isolation and does not control for the overlapping impacts of multiple, concurrent changes.

Recent changes to the Maryland RPS include:

- Clean Energy Jobs Act (CEJA) in 2019: Increased percentage requirements to escalate over time up to 50% from Tier 1 sources, including 14.5% from solar by 2030.
- SB 65 in 2021 (Ch. 673): Reduced the amount of solar energy required under the RPS each year from 2022-2029, while leaving the non-solar requirement generally unchanged, before realigning with previous requirements beginning in 2030. SB 65 also extended the Tier 2 requirement in perpetuity at 2.5% and eliminated black liquor as an eligible technology.
- HB 376/SB 153 in 2021 (Ch. 174/175): For municipal utilities, limited Tier 1 requirement to 20.4%, including 1.95% from solar and up to 2.5% from OSW, and removed any Tier 2 requirement after 2021.
- HB 1007 in 2021 (Ch. 164): Created a carve-out in Tier 1 for post-2022 geothermal, beginning with the 2023 compliance year. This law was subsequently adjusted through correctives issued as part of SB 406 in 2022 (Ch. 135).
- SB 526 in 2022 (Ch. 578): Required electric companies, instead of electricity suppliers, to purchase Offshore RECs (ORECs), and permitted electric companies to recover their costs through a non-bypassable surcharge paid by all distribution customers.

Among the findings in this section, including those from the 2019 RPS Report that still hold, are the following:

- Increasing the Tier 1 non-carve-out requirements under CEJA corresponded with continued new renewable energy development and deployment in PJM.
- The creation of a solar carve-out has led to the development of over 1.6 GW of distributed and utility-scale solar in Maryland as of February 2024.[99]
- Supply chain issues and a backlog in the PJM interconnection queue have affected the rate of solar development in Maryland. As a result, use of the solar ACP sharply increased to nearly $77 million in 2021 and $85.85 million in 2022, both sharp increases from $29,800 in 2020. The cost of SRECs rose to $72.59 in 2021 but dropped to $57.80 in 2022, as compared to $66.10 in 2020.
- To address the slowdown in solar development, the Maryland General Assembly enacted SB 65 in 2021 that decreased the growth rate of the solar carve-out and moved the maximum 14.5% level to 2030 from 2028. SB 65 also increased the solar ACP beginning in 2023, before gradually returning to the prior level by 2030.
- Reliance upon ACPs for the non-carve-out portion of Tier 1 has remained relatively small, although growing, amounting to just under $270 in 2020, $233,000 in 2021, and $677,490 in 2022.
- The OSW carve-out of the Maryland RPS led to four approved OSW projects totaling 2,022.5 MW of capacity. Additionally, the Maryland General Assembly in 2023 set a goal of an additional 6,500 MW of OSW by 2031 for a total of approximately 8,500 MW (see POWER Act - SB 781), as well as directed the Maryland Department of General Services (DGS) to issue an OSW procurement for up to 5 million MWh. Despite substantial increases in Maryland targets, no OSW generation has come online, and considerable uncertainty exists regarding previously approved projects. In February 2024, Orsted withdrew from its contracts with Maryland for the Skipjack OSW projects. As discussed further below, the Maryland General Assembly in 2024 addressed the uncertainty with OSW by passing HB 1296.
- Geothermal energy is a relatively small contributor to the Tier 1 requirement; however, the carve-out and definition change established in 2021 by the passage of HB 1007 has laid the groundwork for an increase in the number of geothermal projects beginning in 2023.
- The 2008 requirement that RECs from control areas adjacent to PJM must be delivered into PJM has, over time, reduced imports from outside PJM. Whereas the 2019 RPS Report found that imports from outside of PJM had modestly declined, recent data shows reductions to nearly zero in 2022.

The first part of this section will discuss legislative changes since the 2019 RPS Report and then will

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[99] EIA Electric Power Monthly, February 2024, eia.gov/electricity/monthly/.

provide an update on the impacts of previous changes to the Maryland RPS.

Changes to the Maryland RPS Since 2019

Raising Total Tier 1 Percentage Requirements

CEJA increased the Maryland RPS to 50% of its electricity sales from Tier 1 renewable energy sources by 2030, with a 14.5% solar carve-out. As discussed below, though, separate legislation (SB 65) enacted in 2021 slowed the pace of the growth of the solar carve-out and moved the maximum 14.5% level to 2030 from 2028.

Within PJM, Delaware, Illinois, Michigan and Virginia have all increased their RPS target since Maryland enacted CEJA. Additionally, some (but not all) other existing state RPS policies have built-in increases in RPS requirements year over year. That increase in RPS demand, accompanied by increases in corporate demand for renewable energy, have driven Tier 1 REC prices in Maryland higher since the 2019 RPS Report. Tier 1 non-carve-out REC prices have risen from $6.54 in 2018 to $17.80 in 2022. Tier 1 non-carve-out REC prices are compared to the overall Maryland RPS Tier 1 requirement in **Figure B-1**.

Slowing the Level of Increase in the Solar Carve-out

As noted above, CEJA increased the solar carve-out to 14.5% by 2028. In 2021, SB 65 reduced the amount of solar energy required between 2022 and 2029 and moved the 14.5% maximum solar carve-out level to 2030 from 2028. SB 65 also reduced the level of the decrease in the solar ACP rate between 2023-2029 (**Table B-1**). Non-solar ACPs were unchanged. Figure B-2 compares PV generation in Maryland as a share of the total sales alongside the state's solar carve-out requirements.

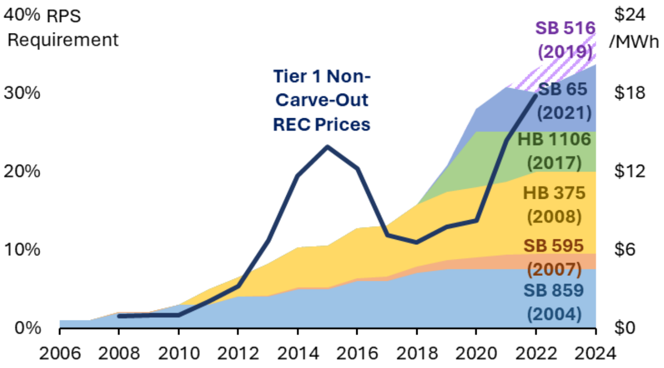

Figure B-1. Maryland RPS Tier 1 Requirement and Tier 1 Non-Carve-out REC Prices

Source: REC prices sourced from the Maryland Public Service Commission, *Renewable Energy Portfolio Standard Report with Data for 2022*, November 2023, psc.state.md.us/wp-content/uploads/CY22-RPS-Annual-Report_Final-w-Corrected-Appdx-A.pdf.

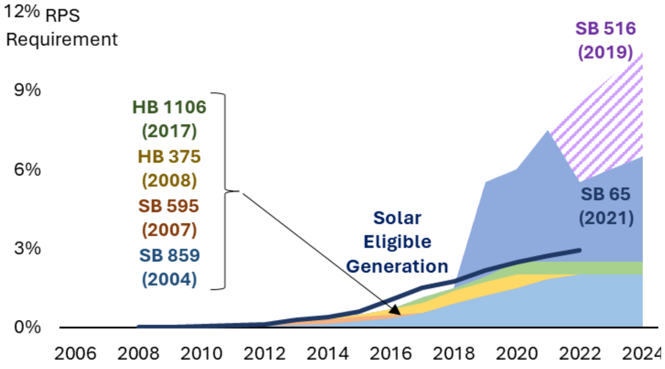

Figure B-2. Maryland RPS Solar Carve-out Requirement and Estimated PV Generation in Maryland as a Share of Total Sales

Sources: EIA Electric Power Monthly, February 2024, eia.gov/electricity/monthly/.

Table B-1. Current SREC Requirement and Solar ACP under SB 65

	Prior and Current SREC Requirement				Prior and Current Solar ACP			
Year	Tier 1 Total	Solar	Tier 1 Total	Solar	Nonsolar	Solar	Nonsolar	Solar
2022	33.10%	8.50%	30.10%	5.50%	30.00%	60.00%	30.00%	60.00%
2023	35.40%	9.50%	31.90%	6.00%	30.00%	45.00%	30.00%	60.00%
2024	37.70%	10.50%	33.70%	6.50%	27.50%	40.00%	27.50%	60.00%
2025	40.00%	11.50%	35.50%	7.00%	25.00%	35.00%	25.00%	55.00%
2026	42.50%	12.50%	38.00%	8.00%	24.75%	30.00%	24.75%	45.00%
2027	45.50%	13.50%	41.50%	9.50%	24.50%	25.00%	24.50%	35.00%
2028	47.50%	14.50%	43.00%	11.00%	22.50%	25.00%	22.50%	32.50%
2029	49.50%	14.50%	47.50%	12.50%	22.50%	22.50%	22.50%	25.00%
2030+	50.00%	14.50%	50.00%	14.50%	22.35%	22.35%	22.35%	22.50%

Source: SB 65.

Increasing the Offshore Wind Carve-out

The Maryland RPS includes a Tier 1 carve-out for OSW. Under the Maryland Offshore Wind Act enacted in 2013, the Maryland PSC set the share of the RPS met by this carve-out based on the projected annual creation of ORECs by qualified OSW projects, initially required not to exceed 2.5% of total retail sales. In 2017, the Maryland PSC granted ORECs for a proposed 248-MW project by US Wind and a 120-MW project by Skipjack Wind for a combined total of 368 MW ("Phase 1"). CEJA directed the PSC to solicit 1,200 MW of additional OSW by 2026. In December 2021, the PSC approved OREC proposals from US Wind and Skipjack for another 1,654 MW of OSW ("Phase 2") for a total capacity of 2,022.5 MW.

In 2023, the Maryland General Assembly enacted SB 781, otherwise known as the POWER Act, setting a goal of 8,500 MW of OSW capacity by 2031 and authorizing the Maryland PSC to work with other parties in exploring offshore transmission solutions to support OSW, including an open-access collector transmission system to allow for the interconnection of multiple qualified OSW projects at a single substation. By July 1, 2025, the Maryland PSC is required to issue, or request PJM to issue, one or more requests for proposals for OSW transmission facilities and onshore transmission upgrades and expansions intended to support OSW plants. If necessary, the PSC may issue, or request that PJM issue, additional transmission solicitations after 2025. Among other things, the transmission solicitations shall direct proposals to allow transmission lines to connect in a meshed manner and to share landing points and consider other onshore and offshore clean energy generation and storage facilities. The PSC must make its selection(s) by December 1, 2027, after public notice and a hearing.

In addition to the transmission provisions, the POWER Act directs the Maryland DGS to issue a solicitation for 5 million MWh annually of OSW and RECs by July 1, 2024, although the Maryland DGS is not required to actually enter into a contract from the solicitation.[100] In evaluating the bids, the Maryland DGS must compare the social cost of GHG emissions for OSW with the social cost of GHG emissions for nonrenewable energy from wholesale electric markets, and whether an applicant's proposal provides for financial and technical assistance to support monitoring and mitigation of wildlife and habitat impacts. Should the Maryland DGS enter into a Power Purchase Agreement (PPA), the contract must include a community benefit agreement, domestic content preferences, and a description of initial plans and commitments to environmental and natural resources mitigation.[101]

In February 2024, Orsted withdrew from its contracts with the State of Maryland, stating that higher development costs would make the projects uneconomic without an adjustment in contract pricing. The Maryland General Assembly responded by passing HB 1296, enacted as Chapter 431 and directing the Maryland PSC to open an amended Phase 2 OSW project proceeding limited to evaluating revised project schedules, sizes, or pricing for a previously approved Phase 2 project. Phase 1 projects can also increase the maximum amount of ORECs and amend project schedules during this proceeding. The law also amends an existing requirement for the Maryland DGS to issue an OSW energy procurement by removing the 5 million MWh limitation and to require a second procurement. Finally, HB 1296 requires the Maryland PSC, DGS, MEA, and other state agencies to develop a plan by January 1, 2025 for meeting the 8,500-MW OSW goal.

Elimination of Black Liquor

SB 65 also eliminated black liquor as an eligible Tier 1 resource for the Maryland RPS effective October 1, 2021, although RECs from black liquor under existing contracts are still eligible for the RPS until the contracts expire. Because of that provision, the percentage of black liquor RECs used for compliance with the Maryland RPS has not changed meaningfully. Until SB 65 was enacted, Maryland was the only state in the region that included black liquor as an eligible Tier 1 resource besides Pennsylvania, where black liquor facilities must be located in-state to qualify. The only facility in Maryland that had generated RECs from black liquor, Luke Mill in Allegany County, closed in 2019. Black liquor historically has been a significant source of Tier 1 RECs, although that share has declined in recent years. In 2008, black liquor met 38% of the Tier 1 requirements.[102]; that portion dropped to 13.3% by 2022.[103]

Tier 1 Carve-out for Geothermal

Geothermal has been an eligible technology for the Maryland RPS since 2012 and accounted for 2,888 RECs in 2020. In 2021, HB 1007 created a carve-out for post-2022 geothermal systems in Tier 1 of Maryland's RPS, beginning in 2023 at 0.05% and increasing each year until reaching 1.0% in 2028. The definition of

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[100] Five million MWh is about 1,400 MW of offshore wind, assuming a 40% capacity factor.

[101] Stephen M. Ross, Maryland Department of Legislative Services, *Fiscal and Policy Note: Offshore Wind Energy - State Goals and Procurement (Promoting Offshore Wind Energy Resources Act)*, April 28, 2023. mgaleg.maryland.gov/2023RS/fnotes/bil_0001/sb0781.pdf.

[102] Maryland Public Service Commission, *Renewable Energy Portfolio Standard Report of 2010 With Data for 2008*. February 2010. psc.state.md.us/wp-content/uploads/MD-RPS-2010-Annual-Report.pdf.

[103] Maryland Public Service Commission, *Renewable Energy Portfolio Standard Report With Data for Calendar Year 2022*. November 2023. psc.state.md.us/wp-content/uploads/CY22-RPS-Annual-Report_Final-w-Corrected-Appdx-A.pdf.

"geothermal heating and cooling system" was changed to no longer require that the system replace inefficient heating or cooling systems. At least 25% of the required geothermal carve-out must be from systems installed at low- or moderate-income (LMI) single- or multi-family housing units, or institutions that primarily serve LMI individuals and families. A post-2022 geothermal system with a 360,000-Btu (British thermal unit) capacity is eligible for the Maryland RPS only if the geothermal company provides sustainable wages; health care; career advancement training;[104] a retirement plan; paid time off; workers' compensation and unemployment insurance; and the right for employees to bargain collectively. As of 2022, 719 facilities produced 21,131 geothermal RECs, marking an initial increase even before implementation of the carve-out.[105] Because of the small size of these systems, total geothermal output represents less than 1% of Tier 1 RECs retired for compliance with Maryland's Tier 1 non-carve-out requirement in any given year.

Tier 2

The Tier 2 requirement first ended at the conclusion of 2018 but was restored by CEJA until the end of 2020, at which time the Tier 2 requirement expired again. SB 65, enacted in 2021, made the Tier 2 requirement permanent as of October 1, 2021, bringing the total Maryland RPS requirement to 52.5%. Hydro facilities operating before January 1, 2004, other than pumped storage hydro, remain the only eligible technology. As before, the ACP for Tier 2 remains at $15, and RECs from Tier 1 sources can be used to meet the Tier 2 requirement. Only one facility in Maryland is registered as a Tier 2 facility: the Conowingo Dam hydro plant. As a result, the majority of Tier 2 RECs originate from out of state. In 2022, about 97% of Tier 2 RECs came from North Carolina, Virginia, West Virginia and Tennessee, with Tier 2 RECs originating from Maryland comprising 3%.[106] Tier 2 REC prices have risen sharply since 2020, from $1.06 in 2020 to $7.42 in 2022.[107]

Update on Changes to the Maryland RPS Made Before 2019

In 2008, generation was required to be either within PJM or in a control area that is adjacent to the PJM region if the electricity accompanying the RECs is delivered into the PJM region. **Figure B-3** shows the origin of Tier 1 RECs retired for the Maryland RPS compliance over time. As of 2022, the amount of Tier 1 RECs from outside PJM was nearly 0%. Historically, many of the RECs from outside PJM came from wind and hydro resources. As shown in **Figure B-4**, the share of Tier 1 RECs from these resources and outside of PJM reached 0% in 2022 even as wind and hydro RECs continue to support a large share of Tier 1 non-carve out compliance.

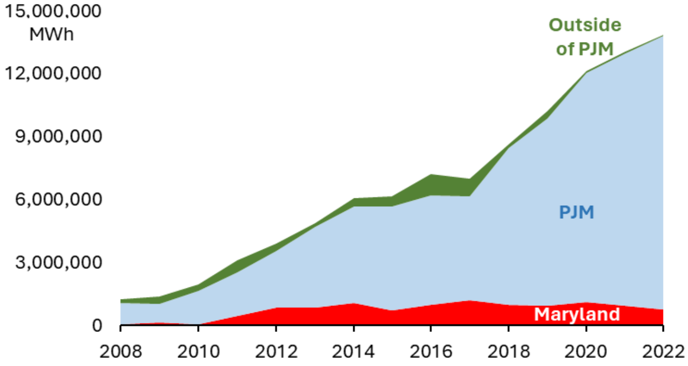

Figure B-3. Origin of Tier 1 RECs Retired for Maryland RPS Compliance

Source: RPS Retired Certificates for Reporting Year.

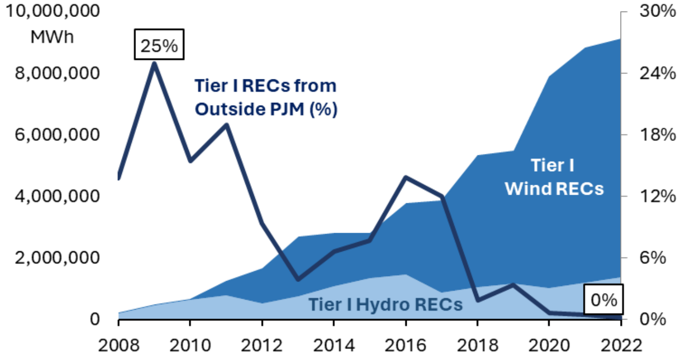

Figure B-4. Tier 1 Hydro and Wind RECs Retired by Plants Outside of PJM States

Source: RPS Retired Certificates for Reporting Year.

Other Maryland Policies Affecting the Maryland RPS

Net Metering

The enactment of HB 569 in 2021 increased Maryland's net metering cap from 1,500 MW to 3,000 MW. As of June 30, 2023, net metering capacity in Maryland was 1.022 GW. Solar represented the vast majority of that capacity at just over 1 GW.[108]

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[104] A minimum of 10% of employees working on a qualifying geothermal installation under this section must be enrolled with a state or federally approved apprenticeship program.

[105] Maryland Public Service Commission, *Renewable Energy Portfolio Standard Report With Data for Calendar Year 2022*, November 2023. psc.state.md.us/wp-content/uploads/CY22-RPS-Annual-Report_Final-w-Corrected-Appdx-A.pdf.

[106] Ibid.

[107] Ibid.

[108] Maryland Public Service Commission, *Report on the Status of Net Energy Metering in Maryland*, November 1, 2023. psc.state.md.us/wp-content/uploads/2023-Net-Metering-Report.pdf.

Community Solar

Maryland has 113 MW of community solar in operation as of June 30, 2023. Another 583 MW has been offered to utilities, and 426 MW of that has been accepted.[109] In 2023, HB 908 made Maryland's community solar pilot program, established in 2015 and slated to expire at the end of 2024, permanent. HB 908 also requires community solar projects to dedicate 40% of output to LMI subscribers and removes the cap of 418 MW in favor of the net metering cap of 3,000 MW.[110,111] Finally, HB 908 expands eligible areas for development of multiple community solar systems on contiguous land parcels to include industrial zones, parking lots, brownfields, building rooftops, or airports, as long as total capacity is less than 5 MW.

Co-located Solar

Enacted in 2023, HB 1188 exempts co-located solar facilities from the CPCN process in Maryland if individual solar facilities are less than 2 MW and aggregate co-located solar capacity is no more than 14 MW.[112]

Energy Storage Target

Although not directly tied to the Maryland RPS, the Maryland General Assembly in 2023 enacted a target for the cost-effective deployment of energy storage of 750 MW by 2027; 1,500 MW by 2030; and 3,000 MW by 2033. The Maryland PSC is required to create the Maryland Energy Storage Program by July 1, 2025, to design competitive procurement mechanisms and to reduce the energy storage target if the specified target is not cost-effective.[113]

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[109] Ibid.

[110] Maryland Public Service Commission, "Community Solar Pilot Program." psc.state.md.us/electricity/community-solar-pilot-program/. Accessed August 25, 2023.

[111] Stephen M. Ross, Maryland Department of Legislative Services, *Fiscal and Policy Note: Electricity - Community Solar Energy Generating Systems Program and Property Taxes*. April 12, 2023. mgaleg.maryland.gov/2023RS/fnotes/bil_0008/hb0908.pdf.

[112] Chapter 460, *An Act Concerning Public Utilities – Certificate of Public Convenience and Necessity and Meter Aggregation*. May 8, 2023. mgaleg.maryland.gov/2023RS/chapters_noln/Ch_460_hb1188E.pdf.

[113] Stephen M. Ross, Maryland Department of Legislative Services, *Energy Storage - Targets and Maryland Energy Storage Program - Establishment*, Fiscal and Policy Note on House Bill 910. April 12, 2023. mgaleg.maryland.gov/2023RS/fnotes/bil_0000/hb0910.pdf.

APPENDIX C. Experience with the Maryland RPS to Date

The following text further explains how Maryland LSEs comply with the Maryland RPS and the ways that in-state Maryland generators contribute to RPS compliance both in Maryland and elsewhere in PJM. This analysis updates previous discussion included in the 2019 RPS Report.

Location

The Maryland RPS requires that eligible generation either be (1) located within PJM; or (2) in a control area that is adjacent to the PJM region if the electricity accompanying the RECs is delivered into the PJM region. As is also the case in most PJM states, Maryland RPS-eligible RECs can be traded or transacted until notice that the REC is retired is provided to PJM-GATS, the system used to register RPS-eligible facilities and track RECs. At that point, RECs can no longer be transferred to other parties. LSEs then submit RPS compliance reports to the Maryland PSC that indicate the number of RECs that have been retired for purposes of complying with the Maryland RPS.

Since the inception of the Maryland RPS, most compliance requirements have been met by RECs from out-of-state resources. This share has remained relatively flat since 2011 despite growth in the overall number of RECs retired, as shown in **Figure C-1**. According to the Maryland PSC's most recent *Renewable Energy Portfolio Standard Report*, about 84% of the Maryland RPS is met through out-of-state resources as of 2022.[114]

RPS Tier 1 Non-Carve-out Fuel Mix

Maryland relies on six primary fuel sources (wind, black liquor, hydro, wood/biomass, MSW, and LFG) to meet the Tier 1 non-carve-out portion of its RPS. Of these resources, wind has experienced the largest increases over the last decade in terms of percentage share of RPS compliance, as shown in **Figure C-2**. As discussed in Appendix F, Maryland is among a select few PJM states that accept MSW, LFG, and/or black liquor RECs as eligible resources for any portion of their RPS.[115]

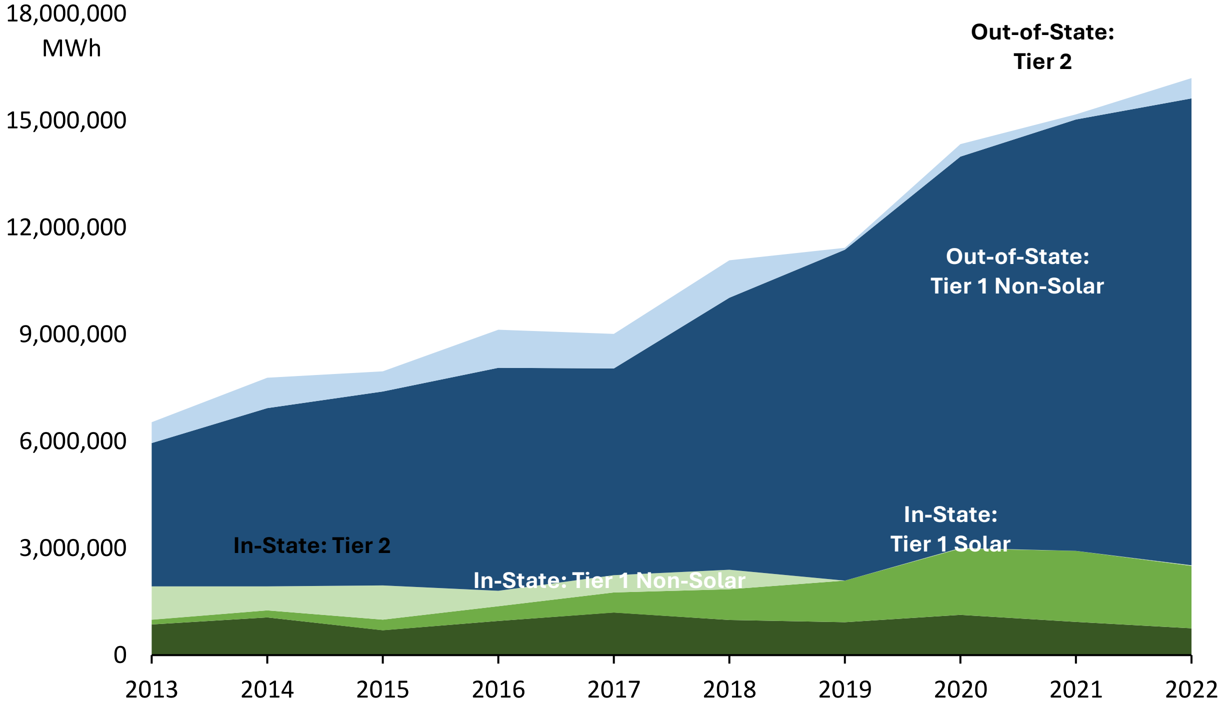

Figure C-1. Maryland REC Retirement, by Location and RPS Category

Source: Maryland PSC *Renewable Energy Portfolio Standard Reports*.

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[114] Maryland Public Service Commission, *Renewable Energy Portfolio Standard Report*, November 2023. psc.state.md.us/wp-content/uploads/CY22-RPS-Annual-Report_Final-w-Corrected-Appdx-A.pdf.

[115] Maryland SB 65 in 2021 (Ch. 673) eliminated black liquor as an eligible RPS resource. However, certain resources remain eligible due to grandfathered contractual arrangements.

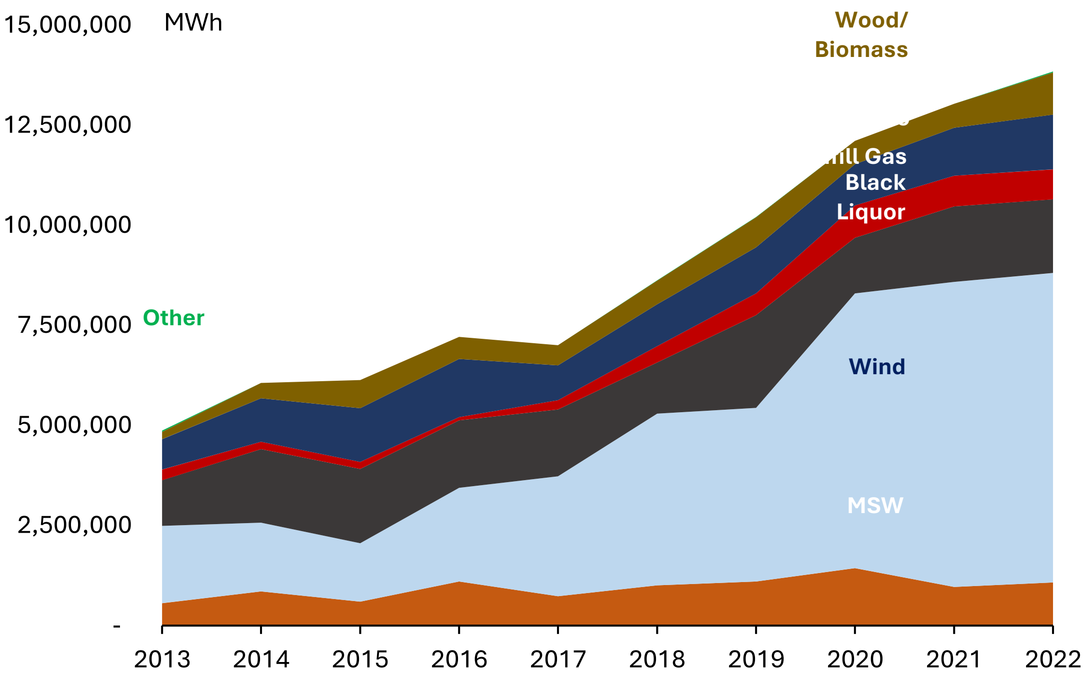

Figure C-2. RECs Retired for Tier 1 Non-Carve-out Maryland RPS Compliance, by Fuel Source

Source: PJM-GATS (December 19, 2023).

In-State Maryland Generation and RPS Policies

Maryland also benefits from other PJM state RPS policies to the extent that RECs from generation in Maryland are retired in support of another state's requirements. **Figure C-3** illustrates REC generation in Maryland by the vintage year that the REC was created and by its specific usage.[116] In most years, a large amount of RECs generated in Maryland are banked.[117] However, as shown in **Figure C-3**, approximately 20% of in-state RECs were retired for other state RPS policies in 2022, the second highest level in the last decade. The largest source of banked RECs in Maryland is hydro. Most in-state RECs retired for the Maryland RPS, meanwhile, are from solar generation and used for the solar carve-out. **Figure C-3** also includes the total number of RECs retired for the Maryland RPS over time, which shows that Maryland generated enough RECs to meet a large share of its RPS requirement in the early years of the RPS, especially when the Tier 2 requirement was equal to or in excess of the Tier 1 requirement. In-state REC generation, however, has not kept pace with recent increases in the Maryland RPS. **Figure C-4** shows the composition of all in-state RECs by resource type. Solar generation has increased the most in recent years, which is consistent with the increasing solar carve-out.

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[116] The categories displayed in **Figure C-3** are defined as follows: "Used for MD RPS" reflects RECs created in a given year and used for Maryland RPS compliance in that same year. "Used for Other RPS" includes RECs created in a given year and then sold into other state RPS markets that same year, inclusive of voluntary markets. "Banked," which is labeled as "Available" by PJM-GATS beginning in the 2015 reporting year, means that a REC created in a given year was not yet retired in that given year and is still available for usage in subsequent years. (Note that the reported "Banked" category is not cumulative despite RECs being available for multiple years.) "Other" encompasses several categories, including "Bulletin Board," "Pending Transfer," and/or "Active," that are generally small applications of RECs.

[117] A REC generated in one year may be used to satisfy the RPS requirement in that same year, the following (second) year, or the third year. In other words, Maryland allows RECs to be "banked," or saved, for up to three years.

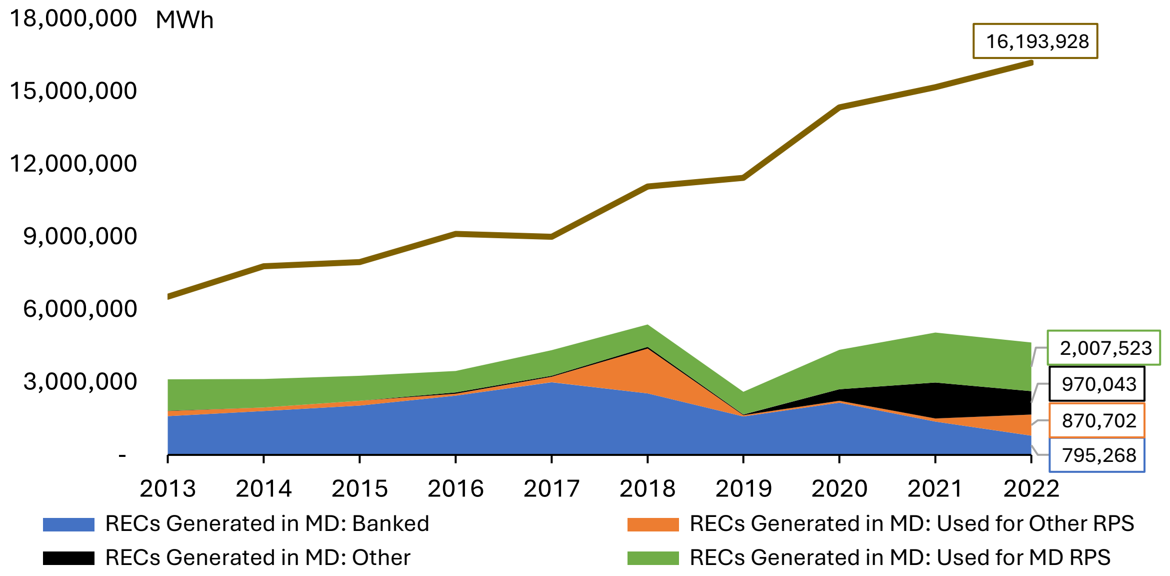

Figure C-3. Maryland REC Generation and Retirement, by Usage

Source: Maryland PSC *Renewable Energy Portfolio Standard Reports*. Note that the decrease of in-state RECs in 2019 corresponds with a brief lapse in Maryland's Tier 2 requirement.

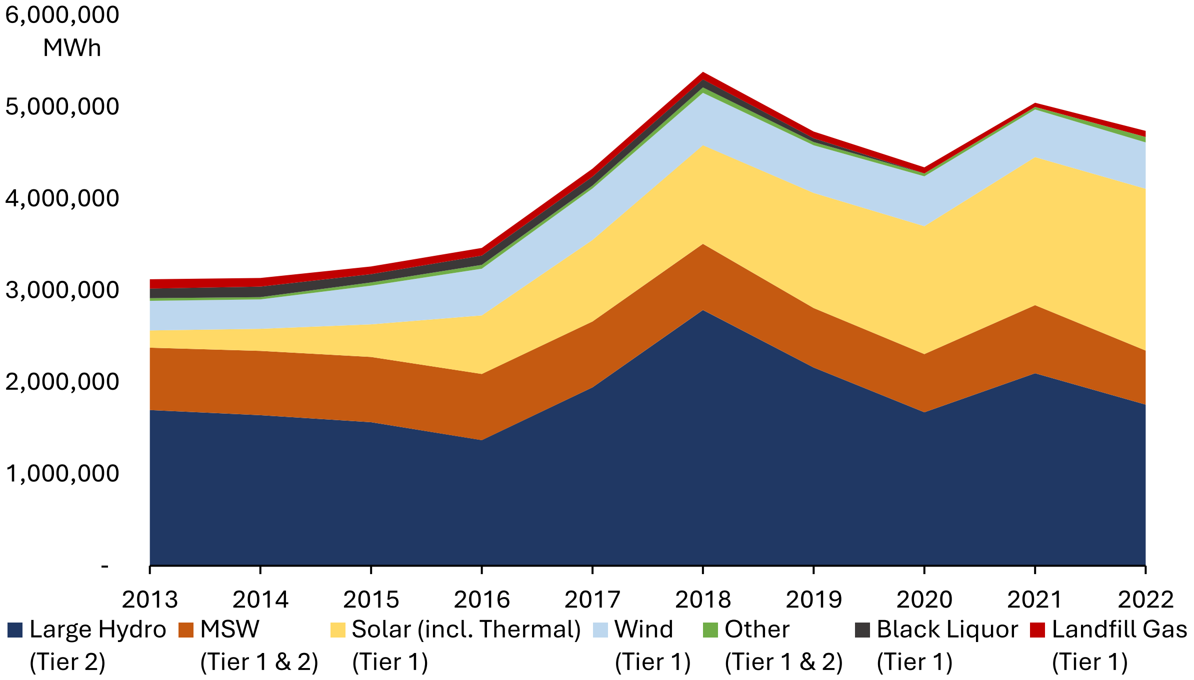

Figure C-4. Maryland In-State RECs, by Fuel Source

Source: Maryland PSC *Renewable Energy Portfolio Standard Reports*.

Alternative Compliance Payments and Renewable Energy Credit Prices

Figure C-5 and **Figure C-6** identify the non-carve-out (Tiers 1 and 2, not including OREC requirements) and solar carve-out ACP levels in Maryland, respectively. LSEs may request from the Maryland PSC a one-year delay from complying with the solar carve-out of the Maryland RPS if the cost of purchasing SRECs is equal to or exceeds 6% of the LSE's total annual retail electricity sales revenue in Maryland. Qualified Industrial Process Loads (IPL) are eligible for a reduced ACP of $2.00 in place of solar and Tier 1 non-carve-out RECs.[118]

Figure C-5 and **Figure C-6** also show average historical non-carve-out and solar carve-out REC prices and recent forward prices. Historically, REC prices were lower than the corresponding ACP. In recent years, however, the prices have converged. Notably, ACPs increased to $77.1 million in 2021 and $86.6 million in 2022, compared to $67,790, $7.7 million, and $52,240 in 2020, 2019, and 2018, respectively. Most ACPs were paid in lieu of SRECs.

An RPS or CES facilitates the growth of renewable energy supply by creating demand for renewable energy. REC prices increase if there is a shortfall of RECs necessary to meet state RPS requirements, and an increase in REC prices can induce development of new renewable energy capacity, the importing of RECs from outside the state or region, or both. A similar process applies to CERCs. REC or CERC payments complement other sources of revenue, such as energy and capacity market payments, and help offset generator expenses, including capital costs and ongoing O&M costs.

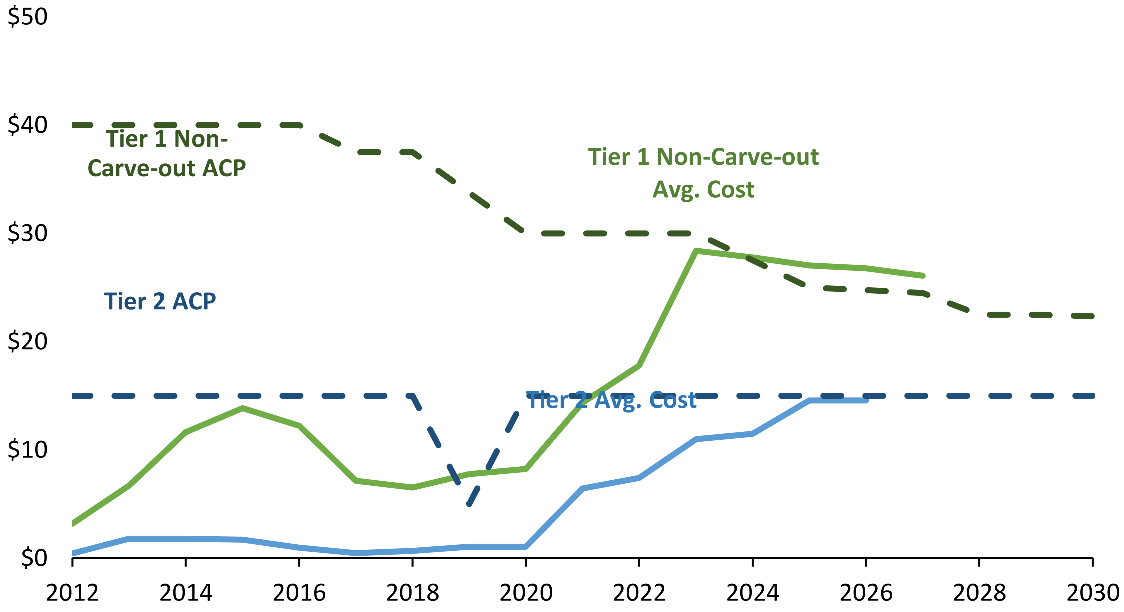

Figure C-5. Maryland Tier 1 Non-Carve-out and Tier 2 Average Cost of RECs Compared to Alternative Compliance Payment Costs

Source: Average costs for 2012-2022 sourced from the Maryland PSC 2022 *Renewable Energy Portfolio Standard Report*. Average costs for 2023-2027 sourced from S&P Commodity Pricing.

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[118] Almost all eligible IPL customers avail themselves of the ACP option. For modeling purposes, the IPL forecasted loads were reduced by 2.14% to account for industrial exemption from the RPS requirements. This percentage is the average amount of IPL load from 2016-2020.

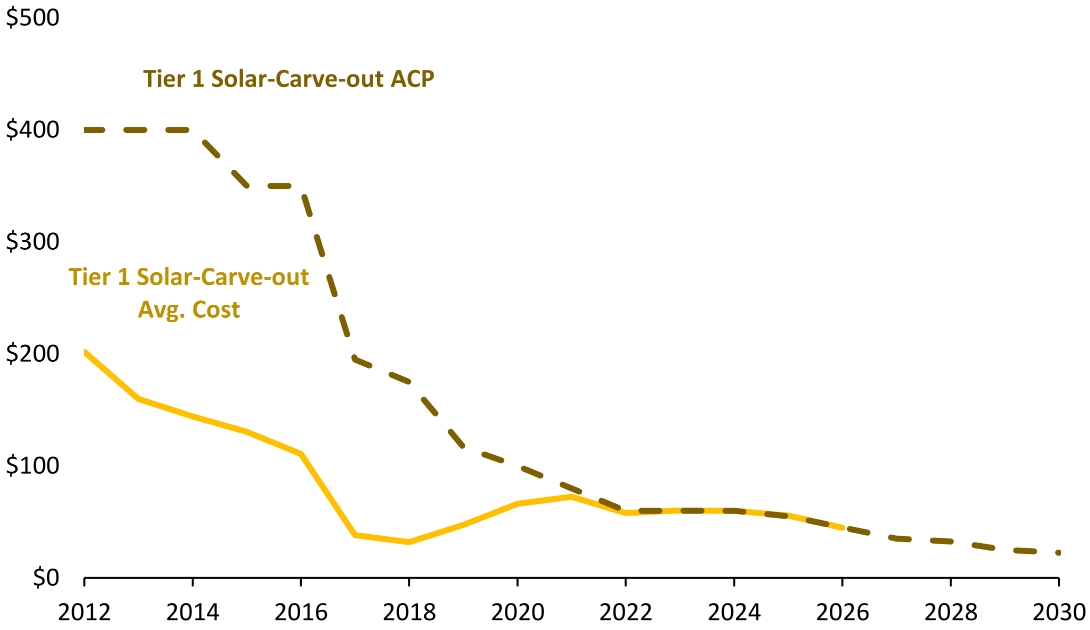

Figure C-6. Maryland Tier 1 Solar Carve-out Average Cost of RECs Compared to Alternative Compliance Payment Costs

Source: Average costs for 2012-2022 sourced from the Maryland PSC 2022 *Renewable Energy Portfolio Standard Report*. Average costs for 2023-2026 sourced from S&P Commodity Pricing.

APPENDIX D. WIS:dom-P Model Setup [see separately attached file]

APPENDIX E. IMPLAN Model

For this study, Exeter relied upon the same approach developed in the 2019 RPS Report. This choice reflects Exeter's evaluation that critical assumptions regarding impacted industries and in-state final demand estimates have not significantly changed between the two reports. **Figure E-1** summarizes the essential IMPLAN modeling process used by Exeter. Please see Section 3.4.1 of the 2019 RPS Report for further detailed breakdown and discussion of the methodology used in both reports. Note that IMPLAN has updated its aggregated industry list since the 2019 RPS Report to "IMPLAN 546." Additionally, the IMPLAN database applied to this report uses the 2022 economy as the base data for estimating economic impacts, and therefore may capture unique effects from the Covid-19 pandemic and subsequent recovery.

Approach

This study used IMPLAN to model the economic impacts from construction and operation of seven different resource technologies: utility-scale PV (UPV); distributed PV (DPV), representative of the sum of rooftop PV and community PV; utility-scale energy storage (UES); distributed energy storage (DES); onshore wind (wind); offshore wind (OSW); and ground source heat pumps (GSHP).

Annual forecasted installed capacities were developed for the 2025-2040 period across six separate scenarios: 100% RPS-1, 100% Clean-1, 100% RPS-2, 100% RPS Max-2, 100% Clean High Electric-2, and 100% RPS High Electric-2.

Using a bill-of-goods approach, annual OCC and O&M costs were broken down by IMPLAN 546 industry type. The breakdowns relied heavily on previously published benchmarking reports from NREL and various other industry documents. Once the industry cost proportions were developed, a final demand estimate was created by determining the proportion of each industry anticipated to be directly tied to in-state production. This final demand estimate relied heavily on the 2019 RPS Report for the PV and OSW technologies, whereas for the newly modeled technologies (wind, energy storage, and GSHP), estimates were based on IMPLAN's industry-employment data and reasonable deductions based on anecdotal evidence and various industry reports.

The resulting final demand estimates per industry were applied to the total construction and O&M costs for the 2025-2040 period. Annual costs were estimated per technology using forecasted OCC and fixed O&M costs from NREL's ATB (2023 edition). The ATB develops costs for several sensitivities. Exeter utilized NREL's middle-of-the-road scenarios, including the moderate technology development, market, and 30-year cost recovery period scenarios. Annual construction costs were based on the forecasted installed capacity per year (incremental), whereas the annual O&M costs were based on the aggregate fleet capacity including the year estimated (cumulative).

Note that forecasts over large time periods are inherently susceptible to estimation error, especially in the latter years of the forecast period. IMPLAN cautions that the maximum forecast period, using its I-O model, is five years. IMPLAN relies upon industry interactions (multipliers) set during a specific year; thus the further one forecasts away from the base year of the model, the higher the probability that the economic multipliers will significantly change and therefore lose reliability.

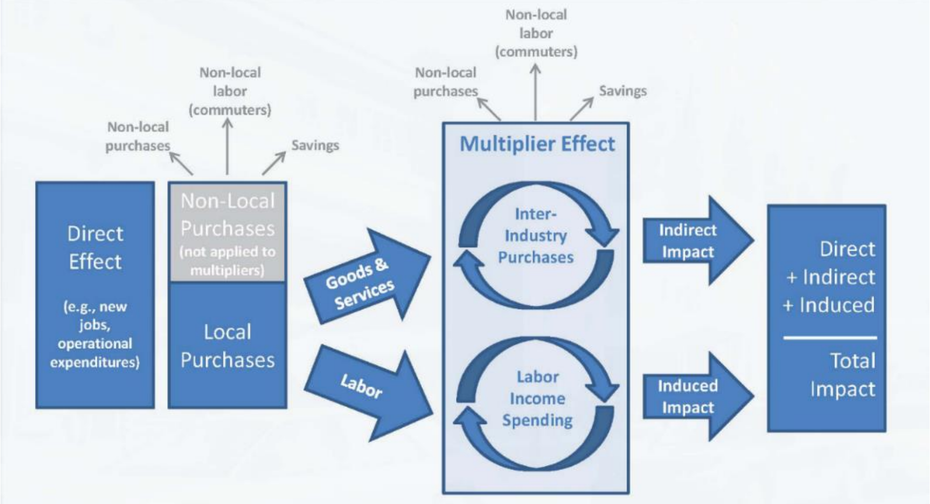

Figure E-1. Impact of a Change in Spending in an Input-Output Model

Source: Adapted from AKRF Inc., North Bergen Liberty Generating, LLC: *Economic and Fiscal Analysis*, August 2017, documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={CF578449-B169-4EAF-9661-BE1A91A35A3B} (webpage now cached).

Assumptions

Table E-1 through **Table E-12** provide the final demand estimates per technology and category (OCC versus O&M).

Table E-1. Utility-Scale PV and Distributed PV Overnight Capital Costs Apportioning

NREL Category	IMPLAN 546 Sector	UPV Cost ($/kW)	% of Total UPV OCC Costs	UPV In-State Attribution	UPV Maryland Final Demand	DPV Cost ($/kW)	% of Total DPV OCC Costs	DPV In-State Attribution	DPV Maryland Final Demand
Install Labor & Equipment, Developer Net Profit	Construction of new power and communication structures	$0.16	18%	100.00%	18.17%	$0.29	17%	100.00%	16.83%
Total Construction		**$0.16**	**18%**			**$0.29**	**17%**		
Module	Semiconductor and related device manufacturing	$0.34	39%	0.00%	0.00%	$0.43	25%	0.00%	0.00%
Inverter	Power, distribution, and specialty transformer manufacturing	$0.04	5%	0.00%	0.00%	$0.06	3%	0.00%	0.00%
Structural BOS	Fabricated structural metal manufacturing	$0.13	15%	0.00%	0.00%	$0.13	8%	2.00%	0.15%
Electrical BOS	Other communication and energy wire manufacturing	$0.08	10%	0.00%	0.00%	$0.29	17%	2.00%	0.33%
Total Manufacturing		**$0.60**	**69%**			**$0.90**	**53%**		
Engineering, Procurement, and Construction (EPC) Overhead, Developer Overhead	Architectural, engineering, and related services	$0.07	8%	100.00%	8.30%	$0.47	27%	100.00%	27.50%
Land Acquisition; Permitting, Inspection and Interconnection (PII); Permitting Fee; Transmission Line	Legal Services	$0.04	5%	100.00%	4.64%	$0.05	3%	100.00%	2.79%
Total Services		**$0.11**	**13%**			**$0.52**	**30%**		
TOTAL		**$0.86**	**100%**	**42.9%**	**31.11%**	**$1.71**	**100%**	**43.4%**	**47.60%**

Note: Contingency costs are applied proportionally to all manufacturing industries.

Table E-2. Utility-Scale PV and Distributed PV Operations and Maintenance Costs Apportioning									
NREL Category	IMPLAN 546 Sector	UPV Cost ($/kW)	% of Total UPV OCC Costs	UPV In-State Attribution	UPV Maryland Final Demand	DPV Cost ($/kW)	% of Total DPV OCC Costs	DPV In-State Attribution	DPV Maryland Final Demand
Administrator/ Asset Mgmt/ Security	Office and administrative services	$1.84	11%	100.00%	11.44%	$2.34	14%	100.00%	13.61%
Pest/Vegetation	Landscape & horticultural services	$0.58	4%	100.00%	3.60%	$0.67	4%	100.00%	3.90%
Cleaner	Services to buildings	$1.80	11%	100.00%	11.15%	$2.08	12%	100.00%	12.12%
Inspector	Architectural, engineering, and related services	$1.76	11%	100.00%	10.92%	$2.16	13%	100.00%	12.58%
Land Lease/ Insurance	Other real estate	$5.77	36%	100.00%	35.83%	$7.72	45%	100.00%	44.85%
Hardware Replacement	C&I machinery and equipment repair and maintenance	$4.36	27%	0.00%	0.00%	$2.23	13%	**0.00%**	0.00%
TOTAL		**$16.11**	**100%**	**83.3%**	**72.95%**	**$17.21**	**100%**	**83.3%**	**87.06%**

Note: Property Tax has been allocated to the Land Lease cost category and Hardware Replacement has been excluded (covered by warranties) by assigning an in-state apportion of 0%, which is likely the correct final demand proportion as well. UPV and DPV apportions relied on 2019 RPS Report breakdowns to inform industry selection.

Table E-3. Utility-Scale Energy Storage Overnight Capital Costs Apportioning					
NREL Category	IMPLAN 546 Sector	Cost ($/kW)	% of Total OCC Costs	In-State Attribution	Maryland Final Demand
Developer Cost (PII; Contingency; Profit, Overhead; and Engineering, Procurement, and Construction [EPC] Overhead)	Architectural, engineering, and related services	$240.73	15.3%	100.0%	15.3%
Installation Labor & Equipment	Construction of new power and communication structures	$48.72	3.1%	100.0%	3.1%
Total Construction		**$289.45**	**18.4%**		
Electrical BOS	Other communication and energy wire manufacturing	$187.81	11.9%	0.5%	0.1%
Structural BOS	Fabricated structural metal manufacturing	$15.06	1.0%	0.5%	0.0%
Battery Inverter	Power, distribution, and specialty transformer manufacturing	$102.83	6.5%	0.0%	0.0%
Lithium-ion Battery Cabinet	Storage battery manufacturing	$954.06	60.6%	0.0%	0.0%
Total Manufacturing		**$1,259.75**	**80.0%**		
Permitting, Inspection and Interconnection (PII)	Legal services	$25.83	1.6%	100.0%	1.6%
Total Services		**$25.83**	**1.6%**		
TOTAL		**$1,575.02**	**100%**	**43.0%**	**20.1%**

Note: Sales tax is applied proportionally to all manufacturing industries. Based on a standalone utility-scale Li-ion battery storage system (60 MW - 240 MWh).

Table E-4. Utility-Scale Energy Storage Operations and Maintenance Costs Apportioning				
NREL Category	IMPLAN 546 Sector	% of Total O&M Costs	In-State Attribution	Maryland Final Demand
Administrator/Asset Management/Security	Office and administrative services	9.0%	100.0%	9.0%
Land Lease/Property Tax	Other real estate	14.0%	100.0%	14.0%
Insurance	Insurance agencies, brokerages, and related activities	12.0%	100.0%	12.0%
Scheduled/Unscheduled Maintenance	C&I machinery and equipment repair and maintenance	25.0%	100.0%	25.0%
Battery Augmentation/System Inspection Monitoring	Architectural, engineering, and related services	40.0%	100.0%	40.0%
TOTAL		**100.0%**	**100%**	**100.0%**

Note: Contingency costs are allocated proportionally across all other cost categories.

Table E-5. Distributed Energy Storage Overnight Capital Costs Apportioning					
NREL Category	IMPLAN 546 Sector	Cost ($/kW)	% of Total OCC Costs	In-State Attribution	Maryland Final Demand
Developer Cost (Profit, Overhead, Engineering)	Architectural, engineering, and related services	$3,961.00	21.1%	100.0%	21.1%
Install Labor	Construction of new power and communication structures	$1,081.00	5.8%	100.0%	5.8%
Total Construction		**$5,042.00**	**26.8%**		
BOS	Other communication and energy wire manufacturing	$1,751.38	9.3%	2.0%	0.2%
Battery Inverter	Fabricated structural metal manufacturing	$2,563.92	13.6%	2.0%	0.3%
Battery	Power, distribution, and specialty transformer manufacturing	$3,948.70	21.0%	0.0%	0.0%
Total Manufacturing		**$8,264.00**	**44.0%**		
Permitting Inspection Interconnection (PII)	Legal services	$1,633.00	8.7%	100.0%	8.7%
Sales and Marketing	Advertising, public relations, and related services	$3,851.00	20.5%	75.0%	15.4%
Total Services		**$5,484.00**	**29.2%**		
TOTAL		**$18,790.00**	**100%**	**54.1%**	**51.4%**

Note: Sales tax and Supply Chain costs are applied proportionally to all manufacturing industries. Based on a Li-ion battery storage system (5 kW - 12.5 kWh)

Table E-6. Distributed Energy Storage Operations and Maintenance Costs Apportioning				
NREL Category	IMPLAN 546 Sector	% of Total O&M Costs	In-State Attribution	Maryland Final Demand
Administrator/Asset Management/Security	Office and administrative services	5%	100%	5%
Insurance	C&I Machinery and Equipment Rental and Leasing	9%	100%	9%
Scheduled/Unscheduled Maintenance	Insurance carriers, except direct life	86%	100%	86%
TOTAL		**100%**	**100%**	**100%**

Note: Based on a Li-ion battery storage system (5 kW - 12.5 kWh). DES used a unique industry (Marketing) and Exeter assumed a portion of this industry to be sourced from out of state.

Table E-7. Onshore Wind Overnight Capital Costs Apportioning					
NREL Category	IMPLAN 546 Sector	Cost ($/kW)	% of Total OCC Costs	In-State Attribution	Maryland Final Demand
Assembly and Installation	Construction of new power and communication structures	$94.33	6%	85%	5%
Site Access, Staging, and Facilities	C&I machinery and equipment rental and leasing	$47.33	3%	100%	3%
Total Construction		**$141.67**	**9%**		
Turbine (Rotor + Nacelle)	Turbine and turbine generator set units	$729.33	44%	0%	0%
Tower	Rolled steel shape manufacturing	$250.33	15%	1%	0%
Electrical Infrastructure	Power, distribution, and specialty transformer manufacturing	$69.33	4%	0%	0%
Foundation	Fabricated structural metal manufacturing	$111.33	7%	5%	0%
Total Manufacturing		**$1,160.33**	**70%**		
Engineering and Development + Project Management	Architectural, engineering, & related services	$49.33	3%	100%	3%
Warranty	Insurance carriers, except direct life	$120.33	7%	0%	0%
Total Services		**$169.67**	**10%**		
Wind Turbine Transport	Truck transportation	$177.33	11%	100%	11%
Total Transport		**$177.33**	**11%**		
TOTAL		**$1,649.00**	**100%**	**43%**	**22%**

Note: Construction finance expenses (5.8%) have been removed to align with OCCs presented throughout this report, and contingency costs are allocated proportionally across all other cost categories.

Table E-8. Onshore Wind Operations and Maintenance Costs Apportioning					
NREL Category	IMPLAN 546 Sector	Cost ($/kW)	% of Total OCC Costs	In-State Attribution	Maryland Final Demand
Asset Management/ Contract Security	Office and administrative services	$3.36	9.5%	100.0%	9.5%
Electrical Usage/Grid	Electric power transmission and distribution	$0.96	2.7%	100.0%	2.7%
Facilities	C&I machinery and equipment rental and leasing	$2.06	5.8%	100.0%	5.8%
Insurance	Insurance carriers, except direct life	$2.66	7.5%	100.0%	7.5%
Land Lease/ Property Taxes	Other real estate	$9.26	26.2%	100.0%	26.2%
Turbine	Turbine and turbine generator set units manufacturing	$14.36	40.6%	0.0%	0.0%
Onsite Technicians	Commercial and industrial machinery and equipment repair and maintenance	$2.70	7.6%	90.0%	6.9%
TOTAL		**$35.34**	**100%**	84.3%	**58.6%**

Note: Contingency costs are allocated proportionally across all other cost categories.

Table E-9. Offshore Wind Overnight Capital Costs Apportioning

NREL Category	IMPLAN 546 Sector	Cost ($/kW)	% of Total OCC Costs	In-State Attribution	Maryland Final Demand (Scaled)[1]
Assembly and Installation	Construction of new power and communication structures	$275.00	6.2%	80.0%	5.1%
Total Construction		**$275.00**	**6.2%**		
Turbine	Turbine and turbine generator set units	$1,288.31	29.0%	0.0%	0.0%
Electrical Infrastructure	Power, distribution, and specialty transformer manufacturing	$1,073.00	24.1%	0.0%	0.0%
Tower	Rolled steel shape manufacturing	$503.69	11.3%	13.0%	1.5%
Substructure Foundation	Fabricated structural metal manufacturing	$655.00	14.7%	15.0%	2.3%
Total Manufacturing		**$3,520.00**	**79.1%**		
Engineering, Management, Development	Architectural, engineering, & related services	$144.00	3.2%	100.0%	3.3%
Decommissioning & Plant Commissioning	Legal services	$206.00	4.6%	100.0%	4.7%
Construction Insurance	Insurance carriers, except direct life	$90.00	2.0%	10.0%	2.1%
Lease	Other real estate	$213.00	4.8%	100.0%	4.9%
Total Services		**$653.00**	**14.7%**		
TOTAL		**$4,448.00**	**100%**	**46.4%**	**23.9%**

Note: Construction finance expenses (4.1%) have been removed to align with OCCs presented throughout this report, and contingency costs are allocated proportionally across all other cost categories. Note that OSW relied on 2019 RPS Report assumptions regarding in-state manufacturing commitments, thus estimates are conservative.

[1] Final demand has been scaled using the MW-weighted average of the previous manufacturing commitments made by the Skipjack and US Wind projects (as used in the 2019 50% Study).

Table E-10. Offshore Wind Operations and Maintenance Costs Apportioning

NREL Category	IMPLAN 546 Sector	% of Total OCC Costs	In-State Attribution	Maryland Final Demand	Scaled Final Demand[1]
Transportation, Communication, and Public Utilities (TCPU)	Water transport	23.0%	100.0%	23.0%	14.7%
Construction	C&I machinery and equipment repair and maintenance	7.4%	100.0%	7.4%	4.7%
Machinery (Corrective Maintenance Parts)	Turbine & turbine generator set units manufacturing	53.3%	0.0%	0.0%	0.0%
Misc. Services	C&I machinery and equipment rental and leasing	11.5%	100.0%	11.5%	7.4%
Machinery	Other engine and equipment manufacturing	4.9%	100.0%	4.9%	3.2%
TOTAL		**100.0%**	**80%**	**46.7%**	**30.0%**

Note: Contingency costs are allocated proportionally across all other cost categories. Note that only two of the six scenarios modeled in IMPLAN built GSHP greater than 0 MW.

[1] Final demand has been scaled using the MW-weighted average of the previous manufacturing commitments made by the Skipjack and US Wind projects (as used in the 2019 50% Study).

Table E-11. Ground Source Heat Pump Overnight Capital Costs Apportioning

Industry Category	IMPLAN 546 Sector	Cost ($/kW)	% of Total OCC Costs	In-State Attribution	Maryland Final Demand
Installation	Construction of other new residential structures	$514.29	29.9%	100.0%	29.9%
Total Construction		**$514.29**	**29.9%**		
Heat Pump	Air conditioning, refrigeration, and warm air heating equipment manufacturing	$714.29	41.5%	5.0%	2.1%
Piping	Plastics pipe and pipe fitting manufacturing	$171.43	10.0%	0.0%	0.0%
Total Manufacturing		**$885.71**	**51.5%**		
Engineering/Permitting	Architectural, engineering, & related services	$142.86	8.3%	100.0%	8.3%
Lawncare	Landscape & horticultural services	$178.57	10.4%	100.0%	10.4%
Total Services		**$321.43**	**18.7%**		
TOTAL		**$1,721.43**	**100%**	**61.0%**	**50.6%**

Note: Cost estimates are based on a 4-ton (14-kW) GSHP system.

Table E-12. Ground Source Heat Pump Operations and Maintenance Costs Apportioning

Industry Category	IMPLAN Sector 546	Cost ($/kW)	% of Total OCC Costs	In-State Attribution	Maryland Final Demand
Air-Conditioner, Window, Repair and Maintenance Services (Annual checkup)	Personal and household goods repair and maintenance	$14.29	100.0%	100.0%	100.0%
TOTAL		**$14.29**	**100%**	100.0%	**100.0%**

Note: Cost estimates are based on a 4-ton (14-kW) residential system.

Key Resources and References

- All Technologies
  - NREL 2023 Annual Technology Baseline. atb.nrel.gov/electricity/2023/index
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APPENDIX F. Excluding Certain Technologies from the Maryland RPS

This section addresses whether there are enough eligible resources to meet both current and potentially higher Maryland RPS requirements, and whether it is possible to reach these targets if certain technologies are no longer eligible for the Maryland RPS. As discussed in the 2019 RPS Report, the primary effect of decreasing resource availability (either in terms of quantity of eligible RECs per resource or diversity of eligible resources) is that REC prices increase. This increase in REC prices is capped by the ACP. The following section updates the 2019 RPS Report analysis with 2022 data, the most recent year available from the Maryland PSC. Key findings from this analysis include:

- Maryland has access to a large pool of resources that produce Maryland RPS eligible RECs. In 2022, Maryland RPS eligible resources generated 46.3 million RECs compared to the 16.2 million RECs demanded in Maryland that same year. PJM resources generated 81.5 million RECs eligible to serve RPS requirements in Maryland and elsewhere. High levels of REC availability, similarities in state RPS policies, and the interchangeability of RECs all help to moderate the price and compliance impacts of any one state's RPS policy changes.
- Nearly half (48%) of RECs retired in Maryland were sourced from land-based wind in 2022, with 99% of these RECs coming from out-of-state wind resources. Together, MSW, land-based wind, and hydro, comprised nearly 67% of the Tier 1 RECs used to comply with the Maryland RPS in 2022. Under current conditions, as non-carve-out Tier 1 REC supply exceeds demand, excluding any one of these resources from the Maryland RPS is expected to have minimal effect on Maryland's ability to meet future targets. Likewise, eliminating small hydro or MSW also would not substantially alter compliance.
- As of October 1, 2021, black liquor is no longer an eligible resource for the Maryland RPS besides resources committed through existing contracts. The exclusion of black liquor will put short-term upward pressure on Tier 1 non-carve-out REC prices as existing contracts expire, but will not affect Maryland's ability to meet its RPS requirements.

These findings are sensitive to Exeter's assumptions regarding REC availability. Notably, the surplus of available RECs identified in the 2019 RPS Report has diminished due to shifts in policy, economic, and regulatory conditions, including interconnection queue constraints and challenging macroeconomic conditions such as higher interest rates and supply chain challenges. Continued resource development challenges have the potential to reduce the pool of RECs available to meet future RPS requirements in PJM states and, as a result, impact REC prices.

Maryland's Position in the PJM REC Market

In 2022, of the almost 97 million RECs available in PJM, approximately 39% of Tier 1 non-carve-out RECs and 7.1% of Tier 2 RECs were eligible to meet Maryland RPS requirements, as shown in **Table F-1**. Of these eligible RECs, only 14.4 million RECs, or 36.8% and 8.6%, respectively, of Maryland eligible Tier 1 non-carve-out RECs and Tier 2 RECs, were used to satisfy Maryland RPS requirements. This breaks out into 13.8 million Tier 1 non-carve-out RECs and about 590,000 Tier 2 RECs. For SRECs, 99% of Maryland-eligible SRECs were used to meet the solar carve-out of the Maryland RPS.

The total number of RECs retired for the Maryland RPS has increased 48% since 2018, with Tier 1 non-carve-out and Tier 1 SREC retirements increasing 63% and 107%, respectively.[119] Over the same period, the supply of Maryland RPS eligible RECs in PJM only increased 23%, including 32% and 66% increases in RECs eligible for Maryland's Tier 1 non-carve-out and Tier 1 solar carve-out requirements, respectively. Note that Maryland's SREC requirement can only be met by solar connected to the Maryland distribution grid, and that SRECs cannot be used to meet Tier 1 non-solar carve-out requirements. A Maryland SREC supply deficiency in 2021 and 2022 resulted in the retirement of banked RECs and increased reliance on ACPs. Notably, ACPs increased to $77.1 million in 2021 and $86.6 million in 2022, compared to $67,790, $7.7 million, and $52,240 in 2020, 2019, and 2018, respectively.[120] These payments offset approximately 1.4 million RECs required by the Tier 1 solar carve-out.[121] Assuming a 19.4% average solar PV capacity factor, the ACPs offset approximately 864 MW of solar capacity.[122] This apparent deficit reflects some energy suppliers in

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[119] Over the same period, Tier 2 REC retirements decreased 63%. This is due to the temporary expiration of Tier 2 REC in 2020.

[120] Maryland Public Service Commission. Renewable Energy Portfolio Standard Report With Data for Calendar Year 2022. November 2023. psc.state.md.us/wp-content/uploads/CY22-RPS-Annual-Report_Final-w-Corrected-Appdx-A.pdf.

[121] ACP payments of $86,584,883 divided by $60 ACP equals approximately 1,443,081 RECs.

[122] The 19.4% capacity factor is based on the utility scale solar capacity factor from the Lawrence Berkley Lab Utility Scale: Project-level Performance data (emp.lbl.gov/pv-capacity-factors). The 1,443,081 RECs were converted to MW by dividing it by the product of 0.194*8760 hours.

Maryland choosing to pay the ACP in place of retiring Maryland RPS Eligible Tier 1 Solar RECs.

Despite the slower rate of growth in eligible PJM-wide REC supply relative to Maryland REC demand, Maryland requirements still comprise a moderate share of the total pool of retired RECs. Maryland REC retirements equal approximately 20% of the 72.6 million RECs retired in PJM (see **Table F-2**) in 2022, which is a slight increase compared to 18.9% of RECs retired in PJM in 2018. As described in the 2019 RPS Report, a broad range of resources are already available to provide RECs and, in the long term, the RECs market will adjust to changes in resource eligibility. See the 2019 RPS Report for further explanation.

Table F-1. RECs Certified in PJM and Maryland Compared to Maryland's REC Requirements, 2018 & 2022

	Tier 1 Non-Solar	Tier 1 Solar	Tier 2	Total
2018				
PJM RPS Eligible RECs				**83,408,686**
Maryland RPS Eligible RECs	28,485,118	1,069,550	8,074,434	**37,629,102**
% of PJM RECs	*34.2%*	*1.3%*	*9.7%*	***45.1%***
Maryland RPS Requirement	8,515,665	846,256	1,580,350	**10,942,271**
% of PJM RECs	*10.2%*	*1.0%*	*1.9%*	***13.1%***
% of MD RECs	*29.9%*	*79.1%*	*19.6%*	***29.1%***
2022				
PJM RPS Eligible RECs				**96,814,643**
Maryland RPS Eligible RECs	37,670,943	1,771,346	6,838,008	**46,280,297**
% of PJM RECs	*38.9%*	*1.8%*	*7.1%*	***47.8%***
Maryland RPS Requirement	13,849,611	1,753,987	590,330	**16,193,928**
% of PJM RECs	*14.3%*	*1.8%*	*0.6%*	***16.7%***
% of MD RECs	*36.8%*	*99.0%*	*8.6%*	***35.0%***

Source: 2022 data per PJM-GATS as of February 2024.

Table F-2. RECs Retired in PJM, by State (2018 & 2022)

	Tier 1 Solar	Non-carve-out Tier 1 and RPS Compliance[1]	Tier 2	Total	Percent Share
2018					
DC	67,893	1,684,954	112,592	**1,865,439**	3%
DE	127,452	688,582	-	**816,034**	1%
IL	76,109	4,034,884	-	**4,110,993**	7%
MD	846,256	8,515,665	1,580,350	**10,942,271**	19%
NJ	2,357,814	9,166,102	1,758,180	**13,282,096**	23%
OH	200,620	5,124,597	-	**5,325,217**	9%
PA	596,481	9,182,921	11,623,329	**21,402,731**	37%
VA	-	-	-	**-**	0%
Total[2]	**4,272,625**	**38,397,705**	**15,074,451**	**57,744,781**	**100%**
2022					
DC	263,920	3,044,447	-	**3,308,367**	4%
DE	180,791	993,249	-	**1,174,040**	1%
IL	778,341	1,826,266	-	2,604,607	3%
MD	1,753,987	13,849,611	590,330	16,193,928	20%
NJ	3,560,641	10,863,600	1,828,092	16,252,333	20%
OH	259,620	4,644,205	-	4,903,825	6%
PA	644,791	10,941,918	13,895,805	25,482,514	32%
VA	-	10,138,117	-	10,138,117	13%
Total[3]	**7,442,091**	**56,301,413**	**16,314,227**	**80,057,731**	**100%**

Source: 2022 data per PJM-GATS as of February 2024. *Note:* The "Reporting Year" for DE, IL, NJ and PA is from June 2021-May 2022. The remaining states align their reporting year with the calendar year.

[1] For purposes of this analysis, the term "Non-carve-out Tier 1" will be considered inclusive of the "RPS Compliance" category of states without a "tiers" distribution.

[2] Michigan and North Carolina have their own systems to track RECs—Michigan Renewable Certification System Public Records and North Carolina Renewable Energy Tracking System REC Issuance and Retirement, and therefore are not included.

Elasticity of Maryland REC Prices

As discussed in the 2019 RPS Report, REC supply is thought to be elastic, meaning capable of responding to price signals and re-equilibrating. Elasticity, however, can vary in the near term based on market conditions.[123] Exeter replicated its elasticity analysis from the 2019 RPS Report and identifies point elasticities of 0.10 and 0.26 from 2020-2021 and 2021-2022, respectively. These estimates indicate that prices were unresponsive to demand. For example, from 2021-2022, Tier 1 non-solar REC prices increased 24% (from $14.36 to $17.80), while REC demand only increased 6% (from 13.0 million to 13.8 million). By contrast, from 2019-2020, point elasticity was 3.09, meaning that as demand increased, prices increased. This result indicates supply did not keep up with demand, creating either a deficiency or less of a surplus that put upward pressure on prices. From 2014-2022, point elasticity is 2.43, consistent with the expectation of long-run elasticity. This relationship is illustrated in **Figure F-1**.

Figure F-1. Year-over-Year Change in Maryland Tier 1 Non-Carve-out REC Requirements and Prices

Data Source: Public Service Commission of Maryland. *Renewable Energy Portfolio Standard Report with Data for Calendar Year 2022*. psc.state.md.us/wp-content/uploads/CY22-RPS-Annual-Report_Final-w-Corrected-Appdx-A.pdf.

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[123] Point elasticities are measured respective to one (1). A measurement greater than one suggests that price is more responsive to demand (i.e., elastic), while a measurement less than one suggests it is less responsive (i.e., inelastic).

Impacts of Removing Individual Technologies from Maryland RPS

LSEs primarily met their Maryland RPS requirements in 2022 by retiring wind, solar, black liquor, hydro, and MSW RECs, as shown in **Table F-3**. RECs retired in both Maryland and PJM, by technology, are listed in **Table F-3** to show the differences in the PJM and Maryland eligible pools of resources.

Black liquor has since been removed as a Maryland RPS eligible resource following the passage of SB 65 in 2021, effective on October 1, 2021, and therefore is excluded from the below analysis. The 2019 RPS Report provided an analysis on the probable effects of removing black liquor as a resource eligible for Maryland RPS. In short, because a wide geographic pool of RECs can be drawn upon to replace black liquor, the impact of removing this resource is limited. Despite the recent change in eligibility, Maryland continues to utilize a large portion (over 80%) of the black liquor RECs certified in PJM, since black liquor under existing contracts can still be utilized for the Maryland RPS until the contract expires. As the use of black liquor RECs in Maryland winds down, RECs from other eligible technologies will be substituted.

Solar, OSW, and geothermal are also excluded from the below analysis because each has a separate carve-out requirement that requires that eligible resources be connected to Maryland's distribution system. As such, changes in the eligibility of these resources have minimal impact on the overall REC market equilibrium, holding all else equal. As conditions change, however, REC prices will also fluctuate for reasons independent of resource eligibility. For example, REC scarcity due to interconnection queue issues will put upward pressure on prices, especially as REC demand increases.

Excluding Onshore Wind

Under current conditions, eliminating onshore wind as an eligible Maryland RPS resource would not result in a large impact to REC prices in PJM, when Maryland's eligible Tier 1 REC supply exceeds demand. Wind is a widely accepted RPS resource across PJM states and, therefore, any wind RECs unused in Maryland would be used for other PJM states' RPS requirements. In turn, as discussed in the 2019 RPS Report, excluding onshore wind could allow Maryland LSEs to substitute missing onshore wind RECs with other Tier 1 resources that become available because other PJM states utilized the onshore wind that Maryland did not utilize. That is, Maryland would continue to satisfy its RPS requirements as long as these "freed-up" Tier 1 resources exceed the amount of wind RECs Maryland would have otherwise retired. This is a plausible assumption under current conditions because as of 2022, there were 12,993 GWh of Maryland-eligible, non-onshore wind RECs retired in other PJM states. By comparison, Maryland relied on 7,700 GWh of onshore wind RECs to meet its 2022 compliance goals (**Table F-3**). This pool of non-onshore wind RECs includes LFG, other biomass gas (OBG), wood waste, waste heat, and hydro RECs that were retired in the same category (i.e., Tier 1, non-solar).

Excluding Small Hydro

Excluding small hydro would likely not result in changes to REC prices, or in Maryland's ability to meet its RPS targets, as per current REC supply and demand conditions. As discussed in the 2019 RPS Report, other states in PJM include small hydro as an eligible resource. Therefore, similar to onshore wind, removing the resource from Maryland eligibility would not have a significant impact on REC prices. Additionally, small hydro REC retirements make up only 12% of Maryland REC retirements in 2022 (**Table F-3**). In the long term, as more eligible resources are added, such as onshore wind, both current and future small hydro RECs demand could be replaced with new, substitute RECs in a process that has minimal effect on REC price or availability.

Excluding Municipal Solid Waste

Removing MSW as a Maryland RPS eligible resource would have a larger impact on REC prices and resource targets compared to small hydro. Unlike small hydro, MSW is not largely accepted in other PJM states, per current regulations. In 2022, Maryland, New Jersey, Pennsylvania, and Virginia retired a total of 4.89 million MSW RECs. In Ohio and Maryland, MSW is a Tier 1 or Tier 1 equivalent resource.[124] In New Jersey and Pennsylvania, MSW is a Tier 2 or Tier 2 equivalent resource.[125] Indiana's voluntary and Virginia's mandatory RPS programs also accept the resource.[126] Due to these limitations, it is less plausible that any MSW RECs that Maryland would have used could be used in other states. Therefore, removing MSW as an eligible resource may cause a reduction in PJM-wide eligible REC supply and thus result in an increase in REC prices. However, the increase would likely be marginal because the Maryland retired MSW RECs in 2022 make up only 5% of the RECs retired in PJM, as shown in **Table F-3**. Additionally, Maryland retired only

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[124] For Ohio see Rule 4901:1-40-4. Michigan removed MSW as a Tier 1 or Tier 1 equivalent resource in 2023.

[125] For Pennsylvania see 73 P.S. § 1648.2. For New Jersey see N.J.A.C. 14:8-2.6. Per New Jersey regulations, MSW must either be located in New Jersey or located in a state with retail electric competition and must be approved by the regulatory commission.

[126] These programs do not have tiers. For Indiana see Indiana Code 8-1-37. For Virginia see Code of Virginia § 56-585.5.

1 million MWh of MSW RECs in 2022, or less than 7% of total Maryland retired RECs (**Table F-3**). This quantity is below the total pool of available, unutilized RECs in PJM that could be retired to replace the resource. As the availability of other eligible resources increases in the longer term, current and future MSW RECs could be replaced and not have a large effect on REC price or availability.

Excluding Out-of-State Resources

If Maryland were to exclude out-of-state RECs (i.e., all Maryland eligible RECs must come from resources interconnected to Maryland's bulk power system), it would substantially increase REC prices (up to the ACP) in the short run due to immediate supply shortfalls. Maryland is primarily a REC importer; in 2022, Maryland retired 11 times more Tier 1 non-carve out RECs than it generated (see **Table F-4**). Further, although Maryland already supplies its own SRECs, the state has experienced SREC deficiencies in recent years. The conditions leading to these shortfalls, including interconnection queue issues, would also likely delay the development of new resources to support an entirely in-state RPS. As discussed in the 2019 RPS Report, there are also concerns about Maryland's ability to meet an all in-state RPS in the long run related to availability of suitable space, cost, and siting requirements.

Maryland does generate more Tier 2 resources than it retires. Therefore, excluding out-of-state RECs for this category is not expected to result in large changes to Tier 2 REC prices or create supply constraints. It may, however, have secondary impacts on REC prices in other states that utilize RECs from Maryland Tier 2 eligible resources to support their non-carve-out Tier 1 requirements.

Table F-3. Maryland RECs Certified and Retired in 2022

Fuel Source	RECs Retired in Maryland (GWh)	Percent	RECs Retired in PJM (GWh)	Percent
Biomass - Agricultural Crops		0.0%	-	0.0%
Blast-Furnace Gas		0.0%	1,414.3	1.7%
Black Liquor	1,843.2	11.4%	2,248.7	2.8%
Geothermal	21.1	0.1%	30.2	0.0%
Hydropower (conv. and small)	1,962.2	12.1%	11,940.3	14.6%
Landfill Gas	746.0	4.6%	2,636.7	3.2%
Municipal Solid Waste	1,076.4	6.6%	3,958.8	4.9%
Other Biomass Gasses	76.8	0.5%	197.6	0.2%
Other Biomass Liquids		0.0%	7.1	0.0%
Solar (incl. Solar Thermal)	1,754.0	10.8%	19,435.2	23.8%
Wood Solids	974.2	6.0%	2,460.3	3.0%
Wind	7,735.4	47.8%	37,198.6	45.6%
Total	**16,189.4**	**100.0%**	**81,527.8**	**100.0%**

Source: 2022 data per PJM-GATS as of February 2024.

Table F-4. RECs Generated and Retired in Maryland in 2022

	Maryland Generated[1]	Maryland Retired
Tier 1	1,219,874	13,849,611
Tier 1 Solar	1,764,095	1,753,987
Tier 2	1,756,123	590,330

[1] *Source:* psc.state.md.us/wp-content/uploads/CY22-RPS-Annual- Report_Final-w-Corrected-Appdx-A.pdf, Table 9.

APPENDIX G. REC Availability to Meet Existing RPS Requirements

The purpose of this appendix is to compare the future Maryland RPS requirements with forecasted available RECs. When looking at this data holistically, a determination can be made about the near- and long-term effects of excluding any resource and its impact on Maryland's ability to meet its RPS targets. The Geothermal carve-out is not included due to the size of the carve-out (1% or less of retail sales each year from 2023-2030) as well as a lack of data and historical track record to base initial estimates. Key findings from this analysis include:

- Available SRECs will grow from approximately 3,000 GWh in 2023 to 9,000 GWh in 2030.
- Offshore wind capacity is expected to generate approximately 7,100 GWh RECs per year beginning in 2027. This finding is sensitive to assumptions regarding the OSW development schedule; changes in the OSW operation date will alter the Tier 1 non-carve-out requirement and Maryland compliance.
- Onshore wind is the only non-carve-out Tier 1 resource expected to experience significant growth through 2030.
- The SREC resources' shortfall is expected to continue, at least in the short term.
- These findings are sensitive to Exeter's assumptions and market conditions, as described below.

RPS requirements, in GWh, were determined using the Maryland Energy Sales Forecasts table of the Maryland PSC's Ten-Year Plan for 2022-2031. The forecasted sales were reduced by 2.14% to account for industrial load exemptions from the RPS requirements. The applicable Maryland annual RPS requirements are applied to each investor-owned utility's (IOU's), cooperative's, and municipal utility's adjusted forecasted load for the years 2023-2030. The resulting forecasted RPS load requirement was used to compare the REC requirement to the expected available resources from 2023-2030.

Solar

The forecast of available SRECs consists of separate forecasts of expected energy production from existing utility-scale solar, existing small-scale solar, utility-scale solar growth, and small-scale solar growth. The existing solar forecasts use PJM-GATS data to identify online Maryland capacity that is likely to remain operational in 2023-2030.[127] Small-scale solar capacity growth is based on an 8% growth factor for each year.[128] Utility-scale solar capacity growth was estimated by summing the expected new capacity from projects in the PJM interconnection queue for each year between 2023-2030, and then adjusting new capacity downwards based on an expected queue completion rate. Potential new capacity in the queue with an Interconnection Service Agreement, completed Weather Sensitivity Analysis, or a queue label of AD2 or earlier (i.e., entered the queue prior to March 30, 2018) were adjusted downward by 65%, while the capacity value of all remaining projects was adjusted downward by 91%.[129] These adjustments reflect historical queue drop-out rates.[130]

Exeter also adjusted the quantity of RECs expected to be available from existing solar resources to account for both the degradation of existing solar resources and the reservation of certain solar assets for private use. For degradation, Exeter assumed an annual degradation factor of 0.07%.[131] Exeter also assumed approximately 22% of the solar projects reported in PJM-GATS are reserved for private company use (i.e., not retired by suppliers as Maryland SRECs, but rather commissioned by a private company to meet its own renewable energy targets).[132]

Comparing the forecasted SRECs and solar carve-out RPS requirement shows that, in most years, Maryland is just barely expected to meet its solar carve-out RPS requirement based on the provided assumptions. As shown in **Figure G-1**, from 2025-2029, Maryland surpasses its solar target by 300 GWh or less in most years. Additionally, the forecasts suggest a nearly 1,000 GWh shortfall in 2030. Under this forecast scenario,

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[127] Assumes an 18% capacity factor for small-scale solar based on the VCE WIS:dom-P average capacity factor for the PJM community and residential solar. Also assumes a 19.4% capacity factor for utility-scale solar based on the Lawrence Berkeley National Laboratory Utility Scale: Project-level Performance data emp.lbl.gov/pv-capacity-factors.

[128] The 8% growth rate is determined by calculating the cumulative year-over-year growth rate for EIA distributed solar.

[129] For example, a solar project with 8 MW of capacity that has a wholesale market participation agreement is adjusted down to 2.8 MW, which is 8 * (1-0.65) = 2.8.

[130] The percentages used for these capacity adjustments were adopted from similar analysis conducted in Ammann, D. "Waiting Game: How the Interconnection Queue Threatens Renewable Development in PJM." NRDC. May 2023.

[131] Assumes a degradation of 0.07% per year for all projects that is consistent throughout the life of the solar project. This means that projects that came online in 1997 and 2023 both have the same annual degradation factor. Also assumes that projects are repowered, not retired.

[132] This assumption is based on the difference between the PJM-GATS solar (including solar thermal) that is certified in PJM, adjusted for degradation, compared to the retired SRECs for 2022.

available SRECs would grow from approximately 2,700 GWh in 2023 to 6,700 GWh in 2030.

Offshore Wind

The OSW carve-out is equal to specified levels of contracted capacity. The quantity of ORECs used to meet the Maryland RPS, therefore, equals the total production of OSW in the years it is online. Using information regarding the construction and operation of Maryland's OSW projects as of late 2022, Exeter estimates production to begin in 2027, as shown in **Figure G-2**. Following the initial startup of generation, OSW is expected to have consistent output of approximately 7,100 GWh from 2027-2030. This finding is sensitive to assumptions regarding the OSW development schedule.[133] If the OSW operation date is further delayed, then Tier 1 non-carve-out resources will need to make up the difference of the 7,100 GWh for each year delayed to maintain Maryland compliance. In this analysis, OSW RECs are equal to the expected output of the project capacity (2,022 MW) converted to GWh.[134] RPS carve-out rates are separately applied to each IOU's, cooperative's, and municipal utility's adjusted forecasted load for the applicable years, as discussed above.

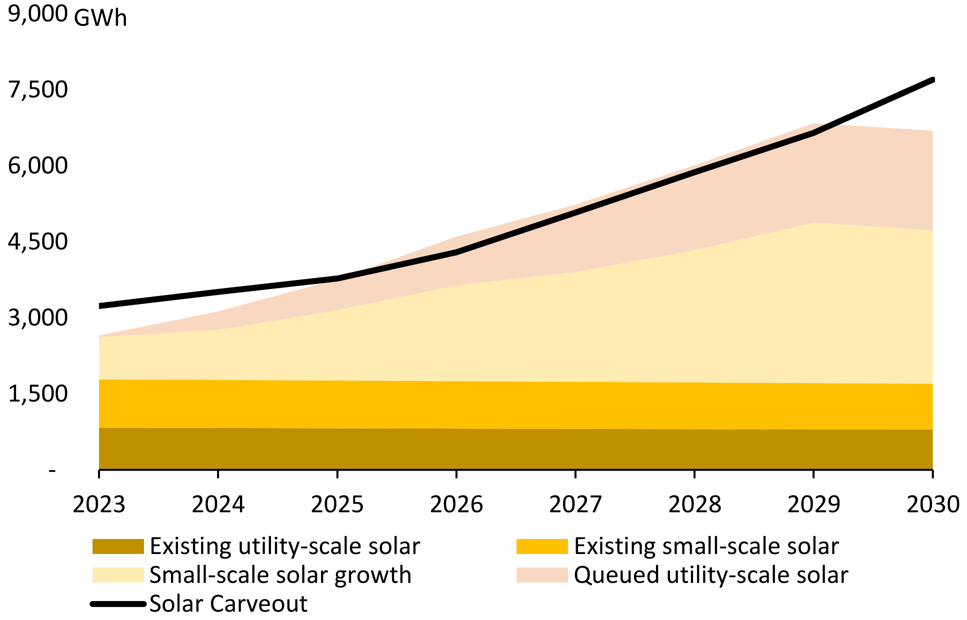

Figure G-1. Maryland Solar Carve-out RPS Resource Projections

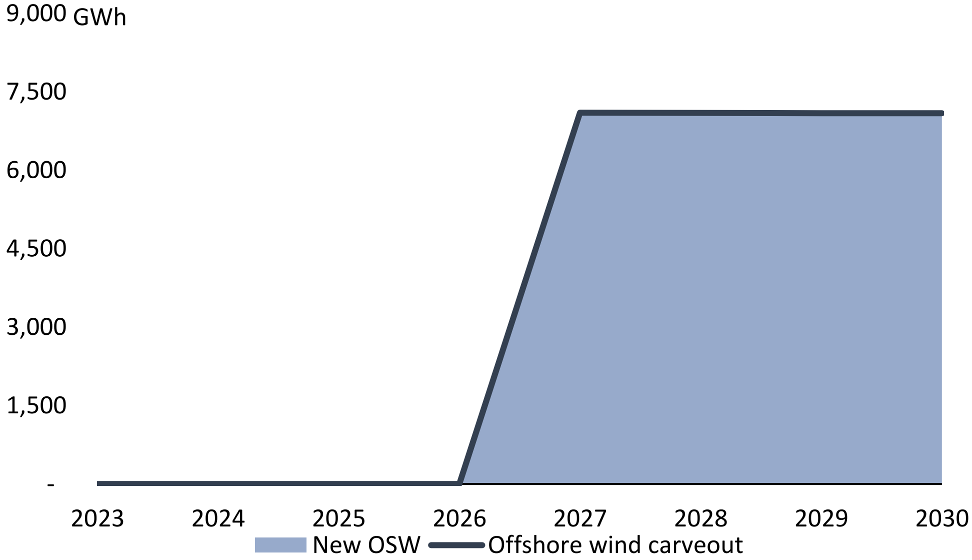

Figure G-2. Maryland Offshore Wind Carve-out RPS Resource Projections

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[133] These assumptions also do not reflect the new OSW targets established through the POWER Act of 2023 or the recent Orsted decision to withdraw from its contract with Maryland to develop the two Skipjack Wind projects.
[134] Assumes a 43.3% capacity factor based on information from the DOE Offshore Wind Market Report: 2022 Edition.

Non-Carve-out Tier 1 Resources

Non-carve-out Tier 1 resource requirements and forecasted load for 2023-2030 are shown in **Figure G-3**. For this analysis, separate forecasts for "baseline," "available," and "new" Tier 1 resources were estimated, as described below.

- Baseline Supply: Baseline Tier 1 resources consist of retired RECs for geothermal (GEO), LFG, MSW, OBG, small hydro, wood and waste solids, and onshore wind retired for 2022. These retired RECs are intended to show the typical retirement that Maryland should expect from its existing non-carve-out resources. There are no projects in the PJM queue for Tier 1 baseline resources except onshore wind. Therefore once the other baseline resources (e.g., GEO, LFG, MSW, OBG, etc.) are retired, they will not be replaced by the same resources.
- Available Supply: The "available RECs" show the unretired RECs that were still available in 2022 (as of February 2024). A similar number of RECs are assumed for these same resources going forward. This metric and the baseline metric are intended to represent what resources are available and have historically been retired, and the resources that are available and still have the bandwidth in the future to be retired as a Tier 1 non-carve-out resource.
- New Supply: Onshore wind growth is treated separately from the non-carve-out resources, as onshore wind is the only resource expected to experience significant growth. Onshore wind growth is modeled as a portion of Maryland's expected share of future onshore wind. The onshore wind data is a summation of the onshore wind capacity expected to come online from 2024-2030 based on PJM queue data. Maryland's expected portion of this resource is calculated by taking each PJM state's share of 2022 retired onshore wind RECs (i.e., the share of available RECs used to meet each state's respective RPS requirements) and adjusting it each year by each state's share of its RPS demand requirements (i.e., the share of RECs required to meet each state's respective RPS requirements).[135,136]

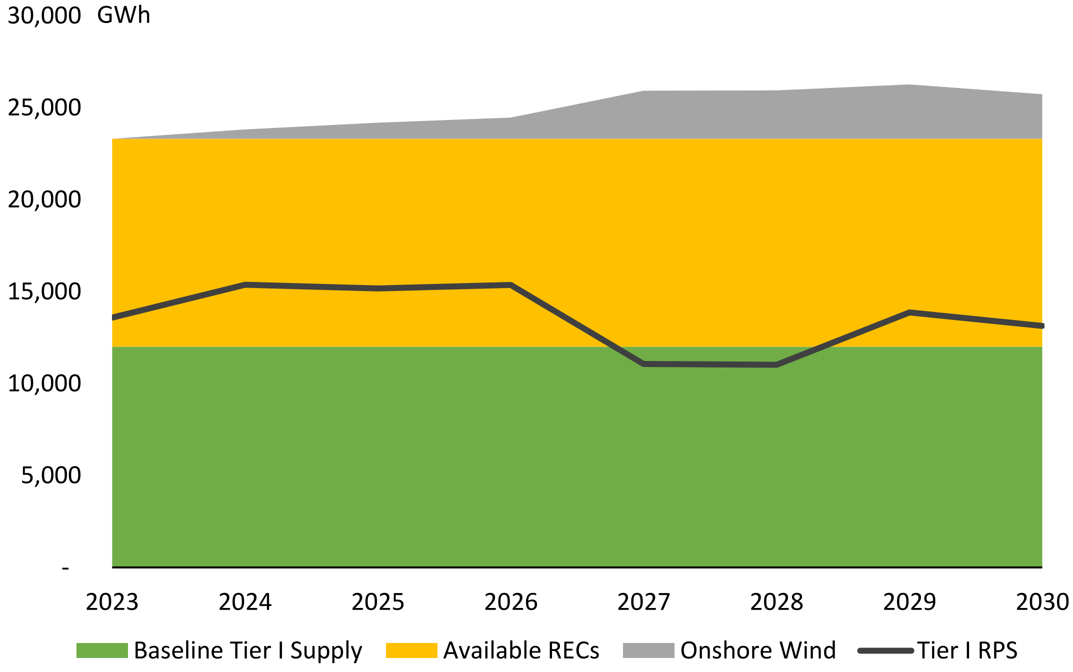

Figure G-3. Maryland Tier 1 (Excluding Carve-outs) RPS Resource Projections

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[135] This analysis includes the following PJM states: Delaware, Illinois, Maryland, New Jersey, Pennsylvania, Virginia, and the District of Columbia. Certain PJM states are not included because they have separate systems to track RECs or do not have an RPS requirement.

[136] These adjustments account for changes in each state's demand for onshore wind to meet its RPS requirements. That is, as a state's RPS requirement increases (or decreases), other states' share of that resource may decrease (or increase).

APPENDIX H. Nuclear Study Summary

In January 2020, the Maryland DNR's Department of Natural Resources: Maryland Power Plant Research Program (PPRP) released "Nuclear Power in Maryland: Status and Prospects" (Nuclear Study). The Clean Energy Jobs Act of 2019 directed PPRP to include as part of the 100% RPS Study "the findings and recommendations of the study of nuclear energy and its role as a renewable or clean energy resource conducted by the Program." The following is a high-level summary of the Nuclear Study, including issues affecting nuclear deployment and policy recommendations.

At the time of the Nuclear Study publication, nuclear power was supplying 20% of the world's electricity and accounted for 34% of the electricity generated in Maryland. Calvert Cliffs is the only nuclear power plant operating in Maryland and has licenses until July 31, 2034 for Unit 1 and August 13, 2036 for Unit 2. The report also highlighted nearby power plants in the PJM service area in Pennsylvania (Peach Bottom Atomic Power and Beaver Valley), New Jersey (Hope Creek and Salem), and Virginia (North Anna and Surry).

The Nuclear Study highlights several issues affecting new nuclear power development and continued operation of existing resources, including increased competition from natural gas and renewable energy power sources, nuclear plant cost and construction issues, and public perception of nuclear power.

First, the Nuclear Study notes that nuclear is not as cost-competitive as power plants fueled by natural gas, or renewable energy projects such as wind and solar. In some instances, energy and capacity prices in PJM are lower than the cost for nuclear plants to produce energy and, as a result, nuclear plants are not dispatched or committed in energy or capacity markets, respectively.

The second issue the Nuclear Study discusses is challenges with cost and construction delays. The report cites numerous examples of such delays, including the V.C. Summer Nuclear expansion project in South Carolina, a decade-long $9 billion project that was ultimately scrapped due to increased costs and construction duration, ending with the reactor supplier company filing for bankruptcy. A more recent example is Units 3 and 4 of the Vogtle nuclear plant in Georgia, which were seven years late and $17 billion over budget. These issues are not unique to the U.S., with new nuclear power plant construction projects in Finland, France, and the United Kingdom encountering similar problems.

Third, public confidence regarding the safety of commercial plants is a concern, especially in the wake of the 2011 Fukushima disaster in Japan which resulted from the 9.0 magnitude Tohoku earthquake and subsequent tsunami. The Fukushima disaster had a substantial impact on the local population, with Japanese authorities evacuating 200,000 from the region. Ultimately, 15,000 people lost their lives due to the earthquake, tsunami, and harm sustained during evacuation. While the radiological consequences of the event were minimal (despite four plant workers becoming sickened by radiation during the disaster), positive perception of nuclear power waned in the years following. In fact, the accident resulted in a temporary shutdown of the whole Japanese fleet of commercial nuclear power reactors in 2012. Further, in the wake of Fukushima, many countries announced plans to phase out nuclear energy: Belgium, Germany, South Korea, Spain, Switzerland, and Taiwan.

The Nuclear Study goes on to provide a list of policies that can be used in Maryland to promote new or existing nuclear power. These policies include incorporating nuclear into a state RPS or CES through the provision of ZECs, cap-and-trade arrangements that support nuclear among other zero-carbon energy sources, and financial support mechanisms such as grants, direct loans, tax exemptions, and Feed-in Tariffs, among others (see the full table below). The report notes that each policy has varying impacts, has different levels of risk and cost to ratepayers and taxpayers, and differs with regard to support of the nuclear industry. Each policy also has its own unique legal, regulatory, economic, and political challenges. Notably, some policies are compatible with each other while others are not. The report does not endorse one policy over another but lays them out in general terms by type, cost to taxpayers, cost to ratepayers, time to implement, and principal beneficiary. The report also offers initial conclusions and best practices for future policy implementation.

The report notes several factors to consider when weighing policy initiatives to support nuclear: Maryland's competitive markets, state budget constraints, and research and development objectives. First, Maryland's retail electric competition was established with the understanding that generation will operate as a competitive market, requiring little government oversight or intervention. Policies to support nuclear power could thus be viewed as interference with the competitive markets. Second, nuclear power plants are large and capital-intensive, and the amount of capital necessary to develop new plants may be difficult for state budgets to absorb. Third, advanced nuclear power technologies in development potentially offer reductions in capital costs, but these technologies are not yet market ready. Furthermore, any research and development to commercialize advanced nuclear power technologies requires support from the private sector or federal agencies such as the DOE. That said, Maryland has research and development capabilities at the University of Maryland that could be brought to bear should Maryland decide to make research and development investments.

The Nuclear Study notes that any policies to support new or existing nuclear facilities should consider cost and time specificity, how targeted the policy will be, and who will be the beneficiaries. Policy interventions should also be context-dependent. Maryland should not pursue policies such as ZECs if the Calvert Cliffs nuclear power plant is financially competitive in the PJM market. Instead, Maryland may wish to take incremental, low-cost steps to support nuclear power, such as excluding generation from nuclear power plants in Maryland from electricity sales that are subject to the Maryland RPS.

For existing reactors, the most effective policies would internalize nuclear benefits, meaning the benefit of low-emission generation, while controlling costs. Some effective policies might include assigning a value to the benefits through a carbon tax or a cap-and-trade program. Additionally, assigning indirect value, such as funding generators based on their attributes using RPSs or ZECs, could also support nuclear.

There are several strategies for controlling costs of any policy initiatives that support nuclear power. First, cost caps are helpful to ensure ratepayer money is not excessively spent. Such policies might include ACPs if nuclear is added to a RPS or CES hard limits on ratepayer or state costs for direct funding mechanisms, or limits based on production milestones for support directed at new nuclear technologies. Second, states can also promote competition with new and existing technologies by allowing nuclear to compete with other technologies such as renewable energy. A competitive procurement process can also be designed to meet an intended outcome such as a decarbonized grid without locking Maryland into a specific resource mix. Third, policymakers also have the flexibility to reassess which initiatives are necessary by creating rules that account for market conditions, such as the financial condition of a particular plant. States themselves can also implement provisions to require reevaluations before funding or policies are extended. For example, in New Jersey, the Board of Public Utilities must reassess whether nuclear plants are eligible for ZECs every three years.

Internalizing benefits and cost control are also important for new nuclear power plants. The Nuclear Study suggests that, for new plants, funding could be dispersed based on reaching achievement milestones, such as obtaining regulatory approvals quickly. The report also highlights the possibility of co-funding, which could be required for companies seeking state financial support. Essentially, the licensing and research and development costs would be dispersed among all interested parties. Funding and/or incentives can also center on rewarding performance based on actual generation, not investment. All the above strategies have the effect of ensuring that state resources are always tied to tangible outcomes and facilitating forward progress.

The Nuclear Study concludes that new nuclear projects can benefit the most from policies such as grants, loans, tax incentives, and public-private partnerships. The report suggests that Maryland could create designated areas that are pre-approved and licensed for deployment, testing, and operation of nuclear plants, to reduce upfront costs. The report also noted that Maryland could make production tax credits available for nuclear power plants but with either a sunset date for the incentive or a cost cap to limit costs, or both. Maryland can also establish contingent, standing support mechanisms in the event a nuclear power plant is financially insolvent, such as requiring that the nuclear power plant financial statements be reviewed before being eligible for any supportive mechanisms. Should financial need be demonstrated, policy initiatives should allow for competition based on desired attributes, through ZECs or state procurement processes.

Approach	Summary	Cost to Taxpayers	Cost to Ratepayers	Time to Implement	Principal Beneficiary
Alter an Existing RPS (State Energy Portfolio Standards)	Within either a single or multi-tiered RPS, states can potentially support nuclear by adding it to a tier or creating a new tier.	0: Minimal additional admin costs	1: Low if nuclear included in secondary tier and/or competes with other resources 4: Mod./High if a there is a nuclear power carve-out	Short: MD can utilize existing RPS constructs as a foundation or borrow from other states that have a separate tier for nuclear power.	New or existing plants: Competition among eligible resources likely disadvantages new nuclear and constrains benefits to existing nuclear, except in the case of carve-outs.
Clean Energy Standard (State Energy Portfolio Standards)	A CES includes other resources that are often excluded from RPS policies such as nuclear power. States can support nuclear power by implementing a CES in lieu of an RPS or as a complementary policy.	0: Minimal additional admin costs	1: Low if nuclear competes with other resources 4: Mod./High if there is a nuclear power carve-out	Short: MD can utilize existing RPS constructs as a foundation or borrow from other states with a CES.	New or existing plants: Competition among eligible resources likely disadvantages new nuclear power and constrains benefits to existing nuclear power, except in the case of carve-outs.
Exclude Nuclear Sales from RPS (State Energy Portfolio Standards)	This approach accounts for nuclear power in an RPS or CES by netting nuclear generation out of total electric sales. Doing so avoids compensating existing nuclear power plants that may not need financial assistance while also recognizing nuclear power's carbon-free attributes.	0: Minimal additional admin costs	0: No ratepayer costs	Short: Requires minimal changes to the RPS. No RECs are provided.	Existing plants: Recognizes the carbon-free attributes of nuclear but does not provide compensation. Could sharply reduce the Maryland RPS requirement for renewable energy unless the target is increased.
Zero Emission Credits	ZECs provide compensation for financially challenged nuclear facilities. ZECs differ from RECs because they are generally allocated in advance, are not eligible for trading, and serve a closed market.	0. Minimal additional admin costs	2: Low/Mod. if designed to meet short-term financial need or subject to financial controls such as cost caps 4: Mod./High if set equal to social cost of carbon or provided irrespective of need	Long: ZECs are administratively complex, require time to design and implement, require regulatory oversight, and must design a system for recipient selection and ZEC allocation.	Existing plants.
Customer Surcharge Accounts	A special-purpose account that supports a specific function or initiative, such as nuclear power research and development, plant upgrades, or subsidies to sustain operations. These accounts are funded through a non-bypassable, per-kWh surcharge on customer electric bills.	1: Admin costs	3: Mod./High if collected to pay a known cost (e.g., previous year losses) 5: High if collected for open-ended use	Medium: Surcharges are a common, existing funding mechanism. However, the distribution of account funds can be administratively complex and is often politically controversial.	New or existing plants: Fund can be tailored to meet the financial requirements of economically imperiled nuclear plants, to support nuclear power research and development, or to fund upgrades at existing plants.
State-Required Procurement of Clean Energy Resources	A requirement that regulated utilities procure power from specific resources, usually via a PPA. Resources are selected either via a competitive procurement process or an administrative proceeding.	1: Admin costs	2: Low/Mod. if procurement process is competitive 4: Mod./High if administratively selected or if solicitation process is not competitive (i.e., limited to single technology or does not have large number of bidders)	Medium: PPAs are common. However, solicitations can be designed in a myriad of ways. Overseeing a PPA process can be time-consuming if there are many selection criteria, many bids to evaluate, or if losing bidders challenge the bidding results.	New or existing plants: Competition among eligible resources likely limits opportunities for new and financially challenged existing nuclear power plants, unless above-market-cost resources are specifically allowed.
Cap and Trade (Assigning a Cost to Carbon)	An initiative that limits total CO_2 emissions and allows emitters to determine how they will get under the cap. Emitters have the option to purchase and sell emission rights to and from each other.	3: Moderate upfront costs from admin. Set-up; low after that if market is well-functioning	3: Low/Mod. from the passthrough of supplier costs (depending on carbon prices). Can be reduced via refunds to ratepayers.	Medium/Long: Identifying an emission cap, allocating permits, and designing a trade system can be time-intensive. Requires market monitoring to ensure markets are competitive and well-functioning.	Existing plants: Limiting emissions or imposing a price for emissions provides a cost advantage to low-emission nuclear power.

Approach	Summary	Cost to Taxpayers	Cost to Ratepayers	Time to Implement	Principal Beneficiary
Carbon Tax (Assigning a Cost to Carbon)	An initiative that sets a fixed price for carbon emissions and then allows the market to respond.	2: Low/Mod. costs from admin, management of taxes and tax revenues	3: Mod. from the passthrough of supplier costs. Can be reduced by recycling tax payments.	Medium: Can utilize existing tax collection systems. Identifying appropriate tax level and who it applies to can be challenging.	Existing plants: Limiting emissions or imposing a price for emissions provides a cost advantage to low-emission nuclear power.
Advance Cost Recovery	A regulatory construct that allows utilities to recover the costs of constructing a new power plant prior to project completion.	0: No taxpayer costs	5: Mod./High as a result of risk shifted onto ratepayers (historically)	Short: Changes regulatory processes, but has few other admin burdens	New plants: Designed to expedite cost recovery during the development and construction of new plants, making these projects more attractive to investors.
Feed-in Tariff	A policy approach that provides a long-term purchase agreement for electricity at a specific price, usually paired with grid access and priority dispatch, or a premium above a spot market price	1: Admin costs	2: Low/Mod. if tariff price is set low (but may have little positive impact on power plant development) or if cost caps are in place 5: High if technologies are not commercially mature or if technology cost reductions exceed projections	Medium/High: Can be designed in a myriad of ways. Requires extensive monitoring to provide corrective action if necessary.	New plants: Designed to incentivize the development of new plants on the basis of production-based payments. Limited experience in U.S.; more prevalent overseas.
Grants	Partial or full funding for specific projects and programs, including infrastructure, labor training, and research and development.	0: No or limited taxpayer costs.	2: Low/Mod. assuming funding is from a system benefits charge, especially if potential recipients compete.	Short/Medium: Common approach to funding and can be easy to administer unless new initiatives or solicitations have to be put in place. Flexible to change	New or existing plants: Grants provide funding that supports all stages of development and operation. Grants are especially beneficial during the early stages of developing new or commercially immature technologies.
Direct Loans (Loan Programs)	Loans provided directly to the borrower through an institution, such as a government agency, or a third party, such as a clean energy bank.	0: No or limited taxpayer costs.	5: High, assuming funding is from a system benefits charge. High capital requirements. State absorbs risk of default. Some ongoing servicing and monitoring costs	Short: Already a common approach to loans for large projects	New plants (primarily): DOE loan program helping construction of nuclear owner plants. Could apply to existing plants, but not common.
Matching Loans (Loan Programs)	State loans that match loans from private lenders in order to encourage energy project development in the private sector as well.	0: No or limited taxpayer costs	2: Low/Mod. assuming funding is from a system benefits charge. Moderate capital requirements. State absorbs some risk of default. Some ongoing servicing and monitoring costs	Short: Already a common approach to loans for large projects	New plants.
Interest Rate Buy-Down (Loan Programs)	States work with private lenders in offering below-market interest rate loans by subsidizing the interest rate through a lump-sum payment.	2: Moderate capital requirements. Funding not recycled. State has no underwriting responsibilities or default risk	0: No ratepayer costs	Short: Already a common approach to reducing financing costs	New plants: Reduces the cost of bank loans during the construction phases of new nuclear power plants.
Linked Deposits (Loan Programs)	Allows participating banks to make below-market interest payments on state deposits. In return, the bank then uses the funds from the state deposits to provide low-interest loans to energy projects.	2: Low direct cost (admin), but indirect costs through reduced earned interest payments.	0: No ratepayer costs	Short: No legislative action needed	New plants: Reduces the cost of bank loans during the construction phases of new nuclear power plants.

Approach	Summary	Cost to Taxpayers	Cost to Ratepayers	Time to Implement	Principal Beneficiary
Securitization (Loan Programs)	Form of loan refinance through which investor-backed utility debt and equity is pooled and then resold as consumer-backed utility equity.	1: Admin costs	3: Mod.: debt is paid by ratepayers, who also absorb risk. Usually only covers a portion of total costs, however, and is of limited duration	Medium: Less common in energy sector; may require new laws. Some administrative requirements to establish collection mechanisms, transfer debt, etc.	New or existing plants: Can help collect funds to support existing plants, help finance research and development, or to support costs for new plants.
Investment Tax Credits (Tax Incentives)	Credits that allow businesses to deduct a certain percentage of capital investment costs from their state income taxes for investments in eligible energy projects.	3: Costs incurred after investment. Limited direct cost (admin), but indirect costs through reduced tax receipts. Annual, cumulative, or per-project cost or credit caps can limit impact on government tax revenues.	0: No ratepayer costs	Short: Already a common approach to support new generators. Easy to administer, flexible to change	New plants: Can be targeted toward investment in new nuclear power plants. Companies with or without minimum tax liability will not be able to take full advantage of the tax credit unless it sells or leases projects to other companies or investors.
Production Tax Credits (Tax Incentives)	Credits that reduce a business' income tax liability based upon the amount of energy generated by an eligible energy project over a period of time.	3: Costs incurred after production. Limited direct cost (admin), but indirect costs through reduced tax receipts. Annual, cumulative, or per-project cost or credit caps can limit impact on government tax revenues.	0: No ratepayer costs	Short: Already a common approach to support new generators. Easy to administer, flexible to change	New plants: Targeted to incentivize capital investment in new nuclear power plants. Companies with or without minimum tax liability will not be able to take full advantage of the tax credit unless they sell or lease projects to other companies or investors.
Sales Tax Exemptions (Tax Incentives)	Exemption that excludes certain purchases from sales and use taxes.	1: Low cost if limited in scope. No direct cost, but indirect costs through reduced tax receipts	0: No ratepayer costs	Short: Already a common way to incentivize certain purchases. Easy to administer, flexible to change	New or existing plants: Reduces current and future tax liability for expenditures related to development of nuclear power plants. Not considered enough of an incentive to stimulate action by itself.
Property Tax Exemptions (Tax Incentives)	Exemptions that allow a business to exclude the added value of an energy system from the valuation of their property for taxation purposes.	1: Low cost if limited in scope. No direct cost, but indirect costs through reduced tax receipts	0: No ratepayer costs	Short: Already a common way to incentivize relocation. Easy to administer, flexible to change	New or existing plants: Reduces current and future tax liability to develop a new project or continue to operate an existing reactor in a specific area.
Reliability Support Services	In certain circumstances, utilities may enter temporary agreements to subsidize power plants (including nuclear power) on the grounds of reliability. These arrangements are generally subject to FERC review.	0: No taxpayer costs	3: Mod. if ratepayers are obligated to pay for noncompetitive production at the minimum level necessary to support operation	Medium: High degree of legal and regulatory involvement. Arrangements can be implemented during the review process.	Existing plants: Tailored to meet the minimum financial requirements of economically imperiled power plants.
State Acquisition and Public-Private Partnerships	An arrangement that involves more direct government involvement in power production, including partial or complete ownership of nuclear power plants and related assets.	2: Moderate cost if government shares risks (i.e., partnership) 5: High cost if risk and costs are shifted onto government in full (i.e., ownership)	0: No ratepayer costs if plant production is unchanged after acquisition 4: Mod./High if ratepayers are obligated to pay for noncompetitive production	Long: Introduces legal issues. Administratively complex. Must design one-off arrangements for ownership, management, etc.	New and existing plants: Government helps absorb some project risk and costs, either by acquiring an existing plant or developing a new plant.
Payment-in-Lieu of Taxes	A negotiated payment agreement that guarantees an upfront payment, often recurring, in exchange for exemption from regular tax assessment and related obligations.	1: Low cost if limited in scope. No direct cost, but indirect costs through reduced tax receipts	0: No ratepayer costs	Short: Already a common approach to taxes for large projects, especially at the local level.	Existing plants: Reduces uncertainty regarding future tax obligation for plants once they are in service.

APPENDIX I. Just Transition Policy References

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