Reaching 100 Percent Net Carbon-Free Electricity in Maryland

January 2025

Maryland Energy Administration

Reaching 100 Percent Net Carbon-Free Electricity in Maryland

Prepared for:

Governor Wes Moore

By the Maryland Energy Administration

January 2025

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List of Acronyms

ACC2 – Advanced Clean Cars 2 Regulations

ACP – Alternative Compliance Payment

ACT – Advanced Clean Trucks Regulations

ARRA – American Recovery and Reinvestment Act

BTMPV – Behind the Meter Photovoltaic

CBO – Congressional Budget Office

CC – Combined Cycle

CCS – Carbon Capture and Storage

CPCN – Certificate of Public Convenience and Necessity

CSNA – Climate Solutions Now Act of 2022

DPL – Delmarva Power and Light

DSM – Demand Side Management

EIA – U.S. Energy Information Administration

EMM – Electricity Market Module

EPA – U.S. Environmental Protection Agency

ES – Energy Storage

EVs – Electric Vehicles

FC – Fuel Cell

GHG – Greenhouse Gas

GW – Gigawatt

GWh – Gigawatt Hour

IC/GT – Internal Combustion/Gas Turbine (including bio gas & bio solids)

IOU – Investor-owned Utilities

IPL – Industrial Process Load

ITC – Investment Tax Credit

IRA – Inflation Reduction Act

ISO – Independent System Operator

LCOE – Levelized Cost of Electricity

LMER – Locational Marginal Emissions Rates

LMP – Locational Marginal Pricing

MDE – Maryland Department of the Environment

MEA – Maryland Energy Administration

MW – Megawatt

MWh – Megawatt Hour

NERC – North American Electric Reliability Council

NREL – National Renewable Energy Laboratory

NUC – Nuclear

O&M – Operations and Maintenance

OREC – Offshore Wind Renewable Energy Credit

OSW – Offshore Wind Energy

PJM – PJM Interconnection Inc.

PPA – Power Purchase Agreement

PSC – Maryland Public Service Commission

PSO – Power System Optimizer

PSH – Pumped Storage Hydro

PTC – Production Tax Credit

PUA – Maryland Code, Public Utilities Article

PV – Photovoltaic

REC – Renewable Energy Credit

RFP – Request for Proposals

RGGI – Regional Greenhouse Gas Initiative

RPS – Renewable Energy Portfolio Standard

RTO – Regional Transmission Organization

SCC – Social Cost of Carbon

SREC – Solar Renewable Energy Credit

ST – Steam Turbine (biomass, refuse, or gas-fired)

TCR – Tabors Caramanis Rudkevich

Executive Summary

In June of 2024, Governor Wes Moore committed to putting the state on a pathway to 100% clean energy. This commitment was formalized through an executive order signed on June 4th, 2024 directing the Maryland Energy Administration (MEA) to develop a framework for this clean energy standard. In addition to the environmental and health benefits for Marylanders, this report shows that the decarbonization of the state's electricity sector also will contribute to longer-term lower wholesale electricity prices. These savings come from low-to-zero marginal cost renewable energy being cheaper to produce.

The path to achieving these goals, however, is subject to challenges. Current assessments indicate that Maryland is below trajectory to meet its existing clean energy targets, in particular those renewable targets set for 2030. Electricity demand and supply factors, coupled with the macroeconomic and business environments, have created barriers to the greater progress expected from these policies. Adjustments can be made in order to accelerate progress on these targets and to put the state on a path to meet a new standard. This report presents various modeling scenarios and policy options that could help Maryland reach its ambitious clean energy goals. The modeling presented in this report is designed to provide a comprehensive understanding of the challenges and potential solutions in meeting the state's goals.

Current Challenges

<u>Demand-Side Pressures</u>
After spending several years with flat load growth, Maryland's demand is set to increase across multiple sectors as a result of electrification and new large commercial and industrial loads.

<u>Supply-Side Constraints</u>
Maryland's Renewable Portfolio Standard (RPS) serves as a key driver of the state's clean energy transition, highlighting the importance of accelerating renewable energy deployment. The advancement of clean energy technologies, including solar and wind, presents opportunities to overcome challenges such as siting, interconnection, and financing. By addressing these issues, Maryland is poised to strengthen its renewable energy infrastructure. Additionally, as the offshore wind sector adapts to changing economic conditions and explores innovative solutions, the state continues to refine its approach to achieving its ambitious renewable energy goals.

Modeling Outcomes and Analysis

MEA's consultant, Tabors Caramanis Rudkevich (TCR), modeled a Base Case (business-as-usual) model, a broad decarbonization scenario, and then followed with low, medium, and high renewable scenarios. While the modeling lays the foundation for our recommendations, they are not recommendations in and of themselves, but are instead meant to test intuition and hypotheses about Maryland's energy mix and related goals. **Additionally, this modeling is done under the restriction that the generation is built in-State.** This is done for a couple reasons. One, there are reliability and economic benefits that come from new build generation connected to the State's local network. In some cases, this may also reduce the need for additional transmission projects.[1] Striving for local builds will help to add these additional benefits. It also makes sense given the type of modeling conducted, where it is attempted to focus on the Maryland grid, versus the PJM-wide grid: there is obviously more control over Maryland as opposed to the PJM network. **It is difficult, however, for the State to cover an existing 40% import deficit with additional generation in a span of ten years, which is why additional scenarios will include potential outcomes of 20-40% imports.**

<u>High-level Takeaways</u>

Approximately 1.2 GW of planned renewable capacity is expected to come online in Maryland by 2035. An additional 7.4–11.2 GW of clean energy capacity will be needed to achieve a net-zero carbon footprint, depending on the overall decarbonization portfolio. This represents a 62-93% increase in Maryland's total installed capacity relative to 2024-levels.

The additional renewable capacity added to the system to achieve Maryland's clean energy goals reduces average LMPs in Maryland. Average 2035 wholesale energy prices in BGE and PEPCO service territories are expected to decrease by as much as $22–$27/MWh (2024$) compared to the business-as-usual scenario due to the impacts of additional renewable generation in the market, which operates at low- to zero-marginal cost.

Solar photovoltaic (PV) and land-based wind are the least-cost clean energy alternatives, but limited resource potentials within Maryland result in the need for additional clean energy technologies.

Maryland's geographic location positions it as a potential leader in offshore wind energy, however, limited transmission infrastructure on the Eastern Shore caps the amount of offshore wind that can contribute to serving Maryland's load, without expansion. The industry has also witnessed other setbacks that have delayed deployment.

Once PV and wind potentials have been maxed out, the model adds nuclear to offset the remaining emissions from Maryland's load. Given existing transmission infrastructure in DPL, achieving a net-zero carbon footprint through capacity additions in Maryland would require 3.4–4.3 GW of additional nuclear capacity.

Scenarios

<u>Base Case Scenario</u>

The Base Case scenario projects the continuation of existing trends and policies through 2035. Key capacity changes include an increase in solar PV to 1.4 GW, onshore wind reaching 454 MW, and a 36% increase in combined cycle gas. While coal plants are projected to retire completely by 2028, the substantial increase in combined cycle gas capacity indicates that

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[1] For example, as the State looks to the shutdown of Brandon Shores and Wagner power plants, additional transmission is needed to cover the supply gap from these facilities.

natural gas could possibly play a major role in replacing retiring coal plants absent growth in other clean energy technologies.

Decarbonization Scenario

The Decarbonization Scenario presents a more dramatic transformation, adding 9.6 GW of clean energy generation above the Base Case. This scenario includes:

- Solar PV expansion to 3.9 GW;
- Onshore wind growth to 1.3 GW;
- Offshore wind development reaching 3.9 GW; and
- An 185% increase in nuclear capacity through traditional and small modular reactors

The model's preference for nuclear over additional offshore wind at certain deployment levels suggests important considerations about grid reliability and the challenges of intermittent renewable generation. Additionally, the likelihood of nearly doubling nuclear energy in the next 11 years, even if focused more on small modular reactors than conventional reactors, is extremely unlikely. The retention of some gas-fired plants indicates their value for grid stability and during peak demand periods, even in a net-zero system.

Additional Scenarios Analyzed

Three variants were modeled with different renewable deployment levels:[2]
Low Renewables (solar max 8%, OSW max 2 GW, additional constraints listed below)
Mid Renewables (solar max 10%, OSW max 4 GW, additional constraints listed below)
High Renewables (solar max 14.5%, OSW max 8.5 GW, additional constraints listed below)

Important notes regarding all three scenarios:

- All scenarios maximized available PV and onshore wind capacity
- Higher renewable scenarios required greater total capacity due to lower capacity factors
- The High Renewables scenario showed highest exports to PJM but also increased curtailment[3]
- All scenarios relied on nuclear capacity additions

The analysis of multiple renewable deployment scenarios provides insights into the trade-offs involved in different decarbonization pathways. It underscores the need for a balanced energy mix in achieving decarbonization goals. At various levels of renewable capacity, the findings highlight the need for additional firm, dispatchable, clean power sources, suggesting that renewable energy deployment may not be sufficient on its own. Policymakers could explore strategies to ensure the deployment of various technologies, including energy storage, nuclear power, and Grid Enhancing Technologies (GETs) to meet these needs. This is particularly true in the ambitious deployment scenarios that saw increased curtailment.

[2] Full list of max constraints available on page 47.
[3] This is when generators are forced to not produce power they could otherwise be producing, typically due to oversupply at certain times or congestion.

Cost and System Implications
The modeling suggests that although there are upfront investment costs to building out a decarbonized generation fleet, there are significant long-term benefits from increased reliability and resilience, local economic development, and GHG emission mitigation. Furthermore, there are enduring reductions in PJM wholesale costs for electricity through supply increases in constrained areas, particularly with lower cost generation like solar. Additional environmental benefits extend beyond Maryland's borders, with the Decarbonization Scenario achieving net-negative emissions by 2035. Total PJM system-wide CO_2 emissions decrease by 23.7 million short tons, representing approximately $7.1 billion in Social Cost of Carbon benefits.

Based on observation and discussion with industry, MEA offers up the following broad set of potential reforms for consideration.

Recommendations

Offshore Wind Development Reforms: A comprehensive set of reforms is needed to accelerate offshore wind development.

1. The state should eliminate the requirement for interconnection on the Delmarva Peninsula;
2. Enable multi-jurisdictional offshore wind renewable energy credit (OREC) procurements, and;
3. Implement more flexible pricing mechanisms, creating a structured process for project withdrawals and applications, coupled with an escrow account system that would ensure developer commitment while avoiding excessive penalties.

Solar Market Enhancement:

1. Maintain a consistent Alternative Compliance Payment (ACP) to accelerate solar deployment. This stability is crucial for incentivizing development across all solar market segments, particularly when compared to competing states in the region.

Nuclear Power Integration: Nuclear power represents a crucial component of the clean energy mix, offering reliable, emissions-free baseload generation.

1. Establish a dedicated procurement process for new nuclear development, considering a structure adapted from the existing Offshore Wind Renewable Energy Credit (OREC) program, and;
2. Develop specific financial support mechanisms recognizing nuclear's unique challenges and benefits.

Strategic Power Purchase Agreements (PPAs): PPAs are agreements between a buyer and a power producer to supply electricity at a determined price over a specified period of time. These agreements can be used to

1. Explore opportunities for out-of-state power purchase agreements within the PJM network to take advantage of lower construction costs in other regions, capitalize on higher emissions reduction potential in certain areas, and provide flexibility in meeting clean energy goals while managing costs.

Technology Innovation and Implementation: The state must maintain flexibility to incorporate emerging clean energy technologies as they become commercially viable. Priority areas for consideration include long-duration energy storage systems, carbon capture and sequestration technologies, hydrogen-fueled generation facilities, and advanced grid management systems.

Conclusion

Meeting the state's electricity needs with 100% clean energy presents Maryland with extraordinary challenges, but also opportunities for leadership in the clean energy transition, while increasing reliability, aiding economic development, reducing GHG emissions, and driving down wholesale costs. **The above recommendations will move Maryland forward, but even with these reforms in place, meeting this goal is uncertain.** Success will require a coordinated approach combining policy reforms, infrastructure investment, and technological innovation. Without these comprehensive changes, Maryland risks falling short of its clean energy objectives and climate goals.

The State must act decisively to implement the recommended reforms, above, to move Maryland in the right direction, while maintaining flexibility to adapt to changing technological and economic conditions. This transition demands unprecedented collaboration between government agencies, utilities, private sector developers, and other stakeholders. While the challenges are significant, the benefits of pursuing these goals makes this effort essential for Maryland's future. Pursuing energy reliability, improved environmental outcomes, and economic development opportunities should remain among Maryland's highest priorities.

Introduction

This report aims to provide data, highlight challenges and obstacles, and offer pathways to decarbonize the Maryland grid by 2035. The Climate Solutions Now Act of 2022 sets ambitious goals for climate mitigation in Maryland, including a 60% reduction in GHG emissions by 2031 and carbon neutrality by 2045. In line with these objectives, Governor Wes Moore pledged to reach 100% clean generation in Maryland by 2035 and signed an executive order on June 4th to advance the State's Climate Pollution Reduction Plan in which MEA was tasked with establishing a framework for a clean energy standard to achieve 100% clean electricity in Maryland by 2035.

To meet the Governor's goals in the electricity sector, the state must overcome challenges affecting both demand (load) and supply of clean electricity. Namely, the State faces increasing load and a lag in getting clean energy technologies online, including solar (both utility-scale and residential/commercial), onshore and offshore (OSW) wind, and energy storage as an enabling technology.[4] The recent national election adds an additional level of uncertainty as future policies around energy and the environment are not fully known at this time.

The implementation of signature policies in the State aimed at reducing GHG emissions in the power sector has encountered setbacks, leading to slow progress. The effectiveness of our primary clean energy generation policy tool, the Renewable Portfolio Standard (RPS), has been hindered by delays in deploying renewable energy resources. Challenges such as siting, interconnection, and financing have plagued solar energy projects across the State, while offshore wind initiatives have experienced significant delays due to economic factors impacting previously awarded contracts. These ongoing delays are expected to persist, causing the State to further lag behind its regulatory goals and targets, thereby impeding grid decarbonization.

Meanwhile, with regards to demand, electric load is projected to increase. Statewide increases in both building electrification and electric vehicle deployments will increase demand more broadly, due to policy drivers and shifting consumer preferences. The State is also looking at load increases from relatively new sectors, notably from the forecasted deployment of data centers, the sizes of which are currently unclear. Moreover, EmPOWER Maryland, the primary demand reduction program in the State, which has delivered financial, grid, and GHG emission reductions benefits since its 2008 inception, is changing. It has evolved into a combined demand reduction and electrification program, the latter of which will add load to the grid. We will be unable to continue relying on EmPOWER for similar past reductions in load – instead of plateauing as in recent years, load will increase.

MEA undertook "Reaching 100 Percent Net Carbon-Free Electricity in Maryland" in recognition of the challenges facing the State to thoroughly examine the necessary elements for a future in-State mix of clean energy resources. The study models 100% clean energy scenarios in Maryland, based on electricity consumption, taking into consideration the policy environment,

[4] Supply-side in this report refers to generation, or the "supply" of generation, while demand-side refers to the energy demands of the State, or the State's load. Demand and load are used interchangeably in this report.

PJM market and load forecast, generation capacity, generator retirements, and generator queues. The modeling scenarios also treat the objective as achieving 100% in-State, clean generation, following a 100% consumption-based model, similar to the RPS. MEA is currently awaiting further scenarios demonstrating outcomes and options to the State if we are unable to fully meet our requirements (i.e. other ways to satisfy the clean energy objective for Maryland consumers) by examining 20-40% import scenarios, as well as higher load scenarios.

This report incorporates some familiar, and some new, clean energy resources for the State to achieve its decarbonization goals. The familiar "clean generation" resources used in this report are listed below and are consistent with Maryland law. They include Tier I and Tier II "renewable sources" as defined in Maryland's RPS, Md. Code, Public Utilities Article (PUA) §7-701 (e.g., solar, wind, geothermal, hydroelectric, qualifying biomass, etc.). **MEA is also recommending the inclusion of advanced nuclear generation, which is consistent with the definition of "advanced clean energy" in Maryland Code, Economic Development Article §8-801**. Nuclear energy is an established, reliable, carbon-free energy source, and is now buttressed by significant federal funding and support. MEA is also recommending the inclusion of battery storage in the mix, especially long-duration battery storage, which has the potential to smooth load and close generation gaps in certain scenarios.

MEA engaged the services of TCR to conduct this modeling work. As described below, TCR utilized a framework with a carbon-neutral approach to 100% clean generation. In the model, excess emissions-free generation from "clean" sources were used to offset any remaining emissions-based generation (such as natural gas) that remains on the Maryland geographic network.[5]

This modeling effort seeks to measure and quantify the anticipated impacts from several possible policy scenarios. It is important to keep in mind, however, this is a significant forecasting effort involving many trade-offs and projections about "possible futures." As with all such modeling analyses, the uncertainty inherent in predicting impacts only expands as impacts are analyzed further into the future. These results are starting points for discussion and may point to the need for a more regular and systematized analysis of this type going forward.

This report will move broadly from an overview of Maryland's current status on its clean generation goals, primarily using the RPS targets as the yardstick to measure progress. After an understanding of where the State is, the report will shift to the modeling effort by TCR, and review some possible scenarios and outcomes for the State in moving forward on a 100% clean generation goal. Following will be a brief review of other State efforts to decarbonize their grids, and, finally a concluding section with preliminary suggestions for the State.

[5] Maryland emissions were calculated hourly, and the model ensures that the sum total emissions over all hours in the year is zero, but does not enforce that the net-emissions in each hour must be zero.

Maryland’s Current Clean Generation Goals

This section provides an overview of the supply and demand factors operating on the Maryland energy system – those that pertain to reaching a clean generation goal in the state. This starts from the demand side, reviewing the key components impacting load. This section then switches to the supply side for a better understanding of the generation challenges inherent in the State. The section concludes with a more focused examination of solar and offshore wind, given these two resources are meant to provide the bulk of Maryland’s clean generation.

Primary State Policies and Goals Impacting Supply and Demand

Broadly speaking, there are two main policy instruments with a sustained impact on supply and demand in the State: EmPOWER Maryland, the State’s energy efficiency program, which has helped to flatten load growth since 2009 (after implementation) and the RPS, which sets a renewable energy target of 50 percent for the State (plus the existing 2.5 percent for large scale hydro). Certainly, there are a host of other policies that have been enacted over the years that impact both supply and demand,[6] but these are the key policies used to achieve load reduction and renewable generation goals.[7]

EmPOWER Maryland

EmPOWER Maryland provides financial incentives and technical support through participating utilities for energy-efficient appliances, lighting, and home improvements. These measures help consumers reduce their energy consumption, leading to lower utility bills and decreased overall demand.

Energy efficiency historically has been one of the most cost-effective ways to counterbalance growing electricity demand. In the mid-2000s, the Maryland grid had severe reliability concerns and received a warning from the North American Electric Reliability Council (NERC). This led in 2008 to the establishment of EmPOWER Maryland, which is a comprehensive, utility-led energy efficiency initiative aimed at reducing energy demand and fostering sustainable energy practices throughout the state. The initial goal was a 15 percent reduction in consumption and peak demand by 2015, from a 2007 baseline. This was then updated in 2017 to target a 2 percent reduction in annual energy sales. In 2022, through the CSNA, the goal again was ratcheted up, with the percentage moving from 2 to 2.25 in 2025 and 2026, and then to 2.5 percent by 2027. This program has significantly reduced Maryland's energy demand over the past 15 years.

By promoting energy-saving practices and technologies, EmPOWER Maryland has contributed to substantial reductions in peak energy demand as well. This is critical for minimizing strain on the grid during high-demand periods and reducing the need for additional, often less environmentally friendly, power generation.

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[6] E.g., net energy metering has perhaps a greater impact on increasing residential solar deployments than the RPS.

[7] Certainly, policies like net energy metering have had a significant impact on the residential solar market, but these act as adders in order to assist the State in achieving its targets set in the RPS.

The program has led to measurable energy savings across the State, helping to curb GHG emissions and improve air quality. At the end of 2023, the utilities' EmPOWER Maryland programs have collectively saved a total of 16,237,812 MWh and 3,165 MW.[8] The anticipated savings linked to EmPOWER Maryland programs exceed $14.5 billion over the lifespan of the installed measures for the energy efficiency and conservation programs.

Utilities have invested over $4.1 billion in the EmPOWER Maryland programs to date, with approximately $2.9 billion allocated to energy efficiency and conservation programs and $1.1 billion dedicated to demand response programs.

To date, 73,285 limited-income customers have taken part in EmPOWER Maryland through the Residential Limited-Income Programs.[9] In 2023, 13,513 limited-income households participated in the program. The average savings per participant in 2023 amounted to 478 KWh. The total expenditure on limited-income energy efficiency programs to date stands at approximately $264.4 million.[10]

Perhaps the most significant change to the program is the requirement that participating utilities offer incentives for electrification – including for measures like heat pumps. Additionally, lighting is now excluded as an eligible category for efficiency gains. Lighting historically has been one of the primary drivers of demand reductions, given its relative ease to deploy and lower costs, coupled with large gains. Combined, these respective changes in programmatic requirements are emblematic of the fact that it is getting harder to "squeeze out" demand reductions from purely swapping out appliances for more efficient alternatives. With changes to the EmPOWER program, Maryland joins a number of states that have updated their energy efficiency policies to encompass beneficial electrification.

The Renewable Portfolio Standard

The RPS is aimed at promoting renewable energy adoption and reducing the state's carbon footprint. Established in 2004 and amended several times, this standard mandates that a specified percentage of Maryland's electric load must be generated from renewable sources. The policy has become more stringent over time, with the most recent significant update in 2019, which set a target of 50 percent renewable energy by 2030, up from 25 percent by 2025.[11]

Under this standard, a variety of renewable energy sources qualify, including solar, wind, biomass, geothermal, and small hydroelectric facilities. The RPS, however, places a particular emphasis on solar and OSW through specific carve-out provisions. For solar, the target is set at a carve-out rate of 14.5 percent of Maryland's consumption by 2030 and provides a separate procurement mechanism contained for OSW, which results in the award of ORECs.[12] There was an initial combined procurement from two companies (US Wind and Ørsted) of 368 MW, which

[8] For context, current Maryland peak load is roughly 14,000 MW.
[9] 2024 PSC EmPOWER Maryland Energy Efficiency Act Report.
[10] Ibid.
[11] The Clean Energy Jobs Act of 2019.
[12] This is a special procurement, operating more like a PPA contract. Therefore, ORECs are fixed and not subject to the same market dynamics as the Tier 1 components.

was expanded to an additional minimum of 1,200 MW.[13] Due to delays in the OSW industry, primarily due to macroeconomic conditions, Maryland does not currently have any OSW deployed.

To ensure compliance, the RPS operates on a system of Renewable Energy Credits (RECs). Electricity suppliers in Maryland must submit these credits to demonstrate that they are meeting the required percentages of renewable energy.[14] Each REC represents one MWh of electricity generated from a qualifying renewable source. This is the same for Tier 1 or 2 RECs, including solar, and the State's ORECs. RECs, SRECs and ORECs embody all the energy and environmental attributes of the generated energy. See the full compliance list out to 2030, and the concomitant annual percentage requirements in Table 1.

Table 1. Annual RPS Requirements (Percent of Maryland Load)

Renewable Portfolio Standard Requirements (2022-2030+)

Annual Requirements as a Part of Consumption/Load (all figures are percentages)

Year	Tier 1 Non Carve-out	Solar	OSW	Post 2022 Geothermal	Tier 2	Total
2022	23.24	5.50	NA	NA	2.50	32.60
2023	23.82	6.00	NA	0.05	2.50	34.40
2024	26.91	6.50	0.14	0.15	2.50	36.20
2025	26.59	7.00	1.66	0.25	2.50	38.00
2026	26.89	8.00	2.61	0.50	2.50	40.50
2027	18.23	9.50	13.02	0.75	2.50	44.00
2028	17.98	11.00	13.02	1.00	2.50	45.50
2029	22.98	12.50	13.02	1.00	2.50	52.00
2030	21.48	14.50	13.02	1.00	2.50	52.50

Source: *Maryland Public Service Commission.*[15] *Tier 1 Excluding Carve-outs includes geothermal, qualifying biomass, poultry litter, wastewater, etc. Tier 2 is hydroelectric power other than pump storage generation. See PUA §7-701.*

If compliance entities fail to meet these standards, by submitting RECs for compliance, they must then pay the Alternative Compliance Payment (ACP), which serves as a cost containment mechanism and alternative payment if there are no available RECs on the market. See Table 2 for the ACP schedule.

[13] Ørsted canceled its contract in 2024, but still retains the lease area.
[14] Both utilities and retail suppliers must comply. For instance, a utility will assess its annual load and then match the percentage required to either REC submissions or ACP payments.
[15] Maryland Public Service Commission, Renewable Portfolio Standard Report: With Data for Calendar Year 2022, November 2023, 5.

Table 2. ACP Schedule ($/MWh)

Alternative Compliance Fee Schedule (2022-2030+)

Distribution of Fees Across Different Categories (all figures are in $USD)

Compliance Year	Tier 1 Non Carve-out	Solar	Post 2022 Geothermal	Tier 2	IPL Tier 1
2022	30.00	60.00	NA	15.00	2.00
2023	30.00	60.00	100.00	15.00	2.00
2024	27.50	60.00	100.00	15.00	2.00
2025	25.00	55.00	100.00	15.00	2.00
2026	24.75	45.00	90.00	15.00	2.00
2027	24.50	35.00	80.00	15.00	2.00
2028	22.50	32.50	65.00	15.00	2.00
2029	22.50	25.00	65.00	15.00	2.00
2030	22.35	22.50	65.00	15.00	2.00

Source: *Maryland Public Service Commission.*[16]
Note: Reproduced from PSC 2023 RPS report (Reporting on 2022).

There is strong focus on solar and offshore wind in the RPS, hence the larger carve-outs and requirements, but there are several other eligible technologies in the Tier 1 category that are not widely deployed. Onshore wind is one category, which is challenging in Maryland due to geographic factors, especially wind speeds, which are low relative to other parts of the country.[17] There is some qualifying biomass generation activity in the State, along with waste, refuse, and poultry litter energy, but these tend to have challenging economics and in some cases face substantial public opposition.[18] Geothermal is in the category as well, but the deployment is marginal. Other eligible categories are ocean (tidal), fuel cells, and small-scale hydro facilities. Our Tier 2 resource is conventional hydroelectric power.

The OSW RPS requirements do not create a carve-out REC market similar to solar, but instead create targets (the latest of which was amended by the POWER Act (SB781) in 2023, establishing an 8.5 GW target) for a State-led procurement process. That process is originally the OREC process through the Maryland Public Service Commission (PSC), which held competitive solicitations for the original awards. The law imposes a ratepayer impact cap, effectively only allowing enough for one project, which is now a rebid process by US Wind. The other procurement mechanism available is through the Maryland Department of General Services (DGS), which is running a procurement per the POWER Act. DGS should be able to issue a request for proposals (RFP) in late 2024.

[16] Ibid, 6.
[17] Wind Energy in Maryland, WINDExchange, https://windexchange.energy.gov/states/md
[18] There is also debate as to whether these resources should be considered "clean" or GHG-neutral.

Maryland Load (Demand)

There are two approaches to examining system load. First, there is aggregate load, which counts the cumulative amount of gigawatt hours (GWh) consumed in the State annually, and is the focus of this report. This is cumulative load that occurs all the time, every single day, every hour of the day and accounts for all actual electricity consumed in the State. The other type involves peak load, which is effectively a measure of the maximum amount of demand on the system at a given time. Understanding peak load, especially during the most strenuous time of day, and year (such as 6 PM on a hot summer day), provides an understanding of grid stress and reliability.[19] An analogous example is a city's road network: cumulative load measures the amount of vehicles that utilize city roads throughout the year, accounting for all vehicles on the road over that time period, while peak load measures the maximum amount of vehicles on the road at one moment in time. When peak load is excessive, heavy use of the grid can result in congestion, the same way there is heavier traffic during the busiest time of day (think rush-hour traffic). The latter approach (the peak) translates into system reliability and is not examined in this report because that is not the type of modeling conducted for long-term capacity expansion models. For the type of electricity mix forecasting examined in this report, the aggregated approach is used, measured in GWh or MWh.

Maryland's cumulative annual load has been generally declining over the past 20 years. The EmPOWER Maryland program played a pivotal role in this positive trend by effectively reducing energy consumption. Maryland has consistently ranked in the top 10 on the American Council for an Energy-Efficient Economy scorecard for energy efficiency implementation.[20] The general trend to plateau or decrease is apparent in Figure 1 below.

[19] Grid design has redundancy built in (physically and to the planning process) so that if a component of the system is lost at a given time, the grid is still supposed to be operational.

[20] American Council for an Energy-Efficient Economy https://database.aceee.org/state/maryland

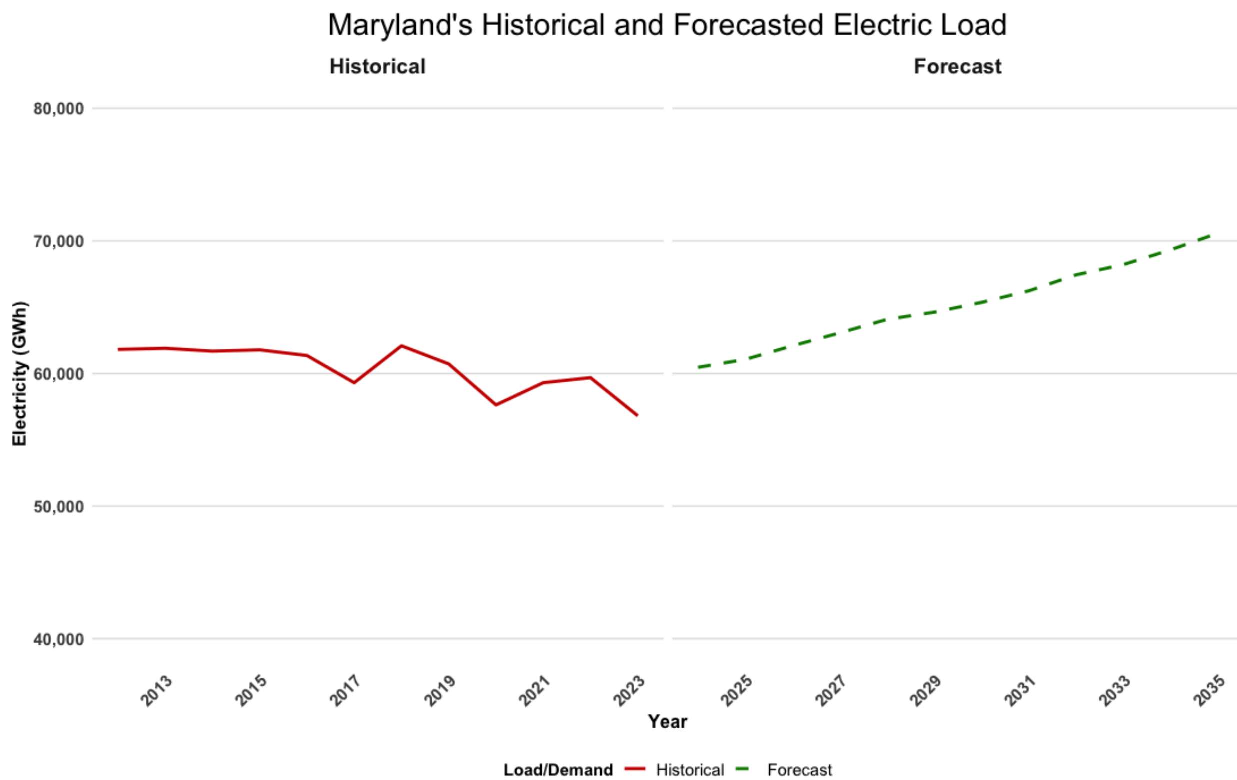

Figure 1. Maryland load over time
Note: 2023 load data is provisional, EIA

It is expected, however, that load will increase in the future. Increased electrification, meaning the displacement of fossil fuel-powered technologies in favor of electric alternatives in both buildings and vehicles, is going to drive an increase in load going forward. This makes intuitive sense as, for instance, households with gas-fired heating and cooling convert to heat pumps and as combustion engine vehicles are shifted to electric vehicles (EV). The latter in both cases draw on the electricity grid in order to operate – this creates a shift in demand from one energy source to another. Another potential change to demand that could have a major impact is data center growth.

Load forecasts are very impactful to modeling long-term outcomes. A hypothetical higher load scenario means the State will need to deploy more clean generation to meet a 100% goal. The opposite would be true in a hypothetical lower load scenario, where the State would need to deploy less clean generation in order to meet its goal. Since the modeling component of this report is a forward-looking exercise to determine the appropriate generation mix in 2035, we rely on load forecasts, buttressed by an assortment of assumptions about the future. That means these forecasts are best guesses about possible futures and are helpful in the long-term planning process, but are subject to change.

Looking forward, future scenarios will be impacted by the State's electrification efforts. Prompted by the enactment of a suite of pro-electrification policies in the CSNA, notably the establishment of a building energy performance standard (BEPS), the PSC tasked The Brattle

Group with conducting a study to assess the effects of high electrification of the buildings, transportation, and agricultural sectors on the Maryland grid through 2031.[21]

Under the three high-electrification scenarios examined by Brattle (Electrification with Legacy Technologies; Electrification with Best-in-Class Technologies; and Electrification with Fuel Backup, respectively), electricity sales (demand) are projected to increase at different rates. All three scenarios assume the achievement of the BEPS for buildings over 35,000 square feet (Maryland Department of the Environment (MDE) estimates that this policy will affect 9,529 buildings across the state)[22] and the achievement of the Advanced Clean Cars (ACC2) and Advanced Clean Trucks (ACT) standards for vehicle sales. It is as yet unclear if BEPS will be achieved. Under the ACC2 standards, manufacturers are required gradually to increase the zero-emission vehicle share of their total car sales to 100 percent by 2035. Under the ACT standards, manufacturers are required gradually to increase the zero-emission vehicle share of medium- and heavy-duty vehicle sales by 2035 to 55 percent of Class 2b—3 truck sales, 75 percent of Class 4—8 straight truck sales, and 40 percent of truck tractor sales.

The Electrification with Fuel Backup and Electrification with Legacy Technologies scenarios both project that electricity sales will grow at a rate of 0.9 percent per year from 2022 to 2031, resulting in about 62,916 GWh in 2031 (up from 58,285 GWh in 2022). In the Electrification with Best-in-Class Technologies scenario, however, the adoption of more efficient cold-climate heat pumps is anticipated to reduce energy consumption for space and water heating, resulting in a slightly lower sales growth rate of 0.6 percent per year reaching 61,558 GWh.[23] Maryland energy sales are forecasted to rise by 1,848 GWh by 2032, 2.9 percent greater than energy sales in 2023 and a compounded annual growth of 0.32 percent.[24] Figure 2 below is directly from the report and gives a better idea of the differences between scenarios.

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[21] This report was released in January 2024.

[22] https://mde.maryland.gov/programs/regulations/air/Documents/BEPS/BEPS%20TSD%20PACKAGE%20FINAL%20(12-5-2023).pdf

[23] Sergici S., Ramakrishnan A., Peters K., Hledik R., Hagerty J.M, Snyder E., Olszewski J., Ethier H, (2023) An Assessment of Electrification Impacts on the Maryland Electric Grid, Prepared for the Maryland Public Service Commission, Brattle: https://www.psc.state.md.us/wp-content/uploads/MD-PSC-Electrification-Study-Report.pdf

[24] Ibid

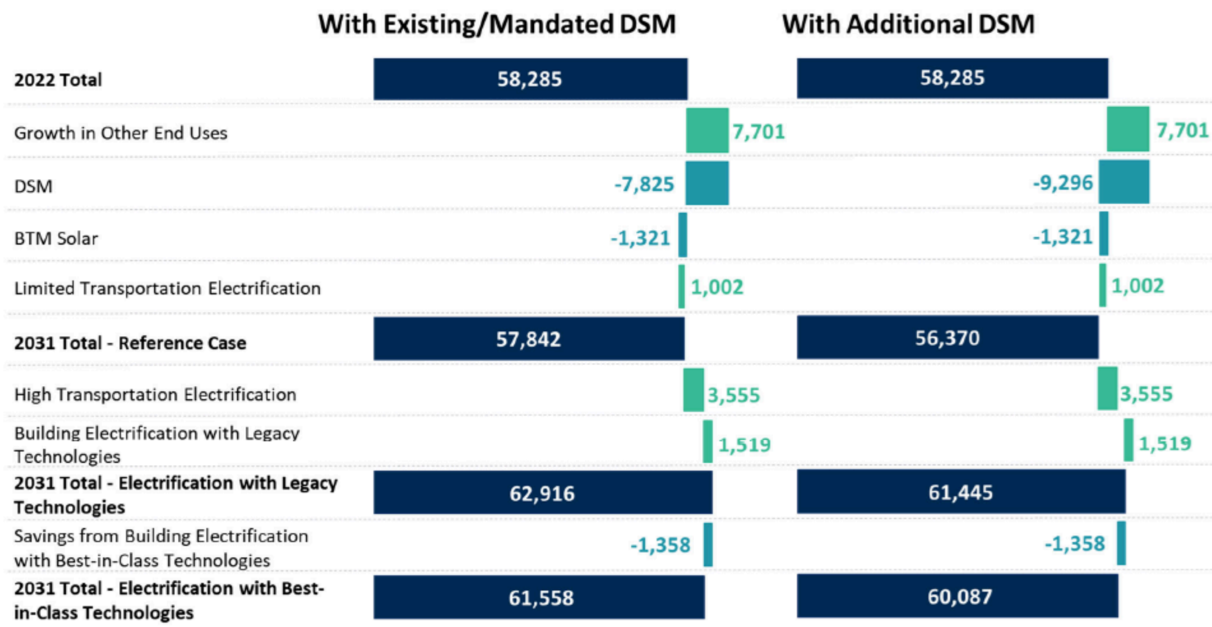

Figure 2. Projected changes (in GWh) in Maryland electricity sales (Source: Maryland PSC)[25]

The high-electrification scenario assumes that by 2030, fossil fuel equipment is phased out through policy, all new heating equipment sales are heat pumps and the ACC2 and ACT regulations are achieved.[26] Also, in the high-electrification scenarios, the Maryland energy system is expected to transition from summer-peaking to winter-peaking around 2026-2027. Furthermore, the load growth through 2031 is projected to vary from 0.6 percent to 2.1 percent per year with existing and mandated demand-side management (DSM) programs.

Policies promoting the electrification of heating systems and transportation, especially the increasing adoption of EVs, are significant contributors. Regionally, PJM estimates there will be about 500,000 light-duty EVs in its territory in 2024, with projections of approximately 23 million by 2039, creating new demands on the grid, not just for Maryland. Maryland's ACC2 mandates manufacturers to gradually raise the proportion of EVs they offer, eventually reaching 100 percent of passenger car and light truck sales by model year 2035. Additionally, the Inflation Reduction Act (IRA) expanded and extended several tax credits to boost electrification, as well as created the Home Electrification and Appliance Rebates program. As determined by the U.S. Department of Energy funding formula, Maryland (via MEA) will receive $68.21 million to incentivize residents to switch to electric appliances, such as heat pumps, stoves and cooktops, and clothes dryers.[27]

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[25] Id at page 23
[26] Id page 9; The advanced clean trucks rule sets targets for delivery of new zero-emission medium- and heavy-duty vehicles to the state that gradually increase each year. Zero-emission truck sales would need to comprise 55% of pickup truck/van sales, 75% of rigid/box truck sales, and 40% of truck tractor sales by 2035.
[27] https://dlslibrary.state.md.us/publications/JCR/2023/2023_16.pdf

It is, however, not only electrification that contributes to Maryland load forecast projections. Other key drivers include the following:

- **Renewable Energy Integration**
  The integration of behind-the-meter solar generation and battery storage solutions is expected to impact load forecasts by reducing net load growth while contributing to overall grid reliability and efficiency.

- **Economic and Demographic Factors**
  Economic growth, population increases, and shifts in industrial activity also will contribute to demand increase. The long-term forecast incorporates these factors, alongside historical weather data and trends in energy efficiency, to predict future electricity consumption accurately.

- **Data Center Expansion**
  Maryland, particularly in the Quantum Frederick campus within the FirstEnergy service area, will be seeing substantial growth in data center loads, reflecting the broader trend of increased data center activity across the PJM footprint. The projected demand increases from data centers in Frederick are 800 MWs by 2027 and then an additional 2,200 MWs (3 GWs total) by 2033. To give an idea of this scope, peak load for Maryland is roughly 13-14 GWs, so an additional 3 GWs represents roughly a 19-23 percent increase in potential State-wide peak load focused on the FirstEnergy/Potomac Edison service territory.[28]

PJM Interconnection's 2024 Long-Term Load Forecast[29] reflects various factors influencing electricity demand over the next 10 years and 15 years. The PJM forecast projects an annual growth rate for the PJM Regional Transmission Organization (RTO) of 1.6 percent for summer peak demands and 1.9 percent for winter peak demands across its service territory to 2033/2034 (10 years).[30]

For the modeling scenarios, the consultant utilized the PJM load forecast for Maryland and present middle ground numbers, as compared to the lower PSC forecast and the higher forecast found in the Pathways report. For instance, PSC projected load in 2030 is 64,940 GWh and the Pathways projected load (under current policies) is 74,423 GWh.[31] The PJM forecast for 2030 is 69,578 GWh.

Maryland as an Importer of Electricity

Bridging the gap between demand and Maryland-sited supply are imports – Maryland operates at an energy generation deficit and is unable to sustain its own load independently. Because Maryland demands more electricity than it currently generates, it must import electricity from

[28] Frederick is part of the Potomac Edison service territory.
[29] PJM Interconnection's 2024 long-term load forecast predicts electricity demand in the PJM territory over the next 10 and 15 years, starting in 2024.
[30] PJM Load Forecast Report January 2024 prepared by PJM Resource Adequacy Planning Department
[31] Current PSC load forecast also only goes out to 2032.

other states in the PJM territory in order to close that gap. Imports for 2023 were approximately 36 percent, down from 38 percent in 2022 due to a decrease in demand. The following graph, Figure 3, shows this trend over time.

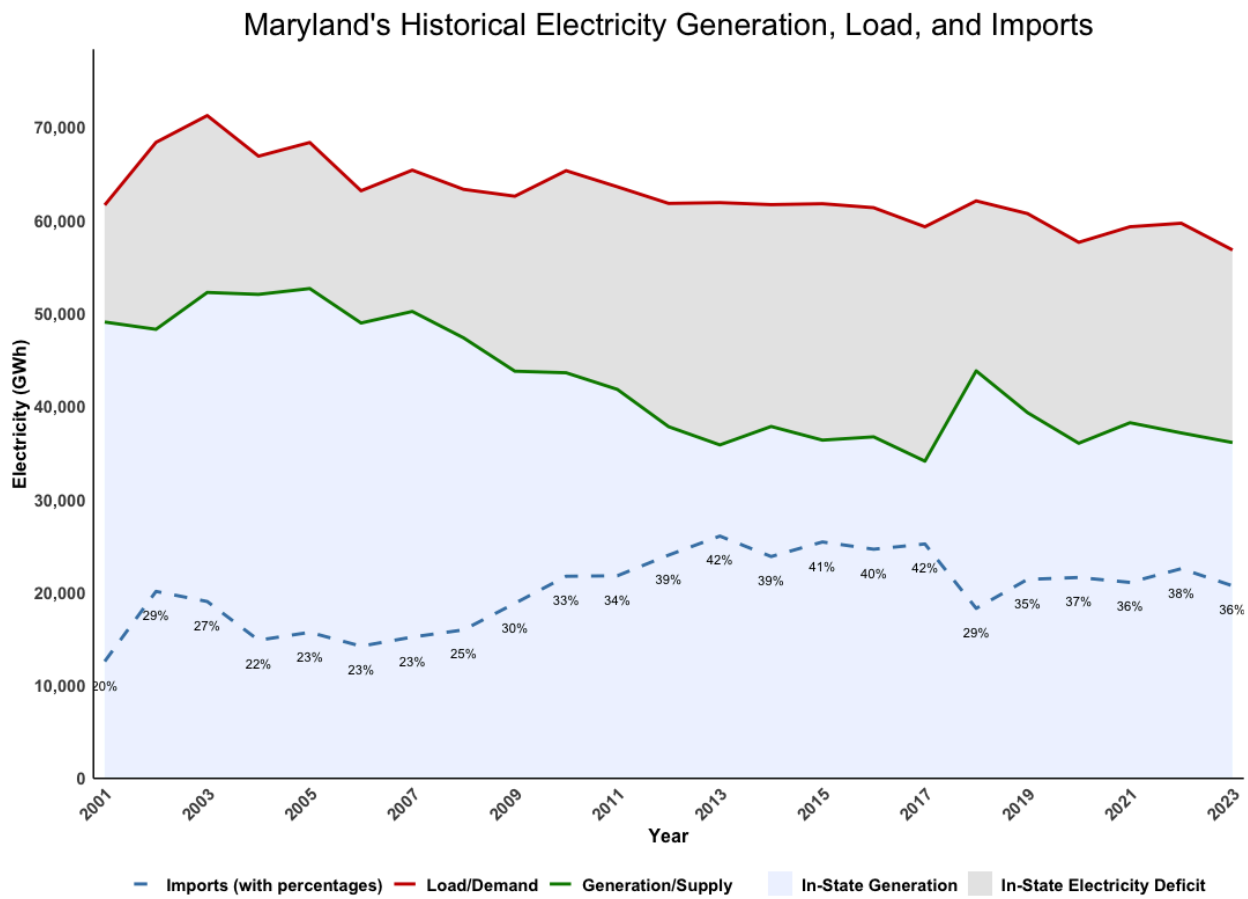

Figure 3. Maryland's Historical Load, Generation, and Imports.
Notes: EIA data. The gray zone between Load/Demand and Generation/Supply in the graph is the deficit (load minus generation), or imports, which is then quantified using percentages and the dotted line below.

In effect, this system is operating as it should, allowing for adequate resources to be constructed throughout the region where it makes the most economic and geographic sense – this is one of the benefits of being part of a power pool like PJM. Construction elsewhere may very well mean Maryland is importing cheaper electricity from outside State borders instead of generating potentially more expensive electricity locally. A lack of in-State generation, however, can create resource adequacy problems by not having enough generation in the right geographic areas creating capacity constraints, congestion, or necessitating the need for costly transmission build outs.

The values in Figure 3 are aggregate amounts of energy, measured in GWh – as such, the graph does not demonstrate zonal or geographic-specific deficits, which is where those localized reliability problems can become problematic. Beyond reliability concerns, these issues will raise prices in that zone, reflected in the locational marginal pricing (LMP) for that area of served load. BGE is currently a congested territory, lacking in both efficient and adequate transmission capacity and local generation resources, especially with the scheduled decommissioning of the Brandon Shores and Wagner facilities, two fossil fuel-fired plants located just south of Baltimore.[32]

[32] 2025/2026 Base Residual Auction Report, PJM, July 2024, https://pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2025-2026/2025-2026-base-residual-auction-report.ashx

Maryland's Current Electricity Generation Profile

Maryland's energy mix has changed significantly over the past 15 years. Notably, as can be seen in Figure 4, coal has gone from the overwhelming dominant producer of electricity in the State at nearly 30,000 GWh in 2007, to a marginal producer at around 2,500 GWh in 2023. While not a one-to-one replacement, natural gas generation has increased dramatically from a marginal generation source to a dominant one in the current energy mix. This trend is in line with national trends and is a direct result from the utilization of fracking and horizontal drilling techniques that experienced rapid market penetration in the early-2010s. As a result, lower-cost natural gas generation grew rapidly over the same time period. Another notable observation is the stable output of nuclear generation, which has remained at a similar or slightly higher output over time. Conventional hydroelectric has remained stable as well, with fluctuations based on water flow in the Susquehanna River.

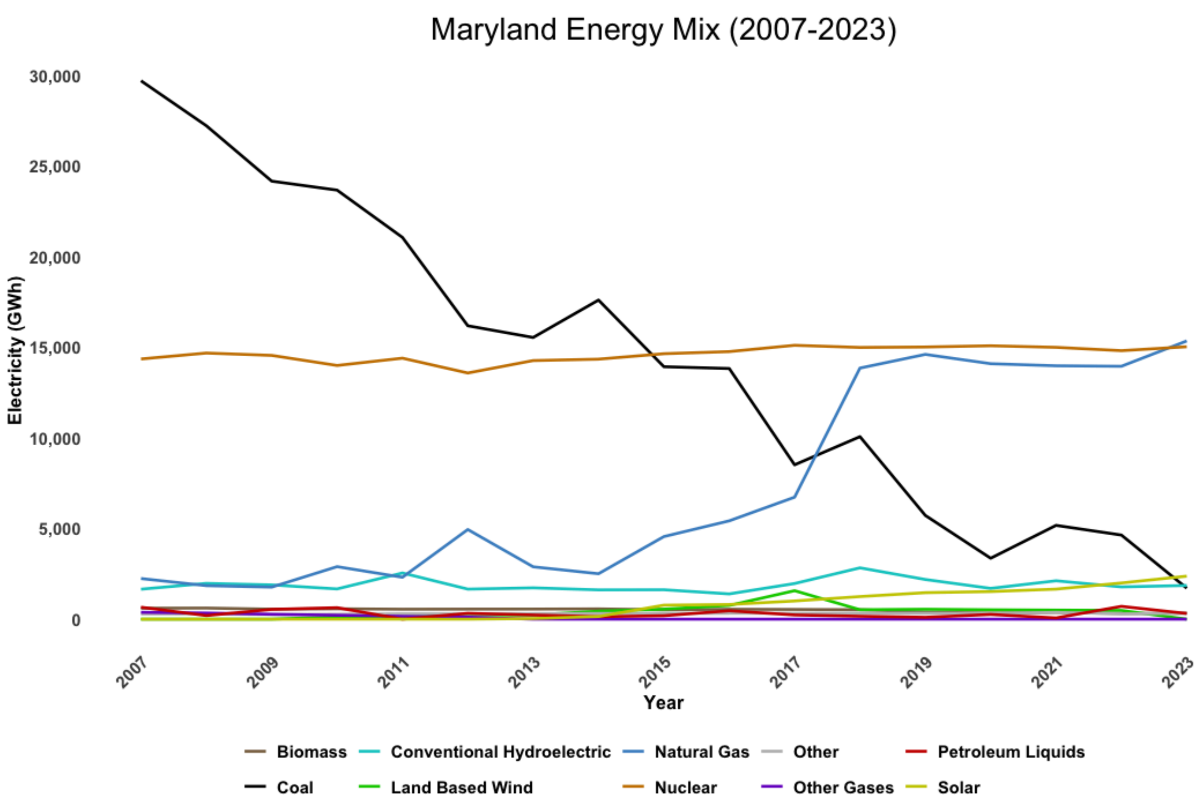

Figure 4. Maryland's historical energy mix.

Generation in Maryland is dominated by natural gas and nuclear energy. These two sources account for 41 and 40 percent of electricity generation in Maryland, respectively. Solar, hydroelectric, and wind make up a combined 12 percent of electricity generation. Due to plant closures and run-time restrictions, coal now only accounts for around 5 percent of the State's generation mix. Some forms of generation found in Figure 4 above are now marginal amounts under 1 percent, and therefore were not included in Figure 5 below,[33] showing a snapshot of Maryland's current generation mix in GWh, as of the most recently available data, 2023.

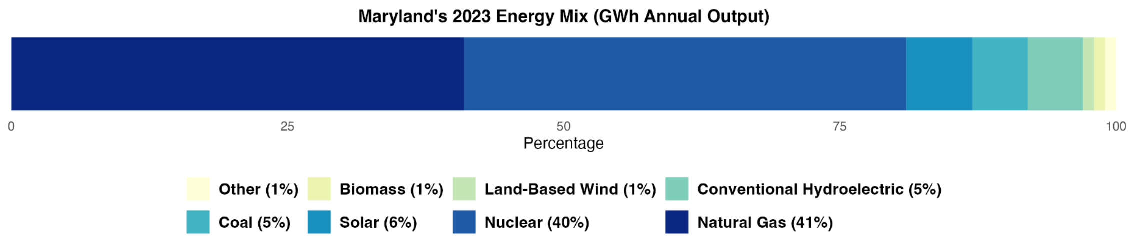

Figure 5. 2023 Snapshot of Maryland's energy mix.

As the primary measuring stick for clean energy progress in the State, it's helpful to look at Maryland's generation profile in the context of existing policy. **In terms of our existing RPS targets, Maryland is falling short of its goals.**

While the RPS targets can be met by multiple renewable energy sources, the two key generation types that are meant to provide the majority of the State's carbon-free generation are solar and OSW. Other energy sources are not able to be deployed at scale in Maryland to make meaningful inroads on the energy mix. This includes onshore wind, which lacks adequate wind speeds throughout the State for profitable project development.[34] Hydroelectric generation is also limited by geography.

The latest RPS compliance report from the PSC contains data for calendar year 2022. The amount of electricity generated from Maryland sources is not sufficient to meet RPS goals and a significant amount of RECs are instead purchased from outside Maryland to satisfy RPS requirements. Alternatively, there has been a large uptick in ACP payments in the past two years; first in solar ACP payments and more recently in Tier 1 non carve-out RECs as well. This means that many Maryland compliance entities are instead opting to pay ACP in order to satisfy compliance. See Maryland- generated RECs in 2022 in Table 3. This gives a general understanding of the types of generation being produced in-State for compliance purposes.

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[33] And due to rounding.
[34] See national map showing comparative wind speeds here: https://energy.maryland.gov/Pages/Info/renewable/windmaps.aspx ; Wind speeds over 6.5 m/s are generally considered economically viable: https://css.umich.edu/publications/factsheets/energy/wind-energy-factsheet#:~:text=Wind%20Resource%20and%20Potential&text=The%20distribution%20of%20wind%20energy,are%20generally%20considered%20commercially%20viable

Table 3. 2022 Maryland-Generated RECs by Fuel Source

Maryland Distribution of RECs Generated in 2022

Including Totals by Category

Classification	Fuel Type	MD RECs (Quantity)
Tier 1 Non-carve out	Geothermal	30,113
Tier 1 Non-carve out	Landfill Gas	63,606
Tier 1 Non-carve out	Municipal Solid Waste	590,886
Tier 1 Non-carve out	Small Hydro	19,710
Tier 1 Non-carve out	Wood Waste	11,972
Tier 1 Non-carve out	Wind	503,587
Tier 1 Solar	Solar PV	1,761,424
Tier 1 Solar	Solar Thermal	2,671
Tier 2	Large Hydro	1,756,123
Tier 1 Non-carve out Total		1,219,874
Tier 1 Solar Total		1,764,095
Tier 2 Total		1,756,123
Total Renewable Generation		4,740,092
Tier 1 Non-carve out RPS Target		13,545,434
Tier 1 Solar RPS Target		3,205,675

Note: Reproduced from PSC 2023 RPS Report (Reporting on 2022). Used 2022 load from January 2024 PSC Electrification study to calculate RPS amounts: 58,285 GWh/58,285,000 MWh.

In order to close the gap, Maryland imports RECs from elsewhere in PJM. See in Table 4 the size and disposition of REC imports for the 2022 compliance period.

Table 4. 2022 Maryland RECs Retired by State

2022 MD RECs Retired by State

Distribution of MD-retired RECs by State and Tier

State	Tier 1	Solar	Tier 2	All Tiers
IL	4,617,385	0	0	4,617,385
VA	3,018,067	0	2,500	3,020,567
MD	751,054	1,753,987	20,000	2,525,041
PA	1,578,684	0	7,119	1,585,803
IN	1,412,349	0	0	1,412,349
NC	539,240	0	340,337	879,577
OH	862,708	0	0	862,708
WV	775,926	0	24,685	800,611
TN	10,000	0	195,689	205,689
KY	90,585	0	0	90,585
DC	71,982	0	0	71,982
MI	54,758	0	0	54,758
NJ	27,068	0	0	27,068
ND	17,508	0	0	17,508
DE	15,103	0	0	15,103
MN	7,194	0	0	7,194
Total	13,849,611	1,753,987	590,330	16,193,928

Based on submitted compliance reports, Maryland's total retail electricity sales in 2022 reached approximately 58.9 million MWh. Of this total, 57.8 million MWh were subject to RPS compliance, while 1.2 million MWh were exempt. The cost associated with retiring these RECs in 2022 amounted to $355.4 million, an increase from $332.7 million in 2021.

In 2022, renewable energy sources in Maryland generated about 1.2 million Tier 1 non-solar RECs, 1.8 million Tier 1 SRECs, and 1.8 million Tier 2 RECs. This does not amount to significant percentages of State generation. Over the past two years, there have been significant shortfalls of or with domestically generated solar energy, resulting in the requirement for significant ACP payments. For instance, in calendar year 2022, Solar ACP payments were $85,859,393.[35] For 2023, preliminary information for both solar and Tier 1 non carve-out ACP indicate significant payments. It should be noted, MEA is not expecting meaningful growth in the Tier 1 non carve-out category over the next 3-5 years PJM-wide and 5-10 years in Maryland. We can see the State’s overall status in Figure 6 below.

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

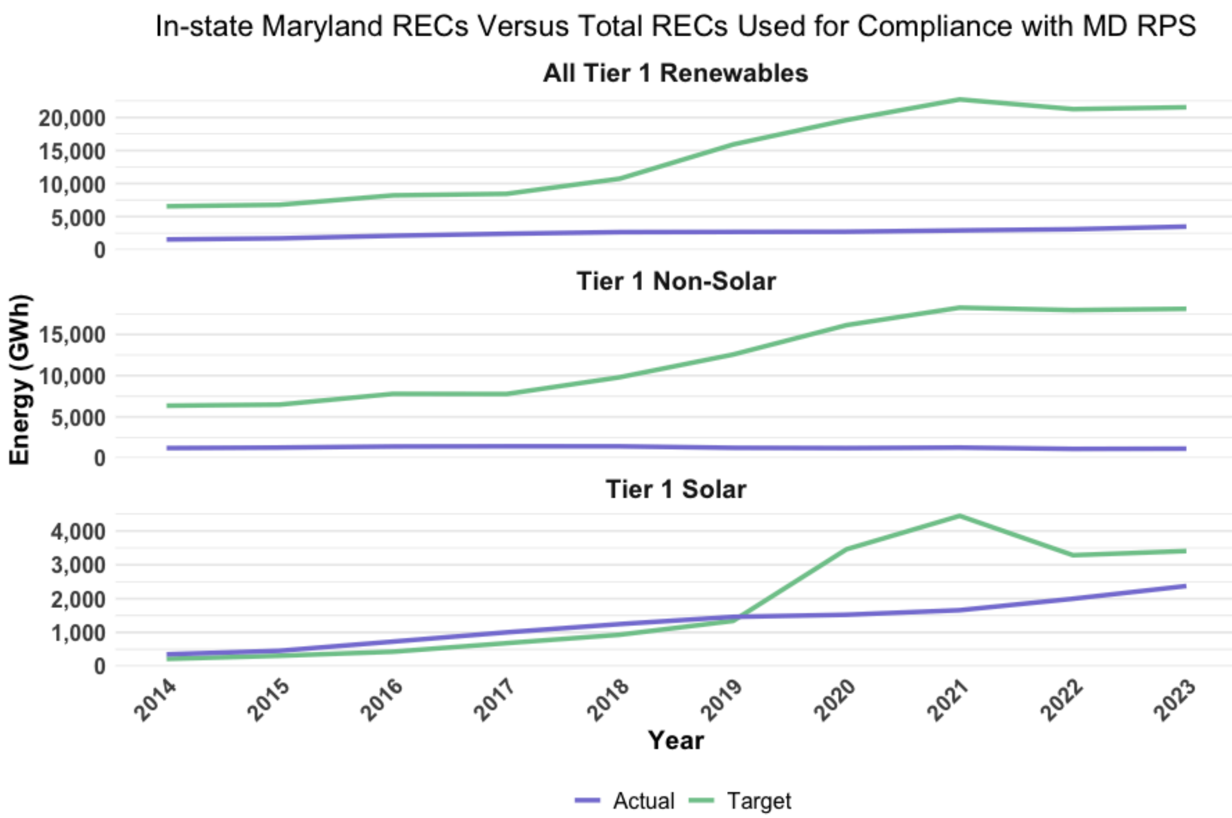

Figure 6. Tier 1 RPS targets compared against actual amounts **based on RECs generated in-State**.

Status of Solar

Before 2010, Maryland had less than 10 MW of installed solar capacity. As solar costs dropped, installations grew and the $27 billion infusion from the 2009 American Recovery and Reinvestment Act (ARRA) significantly boosted growth between 2014 and 2018. By 2018, the market stabilized at increases of 55 MW/year for residential and 20 MW/year for commercial. The Community Solar program, launched in 2017, began installing projects in 2020. The industry has continually encountered headwinds, however, since then. Solar tariffs introduced in 2018 led to price increases and the COVID-19 pandemic greatly reduced residential and commercial solar growth in 2020. Post-pandemic, supply chain issues further delayed recovery. And, in 2024, additional tariffs on major solar module manufacturing countries were imposed, increasing prices further.

With the passage of the IRA in 2022, the federal government will infuse considerable funding to many facets of the solar industry, as well as improving the Investment Tax Credit and Production Tax Credit values, which helps defray the costs of numerous projects. While this funding is likely to spur the solar industry, this again represents a policy-based infusion of capital into the industry, likely producing an increase of solar installation in the 2028-2034 timeframe.[36] Part of the reason for this timeframe is because of the interconnection queue pause. In February 2023, PJM Interconnection stated that it would stop accepting new applications for grid interconnection. This action was taken in an attempt to reform its interconnection queue process, with the goal of providing more timely decisions on interconnection. Given the backlog of projects currently in the queue, it is unclear how this decision will affect the review of projects currently in the pipeline. At present, projects take about 4 years to get through PJM and about 12-18 months to get through the PSC, so projects entered into the PJM interconnection queue are unlikely to be online for approximately 7-8 years after.[37]

Another contributing factor to growth going forward is community solar. In January 2025, the Maryland Community Solar Pilot Program will convert into a permanent program. This will remove yearly caps on program capacity, likely resulting in a one-year surge of community solar approvals in 2025 and projects coming online in 2027 and 2028. In 2023, the Maryland legislature authorized community solar projects to be built as large as 5 MW, as opposed to being constrained to 2 MW, encouraging the development of larger projects.

Prior to 2017, large solar projects were rare within Maryland and Community Solar projects had yet to be built. As such, in 2016, approximately 50 percent of the solar capacity in Maryland was from residential solar arrays. With the advent of Community Solar, and with some large utility-scale projects being improved, the percentage of residential solar has decreased, and is likely to continue to drop. By 2026, only 30 percent of the solar capacity is expected to come from residential solar. Large-scale solar projects are more cost effective to install than residential projects and are therefore better to achieve RPS goals. As additional community solar and utility-scale projects are added, the residential percentage is expected to approach the 20 percent nationwide value.

Potential future trends for solar deployments imply deficits in needed generation. If we look at future scenarios related to projected solar generation, challenges remain. Using the PJM load forecast, and assuming that the solar projects currently in the active Certificate of Public Convenience and Necessity (CPCN) process (or projects clear of the CPCN but awaiting financing) are actually built on time, we can get a rough idea of near-term deployments. These assumptions imply we would need to build an additional 565 MW per year to meet the established solar goal in the RPS, with a 2030 target. Figure 7 presents a forecast based on best available estimates.

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[36] The IRA with ITC/PTC subsidies has greater longevity than ARRA.
[37] PJM is undergoing a reform effort on its interconnection process.

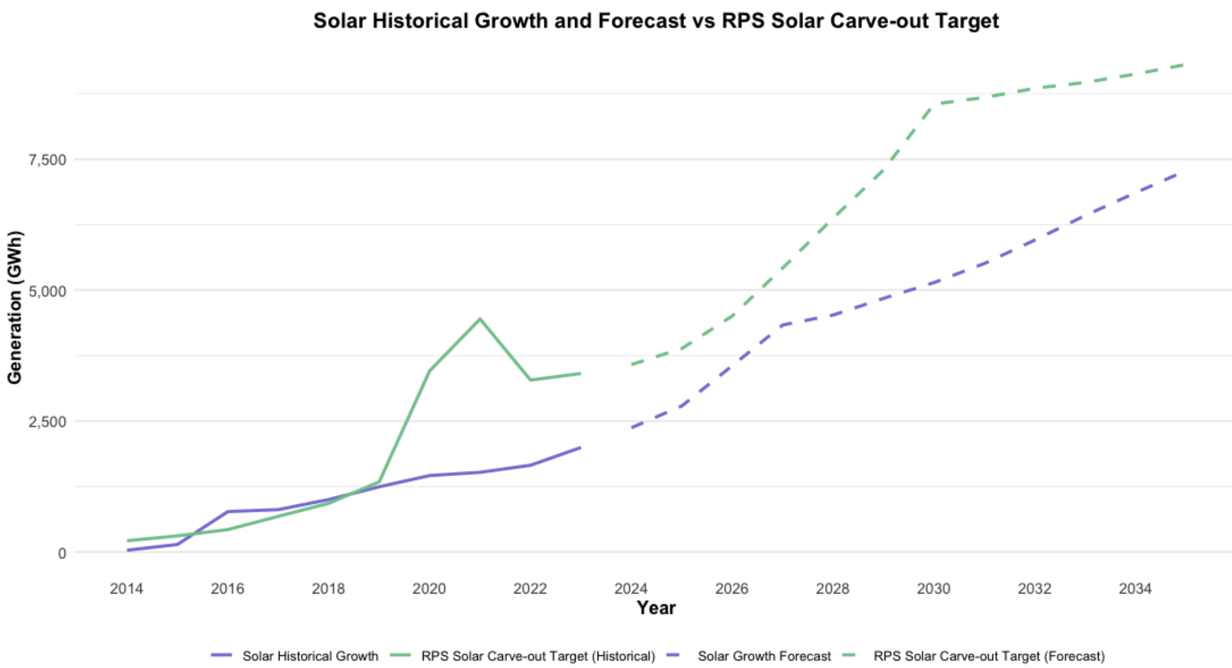

Figure 7. Cumulative solar growth, historical and forecast, compared to RPS targets.
Notes: These include projections based on known projects that are in the PJM queue or have received an Interconnection Service Agreement and are awaiting a CPCN, or have received a CPCN.

Status of Offshore Wind

OSW represents Maryland's most significant renewable energy potential, with the 2023 POWER Act raising the State's OSW goal from a minimum additional 1.2 GW by 2030 to an aggregate target of 8.5 GW by 2031. This expansion presents immense economic development opportunities, while fostering collaboration across the clean energy sector to strengthen supply chains and workforce capabilities. But challenges related to supply chain constraints, State procurement methods, and manufacturer competition persist.

Prior to 2024, the State had two projects awaiting development – both delayed, but still moving forward. The State issued round 1 OREC awards in 2017. Both projects had certain content requirements (required investments for manufacturing and job growth). In the round one solicitation, Ørsted committed to ensuring that 34 percent of all capital expenditures during construction were in-State, which was projected to create 1,397 direct jobs. Orsted planned to use the Ocean City port for operations and maintenance (O&M) and the TradePoint Atlantic facility in Baltimore as the marshaling port. Ørsted also planned to establish a permanent operations center in Maryland for the Skipjack 1 project, invest $25 million in a steel fabrication plant at TradePoint Atlantic, and invest $13.2 million in the TradePoint Atlantic shipyard port facility. Similarly, US Wind was required to allocate 19 percent of its capital expenditures in-State, which is projected to create 3,580 direct jobs and proposes to use the same port facilities as Ørsted. US Wind also planned to invest $51 million in a steel fabrication plant and $26.4 million in the TradePoint Atlantic shipyard port facility, along with establishing a permanent operations center in Maryland for the MarWin project.

A second round of OREC awards was conducted in 2021. In round two, Ørsted's in-State expenditures amounted to $410 million, which included using TradePoint Atlantic for marshaling, the Ocean City port for O&M, and establishing a permanent operations center for the Skipjack projects. Ørsted also planned to create a turbine tower manufacturing facility at TradePoint Atlantic, upgrade Crystal Steel for fabrication, and establish a grant fund for environmental organizations, resulting in 3,081 direct jobs. US Wind's in-State expenditures reached $570 million, involving the creation of a monopole factory at Sparrows Point, a partnership with UMBC for research, and using TradePoint Atlantic and Ocean City port facilities for marshaling and O&M. US Wind also aimed to establish a permanent operations center for the MarWin and Momentum Wind projects, creating 7,244 direct jobs.

The most notable setback after the awards in 2017 and 2021 was Ørsted's cancellation of its OREC awards in late 2023. Before the cancellation, that project combined with US Wind's represented roughly 2 GW of capacity. Ørsted's withdrawal left the State only with US Wind's remaining approximately 1 GW project. The legislature acted quickly in the 2024 session to provide supporting legislation that enabled US Wind to file a rebid application (ongoing), allowing them to fill out their entire lease area, while still remaining under existing ratepayer impact caps set by the legislature. Ørsted's intention to pursue development in their lease area remains unclear.

The US Wind investments remain intact, and some of the investments were made by Ørsted before canceling its OREC contracts.[38] Through US Wind's recent rebid application at the PSC, it has indicated that the company will be able to build out approximately 1.7 GW of capacity in its lease area, effectively filling out the entirety of the space, and are proposing to take on additional in-State investments.

An additional positive development also occurred in August 2024, with the conclusion of the most recent BOEM Central Atlantic auction, with additional lease space for Maryland made available. This process yielded a provisional winning bid by Equinor for about 100,000 acres of lease space, enough for approximately 1.5-2.1 GW of capacity.

Determining projected MWh produced per year for all three Maryland lease areas is difficult, given that US Wind is the only company with an active contract (or application) demonstrating concrete numbers. From US Wind's public rebid application, it projects a 1.7 GW field with commercial operations for the first phase by 2028. The subsequent three phases are expected to come online by 2030. The projected annual MWh generation for the full project is 6,966,836.[39] It is not unreasonable to expect the other two projects (in the lease areas held by Equinor and Ørsted) will be somewhat comparable in size and output, which would result in total projects

[38] This includes funding directed to MEA for business and workforce development programs.
[39] Per US Wind's Public Rebid Application.

sized at a minimum of 5.1 GW and would generate roughly 20,900,508 MWh total, providing a significant amount of generation to the State. This level of output will be roughly one-third of Maryland’s current annual demand.

Model Overview and Basic Study Assumptions

For this study, TCR models the PJM market as a standalone system and the interchange between PJM and neighboring RTOs/ISOs as a fixed scheduled flow. TCR retains the entire eastern interconnection topology for accurate power flow analysis. The modeling and input assumptions specific to the PJM Interconnection LLC (PJM) power system and energy market model are described below. The dataset is specifically assembled and designed for use by the Power System Optimizer (PSO) within the ENELYTIX® modeling environment.

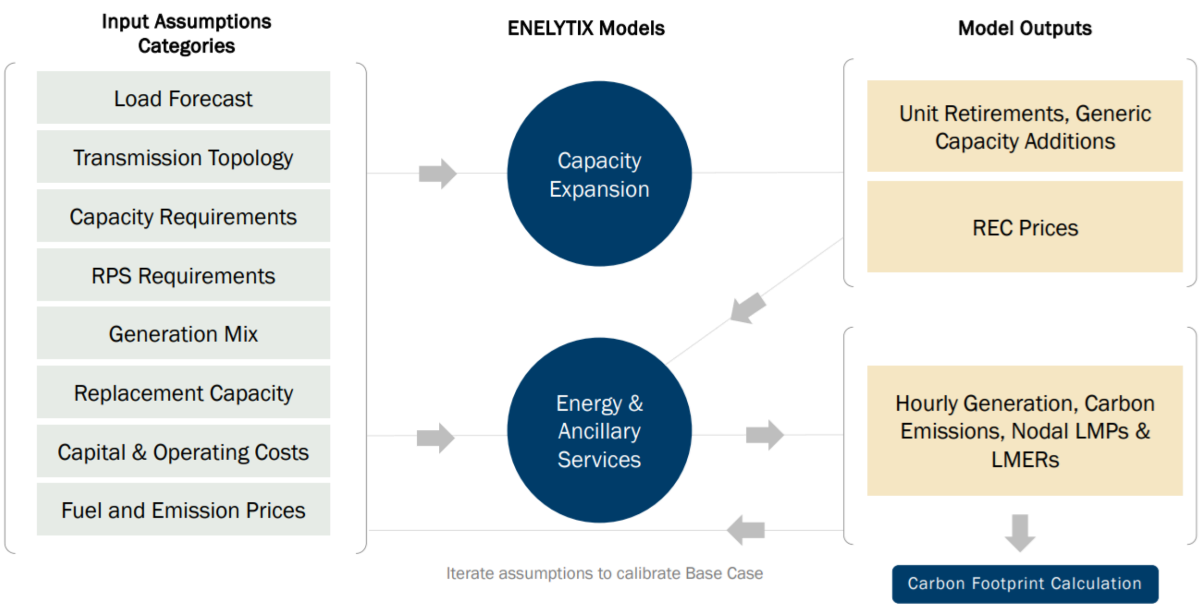

Figure 8. Overview of the Model

Additionally, the TCR model goes one step further by utilizing hourly plant level emissions data to better understand when carbon-emitting resources are used the most. The primary examination of a decarbonized system used in the base case and decarbonization scenarios is a marginal based emissions accounting approach. In this model, an overbuild of emissions-free generation is used to offset any remaining emissions-based generation that remains on the Maryland geographic network.

Locational Marginal Emissions Rates

The carbon footprint of the base case scenario is estimated using a carbon accounting methodology based on locational marginal emission rates (LMER). The LMER-based carbon accounting measures the change in system-wide emissions in response to a marginal increase or decrease in demand at a given node and has units of CO_2 per megawatt-hour. LMERs vary by time and location on the grid and can be used to attribute grid emissions to individual loads, generators, and transmission assets on the grid.

The carbon footprint of electricity load at a specific location (e.g., node or aggregated load area) at a particular time is calculated as the product of the electricity consumed and the LMER at that location. The net emissions attributable to electricity generation at a specific location (e.g., generator node) is calculated as the difference between the physical emissions released and the system-wide emissions displaced (computed as a product of the unit-specific generation and the LMER at the unit's electrical location). To calculate Maryland's carbon footprint for a given year, TCR calculated the hourly carbon footprint of all loads, generators, and transmission in Maryland and summed over all hours in the year. Under the Base Case capacity expansion, Maryland's electric-sector carbon footprint decreases to 23.2 million short tons-CO_2 by 2035.

Regional Policy Environment

Because Maryland is part of the broader PJM network, in order to more accurately understand the needs of the state, an analysis was conducted of Maryland within this broader system to account for inflows and outflows of electricity. PJM coordinates the movement of electricity through all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. PJM's footprint encompasses several major U.S. load centers, including the metropolitan areas in and around Baltimore, Chicago, Columbus, Cleveland, Dayton, Newark and northern New Jersey, Norfolk, Philadelphia, Pittsburgh, Richmond, Toledo and the District of Columbia.

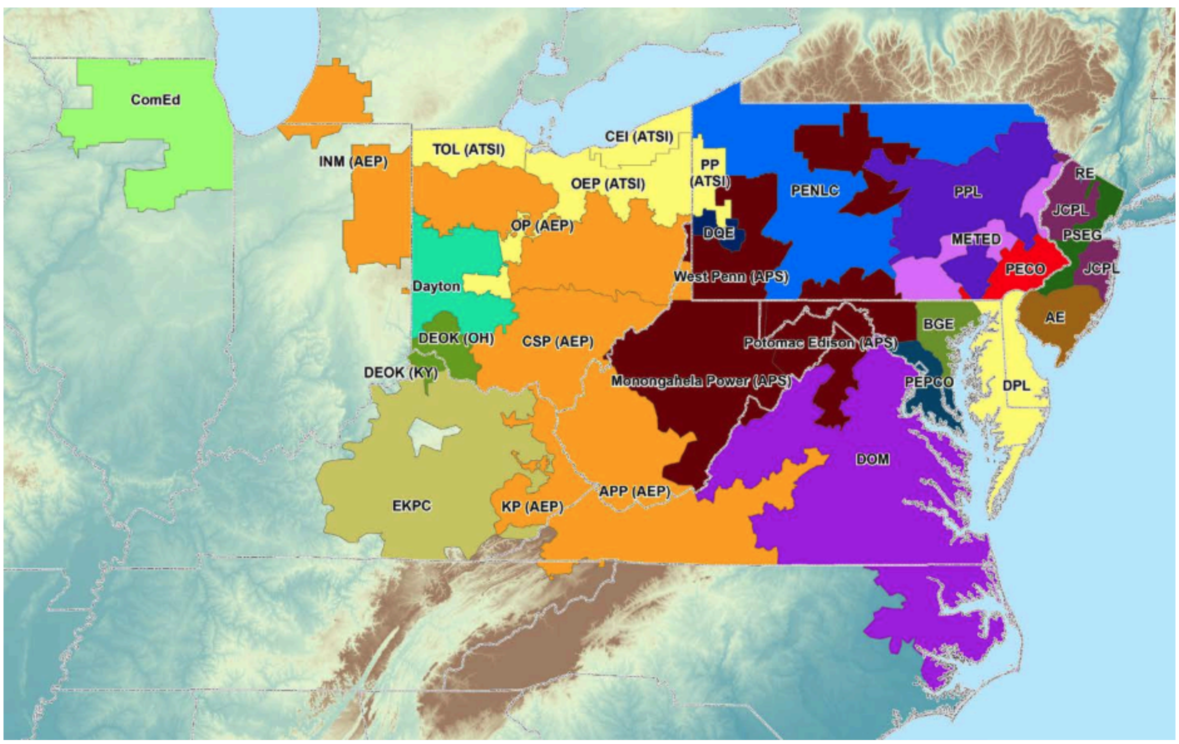

Figure 9. The 13-state PJM Network
Source: PJM

The model utilizes the following legislation, plans, and draft regulations from PJM states to provide a background for the development of the base case for the PJM system. The policies used for this model include the following.

RPS for PJM states:
Several states in the PJM region are mandated to procure clean energy resources through RPS and similar policies. Definitions of "clean energy" vary by state. The goals of the RPS programs in the PJM territory used in the model are outlined below:

- **Delaware** – 40 percent renewable energy by 2035, 10 percent from solar photovoltaic (PV) by 2035
- **Illinois** – 25 percent renewable energy by 2025, 50 percent by 2040; 45 percent of renewable energy credits to be procured from wind projects and 55 percent from PV projects, of which at least 50 percent from distributed or community solar PV
- **Maryland** – 50 percent from Tier 1 resources and 2.5 percent from Tier 2 resources by 2030; 14.5 percent of retail electricity sales must come from solar resources by 2030; at least 1,200 MW of offshore wind and 1 percent geothermal by 2030
- **Michigan** – 50 percent renewable energy by 2030, 60 percent by 2035; 80 percent clean energy by 2035, 100 percent by 2040. "Clean energy" in Michigan includes nuclear and combined capture and storage (CCS) gas that is 90 percent effective.
- **New Jersey** – 35 percent Class I renewable energy by 2025, 50 percent by 2030; 2.5 percent Class II renewable energy each year; annual solar requirement that reached a maximum of 5.1 percent in Energy Year (EY) 2021 and decreases to 2.21 percent in EY 2030 600 MW of energy storage by 2021, increasing to 2,000 MW by 2030; targeting 3,500 MW of OSW (no statutory timeline).[40] As described below, this policy is due to change by the end of 2024. New Jersey also issued an Executive Order bringing its OSW goal to 11 GW, but was not included in this model.
- **North Carolina** – 12.5 percent for investor-owned utilities (IOUs) and 10 percent for municipal utilities and electric cooperatives by 2021, 0.2 percent solar by 2018, 0.2 percent swine waste by 2024 (IOUs) and 2026 (municipal utilities and electric cooperatives), 900,000 MWh poultry waste by 2023
- **Ohio** – 8.5 percent renewable energy by 2026
- **Pennsylvania** – 8 percent from Tier 1 "alternative energy" resources and 10 percent from Tier 2 "alternative energy" resources by 2021, 0.5 percent solar PV by 2021. "Alternative energy" includes coal mine methane and waste coal.
- **Virginia** – 100 percent by 2045 (Dominion Energy Virginia) and 2050 (Appalachian Power). At least 16,700 MW of solar or onshore wind by 2036; one or more OSW facilities with an aggregate capacity up to 5,200 MW; at least 3,100 MW of energy storage capacity by 2036
- **District of Columbia** – 100 percent by 2032, 5 percent from local solar power by 2032, increasing to 10 percent by 2041

[40] The model used established legislation, rather than New Jersey's Executive Order (September 2022) calling for a target of 11,000 MW of OSW by 2040.

The TCR model does not utilize voluntary renewable/clean energy targets. Indiana, Kentucky, Tennessee and West Virginia either have no RPS or have a voluntary renewable energy target.

Carbon Cap and Trade Programs:
Within the PJM region, Delaware, Maryland, New Jersey, and Pennsylvania[41] participate in the Regional Greenhouse Gas Initiative (RGGI), a market-based, cap-and-trade program targeting carbon dioxide emissions from power plants. Under the market, power plants purchase allowances for carbon dioxide emissions during quarterly auctions. This initiative is also taken into consideration in the design of the model.

Classification of Clean Generation Technologies Utilized in this Report

In alignment with current State policy, the report first draws on existing Maryland law and the technologies included in the RPS. As a recap, the eligible technologies in the RPS are listed here:

Tier 1 Renewable Sources

- Solar, including energy from PV technologies and solar water heating systems
- Wind
- Qualifying Biomass
- Methane from a landfill or wastewater treatment plant
- Geothermal
- Ocean
- Fuel Cell that produces electricity from a Tier 1 source
- Hydroelectric power plant less than 30 MW capacity
- Poultry litter-to-energy
- Waste-to-energy
- Refuse-derived fuel
- Thermal energy from a thermal biomass system

Tier 2 Renewable Sources

- Hydroelectric power other than pump storage generation

Clean Energy Additions

Nuclear

In recognition of the need for additional clean energy resources in the State, and in accordance with the definition of "clean energy" under Maryland law (Md. Code, Economic Development Article §8-801), the report and modeling *includes nuclear generation* as a clean generation resource because it does not produce GHG emissions during operation.

Energy Storage

Energy storage is not a component of the RPS because it is not generation in the purest form, but is certainly an enabling technology in certain scenarios. And, as the technology develops and

[41] Pennsylvania's participation has been volatile and is currently undergoing legal review within the State.

costs decline, storage, especially long-duration storage, may have an increasing role to play on Maryland's grid.

Economic and Financial Assumptions

All financial assumptions are reported in 2024 dollars (2024$). The rate of inflation assumed in the model tracks the Congressional Budget Office (CBO) 2023 Long-Term Budget Outlook through 2026 and is assumed to be 2 percent thereafter, as shown in Figure 10.

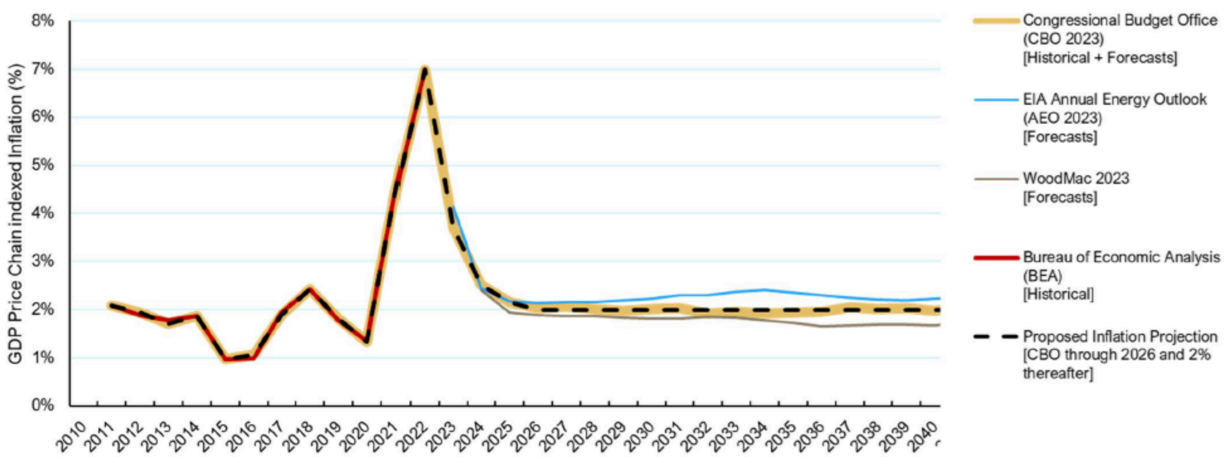

Figure 10: Inflation Estimates

Other financial assumptions like the capital costs for individual generation technologies were drawn from a mix of sources. TCR relies on unit parameters such as capacity, heat rate, emissions, and cost assumptions for future generating resources from the 2023 capital cost assumptions report developed by the EIA for its 2023 Annual Energy Outlook. TCR also uses the NREL 2023 Annual Technology Baseline to cross benchmark and augment the cost database. TCR inflates all costs to 2024 dollars and accounts for any variations in those costs by energy area based on the EIA Electricity Market Module (EMM).

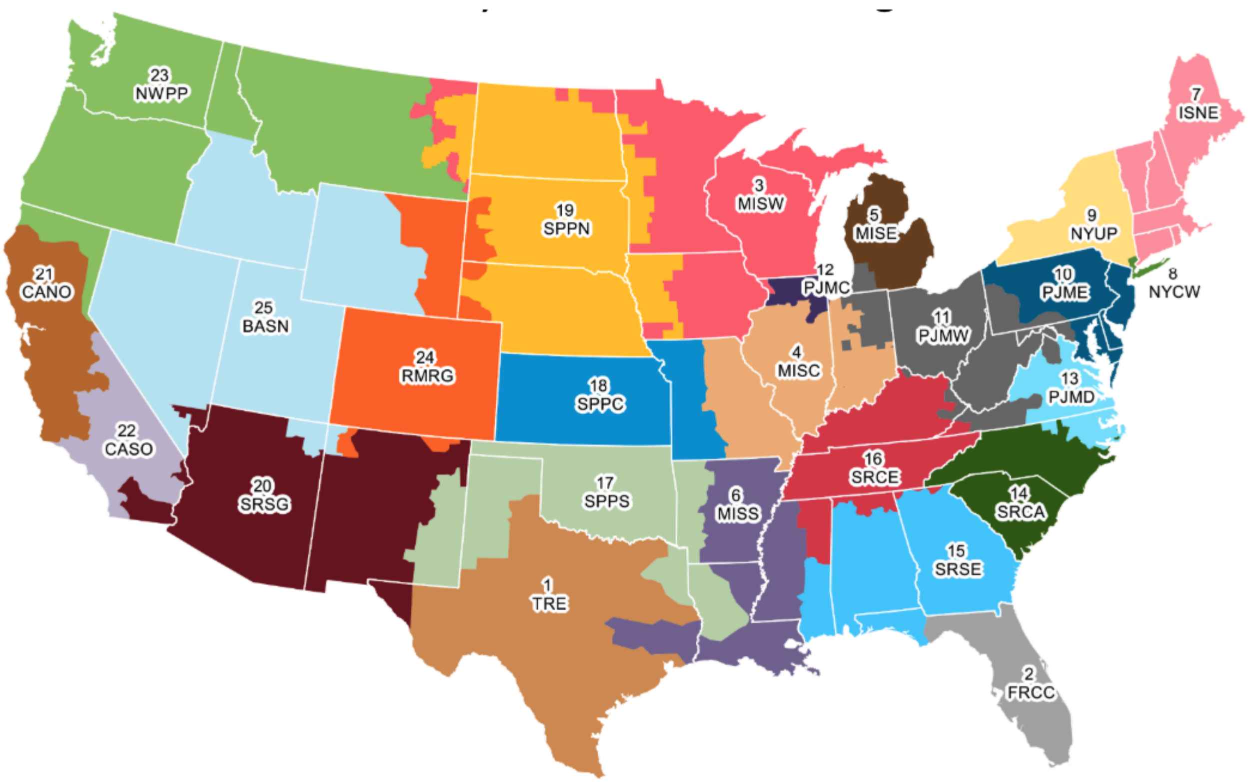

Figure 11.

Going by the EMM and for the purposes of this study, it is important to note that PJME consists of BGE, PEPCO, and DPL. PJMW consists of APS, which includes the Potomac Edison territory in West Maryland.

Table 5. Representative Technology Cost Assumptions for Technology Types Utilized in the Base Decarbonization Case

Generation Type	Install Cost ($/kw)	Finance Period (Yrs)	Fixed Charge Rate	FOM ($/Yr)
Battery Storage PJME	$950.87	20	6%	$151.35
Nuclear (Traditional) PJMW	$8,086.49	20	6%	$142.36
Nuclear (SMR) PJME	$9,945.49	20	6%	$127.37
Nuclear (SMR) PJMW	$8,673.21	20	6%	$111.07
PV PJME	$1,133.90	20	6%	$19.20
PV PJMW	$1,071.40	20	6%	$18.14
Offshore Wind PJME	$5,551.18	20	6%	$147.16
Onshore Wind PJME	$1,543.85	20	6%	$31.16
Onshore Wind PJMW	$1,165.14	20	6%	$23.52

Notes: The differences per each EMM region reflect different build costs (e.g., property acquisition, etc.) within those regions. **All cost assumptions have either ITC or PTC calculations built in, except for the three nuclear categories.**

Other Useful Information[42]

To simulate hourly operation of PJM, ENELYTIX requires hourly demand data for PJM areas. TCR prepares hourly load shapes for each PJM area using historical data obtained from PJM, as well as the monthly energy and peak forecasts published by PJM.

To project future load, the model uses PJM's 2024 forecasts, which include net load and BTMPV generation, and extend through 2039. The forecasts were released on December 27, 2023. When necessary to extend the peak and energy forecasts through the full modeling period, TCR applies a single-year growth rate from the last year of the forecast.

TCR obtained an operating generation assets list from S&P Global's Assets Database as of October 17, 2023. Based on this list of operating assets, TCR applies projected generation addition and retirement information from the S&P Global database to capture the scheduled changes in PJM's generation mix. After introducing scheduled capacity additions and retirements, future additions and retirements are determined by the ENELYTIX capacity expansion model. The capacity expansion module chooses from a predefined list of potential future generation resources to satisfy resource adequacy and environmental constraints. There are two categories of generation resources that can be added by the capacity expansion module. The first category includes the fossil fuel-based conventional sources of generation that are built in discrete increments based on the size and attributes of the reference unit. The second category includes variable renewable resources, such as wind and PV, that the model can build in varying size increments up to their resource potential. Additionally, the capacity expansion module can add battery storage.

TCR develops projections of the monthly spot price of natural gas to each gas-fired unit in PJM using projections of spot prices at the market hubs serving the units. The projections of natural gas spot prices at each market hub are obtained from Wood Mackenzie's North America gas markets long-term outlook. The current forecast prices utilize Wood Mackenzie forwards from October 2023. Monthly prices are converted to 2024 dollars using the monthly inflation rates assumed in the model.

[42] There are many other assumptions that go into this model – only a small portion are covered in this report, but more information is available upon request.

Modeling Results

Base Case Scenario

The Base Case Scenario, also known as the business-as-usual (BAU) scenario, serves as a reference point. It reflects the continuation of existing trends and policies without any specific interventions. In this scenario, it's assumed that current conditions, policies, and practices remain unchanged over the modeling period. This also means the BAU scenario will show higher growth in gas plants and total generation capacity of all types added is roughly 3.7 GW. Essentially, it represents a hypothetical future state where no additional actions or measures are implemented beyond what is already in place or planned. This gives a baseline to understand where the current trajectory of the generation mix is headed by 2035.

Taking into consideration the policy environment and the planned retirement of generating plants like Warrior Run, Brandon Shores, and Herbert Wagner, a baseline capacity mix for Maryland is developed.[43] Figure 12 shows the base capacity mix in Maryland through 2035.

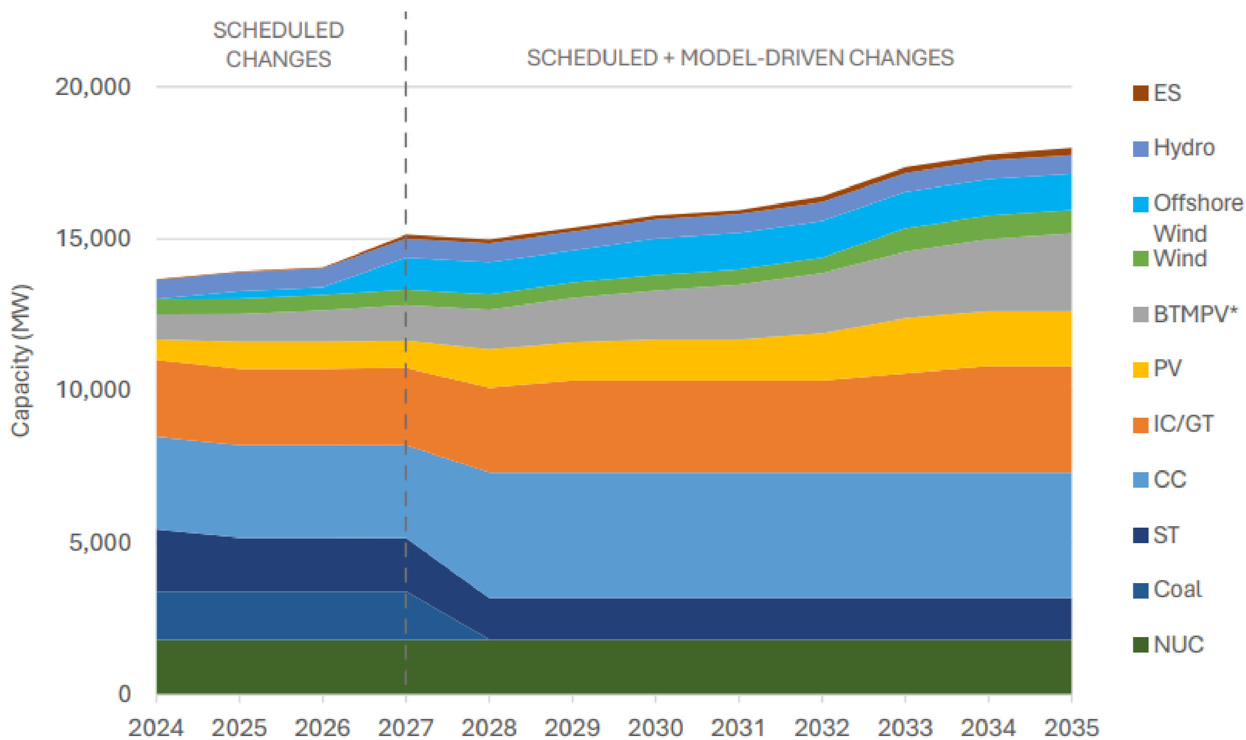

Figure 12. Base Case results out to 2035.
Notes: ES – Energy Storage, PSH – Pumped Storage Hydro, BTMPV – Behind-the-Meter Solar Photovoltaic, PV – Solar Photovoltaic, FC – Fuel Cell, IC/GT – Internal Combustion/Gas

[43] Warrior Run was retired in mid-2024. Brandon Shores and Wagner are now subject to a potential reliability must run agreement from PJM, which would extend their operations to 2028.

Turbine (including bio gas & bio solids), CC – Combined Cycle, ST – Steam Turbine (biomass, refuse, or gas-fired), NUC – Nuclear

Solar PV and onshore wind capacity increase to 1.4 GW and 454 MW, respectively, by 2035. Combined cycle gas plant capacity is expected to increase by 36 percent. OSW capacity increases to 1.2 GW by 2030 and all coal capacity is projected to retire by 2028.

It should also be noted that this mix is not simply reflecting the policy instruments and goals of Maryland. It also reflects a certain degree of economic and system trends. For instance, OSW clearly does not achieve policy targets, given that the model operates off the currently contracted amount and then assumes economic deployment. This mix also clearly indicates strong growth in behind-the-meter solar and combined cycle natural gas plants.

The incremental additions and retirements by year in the Base Case scenario are shown in Figure 13 and 14 below. Under the Base Case capacity expansion, the model adds 913 MW of PV, 264 MW of onshore wind, and 144 MW of OSW on top of planned additions. Almost all retirements included in the Base Case capacity expansion are planned retirements, with the model choosing to also retire a small steam turbine unit on the campus of the University of Maryland.

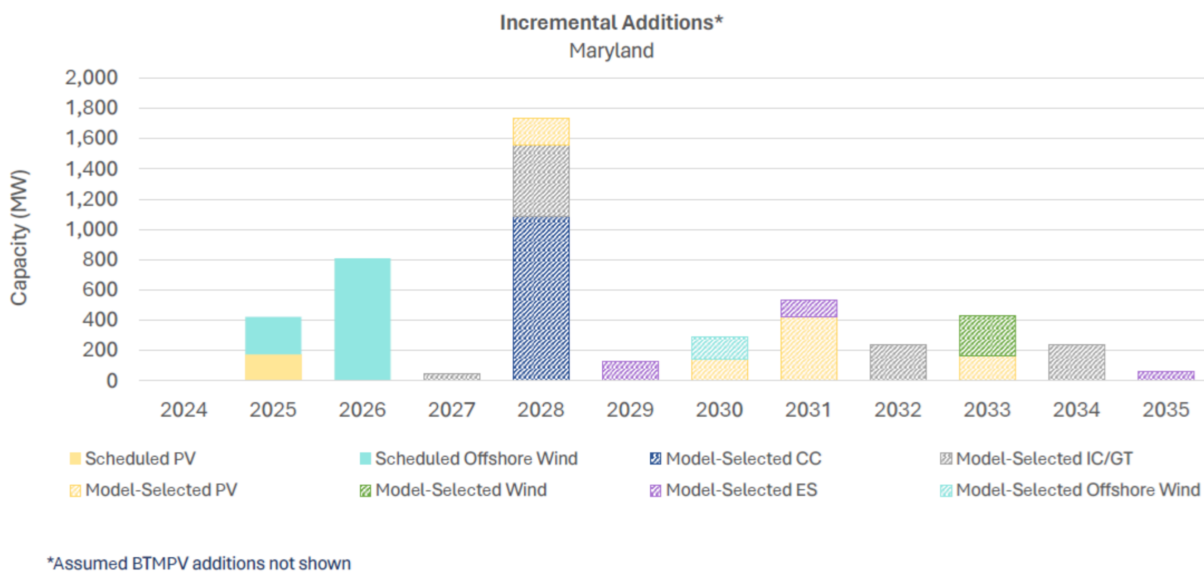

Figure 13. Incremental additions

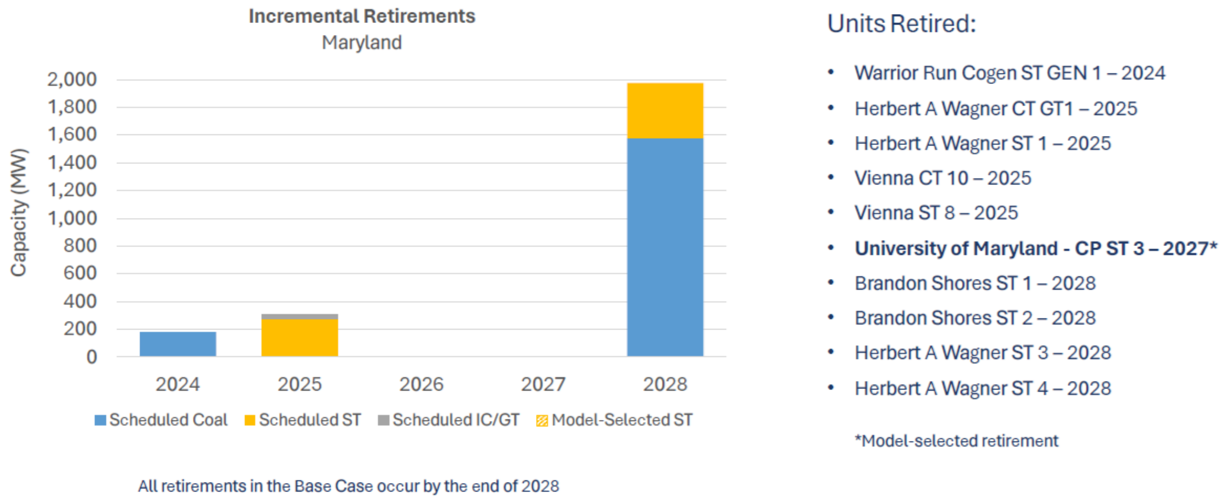

Figure 14. Incremental Retirements

Under the current policy trajectory, there are continued decreases in carbon emissions occurring in the Maryland power sector. Much of this reflects policy instruments like the RPS, which is why significant decreases occur up to 2030 and then plateau, as reflected in Figure 15.

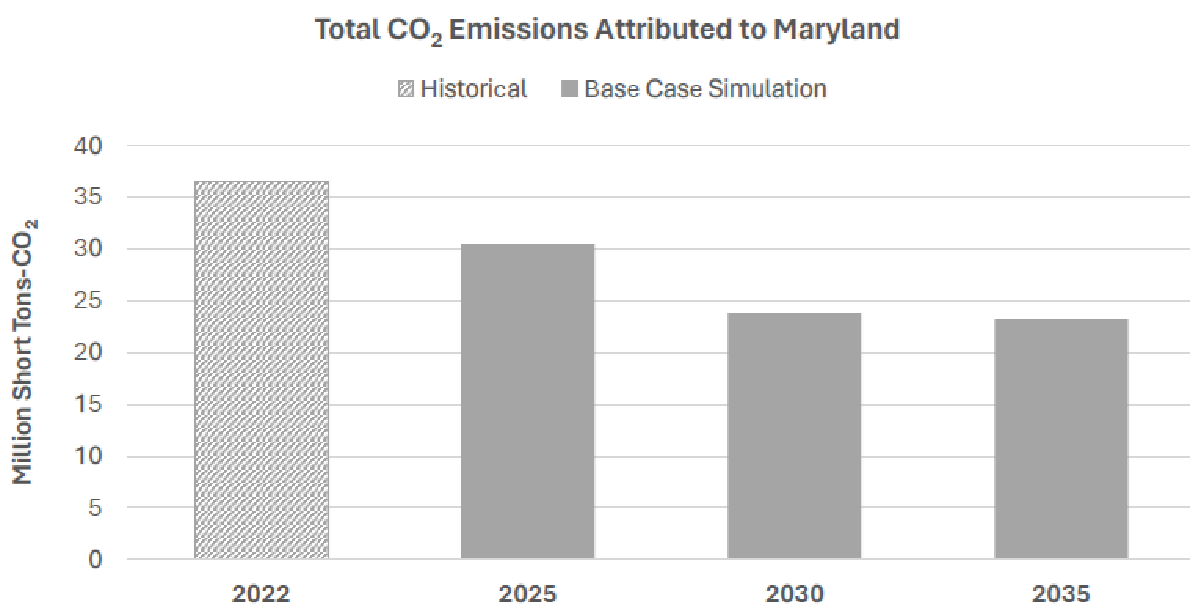

Figure 15. Power sector emissions under the base case scenario.

Under the Base Case Scenario capacity expansion, net-negative emissions from Maryland generation offsets approximately half the emissions attributable to Maryland's load. Emissions attributable to congestion decrease over time as the model builds cost-effective generation assets near load centers.

Decarbonization Scenario

The primary purpose of this scenario is to include minimal restraints and see what the model produces as an optimal generation mix. The decarbonization scenario has the following minimal restrictions:

- 100 percent net carbon free by 2035
- Capacity additions needed to reach net-zero required to be in-State
- Maximum aggregate amount of solar: ~3.9 (plus 2.5 BTMPV) GW
- Maximum aggregate amount of onshore wind: ~1.3 GW

It was necessary to restrict solar and onshore wind within reasonable limits. Unrestrained, given the lower comparative capital costs of both solar and wind, the model, which preferences least-cost construction, would severely overbuild either or both of these technologies to unrealistically high levels (typically over 15 GW). Since this is a model, with many simplifying assumptions, it does not fully capture important, real-world considerations like build times and land use restrictions, among other factors. But it gives a general understanding of a potential cost-effective mix.

Under the Decarbonization Scenario, the model retires an additional 634 MW of thermal capacity by 2032. Figure 16 shows the additional retirements from the base case. Additionally, the model adds approximately an additional 9.6 GW of clean energy generation above the planned, or Base Case, capacity expansion levels to reach a net-zero carbon footprint by 2035.

Figure 16. Additional fossil-based retirements under the Decarbonization Scenario.

In the new capacity mix under the Decarbonization Scenario, all coal capacity retires by 2028 per planned retirements and retains several gas-fired thermal plants. Nuclear capacity increases by 185 percent with the addition of one traditional nuclear unit and two small modular reactors,[44] PV and onshore wind capacity increase to 3.9 GW and 1.3 GW, respectively, over

[44] There is further discussion elsewhere in the document, but it bears noting here that MEA does not think it is realistic to think this much nuclear generation could be built by 2035 – it would be challenging to have any one of these plants built before then.

2024-levels and OSW capacity increases to 3.9 GW. The model maxes out available PV and onshore wind and supplements with nuclear and OSW. This is an important point, as it provides an overriding understanding of how the model is operating for the Maryland case, given constraints. The State sets certain builds of solar and onshore wind, which is then supplemented by the more costly nuclear or offshore wind at different rates. Figure 17 shows the capacity mix under the Decarbonization Scenario and the evolution of that mix is shown in Figure 18.

Nuclear growth in the Decarbonization Scenario is particularly noteworthy. Nuclear can be thought of as similar in many ways to OSW in terms of supply chain complexity, capital costs, and timelines for deployment, yet the model chose not to fully build out OSW and instead pursue nuclear, because at a certain point OSW growth results in higher levels of curtailment (the turbines spin but don't add any power to the grid, because the grid is at capacity), effectively reducing profitability (and GHG emission mitigation potential) of those projects. Curtailment is not expected for the US Wind filed OSW project. Curtailment can also be avoided by a larger transmission buildout, in this case, likely on the Eastern Shore. ***It is also important to note that even though nuclear is eligible for ITC or PTC credit, this was not applied in the current modeling scenarios.*** This was an oversight that was allowed to remain, and ultimately does not change the story of generation in the State. Given time constraints and a good outcome for nuclear in the model — even with this handicap in place, nuclear already has a substantial showing in the scenario outputs, likely exceeding the amount of new nuclear the State would be able to construct in the given timeframe anyway. It is notable that without the significant subsidies provided by the IRA, new-build nuclear was still cost competitive with other capital intensive technologies.

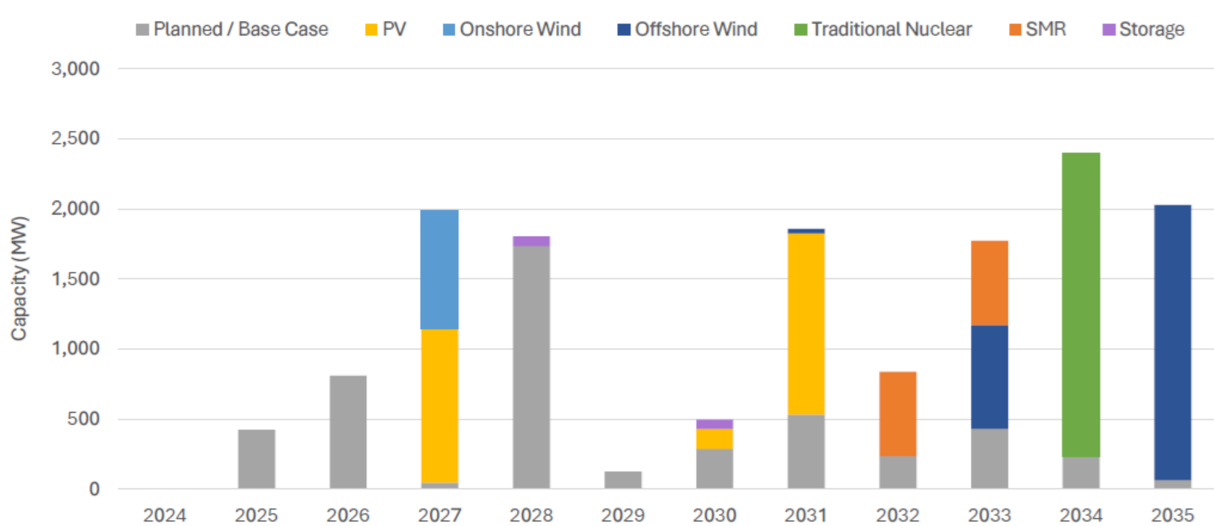

Figure 17. Capacity additions to meet the 2035 goal.
**ITC/PTC applied to all clean technologies except for nuclear, which is also ITC/PTC eligible.*

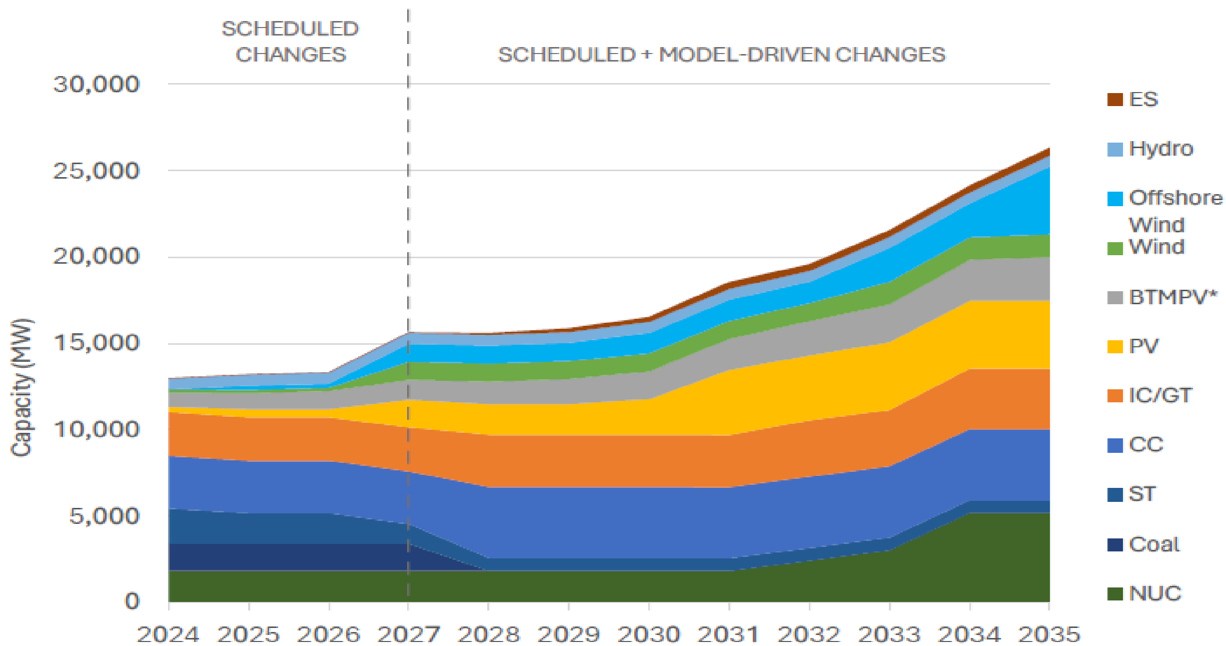

Figure 18. Decarbonization scenario results out to 2035.
Notes: ES – Energy Storage / PSH – Pumped Storage Hydro / BTMPV – Behind-the-Meter Solar Photovoltaic / PV – Solar Photovoltaic / FC – Fuel Cell / IC/GT – Internal Combustion/Gas Turbine (including bio gas & bio solids) / CC – Combined Cycle / ST – Steam Turbine (biomass, refuse, or gas-fired) / NUC – Nuclear
**ITC/PTC applied to all clean technologies except for nuclear, which is also ITC/PTC eligible.*

More precise capacity estimates are shown in Table 6. This gives the exact amount of each technology in the mix, on a cumulative basis, for each year of the scenario out to 2035.

Table 6. Cumulative capacity under the decarbonization scenario.

Cumulative Capacity (MW)

Year	NUC/SMR	Coal	ST	CC	IC/GT	PV	BTMPV	Onshore Wind	Offshore Wind	Hydro	ES
2024	1,816	1,578	2,045	3,049	2,528	320	810	190	0	623	30
2025	1,816	1,578	1,766	3,049	2,501	495	908	190	248	623	30
2026	1,816	1,578	1,766	3,049	2,501	495	1,034	190	248	623	30
2027	1,816	1,578	1,147	3,049	2,547	1,590	1,168	1,038	1,057	623	30
2028	1,816	0	750	4,132	3,021	1,768	1,306	1,038	1,057	623	98
2029	1,816	0	750	4,132	3,021	1,768	1,453	1,038	1,057	623	223
2030	1,816	0	750	4,132	3,021	2,055	1,611	1,038	1,200	623	289
2031	1,816	0	733	4,132	3,019	3,771	1,792	1,038	1,233	623	399
2032	2,416	0	733	4,132	3,256	3,771	1,991	1,038	1,233	623	399
2033	3,016	0	733	4,132	3,256	3,938	2,186	1,302	1,972	623	399
2034	5,172	0	733	4,132	3,493	3,938	2,369	1,302	1,972	623	399
2035	5,172	0	733	4,132	3,493	3,938	2,548	1,302	3,936	623	463

Notes: These numbers should not be taken as variable model outputs.

Maryland decarbonization also has impacts on the capacity and generation in the regional PJM system. Generation from new nuclear, PV, and wind capacity in Maryland predominantly displaces generation from CC units (both in Maryland and throughout PJM) when compared to the Base Case Scenario, as gas is more expensive than coal in the model. The change in PJM system-wide capacity and generation between the Base Case and Decarbonization Scenario is shown in Figure 19.

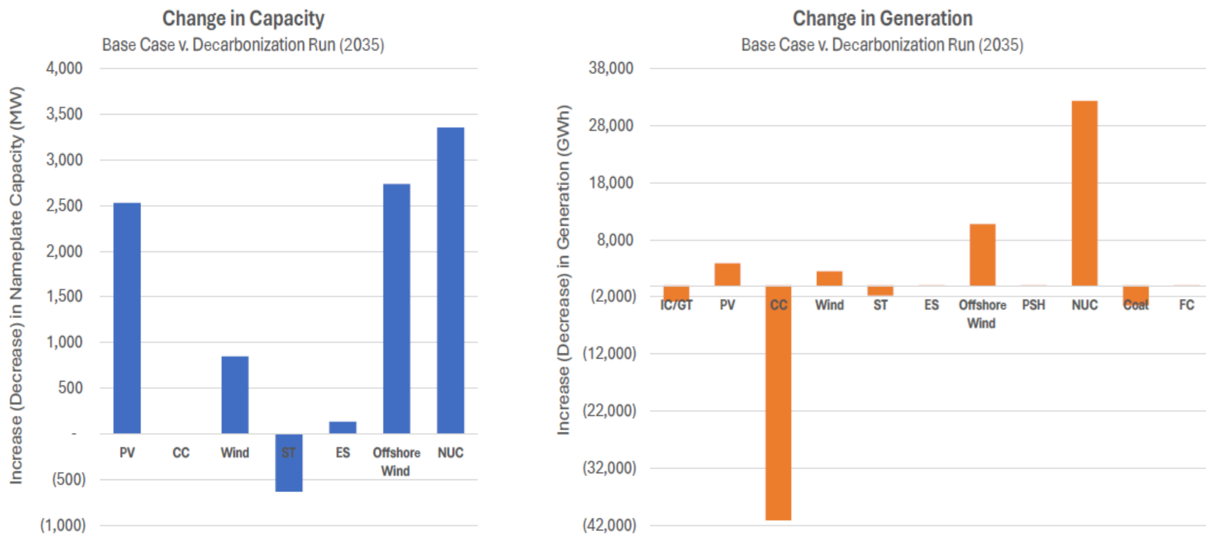

Figure 19. Changes in PJM-wide capacity under the Decarbonization Scenario.

Total PJM system-wide physical CO2 emissions decrease by approximately 23.7 million short tons between the Base Case and the Decarbonization Scenario. These emissions are fully attributable to Maryland (by model configuration and confirmed with the LMER-based carbon footprint calculation), reducing Maryland's electric sector carbon footprint to -0.08 million short tons by 2035. The net-negative emissions from Maryland generation doubles relative to the Base Case due to higher levels of clean energy capacity, while exports of Maryland renewable generation to PJM offsets the remaining emissions attributable to Maryland load. Figure 20 illustrates the effects on carbon emissions from decarbonization.

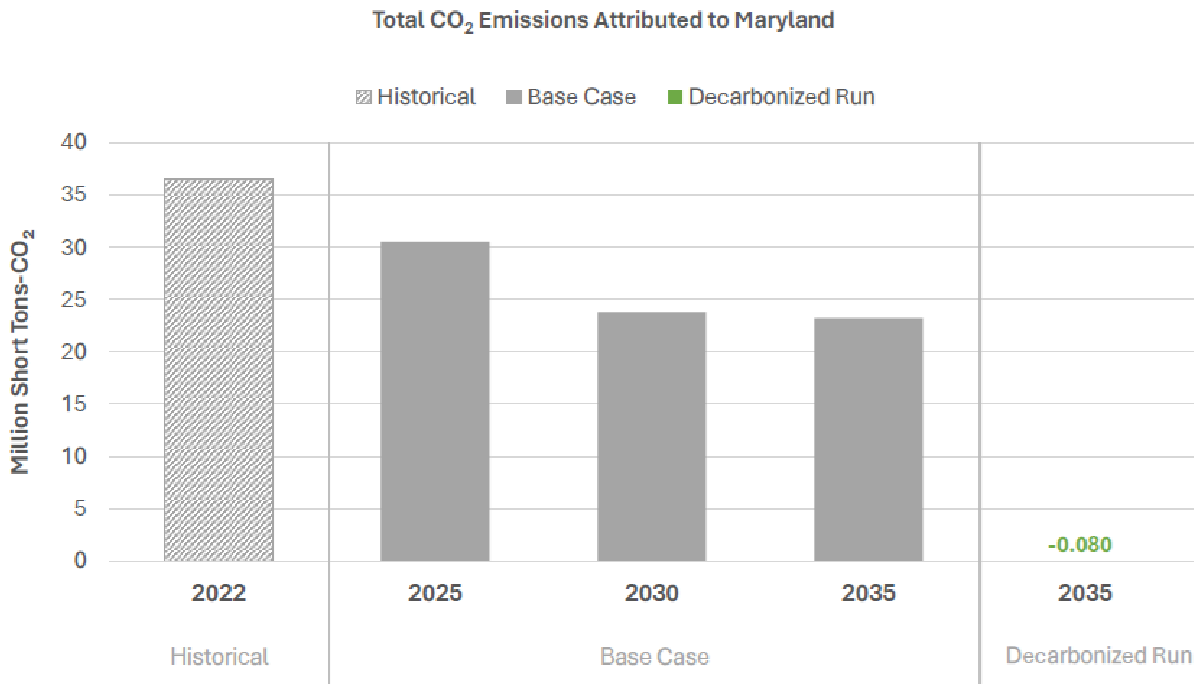

Figure 20. Total CO2 emissions attributable to Maryland.

Due to the constraints and objectives given to the model, Maryland becomes a net-exporter of energy to PJM under the Decarbonization Scenario as shown in Figures 21 and 22. The model basically reflects the desire to decarbonize the Maryland grid through geographically indigenous sources, but as discussed earlier, this is done through the LMER accounting, effectively netting out remaining fossil generation through a clean energy overbuild. This means at certain times, there will be excess generation available for export to PJM. This is a drastic shift for the State, going from a 36-38 percent importer of electricity to an exporter.

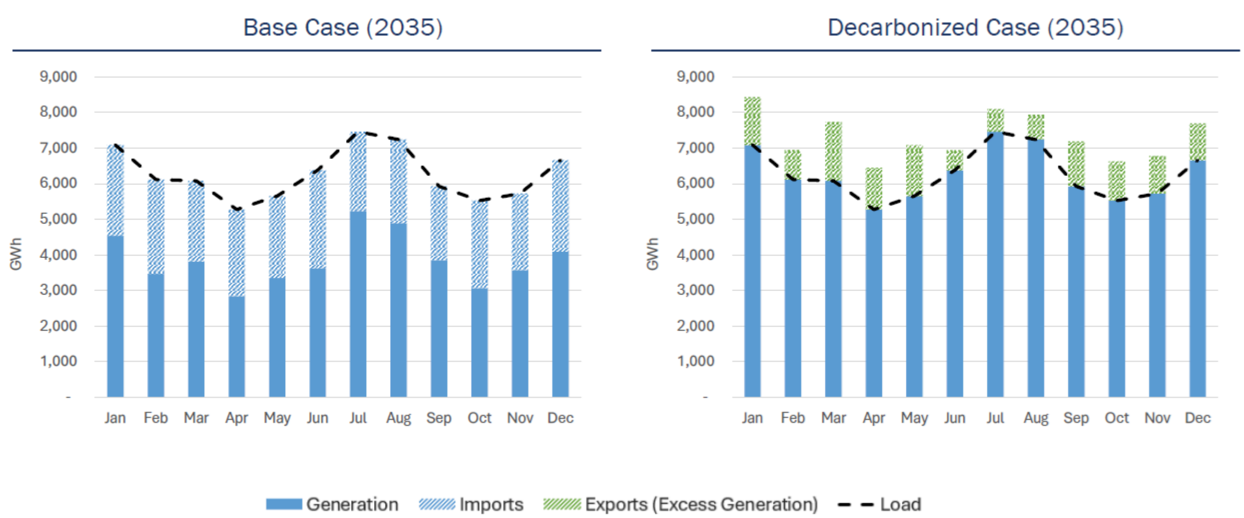

Figure 21. Change in imports and exports over the scenario period.

Looking a little closer at the comparison mixes in Figure 22, between the 2035 end-states for both the Base Case and Decarbonization Case, this large shift from importer to exporter is evident. This graph also shows the points throughout the year of higher and lower generation available for export, much of which seems to be driven by OSW. OSW, hydro, wind, and PV will sell into the grid whenever they are generating power, which accounts for some of the irregular hours and rationale for those generators acting as marginal exporters for the State. The additional nuclear power, in conjunction with the existing power from Calvert Cliffs, provides a much higher level of baseload capability throughout the year.

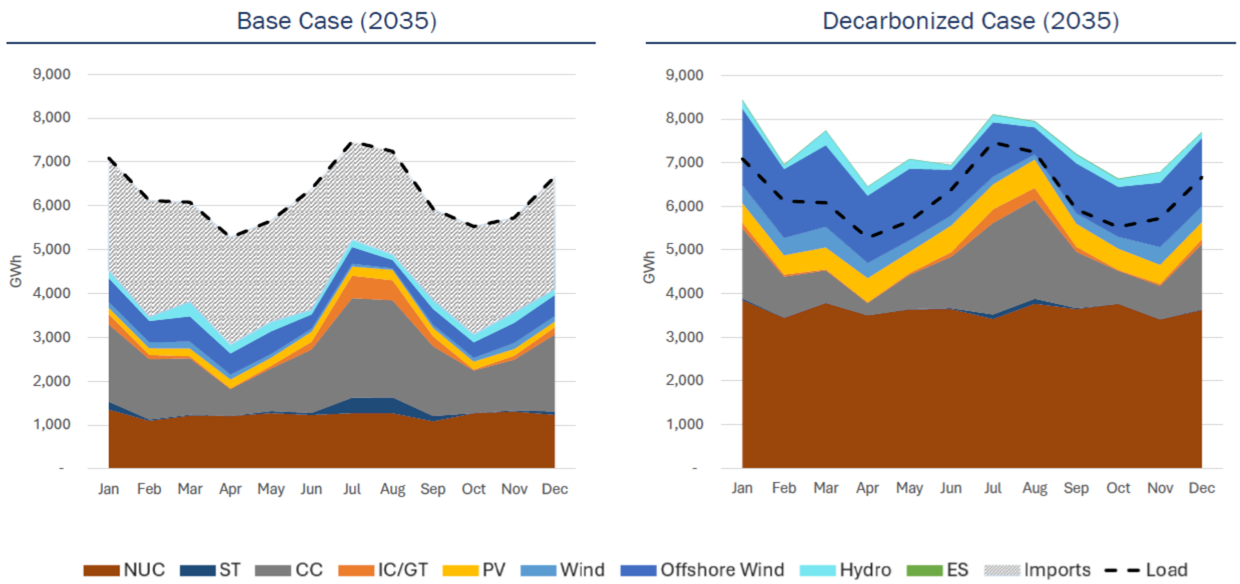

Figure 22. Comparison of the 2035 energy mix for both the Base Case and Decarbonization Case.
**ITC/PTC applied to all clean technologies except for nuclear, which is also ITC/PTC eligible.*

Maryland's renewable resources see negligible curtailment under both the Base Case and Decarbonization Scenarios as seen in Figure 23. This is an important point because energy curtailment is essentially wasted electricity and decreases the business case for the projects. This does not occur in the Base Case scenario and occurs only slightly in the Decarbonization Case. As a reminder, much of this curtailment is due to transmission constraints, so the most efficient solution here would be to build out additional transmission in the region.

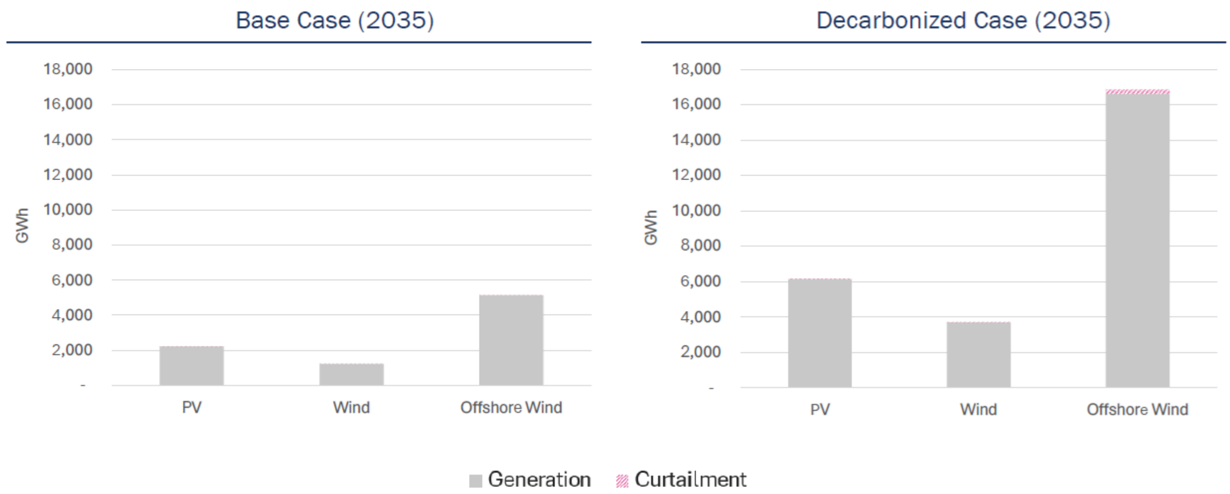

Figure 23. Variable generation curtailment

Both the Base Case and Decarbonization Scenarios should essentially be viewed as bookend scenarios, representing, on the one hand, an absence of any additional policy support (beyond what is currently in law) and a completely unrestrained approach to building the system in order to achieve the 100% decarbonized goal. Next, we review some different scenarios based on adjusting the constraints and caps on the variable generation technologies (OSW, onshore wind, solar).

Additional Decarbonization Scenarios

TCR modeled three additional decarbonization scenarios, meant to game out different potential scenarios for the State. Of particular interest is what would occur with different levels of renewables deployment, and how the model would reconfigure deployments as a result. We reviewed low-renewable, mid-renewable, and high-renewable scenarios, representing different potential levels of renewable resource availability constraints. In each scenario, the model maxes out available PV and onshore wind capacity, and supplements with OSW and either traditional nuclear or SMR capacity. Table 7 shows the upper limits on installed capacity for each scenario. Note, these are resource constraints – the model was not forced to deploy these resources.

Table 7. The different constraints applied per scenario

Upper Limits on Installed Capacity

Scenario	Solar (% Energy Req.)	Solar MW Equiv.	Onshore Wind (MW)	Offshore Wind (MW)	Storage (MW)
Low Renewables	8%	3,812	400 MW	2,000 MW	1,000
Mid Renewables	10%	4,765	500 MW	4,000 MW	2,000
High Renewables	14.5%	6,909	1,000 MW	8,500 MW	3,000

Scenarios that utilize more renewable energy require greater total incremental capacity due to the lower capacity factor of renewables relative to nuclear. Incremental retirements (above Base Case levels) are consistent across Decarbonization Scenarios, with the additional retirement of one additional steam turbine in the High Renewables Scenario. Figure 24 shows the incremental additions for each scenario.

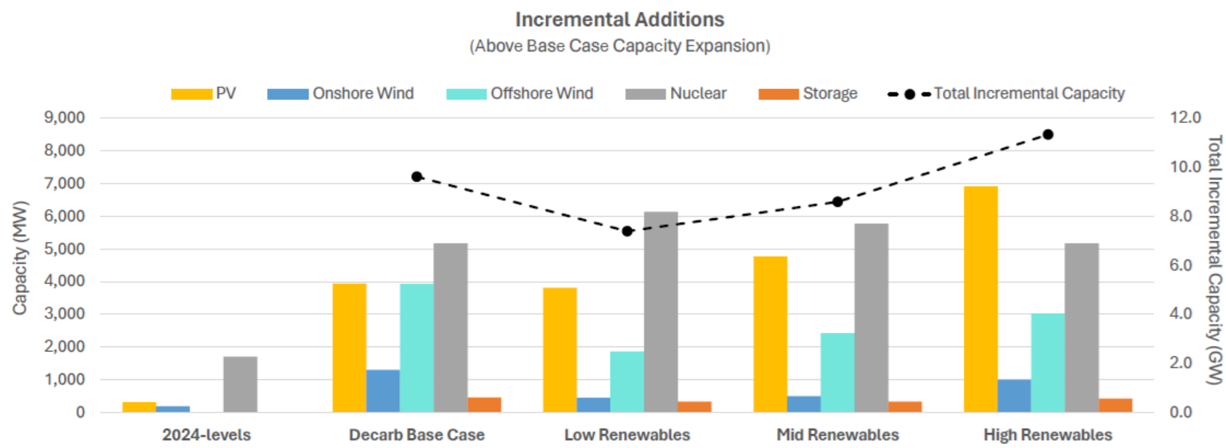

Figure 24. Generation deployment in the four decarbonization scenarios compared to current levels.

The High Renewables Scenario sees the highest levels of exports to PJM, with the lowest amount occurring in the Low Renewables Scenario. This is consistent with the earlier discussion regarding variable generation always selling energy to the wholesale market when it is generated, regardless of price. Figure 25 shows the generation mix and the load for each of the scenarios.

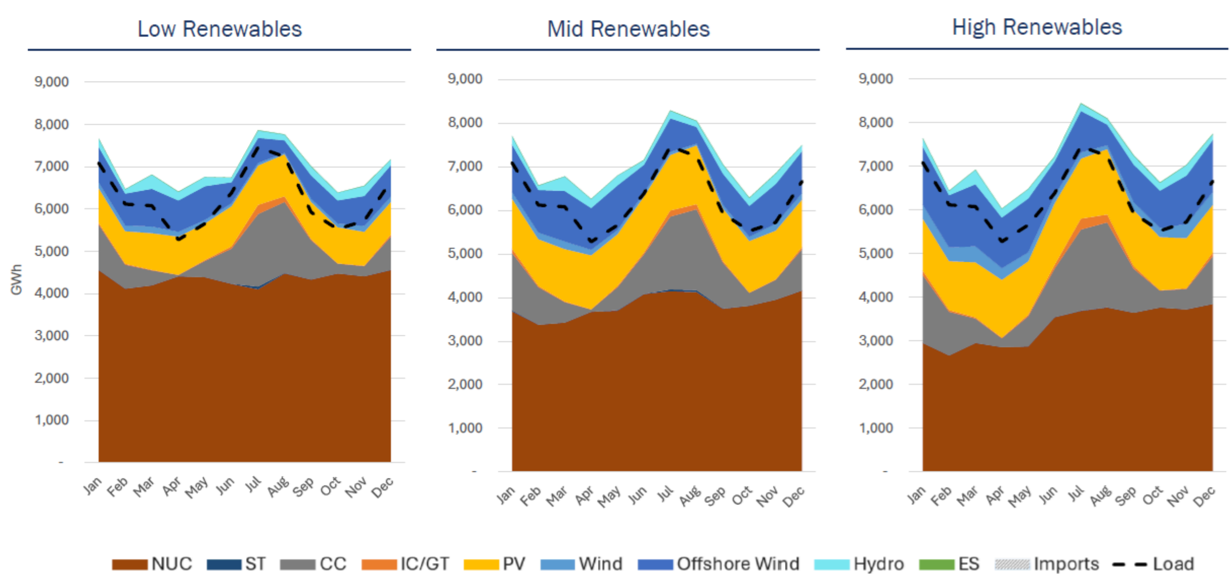

Figure 25. The 2035 generation mixes across the Low-, Mid-, and High Renewables scenarios.

Renewable curtailments are negligible in the Low- and Mid Renewables scenarios, with additional OSW curtailment seen in the High Renewables scenario as shown in Figure 26.

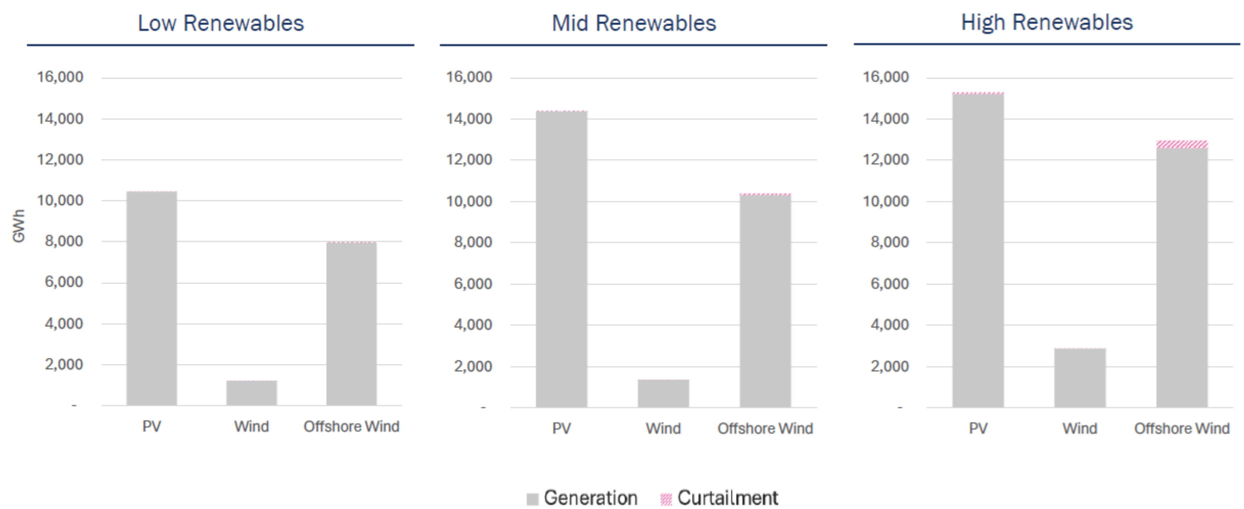

Figure 26. Curtailment across the Low-, Mid- and High Renewables scenarios

In the High Renewables scenario, OSW is ineffective at offsetting emissions beyond a certain level, as OSW generation is curtailed and marginal emission rates in DPL drop to lower levels relative to other energy areas in Maryland. As a result, all three additional scenarios rely on nuclear capacity additions.

Cost Implications of Each Scenario

The modeling looks at a couple different costs related to these scenarios. One is the impacts to long-term wholesale energy prices, systemwide prices but also the localized prices. The other is the actual full capital costs of the generator build out. The cost of wholesale energy to serve Maryland load reflects differences in resulting locational marginal prices (LMPs) across Decarbonization Scenarios.[45] Average LMPs are lower in the Decarbonization Scenarios relative to Historical and Base Case levels due to additional local generation to serve load and from the additions of zero-marginal cost (renewable) resources as shown in Figure 27. This is an important point: the "fuel" cost of renewable generators is effectively zero. Wind and sunshine do not cost anything additional. This is different from other generators, where there are capital costs associated with financing and construction of the facilities, but also variable fuel costs. Generators will typically bid into the energy market based on these variable fuel costs, meaning

[45] The costs shown in Figure 27 are calculated by multiplying Maryland's wholesale energy requirement by the corresponding zonal LMPs. Importantly, this metric should not be confused with the total cost borne by ratepayers via utility bills, which also includes the recoupment of utility capital costs, as well as transmission and distribution tariff charges, among other costs.

renewable sources have the capability to drive down system costs with low bids, since they primarily need to cover only their capital costs, and not fuel costs.

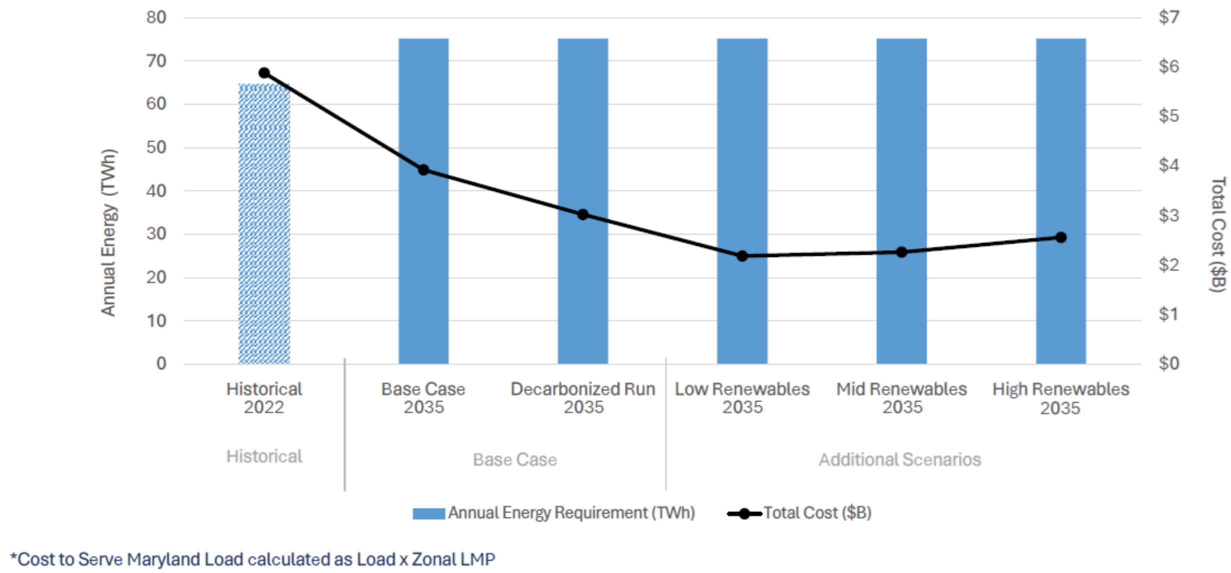

Figure 27. Comparative costs to serve Maryland load at the system level.

The Low Renewables Scenario sites the most capacity in BGE and PEPCO service territories (Maryland's high-load energy areas), relieving congestion and driving down LMPs and the cost to serve Maryland load. It should be noted, these are closer to short term, localized costs to serve load. A separate issue would be longer-term, capacity issues resulting from declining generation in the PJM portfolio. Figure 28 shows the cost for average LMPs by energy area and scenario for 2035.

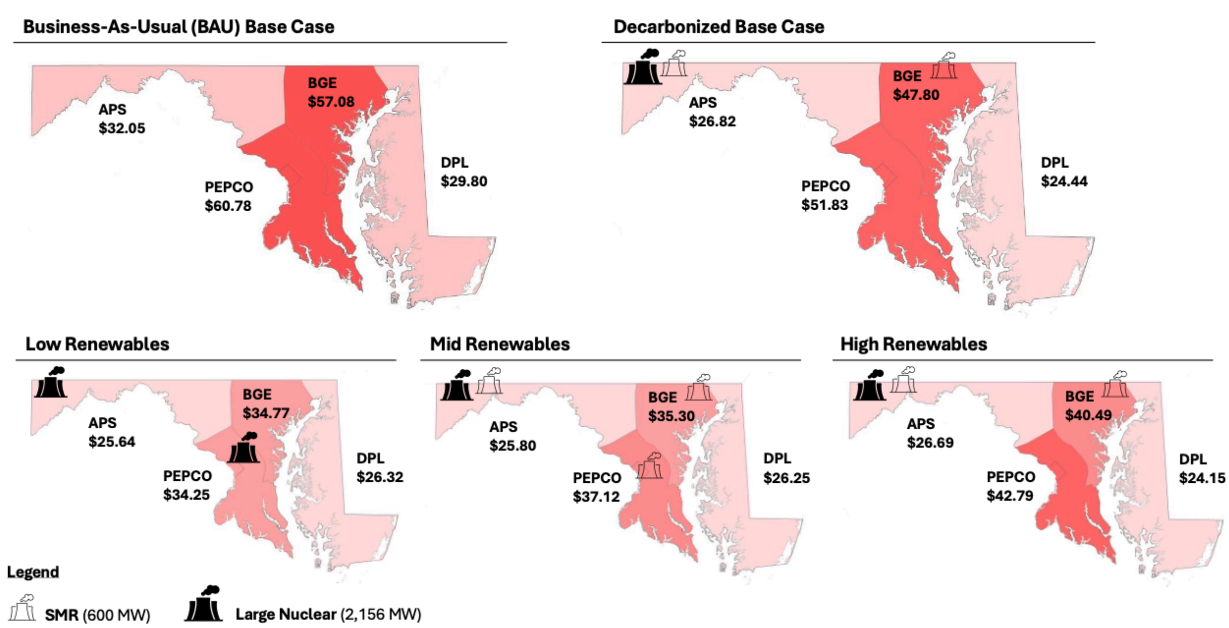

Figure 28. Zonal prices in 2035 for each scenario.

The total system costs vary across scenarios. Differences in total cost between portfolios is driven by variation in the total capacity installed and the resource types, as seen in Figure 29. The total operations, maintenance, and installation costs of the decarbonization portfolio over the life of the assets (assuming a 20-year asset life)[46] is shown in the figure below. It is important to note, if any new nuclear is constructed, the cost would be reduced by the commensurate amount per ITC or PTC application, which was not reflected in the modeling.

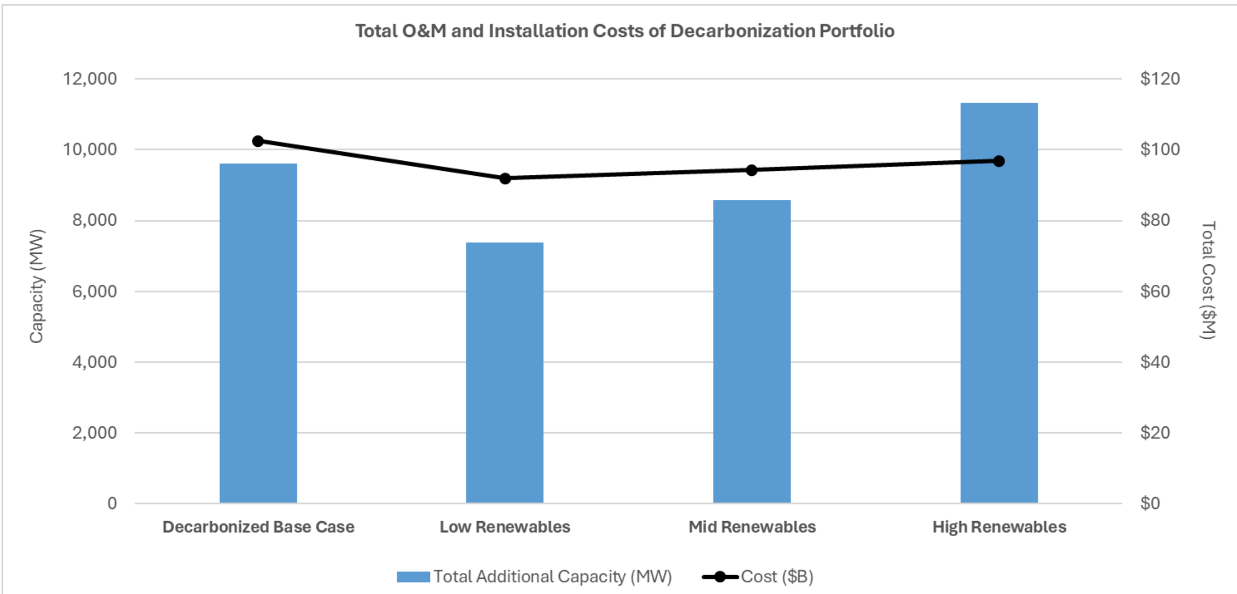

Figure 29. Full system cost of each scenario. This is the aggregate cost of the entire portfolio based on capital costs and operations and maintenance costs. *This does not reflect a cost to the State.*

Extended Discussion on Cost Implications:
It is important to emphasize that the overall system costs are not solely attributable to the State (ratepayers or taxpayers). In other words, Marylanders are not expected to fully fund those costs.[47] Rather, these costs reflect the combined capital costs and ongoing operations and maintenance of each plant through 2035.

Furthermore, the power plant buildout presented in this report and modeling exercise primarily encompass costs within the renewables sector, where above-market costs have already been factored in. The renewable build outs in these various scenarios do not surpass the established RPS amounts (for solar or other technologies), nor do they exceed the established OSW goal set by the POWER Act in 2023 or the Energy Storage Program (HB0910/CH0570). This implies these technologies do not require new funding authorization, and that authorized funding has

[46] Typically, many plants last much longer than 20 years, but this is the standard economic lifespan for plants.
[47] The actual cost would be the direct subsidy provided over market rates to build the generation. The costs of any plant in PJM, are otherwise socialized throughout the portfolio when generation bids into the market.

already been incorporated from past legislation. Both sets of technologies – solar and offshore wind – already have funding authorization covered by supportive policy. It should also be noted that by characterizing nuclear as a clean energy resource, we are implying the existing generation from Calvert Cliffs generating station can be credited toward the State's clean energy goals. Between the authorized spending in the RPS and the POWER Act, and the inclusion of Calvert Cliffs, the majority of the build outs presented represent authorized costs, which would not be covered under a new 100% goal. The remaining new generation that is not covered by existing policy would be attributed to the nuclear build out.

A preliminary estimate of monthly rate impacts follows in Table 8. These should be considered as an estimated range, and preliminary. Attempting to understand these costs and benefits netted out of the costs over a 10-year period is a very difficult estimate to make and there are many caveats.

Table 8: Estimated Monthly Ratepayer Impacts

Estimated Monthly Ratepayer Impacts of Nuclear Plants

Monthly Bill Impacts in Dollars per Customer

Plant	Capacity	Monthly Impact (Low)	Monthly Impact (High)
Nuclear Portfolio	3,356 MW	$10.71	$21.98
PJM W SMR	600 MW	$1.77	$3.79
PJM E SMR	600 MW	$2.51	$4.53
PJM W Traditional Nuclear	2,156 MW	$6.43	$13.67

Notes: *Internal estimates. MEA views these estimates as conservative. These costs also do not include the ITC/PTC. Revenue estimates also include only energy market revenues. These MW totals are reflective of the decarbonization portfolio. Nuclear costs should be viewed as variable, however, the actual costs for Vogtle 3 and 4 (combined ~2,228 MW) reflect roughly $14.10 in monthly ratepayer impacts, aligning with the higher estimate for a similar reactor setup in this table.*

It can also be helpful to review comparative costs between other technologies on a levelized cost basis. Figure 30 below uses NREL's Levelized Cost of Electricity (LCOE) estimates. LCOE is a metric that calculates the average net present cost of generating electricity for a generator over its entire lifespan. It is a tool that allows for consistent comparison between different electricity generation methods. The LCOE indicates the average revenue per unit of electricity needed to cover the costs of constructing and operating a power plant throughout its expected financial life and operational cycle. This measure encompasses various expenses, including investment expenditures, operations and maintenance costs, fuel costs, financing costs, and decommissioning costs, and can be viewed as a breakeven cost for a particular technology.

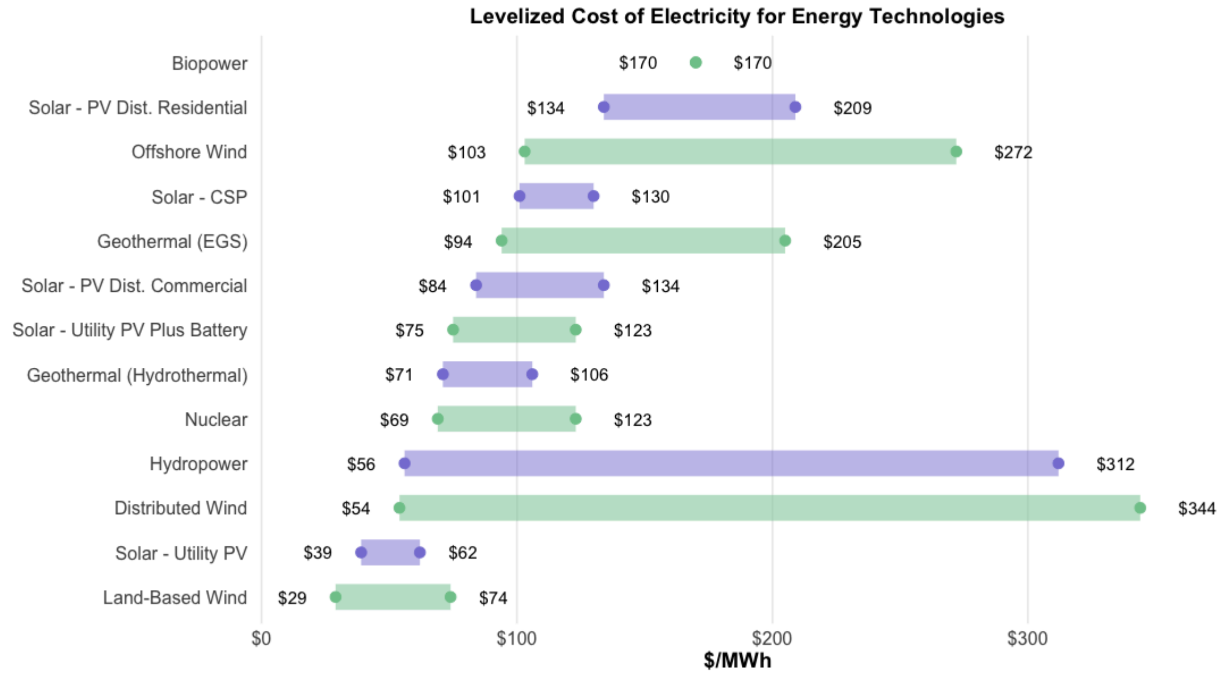

Figure 30: Levelized Cost of Electricity, National Renewable Energy Laboratory

Finally, system costs do not cover other benefits accrued to the State and its residents by avoiding significant emissions from the power sector. The best approach to quantifying this is to use Social Cost of Carbon (SCC) calculations. The SCC is a framework that seeks to quantify the damage and death resulting from long-term climate impacts. According to the EPA, the social cost of GHG emissions — which consists of the social costs of carbon, methane, and nitrous oxide — is a comprehensive metric that includes the value of all future climate change impacts, including changes in net agricultural productivity, human health effects, property damage from increased flood risk, changes in the frequency and severity of natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services.

In November 2023, the EPA released a report that significantly increased its recommended SCC to $204 per metric ton for 2023 at a 2 percent discount rate.[48] The SCC is used to quantify the long-term economic damages associated with an incremental increase in carbon emissions. By putting a price on the environmental damage caused by carbon emissions, the SCC provides a way to incorporate the external costs of climate change. Using TCR's calculations, there are roughly 30.5 million short tons of CO_2 emissions in the Maryland power sector, in 2025 – these are fully avoided by 2035. Using the EPA November 2023 SCC calculations for 2035, the *value of these avoided emissions is approximately $7.1 billion in 2023 dollars*, using a 2 percent discount rate. Beyond the use of SCC to calculate carbon reduction benefits, there would be

[48] Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances November 2023. Values in Appendix A-5.
https://www.google.com/url?q=https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf&sa=D&source=docs&ust=1726288826415773&usg=AOvVaw1j9zQVWYqF5ZnHo5gnVqFd

other economic benefits as well, resulting from the construction and operation of new generation facilities in-State.

Preliminary Conclusions

Achieving 100 percent clean generation by 2035 will be incredibly difficult. Using the main decarbonization scenario as a template, Maryland will need to build roughly 9.6 GW of additional generation over the base case deployments (a mix of solar, wind, OSW, and nuclear),[49] along with some associated transmission infrastructure, and provide above-market-rate State funding for the majority of that new generation, much of which is already locked in given existing support mechanisms, like the RPS. Some of this generation is additional in order to provide an offset to the gas plants operating in the State.

Additional support and reform is necessary in order for Maryland to make significant progress on its existing and future clean energy generation goals. Insufficient funding and financial opportunities remain barriers, especially in a higher-cost, higher-interest rate environment, which provides serious impediments to companies acquiring the necessary capital for their projects. This culminates in a significant increase in the amount of RPS compliance entities in the state opting to pay for their portion of clean electricity through the ACPs built into the RPS as a cost containment mechanism. The ACP is meant to serve as a cost ceiling, suppressing the cost of RECs in the marketplace. Since RECs are produced by renewable generation in PJM and PJM-adjacent territories, this strongly suggests that renewable energy is not being constructed at a rapid enough pace, that costs in the market are too low to incentivize further renewable development at a rapid pace, and that compliance entities are instead —due to a lack of available RECs for compliance —utilizing ACP fees to meet their obligations. Since the REC market is also regional, this indicates a broader issue beyond Maryland – there is simply not enough renewable generation available in PJM, nor is it growing fast enough to keep pace with RPS obligations.

Without considerable increases in generation, Maryland will be unable to reach its goals and will remain a net importer of electricity, which will continue to contain the carbon content reflective of the generation mix of the 13-state PJM network. Furthermore, without pursuing all options available to decarbonize the grid, Maryland will likely slip further into a generation deficit with additional demands on the grid that will materialize before 2035. **If growth constraints continue in solar and wind deployments, the State will need to accept more imports and increase offset payments, likely RECs, or find new generation sources to fill the gap, or likely, both. Furthermore, these generation difficulties exist within the challenges of forecasted increases in load growth coming from electrification and data centers. In order to help meet these demands, nuclear appears to be the likeliest mid to long-term potential source of mid- to large scale, emissions-free generation.**

Policy innovation, which likely incentivizes new nuclear build and, importantly, captures existing clean generation within the region, particularly dispatchable, baseload generation, will be imperative in the years leading towards 2035. The existing and projected gap in generation covering consumption means it is necessary to utilize all generation types available that are

[49] This would be in-State generation.

emissions-free. The first decarbonization scenario saw nuclear capacity increasing by 185 percent with the addition of one traditional nuclear unit and two small modular reactors. While this outcome might not be realized in the given timeframe, excluding emissions-free resources to satisfy decarbonization goals, particularly at a time when Maryland is operating at a domestic generation to consumption deficit, is not optimal for the State's clean energy goals.

This report suggests several reforms be instituted that can assist OSW, solar, and nuclear growth in the State. These are covered below.

Potential Reforms

Offshore Wind

- **Remove Delmarva Peninsula Interconnection Requirement**: Stemming from the Maryland Offshore Wind Energy Act of 2013, there is a restriction in place that requires project interconnection to a point(s) on the Delmarva Peninsula. Removing this restriction increases interconnection flexibility, mitigating a challenge to current projects. Other protections for supply chain investments, etc. would need to be retained.
- **Authorize Multi-Jurisdictional OREC Procurements**: This would provide specific authorization to engage in agreements with neighboring states (or the District of Columbia) to hold joint OSW procurements. The benefit of a multi-jurisdictional procurement is that it allows states to procure OSW in larger amounts at a lower cost, which can result in reduced ratepayer impacts and increased supply chain investment and job creation in the region.
- **Adjust Ratepayer Impact Caps**: Current caps are highly unrealistic for the goals set by the Maryland General Assembly and need to be either removed or changed to an internal price cap that resides confidentially with the PSC. Alternatively, the ratepayer impact methodology could be replaced with the societal cost test, which more thoroughly includes the broader benefits from clean energy, including valuation of the health benefits.
- **OREC Price Indexing**: This allows automatic adjustments for inflation and has become the industry standard, especially given the recent inflationary cycle.
- **OREC Price Schedule Flexibility**: This would allow greater flexibility to extend the current 20-year terms for OREC contracting beyond that amount.
- **Withdrawal Process and Penalties**: There should be a formal process for OREC withdrawals; however, a fee should not be included. Ultimately, the penalty costs are incorporated into total project costs once the OSW project is rebid into a future procurement process. This artificially increases the cost of OSW development and ratepayer impacts and should be avoided.
- **Application Escrow Account**: In lieu of implementing strict penalties on OSW developers, the OREC program should require developers to deposit $5 million into an escrow account. The purpose of these funds is to reimburse the State for resources expended in the OREC application review process if the developer withdraws from the program or cancels the project.
- **Remove Prohibition on Transmission Lines or Cables Through Assateague Island**: Finding acceptable paths to interconnect into Maryland, or the Delmarva

Peninsula more broadly, have been exceptionally difficult. Providing an allowance for cables to run underground through the State-controlled portion of Assateague Island would provide a much-needed alternate route to substations located inland in Southern Maryland.

Solar

Adopt a Consistent ACP Value that is Sufficient to Spur Solar Development:
Maryland's Solar ACP statutory cost is scheduled to continue decreasing year-over-year. In 2025, SREC ACP will decline further from the current value. Since the ACP acts as a cost cap, it does not allow SREC values to adjust higher in response to low SREC supply and limited development. Providing a constant ACP, and therefore the freezing current ACP, is more likely to spur development of at least the most economically efficient solar developments and it provides market certainty for all types of solar development that can be complemented by additional subsidies for the targeted development of different solar market segments.

Nuclear

Establish a Procurement Process for New Nuclear Development:
Similar to OSW and its OREC process, without a dedicated procurement structure in place, Maryland is unlikely to attract the attention of nuclear developers. The State can correct this situation by including nuclear energy in the clean generation mix along with a special procurement mechanism, similar to a procurement methodology used for OSW in the northeast.[50] Nuclear energy is a capital intensive energy source. It is highly unlikely a developer would choose to pursue Maryland as a serious alternative without a dedicated procurement process in place providing project funding and guaranteed offtake at above-market rates (similar to OSW developers). Without such a mechanism, the State would not be able to attract development. Toward this end, it is possible the existing OREC structure could be adapted for nuclear procurements.

Clean Power Purchase Agreements

The underlying logic here is that power does not recognize geographic boundaries – power flows into and out of Maryland's economy. There is a clear and very likely near-future risk that existing, and new build, clean generation will be captured outside of Maryland's economy – generation that Maryland has assumed will continue to accrue to its direct and indirect emissions accounting. This emissions backsliding is a virtual certainty under Maryland's existing clean energy policies. The Microsoft 20-year Power Purchase Agreement for the generation of a re-opened Three Mile Island nuclear facility is the leading edge of this future – clean generation being sought after, captured, and removed from the market. Bilateral Power Purchase Agreements are common within the market and may well be the least cost, and necessary, mechanism for Maryland to reach its clean energy aspirations and forestall otherwise inevitable backsliding.

[50] Maryland uses Offshore Wind Renewable Energy Credits (ORECs) awarded through a competitive process at the PSC. Other OSW projects use Power Purchase Agreements (PPAs), which may be more appropriate for nuclear procurements. Public Private Partnerships can also be considered along with additional State guarantees.

Explore New Clean Generation Technologies for Maryland

Maryland should not close itself off to the possibility of additional clean energy generation technologies. The energy sector is dynamic and the landscape is constantly changing. As of yet, there does not exist any new, firm, dispatchable generation technologies that are both cost competitive and mature. Maryland needs to be open to these technologies if they become available, and should not exclude them in favor of other, existing technologies. There are several technologies that could provide vital resources to the State, ranging from long-duration storage to carbon capture and sequestration technologies, and to gas plants fueled by hydrogen. The large gap between our existing clean generation resources in the State and our clean generation goals should have policymakers poised to respond when market dynamics change.

Appendix A: A Review of Other PJM States' 100 Percent Clean Generation Goals

"Clean energy" has various definitions among the states, including 100 percent carbon-free electricity consumed in the state (e.g., Michigan, Virginia), or broader 100 percent GHG reduction goals (e.g. Delaware, North Carolina). Illinois' new law also focuses on decarbonizing gas generation assets.

Mechanisms vary, with some states ordering state agencies to enact a plan (e.g. New Jersey), the utility to enact a plan (e.g. Michigan), or have the requirements for utilities outlined in legislation (e.g. Virginia).

Most states in the PJM are deregulated, except North Carolina. Michigan and Virginia have some vertically integrated utilities.[51]

Among the non-PJM states, California – also deregulated – was the first to enact a 100% clean energy standard, which it did in 2018 with SB100, establishing an RPS electricity from retail sales and state loads from 100 percent renewable and zero-carbon resources by 2045[52]. A 2021 report on SB 100 found that: construction of clean electricity generation and storage facilities must be sustained at record-setting rates; natural gas is necessary during bridge - would cost extra $8bn by 2045 to eliminate it; achieving 100 percent clean electricity will increase the total annual electricity system costs by 6 percent relative to the cost under the state's RPS requirement of having at least 60 percent clean electricity by the end of 2030.

Delaware

- **RPS**: 40 percent by 2035 (10 percent Solar by 2035).
- **Tier 1 Eligible**: Electricity derived from solar, wind, ocean, geothermal, fuel cell powered by renewable fuels, combustion of gas from the anaerobic digestion of organic material, small hydroelectric facility (30 megawatts or less), sustainable biomass, excluding waste to energy, landfill methane gas.
- **GHG Target**: 50 percent by 2030 and Net-Zero by 2050.

The Delaware Climate Change Solutions Act of 2023 (the Act), also known as House Bill 99, was signed into law on August 3, 2023.[53] The Act sets a GHG reduction goal of 50 percent compared to a 2005 baseline by 2030 and a goal of net-zero emissions by 2050.[54]

The Act further requires that the state take the emissions reduction goals and climate change more generally into account when promulgating regulations or rules and when making significant investments or purchases through procurement processes. The state will now

[51] *See*, e.g., www.epa.gov/green-power-markets/power-market-structure
[52] 2015 legislation made Hawaii the first state to set a 100% RPS.
[53] legis.delaware.gov/BillDetail/130272
[54] legis.delaware.gov/json/BillDetail/GenerateHtmlDocumentEngrossment?engrossmentId=25785&docTypeId=6

periodically update its climate action plan (every 5 years) and must develop strategies to increase resiliency for climate-related challenges. Lastly, the Act recognizes the disproportionate impact of climate change on overburdened and underserved communities, as well as coastal communities, and it requires that the climate action plan be equitable (i.e. not disproportionately impacting overburdened and underserved communities.[55]

District of Columbia

- **RPS**: 100 percent by 2032 (15 percent Solar by 2041).
- **Tier 1 Eligible**: Renewable sources include solar (and solar thermal), wind, qualifying biomass (>65 percent efficiency), methane from a landfill or wastewater treatment plant, geothermal, ocean, including energy from waves, tides, currents, and thermal differences, and a fuel cell that produces electricity from a Tier 1 renewable source generated from qualifying biomass or methane from a landfill or wastewater treatment plant.
- **GHG Target**: N/A.

The Clean Energy DC Omnibus Amendment Act of 2028 was signed into law in January of 20019.[56] The Act updated the District's RPS, requiring electricity suppliers to offset 100 percent of their volumetric electricity sales with RECs by 2032 with a minimum of 15 percent coming from "local solar" by 2041.[57]

Though the results of which are not statutorily binding, currently under development is the Clean Energy DC 2.0 ("CEDC 2.0").[58] CEDC 2.0 is an energy and climate action plan that will present a "roadmap" to achieve a GHG emission reduction target of 60 percent by 2030 compared to a 2006 baseline and carbon neutrality by 2045.[59] A public draft of the plan is currently available.[60] The draft plan calls for actions to be taken in four areas: buildings, energy, transportation, and the green economy.[61]

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[55] *Id.*

[56] doee.dc.gov/service/renewable-energy-disrict#:~:text=In%20January%202019%2C%20Mayor%20Bowser,electricity%20by%20the%20year%202032.

[57] *Id. See also*, code.dccouncil.gov/us/dc/council/laws/24-314.

[58] clean-energy-dc-dcgis.hub.arcgis.com/

[59] *Id.*

[60] ago-item-storage.s3.amazonaws.com/ec0f4b33112e4f31a5752181dcc8cd85/CEDC_2.0_Policy_Roadmap_Public_Review_Draft.pdf

[61] ago-item-storage.s3.amazonaws.com/9b01581b291d47d6aa875af5145b44bd/CEDC_2.0_Public_Partial_Draft_Slides.pdf

Illinois[62]

- **RPS**: 50% by 2040 (Solar 55% / Wind & Hydro 45%).
- **Tier 1 Eligible**: Wind, Solar thermal energy, PV cells and panels, biodiesel, anaerobic digestion, crops and untreated and unadulterated organic waste biomass, in-State landfill gas, hydropower that does not involve new construction or significant expansion of hydropower dams, waste heat to power systems, qualified combined heat and power systems.
- **"Clean Energy" Target**: 100 percent by 2045. "Clean Energy" means energy generation that is substantially free (90 percent or more) of carbon dioxide emissions by design or operations, or that otherwise contributes to the reduction in emissions of environmentally hazardous materials or reduces the volume of environmentally dangerous materials.

Illinois has a goal of 100 percent "clean energy" by 2050, with interim goals of 40 percent renewable energy by 2030 and 50 percent by 2040.[63] The state has over 8.6 GW of wind, solar PV, and storage capacity, making Illinois the fifth largest generator of renewable electricity in the United States.[64] As of 2021, clean energy sources like wind and solar account for 11 percent of Illinois' net electricity generation, in addition to over 12.4 GW of nuclear capacity.[65]

Senate Bill 2408 makes changes to the Illinois Power Agency Act to double investment in renewable energy, requires that all private oil and coal electricity generation stations reach zero emissions by 2030, requires municipal col generating stations to be carbon free no later than 2045 (with interim requirements that could require the retirement of one or more generation units if certain goals are not met), requires that private natural gas generating stations to reach zero emissions by 245 (and prioritizing those near environmental justice communities), requires all units that utilize combined heat and power or cogeneration technology to reach zero emissions by 2045 (unless units are converted to green hydrogen or another technology that can achieve zero carbon emissions), it creates a "coal to solar" program to support the transition to renewable technologies, and it requires the Illinois Environmental Protection Agency and Illinois Commerce Commission to conduct a study every 5 years on the State's progress toward its renewable energy goals and projected resource adequacy and reliability in the state, amongst other provisions.[66]

Michigan[67]

- **RPS**: 60 percent by 2035

[62] Only part of Illinois is in PJM (ComEd/Exelon). Part of the state is served by the Midcontinent System Operator (MISO) (Ameren).
[63] www.illinois.gov/news/press-release.23893.html
[64] www.energy.gov/articles/energy-facts-impact-investing-america-agenda-illinois#:~:text=Illinois%20has%20a%20statewide%20goal,12.4%20GW%20of%20nuclear%20capacity.
[65] *Id.*
[66] www2.illinois.gov/IISNews/23893-Climate_and_Equitable_Jobs_Act.pdf
[67] Michigan is largely but not completely vertically integrated.

- **Tier 1**: Biomass (with certain feedstock), Solar & solar thermal energy, Wind energy, Kinetic energy of moving water or thermal transfer, methane digesters (with certain feedstock). Does not include: pumped hydro, hydro with a dam constructed post 2008, incinerators. Energy storage (including pumped hydro) gets renewable energy credit if charges from renewable energy off-peak and dispatched on-peak.
- **"Clean Energy Standard"**: 80 percent by 2035 and 100 percent by 2040
- **"Clean Energy System"**: Includes nuclear, carbon capture and storage (CCS) gas, any resource that generates electricity or steam without emitting GHG. Nuclear and carbon captured/stored gas that is 90 percent effective count as 'clean energy'. Annual energy efficiency savings above 2 percent can also count as 'clean.'[68]

Michigan Governor Gretchen Whitmer issued Executive Directive No. 2020-10 in September of 2020. The Directive established a goal for the state to achieve economy-wide carbon neutrality by 2050. This Directive built upon existing goals established by Executive Directive No. 2019-12, "which committed Michigan to join the United States Climate Alliance, align with the decarbonization goals outlined under the Paris Agreement, and achieve a 26-28 percent reduction in GHG emissions compared to 2005 levels by 2025."[69]

In November of 2023, the Michigan Legislature passed Senate Bill 271, codifying its energy goals. The bill would amend the Clean and Renewable Energy and Energy Waste Reduction Act to require regulated electric providers to purchase and retire RECs equivalent to the following percentages of their volumetric electricity sales: 15 percent through 2029, 50 percent in 2030 through 2034, 60 percent in 2035 and thereafter.[70] The Clean and Renewable Energy and Energy Waste Reduction Act also requires: 1) regulated electric providers to achieve a clean energy portfolio of at least 80 percent in 2035 through 2039 and 100 percent in 2040 and thereafter; 2) electric providers and electric suppliers to submit plans to the Michigan Public Service Commission ("MPSC") to procure energy storage systems to meet their share of a statewide target of at least 2,500 megawatts of storage capacity by the end of 2029; and 3) electric providers to submit an annual report to the MPSC documenting their electricity storage systems within their respective service territories.

New Jersey[71]

- **RPS**: 50 percent by 2030 (Solar: An additional 750 MW of solar capacity (300 MW transmission interconnected, 300 MW net metered, and 150 MW community solar) per year from 2022-2026).
- **Tier 1**: Solar technologies (including PV), wind, fuel cells powered by renewable fuels, geothermal, wave or tidal action, methane gas from landfills or a biomass facility, hydroelectric facilities of 3 MW or less that are located in NJ and placed in service after July 23, 2012.

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[68] *See* Mich. Comp. Laws. § 460.1003.
[69] www.cesa.org/projects/100-clean-energy-collaborative/guide/state-summaries/
[70] legislature.mi.gov/documents/2023-2024/publicact/htm/2023-PA-0235.htm
[71] www.cesa.org/projects/100-clean-energy-collaborative/guide/state-summaries/

- **Clean Electricity**: 100 percent clean electricity by 2035 (Executive Order). The goal is only a 100 percent clean energy annual match; it does not involve achieving 24/7 clean energy or shutting down all fossil fuel units in the state. Also, though this currently is just a goal, pending Senate Bill S2978 would mandate achieving this definition of 100 percent clean energy by 2035 if enacted.

In February 2023, New Jersey Governor Phil D. Murphy issued Executive Order No. 315, which established a goal for New Jersey Board of Public Utilities ("NJBPU") to revise its 2019 Energy Master Plan such that "100 percent of electricity sold in the state to be from clean sources ... by 2035 ... through clean energy market mechanisms paired with support for a clean energy standard in New Jersey.[72] This complemented a pre-existing deep decarbonization goal outlined in the state's Global Warming Response Act of achieving 80 percent emissions reductions by 2050. The Governor's Executive Order stated that a NJBPU's Ratepayer Impact Study (Brattle), released August 17, 2022, found that the pathway to achieving a 100 percent clean energy standard by 2035 would cost only approximately 2 percent more than the pathway to achieve 100 percent clean energy by 2050.[73] New Jersey's revised Energy Management plan will ostensibly be released at a later date in 2024.

Governor Murphy's previous executive order, Executive Order No. 28, directed the NJBPU to develop a state Energy Master Plan (EMP) for all sectors of the state to achieve a goal of 100 percent renewable energy.[74] Released in early 2020, the report entitled 2019 New Jersey Energy Master Plan: Pathway to 2050 defines "100 percent clean energy by 2050" to be "maximum electrification" of both the buildings and transportation sectors and carbon-neutral electricity generation.

North Carolina (vertically integrated)

- **RPS**: 12.5 percent by 2021. "Renewable energy resource" means a solar electric, solar thermal, wind, hydropower, geothermal, or ocean current or wave energy resource; a biomass resource, including agricultural waste, animal waste, wood waste, spent pulping liquors, combustible residues, combustible liquids, combustible gasses, energy crops, or landfill methane; waste heat derived from a renewable energy resource and used to produce electricity or useful, measurable thermal energy at a retail electric customer's facility; or hydrogen derived from a renewable energy resource. "Renewable energy resource" does not include peat, a fossil fuel, or nuclear energy resource.
- **GHG Target**: economy-wide neutrality by 2050.

On January 7, 2022, North Carolina Governor Roy Cooper signed Executive Order No. 246. The Order sets a statewide GHG reduction goal of 50 percent below 2005 levels "as soon as possible", but no later than 2050.[75] The order also set a zero-emission vehicle or "ZEV" goal of at

[72] nj.gov/infobank/eo/056murphy/pdf/EO-315.pdf, pg. 6.
[73] *Note*, the study, p. 15, assumed renewable generation would increase and natural gas demand would decrease, compared to current 2050 policies, while nuclear generation would remain constant.
[74] nj.gov/infobank/eo/056murphy/pdf/EO-28.pdf, pg. 2..
[75] governor.nc.gov/executive-order-no-246/open, pg.2.

least 1.25 million vehicles and 50 percent of in-State sales by 2030.[76] Additionally, the order: requires the North Carolina Department of Environmental Quality ("NCDEQ") to update its GHG Inventory, requires Cabinet agencies and "interested stakeholders" in partnership with the Policy Office within the Governor's Office, to conduct a "Pathways Analysis" to evaluate emissions reduction strategies to achieve economy-wide net-zero GHG emissions, and requires the North Carolina Department of Transportation to work with the NCDEQ for the development of a Clean Transportation Plan for the decarbonization of the transportation sector, amongst other initiatives.[77]

Previously, the Governor had issued Executive Order No. 80, which required the NCDEQ to develop a "Clean Energy Plan" to encourage the use of clean energy sources including wind, solar, and energy efficiency as well as "other innovative technologies in the public and private sectors". In October of 2019, the North Carolina Clean Energy Plan: Transitioning to a 21st Century Electricity System proposed that the state seek GHG emissions reductions of 70 percent in comparison to 2005 levels by 2030 and carbon neutrality no later than 2050.

In October of 2021, Governor Cooper signed House Bill 951, "Energy Solutions for North Carolina".[78] The bipartisan law requires the North Carolina Utilities Commission to "take all reasonable steps to achieve a [70 percent] reduction in emissions of carbon dioxide from electric public utilities from 2005 levels by the year 2030 and carbon neutrality by the year 2050".[79] The law further defines carbon neutrality as limited to electric generation facilities.[80]

Virginia (mostly vertically integrated utilities)

- **RPS**: 100 percent carbon-free electricity by 2045 (Dominion w/ 2035 Carve-out of 16,100 MW total solar or onshore wind) and by 2050 (APCo w/ 2030 Carve-out 600 MW total solar or onshore wind).
- **Tier 1**: Solar, wind (onshore and offshore), certain hydro, certain in-State waste-to-energy and landfill gas, certain in-State biomass.

The Virginia Clean Economy Act requires Dominion Energy Virginia and American Electric Power, collectively "Utilities," to retire carbon-emitting electric generating units located in the state and to procure the generating solar or wind capacity.[81] This law replaces the state's voluntary RPS with a mandatory one, requiring the Utilities to produce their electricity from 100 percent renewable electricity by 2050 (2045 for Dominion Energy Virginia).[82] If the Utilities do not meet their respective RPS requirements they must make "deficiency payments," not unlike

[76] *Ibid.*
[77] *Id.* at 3.
[78] governor.nc.gov/news/press-releases/2021/10/13/governor-cooper-signs-energy-bill-including-carbon-reduction-goals-law.
[79] www.ncleg.gov/Sessions/2021/Bills/House/PDF/H951v5.pdf, pg. 1.
[80] *Ibid.*
[81] lis.virginia.gov/cgi-bin/legp604.exe?201+sum+HB1526S.
[82] *Ibid.*

Maryland's alternative compliance payments.[83] Revenue from deficiency payments are deposited in an account administered by the Virginia Department of Mines, Minerals and Energy for use in programs to support job training, renewable energy, and energy efficiency measures.[84] Additionally, the law creates a cap and invest program within the State Air Pollution Control Board, authorizing the Board to establish an allowance auction program.[85]

The bill also:

> "*(i) requires, by 2035, American Electric Power and Dominion Energy Virginia to construct or acquire 400 and 2,700 megawatts of energy storage capacity, respectively; (ii) establishes an energy efficiency standard under which each investor-owned incumbent electric utility is required to achieve incremental annual energy efficiency savings… (iv) revises the incentive for electric utility energy efficiency programs… (vi) establishes requirements regarding the development by Dominion Energy Virginia of qualified offshore wind projects having an aggregate rated capacity of not less than 5,200 megawatts by January 1, 2034… (vii) requires each utility to include, and the Commission to consider, in any application to construct a new generating facility the social cost of carbon… (xi) amends the net energy metering program by increasing the maximum capacity of renewable generation facilities of participating nonresidential eligible customer-generators from one to three megawatts… (xii) establishes the Percentage of Income Payment Program (PIPP), which caps the monthly electric utility payment of low-income participants at six percent, or, if the participant's home uses electric heat, 10 percent, of the participant's household income… [and] (xvi) requires the Secretary of Natural Resources and the Secretary of Commerce and Trade, in consultation with the State Corporation Commission and the Council on Environmental Justice and appropriate stakeholders, to report to the General Assembly by January 1, 2022, any recommendations on how to achieve 100 percent carbon-free electric energy generation by 2045 at least cost for ratepayers…*"[86]

[83] *Ibid.*
[84] *Ibid.*
[85] *Ibid.*
[86] *Ibid.*

Appendix B: 100 Percent Goals Summary Including Non-PJM States[87]

State	GHG Goal	Electricity Goal	Comments
California		100% carbon-free electricity by 2045	2018 legislation (SB 100) extended and expanded the existing state RPS. State agencies are required to submit implementation plans by January 1, 2021. Also in 2018, Gov. Jerry Brown's Executive Order B-55-18 set a goal of statewide carbon neutrality by no later than 2045, with net negative GHG emissions thereafter.
Colorado		100% carbon-free electricity by 2050 for Xcel Energy	A 2019 law (SB 19-236) codified a pledge previously made by Xcel, whose service territory covers approximately 60% of the state's load. It is mandatory "so long as it is technically and economically feasible."
Connecticut		100% carbon-free electricity by 2040	Governor Ned Lamont's 2019 Executive Order (Number 3) set a 2040 goal for carbon-free electricity and asked the Department of Energy and Environmental Protection to develop a decarbonization plan for the power sector, in line with previous legislation to cut economy-wide carbon emissions by 80% below 2001 levels by 2050. In May 2022, Senate Bill 10, An Act Concerning Climate Change Mitigation, placed the goal into law.
Delaware	100% reduction in GHG emissions	–	HB 99, signed by Gov. John Carney in August 2023, requires Delaware to reduce state-wide GHG emissions by 50% from 2005 levels by 2030 and 100% by 2050.
District of Columbia		100% renewable energy by 2032 through the RPS	The Clean Energy DC Omnibus Amendment Act of 2018 (DC Act 22-583) amended the existing RPS to mandate 100% renewable electricity by the year 2032.
Hawaii		100% renewable energy by 2045 through the RPS	2015 legislation (HB623) made Hawaii the first state to set a 100% RPS for the electricity sector.
Illinois		100% clean energy by 2050	2021 legislation (SB2408) established a goal of 100% clean energy by 2050, with interim targets of 40% by 2030 and 50% by 2040.

[87] Information sourced from the Clean Energy States Alliance. Some states only have a GHG reduction goal or an RPS goal, not a clean energy goal.

Louisiana	Net zero GHG emissions by 2050	–	Governor John Bel Edwards' 2020 Executive Order (JBE 2020-18) established a Climate Initiatives Task Force to develop a roadmap and make recommendations.
Maine		100% clean energy by 2050	2019 legislation (LD 1494) increased Maine's RPS to 80% by 2030, and set a goal of 100% by 2050. Also LD1679 sets an economy-wide goal of 80% cuts to GHG by 2050.
Maryland	Net-zero GHG emissions by 2045	–	The General Assembly enacted the Climate Solutions Now Act of 2022. This wide-ranging legislation includes the 2045 net-zero goal. The Governor issued a clean energy executive order in June 2024.
Massachusetts	Net-zero GHG emissions by 2050	–	In 2020, the Secretary of Energy and Environmental Affairs set a 2050 net-zero GHG emissions goal under the authority of 2008 legislation. The same goal was then included in a March 2021 climate action law (Bill S.9). A decarbonization roadmap was released at the end of 2020.
Michigan		100% carbon-free electricity by 2040	Senate Bill 271 (2023) requires all utilities to have a portfolio of 60% renewable energy by 2035, and 80% "clean energy"—which includes carbon capture and storage—by 2035 and 100% by 2040.
Minnesota		100% carbon-free electricity by 2040	2023 legislation (SF 4) requires electric utilities to get 100% of the electricity they sell from carbon-free sources by 2040, including renewables and nuclear power. There are interim targets of 80% carbon-free power in 2030 and 90% in 2035. The legislation also increases the state's Renewable Energy Standard to 55% by 2035.
Nebraska		Net-zero carbon emissions from generation resources by 2050 for Nebraska Public Power District and Omaha Public Power District; 2040 for Lincoln Electric System	Nebraska is the only state served solely by publicly owned utilities. As of December 2021, the three public utilities that serve the vast majority of customers have all adopted 100% clean energy goals.

Nevada		100% carbon-free electricity by 2050	2019 legislation (SB 358) raised the RPS to 50% by 2030, and set a goal of a net-zero emission power sector by 2050.
New Jersey		100% carbon-free electricity by 2035	Governor Phil Murphy's Executive Order 315 in 2023 set a goal of ensuring 100% of energy sold in the state comes from clean sources by 2035 and directed BPU to develop an updated Energy Master Plan by 2024.
New Mexico		100% carbon-free electricity by 2045	2019 legislation (SB 489) requires utilities to have a zero-carbon power supply by 2045, including at least 80% from renewables, with the exception of rural electric coops which have a 2050 target date.
New York		100% carbon-free electricity by 2040	2019 legislation (S6599) requires zero-emissions electricity by 2040 and sets a goal of cutting all state GHGs 85% by 2050. A Climate Action Council will develop a plan.
North Carolina		Carbon neutrality in the electricity sector by 2050	2021 legislation (HB 951) requires the North Carolina Utilities Commission to "take all reasonable steps" to achieve a 70% reduction in CO2 emissions from electric generating facilities in the state by 2030 and carbon neutrality by 2050. The 2022 Executive Order 246 sets an economy-wide target of net-zero emissions by "no later than 2050," sets a goal that half of new vehicle sales must be EVs by 2030, incorporates environmental justice and equity into climate programs, and has other measures.
Oregon	GHG emissions reduced 100 percent below baseline emissions by 2040	–	2021 legislation (HB 2021) requires investor-owned utilities to reduce GHG emissions associated with the electricity they sell to 80 percent below baseline emissions levels by 2030, 90 percent below baseline emissions levels by 2035, and 100 percent below baseline emissions levels by 2040.
Puerto Rico		100% renewable energy for electricity by 2050	2019 legislation (SB1121), the Public Energy Policy Law of Puerto Rico, set a timeline for reaching 100% renewable electricity by the year 2050.
Rhode Island		100% renewable energy electricity by 2033	Governor Gina Raimondo's 2020 Executive Order (20-01) requires the Office of Energy Resources to "conduct economic and energy market analysis and develop viable policy and programmatic pathways" to meet 100% of statewide electricity deliveries with renewables by

			2030. 2022 legislation (H7277 SUB A) updates the state's RPS to require 100% of RI's electricity to be offset by renewable production by 2033.
Virginia		100% carbon-free electricity by 2045 for Dominion Energy and 2050 for Appalachian Power Company	The 2020 Virginia Clean Economy Act (House Bill 1526 and Senate Bill 851) requires zero-carbon utilities by 2050 at the latest.
Washington		100% zero-emissions electricity by 2045	2019's Clean Energy Transformation Act (SB5116) applies to all utilities. The state Commerce Department started a rulemaking process in August 2019. Utilities must file implementation plans by January 2022.
Wisconsin		100% carbon-free electricity by 2050	Governor Tony Evers' Executive Order (EO38) in 2019 directed a new Office of Sustainability and Clean Energy to "achieve a goal" of all carbon-free power by 2050.