Addendum

Energy Transition in PJM: Flexibility for the Future

Scenario Development

Generation Expansion Drivers

This study is the fourth installment of PJM's multiphase effort to assess the impacts of renewable integration and is intended to continue to inform stakeholders and policymakers. This fourth phase shifts focus to the longer term to identify and examine the opportunities and challenges that may arise if current state and federal energy policy goals are met or accelerated. As work on this report began in early 2023 and is meant to be an extension of, and comparable to, previous work in the Energy in Transition Series, the state and federal energy regulations and policy goals/targets are those in place as of the end of 2022. This happens to be similar to the Independent State Agencies Committee (ISAC) State Policies Workbook as December 1, 2023, but the study does not explicitly cover this list. The evaluation period has been extended to 2035 and seeks to reflect the rate of renewable integration in neighboring regions and the resulting impact on regional interchange.

Installed Capacity by Resource Type summarizes the total installed capacity (ICAP) by resource type for each scenario.

Table 1. Installed Capacity by Resource Type

	Base	Policy	Accelerated
Offshore Wind	1,469	14,908	14,908
Onshore Wind	3,890	16,775	101,391
Onshore Wind Hybrid	-	45	400
Solar	18,081	42,247	77,366
Solar/Storage Hybrid	1,680	3,470	53,378
Battery Energy Storage	386	6,451	27,473
Coal	39,940	25,711	15,765
Natural Gas	99,772	82,256	62,762
Nuclear	34,003	34,003	34,003
Oil	5,949	4,266	727
Hydro	9,526	9,521	9,555
Other Renewable	1,330	1,370	1,262
Other	292	373	302
Demand Response	7,286	7,286	7,129
Total	223,604	248,681	406,422

Renewable Portfolio Standards

Table 2 summarizes the Renewable Portfolio Standards utilized in this study. These mandated state RPS targets require that a certain percentage of a state's load is served by qualified renewable energy resources. State RPS policies also vary by eligible resource technology, in-state resource carve-out requirements and required qualified resource location. In addition, some in-state resource carve-outs are crafted as a percentage of energy, while others specify the minimum renewable capacity to be developed in state.

Eight of the 10 PJM states with mandatory RPS targets include solar-specific requirements, the details of which vary by state. Some include in-state solar carve-outs as a percentage of total state energy demand. Others permit their solar carve-outs to be met by solar resources located anywhere within the PJM footprint. Still others, particularly those located along PJM's seams, allow solar commitments from resources located outside the PJM footprint to meet RPS targets and goals.

Table 2. PJM State RPS Targets*

☼	**NJ:** 50% by 2030**	☼	**PA:** 18% by 2021***		**OH:** 8.5% by 2026****
☼	**MD:** 50% by 2030**	☼	**IL:** 50% by 2040		**MI:** 15% by 2021
☼	**DE:** 40% by 2035	☼	**VA:** 100% by 2045/2050 (IOUs)		**IN:** 10% by 2025***
☼	**DC:** 100% by 2032	☼	**NC:** 12.5% by 2021 (IOUs)		

☼ Minimum solar requirement

* Targets may change over time; these are recent representative snapshot values
** Includes an additional 2.5% of Class II resources each year
*** Includes nonrenewable "alternative" energy resources
**** Eliminated after 2026

Offshore Wind Targets

Table 3Table 3 summarizes current offshore wind procurement targets for states in PJM utilized in this study, per respective state policies.

Table 3. PJM States' Policy Targets for Offshore Wind*

	Offshore Wind Target (MW)	Policy Target Date
Maryland	2,022.5	2030, per December 2021 award
New Jersey	11,000	2040, per Gov. Murphy's September 2022 Executive Order
Virginia	5,200	2034

**North Carolina also announced an offshore wind target of 8,000 MW by 2040 per Gov. Roy Cooper's Executive Order No. 218, which was issued June 9, 2021. This target was not included in the Offshore Wind Transmission Study's Phase 1 scenarios.*

Energy Storage Targets

Storage development is also being driven by both explicit and implicit state policy objectives. Explicit state targets include Virginia's 3,100 MW of storage by 2035 and New Jersey's 2,000 MW target by 2030, as outlined in its 2019 Energy Master Plan. Maryland also has an energy storage pilot program that was implemented in 2019 to develop storage capacity within the state.[1] Implicitly, storage is being developed to complement the influx of renewable resources driven by state RPS targets.

Generation Expansion Siting

The location and size of renewables to meet each state's RPS requirements were determined using the following steps:

1 | Determined each state's 2035 RPS energy requirements

2 | Accounted for existing renewables modeled in 2026 RTEP Base case today from 2021 RTEP cycle; converted to energy based on PJM-determined capacity factors; subtracted from each state's respective RPS energy requirement

3 | Where additional gigawatt-hours were needed for each state, capacity factor-converted gigawatt-hours were obtained from renewable-powered units in PJM's interconnection process queue ranked by study agreement execution status – Interconnection Service Agreement, Facility Study Agreement, Impact Study Agreement, then Feasibility Study Agreement – and queue position order for each status, to the extent needed.

4 | Where additional gigawatt-hours were still needed to meet a state's RPS requirement, then active-status queued units in each such state were scaled-up to the reference project size[2] based on renewable technology type: 150 MW for solar, 200 MW for onshore wind and 2,100 MW for offshore wind.

5 | Finally, if even more renewable sites were needed, data from the National Renewable Energy Laboratory (NREL) was utilized to map potential sites ordered by highest renewable capacity factor to the closest PJM substation at 230 kV and above.

[1] "Maryland passes energy storage pilot program to determine future regulatory framework," Utility Dive, 2019.

[2] The notion of "reference project size" in this scenario analysis mirrored that employed in the second phase of the Energy Transition in PJM series, Emerging Characteristics of a Decarbonizing Grid (published in May 2022), as described in the report Addenda. Generic project sizes by technology type from Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies, 2020, report by the EIA.

Generation Deactivation Drivers

Announced Retirements

The 41 GW in the Base case includes those units that have retired through 2021 and part of 2022. The Policy case includes 6 GW that retired in 2022, everything that has retired since 2023, plus assumed retirements due to policy.

Policy-Scenario Retirements

Policy considerations for this study utilized the policies outlined in the Energy Transition in PJM: Resource Retirements, Replacements, and Risks (4R) report, which was an analysis of federal and state policies and regulations in place by the end of 2022. As such, it does not consider more recent regulatory activity including the potential impacts of EPA's rules finalized in 2024, namely the Greenhouse Gas rule, and updates to the Mercury and Air Toxics Standards, Effluent Limitation Guidelines and Coal Combustion Residuals rules. PJM will continue to work with both federal and state agencies on the development and implementation of environmental regulations and policies in order to address any reliability concerns.

Accelerated-Scenario Retirements

Similarly, the Accelerated scenario retirements were based upon the 4R report methodology for potential economics retirements. The economic component of the 4R study estimated unit-specific revenue adequacy based on the Forward Net Energy & Ancillary Service (E&AS) Revenue simulation of energy market revenues, recent RPM capacity auction revenues and Avoidable Cost Rates (ACR). This analysis provided a ranked list of coal, natural gas and oil fuel-type resources, ordered from those deemed most at risk of retirement due to revenue inadequacy, to those that were net profitable. Nuclear resources were not considered at risk of retirement in this analysis, given policy developments toward state-based subsidies for clean energy production. After introducing the ELCC-adjusted installed capacity from the Accelerated generation renewable expansion, the Accelerated retirement target was set to maintain the current PJM Installed Reserve Margin (IRM) levels after increased demand from electrification and data center loads. Thermal resources were then retired in rank order from the economic risk until the retirement target was met.

Load Forecast

Future Load Impacts

As a baseline, this study utilized the 2022 Load Forecast Report. PJM's 2022 Load Forecast used input from the 2021 Energy Information Administration Annual Energy Outlook. This was used as the basis for guiding assumptions on electric vehicles and electric heating in the Reference and Policy demand scenarios.

Electrification is the process of converting an end-use load that uses fossil fuels (or other nonelectric energy sources) to electricity. This most commonly refers to vehicles but can also refer to home and business uses for ambient heating, water heating, cooking and other activities. Transportation and heating could have the greatest impact on load forecast and load shape, and thus, these were the focus of the Electrification scenario.

To guide our assumptions on electrification, Princeton's Net-Zero America study was leaned on as a resource. This study has multiple electrification scenarios, and those were used to help guide assumptions for the period under

study in our analysis. As a result, the Electrification scenario has 17 million electric vehicles in PJM compared with the Policy scenario assumption of only 7.6 million.[3]

In PJM's 2022 Load Forecast, electric heating does not gain traction, as the direction was more toward natural gas heating in much of the PJM service area. Some areas in PJM's southern subregion already rely on electricity to some degree for heating (e.g., Virginia). However, northern Midwest and Mid-Atlantic areas of PJM predominately use nonelectric fuels (mostly natural gas and some propane and fuel oil) and were assumed to have minimal use of heat pumps. The Electrification scenario takes these northern Midwest and Mid-Atlantic areas from 0–10% of homes using heat pumps to 20–25%. The transition for more southern areas is less pronounced from an average of 25% of homes to about 40% in Electrification.

Similar analysis was also performed to produce Electrification assumptions on electric water heating and cooking, as well as commercial heating, water heating and cooking. The study did not take into consideration other forms of electrification such as industrial electrification or hydrogen.

Transmission Topology

The base topology for the production cost model utilized in the energy and ancillary services market simulations was developed from the 2023/2024 Regional Transmission Expansion Plan case and market efficiency processes and includes monitored contingencies included in the 2023/2024 Market Efficiency case. The modeling of the Policy and Accelerated scenarios addressed thermal violations resulting from the resource expansion internal to PJM.

External Interchange

The production cost model allowed flow over external interfaces up to the total transfer capability, assuming perfect market-to-market coordination. Hurdle rates that aim to produce external interchange that align with historical levels were not used. All external transmission zones that directly neighbor the PJM footprint were included in the model as unconstrained single "zone" bubbles where interchange was allowed up to current day limits.

[3] Since this study was conducted, PJM has further refined its assumptions electric vehicles including obtaining a vendor forecast. For vehicle assumptions used in 2024 Load Forecast, see Electric Vehicle Totals.