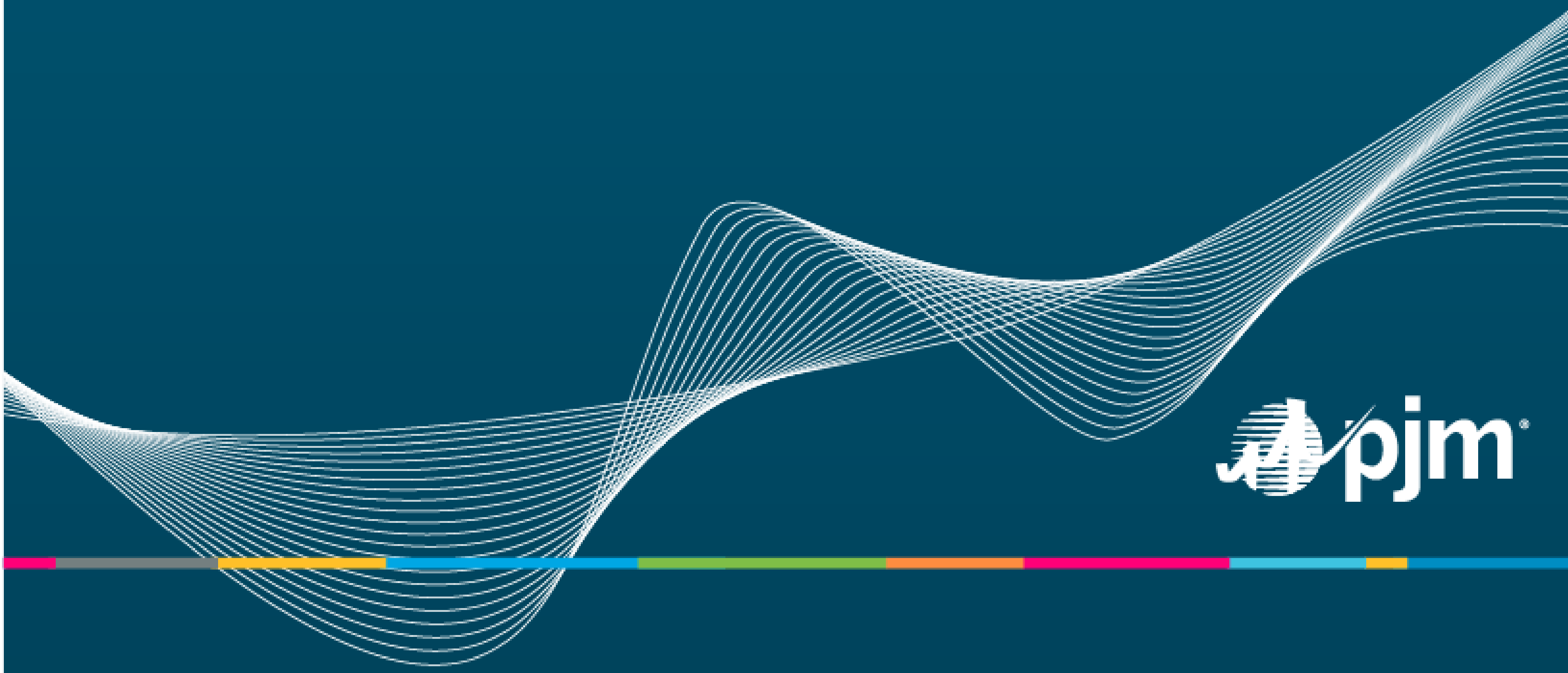
EPA’s Final Clean Power Plan
Compliance Pathways Economic and Reliability Analysis

PJM Interconnection
September 1, 2016



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Executive Summary

On August 3, 2015, the U.S. Environmental Protection Agency issued the Clean Power Plan, a rule limiting carbon dioxide emissions from existing power generation resources, and a proposed federal plan, which would be implemented should the states not act. The federal plan details model rules for regional mass-based and rate-based emissions trading[1], which would be imposed on states that do not submit a state plan or available to states to adopt as part of their state plans. The Organization of PJM States, Inc. requested PJM to analyze the Clean Power Plan for its impact on electricity costs and reliability.

As part of PJM's evaluation of the Clean Power Plan, PJM considered a reference scenario (without Clean Power Plan impacts) and seven possible compliance pathways or variants on mass- and rate-based trading at regional or state levels, which state agencies might undertake in order to achieve the mass targets or emissions-rate targets mandated in the Clean Power Plan. In addition to these compliance pathways, PJM analyzed a number of sensitivities on the reference scenario assumptions.

In light of current market conditions that have put a financial strain on some resources participating in the PJM markets, PJM conducted a sensitivity analysis to evaluate the impact of resource owners' adopting a short-term view in which initial exit decisions are based on only the first five years of the study period, rather than a longer-term view in which these decisions account for the entire 20-year study period. Additional sensitivities include those requested by OPSI: modeling a lower natural gas price, a multi-state split of rate- and mass-based compliance within the PJM region and state renewable portfolio standards.

The key findings from PJM's evaluation of the Clean Power Plan under the various scenarios are intended to inform PJM and its stakeholders of a variety of potential important impacts on resource adequacy and the PJM energy and capacity markets, as well as compliance costs[2] associated with achieving the EPA's CO_2 emissions targets.

Key Findings

- The CO_2 emissions reduction goals of the Clean Power Plan can be achieved within the PJM footprint under each of the seven compliance pathways studied.
    - Each of the seven compliance pathways leads to different emissions levels and trajectories of emissions reduction over the 20-year period studied due to 1) differing definitions of resources whose emissions must be curtailed to achieve the emissions targets, 2) the ability of non-affected sources to help achieve compliance, and 3) the scope of trading of emission rate credits or

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[1] Mass-based compliance is demonstrated for each affected resource by turning in allowances equal to their compliance period emissions, which in total do not exceed an aggregate emissions cap. Rate-based compliance calls for generators to meet a rate-based emissions performance target, expressed in pounds of carbon dioxide per unit of energy produced, and to supply emission rate credits when necessary to meet the target.

[2] Compliance costs associated with any of the studied compliance pathways are defined as the incremental change in fuel, variable operations and maintenance, going forward costs, and investment costs of generation to reliably serve load while also meeting the CPP CO_2 targets.

allowances that impacts the distribution of emissions reductions across a state or across the region.

- Regardless of the compliance pathway, resource adequacy is maintained in the PJM footprint.
    - Regional compliance results in fewer retirements and less combined cycle gas new entry than individual state compliance due to the greater flexibility and options for emissions reductions offered across the entire PJM region.
    - The capacity and energy markets are able to attract sufficient new investment to satisfy PJM's reliability requirements; however, costs will vary with each compliance pathway.
- Running a security-constrained economic dispatch model for the year 2025 shows that total congestion declines under every compliance pathway relative to the reference scenario.
    - Congestion related to historical west-to-east flows on the high-voltage transmission system declines significantly due to coal retirements in the western part of PJM.
    - The decline in congestion on the high-voltage transmission system is partially offset by more localized congestion.
- The cost of compliance for the entire PJM region differs according to the compliance pathway chosen, but regional compliance leads to lower costs than does individual state compliance under both mass-based and rate-based compliance pathways.
    - Levelized compliance costs range from $0.61/MWh for a regional compliance pathway to $1.93/MWh for a state compliance pathway that includes the regulation of both new and existing sources. These costs would be equivalent to 1.1 percent to 3.3 percent, respectively, of the average total wholesale cost of electricity.
- Rate-based compliance pathways result in lower wholesale energy but higher capacity market prices across the PJM footprint than the reference case and mass-based compliance pathways because resources with production subsidies submit energy offers below their cost of production.
    - Emissions rate credits earned by low- and zero-emitting resources act as a production subsidy, resulting in these resources submitting offers into the energy market below their actual fuel and variable operations and maintenance costs.
    - Rate-based compliance results in higher capacity prices because lower energy market prices drive a greater reliance on the capacity market to provide revenues to generation resources (including those zero-emitting resources ineligible to create emissions rate credits) to maintain resource adequacy. This results in increased economic challenges for existing nuclear resources.
    - Rate-based compliance leads to higher levels of renewable resources because renewables receive more revenue from emissions rate credits than from the increase in energy market revenues observed in the mass-based compliance modeling results. (Renewable resources receive

revenues from emissions rate credits, which augment revenue received from the energy market to offset investment costs.)

- The compliance cost of the rate-based pathways is sensitive to the ability of energy efficiency to be measured and verified so it may earn emissions rate credits. When PJM evaluated a sensitivity that assumed states are able to convert only 50 percent of the total amount of energy efficiency deployed within the load forecast into emissions rate credits, the cost of rate-based compliance increased to more than double the cost of trade-ready mass-based compliance, although the overall effects were still less than $1.50/MWh.
- Under mass-based compliance, all resources subject to the Clean Power Plan face an additional cost for emissions in the form of allowances, which results in energy market offers at least as great, or greater than, their actual fuel and variable operations and maintenance costs.
    - Because of higher energy market prices as CO_2-emitting resources reflect the cost of CO_2 allowances, all low-emitting or zero-emitting resources depend less on out-of-market payments to achieve revenue adequacy. This allows existing nuclear resources to become more economically viable because their low-emission characteristic is priced in the market.
    - Not all CO_2-emitting resources, including new gas combined cycle resources, are required to comply with the CPP's emissions limits. However, compared to a rate-based program, a mass-based program does not provide any incentives for resources to participate in the energy market at prices below their fuel and variable operations and maintenance costs.

Key Findings of Sensitivities

Sensitivity on the 20-Year Retirement Decision Horizon

In addition to the OPSI-requested sensitivities, PJM examined initial resource retirement decisions based only on a five-year horizon from 2018 through 2022. This model is intended to represent resource owners adopting a view that only the short-term (five-year) outlook prior to CPP compliance matters for these decisions. Given the retirement decisions from the short-term outlook, the model was run assuming all resources take a longer view over the entire 20-year study period for entry and exit decisions.

Under these decision criteria, PJM could experience 6 GW of nuclear retirements by 2022 (in addition to the previously announced Oyster Creek Nuclear Station retirement included in the reference scenario) while coal-fired retirements could increase by less than 1 GW. More nuclear retirements occurred in the five-year analysis than in the 20-year reference model, showing that nuclear resources would become economic in the long run. Nuclear retirements in the near term would result in increased CO_2 emissions, and an increase in total generation costs, such that overall generation costs would increase by approximately 27¢/MWh under mass-based compliance or 30¢/MWh under rate-based compliance.

Under the near-term lower gas price sensitivity, the number of potential nuclear retirements more than doubles; however, the amount of coal retirements also increases, preventing CO_2 emissions from exceeding the CPP targets.

OPSI Sensitivities

Lower natural gas prices: A lower natural gas price forecast (with gas prices remaining in the \$3-\$4/MMbtu range, in constant 2018 dollars over the 20-year study period) has a greater effect on emissions levels, the retirement of fossil steam resources and new entry of natural gas combined cycle resources than even the most stringent of the studied compliance pathways that also regulate the CO_2 emissions of new natural gas combined cycle resources.

- Because of accelerated retirements, there would be no cost to achieve compliance, and the resulting emissions would be below the final Clean Power Plan targets, even without the Clean Power Plan.
- Coal-fired generation retirements (nearly 30 GW) would be greater than or equal to even the most stringent of the compliance pathways studied.
- Natural gas combined cycle capacity would increase by 35 GW to maintain reserve margins above the reliability requirements.
- The lower gas prices would result in lower wholesale energy prices than observed in the reference case or the rate-based compliance cases studied. However, the lower wholesale energy prices result in the highest capacity market prices observed in any of the simulations as resources needed for resource adequacy would place greater reliance on capacity market revenues to cover going forward and investment costs.

Renewable portfolio standards: Independent of the Clean Power Plan, ensuring that all currently established state renewable portfolio standards are satisfied increases renewable capability and energy output.

- Total generation costs (including production, investment and going-forward costs) increase compared to the compliance pathways evaluated without renewable portfolio standards.
- The increase in renewable resources can reduce the cost of acquiring CO_2 allowances or emissions rate credits and offset negative impacts on revenue for coal-fired resources. Under some situations, this can lead to fewer coal-fired retirements compared to the compliance pathways evaluated without renewable portfolio standards.
- The ability for renewable portfolio standards to reduce wholesale energy market prices and Clean Power Plan compliance costs is partially offset by the costs associated with the payment of alternative compliance payment penalties that are a feature of renewable portfolio standards in some PJM states as well as increased total generation costs overall.

Mix of mass-based and rate-based compliance: The compliance cost advantages of all PJM states adopting either a trade-ready mass or trade-ready rate program persist even when states form subgroups to facilitate rate and mass-based trading. The reduced efficiency and likelihood of uneven treatment of resources subject to the Clean Power Plan across the PJM footprint are no different for individual state compliance versus subgroups of states adopting different compliance pathways.

Introduction

On August 3, 2015, the United States Environmental Protection Agency issued its final rule limiting carbon dioxide emissions from existing power generation resources, known as the Clean Power Plan, which was officially published in the Federal Register on October 23, 2015.[3] The EPA also concurrently issued a proposed federal plan for states spelling out model rules that would allow for regional mass-based and rate-based emissions trading.[4]

In light of the finalized CPP and proposed federal plan and model trading rules, the Organization of PJM States, Inc., requested that PJM conduct a follow-up analysis to the one that PJM did in 2015 on the proposed CPP.[5] This report provides the results of the analysis of the final rule.

The analysis of the final CPP highlights potential reliability and market outcomes under a reference scenario and seven possible compliance pathways that state environmental agencies may choose in order to implement the final CPP. This analysis assumes implementation of the CPP under the final rule timeframe.

PJM takes no position on the CPP but rather has performed this analysis of potential markets and reliability impacts as a neutral source of information. PJM's analysis is not a prediction of future market outcomes or of the decisions that resource owners will make.

For the analysis of the final CPP, PJM adopted the following phased modeling approach to represent the response of generators and the transmission system to the EPA's compliance pathways:

1. Long-term economic analysis in which entry and exit decisions by generation resources are made in the context of energy and capacity market outcomes over a 20-year time horizon
2. Medium-term analysis of a zonal transmission system representation to solve for annual CO_2 emissions constraints and decompose the emissions limitations for further analysis in an hourly transmission constrained model
3. Short-term security constrained economic dispatch for a selected year to examine the level and difference in transmission congestion across different compliance pathways. This model provides a greater granularity regarding CPP market effects, specifically market prices, at the state level.

With regard to modeling long-term economic decisions, PJM employed a modeling framework that optimized generator participation in both energy and capacity markets over a 20-year time horizon to arrive at generator entry and exit decisions. To capture the primary market-based revenue opportunities for generators beyond the PJM energy market,

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[3] *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule*, 80 FR 64,662, October 23, 2015 ("Clean Power Plan") available electronically at https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf.

[4] *Federal Plan Requirements for Greenhouse Gas Emissions From Electric Utility Generating Units Constructed on or Before January 8, 2014; Model Trading Rules; Amendments to Framework Regulations; Proposed Rule*, 80 FR 64,966, October 23, 2015 ("Federal Plan") available electronically at https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22848.pdf.

[5] OPSI letter to the PJM Board of Managers, *Modeling Economic Impacts of Final 111(d) carbon regulations* October 16, 2015 available electronically at http://pjm.com/~/media/about-pjm/who-we-are/public-disclosures/20151019-opsi-letter-regarding-modeling-economic-impacts.ashx.

PJM developed a representation of the renewable energy credit markets, emissions markets at a state or regional level and a representation of PJM's capacity market on a regional basis.

The modeling of the PJM capacity market followed the current shape of the demand curve for capacity and parameters were defined by the current tariff provisions[6] and adjusted each year over the 20-year horizon, based on inflation assumptions. Entry and exit occurs when cost savings can be achieved in the procurement of capacity and clearing of the energy market over the entire 20-year study horizon.

The medium-term and short-term analysis were performed as a single simulation. Consequently, the short-term model has only a single set of outputs. The short-term security constrained economic dispatch (SCED) analysis over a one-year period (for selected years in the analysis) is designed to provide additional detail on energy market results. In particular, it provides some insight into the levels of congestion and changing congestion patterns that could be associated with different compliance pathways. Moreover, the SCED analysis provides details at the state level that may help inform state commissions and environmental regulators about state-specific impacts from the seven different compliance pathways studied.

The analysis proceeds with an extended discussion of the compliance pathways, which include three mass-based and four rate-based compliance pathways. Following the discussion of compliance pathways and key inputs, the analysis then presents a 20-year, long-term economic analysis with emphasis on generator entry and exit, costs of complying with the CPP, energy market prices, emissions prices, and analysis of state versus regional compliance, as well as mass-based versus rate-based approaches.

Subsequent sections examine the short-term, one-year SCED analysis, OPSI-requested sensitivity scenarios and one sensitivity examining the effect of making initial retirement and new entry decisions on only a five-year horizon. The SCED analysis results highlight energy market prices, generation fuel mix and a discussion of congestion and the relation between congestion and the location of entry and exit. The analysis also includes state-by-state details from the short-term SCED runs for the year 2025. The results of the other sensitivity scenarios are presented along the same lines as the results from the compliance pathway analysis over the 20 year horizon.

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[6] The tariff provisions are discussed in *PJM Manual 18: PJM Capacity Market*, Revision 32, April 1, 2016 at 27-28, available electronically at http://pjm.com/~/media/documents/manuals/m18.ashx. The parameters used start with the 2018/2019 Delivery Year Base Residual Auction and are inflated by an assumed inflation rate of 2.25 percent per year, and are available at http://pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2018-2019-bra-planning-parameters.ashx. .

Compliance Pathways

Should states submit a state plan to comply with the CPP, the compliance choices they make with respect to state- versus trade-ready or regional compliance and rate-based versus mass-based compliance will have different impacts on the behavior of resources within the markets. States that fail to submit an approved plan will be subject to the federal plan, which defaults to either a trade-ready rate or trade-ready mass-based form of compliance. Because PJM's modeling is market-based, resources' decisions to enter or leave the market will reflect different costs incurred or revenue opportunities associated with a particular compliance pathway.

Reference Model

The reference model represents a future without the CPP. This means the CPP does not influence any resource entry and exit, dispatch or operating status decisions in this model. The Regional Greenhouse Gas Initiative, which affects new and existing resources in Maryland and Delaware, is the only CO_2 emissions limitation modeled within the PJM footprint.[7] All compliance pathways, including the reference model, assume that existing emissions trading programs for sulfur dioxide and nitrogen oxides remain in place.

Mass-Based Compliance Pathways

Mass-based compliance employs an explicit cap on the emissions from affected sources. Compliance with mass-based emissions targets is achieved by each of the affected sources holding emissions allowances[8] sufficient to cover CO_2 emissions recorded by the affected source's continuous emissions monitoring system at the end of each compliance period.

PJM's modeling implicitly reflects an auction structure in which generators are able to purchase allowances through either an intrastate or multi-state framework, depending on the compliance pathway being assessed. The clearing price in the model represents the marginal costs of abatement[9] required to not exceed the emissions limitation. Assuming that there are no restrictions on trading, the market-clearing price of emissions allowances is not dependent on the allocation method. Therefore, PJM's modeling is applicable to states that choose to auction allowances or to states that allocate allowances directly to generators or another entity. For additional information on the allowances available in the PJM region, see the Environmental Protection Agency's technical support document on unit-level allowance allocations[10] by compliance period.[11]

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[7] RGGI is assumed to remain in place through 2022, but be replaced by the emissions regulation implied by the compliance pathway being studied by 2022, the start of the compliance period.

[8] Holders of emission allowances can emit one short ton (2,000 pounds) of CO_2 for every allowance they possess.

[9] In general, the marginal cost of abatement is a determined by the cost of re-dispatching a more expensive and cleaner source, such as combined cycle natural gas, to displace a less expensive but higher-emitting source such a coal or oil steam.

[10] Data file: Appendix A: Allocations and Underlying Data (xlsx) https://www.epa.gov/sites/production/files/2015-11/documents/tsd-fp-allowance-allocations.pdf

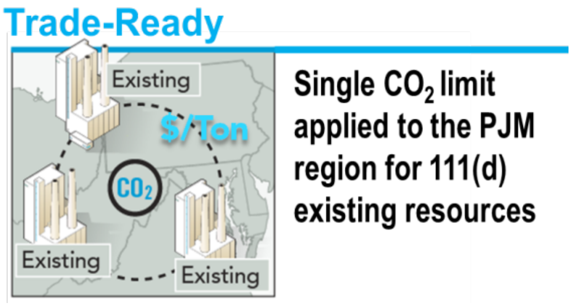
[11] *See* Clean Power Plan, Section VIII State Plans, subsection D State Plan Components and Approvability Criteria at 64,849. Compliance periods for the Clean Power Plan are initially three-year periods, 2022-2024 and 2025-2027, and then in two-year periods thereafter 2028-2029, 2030-2031, etc.

In PJM, generators reflect the cost of allowances in their energy market offers, treating the cost of an allowance just like the cost of fuel or variable operations and maintenance. Consequently, generators' energy market offers will be higher with the CPP. Thus, in general, evaluation of mass-based compliance with the CPP should lead to higher average energy market prices than the reference model.

During Phase 1 of its compliance analysis,[12] PJM evaluated both the existing source targets and existing source targets with new source complement[13] for both intrastate and trade-ready compliance. Each mass-based compliance pathway requires all fossil steam (coal/gas/oil) and combined cycle facilities that began construction before Jan. 8, 2014, to hold allowances equivalent to their CO_2 production.

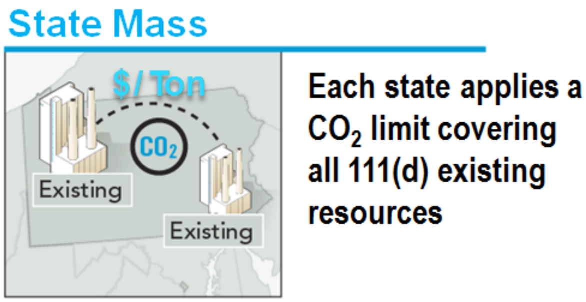
PJM's approach to modeling the mass-based compliance pathways is described below.

a. Trade-Ready Existing Source Emissions Limitation – *States enforce the EPA's emissions limits on existing sources only.*



By definition, trade-ready (or regional) compliance permits affected sources to trade allowances across state lines without any restriction as represented by the graphic.[14] The option carries regulatory risks for the state environmental agency because it does not directly address leakage, and therefore is not presumptively approvable by the EPA.

b. State Existing Source Emissions Limitation – *States enforce the EPA's emissions limits on existing sources only.*



Unlike trade-ready mass-based compliance, affected resources may only trade allowances with other affected sources within the state as shown in the graphic. Since the options for allowance trading are more limited than under the trade-ready mass-based compliance pathway, overall costs to the entire PJM Region should be higher that the trade-ready mass-based compliance pathway. The option carries regulatory risks for the state environmental agency because it does not directly address leakage, and therefore is not presumptively approvable by the EPA.

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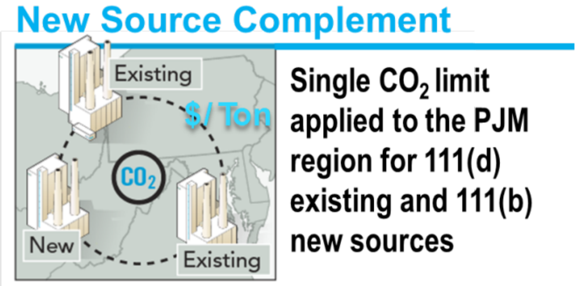
[12] *See* "PJM Clean Power Plan Modeling Preliminary Phase 1 Long-Term Economic Compliance Analysis Results", May 6, 2016 available electronically at http://pjm.com/~/media/documents/reports/20160506-pjm-clean-power-plan.ashx and "PJM Phase 1 Long-Term Economic Analysis of the EPA's Final Clean Power Plan Rule" May 5, 2016 available electronically at http://pjm.com/~/media/documents/reports/20160506-111d-phase-1-long-term-economic-analysis.ashx.

[13] *New Source Complements to Mass Goals Technical Support Document for CPP Final Rule*, August 2015 available electronically at https://www.epa.gov/sites/production/files/2015-11/documents/tsd-cpp-new-source-complements.pdf.

[14] *See* the Clean Power Plan, Section VII, subsection D Addressing Potential Leakage in Determining the Equivalence of State Specific CO2 Emission Performance Goals at 64,822-64,823.

c. Trade-Ready Emissions Limitation with New Source Complement – *States enforce the EPA's emissions limits on existing sources and on new sources.*



In addition to existing sources, new fossil steam and combined cycle gas resources must present allowances equivalent to their CO_2 production. The EPA proposed this alternative approach to prevent shifting of emissions from affected existing resources to new combined cycle sources not covered by 111(d). Affected sources can trade allowances across state lines. PJM modeled this compliance pathway based on the mass goal adjustments provided in the EPA technical support document, "New Source Complements to Mass Goals."[15] This compliance pathway would be presumptively approvable for states that adopt it given that it addresses the "leakage" problem of existing source emissions shifting to new source emissions.

d. State Emissions Limitation with New Source Complement (NSC) – *States enforce the EPA's emissions limits on existing sources and on new sources.*

As with the trade-ready new source complement pathway, new combined cycle gas resources are now included among the affected sources. The EPA envisioned some states may choose to submit state plans without any interstate trading, and this is one possible pathway for a state specific compliance plan that can be compared to the regional trading available with new sources taking on compliance obligations. This compliance pathway would be presumptively approvable for states that adopt it given that it addresses the "leakage" problem of existing source emissions shifting to new source emissions.[16]

Rate-Based Compliance Pathways

In contrast to a mass-based limit on overall emissions, rate-based compliance pathways do not cap overall tons of emissions. Instead, a rate-based compliance pathway mandates that affected resources must achieve a target emissions rate in pounds of CO_2 per megawatt-hour of energy produced (lbs. CO_2/MWh). Under the compliance pathways proposed by the EPA, affected resources could increase their generating efficiency to achieve the mandated emissions rate standard or affected sources could buy emission rate credits from other sources. Similar to allowances, emissions rate credits (ERCs) are tradable commodities to enable CO_2-emitting resources to achieve compliance with the rate standard.

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[15] Technical Support Document: New Source Complements to Mass Goals https://www.epa.gov/sites/production/files/2015-11/documents/tsd-cpp-new-source-complements.pdf

[16] While state enforcement of the new source complement reduces shifting of emissions from existing resources to new resources within the enforcing states, it does not prevent shifting to resources outside the state.

ERCs are created only when low- or zero-emitting resources are generating energy (megawatt-hours); by default, ERCs are allocated to the low- and zero-emitting resources that create them. While there is not an explicit cap on emissions under rate-based compliance, the total amount of ERCs in circulation during a compliance period may limit the amount of emissions that can be produced on a mass (tons) basis – the supply of ERCs must at-least match demand for ERCs. The clearing price for ERCs represents the marginal cost for the supply/demand constraint, which can be based on the cost of re-dispatch from higher-emitting sources to lower-emitting sources but also could represent the incremental cost required to make a renewable resource entering the market economic.

Generators reflect the value of ERCs within their energy market offers. ERC producers reflect the price of the ERCs created as a negative cost or in effect, a production subsidy, in exactly the same manner in which the production tax credit would be reflected in energy offers of wind and solar resources. Buyers of ERCs will reflect the additional cost of the ERCs in their energy market offers similar to mass-based allowance trading. Whether average energy market prices go down or up depend on the level of renewables incentivized to enter the market, but also the number of hours ERC buyers are setting market prices versus ERC sellers.

PJM's approach to modeling the rate-based compliance pathways is described below:

a. All Rate-Based Compliance Pathways

Each rate-based compliance pathway requires all fossil steam (coal/gas/oil) and combined cycle facilities that began construction before Jan. 8, 2014, to either meet the standard on their own, or acquire enough ERCs for compliance with their applicable emissions rate standard.

Renewable energy resources such as wind and solar -- as well as energy efficiency and new nuclear capacity constructed and or deployed after 2012 and existing combined cycle gas resources with emissions rates below the target emissions rate – are modeled as producers of ERCs.[17] There are other producers of ERCs as specified in the final CPP; however, the technologies above are represented in PJM's modeling.

In general, zero-emitting resources have the ability to sell their ERCs to buyers located in different states, even under state-only compliance pathway.[18] This treatment of ERCs confers an advantage to state rate-based compliance over state mass-based compliance in that it confers a "quasi-regional trading" status for state rate-based-only compliance that does not exist for state mass-based compliance. The only limitation on selling renewable resources' ERCs is the requirement that ERCs produced in a mass-based state have a power purchase or similar agreement with the purchasing rate-based state.[19]

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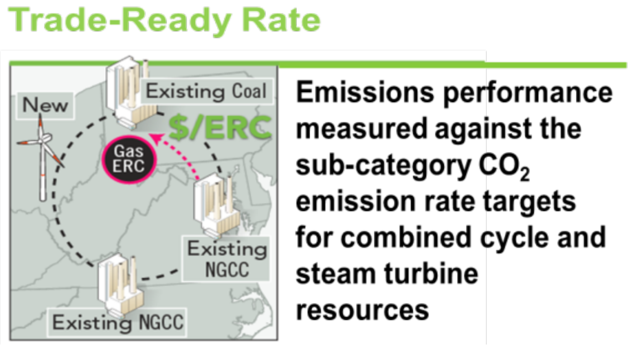
[17] *See* Clean Power Plan, Section VIII K. 1. a (2) (a) entitled "Eligibility date for installation of RE/EE and other measures and MWh generation and savings." at 64,896.

[18] *See* Clean Power Plan, Section VIII K. 1. a (2) (c) entitled "Geographic Eligibility" at 64,897.

[19] *See* Clean Power Plan, Section VIII K. 1. a (2) (c) (i) at 64,897. Only renewable resources qualify for this exception in mass-based states.

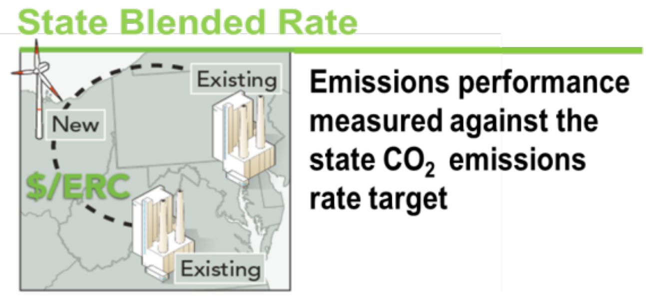
To reduce modeling complexity, energy efficiency embedded in the load forecast was modeled as a reduction in the demand for ERCs in the state(s) in which the load reductions occur. However, all other zero-emitting ERCs are able to be sold throughout the broader market region to resources in the state or region with the highest ERC price.

b. Trade-Ready Rate – *States enforce sub-category rate targets for fossil steam and natural gas combined-cycle resource.*



PJM studied the proposed method described in the federal plan[20], The proposed federal plan creates which balances demand for ERCs with two types of ERCs, gas-shift ERCs (GS-ERCs) produced by existing natural gas combined cycle sources and ERCs produced by all other qualifying sources. Covered thermal resources consume or produce ERCs based on the applicable natural gas combined-cycle rate target or fossil steam rate-target. PJM utilized the methodology described in the EPA's technical support document to assign a GS-ERC production rate to all covered natural gas combined cycles in the PJM footprint. Given the size of the PJM footprint, PJM did not model the EPA's proposed limitation on combined-cycle gas units utilizing GS-ERCs for compliance. Within the PJM region, the level of coal demand for ERCs far exceeds the amount of GS-ERCs that can be produced, and once the ERCs are produced they have the same compliance value to fossil steam resources.

c. Blended Rate – *Individual States enforce the weighted average rate target the EPA calculated based on 2012 generation.*



Thermal resources are able to produce or consume emission rate credits, but are not able to sell emission rate credits outside of the state. Under intrastate compliance, PJM's modeling enforced the geographic restriction on the sale of ERCs produced by thermal resources, but allowed these resources to buy ERCs from any eligible zero-emitting resource in the footprint. The rate targets are defined in the EPA technical support document "Goal Computation Appendix"[21].

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[20] *See* Proposed Federal Plan, Section IV. Rate-Based Implementation Approach

[21] Data File: Goal Computation Appendix 1-5 (XLSX) https://www.epa.gov/sites/production/files/2015-11/tsd-cpp-emission-performance-rate-goal-computation-appendix-1-5.xlsx

d. Regional Blended Rate – *Group of states enforce a single weighted average rate target the EPA calculated based on 2012 generation.*

Thermal resources are able to produce or consume emission rate credits, and are able to trade emission rate credits within the region. Similar to state blended rate compliance there is no geographic restriction on where zero-emitting emission rate credits are produced within the footprint.

Regional Blended Rate

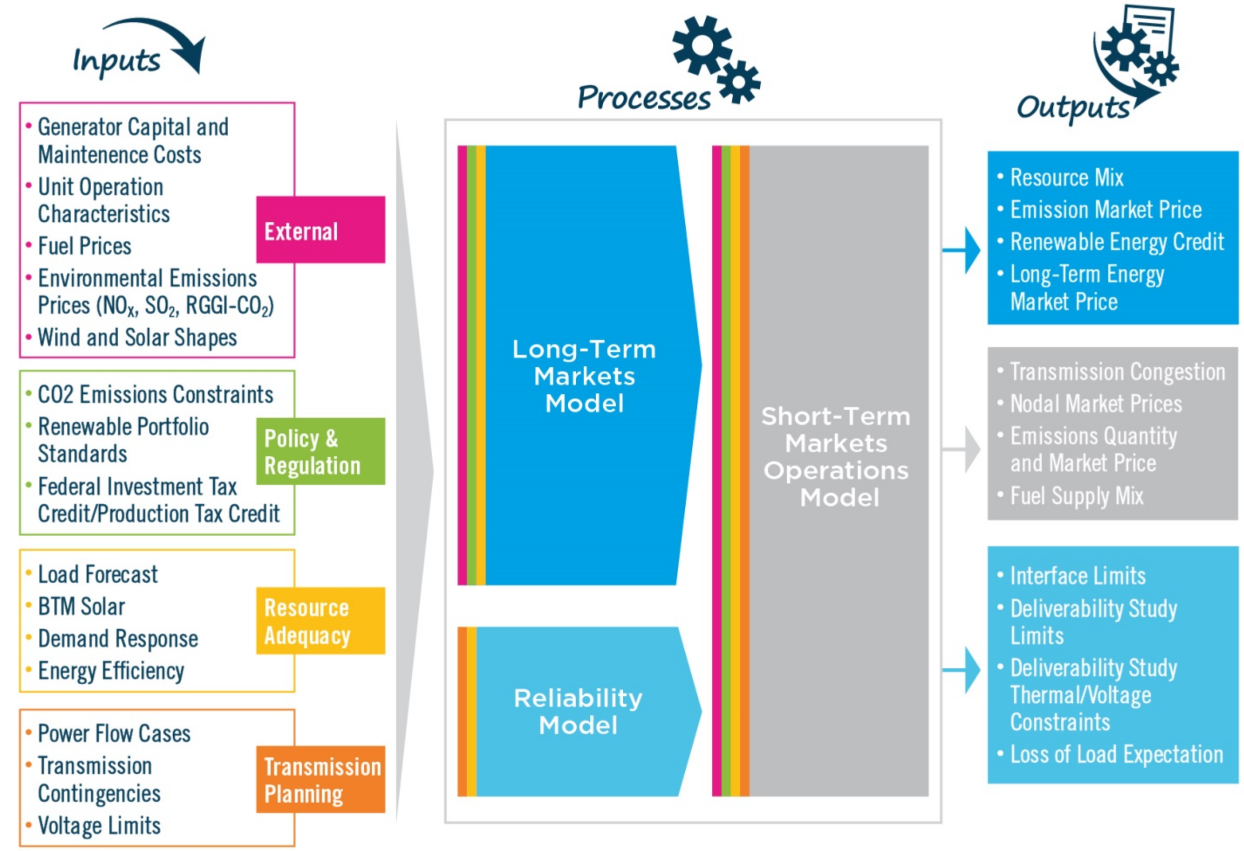
Emissions performance measured against a weighted average of PJM states’ CO_2 emissions rates

Key Model Inputs and Procedures

As shown in Figure 1, PJM's analysis of the CPP is a comprehensive review of the regulation's impacts on both the market and system reliability within the PJM footprint. PJM evaluated each aspect of the CPP as a dynamic system; there are feedback elements between each of the analysis modules. The discussion below will focus on the various key modeling inputs, how they are derived and can impact interpretation of the results.

A full discussion of all model inputs and assumptions ranging from the costs of potential new entry by renewable resources and combined cycle gas facilities, financial assumptions, and load forecast modeling is provided in the Appendix.

Figure 1. PJM's Clean Power Plan Modeling Framework



Natural Gas Prices

Fuel prices – and in particular natural gas prices – are the most significant driver of energy and capacity market prices, resource entry and exit decisions, and the cost of re-dispatch to achieve CO_2 emissions targets. Gas has been the most volatile fuel historically, exhibiting large swings between seasons and even daily during the winter peak periods. Natural gas prices influence all resource decisions.

Coal and nuclear resources historically through 2008 were able to earn high infra-marginal rents[22] in the energy market that would cover most, if not all, of their respective going forward costs, during periods when natural gas combined cycles and combustion turbines set the market price. In addition to traditional "base-load" resources, renewable resources that have high capital costs but negligible operating cost look to the energy market signal created by dispatchable resources that actively set market prices. Over the last eight years, the PJM market, and industry as a whole, has experienced a sustained period of low gas prices. Likewise, the energy market prices have been lower than historical periods. These trends have exerted a significant influence on both the types of resources that comprise the PJM generation interconnection queue and on generator retirement announcements.

The drivers for low gas prices and expected price/infrastructure trends are discussed in the Appendix. Given the views on supply and demand drivers affecting gas prices, various futures could be used in a 20-year economic analysis. Consequently, PJM simulated the CPP under two different forecasts.

For the purposes of conducting market efficiency analyses for the Regional Transmission Expansion Planning (RTEP) process, PJM uses an integrated fuels forecast at the unit level, including coal, oil and natural gas from the vendor ABB.[23]For consistency with the RTEP process, PJM has maintained this forecast for the reference model and as the basis for all CPP compliance pathways analyses. PJM used a proprietary forecast from the consulting firm IHS CERA from February 2016 for a low-natural-gas-price sensitivity analysis. The gas price forecasts are shown in Figure 2. For comparison, PJM has also plotted the reference case gas price forecast from the early release of the 2016 Annual Energy Outlook (AEO) published by the U.S. Energy Information Administration.[24] This forecast tracks closely with the ABB forecast through 2025 and then levels off and follows the trajectory of the IHS CERA forecast as shown in Figure 2. The IHS CERA forecast tracks closely with the recent trend in the forward curve for Henry Hub futures prices.[25]

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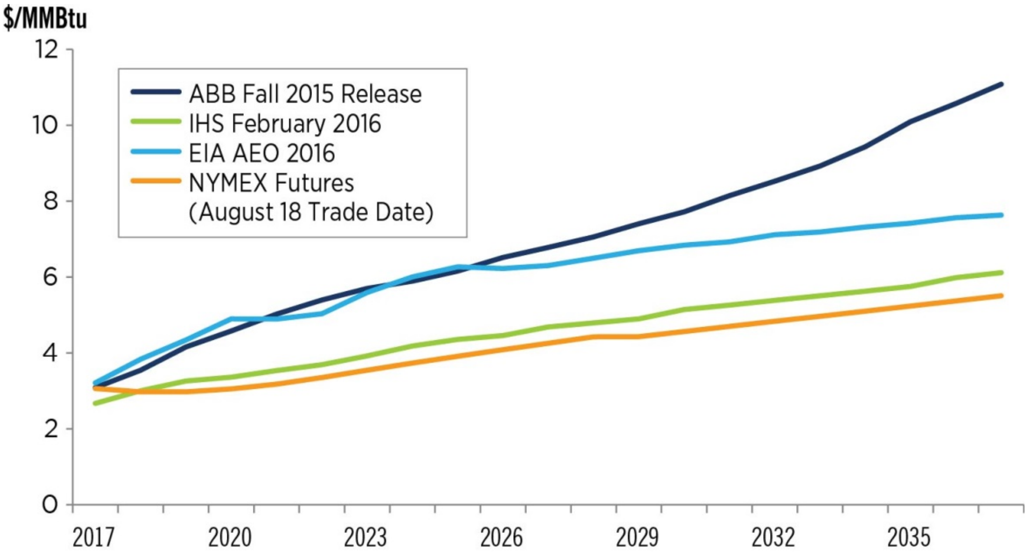
[22] Infra-marginal rent is the difference in operating rate between a resource and the most expensive resource dispatched on the system that also sets the market price. These are also known as net energy market revenues.

[23] Proprietary fuels forecast provided by ABB as part of their standard NERC 15 Powerbase release data

[24] United States Energy Information Administration, *Annual Energy Outlook 2016, Early Release*, May 2016, Reference Case Natural Gas Prices, Table 13. Available electronically at http://www.eia.gov/forecasts/aeo/er/tables_ref.cfm.

[25] CME Group, NYMEX Henry Hub Natural Gas Futures Settlements. Available electronically at http://www.cmegroup.com/trading/energy/natural-gas/natural-gas_quotes_settlements_futures.html. Futures settlements are for the close of trading on August 18, 2016. Since settlements are monthly, the yearly simple average of the monthly settlements is used. Futures only go to the end of 2028. After 2028, the settlement price was adjusted based on the trending prices 2016 through 2028.

Figure 2. Nominal Henry Hub Natural Gas Prices



Source: IHS Inc.

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A lower long-term outlook on natural gas prices as represented by the IHS CERA forecast in Figure 2 makes it more difficult for renewable resources to enter the market, even with the recent extension of the federal tax credits available early in the study horizon.[26] Coal and nuclear resources are heavily dependent upon the net energy market revenues they earn to cover their going forward costs, and the lower gas prices increase their dependency upon the capacity market to remain financially viable. In the model unit entry and exit decisions are based on a 20-year view of market conditions. A lower expected outlook on gas prices beyond 2025 reduces the ability of nuclear and coal resources to recover shorter-term losses with discounted future profits. This could lead to the exit of more coal and/or nuclear resources while also increasing the entry of new combined cycle natural gas resources. The IHS CERA forecasts, while not the lowest possible projection of natural gas prices, is sufficiently lower than the ABB forecast to assess the impact of natural gas prices on CPP compliance.

Life Extension Cost

When resources reach the end of their technical life, they incur incremental cost in order to continue commercial operation. Age-based retirements were not considered in the analysis, and only economically-driven retirements were permitted. As part of the economic analysis, PJM assumed that steam turbine and nuclear resources incur this cost when they achieve 40 years of commercial operation. Likewise, combined cycle and combustion turbine

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[26] For a discussion of these credits, *See* the Appendix section entitled "Federal Investment and Production Tax Credits and Utility Scale Renewable Resources" this paper.

resources incur end-of-life cost at 30 years. PJM based its assumption of life extension cost on the EPA's assumptions as shown in Table 1.[27]

Table 1. Life Extension Cost Assumptions Used in EPA Base Case v. 5.13

Plant Type	Technical Life (Years)	Life Extension Cost as Proportion of New Unit Capital Cost (%)
Biomass – Fluidized Bed	40	6.60%
Coal Steam	40	7.00%
Combined Cycle	30	9.30%
Combustion Turbine and IC Engine	30	4.20%
Oil/Gas Steam	40	3.40%
IGCC	40	7.40%
Nuclear	40	9.00%
Landfill Gas	20	9.10%

The EPA assumes that the investments extend the plants' life by the initial technical life. Section 6.8 in Attachment DD of the PJM tariff[28] specifies rules for how this cost can be reflected in capacity market offer caps used for market power mitigation in the PJM capacity market. In a competitive market, there is no guarantee that resources making these investments will be committed in the PJM capacity market. The model adopts the same approach. The resource should be competitive in the energy market such that some of the incremental capital cost is offset in the resource's capacity market offer. Otherwise, it is likely that the model will commit other resources for the Delivery Year. Figure 3 and Figure 4 illustrate the level of firm (i.e. unforced) capacity participating in the PJM market that was modeled as making investments to extend their initial technical life. Units that achieved the end of their initial technical life before the study horizon are assumed to have sunk their capital cost.

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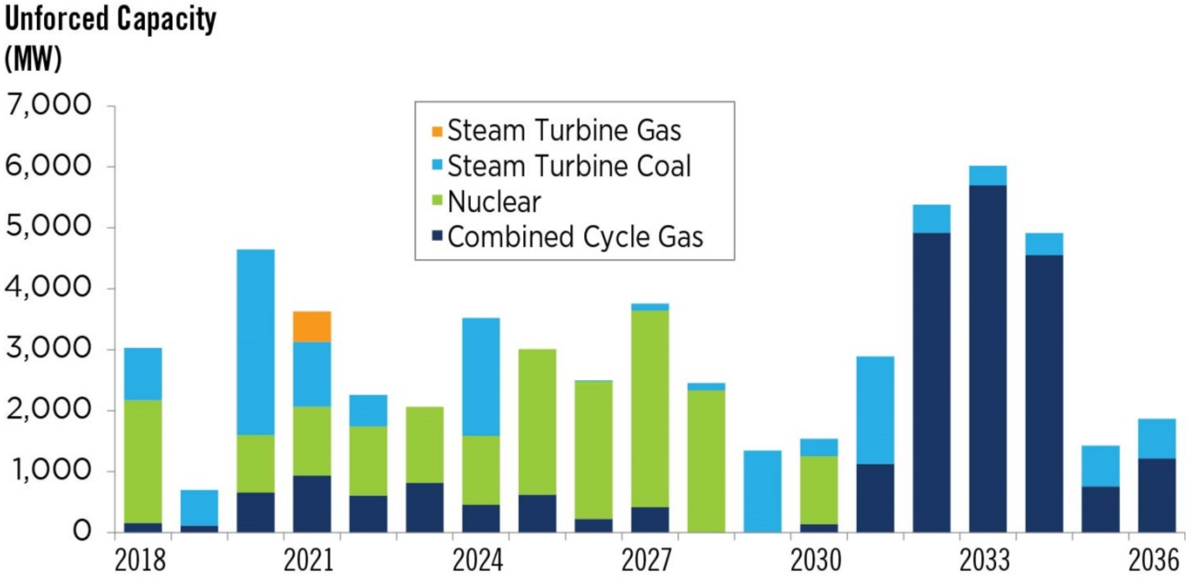
[27] United States Environmental Protection Agency, *Documentation for EPA Base Case v. 5.13 Using the Integrated Planning Model* ("EPA Base Case v. 5.13"), Chapter 4 "Generating Resources", Table 4-10, November 2013. Available electronically at https://www.epa.gov/sites/production/files/2015-07/documents/chapter_4_generating_resources_0.pdf. The entire documentation is electronically available at https://www.epa.gov/airmarkets/power-sector-modeling-platform-v513. Costs in the Base Case v. 5.13 are expressed in 2011 dollars.

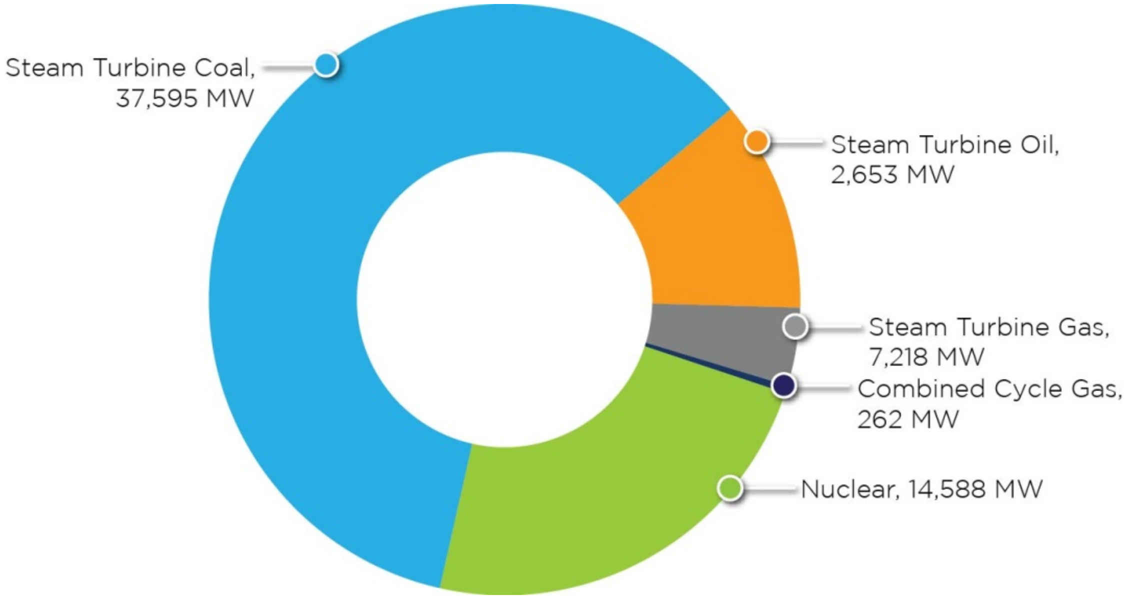
[28] *PJM Open Access Transmission Tariff* ("PJM Tariff)"Attachment DD, Section 6.8 Available electronically at http://pjm.com/media/documents/merged-tariffs/oatt.pdf.

Figure 3. PJM Unforced Capacity Reaching End of Initial Technical Life During the Study Period



An interesting observation from the life cycle analysis is that most of the nuclear fleet has either reached the end of the initial 40-year licensing period or will do so during the interim compliance period. The nuclear plants that received the first 20-year renewal before 2018 will be up for a second 20-year extension (60-80 years) by the 2030s. Low natural gas prices and significant new entry of natural gas combined cycles put nuclear units in a difficult financial situation, with respect to making relicensing and life extension investment decisions. To remain in commercial operation owners of the plants will need to make investments, but bidding the costs of these investments into the capacity market potentially makes the resources less competitive compared to resources that don't incur this cost.

Figure 4. Steam Turbine and Nuclear Units Older than 40-years, Combined Cycles Older than 30-Years by 2018

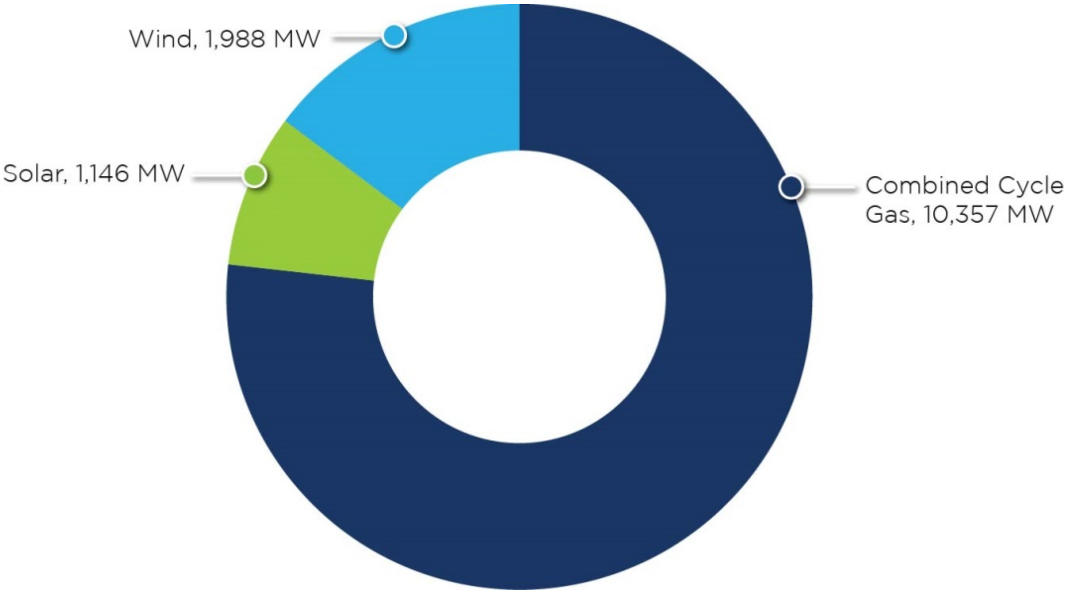


Queue Resources

Planned Generation Resources

In the base model, PJM assumed a certain amount of wind, solar and natural gas resources would enter the model independent of resource economics. Given that natural gas generally enters as a capacity resource for most of its available capacity, PJM applied a higher hurdle before adding these resources as planned resources. Notably, PJM's interconnection projects team assessed the likelihood of the projects moving forward, given the actual status of construction and permitting, and not just the resources' status in the PJM interconnection queue study process. Wind and solar were added to the model as planned resources based on their inclusion in the 2019/2020 Reliability Pricing Model planning power flow model. The assumption on the level of resources added to the model as planned resources versus economic resources does have an impact on interpretation of the results. Investment made in planned resources is considered sunk cost and is not captured in the investment portion of compliance cost. Only the production and fixed operations and maintenance cost is carried forward.

Figure 5. PJM Interconnection Queue Resources Added as Planned Resources (Installed Capacity)



Economic Resources

In the original modeling framework, PJM stated that the only thermal resources that would be allowed to enter the model economically were those that had executed a Facility Study (FSA) or Interconnection Service Agreements (ISA).[29] The basis for this practical limitation was to facilitate the evaluation of compliance in the security constrained economic dispatch (SCED) model in which transmission constraints are enforced, and for which transmission upgrades had already been identified. It became clear in the initial CPP modeling results, however, that this limitation resulted in a more narrow view of all the compliance options available over a 20-year study, in which not only new

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[29] "PJM Clean Power Plan Modeling Preliminary Phase 1 Long-Term Economic Compliance Analysis Results", Appendix at 33. Available electronically at http://pjm.com/~/media/documents/reports/20160506-pjm-clean-power-plan.ashx.

entry but also retirements can be utilized to reduce compliance cost. Restricting new entry over a 20-year horizon to resources with only executed FSAs and ISAs limited potential economic new entry and may result in otherwise uneconomic, higher-emitting resources being retained to ensure resource adequacy.

System Impact Study Resources

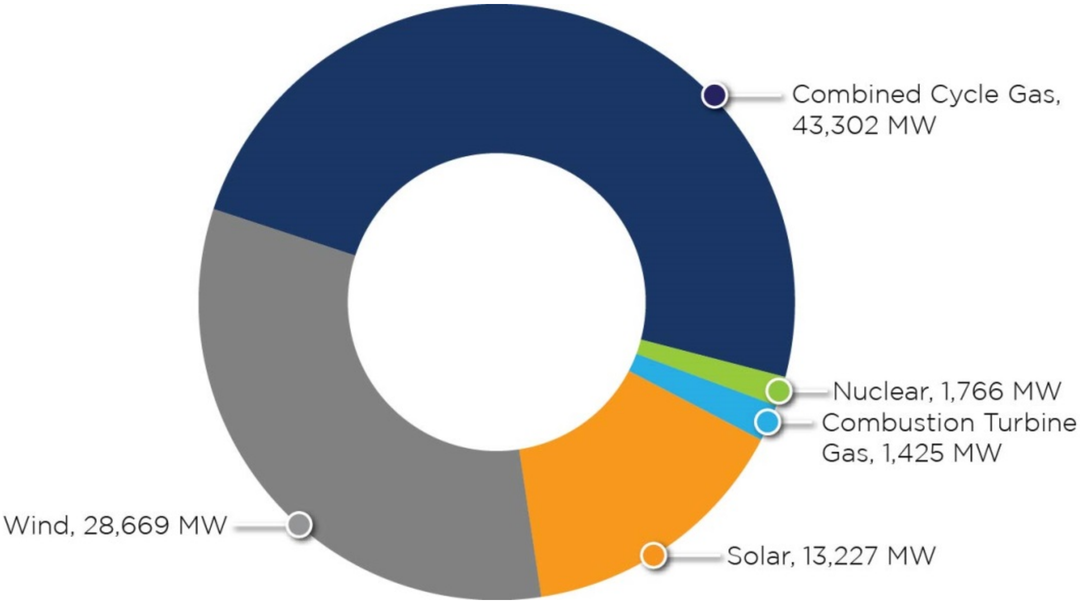
PJM's interconnection analysis group provided a set of units at this stage of the interconnection process that were unlikely to be assessed significant network upgrade costs. The lack of system upgrades is indicative of how the resource would perform in an operations model in which transmission can influence which resources are economic in any dispatch period. The model is able to add these resources economically as early as the requested commercial operation date.

Feasibility Study Resources

More replacement generation capacity expands the range of compliance options, including retiring uneconomic resources, and leads to lower overall costs of compliance with the CPP. Expanding the set of potential new entrants that could displace otherwise uneconomic resources enables a more robust comparison of regional versus state compliance as well as rate- and mass-based compliance over the 20-year analysis.

For the modeling of CPP compliance presented in this paper, PJM permitted the model to select resources in the interconnection queue at the feasibility study stage. Unlike resources more advanced in the interconnection queue process at the FSA or ISA stage, which are allowed to enter the model economically as early as their requested interconnection date, the earliest that these queue projects are allowed to enter the market economically is 2026.

Figure 6. Potential Economic Generating Capacity Additions.



Energy Efficiency and Distributed Solar

Table 2 provides the average energy efficiency available by state, and Table 3 provides the average amount of distributed solar by state that appears in the PJM 2016 Load Forecast.[30] The levels of energy efficiency and distributed solar production are important in that they reduce the amount of generation needed to satisfy load and on their own help in reducing overall emissions levels, which can be helpful in mass-based compliance. With respect to rate-based compliance, energy efficiency and distributed solar can also produce ERCs that can be used for compliance and reduce the need for ERCs to be produced by utility scale wind and solar resources or existing combined cycle gas resources.

ERCs assumed to be produced by energy efficiency and distributed solar are assumed to be produced at zero cost, and have the effect of reducing ERC prices and the cost of compliance in rate-based regimes by creating a ready-made pool of ERCs. Energy efficiency and distributed solar do not have this same effect in mass-based compliance pathways as they do not have the ability to produce allowances that can be used for compliance.

Finally, in the sensitivities performed assuming the enforcement of state renewable portfolio standards, because distributed solar is already embedded in the model and does not have to enter economically, it provides a zero cost way of satisfying renewable portfolio standard solar carve out provisions. Distributed solar drives down the price of solar renewable energy credits as determined in the model, which reduces the amount of utility-scale solar that enters the model economically.

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[30] For an extended discussion of the manner in which energy efficiency and distributed solar factor into the 2016 Load Forecast, see the Load Forecast section in the Appendix to this paper. The yearly values by state were provided to PJM by the Resource Adequacy Planning staff at PJM.

Table 2. Average Energy Efficiency Available to Generate Emission Rate Credits by State and Compliance Period

State	2022-2024	2025-2027	2028-2029	2030-2031	2032-2033	2034-2035	2036-2037
DC	612,200	728,598	823,994	916,465	1,009,181	1,088,102	1,161,310
DE	689,060	810,270	913,925	1,015,235	1,120,362	1,207,356	1,279,985
IL	9,079,815	10,386,254	11,349,246	12,384,509	13,372,237	14,104,276	14,797,638
IN	1,513,224	1,754,156	1,936,476	2,111,505	2,288,658	2,424,091	2,545,112
KY	907,696	1,059,942	1,176,613	1,287,806	1,396,668	1,482,065	1,563,540
MD	3,618,357	4,266,552	4,819,837	5,364,358	5,900,699	6,357,214	6,747,672
MI	275,095	318,895	352,040	383,859	416,064	440,685	462,686
NC	586,548	686,781	774,018	863,275	951,055	1,023,880	1,086,157
NJ	8,106,212	9,490,648	10,447,608	11,361,939	12,232,221	12,928,836	13,550,704
OH	10,753,629	12,328,939	13,511,318	14,685,130	15,817,886	16,664,613	17,446,553
PA	13,494,418	15,973,732	17,814,453	19,527,032	21,147,546	22,451,381	23,636,388
TN	160,672	186,253	205,612	224,196	243,006	257,386	270,236
VA	10,540,140	12,326,946	13,859,900	15,417,049	16,954,546	18,219,882	19,306,084
WV	2,408,448	2,809,768	3,145,360	3,475,045	3,809,779	4,077,624	4,309,390

Table 3. Average Distributed Solar Available to Generate Emission Rate Credits by State and Compliance Period

State	2022-2024	2025-2027	2028-2029	2030-2031	2032-2033	2034-2035	2036-2037
DC	127,641	149,844	188,338	235,675	262,139	279,669	297,282
DE	289,295	375,424	476,529	619,865	727,074	805,375	884,353
IL	188,403	275,637	348,627	409,710	462,637	509,517	556,623
IN	35,598	54,348	68,673	82,757	91,143	96,589	102,116
KY	14,062	20,566	25,144	32,815	36,948	38,903	40,899
MD	781,210	930,635	1,179,549	1,496,009	1,689,037	1,822,258	1,956,827
MI	6,675	10,190	12,876	15,517	17,089	18,110	19,147
NC	85,107	126,090	165,277	202,598	233,977	261,295	288,699
NJ	1,179,422	1,738,914	2,548,749	3,313,272	3,805,549	4,183,829	4,567,020
OH	321,887	457,403	525,610	584,035	642,013	693,904	746,204
PA	493,833	614,076	732,794	873,859	976,361	1,053,703	1,132,082
TN	3,337	5,095	6,438	7,758	8,545	9,055	9,573
VA	1,212,891	1,787,778	2,338,177	2,869,034	3,308,156	3,686,019	4,065,172

Long-Term Economic Model Analysis Results

Many factors affect long-term market prices, future emissions levels and generation entry/exit decisions. Among these are public policy choices, regulations and market drivers such as fuel prices, demand growth and technology changes (including reduced costs and greater efficiencies).

The CPP emissions targets are not enforceable until 2022, and the targets will continue to become more stringent until 2030. In response to new regulations, resource owners will factor in future risks and economic opportunities in evaluating new or existing generation assets. To address the potential effects of the CPP from a competitive wholesale market standpoint, PJM performed a 20-year simultaneous optimization of the energy market, capacity market, ERC and/or allowance markets, and in sensitivity analysis, renewable energy credit markets. While other factors influence resource development, these markets provide the primary signals that drive utility-scale generation development within the PJM footprint.

PJM Market Price Impacts

The key resources evaluated as part of states' potential compliance strategies with the CPP are solar, wind, and natural gas combined cycles, existing fossil steam (primarily coal) and nuclear resources. Because of negligible operating costs, wind and solar are price takers and will displace the most expensive resources operating at any given time.[31] Under rate-based compliance, renewable resources will also be a key source for ERC production. Existing combined cycle gas resources will also provide ERCs, but under both mass- and rate-based compliance, existing and new combined cycle play a prominent role in ERCs and allowance price formation, as the beneficiaries of re-dispatch from higher-emitting to lower-emitting sources.

New combustion turbines, which can also set prices during peak hours, represent a small fraction of the PJM interconnection queue capacity; thus, will not play much of a role in the compliance choices evaluated in PJM's analysis. In every compliance pathway, natural gas combined cycles are the primary resources entering the market that can actively set PJM energy prices and replace fossil steam resources that retire as a result of compliance with the CPP. With this changing configuration of the PJM resource mix characterized by more homogenous entry, the supply curve for energy is much flatter over a wide range of demand levels, which means changing units at the margin results in smaller changes in energy market prices than what can be observed historically.

Within the energy market, as the relative cost of generators changes, re-dispatch or resource substitution occurs across the broader PJM region regardless of whether compliance is implemented on a regional or individual state basis. Substitution will not always result in an increase in the price paid for energy if the resource setting the energy price, often called the "marginal resource" does not change. Likewise, energy prices will not change much if a block of resources has very similar running costs comprised of fuel, variable operations and maintenance and emissions costs offers.

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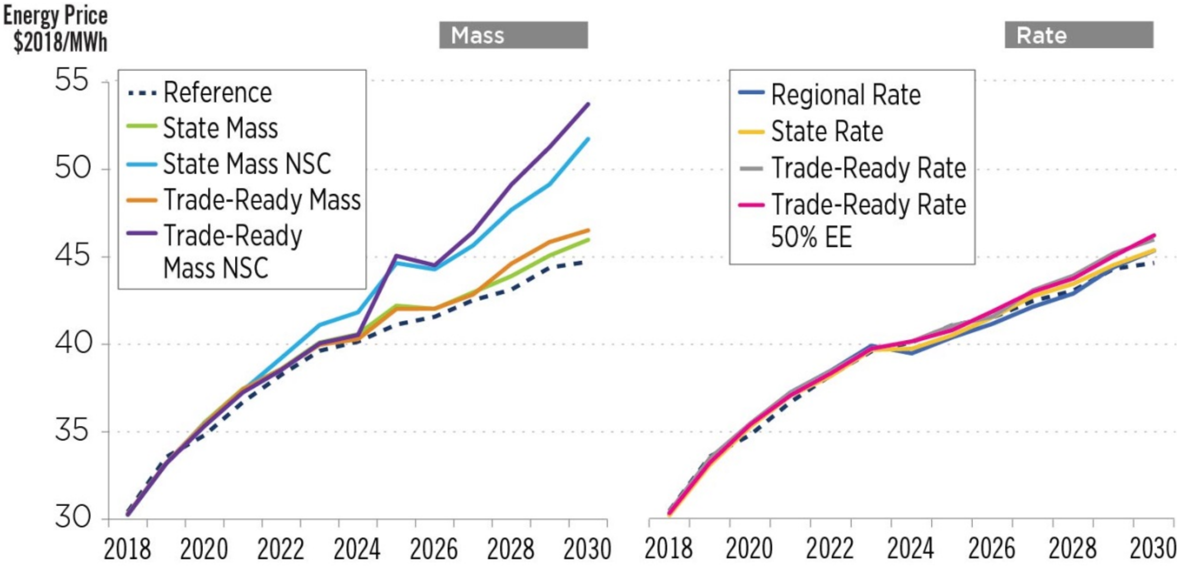
[31] In the long-term market model without transmission constraints, renewable resources will always displace the most expensive resources on the system regardless of location. Under a SCED model where transmission limits are modeled, generally this occurs but renewable resources can also be curtailed.

In each of the compliance pathways, including the reference model, natural gas-fired combined cycle units are the only active price-setting resources to enter the market. Renewables, which have negligible operating costs, generally are price takers. Figure 7 shows the path of energy market prices over the 20-year study period. As discussed above in describing the energy market price effects of the compliance pathways, mass-based compliance leads to higher energy market prices than the reference case absent the CPP. In the absence of regulating new combined cycle gas resources, these effects are relatively small – less than 2.5 percent over 20 years for trade-ready mass compliance. When new combined cycle gas resources are regulated, and must account for the cost of emissions in their energy market offers, the price increases are more significant, 11 percent over 20 years for trade-ready mass new source complement, as seen in Figure 7.

Figure 7. Energy Market Prices for the PJM Region under Mass- and Rate-Based Compliance Pathways



With respect to rate-based compliance, energy market prices overlap those from the reference case energy market prices, and in some cases are even lower than the energy market prices in the reference case. As discussed above, the nature of rate-based compliance is that energy market offers for some existing combined cycle gas resources must fall in order to operate more and earn ERCs[32]. Fossil steam resources are unlikely to be producers of ERCs; so they will reflect the cost of purchasing ERCs in their energy market offers. The countervailing effects of some resources offering higher energy market offers and others, lower energy market offers can result in the average market prices being higher, lower, or even equal to the reference model.

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[32] Whether the generator buys, or is allocated, allowances under mass-based compliance, the generator will reflect the value of the allowance in its energy offer. When allowances are allocated to generators and the generators subsequently consume the allowances, there is lost opportunity cost for the generators to sell them. Likewise, when a generator buys allowances, there are direct costs for consuming the allowance, which are passed through to the energy market. In contrast, rate-based compliance will only lead to the cost of ERCs being reflected positively in energy market prices when higher emitting resources are willing to purchase ERCs. Rather than allocation, ERCs can only be earned through production.

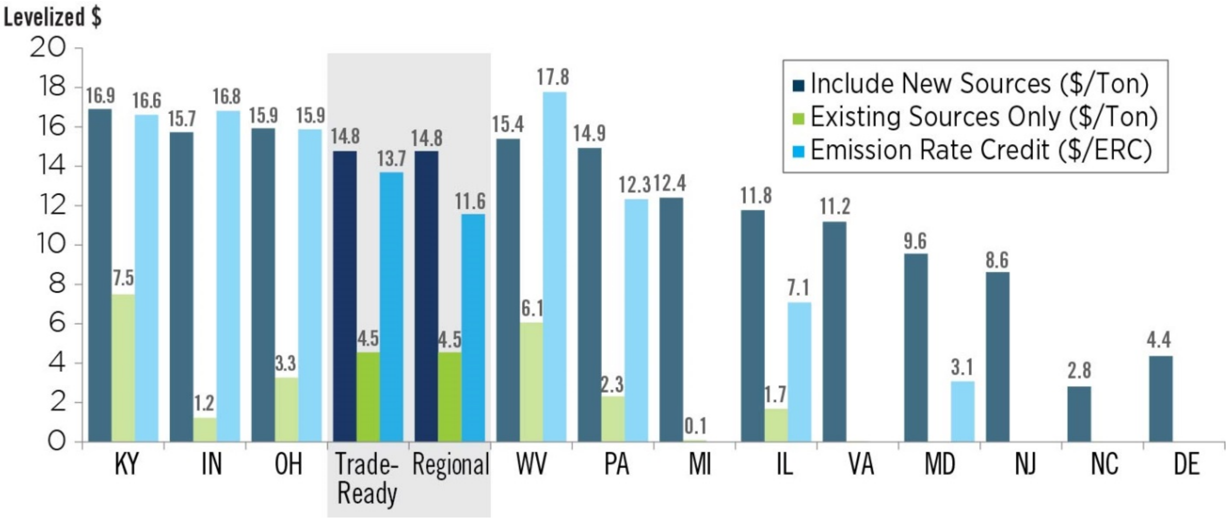
State versus Trade-Ready Compliance

The impact of state compliance on energy market prices depends on a range of factors, including whether states adopt a rate- or mass-based approach, but also time. In some years, as shown in Figure 7, for both mass and rate-based systems, state compliance may lead to higher prices. In other years, because of the resources either brought on-line or retired from the system, it can lead to lower energy market prices.

As shown in Figure 8, resources within the most coal-intense states (e.g. Kentucky and West Virginia) would face higher costs for allowances and/or emission rate credits under a state program than under a trade-ready program. Any time resources within those states set the energy market price, state compliance would result in higher energy market prices than would be set under regional compliance. However, when resources in less coal-intense states – in particular those in Virginia, Maryland, Delaware and New Jersey – are marginal, state compliance potentially would lead to lower energy market prices under either trade-ready rate- or trade-ready mass-based compliance, as these resources would reflect lower costs for CO_2 allowances or CO_2 emission rate credits in their energy market offers.

Compared to preliminary results conducted earlier in the year[33], the level of CO_2 prices is much lower in most states. This is a result of increasing the amount of generating capacity that can be economically selected to enter the model, as discussed in the key inputs section above. A greater level of economic resources that can be selected by the model expands the range of compliance options – since the model can increase the level of retirements without causing the cost of capacity and energy to rise.

Figure 8. Levelized CO_2 Prices in Mass-Based and Rate-Based Markets



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[33] These are levelized allowance and ERC prices. In some years, especially early in the compliance period or when there are a lot of retirements for some modeled compliance pathways, the emission targets are not binding and the prices of allowances or ERCs would be zero for that year

Rate versus Mass Compliance

Rate-based compliance leads to lower energy prices relative to mass-based compliance as described above in the section describing the various compliance pathways. Resources that perform better than the emissions rate target, including new zero-emitting renewables, are incentivized to run in order to earn revenue from ERCs. Renewable resource output is largely not sensitive to market prices because of their negligible operating costs. The emission rate credit provided to renewables will only impact market prices when prices are very low and the renewable resource is contributing to transmission congestion. The resources' willingness to respond to the congestion signal will be directly tied to the emissions reduction credit price.

For existing low-emitting thermal resources, such as combined cycle gas generation, to run more than the baseline level determined by their placement in the PJM generation economic dispatch stack, they must submit a lower energy offer into the energy market. The incremental production enables the generator to earn additional ERCs. If the generator would otherwise have been marginal in the energy market, the reduced offer price represents a reduction in revenue for all other economic resources.[34] The exact amount of revenue reduction is based on the difference in the offer price of the marginal resource and the next-most expensive resource to serve load.

Tax Credits, Renewables and Market Prices

Under either the mass-based with new source complement or the rate-based compliance pathway, most of the renewables enter the market before the start of the compliance period in 2022 – for the purpose of taking advantage of the federal tax credits[35] but as shown in Figure 7, the effect on market prices is not substantial even before the compliance period starts. Therefore, not only does the flatness of the supply curve mute price differences between state and regional compliance, but it also dampens the ability of renewables to cause steep decreases in wholesale market prices.

Emissions Market

The two Clean Power Plan emissions markets, mass-based allowance market and rate-based emission rate credit market, are separate and function differently from one another. In a mass-based framework, the state receives an allocation of allowances and can choose the method by which to allocate them; including, but not limited to, auctioning or a free distribution to resources. This allocation choice determines the beneficiaries of allowance market revenue.[36]

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[34] Lower energy market prices imply that all other resources must place a greater reliance on he capacity market to help cover going forward costs

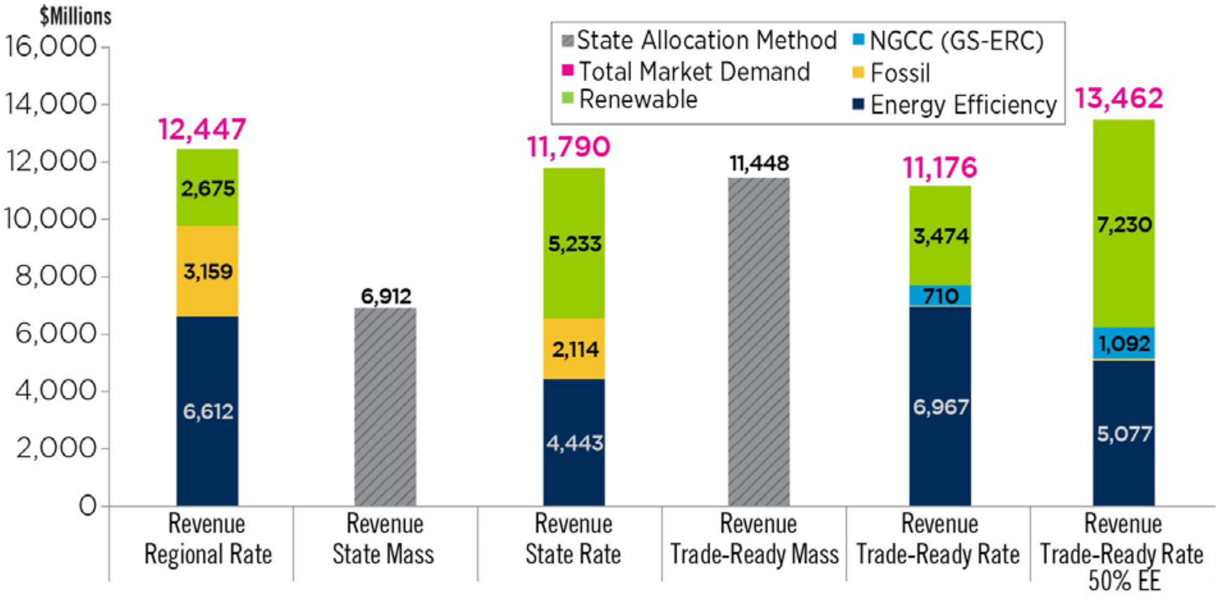
[35] *See* the *Database for State Incentives for Renewables & Efficiency* ("DSIRE") maintained by the North Carolina Clean Technology Center and their entry discussing the ITC and PTC available electronically at http://programs.dsireusa.org/system/program/detail/658 and http://programs.dsireusa.org/system/program/detail/734 respectively. The extension for the ITC and PTC was done under the *Consolidated Appropriations Act, 2016,* December 15, 2015 available https://www.gpo.gov/fdsys/pkg/BILLS-114hr2029enr/pdf/BILLS-114hr2029enr.pdf.

[36] State can determine allocation methodology even when resources within the state are subject to the Federal Plan.

PJM's modeling assumes that affected resources purchase allowances; as such, the allowance value is an annual expense incurred by the resource. As shown in Figure 9, the total revenue collected from the allowance market over the study period is equivalent to the total cost of allowances.

In contrast to an allowance market, the beneficiaries of ERC market revenues are EPA-qualified technologies that generate ERCs. Within PJM's model, affected resources that perform better than the applicable rate target, and zero-emitting (nuclear, energy efficiency, renewable) resources constructed and/or deployed after 2012, can generate ERCs and sell them to affected sources that require ERCs to meet the emissions rate targets. Similar to the allowance market, the total revenue collected (i.e. market size) is equivalent to the total cost of the ERCs.

Figure 9. Net Present Value of Emissions Market



Emission Rate Credit Revenue Impact on Renewable Resources

In a rate-based program, the revenue collected from the ERC market is an important factor to understanding the amount of new entry for renewable resources. The ERC revenue is a direct offset to the cost of bringing renewable resources on-line. PJM's model does not limit the location within the PJM footprint in which renewable ERCs are generated, thus higher total revenues indicate more entry. For example, in the trade-ready rate scenario in which energy efficiency is credited at 50 percent of the level deployed, more of the ERC revenue is directed to renewable resources, which results in greater renewable resource development as shown in Figure 14.

Renewables are unlikely to have operating costs near the marginal resource, and as such, will generally not directly set energy market prices. However, the out-of-market revenue collected in ERC markets can have an impact on energy market prices during high-congestion periods. Because the ERC revenue is tied to the resource's production, it decreases the resource's sensitivity to energy market price signals. As such, when there are two competing zero-emitting resources, electrically in the same location and affected by the same transmission constraints, but only one resource is qualified to earn ERCs, the one that receives the ERC revenue will be able to use it to offset the cost of congestion.

Emission Rate Credit Market Revenue Impact on Combined Cycle Resources

Natural gas combined cycles can earn two types of ERCs depending on whether they comply with the state/regional blended rate target or trade-ready rate targets. In either the state or regional blended program, natural gas combined cycles earn a share of the revenue collected by fossil resources that perform better than the rate target. Whereas in a trade-ready program, in addition to the regular ERCs, all existing natural gas combined cycles earn revenue from selling GS-ERC's to fossil resources.

Natural gas combined cycles at baseline output can produce ERCs. However, to be dispatched out of merit order (fuel and variable operation and maintenance cost), the resources must lower their energy bid based on a portion of the revenue expected to be collected from the sale of ERCs they generate[37]. If the resource would otherwise have been marginal in the PJM energy market, the reduction in the offer price can negatively affect other economic resources, including zero-emitting resources. All of the rate-based frameworks can potentially diminish the size of the PJM energy market by moving revenue out of it and into the ERC market in which there are fewer participating zero- and low-emitting resources.

State Rate versus Regional Rate

The key difference between state rate and regional rate is the result of PJM's assumption that energy efficiency only participates in the state ERC market in which the resource is physically located. Because most of the energy efficiency in PJM is being deployed in states that would have lower ERC prices than those prices resulting from trade-ready rate or regional rate compliance, the total revenue collected for energy efficiency is lower under state rate compliance than either trade-ready rate or regional rate compliance. Because the coal-dominant states cannot access the energy efficiency in other states, and are also isolated from natural gas ERCs in other states, they must buy ERCs created from renewables. Therefore, more of the revenue collected under state rate compliance is directed to renewables, which are not geographically limited.

PJM Capacity Market

The objective of the capacity market is to maximize what is known as market surplus which is analogous to minimizing the cost of procuring capacity to achieve resource adequacy targets.[38] The capacity market is co-

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[37] ERCs are generated when energy is produced.

[38] Graphically, the market surplus accruing to the load or demand-side of the capacity market is the area under the demand curve and to the left of the market clearing price for capacity. Graphically, the market surplus accruing to the suppliers of capacity is equal to the area above the supply/offer curve and to the left of the market clearing price. And the market clearing price is the price at which the quantity demanded of capacity is equal to the quantity supplied. *See* "Base Residual Auction Optimization Formulation" available at http://pjm.com/~/media/markets-ops/rpm/20071212-rpm-optimization-formulation.ashx.

optimized with the energy market[39] within the modeling framework and is done in the two-stage iterative process described below.

Modeling Demand Side of Capacity Market

The demand curve for capacity in PJM, known as the Variable Resource Requirement curve, is constructed based on the reliability requirement for the PJM region and the Net Cost of New Entry (Net CONE) for the Reference Resource which is a two-unit dual-fuel combustion turbine facility.[40] The RPM parameters for the 2019/2020 Base Residual auction were utilized for the CPP analysis and increased by an inflation rate of 2.25 percent per year in subsequent years.[41] Notably, the demand curve is characterized by three segments. Along each segment the prices and quantities can be linearly interpolated based on point A, B and C. Point A represents the unforced capacity quantity just below the reliability requirement (~ 99.8 percent) at a price equal to the greater of gross cone or 150 percent of Net CONE. Point B represents the quantity of unforced capacity that is approximately 2.5 percent above the reliability requirement at a price of 0.75 Net CONE. Point C is the highest quantity of capacity that can be procured through the auction and is approximately 7.6 percent above the reliability requirement at a price of zero. Forecast demand response subtracted from the forecast peak demand and energy efficiency reductions are directly included in the demand forecast and are by construction incorporated into the demand curve for capacity used in the model.

Modeling Supply Side of Capacity Market

On the supply-side of the capacity market PJM cannot predict the behavior of all market participants in response to market conditions. This includes making assumptions on how they may discount their costs, within their bids reflect their expectations regarding the future of energy and capacity market revenues, or on financial and operational risk mitigation strategies they may have in place. Instead, PJM's capacity market model for the CPP analysis took a more formulaic approach based on what exists in the PJM Tariff and basic economic principles of cost recovery for a generator to remain in commercial operation.

While the PJM tariff establishes default offer price ceilings, existing resources do not have a default offer price floor.[42] New resources by default have a minimum offer price, but its application can be waived if the resource provides evidence that it is not receiving any subsidies nor engaged in bilateral agreements that would adversely affect market competition.[43] Therefore, to reflect the basic notion that resources must cover their costs plus a rate of return on investment, in each simulation, PJM assumes that resources' offers reflect their annual net going forward costs[44]

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[39] In the long-term model, both the capacity and energy market is represented for the entire region.

[40] PJM Tariff, definition of Reference Resource.

[41] "Planning Parameters for the 2019/2020 Base Residual Auction", updated June 10, 2016. Available electronically at http://pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2019-2020-bra-planning-parameters.ashx.

[42] PJM Tariff, Attachment DD, Sections 6.7 and 6.8 outline the terms of market power mitigation and the calculation of the Market Seller Offer Cap, but there are no offer floors.

[43] Details of the Minimum Offer Price Rule ("MOPR") can be found in the PJM Tariff, Attachment DD, Section 5.14(h).

[44] In the PJM Tariff these are known as "avoidable costs" or costs that would not be incurred but for remaining in commercial operation. *See* PJM Tariff, Attachment DD, Section 6.8 for the categories and definition of avoidable costs.

observed over the study horizon.[45] To obtain the annual net going forward cost by resource, PJM ran an initial simulation in which all resources are modeled as price-takers. In this initial simulation, resource retirements were not permitted. However, new resources were allowed to enter the market to avoid conditions during the 20-year study horizon in which energy market prices are inflated because the model is short on reserve capacity. Given existing resources' going forward costs and any other investments (i.e. life-extension costs) are recoverable as specified in the PJM tariff, capacity market offers were calculated based on resources' going forward or avoidable cost (including hurdle rate of return) less net energy market revenues.[46] In the second simulation pass, these unit specific net going forward costs were used to determine the capacity market bid prices for participating generating resources.

Resource Adequacy Maintained under All Compliance Pathways

Any amount of capacity cleared more than that implied by point A satisfies the PJM reliability requirement. As shown in Figure 10, the amount of capacity procured stays in between point A and point B for the entire study duration in each of the compliance pathways evaluated. Therefore, resource adequacy is maintained in each of the scenarios.

As shown in Figure 10, the amount of committed capacity declines in 2020, and over time converges toward just meeting the reliability requirement denoted by Point A. The reason for the sharp drop in 2020 is because of resource retirements that occur in 2020. Moreover, because energy market prices are at their lowest levels during the first few years of the study period, coal and nuclear resources require greater revenue from the capacity market to cover their going forward costs in order to remain in commercial operation. As shown in Figure 15, most of the generator retirements occur in 2020. The initial set of retirements causes a spike in the capacity prices and a reduction in committed capacity. By 2020, resources currently advanced in the interconnection queue process enter the market to stabilize capacity prices, as shown in Figure 13, but the amount of capacity added is not sufficient to completely offset the retirements observed in 2020 as shown in Figure 10. Moreover, because the model optimizes both entry and exit over the 20 year study period, it is unlikely to attract significant amounts of new capacity without also retiring existing resources or without sufficient growth in the demand for capacity. Figure 10 illustrates a leveling off of committed capacity through 2025, before it increases again in 2026, as the model optimizes the timing of the new entry to meet incremental demand growth and replace additional retirements.

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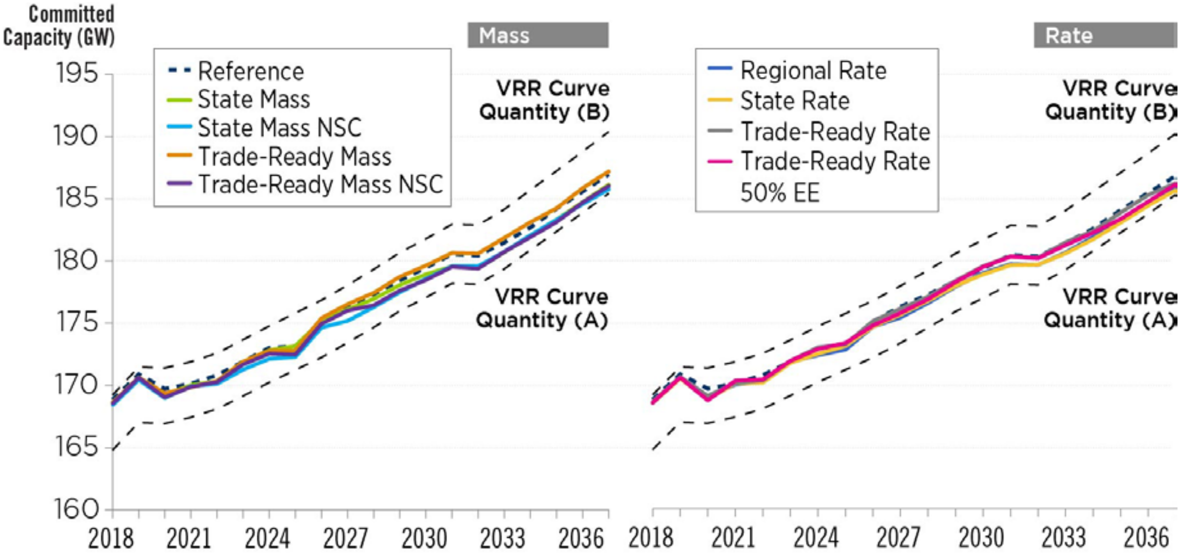
[45] Consistent with historic computation of market seller offer caps and the current practice above Net CONE * B.

[46] Because the model optimizes the energy and capacity markets jointly over the 20-year study period, a capacity market offer is calculated that is the same in real terms for each year over the 20-year horizon that allows generators to cover their net going forward costs.

Figure 10. PJM Region Committed Capacity



This naturally causes capacity market prices to remain between points A and B on the VRR curve. In the actual market, in which there is a diverse collection of resource owners, the timing of resource entry with resource exits is not likely to be as aligned. Larger price variations from year to year are more likely where the committed capacity oscillates between the segment of the curve between point A and B as well as B and C.

Cost of Maintaining Resource Adequacy by Compliance Pathway

Figure 11 illustrates the technology class average net going forward costs associated with nuclear resources.[47] Nuclear resources become more profitable over time, as shown by their declining net going forward costs in Figure 11. The capacity market prices shown in Figure 13 are well above the weighted average of nuclear resource's net going-forward cost beyond 2020.

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[47] In Figure 11 and Figure 12 the net going forward costs is only for resources that remain in commercial operation. It is not possible to calculate these costs once a unit is retired.

Figure 11. Weighted Average Net Going Forward Cost for Existing Nuclear

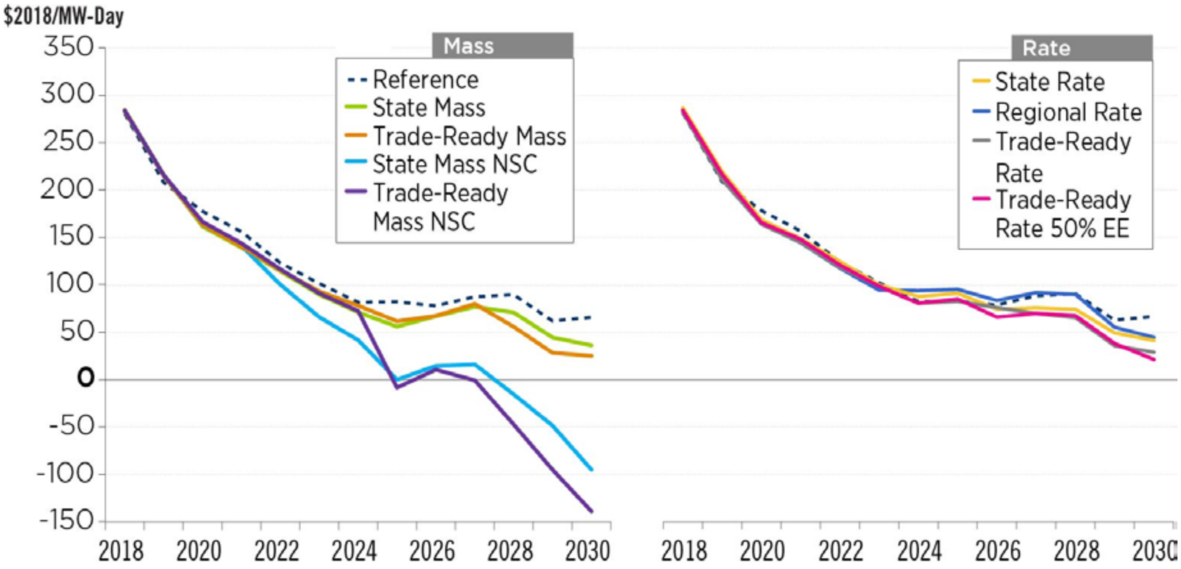
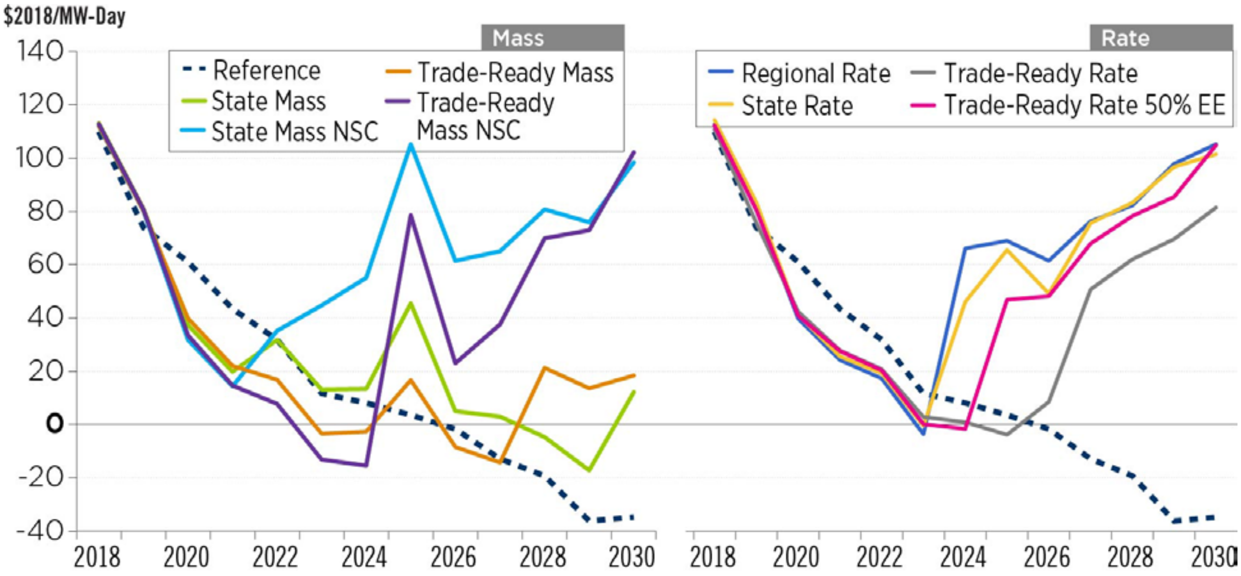


Figure 12 shows the net going forward costs of the coal resources remaining in commercial operation in the model and like the nuclear resources, the weighted average net going forward cost of coal resources that remain in commercial operation are also infra-marginal[48] in the capacity market. Unlike nuclear, the trend of increasing profitability for coal resources does not continue under the compliance pathways. Instead, new entry of more efficient natural gas combined cycles and higher cost associated with procuring emissions allowances or ERCs drives the net going forward cost upwards over time.

Figure 12. Weighted Average Net Going Forward Cost for Steam Turbine Coal



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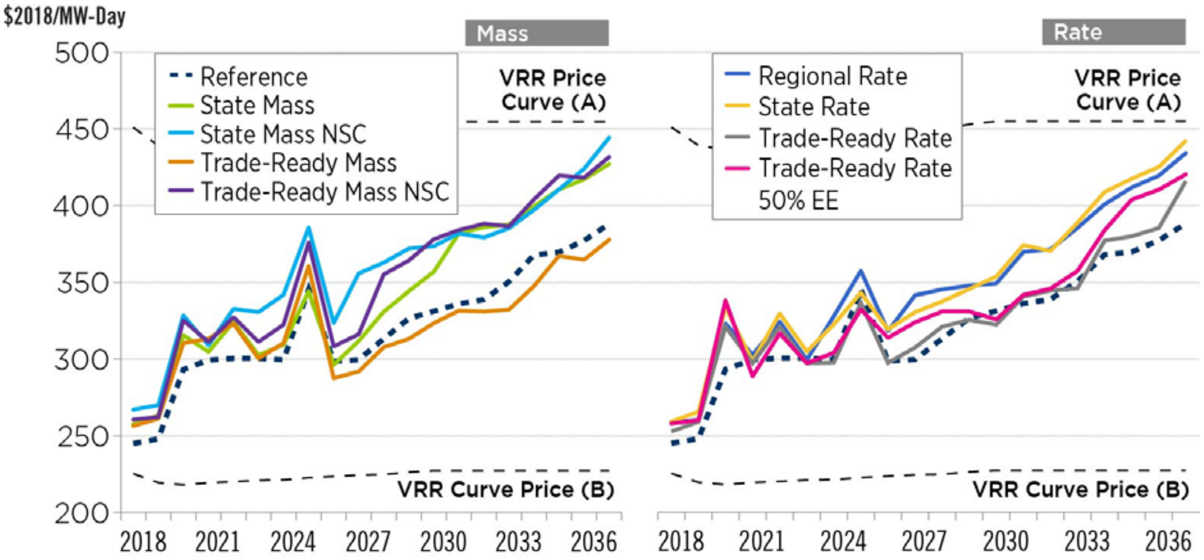
[48] Infra-marginal means the cost of the resource is below the market clearing price or marginal unit's cost.

Overall, the marginal resources in the capacity market are often the new entry combined cycle gas resources that continue to enter over time as demand grows and incremental retirements take place throughout the 20-year study period for each of the compliance pathways. The amount of committed unforced capacity in each year is nearly equal to the capacity that was in service in the previous year comprised of existing resources, less resource retirements, plus new entry resources for the current capacity market auction year. The model will only choose to bring in new resources and retire existing resources when doing so minimizes cost overall and maximizes surplus in the capacity market. Over-time, the opportunities to bring on-line new economic resources based on the current PJM interconnection queue become more limited as shown in Figure 10.[49] The implications for price formation are shown in Figure 13. As the amount of committed capacity gets closer to the installed reserve margin target, or Point A on the demand curve for capacity, the price of capacity also converges towards 1.5 Net CONE.

Figure 13. PJM Capacity Market Prices ($/MW-day)



Choice of Compliance and Capacity Market Prices

The amount of capacity available to be committed is not the only driver of rising capacity prices, however. The choice of compliance pathway, regional versus individual state compliance as well as mass- versus rate-based compliance also plays a role.

Compliance Scenarios versus Reference

In general, the driver for higher capacity prices observed in the compliance pathways is the additional cost of acquiring ERCs and allowances for steam turbine coal resources. While Figure 12 illustrates that coal resources that continue to operate are infra-marginal on average, the compliance driver forces more retirements than the reference model and consequently more and more expensive new capacity to come on-line which keeps capacity prices going

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[49] Given the steepness of the demand curve for capacity between Point A and Point B, small changes in the quantity of committed capacity can result in large changes in prices as seen between 2024 and 2025, and again from 2025 to 2026. In some years, it is possible that bringing in an additional resource would increases costs and reduces surplus. As a result, the model does not commit additional new resources, and effectively the supply curve is a vertical line up to the demand curve where the price is set.

up. The only scenario that does not show a long-term trend of capacity prices increasing above the reference model is the trade-ready mass scenario. Because this compliance pathway does not regulate new sources, energy market prices rise in response to affected sources bidding their allowance cost, but the net cost of new entry does not include the cost of emissions allowances.

State versus Regional or Trade-Ready Compliance

In Figure 13, the difference between trade-ready mass-based and state mass-based compliance capacity prices is substantial from 2026 onward after tracking closely together through 2025. On a mass basis, state-only compliance leads to higher allowance prices and thus lower net energy revenues for resources in states where the state CO_2 price is higher than the trade-ready price. As a greater amount of coal resources retire under state mass-based compliance more expensive new combined cycle resources are needed to achieve resource adequacy.[50]

Trade-ready rate is not directly comparable to either regional rate- or state rate-based compliance because coal resources comply with a different rate target. Lower demand for ERCs delays when retirements occur under trade-ready rate and ultimately drives fewer retirements than either state rate- or regional rate-based compliance. A lower level of retirements avoids the need for more expensive new resources to enter the market, and enables the market to maintain lower capacity prices than other rate-based compliance pathways.

Because zero-emitting ERCs can be traded across state lines under state rate-based compliance, prices for ERCs can converge in some states. ERC price convergence mitigates differences in the capacity market offers for these resources and the level of retirements when comparing state rate-based and regional rate-based compliance.

Generation Retirements and New Entrants

As shown in Figure 14, the combination of natural gas combined-cycle, solar, and wind resource additions more than offset resource retirements – primarily coal resources. In addition to replacing retired capacity, the amount of new capacity added also must support peak load growth over the 20-year analysis to ensure resource adequacy.

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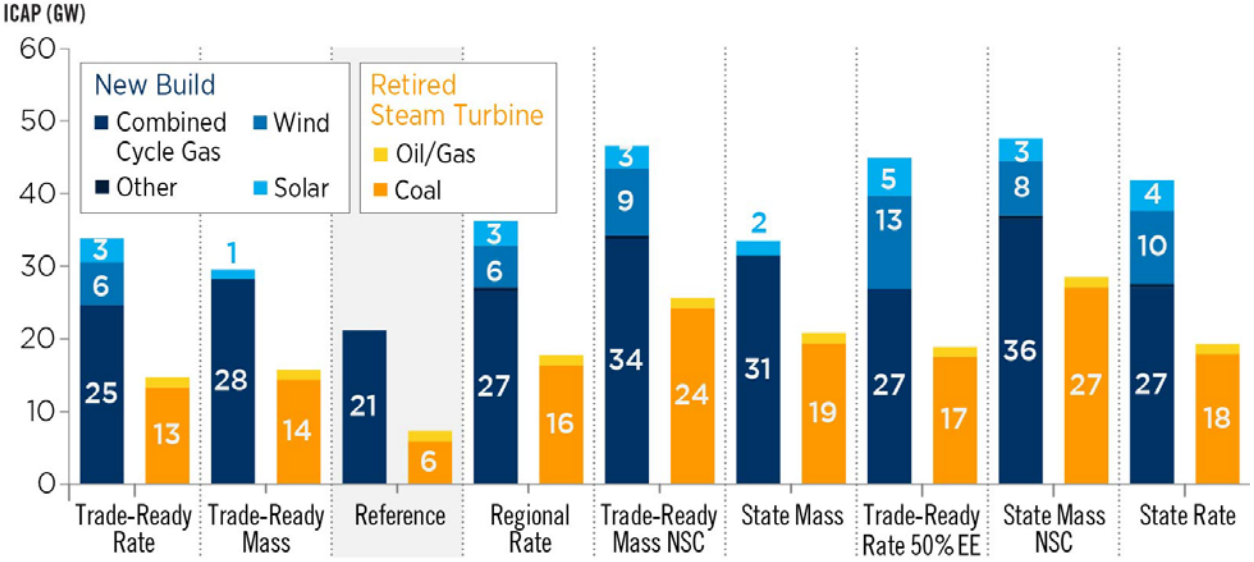
[50] In coal heavy states the Net CONE for combined cycle resources is higher than it is for those states closer to the Marcellus Shale production area. *See* “Final MOPR Offer Prices for the 2019/2020 Base Residual Auction”, January 7, 2016. Available electronically at http://pjm.com/~/media/markets-ops/rpm/rpm-auction-info/final-mopr-floor-offer-prices-for-2019-2020.ashx. This data file shows the CONE and Net CONE values for CONE areas 3 (coal heavy states) and 4 (WMAAC where the gas production areas are located).

Figure 14. Nameplate Capacity (ICAP) Built and Retired in the PJM Region



Economic Incentives for Low- and Zero-Emitting Generation

Renewable Resources

Under all forms of rate-based compliance, renewable resources and energy-efficiency receive one emission rate credit for every megawatt-hour of production regardless of the level of CO_2 emitted from the resources they displace[51]. ERCs provide an additional direct cash flow to these resources. The additional cash payments available under rate-based compliance options supplement the revenues received from the energy and capacity markets. This increases the attractiveness of these resources for compliance relative to resources that aren't eligible to receive ERC's such as new combined cycle gas resources. As can be seen from Figure 14, the rate-based compliance pathways drive much larger amounts of new entry relative to the mass-based compliance options absent regulating the emission from new sources. Reducing the ability of energy efficiency embedded in the load forecast to create ERCs, pushes up ERC prices even more and leads to even more renewable resource entry.

Under mass-based compliance, this same incentive does not exist since there is no direct out-of-energy market payment. Additional revenue comes from increases in energy market prices, which simply are not as great as the direct cash payment from ERCs under rate-based compliance. For example, over the compliance period, the levelized energy price in the trade-ready mass case is only $1.7/MWh greater than the reference case energy price, but over the same period, the trade-ready rate ERC price is nearly $14/MWh a shown in Figure 7, which provides a clear economic advantage for ERC qualifying resources.

If new natural gas combined cycle units are also regulated, both energy and capacity prices will provide a signal for new investment as well as retaining existing zero-emitting resources. As shown in Figure 14, the new source

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[51] With respect to modeling, energy efficiency is embedded in the load forecast and is taken as given. PJM has assumed that all energy efficiency would receive ERCs in all but one compliance pathway sensitivity where it is assumed only 50 percent of the energy efficiency would receive ERCs.

complement – whether implemented at a state level or in a trade-ready framework – drives similar levels of renewable development as do the rate-based compliance options. The key difference is that the energy market price[52], which over the compliance period is $6.9/MWh (state mass NSC) and $8/MWh (trade-ready mass NSC) higher than the reference model, provides the signal to enter the market as opposed to an out-of-market payment.

Natural Gas Combined Cycles

While new natural gas combined cycle resources are not qualified to earn ERCs, each scenario results in significant levels of new combined cycle resources. Combined cycles are needed to maintain resource adequacy. Their capacity value[53] compared to new renewable resources means that it is lower cost to continue to develop combined cycles both to satisfy load growth and to compensate for reductions in the level of operating steam turbine-driven resources, and help in achieving mass-based emissions targets.

Under rate-based compliance combined cycle resources do not benefit from higher energy market prices as shown in Figure 7, or receive ERCs and thus levels of new entry are lower as shown in Figure 14. While energy price increases under mass-based compliance are modest, it provides more net energy market revenues than rate-based compliance.

Because the new source complement further diminishes the net energy market profit of the steam turbine coal resources as shown in Figure 12, this form of compliance increases the level of retirements. Despite facing higher cost of entry, more combined cycle resources enter the market as market prices trend upward and to replace more expensive coal resources.

Nuclear

New nuclear generation was not economically viable in any of the scenarios PJM evaluated. However, existing nuclear as a zero-emitting resource still plays a role in states' ability to achieve compliance. Nuclear resources have relatively low operating costs in the energy market but large going forward cost. Nuclear resources face no direct regulatory risk associated with the CPP, but will prefer more stringent compliance paths that lead to higher energy and capacity market prices. As shown in Figure 11, the new source complement, which increases market prices the most of the compliance pathways, also provides the most revenue support for nuclear resources directly from the PJM energy and capacity market.

Timing of Resource Retirements

Future market conditions represented within the model make it more likely that resources retire earlier in the study horizon. Market prices are at their lowest point early in the study horizon. As time progresses, new resources also come on-line including significant deployments of energy efficiency and distributed solar[54]. The model is able to solve

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[52] Levelized difference in PJM market prices observed between 2022 and 2037.

[53] Combined Cycle gas resources have an Equivalent Demand Forced Outage Rate (EFORD) of nearly 5 percent resulting in 95 percent of their available capacity counting towards capacity value, whereas solar has 38 percent and wind resources 13 percent.

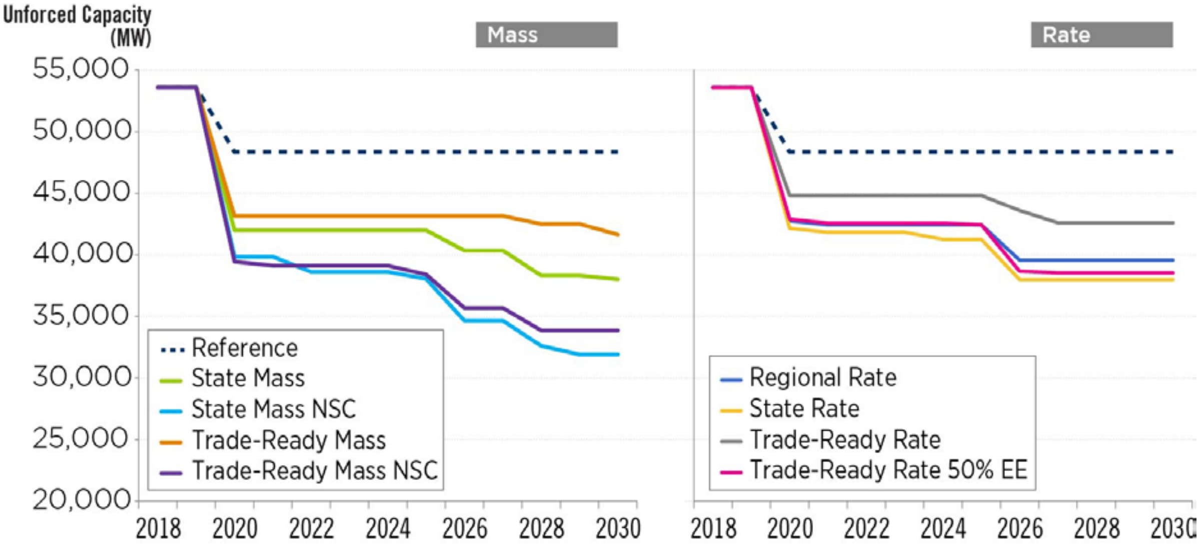
[54] Both Distributed Solar and Energy efficiency are already embedded in the load forecast. PJM does not deploy any additional energy from these resources based on CPP compliance.

in a single step and thus retires resources based upon the opportunity to avoid cost in future years. Cost incurred in the near term, however, have a more significant impact due to discounting effects.

All of the above suggests that resources that are uneconomic when compared to alternatives are likely to retire early in the study horizon. When the CPP is enforced, additional retirements occur later in the study horizon due to decreasing CO_2 targets and higher costs imposed on coal resources, as shown in Figure 15.

Given capacity commitments have already been established for both the 2018/2019 and 2019/2020 delivery year, the model only retires uneconomic resources after 2020. As shown in Figure 15, absent CPP compliance, all retirements would occur in the first year, as the financial outlook for remaining coal units improves over time. On average, the coal resources that continue operating are likely to recover all of their production and going forward costs within the energy market by 2026. CPP enforcement instead drives up the revenue requirements for coal resources relatively early in the compliance period and leads to additional retirements as either the rate- or mass-based targets continue to decline as shown in Figure 15.

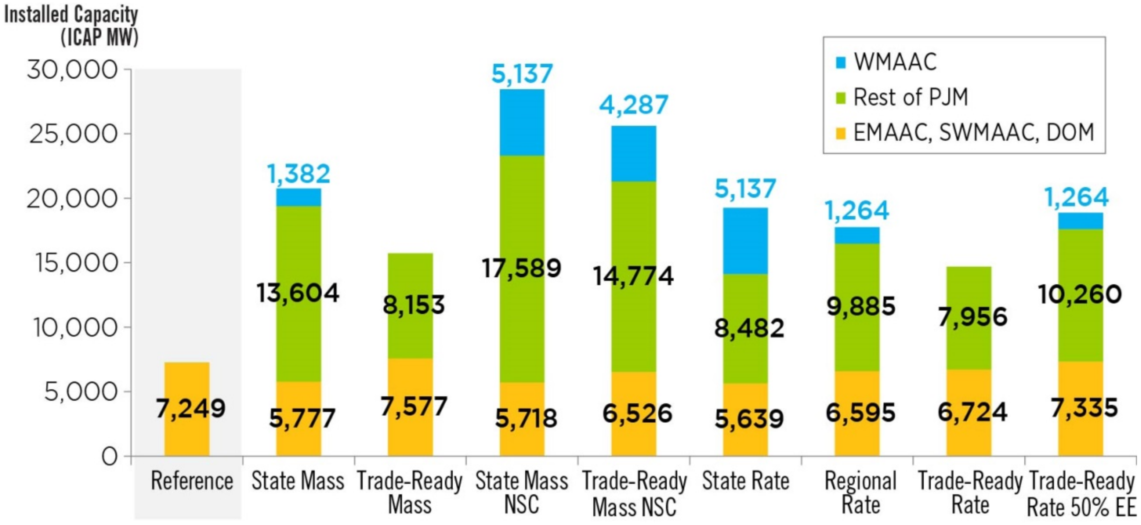
Figure 15. Steam Turbine Coal Unforced Capacity by Year



Differences in Coal Retirements for Intra-State versus Trade-Ready Compliance

For states relatively less constrained on emissions, intrastate compliance reduces the costs associated with acquisition of allowances or emission rate credits for generators in those states. Conversely, in states that are more emissions constrained, costs associated with acquisition of allowances or emission rate credits increases for generators in those states. As shown in Figure 16, trade-ready compliance versus intrastate compliance leads not only to fewer retirements, but also a different geographic distribution of resource retirements.

Figure 16. PJM Coal Unit Retirements (2018 – 2037)



The distribution changes because trade-ready compliance levels the playing field by imposing the same CO_2 price on all resources in the footprint. Consequently, emissions reductions come from the highest-cost resources and generally the least-efficient and/or highest-emitting resources in PJM. In contrast, states with relatively more stringent CO_2 reduction responsibility that adopt state compliance risk imposing higher costs on potentially lower-cost in-state resources, and elevate the likelihood of retirement for those resources while higher cost[55] resources may remain in commercial operation.

The benefit of lower cost of allowances shown in Figure 8 under state compliance for resources in the EMAAC, SWMAAC and DOM[56] PJM sub-regions are clear as there are fewer retirements under individual state compliance pathways – and, even fewer than in the reference model. These resources face the highest retirement risk in the reference model. However, because state compliance reduces the relative cost difference between these resources and those in western PJM, it also reduces their retirement risk.

In contrast, retirements in the rest of PJM, which includes coal-heavy states such as Kentucky, West Virginia, Ohio, Indiana, and Illinois, are lower under trade-ready mass-based compliance pathways where they face the same emission cost as all other coal units, compared to higher allowance prices under individual state mass-based compliance as shown in Figure 8.

Because state compliance increases future costs associated with acquisition of allowances or emission rate credits, particularly in western PJM, the model is able to avoid this cost by replacing the capacity with new natural gas combined cycle resources. When the available economic entrants were limited to only resources advance in the queue process, as was the case in preliminary modeling performed, there were fewer opportunities to replace

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[55] Cost refer to going-forward cost and production cost

[56] EMAAC includes New Jersey, Delaware and the Southeast corner of Pennsylvania. DOM represents the Dominion zone in Virginia and parts of North Carolina. WMAAC represents the rest of Pennsylvania excluding the portion served by APS. SWMAAC includes Maryland and DC. Rest of PJM includes the remaining transmission zones in PJM states.

capacity in order to reduce compliance cost. Instead, trade-ready compliance, which drives higher levels of retirements for higher-cost coal resources in eastern PJM, set the tone for the overall level of retirements.

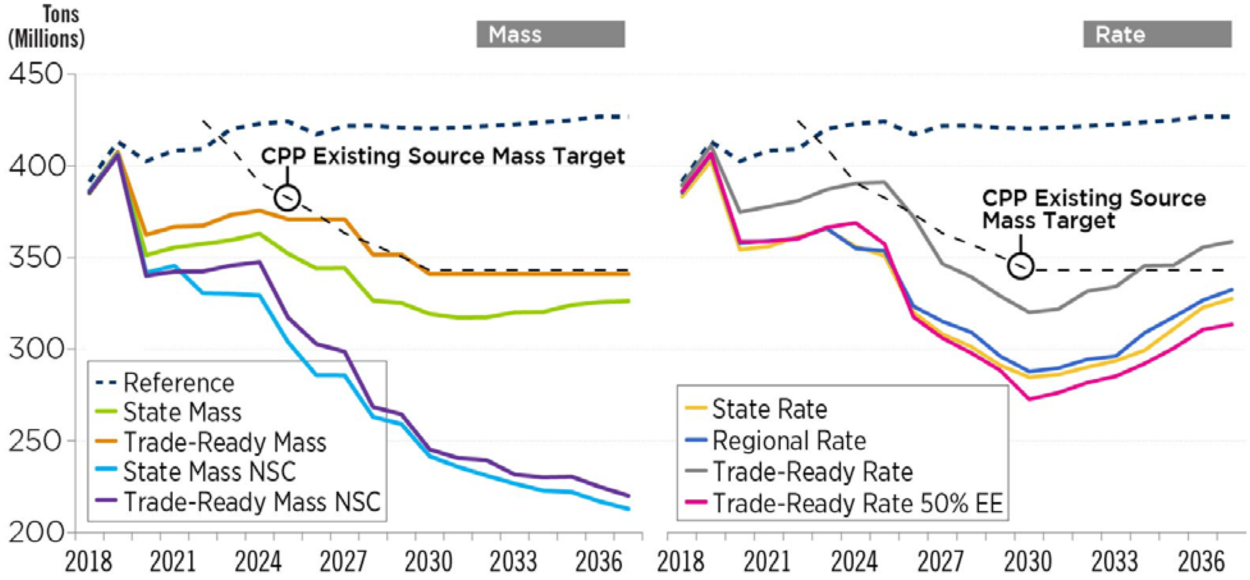
Generator Emissions Compliance

The model enforces environmental compliance using a hard constraint on total tons of emission from affected sources in the case of mass-based compliance, and on emission rates for affected sources for rate-based compliance. This means that the compliance condition that CO_2 emissions remain below the mass-based target (i.e. number of allowances available) or that the supply of emission rate credits match or exceed the demand for emission rate credits is always enforced. In all of the scenarios, enforcement of these constraints were feasible given the set of inputs to the model on load growth and available generation to both support load growth and to provide adequate emission reduction opportunities.

Figure 17 shows emissions from existing sources under both the mass-based and rate-based compliance scenarios. The results show a significant contrast between emissions reductions under trade-ready mass versus state mass compliance. As highlighted above, more economic new build options increases the compliance cost reduction opportunities. In each of the compliance scenarios there is a significant drop in emissions by 2020 associated with resource retirements. Without economic replacement options, it is necessary to carry forward higher-emitting coal resources to ensure resource adequacy.

State compliance led to more retirements compared to regional or trade-ready compliance and thus lower emission levels from existing sources in either a rate- or mass-based compliance framework. In preliminary results, because retirements did not occur as quickly, as emission rate credits became more widely available in the 2030s, eventually existing source emissions under regional and state rate compliance rebounded above the CPP mass-based target. Due to a higher level of retirements at the start of the compliance period, the transition in which existing source emissions under all forms of rate-based compliance exceed the mass-based targets will occur beyond the initial 20-year study horizon.

Figure 17. PJM CO_2 Emissions from Existing Sources



When only evaluating existing sources, the new source complement leads to a significantly lower emissions than any of the rate-based pathways evaluated in this analysis as seen in Figure 17.

Adoption of the new source complement by states pursing a mass-based compliance framework would make the state plan presumptively approvable by the EPA[57]. The Clean Air Act section 111(d) regulation by default only regulates emissions from existing sources and was originally designed as a rate-based program. From the results shown in Figure 18, it is clear that the new source complement would make emissions from all sources comparable to or lower than the emissions levels observed in the regional and state rate-based compliance pathways, and far below the emissions observed in the trade-ready rate compliance pathway. However, as emission rate credits continue to increase beyond 2030 – but the rate-based targets remain constant – the new source complement again leads to far lower emissions in total than other compliance pathways.

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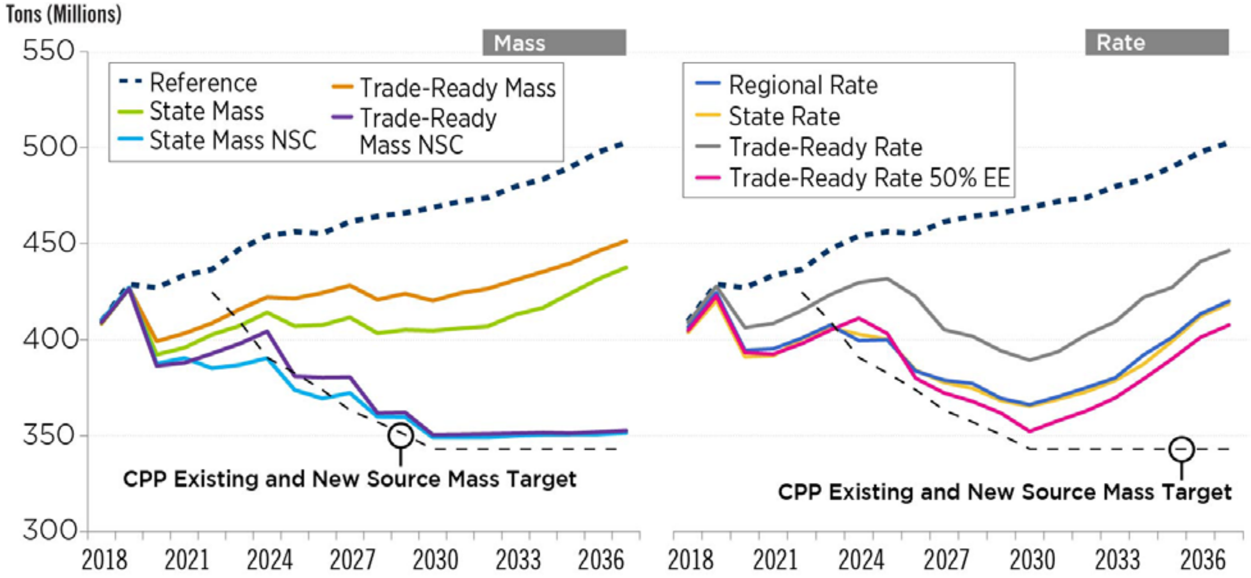
[57] The new source complement would address the EPA's description of leakage as alluded to in the description of the various compliance pathways.

Figure 18. PJM CO_2 Emissions from All Sources



Trade-Ready Rate Compliance versus Regional Rate- and Mass-Based Compliance

As states consider options to make the trade-ready mass-based program equivalent to rate-based programs, it is worth noting that the rate-based programs themselves lead to different CO_2 reduction outcomes as shown above in Figure 18. The primary reason that trade-ready rate compliance leads to fewer emission reductions than regional rate compliance is structural, due to the CPP’s design. Trade-ready rate compliance establishes separate national targets for steam turbine resources and combined cycle resources. In contrast, the mass-based targets for the PJM region are derived from the state and or regional rate targets, respectively.

The prevalence of natural gas combined cycle generation in PJM has the impact of pulling down the rate target, making it more stringent. A lower rate target means higher demand for emission rate credits. Using the results of the reference model, this is illustrated in Figure 19. Higher demand for emission rate credits means lower allowed mass-based emissions until additional deployment of zero-emitting resources occurs. Since the mass-based targets are derived from the regional rate target[58], it is also more stringent in the long-run than the trade-ready rate compliance program for existing sources as shown in Figure 19.

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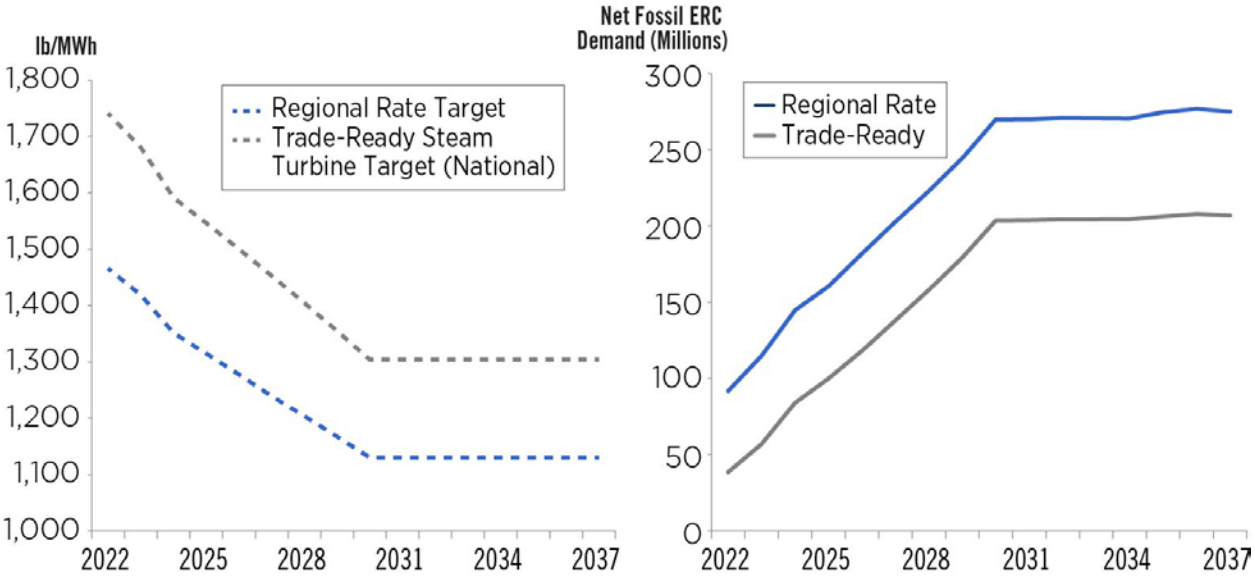
[58] Mass-based targets include an adjustment for renewable resources expected to be developed nationwide.

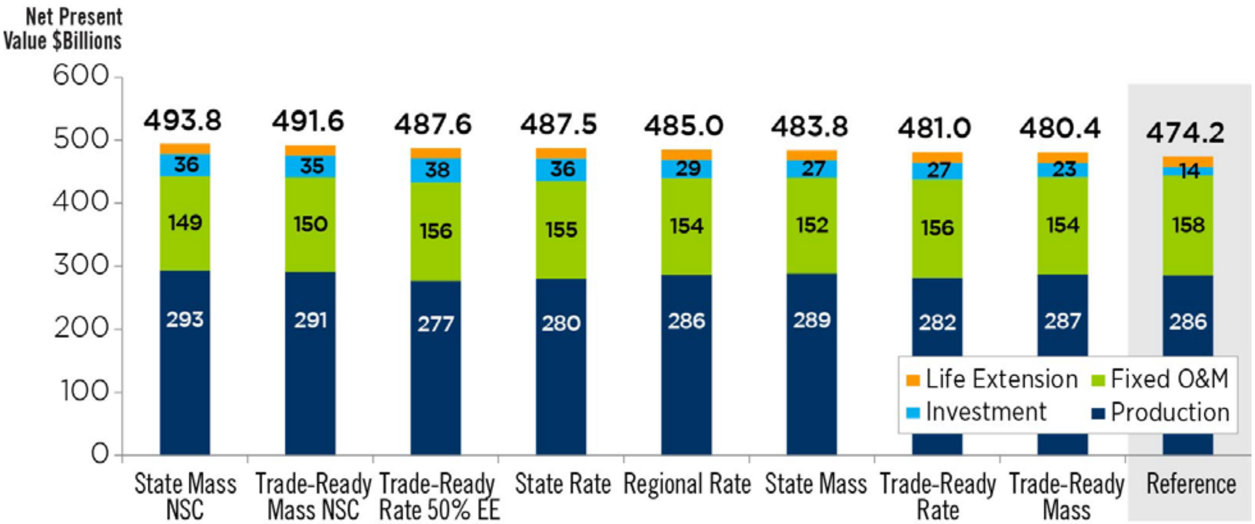
Figure 19. CO_2 Emission Rate-Targets and ERC Demand



Generator Compliance Cost Impacts

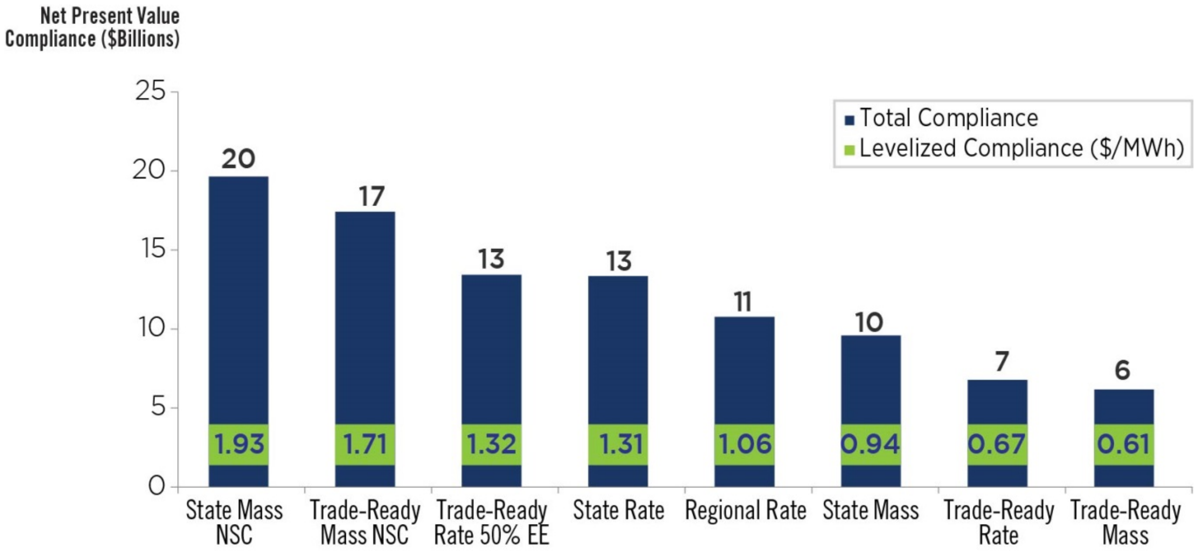
The compliance pathways each provide different economic incentives for existing and new generators that ultimately lead to different mixes of generating capacity fuel types, and aggregate emissions levels. Consequently, the components of generator costs attributable to economically satisfying both resource adequacy requirements and for environmental compliance will vary by compliance pathway. These costs, which include investment costs, fixed operations and maintenance, and production costs (fuel and variable operations and maintenance costs) all vary by compliance pathway. The investment costs represent the annual costs to service debt and pay equity holders as a result of new investments in generation. Whereas, the fixed operations and maintenance cost represents the going forward costs that must be incurred for generators to remain in commercial operation. In the final PJM modeling presented here, PJM incorporated life extension costs by unit in the base model. These are also investment cost but PJM felt it was important to break them out in the reporting. The choice of compliance pathway represents a trade-off between these cost components as shown in Figure 20.

Figure 20. Generation Investment, Fixed O&M and Production Cost (2018-2037)



PJM does not directly pass any of the costs shown in Figure 20 to its members. Instead, PJM’s energy and capacity markets reflect the decisions that states make through choice of compliance pathway and generators make in response to the regulation and compliance pathways chosen by each state. Compliance costs are calculated based on the difference between the generation costs associated with a compliance pathway and the generator costs in the reference scenario in which there is no CPP compliance obligation. For states, especially regulated states where these cost components can be passed to consumers through retail rates, the compliance costs provide an important data-point for comparing the compliance pathways. Compliance costs are shown below in Figure 21.

Figure 21. Net Present Value CPP Compliance Costs



Excluding 2014, the average total PJM wholesale cost between 2012 and 2015 was $57.85/MWh in $2018. The trade-ready mass-based compliance pathway represents the low end of compliance cost at 61¢/MWh[59], and is approximately 1.1 percent of total wholesale costs. State mass-based compliance in which new sources are regulated in addition to existing sources represents the high end of compliance costs at $1.93/MWh, which is 3.3 percent of average total wholesale market cost.

Regional versus State Compliance

Under either rate- or mass-based compliance, adoption of a regional or trade-ready compliance mechanism in which allowances and emission rate credits can be freely traded will result in the lowest overall compliance costs for the region. Trade-ready mass-based compliance results in an increase in the cost of generation of 61¢/MWh compared to 94¢/MWh under state mass-based compliance. Likewise regional rate-based compliance is 25¢/MWh cheaper than state rate-based compliance.

Under regional compliance, the least-efficient and most-costly generators in the footprint are likely to retire first. Under state compliance, however, these same generators – located in states that require lower CO_2 prices than the trade-ready price to achieve state-only compliance – continue operating. This is evident in Figure 16, whereby, coal retirements shift between the LDA regions as a function of state versus regional compliance. Regional compliance provides the largest set of options for compliance, and any in-state restriction is bound to lead to fewer cost-reduction opportunities across the PJM market region, which can come from retirements and or new entry.

Hybrid Retirement and New Entry Model

The standard 20-year analysis assumes that all resources have a "long view" on the market. In addition to discounting future costs and revenues, resources are not as sensitive to short-term conditions in which the resource may have a revenue shortfall or be highly profitable. The capacity market offers are instead based on the annualized net going forward cost observed over 20 years, 2018 through 2037. The model also evaluates retirement and new entry over the full 20 years. This sensitivity is intended to provide another view in which existing resource owners apply much greater weight on near term assumptions for fuels, market prices, etc. This view is used to determine an initial set of retirements that can then be assessed in the standard 20-year evaluation.

Five-Year Outlook

Total energy market revenues are the lowest in the first five years due to lower load, the addition of queue resources with a high likelihood of achieving commercial operation, and natural gas prices being their lowest at the start of the study horizon. The assumption that resources need to recover all costs incurred over this period means that resources must submit higher offer prices into the capacity market. A five-year view is much more likely to result in resource retirements, as the model is more likely to be long on capacity given the initial generator conditions, limited recently announced deactivation notices, and natural gas combined cycles are most competitive over this time

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[59] Compliance costs are calculated on a levelized basis over the entire term of the study horizon. Total generator costs and load (MWh) are discounted based on an 8 percent hurdle rate.

period. The results in the final year of the analysis are carried forward into perpetuity, reflecting the resource owners' position that near-term conditions will persist into the future.

Hybrid Outlook (Five-Year Retirements / 20-year Entry and Exit)

The five-year model does not contain any information about CPP compliance. However, it is used to provide a seed for the CPP evaluation between 2018 and 2037. In the hybrid model, the CPP and expected future market conditions (such as load growth, fuel prices, distributed energy resources) will determine whether there are additional retirements. However, resources that were retired in the five-year model cannot return to the market.

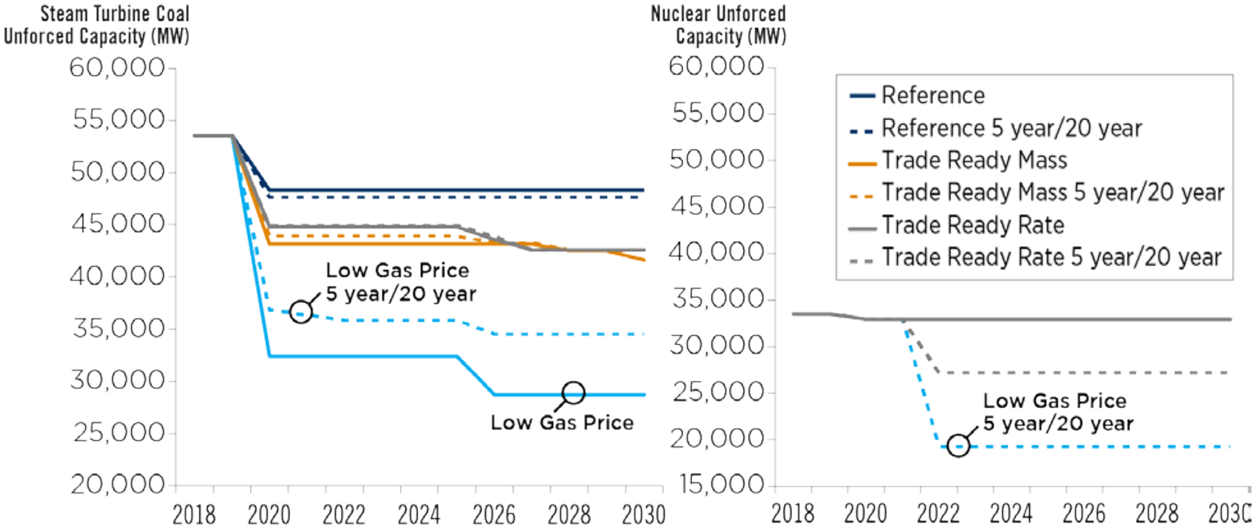
Impacts of Longer-Term Outlook on Resource Entry and Exit

As shown in Figure 22, CPP compliance results in additional retirements for both the hybrid model and the standard 20-year evaluation of trade-ready mass-based and trade-ready rate-based compliance. By the end of the evaluation period, the amount of coal retirements under trade-ready rate-based and trade-ready mass-based compliance are roughly equal in the hybrid model versus the 20-year analysis in which all resources adopt a long-term outlook.

For steam turbine coal resources, the benefits of remaining in the market place are not significantly impacted by either the short-term or long-term study horizon. By 2037, the difference in retirements is only 315 MW and between 2018 and 2037, the difference in retired MW does not exceed 670 MW.

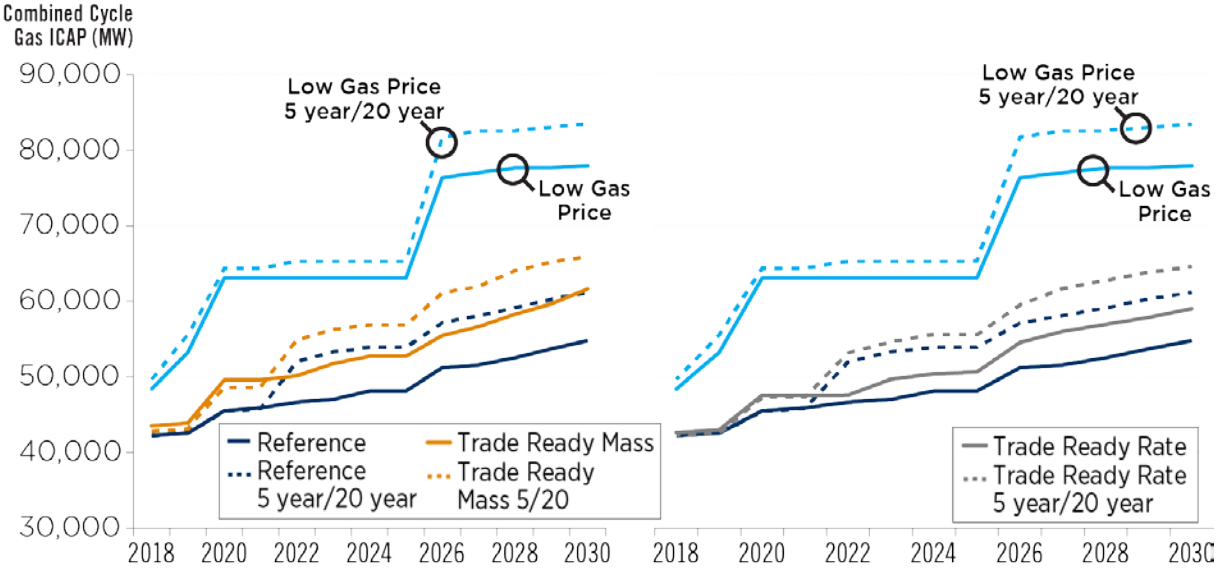
On the nuclear side, resource owners' adoption of a 20-year outlook and being able to weather short-term unfavorable market conditions pays off for the market. In the standard 20-year model, there are no nuclear retirements in the reference or compliance cases, whereas the hybrid model results in nearly 6 GW of nuclear retirements under the reference gas assumption, not including Oyster Creek. The low gas price sensitivity results in just over 14 GW of additional retirements that do not occur in the 20-year model as resource owners adopt a short-term outlook. Adoption of a short-term outlook appears to result in earlier retirement of nuclear resources than would otherwise be cost-effective for serving load and achieving resource adequacy when taking a longer-term view.

Figure 22. Steam Turbine Coal and Nuclear Installed Capacity



On the new entry side, natural gas combined cycle resources are attracted to the market in response to both higher loads and resource retirements. Adoption of a short-term outlook results in a higher level of investment in new natural gas combined cycles than would otherwise be economic (as shown in Figure 23). Exit and entry driven by more weight being placed on the first five years of the study window is likely to increase cost incurred over the full study horizon.

Figure 23. Natural Gas Combined Cycle New Entry

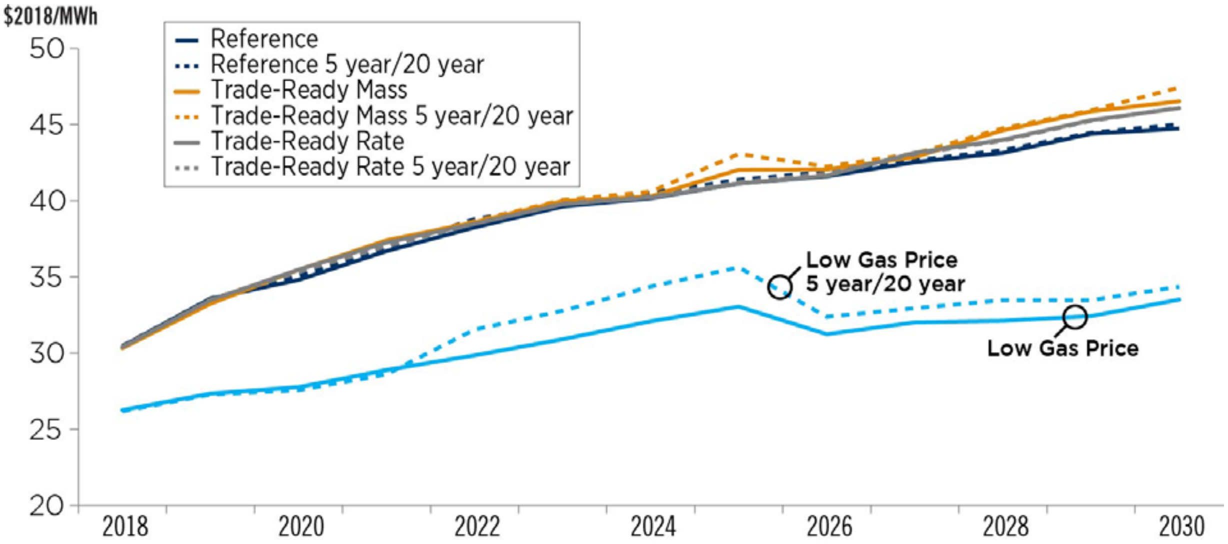


Impacts of Longer Term Outlook on Market Prices

The PJM energy market results, shown in Figure 24, do not show significant differences between the scenarios. With the nearly 6 GW of nuclear retirements that result from the hybrid model, load costs observed over the 20-year analysis, are only 0.5 percent higher in the reference model, 1.1 percent higher under trade-ready mass-based compliance and 0.1 percent higher under trade-ready rate-based compliance. Under the "Low Gas Price" sensitivity, in which there are 14 GW of nuclear retirements, the difference is more significant, at 3.8 percent.

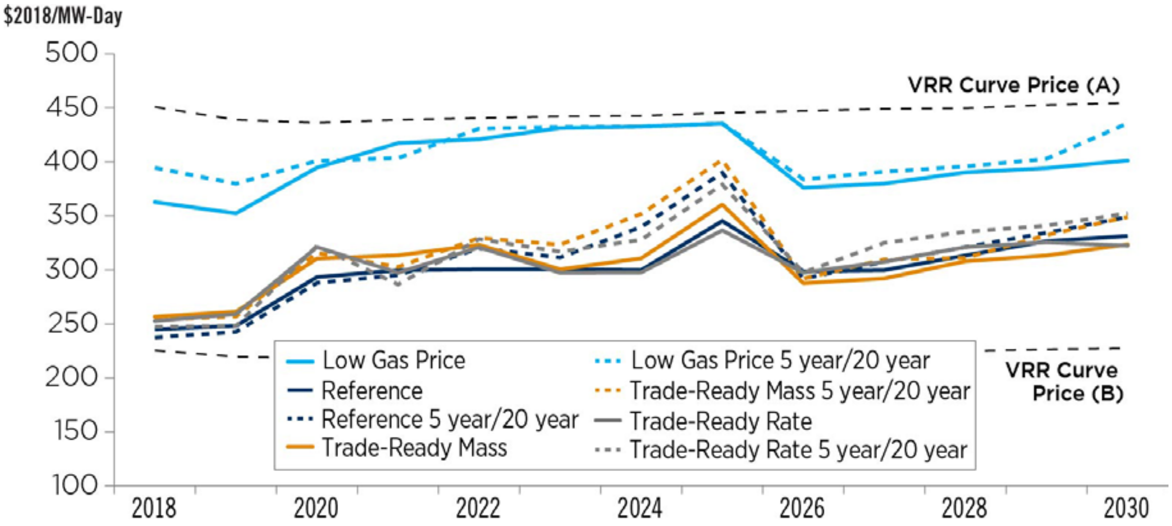
Despite nuclear retirements, more significant increases in energy cost do not occur because nuclear resources, like renewable resources, participate as price takers in the energy market and displace resources that are more expensive. Most of the new entrants in the model are natural gas combined cycle generators, all of which have similar operating characteristics and fuel costs throughout most months in the year, resulting in a flatter supply curve as discussed in the PJM Market Price section of the paper. The increase in energy market cost due to a short-term market outlook ranges from 0.5 percent in the reference model to 1.1 percent under trade-ready mass-based compliance over the 20-year study horizon. Under the "Low Gas Price" sensitivity, the impact is more significant at a 3.8 percent higher cost.

Figure 24. PJM Energy Market Prices



In the capacity market, adopting a short-term outlook will result in higher capacity market prices as shown in Figure 25. The increase is more pronounced in the model prior to 2026 as this is the period in which the impacts of retirements and new combined cycle entry are most impactful. However, once resources currently at the feasibility study stage are available to enter in 2026, the trajectory of capacity prices under the reference gas assumptions is slightly lower than the trend through 2026. It is still generally above the capacity market price paths observed with the longer term outlook, however. The hybrid model results in a steeper jump in capacity prices in both 2022 and 2025, because of nuclear retirements. Over 20 years, adoption of a longer-term outlook results in a 4 percent lower capacity market cost in both the reference and trade-ready rate-based compliance models, and 3.8 percent lower capacity market cost under trade-ready mass-based compliance.

Figure 25. Capacity Market Impact



The capacity market effects observed in the "Low Gas Price" sensitivity are also interesting. Resource retirements in 2020 cause capacity market prices to increase in order to attract new entry; however, unlike the reference model, the capacity market prices plateau through 2026. The capacity market price cannot exceed Point A on the VRR curve[60]. By 2026, additional combined cycle resources are able to enter the market. These resources are located in regions of the PJM system where both the delivered natural gas prices are lower and investment costs are lower. Consequently, their cost of entry is lower which drives capacity market prices back down. The effect of bringing new resources in the "Low Gas Price" sensitivity on-line by 2026 is comparable to the observations from the scenarios based on a reference gas assumption. What is different is, because these resources earn much less in the energy market, more of their cost must be recovered in the capacity market.

Low Gas Price Impacts on CO_2 Emissions Compliance

As shown in Figure 22, under a lower natural gas price, the impacts of the shorter-term outlook on retirements are much more significant. Nuclear retirements more than double by 2022. The increase in nuclear retirements causes a decrease in coal retirements of 5.8 GW and an increase in combined cycle gas capacity of 5.5 GW by 2030. From an emissions compliance standpoint, this would appear to make compliance more difficult. However, if states only regulate existing sources, the resulting CO_2 emissions, illustrated in Figure 26, would remain below the CO_2 targets. Under a mass-based compliance pathway – in which states only regulate emissions from existing sources – the CO_2 prices would be zero, and thus not provide any energy market price benefits for nuclear resources. If states instead adopt a mass-based compliance pathway that regulates both existing and new sources, the targets would limit expected CO_2 emissions below the existing and new source cap as early as 2024. Because of additional coal retirements, the targets would not consistently be lower than the expected level of CO_2 emissions until closer to 2030. Therefore, under both potential compliance pathways, it is unlikely that the CPP would enhance the energy market price signals and alter the decisions of resource owners that have a near-term outlook.

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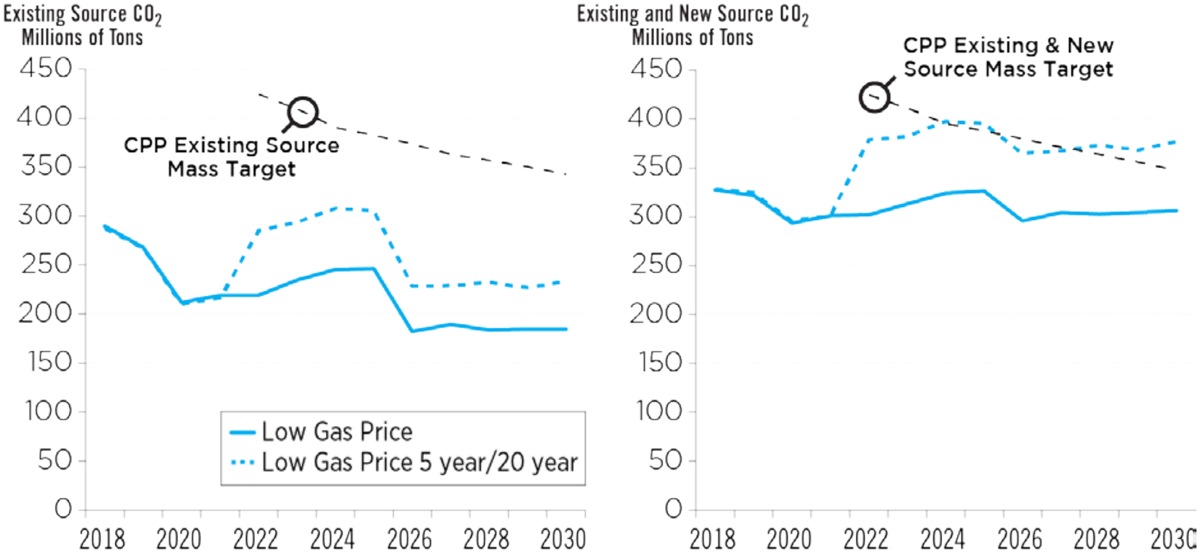
[60] The variable resource requirement curve is based on the cost of new entry for a combustion turbine. And to the left of Point A on the VRR curve, the demand is flat at the price equal to 1.5 Net CONE.

Figure 26. PJM Existing and New Source CO_2 Emissions under the Low Gas Price and Hybrid Model Sensitivities



Impacts of Longer Term Outlook on CO_2 Emissions and Compliance Cost

The hybrid model and resulting nuclear retirements do not cause the CPP mass or rate targets to be infeasible. Under both the trade-ready rate-based and trade-ready mass-based compliance pathways, the CO_2 emissions targets are achieved. In Figure 27, it appears that by 2027, the existing source emissions under trade-ready mass-based compliance are higher than the target. This is not the case, however, as compliance is evaluated based on a three-year step period. Within the model, the average of each step period is enforced, whereas in the Figure 27, the mass-based target is depicted based on the annual CO_2 emission reduction targets set forth by the EPA. CO_2 emissions from all sources are depicted on the right side of Figure 27. Comparing the emissions from all existing and new sources to the existing source emissions shows that new sources serve nearly all the load that would have been served by the 6 GW of nuclear resources that retire by 2022 in the hybrid model. The second observation is that the resulting increase in CO_2 emissions from all sources as a result of nuclear retirements persists throughout the study horizon under both trade-ready rate-based compliance and trade-ready mass-based compliance.[61]

Including new sources in either a state mass-based or trade-ready mass-based emissions may increase allowance prices, and the cost of bringing new resources on-line under the hybrid model assumptions. Given the amount of resources in the PJM interconnection queue today and that will potentially request interconnection, there is no evidence to suggest that achieving the CO_2 targets with new resources included in a mass-based program would be infeasible.

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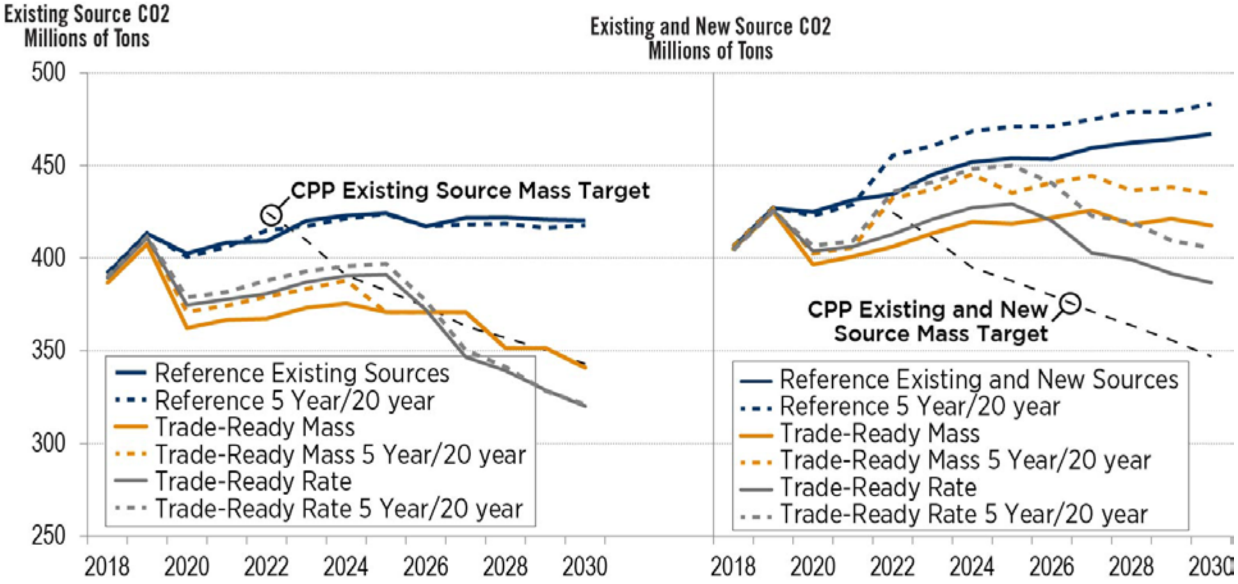
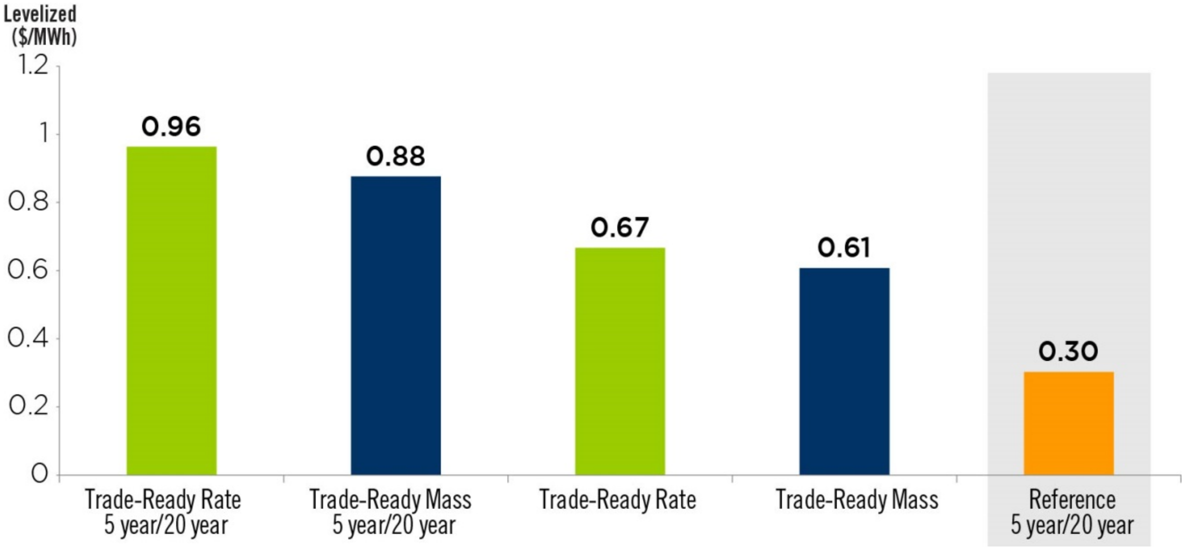
[61] The new source complement would prevent emissions from shifting to new sources and constrain existing and new source emissions under the target.

Figure 27. PJM CO_2 Emissions Comparison of Hybrid Model with Standard 20-Year Outlook Model



The last part of the story is to convey how the hybrid model affects compliance cost. Figure 28 compares the total investment, avoidable cost (fixed operation and maintenance), life extension, and production costs of each of the scenarios compared to the standard reference model in which all retirements and new entrants are optimized over 20 years. Resource owners' adoption of a short-term outlook on market conditions results in an increase in compliance costs of 27¢/MWh if PJM states adopt the trade-ready mass-based compliance path, and 30¢/MWh if PJM states all adopt the trade-ready rate-based compliance path. Most of the increase in cost in the reference model is passed through to the compliance pathways. Trade-ready mass-based compliance results in slightly lower transmission of the cost, which is indicative of coal retirements having a larger benefit for mass-based compliance than rate-based compliance.

Figure 28. Levelized Incremental Cost to Generator Investment, Fixed O&M and Production Costs Relative to the Long-Term Outlook Reference Case



Economic Sensitivities on Long-Term Model

In response to requests from the Organization of PJM States, Inc., PJM performed a range of sensitivities on the compliance pathways, including the reference model. Table 4 illustrates the sensitivities selected for the scenarios identified below. The reference model is the only model in which all of the sensitivities are applicable.

Table 4. Sensitivity Scenarios

Scenario	RPS	Low Gas Price
Reference	+	+
Trade-Ready Mass	+	
Trade-Ready Rate	+	
State Mass	+	
State Rate	+	
Trade-Ready Mass NSC	+	
State Mass NSC	+	
Trade-Ready Rate 50% EE		
Regional Rate	+	
Trade-Ready Rate and Mass		

Renewable Portfolio Standards

PJM studied the impacts of enforcing state renewable portfolio standards on each of the compliance pathways. Each compliance pathway has unique characteristics that impact renewable resource's economic viability, and the renewable portfolio standards (RPS) will interact with each of the compliance pathways differently. PJM's modeling of the RPS does not enforce the state percentage targets for renewable resources. Instead, the modeling of the RPS takes the form of a regional demand curve created by combining each individual state's RPS requirement and ordering them based on the state's alternative compliance penalty.[62] As shown in Figure 29, there is no requirement for the supply of renewables to equal demand from a given year. The market price for renewable energy credits along with energy and capacity prices will continue to rise until it is sufficient to attract new investment or until the price of renewable energy credits reaches a ceiling price represented by the state(s) alternative compliance penalty. By 2030, the weighted average alternative compliance penalty for the PJM region is only $5.8/MWh in all scenarios, down from over $40/MWh in 2018. This represents the weighted average per unit cost imposed on parties with RPS obligations, usually load serving entities, for shortfalls in the procurement of renewable resources.

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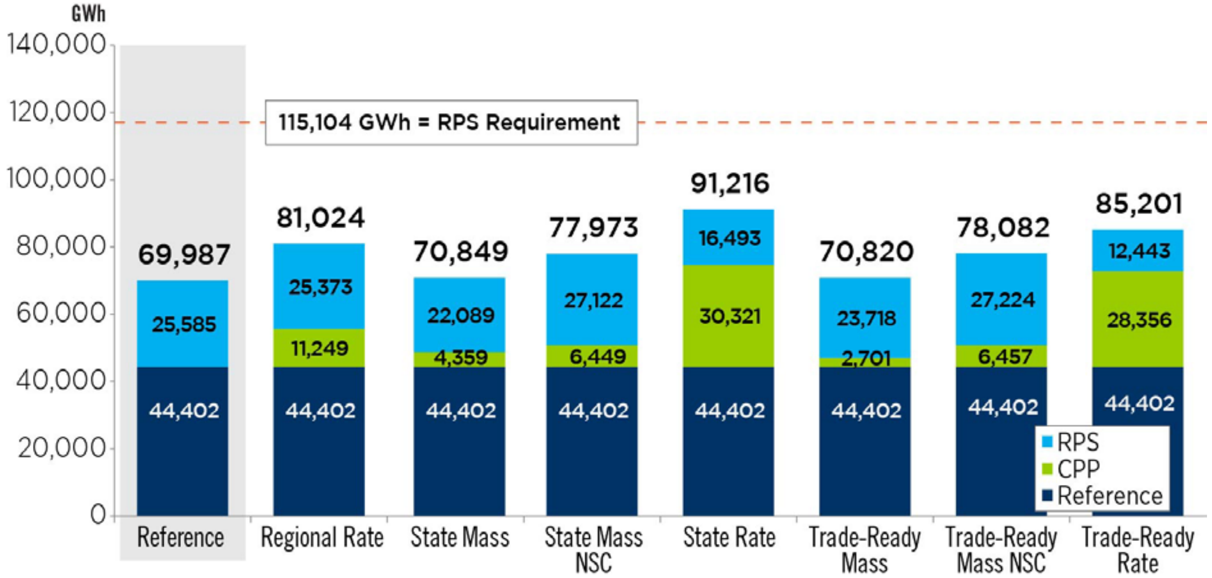
[62] *See* the *Database for State Incentives for Renewables & Efficiency* ("DSIRE") mainlined by the North Carolina Clean Technology Center available at http://programs.dsireusa.org/system/program/.

Figure 29. PJM Renewable Energy Resource Levels by 2030



Rate versus Mass

Rate-based compliance uses ERCs to provide a direct cash flow incentive for zero-emitting resources like renewable resources to enter the market. For renewable resources, ERCs function in the same manner as renewable energy credits for renewable resources, and directly compensate the resource for energy production. When it is cheaper to bring new renewable resources on-line than to re-dispatch from higher-emitting resources to lower-emitting resources, the ERC price represents the cost required to attract new renewable resources to the market. Similarly, renewable energy credits, which are also production-based, are intended to provide renewable resources with additional cash flow to cover their net going forward and investment cost. Consequently, there is a direct relationship between the cost of ERCs and renewable energy credits. This is evident in the production levels observed in 2030 shown in Figure 29, whereby the rate-based compliance scenarios uniformly have higher renewable generation than the mass-based scenarios.

In a mass-based compliance framework, unless renewable resources are allocated allowances, there isn't a direct correlation between allowance prices and renewable energy credits in terms of compensation to renewable resources. The only feedback is in the energy market price. Mass-based compliance will generally lead to higher energy market prices than rate-based compliance, which reduces the need for renewables to secure out-of-market payments, including renewable energy credits.[63] All of the mass-based compliance scenarios result in higher renewable resource levels than the reference model. The most significant increase in renewable resources occurs in the mass-based scenarios that regulate new sources, which is consistent with the fact that this scenario drives both energy and capacity market prices higher than the other scenarios.

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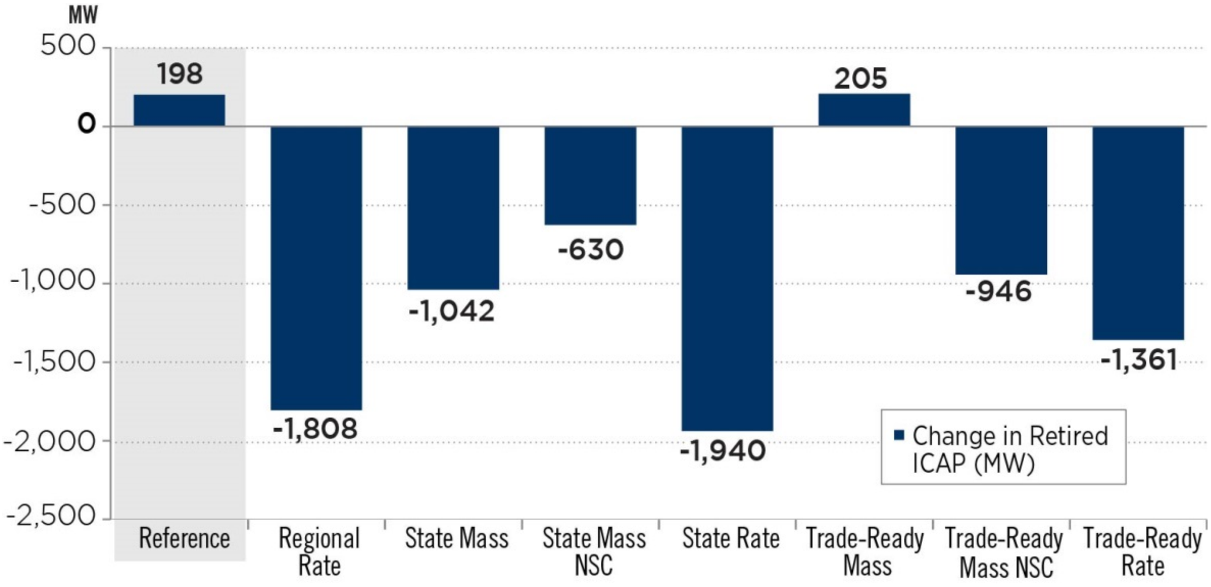
[63] The increase in energy prices under mass-based compliance is based on the emissions rate of the marginal resource and will often be less than one for one with the cost of allowances, whereas renewable resources earn the full ERC price for every MWh they produce.

Generator Retirements

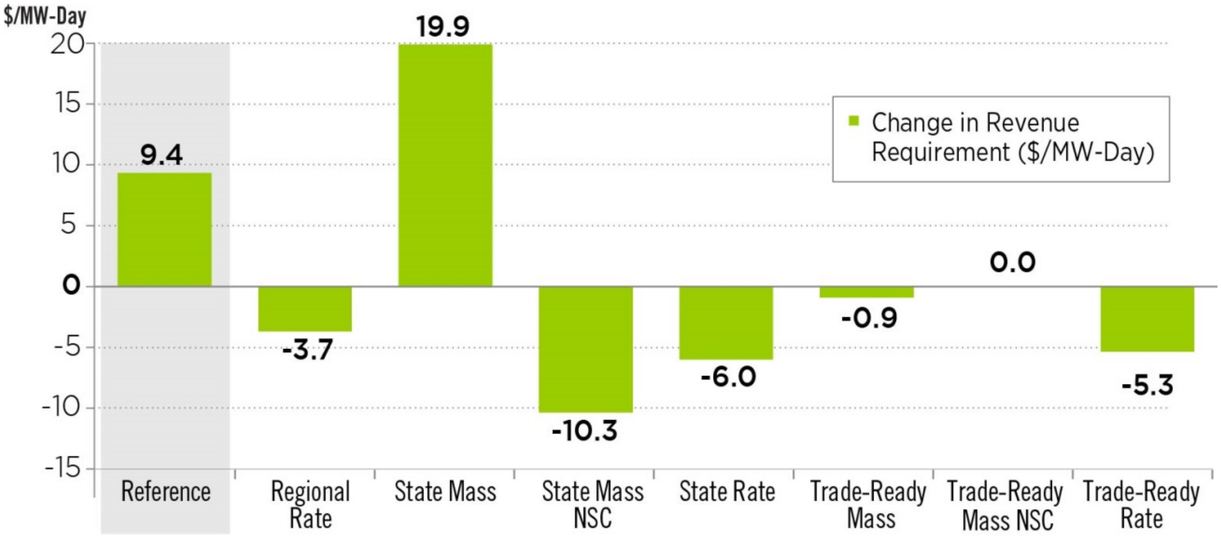
Typically, large increases in the amount of renewable resources displace revenues for fossil resources and lead to higher levels of retirement. However, when renewable portfolio standards are superimposed on emissions regulations, counter-intuitive retirement results are possible. As shown in Figure 30, the renewable portfolio standards cause an increase in retirements of 198 MW in the reference model, which follows conventional intuition. It's worth noting that the system achieves only 61 percent of the total requirement in this scenario because the alternative compliance penalties decline over time. Assuming, more renewables were developed, more retirements could be expected.

Figure 30. Change in Generator Retirements with RPS



In the absence of emissions regulation, renewable resources only impact the revenue side of a fossil resource's cash flow. However, when emissions limits are imposed on fossil resources, renewable resources can also serve a role in reducing the costs of compliance. In contrast to the reference model, with the exception of the trade-ready mass scenario, the renewable portfolio standards cause a decrease in the level of retirements. An increase in renewable resources has the effect of displacing the energy from the most expensive resources on the system, which can be either coal or combined cycle gas resources at any given time. And since renewables are zero-emitting and have negligible operating costs, once their investment hurdle is overcome, they can help achieve the emissions targets at zero marginal cost. Higher levels of renewables reduce the amount of re-dispatch away from coal to combined-cycle gas which not only drives down the price of allowances but also emissions related costs for coal resources in mass-based compliance pathways. Under rate-based pathways, the increase in the supply of ERCs drives the price down also helping reduce the emissions related costs for coal units. All of these effects can be seen in Figure 31 where the net going-forward costs needed from the capacity market for coal steam resources declines when renewable resource production increases.

Figure 31. Change in Levelized Net Going Forward Cost for Steam Turbine Coal Resources

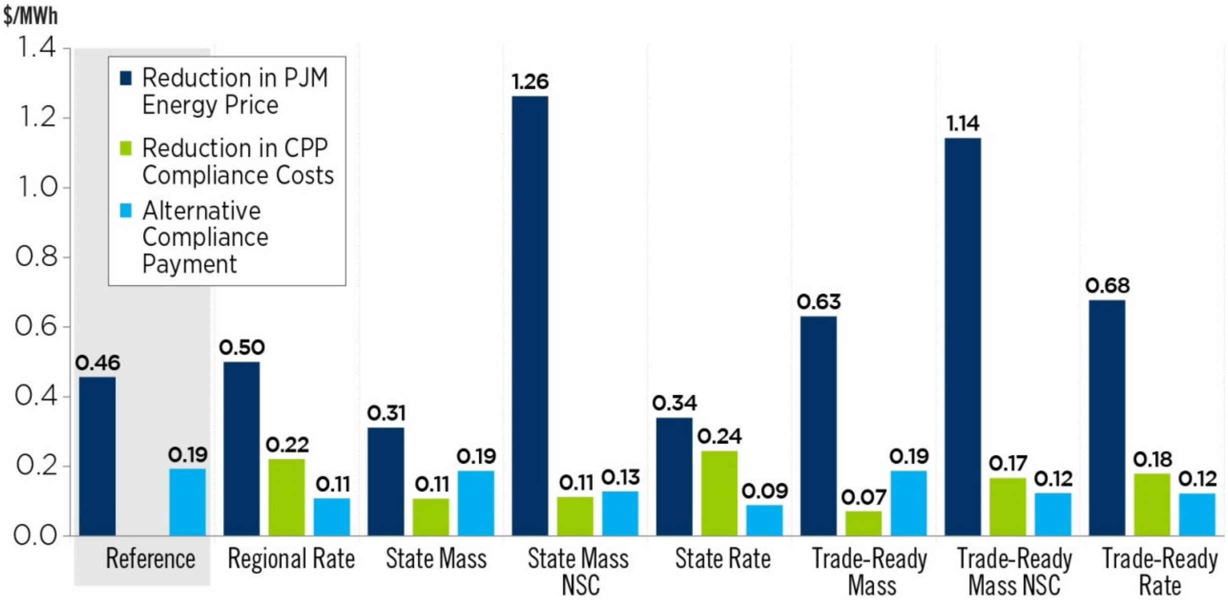


Based on the results it is not possible to conclude that higher levels of renewables will always lead to fewer retirements of CO_2-emitting resources. As shown in Figure 31, the state mass scenario has an increase in the net going-forward cost for coal resources, but still has a decrease in retirements. This occurs because under state mass-based compliance, some states have a CO_2 price equal to zero even without the renewable portfolio standards. Consequently, imposing the renewable portfolio standards only affects revenues for these resources. The retirements under state mass go down, because emissions costs for resources in other states go down.

Generator Cost and Compliance

Given that the states also enforce the renewable portfolio standards in addition to implementing the CPP, the renewable portfolio standards are an important consideration when evaluating CPP compliance. Ideally, the standard should result in lower direct compliance cost associated with the CPP, but also should provide some benefit to load payers through lower energy prices. These reductions do not come free however, as utilities must pay alternative compliance payment penalties for under-procurement relative to the renewable portfolio standards targets. As shown in Figure 32, enforcement of the renewable portfolio standards does result in lower energy prices. It's worth noting that the actual reduction in wholesale market prices will be sensitive to the level of congestion that may ensue when additional energy resources come on-line without supporting transmission. On the compliance side, the renewable portfolio standards uniformly reduce the cost of compliance. The reduction in compliance cost however is offset by the alternative compliance penalty. All of the costs shown in Figure 32 are levelized over the entire study horizon.

Figure 32. Change in Levelized Energy Prices, Compliance Cost , and utility Alternative Compliance Payment Penalties



Lower Natural Gas Prices

The natural gas price is a key driver in shaping the PJM resource mix going forward. Various forecasts exist reflecting different perceived futures for the commodity. The IHS CERA forecast (low gas price sensitivity), which on a real dollar basis grows only about 0.4 percent per annum over the 20-year study period, represents a continuation of the current trend in gas prices in which gas production remains on its current trajectory with cost and productivity improvements.

Due to persistence of low natural gas prices, the negative pressure on energy market profits for resources with high net going-forward costs persists well into the future, as shown in Figure 33. The exit decision for generating units within the model is based on the entire study horizon. However losses up front carry greater weight than profits at the end of the study horizon. This dynamic means that existing resources that are less economic than new entry generation candidates, and are unable to recover their long-run costs retire up front, thus avoiding future cost.

By 2026, gas prices under the forecast used in the reference case rise to $5.5/MMbtu on a real (2018) basis and remaining steam turbine coal units on average can cover their going-forward costs on energy market profits alone as shown in Figure. In contrast, natural gas prices in the low gas price scenario do not achieve that level during the entire study horizon through 2037. Consequently, the coal fleet on average is never able to cover going-forward costs in the energy market alone, even after retiring the most expensive generation units in 2020. By 2026, some coal units in the low gas price sensitivity still are not economic when compared to the cost of new natural gas combined cycle entering the market. Consequently, there are additional retirements. Figure 34 illustrates the change in installed capacity. Based on the reference forecast, natural gas combined cycle units do not exceed coal in installed capacity until 2030. However, this transition occurs by 2020 in the low gas price sensitivity and the gap in installed capacity continues to expand through 2030. By 2030, installed steam turbine coal capacity falls from 59 GW in 2018 to 31 GW, whereas the level of natural gas combined cycle installed capacity grows from 48 GW to 78 GW.

Figure 33. Comparison of Steam Turbine Coal Net Going Forward Cost under the Reference Model and Low Gas Price Sensitivity

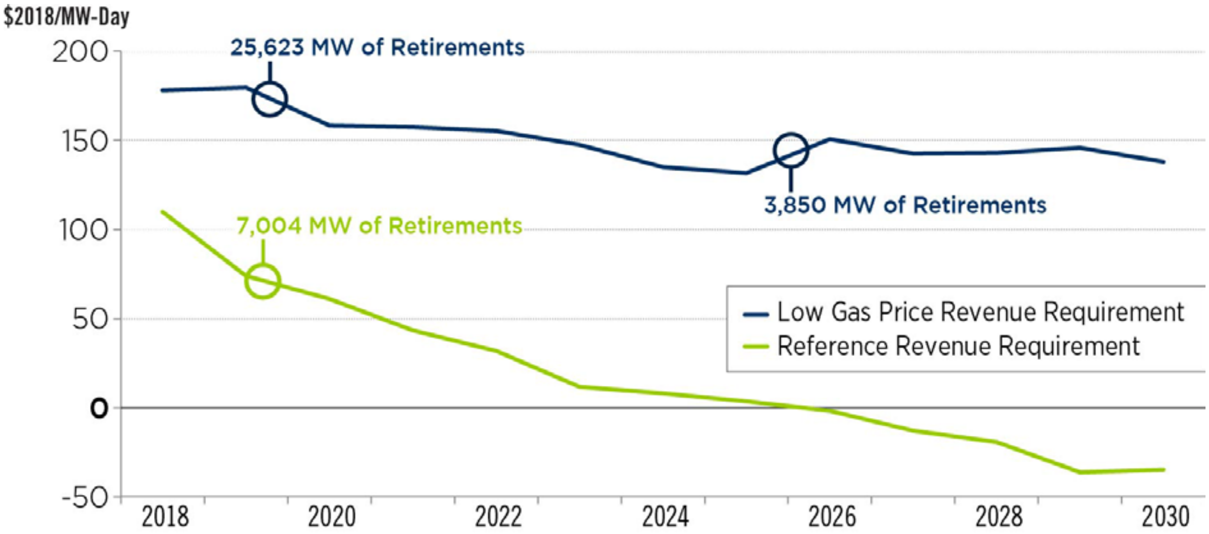
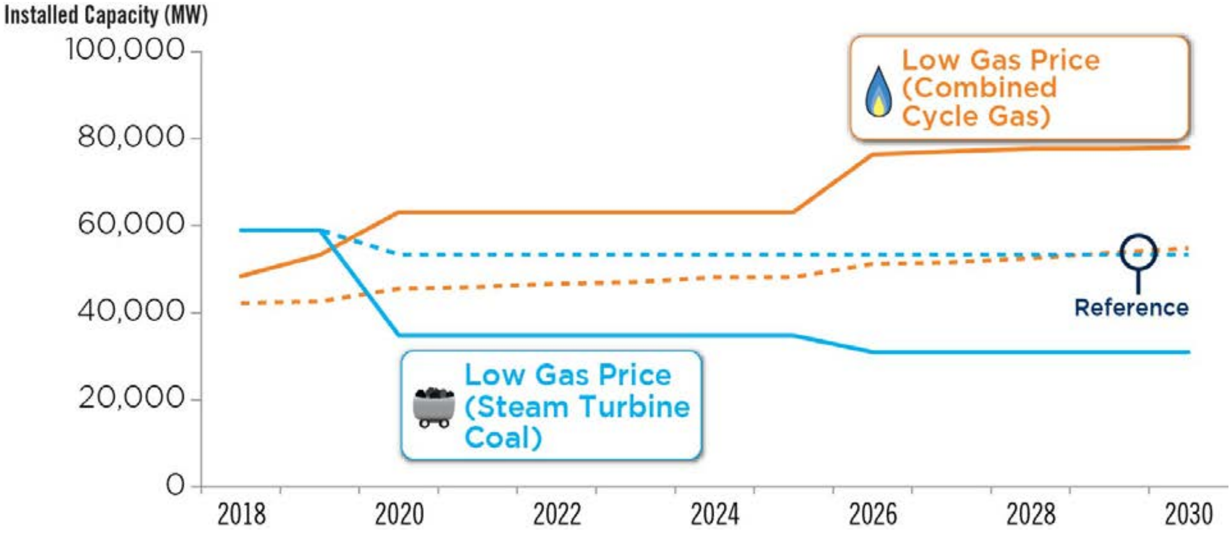


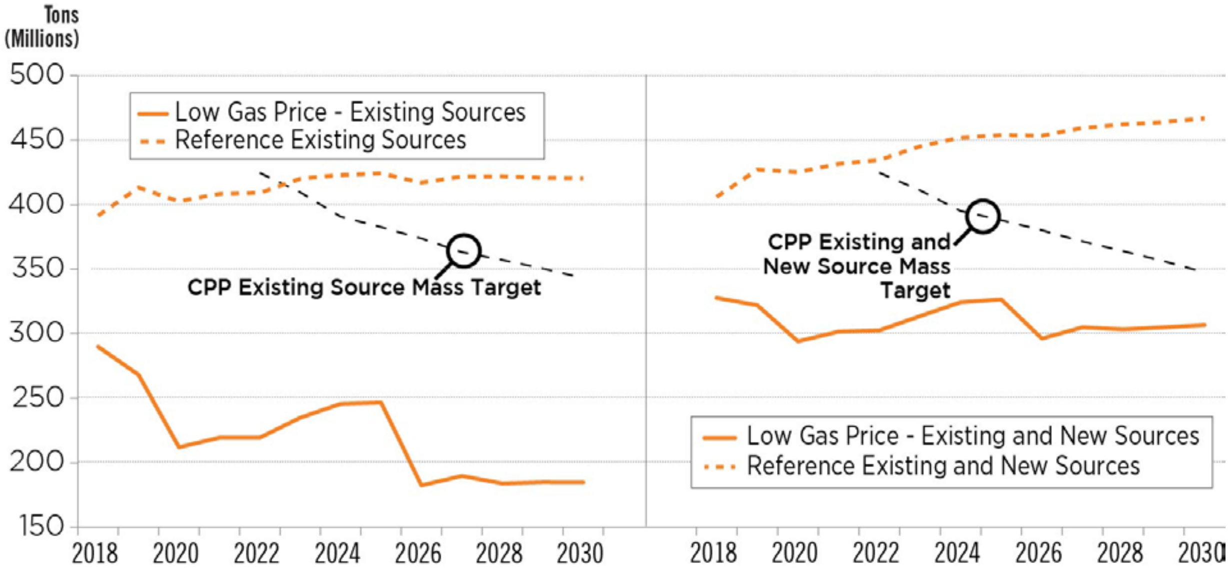
Figure 34. Comparison of Combined Cycle Gas and Steam Turbine Coal Installed Capacity under the Reference Model and Low Gas Price Sensitivity



The large amount of retirements in response to lower natural gas prices leads to a sharp drop in emissions, as shown in Figure 35. Neither the existing source targets nor the new source complement CPP targets intersect with the lower gas sensitivity emissions, which means CO_2 prices would be zero for both these compliance pathways. Under the new source complement, CO_2 emissions from new sources would cause total emissions to continue to rise beyond

2030.[64] The level of CO_2 emissions observed in the low gas price sensitivity render the study of this sensitivity for CPP compliance unnecessary.

Figure 35. Comparison of CO_2 Emissions Under the Low Gas Price Sensitivity



Rate and Mass Mix

Since the proposed CPP regulation states have expressed interest in understanding the impacts of resources being subject to different CO_2 regulation while participating in the same market region. Although, the effects on offer behavior is different for resources in rate-based states, mixing rate- and mass-based compliance within the same market area should have similar impacts as state mass-based compliance or state rate-based compliance. Effectively, resources are complying with a different regulation that will setup potential advantages and disadvantages for resources simply based on physical location and compliance regime under which they are operating.

The purpose of studying different configurations of each state's choice of compliance is simply to understand the impact on resources and PJM's markets of various state compliance decisions. At this point, PJM is not aware of a model that can optimize the compliance choice. Moreover, doing so would be impractical as states have many different considerations in choosing the appropriate compliance pathway – some of the factors considered are economic; others are not. Instead, given a set of initial conditions, including a compliance decision input, the model optimizes resource responses.

To illustrate potential impacts of mixing rate- and mass-based compliance, PJM determined it was best to study one set of states under trade-ready rate and another group as trade-ready mass. While many different factors could be used to define a particular group, PJM defined the groups based upon states located east of the historically binding

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[64] Assuming states allow allowances to be banked there is very little risk of the CPP new source complement targets ever resulting in a positive CO_2 price.

reactive interfaces and those to the south and west of the historically binding reactive interfaces. In system operations, loading on the reactive interfaces is the result of west-to-east transfers of energy and also the cause of a significant amount of PJM congestion. Therefore, for this analysis, PJM wanted to understand how adoption of a different compliance pathway on either side of the interface could impact resources and potentially exacerbate operational issues that could be evaluated in further study. Table 5 describes the scenarios evaluated for this sensitivity.

Table 5. Rate and Mass Groups

	Group ID	States	Compliance
Scenario 1	Group 1 States	MD | DE | VA | NJ | PA	Multi-State Rate with Sub-Category Rate Targets
	Group 2 states	IL | IN | KY | MI | NC | OH | WV	Multi-State Mass
Scenario 2	Group 1 States	MD | DE | VA | NJ | PA	Multi-State Mass
	Group 2 states	IL | IN | KY | MI | NC | OH | WV	Multi-State Rate with Sub-Category Rate Targets

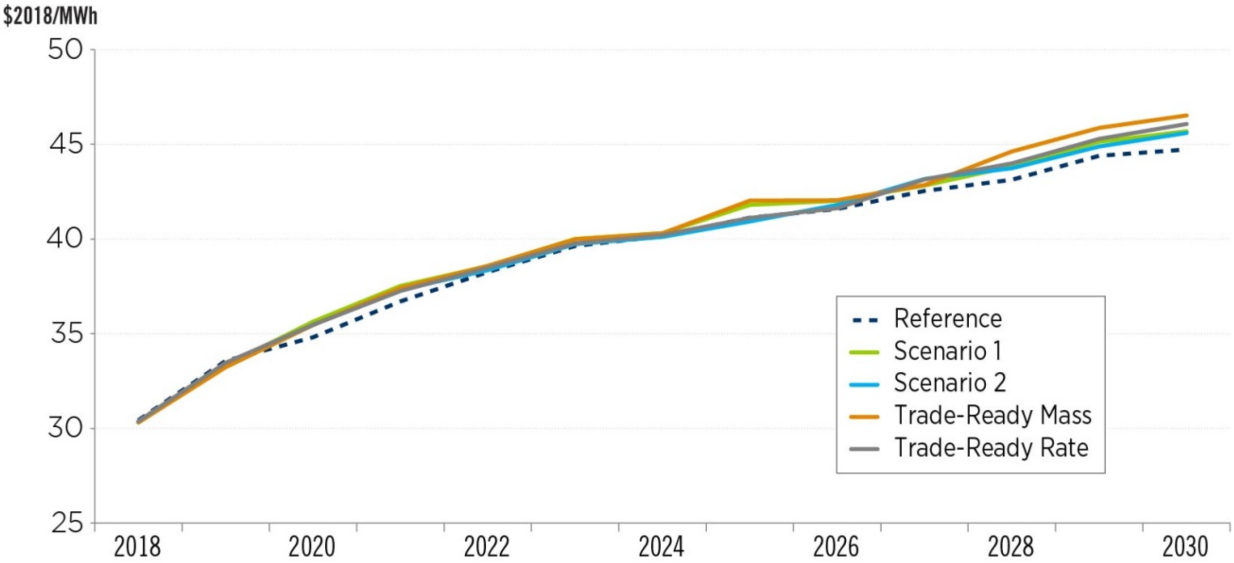
Coincidently, the Group 1 states have the most natural gas combined cycle resources, whereas the Group 2 states, can collectively be characterized as generally more coal-intense states. Similar to state rate-based compliance analysis, there are no limitations on where renewables can be located within the PJM footprint. Technically, to earn ERCs, renewable resources located in mass-based states require a load-serving agreement between the resource owner and a load-serving entity in a rate-based state. This limitation can create an additional economic barrier to trading the ERCs that these resources would otherwise produce. Approximating the barrier's cost is beyond the scope of this model. Unlike supply-side generation, there are no such load agreements for energy efficiency; thus, EE is assumed to reduce load in the physical location. The potential ERCs that energy efficiency in mass-based states could produce represent lost opportunity for reducing compliance cost in rate-based states.

The impacts from this analysis that could have the most significant impacts on PJM operations are the resulting ERC and allowance prices, and the location of retirements. With the exception of the new source complement, the other EPA compliance pathways do not provide any inherent advantages for where new fossil resources would be sited in response to the state compliance decision.

PJM Energy Prices, Emissions and Allowance Prices; Resource Retirements

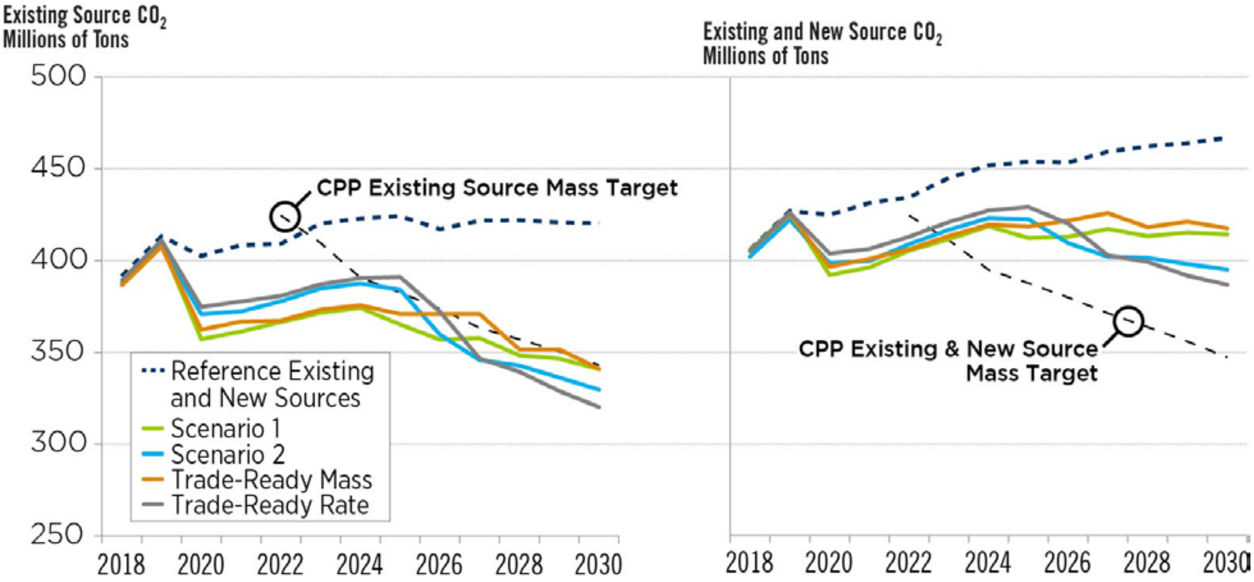
The states studied under a trade-ready mass-based assumption must comply with the aggregate mass-based target for this set of states, whereas the group of states studied as a trade-ready rate-based group must balance demand for ERCs with supply of ERCs.

Figure 36. PJM Energy Market Prices



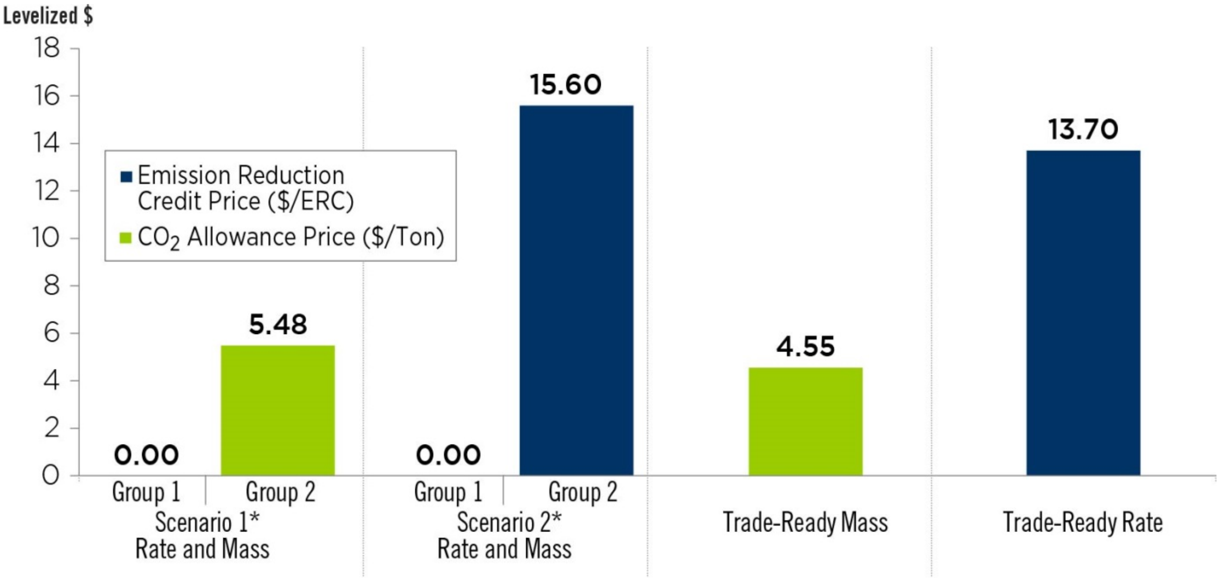
There are no large deviations in the energy prices observed among the compliance scenarios. There is a spike in 2025 with the western states operating under mass-based compliance; this follows the same course as trade-ready mass. With the eastern states in PJM operating under mass-based compliance, energy prices follow the course of the reference case prices more so than the other scenarios. But even these differences are small; consequently, most of the story must be on the emissions compliance, generating resource retirements and compliance cost side.

Figure 37. CO_2 Emissions versus PJM Regional Mass-Based Target



Overall, emissions under each scenario of mixed compliance strategies results in a lower level of emissions from existing resources than the mass-based target for existing resources through 2030 as shown in Figure 37.

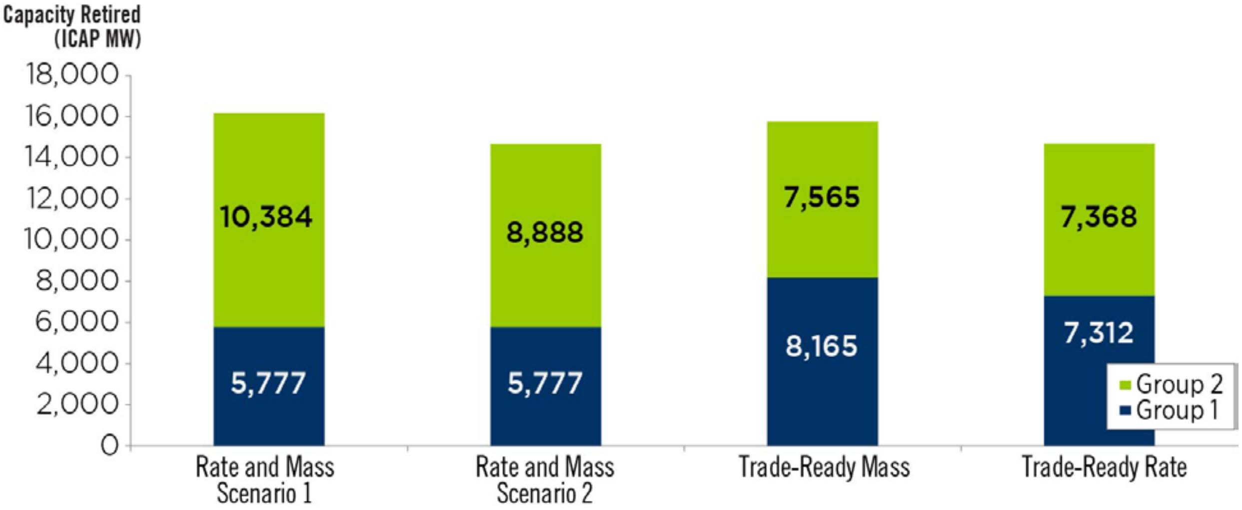
Figure 38. ERC and Allowance Prices in Rate and Mass Mix Scenarios Compared to Trade-Ready Rate and Trade-Ready Mass-Based Compliance



*Note: Reference Table 5, Rate and Mass Groups

The Group 2 states have higher cost of allowances when studied for mass-based compliance than when they participate in a broader trade-ready mass-based program. They also have higher cost of ERCs than under trade-ready rate-based compliance.

Figure 39. Generator Retirements in Rate and Mass Mix Scenarios Compared to Trade-Ready Rate and Trade-Ready Mass-Based Compliance



Higher cost of allowances and or ERCs under sub-regional compliance results in more retirements for Group 2 states. Group 1 states, which face no cost for ERCs or allowances, experience fewer retirements.

Rate and Mass Mix – Group 1 Observations

Because Group 1 states, those states in eastern PJM and east of the historically binding reactive transfer interfaces, collectively are less coal-dominant, they do not represent the greatest demand for allowances or emission rate credits. As a group, because neither the mass-based limit (Scenario 2) nor the rate-based limit (Scenario 1) is binding, resources within these states are given a compliance advantage when compared to a broader regional trading program. As a result, the CO_2 price arising from either trade-ready rate (Scenario 1) or trade-ready mass (Scenario 2) compliance is zero, as shown in Figure 39.

The compliance advantage for resources in the Group 1 states also is evident in the reduced level of retirements relative to the regional trading programs under either mass- or rate-based compliance as shown in Figure 39. This result is consistent with results for state mass-based compliance in which there was a lower level of resource retirements in states that had lower CO_2 prices than the trade-ready price.

Rate and Mass Mix – Group 2 Observations

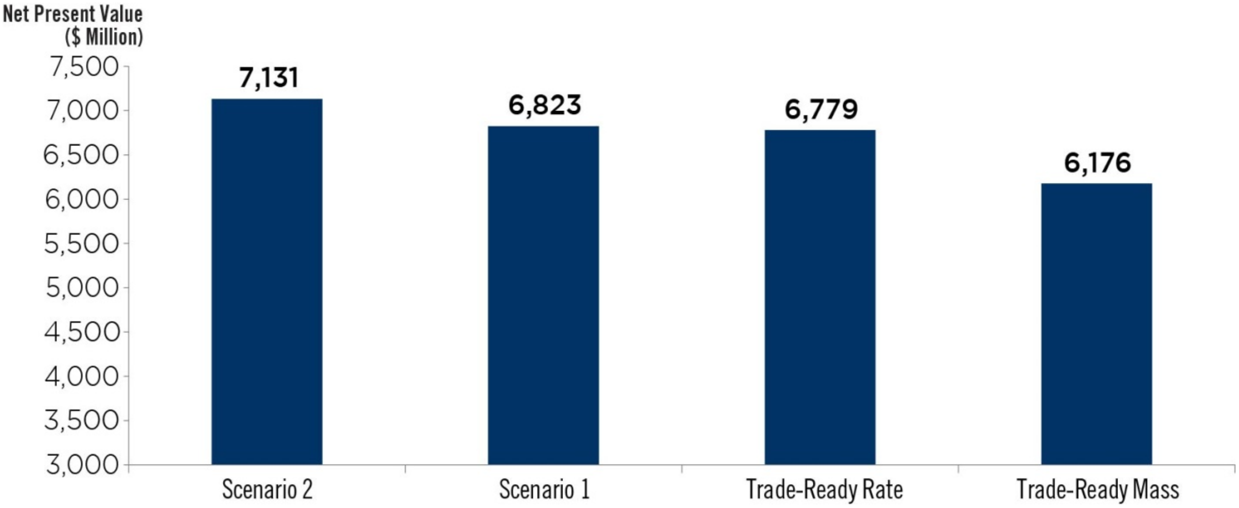
Considering most of the coal resources are located in the Group 2 states, but the level of energy efficiency deployed in these states is less than the Group 1 states, trade-ready rate compliance should result in lower regional emissions from existing sources than the PJM aggregate CPP mass target (as illustrated in Figure 37). The Group 2 states, as coal-dominant states, create most of the demand for ERCs and allowances in the PJM region, but they are isolated from access to ERCs or allowances that would otherwise be generated in the Group 1 states. Likewise, much of the existing combined cycle generation that can generate ERCs are in the Group 1 states and, by extension, create the potential for lower cost emissions reductions. As shown in Figure 38, both the ERC and allowance price for Group 2 states is higher under the rate and mass mix scenarios than the broader trade-ready compliance programs. From a rate-based perspective, the one compliance advantage for resources in Group 2 states is that there is less competition for ERCs that could potentially be produced by renewables. As new renewable resources are deployed, emissions in Group 2 states can eventually increase under Scenario 2, in which Group 2 states are trade-ready rate.

The result of a zero CO_2 price for Group 1 states, when studied under either trade-ready rate or trade-ready mass compliance, is indicative of these states having excess supply of allowances and/or ERCs that cannot be accessed by the resources in Group 2 states. By limiting trading across the region, the Group 2 states have more limited options to achieve compliance as well as fewer opportunities to reduce the cost of compliance for resources in those states. As a consequence under both Scenario 1 and Scenario 2, the level of retirements in Group 2 states is higher than the corresponding trade-ready mass or trade-ready rate scenario in which the entire PJM region adopts a common compliance approach.

PJM Region Compliance Cost

The results support the observation that the resources in Group 2 states drive the compliance outcomes for the broader PJM region. Resources in Group 1 states contribute relatively less to the cost of compliance. While in both scenarios, the CO_2 price for either ERCs or allowances is zero, but costs may go up with the need for more new entry or increased dispatch of resources in the Group 1 states to ensure energy balance. In the rate and mass mix scenarios, Scenario 2 in which the Group 2 states comply with a mass-based target results in lower overall generator compliance cost than Scenario 1 in which resources in Group 2 states are subject to a rate-based target as shown in Figure 40. Consistent with the comparison of state and regional or trade-ready compliance, a broader trade-ready rate or trade-ready mass framework that includes all states results in the lowest compliance cost.

Figure 40. Net Present Value of Generator Compliance Cost



Security Constrained Economic Dispatch Analysis (2025)

The energy market representation used in the long-term model is based upon a simplified representation of generation dispatch, unit outages and the load shape. The long-term model is sufficient for identifying the response of generators to the CPP from an investment perspective, and for making comparisons of the compliance pathways assuming perfect information and foresight. This type of model representation is insufficient, however, to perform a detailed assessment of the PJM transmission system and chronological hourly dispatch in response to the emissions regulation.

PJM is responsible for operating the electric grid in accordance with applicable criteria from the North American Electric Reliability Corporation. This includes maintaining reliability in short-term operations. PJM employed PLEXOS to perform a two-day[65] security constrained unit commitment and economic dispatch (SCED), to dispatch the PJM system on an hourly basis subject to transmission limitations. Such analysis captures the intertemporal nature of generators and system operation in response to various drivers, including emission limitations.

The SCED analysis results described in this section provide a more accurate view of market prices, generation production costs and on CO_2 emissions given an expected resource portfolio. In this section, using the 2025 study year, PJM will revisit the comparison of rate versus mass compliance, and state versus trade ready compliance.

Locational Marginal Prices in the Short-Term Model (2025)

The pricing relationships between the compliance pathways should remain consistent between the operational model and the long-term model used to provide the market signal for resource investment. There were four key observations on market pricing identified in the long-term economic assessment that PJM also expects in the operational model: 1) mass-based compliance pathways would lead to higher market prices relative to rate-based compliance; 2) state compliance may not always lead to higher prices than trade-ready compliance; 3) regulating new sources would lead to the highest market prices as resources submit higher offers to account for more expensive allowances; and 4) rate-based compliance can lead to lower prices than the reference model due to the addition of renewable resources, but also because of low-emitting existing combined cycle resources submitting lower offers into the energy market to run more and earn ERCs.

As shown in Figure 41, the security constrained economic dispatch model results are consistent with each of those expectations. Including new sources in a mass-based program led to the highest cost amongst the compliance pathways and mass-based compliance leads to higher market prices than rate-based compliance. While the SCED model results in slightly higher prices for state compliance under both rate- and mass-based compliance, this result is simply a function of which states have resources on the margin in response to energy demand and/or transmission constraints. And lastly, the trade-ready rate scenario led to market prices slightly below the reference model.

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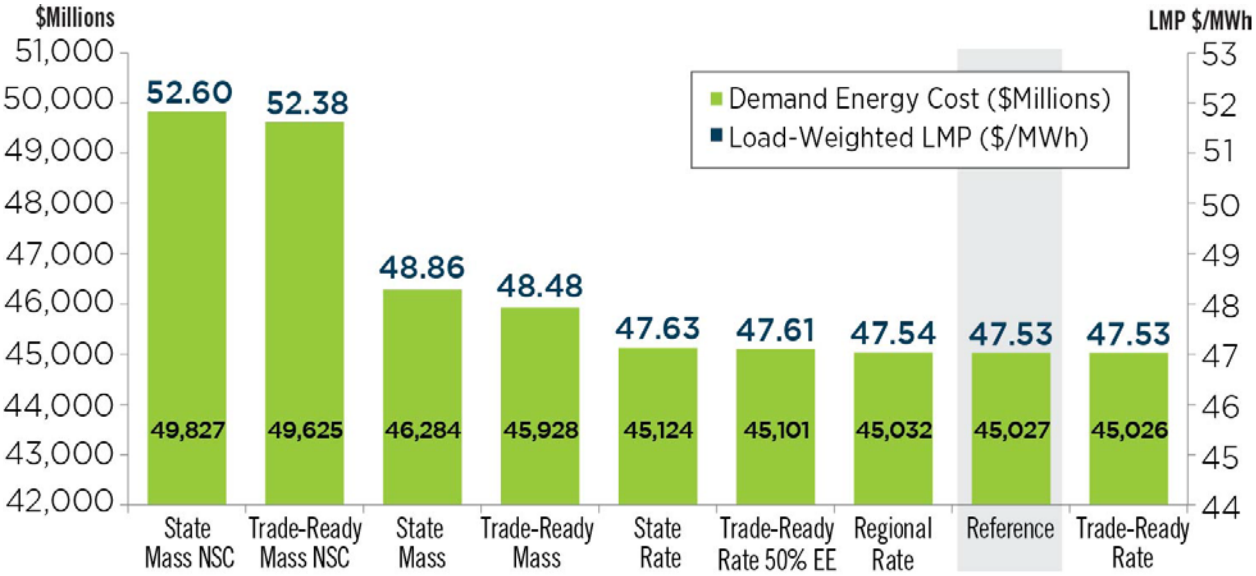
[65] To decrease run-time, PJM utilized a 32-hour look ahead, after evaluating the minimum up and down times of units. Nuclear units and super-critical units with longer lead times were modeled as must-run. The economics of these resources is such that they are always likely to be committed regardless of the compliance pathway.

Figure 41. PJM Energy Cost and Locational Marginal Prices



Transmission Congestion

The key factor that could change pricing relationships between compliance pathways is transmission congestion. Through 2025, PJM limited economic selection of thermal resources to those that were advanced in the interconnection queue process, or for which PJM's interconnection analysis group determined there would be limited deliverability risks. These resources have the highest likelihood of being developed with or without the CPP since they have a higher priority for transmission access than resources that submitted interconnection request at a later date. Despite, these projects' status, the long-term model still retires existing generating units, and this can have an impact on transmission loading. Consequently, before running the SCED model, PJM performed a limited N-1 transmission flowgate screening analysis to ensure there were no NERC reliability criteria violations.

Transmission Screening Analysis

Running the SCED model requires that the same set of transmission constraints be evaluated for each compliance pathway. Otherwise, in one simulation a transmission constraint can distort the comparison of market prices, generator dispatch and emissions with another simulation in which the same transmission element is not monitored. The model was initially loaded with historic flowgates (230 kV and above) that made up the top 25 congested elements reported by the PJM independent market monitor in each year since 2012. This set of transmission constraints was then supplemented based upon DC power flow analysis[66], in which PJM studied the set of single transmission contingencies used in PJM's standard reliability planning process.

After running the long-term economic model, each compliance pathway resulted in a set of generator retirements as well as new entrant resources, which would result in different flows on the transmission system. Specifically, some

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[66] PJM used Powergem's Transmission Adequacy and Reliability Assessment (TARA) to perform a security constrained economic dispatch on select load hours to identify new transmission monitored/contingency pairs.

scenarios result in higher levels of wind generation. While wind generators do not typically pay for transmission to support their energy capability, it was important to the evaluation to assess any new transmission constraints that arise because of specific resource siting in a particular area of the transmission system. Unlike, the natural gas combined cycle new builds which consists of interconnection queue projects, new wind and solar sites were based on National Renewable Energy Laboratory sites that PJM identified as near (within 20 miles) stations that can deliver energy to the PJM 230 kV and above transmission system.

PJM evaluated the generation results in each compliance pathway to identify whether additional 230 kV and above transmission constraints needed to be added to the model. In cases where a wind site was likely to result in significant overloads on a particular transmission facility, PJM identified another location that was less likely to develop overloads but was characterized by similar resource technical potential. This was by no means an extensive siting analysis, nor did PJM do a thorough evaluation of the ability of the wind/solar plant to interconnect at any specific station. The method adopted serves the purpose of evaluating the high voltage transmission system and potential larger operational impacts of a particular compliance pathway.

Transmission Congestion at a High Level

Historically, the reactive transfer interfaces have been the bellwether of changes in transmission flows and in aggregate have accounted for the largest percentage of transmission congestion from year to year. PJM conducted the analysis assuming that the PJM system could operate to the same set of limits on the reactive interfaces under each of the compliance pathways. By performing the analysis this way, PJM can make definitive observations on how the compliance pathways will affect utilization of the high-voltage transmission system. Consequently, the key drivers for changes in congestion are the level and location of coal retirements and new resources. Below are a few key pieces of information to understand the results:

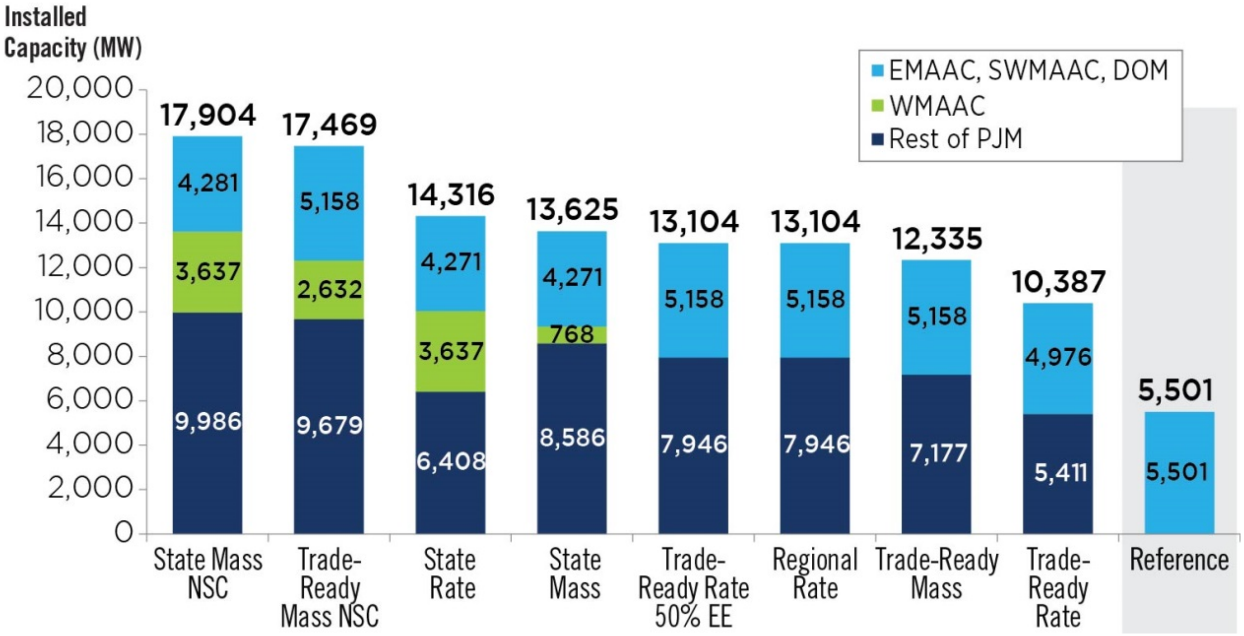
- Scenarios that result in significant changes in the level of economic generation east of the interfaces (EMAAC, SWMAAC and DOM) will influence congestion.
    - A decrease in economic generation in these regions will generally result in higher flows on the high voltage transmission and potentially more congestion
    - Whereas an increase in economic generation would have the opposite impact
- Similarly, significant retirements in western PJM will result in lower loading on the major west-to-east PJM interfaces and potentially cause transmission congestion to decrease.
- Technical resource potential for wind resources is highest in western PJM, whereas solar growth potential is greatest in eastern and southern PJM.

Resource Retirements Studied in SCED Model

Figure 42 illustrates coal retirements that occur by 2025 within each compliance pathway. In the reference model, there's a limited set of retirements, 5.5 GW, compared to as much as 17.9 GW in the scenario. That assumes all states adopt an individual mass-based compliance framework and also include new sources in the program. At the low end is trade-ready rate compliance. This compliance pathway is characterized by an oversupply of ERCs during the initial step compliance period, which delays when CO_2 reductions have to be made.

In the reference model retirements only occur in EMAAC, SWMAAC and DOM delivery areas. Absent replacement capacity, congestion would be expected to increase on the high voltage system to facilitate a higher level of imports into this region. When studied under the CPP, retirements are distributed across the PJM system and depend on the particular compliance pathway evaluated. The high level of retirements in western PJM, which is defined in Figure 42 as "Rest of PJM" would be expected to unload the high voltage system, and perhaps shift where the system is likely to experience congestion. This is in contrast to those retirements in eastern PJM. Retirements, however, are only half the story. Transmission congestion also depends on where economic generation locates relative to more expensive resources and load.

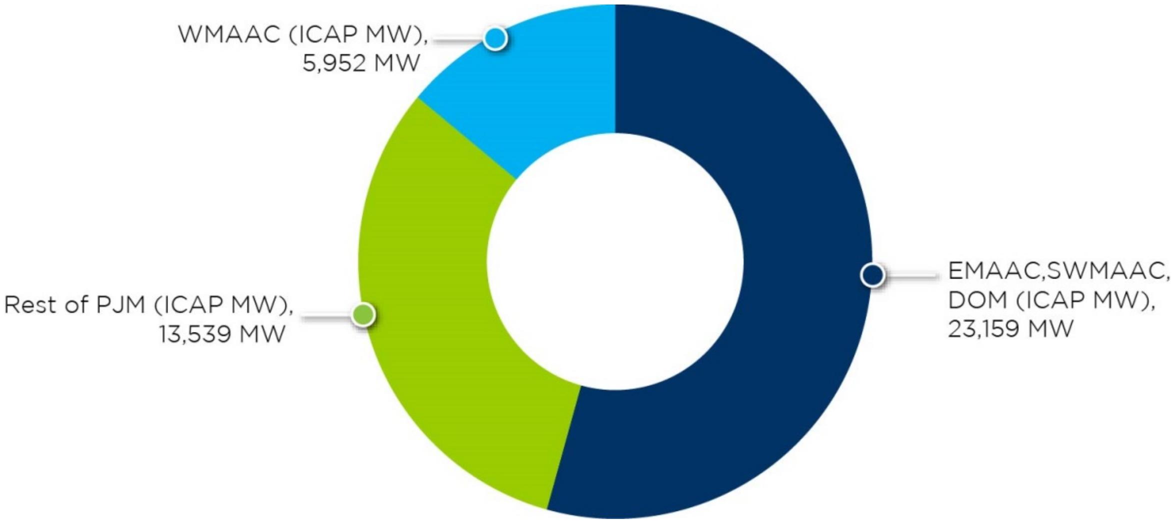
Figure 42. Steam Turbine Coal Retirement Distribution by 2025



New Generators Studied in the SCED Model

As discussed in the earlier sections of the paper, natural gas combined cycles dominate the PJM interconnection queue, and are the only resource represented at a level of available capacity to replace retiring coal resources on both an energy and capacity basis. Today, as shown in Figure 43, natural gas combined cycles units are most prevalent in eastern PJM, closer to major load centers in the Mid-Atlantic region. When natural gas prices were higher and the transmission system was heavily loaded, congestion differentials could contribute to these resources operating more than would otherwise have been economic. In western parts of PJM, on the contributing side to transmission constraints, these resources would have been less economic as they'd need to compete with coal and nuclear for access to the transmission system. They also would be negatively impacted by lower locational marginal prices.

Figure 43. PJM Existing and Planned[67] Natural Gas Combined Cycle Installed Capacity (MW) Distribution



A number of factors have changed the economics for natural gas combined cycles – sustained lower natural gas prices across PJM, significant amounts of retirements since 2011/2012, high voltage system upgrades, and improved efficiencies. These contributed to expanding the range of geographic locations in which these resources are economic. While most of the existing natural gas combined cycle units are located in the Mid-Atlantic region, the model, as shown in Figure 44, is building all of the new capacity in the western portion of the MAAC region, and western PJM. During the winter months in eastern MAAC, the forecasted fuel basis differentials continue to separate from the rest of PJM, and there is significantly higher build cost for new natural gas combined cycles.

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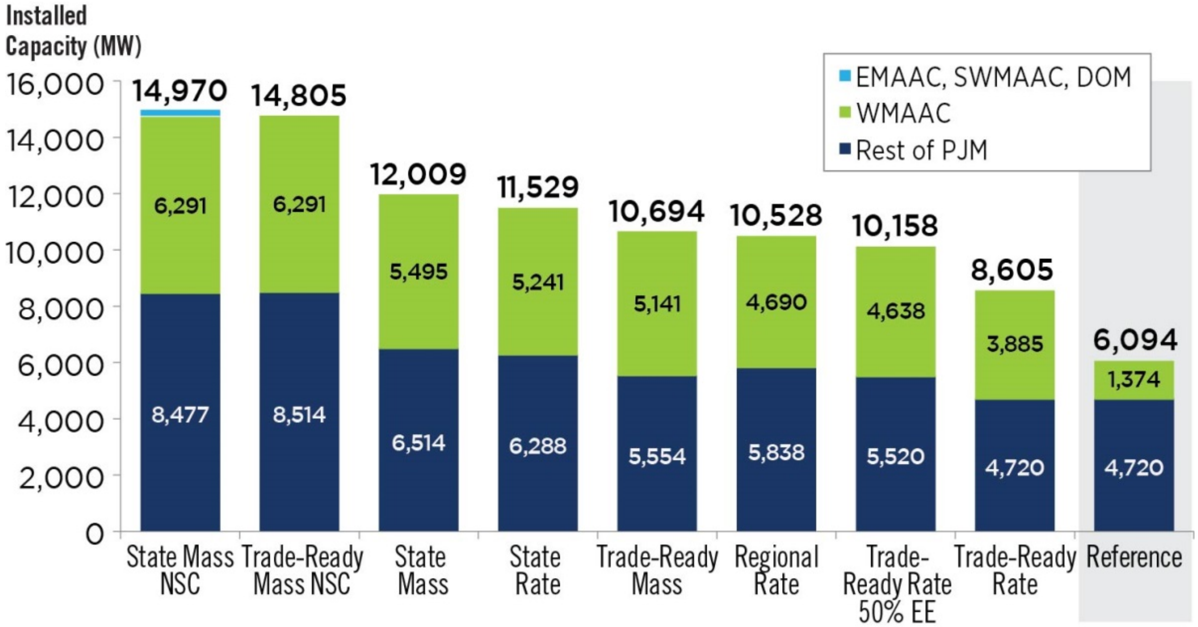
[67] Planned resources as defined in the key inputs are those that are added to the model independent of resource economics. These are resources that are advanced in the interconnection queue process and have evidence of being under-construction.

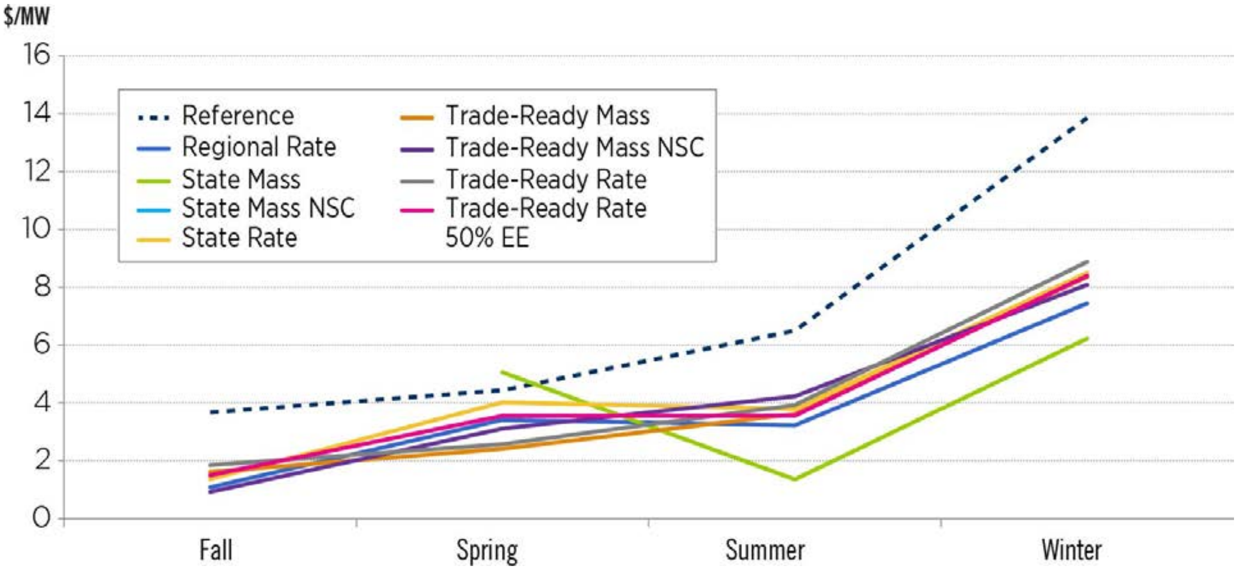
Figure 44. PJM Distribution of New Build Natural Gas Combined Cycles Installed Capacity (MW)



Given the expectation that these resources will not only serve new load, but also replace the energy from retired coal resources, a reasonable question is why would congestion change given that new natural gas combined cycles would utilize the same transmission? Congestion is based on the marginal costs (shadow price) of mitigating transmission constraints (i.e. the change in system production costs resulting from an increase to a transmission facility's limit by 1 MW).

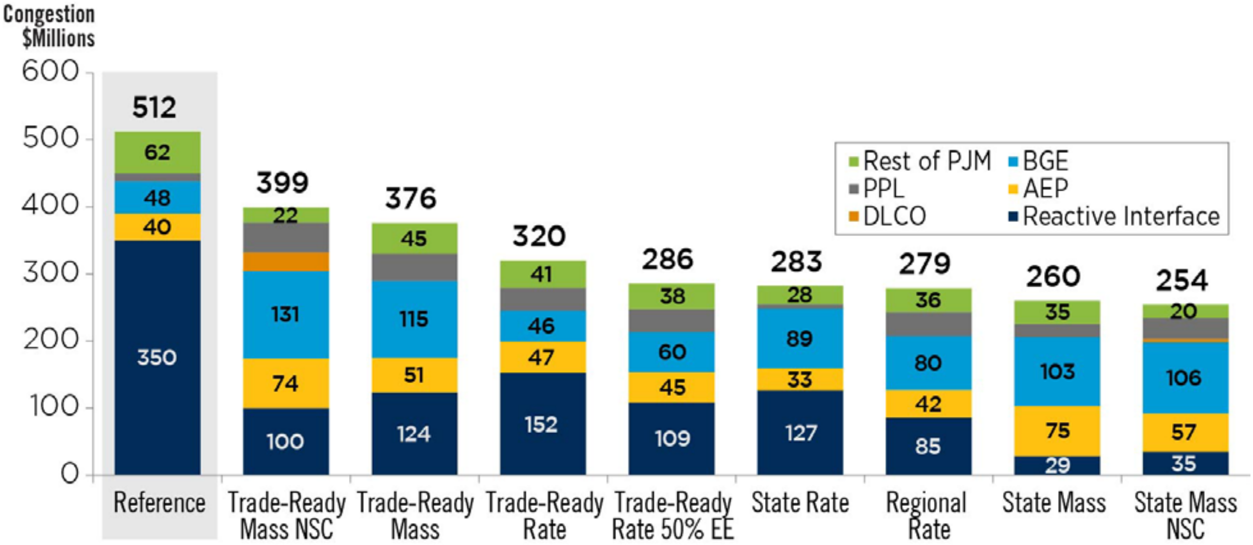
If the economic resource at a certain system load level is contributing to a transmission constraint, and there are similar resources that can mitigate the constraint with only slightly higher operating cost, then the shadow price will not be that high. As a result, the congestion will decrease relative to a scenario in which the resources represent a different technology class. AP South interface is historically one of the most congested facilities in PJM. Not surprisingly, it is also the most significant transmission constraint in the reference model. As part of PJM's backbone transmission system, it is a good example to show how replacing retiring coal units in the west with natural gas combined cycles will impact regional congestion patterns.

Figure 45. AP South 500-kV Interface Shadow Prices ($/MW) by Compliance Pathway



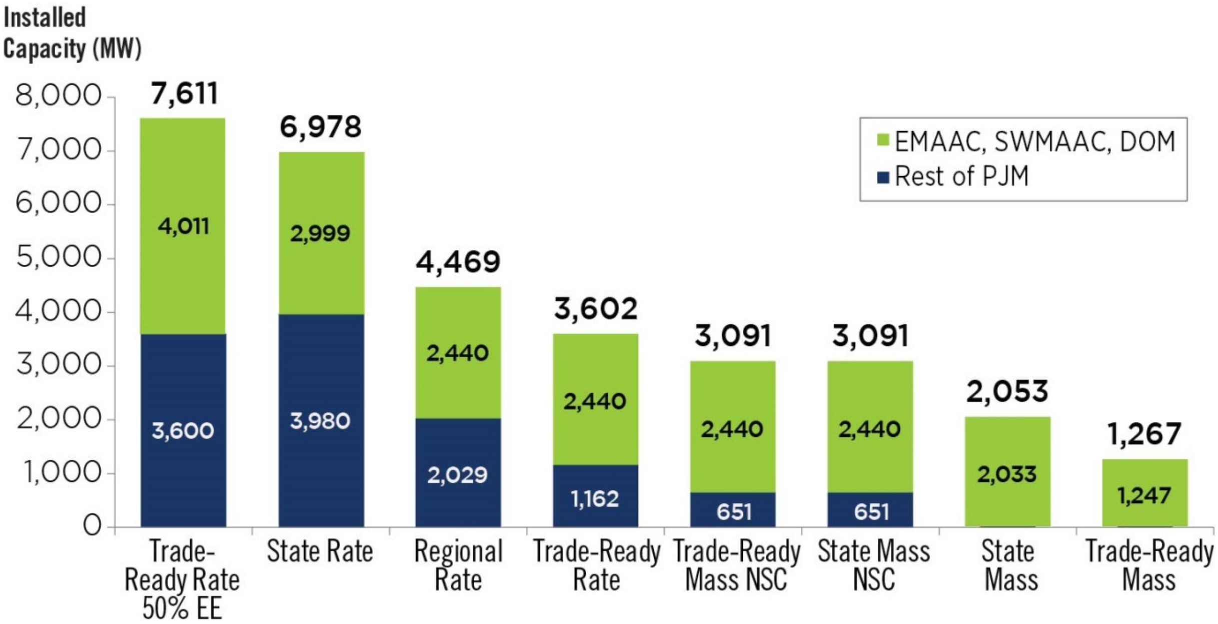
Compared to the reference model, in every season the cost of mitigating congestion on the AP South Interface is much lower than the reference model in which there are fewer coal retirements. As shown in Figure 46, transmission congestion on the reactive interfaces (i.e. PJM 500 kV backbone) goes down significantly relative to the reference model.

Figure 46. PJM Transmission Congestion by Zone



Several questions can be asked based on Figure 46 above. The first is why the state mass-based compliance scenarios result in the lowest congestion of all the compliance pathways, and such a large decrease on the reactive interfaces. The state mass-based compliance scenarios cause the least number of retirements in eastern PJM, while causing the most retirements in western PJM (Rest of PJM). While trade-ready mass that includes new sources also causes a lot of retirements in western PJM, the net system transfer increases by 877 MW due to more retirements in the EMAAC, SWMAAC and DOM area. Lastly, the state mass-based compliance scenarios as shown in Figure 47 cause 2,033 MW and 2,440 MW of renewable resources (such as solar) to be built in the EMAAC/SWMAAC/DOM area of PJM, which is likely to cause a reduction in loading on the PJM high voltage backbone system during peak hours when the most expensive generators are running.

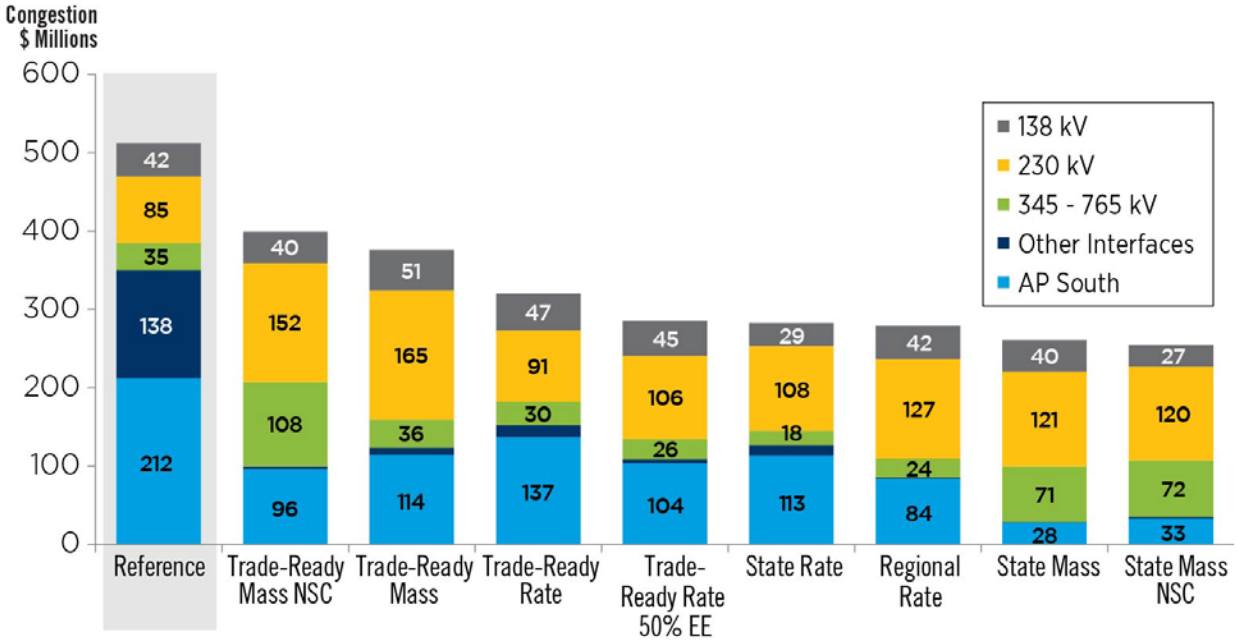
Figure 47. PJM Wind and Utility Scale Solar Economic Installed Capacity Additions



Another question is why, among all the CPP compliance pathways, does trade-ready rate-based compliance have the highest congestion on the reactive interfaces. By 2025, trade-ready rate-based compliance leads to the same number of retirements as the reference model in EMAAC/SWMAAC/DOM region, but lower retirements in WMAAC and the Rest of PJM. The congestion is still much lower than the reference model, and is explained by the amount of utility-scale solar installed in eastern and southern PJM.

The last question is where the congestion goes since it does not show up on the high-voltage system but load has not gone anywhere. Figure 48 below shows that a significant portion of the transmission congestion observed in the reference model on the high-voltage system simply moves a few levels down to the 230 kV transmission system. PJM has robust 345-kV and 230-kV transmission throughout its footprint, however from Figure 46 it is clear that the congestion has migrated to the 230-kV system serving loads in the Baltimore Gas & Electric (BGE) zone. Because of transmission constraints into this region, higher market prices should be expected than other areas of PJM, as illustrated in the state section of the report.

Figure 48. Transmission Congestion by Voltage Level



PJM Fuel Mix

In 2014, coal generation represented about 43 percent of the PJM generation supply and natural gas comprised nearly 18 percent of total generation. By 2015 however, coal generation accounted for only 36 percent of PJM's fuel mix, and natural gas increased its share by 5.6 percent.

By 2025, PJM's reference model natural gas forecast results in coal regaining its share of the market at 42 percent to total fuel supply as shown in Figure 49. The gas price recovery, however, is too late for nearly 5.5 GW of coal resources that retire by 2020 in the reference model; and in addition to already planned natural gas combined cycle capacity additions the model adds 7 GW of economic natural gas combined cycle capacity.

Figure 49. PJM Generation Fuel Mix (2025)

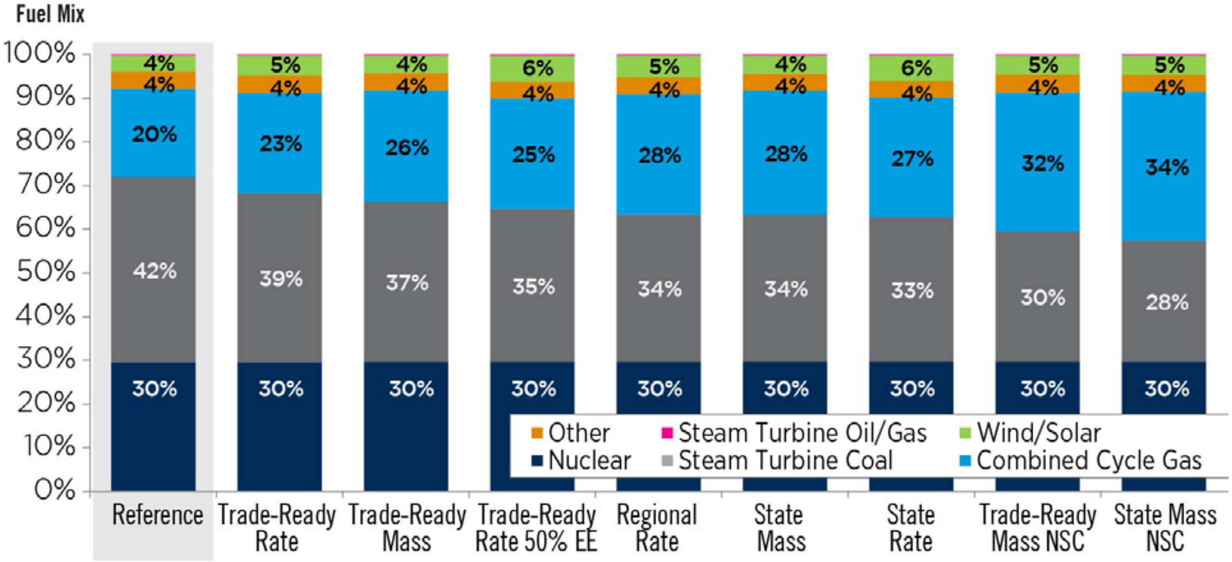
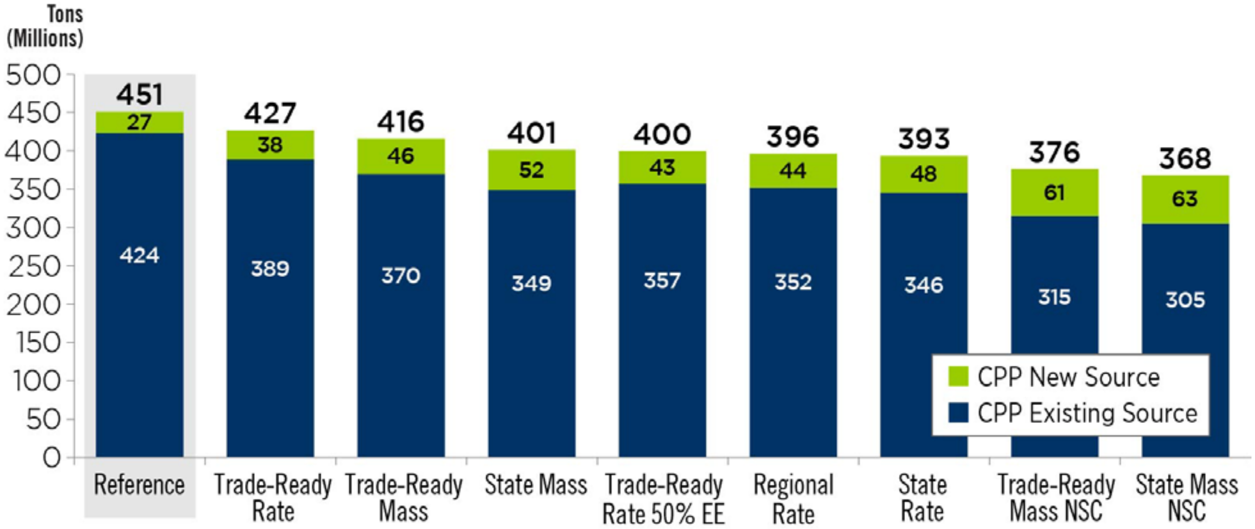
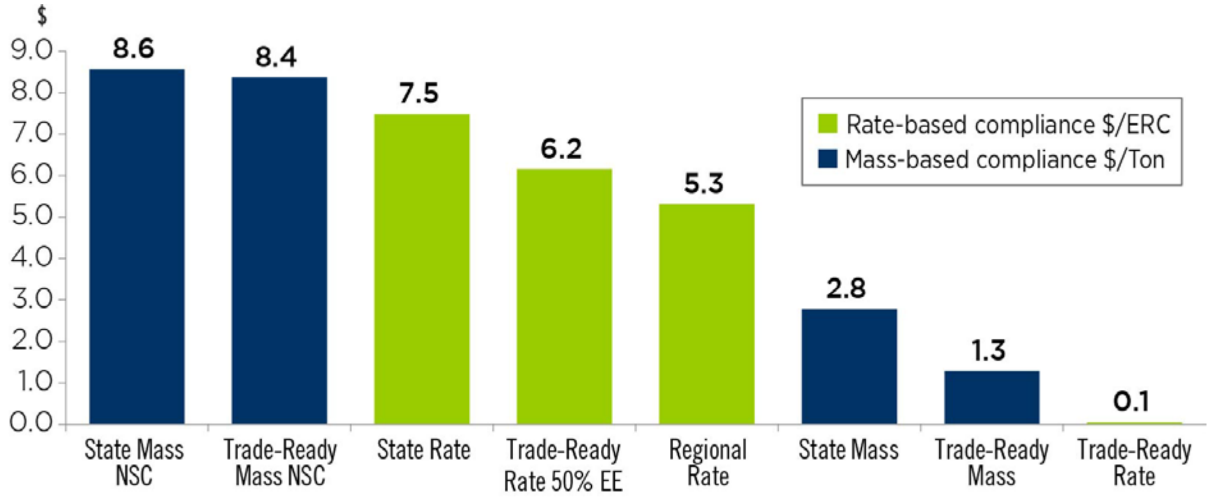


Figure 50. PJM CO_2 Emissions (2025)



As shown Figure 49, CO_2 emissions regulation has the same effect as low natural gas prices on reducing coal output and increasing natural gas combined cycle output. Both the mass- and rate-based compliance scenarios drive a shift from coal to natural gas and, to a much lesser degree, renewable resources in the fuel mix. From the least-stringent compliance scenario (trade-ready rate) to the most stringent (state mass-based that includes new sources), coal units decrease their percentage share of the fuel mix from 3 percent to 14 percent. Some of the shift in fuel mix is due to the CO_2 emissions regulation driving coal retirements. However, some of it is a result of resources choosing not to buy as many allowances or emission rate credits to operate. Figure 51 below shows the weighted average $/ton or $/ERC prices for mass- and rate-based compliance in 2025.

Figure 51. Allowance and Emission Rate Credit Weighted Average Price



During time windows that are too short to bring new renewables or energy efficiency online, there are only two ways to produce additional emission rate credits or remain under a mass-based emissions limit – either through resource retirements or re-dispatch from higher-emitting sources to lower-emitting resources. When the cost of allowances becomes high, retiring units can be a cheaper solution.

State compliance, through higher level of retirements and emission prices, causes a faster transition to more gas generation and lower emissions than regional compliance. The differences in fuel mix and emissions are more pronounced at the individual state level.

State-Specific Results

PJM has prepared state-specific results from the security constrained economic dispatch model for 2025. Rather than a focus on overall regional compliance with the CPP as discussed in the main body of this paper, this section provides information for state environmental regulators, who are responsible for developing and submitting state plans to comply with the CPP. This can help them know whether their choices of compliance options will achieve compliance with the final rule, what the state-specific emissions outcomes might be under different compliance pathways, and the potential impacts on so-called leakage. This section also helps them know the impacts that market prices have on consumers as well as operation of generation within their states.

The tables for each state are organized by the seven compliance pathways in the table columns. The reference scenario (without the CPP) is the first data column. The impact of a particular compliance pathway can be found by comparing the result from the reference scenario to the result of the specific compliance pathway.

The data are organized into groups that coincide with particular interests.

- The first group is related to energy prices and load. The "State LMP" is the weighted average locational marginal price of all loads within the state. The "Energy Price" is the system-wide energy price before considering congestion and losses. The "State LMP" and the "Load (GWh)" can be multiplied to get an aggregate cost to load.
- The second group shows the output of generation resources in the state by technology/fuel type. This information shows how the CPP may affect specific resource types in a state.
- The third group shows the emissions prices under rate-based pathways (ERCs) or mass-based pathways (allowances). It is possible to compare regional versus state-only emission costs.
- Groups 4 through 6 provide the demand and production of ERCs for the regional rate-based compliance pathway, trade-ready rate-based compliance pathway and state rate-based compliance pathway in this order. When combined with the ERC prices, a state's net ERC position and the value of the position can be determined in the ERC market under rate-based compliance.
- The seventh group provides energy efficiency at the state level, which produces ERCs on a one-for-one basis and is not included in other ERC production.
- The eighth block provides information to assess mass-based allowance trading. The CO_2 emissions mass target is equal to the allowances allocated to the state for existing sources only. Emissions from existing resources can be compared with this target to determine if the state is a net buyer or net seller of allowances under mass-based compliance pathways for existing resources that involve regional trading. The CO_2 mass target, plus the new source adjustment, provides the mass limit and incremental allowance allocation. This information can be used to compare emissions under the new source complement compliance pathways that regulate new sources. When combined with allowance prices in Group Three, the net financial allowance position can be determined.

Table 6. Delaware State Detail (2025)

Delaware									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	48.3	48.7	48.3	52.5	52.3	47.9	47.5	47.7
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	13,257,986	13,257,986	13,257,986	13,257,986	13,257,986	13,257,986	13,257,986	13,257,986
Fossil Steam Coal	MWh	0	0	0	0	0	0	0	0
Fossil Steam Oil/Gas		15,362	114,876	95,253	168,242	63,763	81,891	100,114	99,081
Combined Cycle Gas		929,511	2,433,318	2,151,199	4,206,748	2,342,099	2,170,696	2,372,757	2,174,065
Combustion Turbine Oil/Gas		14,665	65,090	59,140	113,920	115,623	59,228	61,898	66,072
Nuclear		0	0	0	0	0	0	0	0
Wind		0	0	0	0	0	0	0	0
Utility Scale Solar		0	0	0	0	0	0	0	0
Other		176,103	630,952	568,123	953,770	904,334	523,538	483,398	520,812
Net State Load (Imports)		12,122,344	10,013,750	10,384,271	7,815,306	9,832,168	10,422,633	10,239,819	10,397,955
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	-	-	-
Allowance	$/Ton	-	-	1.3	-	-	-	-	-
New Source Allowance		-	-	-	-	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	1,389	-
Regional ERC Production		-	-	-	-	-	-	762,705	-
Regional Zero-Emitting		-	-	-	-	-	-	-	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	192,224
Trade-Ready ERC Production		-	-	-	-	-	-	-	64,456
Trade Ready Zero-Emitting		-	-	-	-	-	-	-	-
Gas Shift -ERC Production		-	-	-	-	-	-	-	235,343
State ERC Demand	ERC	-	-	-	-	-	29,611	-	-
State ERC Production		-	-	-	-	-	298,399	-	-
State Zero-Emitting		-	-	-	-	-	230,366	-	-
Energy Efficiency		-	-	-	-	-	810,270	810,270	810,270

Delaware									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
CO_2 Mass Target	Tons	4,963,102	4,963,102	4,963,102	4,963,102	4,963,102	4,963,102	4,963,102	4,963,102
New Source CO_2 Adjustment		109,144	109,144	109,144	109,144	109,144	109,144	109,144	109,144
Existing Source Emissions		426,787	1,165,165	1,018,649	2,048,731	1,087,193	1,020,665	1,125,347	1,033,267
New Source Emissions		0	0	0	0	0	0	0	0

Table 7. Illinois State Detail (2025)

Illinois									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	47.0	48.9	48.5	52.6	52.3	47.5	47.6	47.5
Energy Price	$/MWh	46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	111,347,152	111,347,152	111,347,152	111,347,152	111,347,152	111,347,152	111,347,152	111,347,152
Fossil Steam Coal	MWh	25,751,308	22,184,104	19,645,131	21,373,204	12,035,103	24,186,204	13,364,599	25,756,757
Fossil Steam Oil/Gas		155,985	112,743	162,261	98,317	85,126	143,049	149,329	150,595
Combined Cycle Gas		4,931,677	5,559,715	6,049,250	8,960,002	7,349,762	7,540,628	7,864,573	5,788,826
Combustion Turbine Oil/Gas		471,794	484,959	531,815	623,213	695,083	395,164	485,488	455,017
Nuclear		84,230,881	84,230,881	84,230,881	84,230,881	84,230,881	84,230,881	84,230,881	84,230,881
Wind		12,063,375	12,063,375	12,063,375	12,063,375	12,063,375	22,558,475	16,282,787	13,357,949
Utility Scale Solar		13,108	13,108	13,108	13,108	13,108	13,108	13,108	13,108
Other		230,672	230,770	230,922	231,283	231,751	230,385	230,787	230,723
Net State Load (Imports)		-16,501,648	-13,532,504	-11,579,591	-16,246,231	-5,357,038	-27,950,743	-11,274,401	-18,636,705
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	2.8	-	-
Allowance	$/Ton	-	3.5	1.3	-	-	-	-	-
New Source Allowance		-	-	-	6.6	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	9,147,285	-

Illinois									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
Regional ERC Production		-	-	-	-	-	-	2,633,751	-
Regional Zero-Emitting		-	-	-	-	-	-	6,625,983	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	12,865,154
Trade-Ready ERC Production		-	-	-	-	-	-	-	37,545
Trade Ready Zero-Emitting		-	-	-	-	-	-	-	3,701,144
Gas Shift-ERC Production		-	-	-	-	-	-	-	626,640
State ERC Demand	ERC	-	-	-	-	-	13,663,037	-	-
State ERC Production		-	-	-	-	-	3,062,293	-	-
State Zero-Emitting		-	-	-	-	-	252,717	-	-
Energy Efficiency		-	-	-	-	-	10,386,254	10,386,254	10,386,254
CO_2 Mass Target	Tons	32,426,132	32,426,132	32,426,132	32,426,132	32,426,132	32,426,132	32,426,132	32,426,132
New Source CO_2 Adjustment		502,357	502,357	502,357	502,357	502,357	502,357	502,357	502,357
Existing Source Emissions		31,900,249	27,902,521	25,018,306	28,410,125	16,578,995	31,152,203	18,339,013	32,274,838
New Source Emissions		-	-	-	-	-	-	-	-

Table 8. Indiana State Detail (2025)

Indiana									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	46.8	49.1	48.3	52.7	52.5	47.4	47.4	47.3
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	24,597,183	24,597,183	24,597,183	24,597,183	24,597,183	24,597,183	24,597,183	24,597,183
Fossil Steam Coal	MWh	27,825,990	23,271,693	24,833,815	22,095,421	21,828,671	24,771,803	24,833,132	27,825,990
Fossil Steam Oil/Gas		-	-	-	-	-	-	-	-
Combined Cycle Gas		11,426,291	12,015,019	11,919,837	11,744,970	12,039,771	11,977,502	11,978,685	11,801,332
Combustion Turbine Oil/Gas		70,551	76,821	79,140	124,785	142,359	63,344	72,145	67,644
Nuclear		-	-	-	-	-	-	-	-
Wind		6,337,467	6,337,467	6,337,467	6,337,467	6,337,467	6,337,467	6,337,467	6,337,467
Utility Scale Solar		3,794	3,794	3,794	3,794	3,794	3,794	3,794	3,794
Other		90,011	90,012	90,012	90,011	90,008	90,012	89,998	90,012
Net State Load (Imports)		-21,156,921	-17,197,623	-18,666,882	-15,799,265	-15,844,887	-18,646,739	-18,718,037	-21,529,056
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	10.1	-	-
Allowance	$/Ton	-	0.3	1.3	-	-	-	-	-
New Source Allowance		-	-	-	4.6	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	12,798,450	-
Regional ERC Production		-	-	-	-	-	-	2,205,486	-
Regional Zero-Emitting		-	-	-	-	-	-	1,580,825	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	8,036,486
Trade-Ready ERC Production		-	-	-	-	-	-	-	-
Trade Ready Zero-Emitting		-	-	-	-	-	-	-	1,580,825
Gas Shift-ERC Production		-	-	-	-	-	-	-	662,128
State ERC Demand	ERC	-	-	-	-	-	8,970,989	-	-
State ERC Production		-	-	-	-	-	2,599,594	-	-
State Zero-Emitting		-	-	-	-	-	4,626,280	-	-

Indiana									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
Energy Efficiency		-	-	-	-	-	1,754,156	1,754,156	1,754,156
CO_2 Mass Target	Tons	25,082,380	25,082,380	25,082,380	25,082,380	25,082,380	25,082,380	25,082,380	25,082,380
New Source CO_2 Adjustment		389,682	389,682	389,682	389,682	389,682	389,682	389,682	389,682
Existing Source Emissions		30,236,121	25,788,131	27,313,020	24,606,532	24,410,186	27,268,629	27,332,955	30,266,611
New Source Emissions		2,138,058	2,341,834	2,313,593	2,270,625	2,341,238	2,321,274	2,317,593	2,258,371

Table 9. Kentucky State Detail (2025)

Kentucky									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	46.9	48.8	48.4	52.4	52.2	47.4	47.4	47.4
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	22,490,645	22,490,645	22,490,645	22,490,645	22,490,645	22,490,645	22,490,645	22,490,645
Fossil Steam Coal	MWh	16,001,474	12,341,119	15,545,736	10,679,616	11,490,368	12,807,607	12,758,728	16,253,072
Fossil Steam Oil/Gas		144,193	120,886	155,339	152,930	122,804	246,046	161,356	138,904
Combined Cycle Gas		4,310,199	4,641,306	4,526,981	4,613,650	4,641,320	4,595,697	4,603,245	4,339,876
Combustion Turbine Oil/Gas		227,935	259,722	282,082	397,838	464,130	213,969	258,056	236,259
Nuclear		-	-	-	-	-	-	-	-
Wind		-	-	-	-	-	-	-	-
Utility Scale Solar		-	-	-	-	-	699,389	557,758	327,765
Other		357,281	357,281	357,281	357,281	357,281	357,281	357,281	357,281
Net State Load (Imports)		1,449,564	4,770,332	1,623,226	6,289,330	5,414,742	3,570,657	3,794,221	837,487
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	10.7	-	-
Allowance	$/Ton	-	3.7	1.3	-	-	-	-	-
New Source Allowance		-	-	-	8.2	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	6,634,533	-
Regional ERC Production		-	-	-	-	-	-	18,175	-

Kentucky									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
Regional Zero-Emitting		-	-	-	-	-	-	557,758	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	4,816,569
Trade-Ready ERC Production		-	-	-	-	-	-	-	34,084
Trade Ready Zero-Emitting		-	-	-	-	-	-	-	327,765
Gas Shift-ERC Production		-	-	-	-	-	-	-	-
State ERC Demand	ERC	-	-	-	-	-	4,020,061	-	-
State ERC Production		-	-	-	-	-	57,284	-	-
State Zero-Emitting		-	-	-	-	-	2,910,315	-	-
Energy Efficiency		-	-	-	-	-	1,059,942	1,059,942	1,059,942
CO_2 Mass Target	Tons	12,473,710	12,473,710	12,473,710	12,473,710	12,473,710	12,473,710	12,473,710	12,473,710
New Source CO_2 Adjustment		186,421	186,421	186,421	186,421	186,421	186,421	186,421	186,421
Existing Source Emissions		16,116,976	12,410,399	15,662,462	10,758,830	11,553,091	12,940,994	12,845,211	16,371,128
New Source Emissions		1,712,328	1,843,868	1,798,450	1,832,881	1,843,874	1,825,748	1,828,747	1,724,118

Table 10. Maryland State Detail (2025)

Maryland									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	49.1	49.9	50.0	53.6	53.7	48.7	48.7	48.4
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	71,286,273	71,286,273	71,286,273	71,286,273	71,286,273	71,286,273	71,286,273	71,286,273
Fossil Steam Coal	MWh	20,492	9,792,944	2,907,947	7,422,481	2,740,256	9,680,042	2,837,204	4,316,593
Fossil Steam Oil/Gas		40,137	166,064	173,992	217,249	158,523	138,640	136,132	78,986
Combined Cycle Gas		2,868,119	9,882,405	8,409,003	15,493,028	9,939,306	7,715,237	7,124,613	7,044,728
Combustion Turbine Oil/Gas		116,898	257,435	276,384	366,021	392,774	243,564	248,978	227,419
Nuclear		13,823,357	13,823,357	13,823,357	13,823,357	13,823,357	13,823,357	13,823,357	13,823,357
Wind		1,307,735	1,307,735	1,307,735	1,307,735	1,307,735	1,307,735	1,307,735	1,307,735
Utility Scale Solar		253,656	253,656	253,656	253,656	253,656	253,656	253,656	253,656
Other		3,048,202	3,048,192	3,048,206	3,048,201	3,048,201	3,048,195	3,048,196	3,048,187
Net State Load (Imports)		49,807,677	32,754,485	41,085,992	29,354,544	39,622,465	35,075,845	42,506,401	41,185,611
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	-	-	-
Allowance	$/Ton	-	-	1.3	-	-	-	-	-
New Source Allowance		-	-	-	-	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	1,252,876	-
Regional ERC Production		-	-	-	-	-	-	76,756	-
Regional Zero-Emitting		-	-	-	-	-	-	281,797	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	1,187,263
Trade-Ready ERC Production		-	-	-	-	-	-	-	10,209
Trade Ready Zero-Emitting		-	-	-	-	-	-	-	281,797
Gas Shift-ERC Production		-	-	-	-	-	-	-	23,675
State ERC Demand	ERC	-	-	-	-	-	3,357,940	-	-
State ERC Production		-	-	-	-	-	96,003	-	-

Maryland									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State Zero-Emitting		-	-	-	-	-	-	-	-
Energy Efficiency		-	-	-	-	-	4,266,552	4,266,552	4,266,552
CO_2 Mass Target	Tons	15,842,484	15,842,484	15,842,484	15,842,484	15,842,484	15,842,484	15,842,484	15,842,484
New Source CO_2 Adjustment		236,625	236,625	236,625	236,625	236,625	236,625	236,625	236,625
Existing Source Emissions		110,274	10,275,327	2,984,055	7,878,199	2,813,477	10,118,119	2,903,919	4,386,707
New Source Emissions		1,089,423	3,830,285	3,256,184	5,941,474	3,859,109	2,985,484	2,729,555	2,718,086

Table 11. Michigan State Detail (2025)

Michigan									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	46.9	49.5	48.3	53.1	52.9	47.5	47.4	47.4
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	4,471,619	4,471,619	4,471,619	4,471,619	4,471,619	4,471,619	4,471,619	4,471,619
Fossil Steam Coal	MWh	-	-	-	-	-	-	-	-
Fossil Steam Oil/Gas		-	-	-	-	-	-	-	-
Combined Cycle Gas		3,258,509	5,639,324	4,302,495	7,289,262	5,566,444	4,256,503	6,098,811	4,182,493
Combustion Turbine Oil/Gas		-	-	-	-	-	-	-	-
Nuclear		15,818,167	15,818,167	15,818,167	15,818,167	15,818,167	15,818,167	15,818,167	15,818,167
Wind		-	-	-	-	-	-	-	-
Utility Scale Solar		-	-	-	-	-	-	-	-
Other		128,240	128,243	128,243	128,240	128,238	128,243	128,240	128,243
Net State Load (Imports)		-14,733,298	-17,114,115	-15,777,286	-18,764,051	-17,041,230	-15,731,294	-17,573,600	-15,657,284
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	-	-	-
Allowance	$/Ton	-	0.1	1.3	-	-	-	-	-
New Source Allowance		-	-	-	4.6	8.4	-	-	-
Regional ERC	ERC	-	-	-	-	-	-	-	-

Michigan									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
Demand									
Regional ERC Production		-	-	-	-	-	-	2,300,634	-
Regional Zero-Emitting		-	-	-	-	-	-	-	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	-
Trade-Ready ERC Production		-	-	-	-	-	-	-	84,964
Trade-Ready Zero-Emitting		-	-	-	-	-	-	-	-
GS-ERC Production		-	-	-	-	-	-	-	452,755
State ERC Demand	ERC	-	-	-	-	-	-	-	-
State ERC Production		-	-	-	-	-	1,702,639	-	-
State Zero-Emitting		-	-	-	-	-	-	-	-
Energy Efficiency		-	-	-	-	-	318,895	318,895	318,895
CO_2 Mass Target	Tons	2,945,887	2,945,887	2,945,887	2,945,887	2,945,887	2,945,887	2,945,887	2,945,887
New Source CO_2 Adjustment		49,010	49,010	49,010	49,010	49,010	49,010	49,010	49,010
Existing Source Emissions		1,334,425	2,309,132	1,762,151	2,984,854	2,279,406	1,743,012	2,497,302	1,713,079
New Source Emissions		-	-	-	-	-	-	-	-

Table 12. New Jersey State Detail (2025)

		New Jersey							
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	48.2	48.7	48.1	52.6	52.3	47.8	47.4	47.6
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	81,214,732	81,214,732	81,214,732	81,214,732	81,214,732	81,214,732	81,214,732	81,214,732
Fossil Steam Coal	MWh	901,608	861,694	700,159	1,619,492	457,188	776,326	510,911	774,501
Fossil Steam Oil/Gas		20,940	21,895	20,849	32,860	9,055	16,769	23,878	23,966
Combined Cycle Gas		17,668,336	20,442,753	17,221,150	26,258,197	20,326,902	17,920,605	21,329,537	16,876,115
Combustion Turbine Oil/Gas		377,299	340,221	309,525	609,226	626,336	324,084	322,475	334,040
Nuclear		27,500,229	27,500,229	27,500,229	27,500,229	27,500,229	27,500,229	27,500,229	27,500,229
Wind		0	0	0	0	0	0	0	0
Utility Scale Solar		1,442,595	1,442,595	1,442,595	1,442,595	1,442,595	1,442,595	1,442,595	1,442,595
Other		1,570,493	1,397,319	1,499,280	1,209,025	1,344,579	1,371,865	1,423,698	1,493,664
Net State Load (Imports)		31,733,232	29,208,026	32,520,945	22,543,108	29,507,849	31,862,260	28,661,409	32,769,623
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	-	-	-
Allowance	$/Ton	-	-	1.3	-	-	-	-	-
New Source Allowance		-	-	-	-	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	286,140	-
Regional ERC Production		-	-	-	-	-	-	7,791,774	-
Regional Zero-Emitting		-	-	-	-	-	-	1,525,460	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	722,475
Trade-Ready ERC Production		-	-	-	-	-	-	-	562,657
Trade-Ready Zero-Emitting		-	-	-	-	-	-	-	1,525,460
GS-ERC Production		-	-	-	-	-	-	-	1,826,839
State ERC Demand	ERC	-	-	-	-	-	1,219,607	-	-
State ERC Production		-	-	-	-	-	1,356,504	-	-
State Zero-Emitting		-	-	-	-	-	-	-	-

New Jersey									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
Energy Efficiency		-	-	-	-	-	9,490,648	9,490,648	9,490,648
CO_2 Mass Target	Tons	15,803,237	15,803,237	15,803,237	15,803,237	15,803,237	15,803,237	15,803,237	15,803,237
New Source CO_2 Adjustment		400,936	400,936	400,936	400,936	400,936	400,936	400,936	400,936
Existing Source Emissions		8,294,285	9,429,697	7,887,656	12,804,704	8,941,778	8,266,677	9,440,840	7,827,653
New Source Emissions		0	0	0	0	0	0	0	0

Table 13. North Carolina State Detail (2025)

North Carolina									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	48.6	49.1	49.1	52.8	52.7	48.0	48.0	48.1
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	6,860,116	6,860,116	6,860,116	6,860,116	6,860,116	6,860,116	6,860,116	6,860,116
Fossil Steam Coal	MWh	558,564	574,070	520,221	959,758	312,567	512,148	374,554	544,109
Fossil Steam Oil/Gas		0	0	0	0	0	0	0	0
Combined Cycle Gas		140,338	141,749	144,169	268,716	140,672	126,586	150,921	136,581
Combustion Turbine Oil/Gas		0	0	0	0	0	0	0	0
Nuclear		0	0	0	0	0	0	0	0
Wind		704,678	704,678	704,678	704,678	704,678	704,678	704,678	704,678
Utility Scale Solar		489,662	671,802	671,802	671,802	671,802	726,337	671,802	671,802
Other		615,245	615,245	615,245	615,245	615,245	615,245	615,245	615,245
Net State Load (Imports)		4,351,628	4,152,572	4,204,001	3,639,917	4,415,151	4,175,121	4,342,916	4,187,700
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	-	-	-
Allowance	$/Ton	-	0.0	1.3	-	-	-	-	-
New Source Allowance		-	-	-	0.0	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	218,718	-
Regional ERC Production		-	-	-	-	-	-	35,994	-
Regional Zero-Emitting		-	-	-	-	-	-	660,938	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	216,395
Trade-Ready ERC Production		-	-	-	-	-	-	-	-
Trade-Ready Zero-Emitting		-	-	-	-	-	-	-	660,938
GS-ERC Production		-	-	-	-	-	-	-	14,785
State ERC Demand	ERC	-	-	-	-	-	295,798	-	-
State ERC									

North Carolina									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
Production		-	-	-	-	-	30,628	-	-
State Zero-Emitting		-	-	-	-	-	-	-	-
Energy Efficiency		-	-	-	-	-	686,781	686,781	686,781
CO_2 Mass Target	Tons	1,171,777	1,171,777	1,171,777	1,171,777	1,171,777	1,171,777	1,171,777	1,171,777
New Source CO_2 Adjustment		20,138	20,138	20,138	20,138	20,138	20,138	20,138	20,138
Existing Source Emissions		651,339	670,068	614,604	1,136,017	395,895	597,028	465,641	635,505
New Source Emissions		0	0	0	0	0	0	0	0

Table 14. Ohio State Detail (2025)

Ohio									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	46.7	48.8	48.4	52.5	52.2	47.4	47.5	47.4
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	177,389,467	177,389,467	177,389,467	177,389,467	177,389,467	177,389,467	177,389,467	177,389,467
Fossil Steam Coal	MWh	105,764,393	71,882,253	76,425,423	58,036,363	72,389,178	70,996,205	73,990,002	76,938,876
Fossil Steam Oil/Gas		460,859	440,734	495,156	388,727	445,718	674,153	503,847	475,712
Combined Cycle Gas		38,058,061	53,819,375	46,057,386	59,264,159	63,080,432	51,989,832	47,603,100	40,214,779
Combustion Turbine Oil/Gas		751,113	838,549	878,320	1,289,627	1,423,318	694,600	799,693	735,697
Nuclear		16,740,292	16,740,292	16,740,292	16,740,292	16,740,292	16,740,292	16,740,292	16,740,292
Wind		2,417,103	2,417,103	2,417,103	2,417,103	2,417,103	2,417,103	2,417,103	2,417,103
Utility Scale Solar		164,925	164,925	164,925	164,925	164,925	164,925	164,925	164,925
Other		1,178,893	1,178,883	1,178,924	1,178,898	1,178,917	1,178,868	1,178,880	1,178,884
Net State Load (Imports)		11,853,828	29,907,353	33,031,939	37,909,374	19,549,586	32,533,489	33,991,626	38,523,199
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	10.6	-	-

Ohio									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
Allowance	$/Ton	-	3.9	1.3	-	-	-	-	-
New Source Allowance		-	-	-	12.3	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	37,614,380	-
Regional ERC Production		-	-	-	-	-	-	7,716,543	-
Regional Zero-Emitting		-	-	-	-	-	-	281,128	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	22,700,941
Trade-Ready ERC Production		-	-	-	-	-	-	-	300,487
Trade Ready Zero-Emitting		-	-	-	-	-	-	-	281,128
Gas Shift - ERC Production		-	-	-	-	-	-	-	2,318,309
State ERC Demand	ERC	-	-	-	-	-	29,924,600	-	-
State ERC Production		-	-	-	-	-	8,787,370	-	-
State Zero-Emitting		-	-	-	-	-	8,852,964	-	-
Energy Efficiency		-	-	-	-	-	12,328,939	12,328,939	12,328,939
CO_2 Mass Target	Tons	79,539,771	79,539,771	79,539,771	79,539,771	79,539,771	79,539,771	79,539,771	79,539,771
New Source CO_2 Adjustment		1,296,138	1,296,138	1,296,138	1,296,138	1,296,138	1,296,138	1,296,138	1,296,138
Existing Source Emissions		115,322,588	80,462,791	85,425,459	66,700,595	81,465,080	80,467,732	83,147,042	85,924,375
New Source Emissions		6,883,889	13,132,618	9,766,172	15,035,818	16,342,781	11,662,535	10,147,603	7,471,164

Table 15. Pennsylvania State Detail (2025)

Pennsylvania									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	47.5	48.7	48.1	52.6	52.3	47.6	47.2	47.3
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	169,187,550	169,187,550	169,187,550	169,187,550	169,187,550	169,187,550	169,187,550	169,187,550
Fossil Steam Coal	MWh	96,258,144	84,584,592	91,586,249	55,401,259	67,547,132	59,809,820	86,854,175	96,288,617
Fossil Steam Oil/Gas		278,364	195,422	165,834	152,988	154,173	233,305	196,146	202,709
Combined Cycle Gas		58,548,119	95,885,757	89,075,286	109,633,883	112,843,045	98,679,370	91,812,169	76,115,566
Combustion Turbine Oil/Gas		349,755	329,843	323,270	618,866	639,847	305,520	316,649	306,510
Nuclear		78,367,174	78,367,174	78,367,174	78,367,174	78,367,174	78,367,174	78,367,174	78,367,174
Wind		5,150,664	5,150,852	5,150,852	5,150,852	5,150,852	5,150,852	5,150,852	5,150,852
Utility Scale Solar		57,175	57,175	57,175	57,175	57,175	57,175	57,175	57,175
Other		7,042,571	6,543,313	6,823,656	5,896,276	6,387,634	6,470,100	6,541,840	6,993,841
Net State Load (Imports)		-76,864,417	-101,926,578	-102,361,946	-86,090,923	-101,959,484	-79,885,766	-100,108,632	-94,294,896
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	7.4	-	-
Allowance	$/Ton	-	2.4	1.3	-	-	-	-	-
New Source Allowance		-	-	-	11.1	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	41,319,892	-
Regional ERC Production		-	-	-	-	-	-	14,083,708	-
Regional Zero-Emitting		-	-	-	-	-	-	3,227,820	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	25,666,975
Trade-Ready ERC Production		-	-	-	-	-	-	-	464,039
Trade-Ready Zero-Emitting		-	-	-	-	-	-	-	3,227,820
Gas Shift -ERC Production		-	-	-	-	-	-	-	3,540,026
State ERC Demand	ERC	-	-	-	-	-	32,559,772	-	-
State ERC Production		-	-	-	-	-	13,898,494	-	-

Pennsylvania									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State Zero-Emitting		-	-	-	-	-	2,754,103	-	-
Energy Efficiency		-	-	-	-	-	15,973,732	15,973,732	15,973,732
CO_2 Mass Target	Tons	97,204,723	97,204,723	97,204,723	97,204,723	97,204,723	97,204,723	97,204,723	97,204,723
New Source CO_2 Adjustment		1,740,587	1,740,587	1,740,587	1,740,587	1,740,587	1,740,587	1,740,587	1,740,587
Existing Source Emissions		108,413,220	96,937,642	103,055,544	69,044,188	82,253,432	76,455,320	101,069,685	107,648,063
New Source Emissions		9,591,661	24,375,528	22,266,150	29,607,075	29,640,995	22,526,500	20,811,577	17,248,641

Table 16. Tennessee State Detail (2025)

Tennessee									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	47.5	48.8	48.5	52.4	52.2	47.5	47.5	47.5
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688
Net State Load (Imports)	MWh	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688	2,611,688

Table 17. Virginia State Detail (2025)

		Virginia							
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	48.7	49.1	49.1	52.8	52.8	48.0	48.0	48.1
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	130,962,996	130,962,996	130,962,996	130,962,996	130,962,996	130,962,996	130,962,996	130,962,996
Fossil Steam Coal	MWh	13,985,702	14,724,285	12,374,164	13,478,955	9,728,472	13,456,957	9,911,890	13,086,335
Fossil Steam Oil/Gas		349,179	420,732	404,870	396,352	336,791	339,460	399,068	349,114
Combined Cycle Gas		25,905,564	26,915,403	23,460,917	38,651,963	28,997,090	21,787,309	29,500,100	22,255,349
Combustion Turbine Oil/Gas		628,954	555,915	599,435	813,273	959,625	503,551	536,521	486,782
Nuclear		27,217,835	27,217,835	27,217,835	27,217,835	27,217,835	27,217,835	27,217,835	27,217,835
Wind		106,829	106,829	106,829	106,829	106,829	106,829	106,829	106,829
Utility Scale Solar		280,444	4,447,588	2,793,018	6,512,708	6,512,708	7,870,701	6,543,136	6,543,136
Other		7,992,750	7,252,929	7,957,845	5,713,283	6,469,173	7,057,874	7,512,668	7,957,903
Net State Load (Imports)		54,495,739	49,321,480	56,048,084	38,071,797	50,634,473	52,622,479	49,234,949	52,959,713
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready ERC		-	-	-	-	-	-	-	0.1
State ERC		-	-	-	-	-	0.0	-	-
Allowance	$/Ton	-	0.0	1.3	-	-	-	-	-
New Source Allowance		-	-	-	5.5	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	5,023,821	-
Regional ERC Production		-	-	-	-	-	-	10,466,485	-
Regional Zero-Emitting		-	-	-	-	-	-	6,543,136	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	4,244,177
Trade-Ready ERC Production		-	-	-	-	-	-	-	829,411
Trade Ready Zero-Emitting		-	-	-	-	-	-	-	6,543,136
Gas Shift - ERC Production		-	-	-	-	-	-	-	2,133,264

Virginia									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State ERC Demand	ERC	-	-	-	-	-	12,270,674	-	-
State ERC Production		-	-	-	-	-	4,386,081	-	-
State Zero-Emitting		-	-	-	-	-	147	-	-
Energy Efficiency		-	-	-	-	-	12,326,946	12,326,946	12,326,946
CO_2 Mass Target	Tons	28,990,998	28,990,998	28,990,998	28,990,998	28,990,998	28,990,998	28,990,998	28,990,998
New Source CO_2 Adjustment		623,009	623,009	623,009	623,009	623,009	623,009	623,009	623,009
Existing Source Emissions		23,582,969	24,905,893	21,065,596	27,250,293	20,309,437	21,675,947	21,259,420	21,408,202
New Source Emissions		1,263,780	1,157,262	1,134,692	2,270,448	1,303,523	926,918	806,073	1,014,994

Table 18. West Virginia State Detail (2025)

West Virginia									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	46.5	48.6	48.2	52.3	52.0	47.3	47.3	47.2
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	39,924,738	39,924,738	39,924,738	39,924,738	39,924,738	39,924,738	39,924,738	39,924,738
Fossil Steam Coal	MWh	89,613,834	58,861,285	80,920,068	53,629,303	65,521,608	76,633,188	74,344,464	82,167,032
Fossil Steam Oil/Gas		-	-	-	-	-	-	-	-
Combined Cycle Gas		11,904,652	14,527,302	14,042,341	14,537,542	14,461,782	14,124,168	14,191,065	13,343,531
Combustion Turbine Oil/Gas		351,755	399,683	424,683	670,585	732,924	345,763	387,432	344,851
Nuclear		-	-	-	-	-	-	-	-
Wind		2,889,984	2,893,436	2,893,436	2,893,436	2,893,417	2,893,436	2,893,436	2,893,385
Utility Scale Solar		-	-	-	-	-	-	-	-
Other		1,010,732	1,010,727	1,010,727	1,010,727	1,010,727	1,010,727	1,010,727	1,010,732
Net State Load (Imports)	MWh	-65,846,219	-37,767,694	-59,366,516	-32,816,853	-44,695,720	-55,082,543	-52,902,386	-59,834,794
Regional ERC	$/ERC	-	-	-	-	-	-	5.3	-
Trade-Ready		-	-	-	-	-	-	-	0.1

West Virginia									
	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
ERC									
State ERC		-	-	-	-	-	10.8	-	-
Allowance	$/Ton	-	4.7	1.3	-	-	-	-	-
New Source Allowance		-	-	-	8.0	8.4	-	-	-
Regional ERC Demand	ERC	-	-	-	-	-	-	34,615,172	-
Regional ERC Production		-	-	-	-	-	-	-	-
Regional Zero-Emitting		-	-	-	-	-	-	153,667	-
Trade-Ready ERC Demand	ERC	-	-	-	-	-	-	-	20,402,712
Trade-Ready ERC Production		-	-	-	-	-	-	-	-
Trade-Ready Zero-Emitting		-	-	-	-	-	-	-	153,667
Gas Shift-ERC Production		-	-	-	-	-	-	-	-
State ERC Demand	ERC	-	-	-	-	-	18,919,690	-	-
State ERC Production		-	-	-	-	-	-	-	-
State Zero-Emitting		-	-	-	-	-	16,121,490	-	-
Energy Efficiency		-	-	-	-	-	2,809,768	2,809,768	2,809,768
CO_2 Mass Target	Tons	56,762,770	56,762,770	56,762,770	56,762,770	56,762,770	56,762,770	56,762,770	56,762,770
New Source CO_2 Adjustment		834,677	834,677	834,677	834,677	834,677	834,677	834,677	834,677
Existing Source Emissions		87,252,065	56,560,074	78,085,179	51,572,146	63,074,957	73,862,374	71,640,961	79,302,252
New Source Emissions		4,729,403	5,771,312	5,578,650	5,775,380	5,745,283	5,611,158	5,637,734	5,301,031

Table 19. Washington, D.C. State Detail (2025)

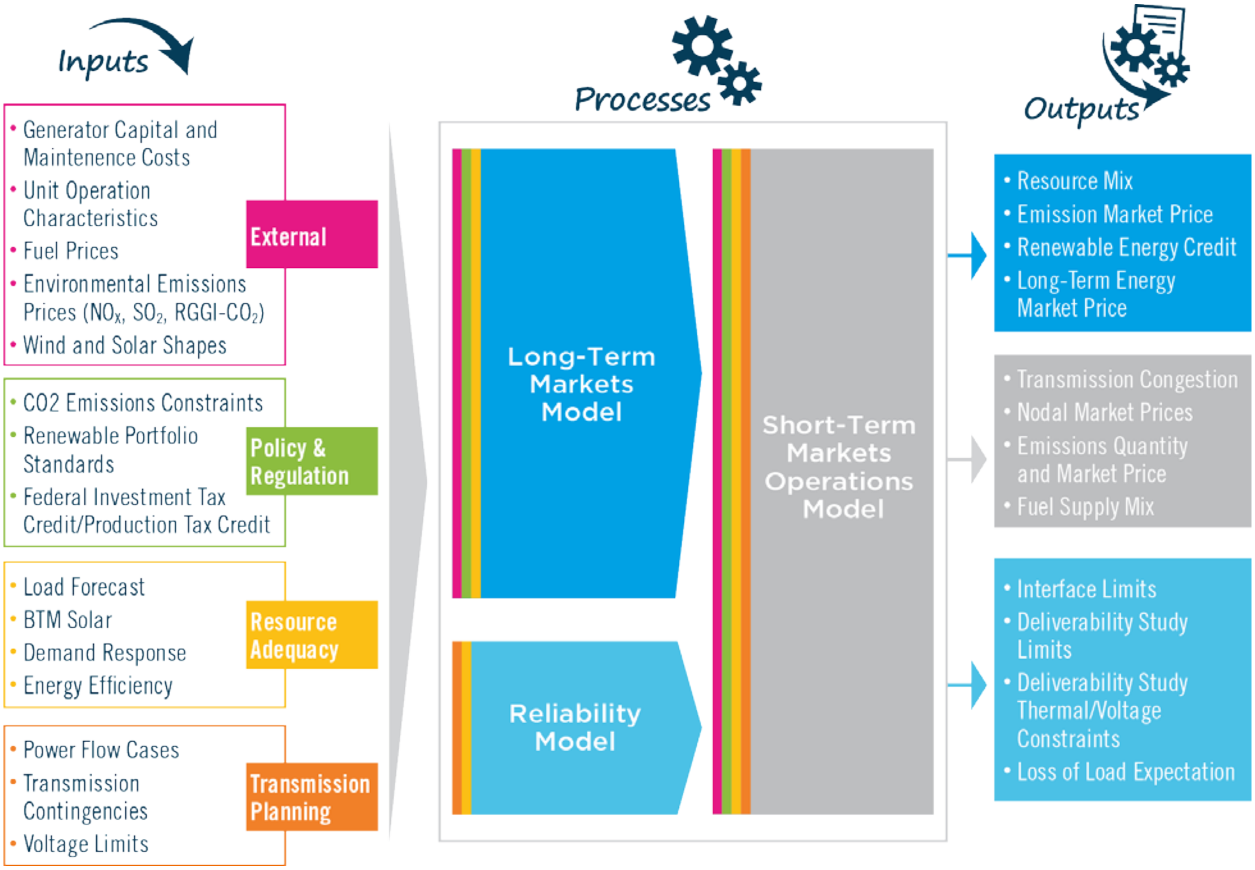
Washington, D.C.	Unit	Reference	State Mass	Trade-Ready Mass	State Mass NSC	Trade-Ready Mass NSC	State Rate	Regional Rate	Trade-Ready Rate
State LMP	$/MWh	49.1	49.4	49.5	53.1	53.1	48.2	48.3	48.2
Energy Price		46.6	48.0	47.5	51.8	51.5	46.8	46.6	46.6
Load	MWh	11,134,565	11,134,565	11,134,565	11,134,565	11,134,565	11,134,565	11,134,565	11,134,565
Fossil Steam Coal	MWh	-	-	-	-	-	-	-	-
Fossil Steam Oil/Gas		-	-	-	-	-	-	-	-
Combined Cycle Gas		-	-	-	-	-	-	-	-
Combustion Turbine Oil/Gas		3,245	3,702	4,305	5,123	5,965	3,060	3,676	3,099
Nuclear		-	-	-	-	-	-	-	-
Wind		-	-	-	-	-	-	-	-
Utility Scale Solar		-	-	-	-	-	-	-	-
Other		-	-	-	-	-	-	-	-
Net State Load (Imports)		11,131,320	11,130,863	11,130,260	11,129,442	11,128,599	11,131,505	11,130,888	11,131,466

Appendix

Key Model Inputs and Procedures – Additional Detail

As shown in Figure 1, the same figure as shown in the body of the paper discussing Key Inputs, PJM's analysis of the CPP is a comprehensive review of the regulation's impacts on both the market and system reliability within the PJM footprint. The discussion below provides additional detail on the various key modeling inputs used in the analysis.

Figure 1. PJM's Clean Power Plan Modeling Framework



Additional External Inputs

PJM performed a comprehensive review of sources of information to support the study assumptions about the cost of new entry for combined cycle gas resources and renewables, technical life and life extension costs, heat rates, capacity factors, and avoidable costs (such as going-forward costs) and depreciation. To remain transparent, PJM limited sources to those publicly available and generally accepted for use within this type of study, which are presented in Table 1.

Table 1. External Input Sources for PJM's Clean Power Plan Model

<table>
<tr><th></th><th>Combined Cycle</th><th>Combustion Turbine</th><th>Nuclear</th><th>Coal</th><th>Solar</th><th colspan="2">Wind</th></tr>
<tr><td>Overnight Capital Costs</td><td>PJM 2014 CONE Study[a]</td><td>PJM 2014 CONE Study[a]</td><td>EPA Base Case v5.13[c]</td><td>N/A</td><td>NREL 2015 ATB (2018 Technology Year)[c]</td><td colspan="2">NREL 2015 ATB (2018 Technology Year)[c]</td></tr>
<tr><td>Technical Life[a]</td><td>30</td><td>30</td><td>40</td><td>N/A</td><td>20</td><td colspan="2">20</td></tr>
<tr><td>Depreciation [b]</td><td>MACRS 20-Year</td><td>MACRS 15-Year</td><td>MACRS 15-Year</td><td>N/A</td><td>MACRS 5-Year</td><td colspan="2">MACRS 5-Year</td></tr>
<tr><td>Avoidable Cost</td><td>PJM 2019/2020 Default ACR[d]</td><td>PJM 2019/2020 Default ACR[d]</td><td>EPA Base Case v5.13[c]</td><td>EPA Base Case v5.13[c]</td><td>NREL ATB 2015 (2018 Technology Year)[c]</td><td colspan="2">NREL ATB 2015 (2018 Technology Year)[d]</td></tr>
<tr><td>Heat Rate (Btu/KWh)</td><td>6,800[a]</td><td>10,300[a]</td><td>10,452[a]</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Capacity Factor</td><td colspan="5">Dispatchable within Model</td><td>NREL 2006 hourly shapes[f]</td><td>NREL 2006 hourly shapes[g]</td></tr>
<tr><td>Locational Costs Adders</td><td>PJM CONE Study[a]</td><td>PJM 2014 CONE Study[a]</td><td>EIA 2013 Capital Costs[f]</td><td colspan="2"></td><td>EIA 2013 Capital Costs[h]</td><td>EIA 2013 Capital Costs[h]</td></tr>
</table>

a. The Brattle Group and Sargent & Lundy, Cost of New Entry Estimates for Combustion Turbine and Combined Cycle Plants in PJM: With June 1, 2018 Online Date, prepared for PJM Interconnection, LLC, (PJM 2014 CONE Study) May 15, 2014. (http://pjm.com/~/media/documents/reports/20140515-brattle-2014-pjm-cone-study.ashx.)

b. United States Internal Revenue Service, Publication 946—Additional Material, Table A-1. (https://www.irs.gov/publications/p946/ar02.html.)

c. United States Environmental Protection Agency, *Documentation for EPA Base Case v. 5.13 Using the Integrated Planning Model* (EPA Base Case v 5.13), November 2013. (https://www.epa.gov/airmarkets/power-sector-modeling-platform-v513.)

d. National Renewable Energy Laboratory, *Annual Technology Baseline 2015* (NREL 2015 ATB), July 2015. Data (http://www.nrel.gov/docs/fy15osti/64077-DA.xlsm) and summary slide presentation (http://www.nrel.gov/docs/fy15osti/64077.pdf.) For modeling purposes, PJM used the 2018 technology year and assumed that costs would remain at these levels in real terms throughout the study period.

e. *PJM RPM Default Avoidable Cost Rates for the 2019/2020 Delivery Year* (PJM 2019/2020 Default ACR). (http://pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2019-2020-default-avoidable-cost-rates.ashx.)

f. http://www.nrel.gov/electricity/transmission/solar_integration_methodology.html

g. http://www.nrel.gov/electricity/transmission/solar_integration_methodology.html

	Combined Cycle	Combustion Turbine	Nuclear	Coal	Solar	Wind
h. United States Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants* April 2013, (EIA 2013 Capital Costs) http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf. These capital costs are used as inputs into the National Energy Modeling System to prepare the Annual Energy Outlook and other requested reports. The cost differentials are reported by NERC Sub-region and state.						

Gas Markets and Infrastructure and Gas Price Forecasts

This section is provided to those readers interested in the dynamics of the natural gas market and how this has impacted various gas price forecasts used in the analysis and discussed within the body of the paper. Natural gas prices are a big driver of the results of PJM's modeling of various compliance pathways for the EPA's CPP.

Its relatively low price has been forecast by some entities such as IHS CERA and, to some extent, the EIA to continue throughout the study period. This is due to the abundance of shale gas resources in North America and in particular the Marcellus shale play, which underlies a significant portion of PJM's footprint as shown in Figure 2.[68] This abundance has led to a sharp decline in natural gas prices beginning in 2007 and, coupled with technological advances improving the efficiency of natural gas wells (shown in Figure 3), sustained low prices. In this same time frame, natural gas generators clearing in the capacity market has increased from 38 percent of the total installed capacity to 44 percent (as shown in Figure 4) and the share of electricity being generated from gas-fired generators increased from 7.7 percent in 2007 to 23 percent in 2015. This increased the importance of the resource to PJM markets and operations.[69]

This growing importance led PJM to participate in a comprehensive analysis of the gas infrastructure's capability to serve the future needs of electric generation. The Gas-Electric System Interface study[70] found that the overall pipeline infrastructure in the region was robust and that minimal potential for natural gas constraints exist in PJM during peak periods five and 10 years into the future. Subsequent to this infrastructure analysis, PJM is participating in efforts underway at the FERC and within the industry to examine new models for funding new gas infrastructure, while also providing more flexible service to generators. This included efforts to modify PJM's forward capacity market to better enable recovery of costs to firm fuel, and the movement of PJM's Day-Ahead Market to better align with the natural gas markets and transportation schedules.

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[68] The map of pipelines and shale gas basins was developed by PJM with information from Ventyx (a division of ABB).

[69] *See* 2015 State of the Market Report, Section 3, Table 3-8 for the 2015 gas percentage. For the 2007 gas percentage, *See* PJM Interconnection, LLC, Market Monitoring Unit, *2007 State of the Market Report: Volume 2* ("2007 State of the Market Report"), Section 3, Table 3-31 at 145, March 11, 2008. Available electronically at http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2007/2007-som-volume2-sec3.pdf.

[70] Information regarding the Eastern Interconnection Planning Collaborative's Gas-Electric System Interface Study may be found at: http://www.eipconline.com/gas-electric.html.

Figure 2. Natural Gas Pipelines, Shale Gas Plays and ISOs

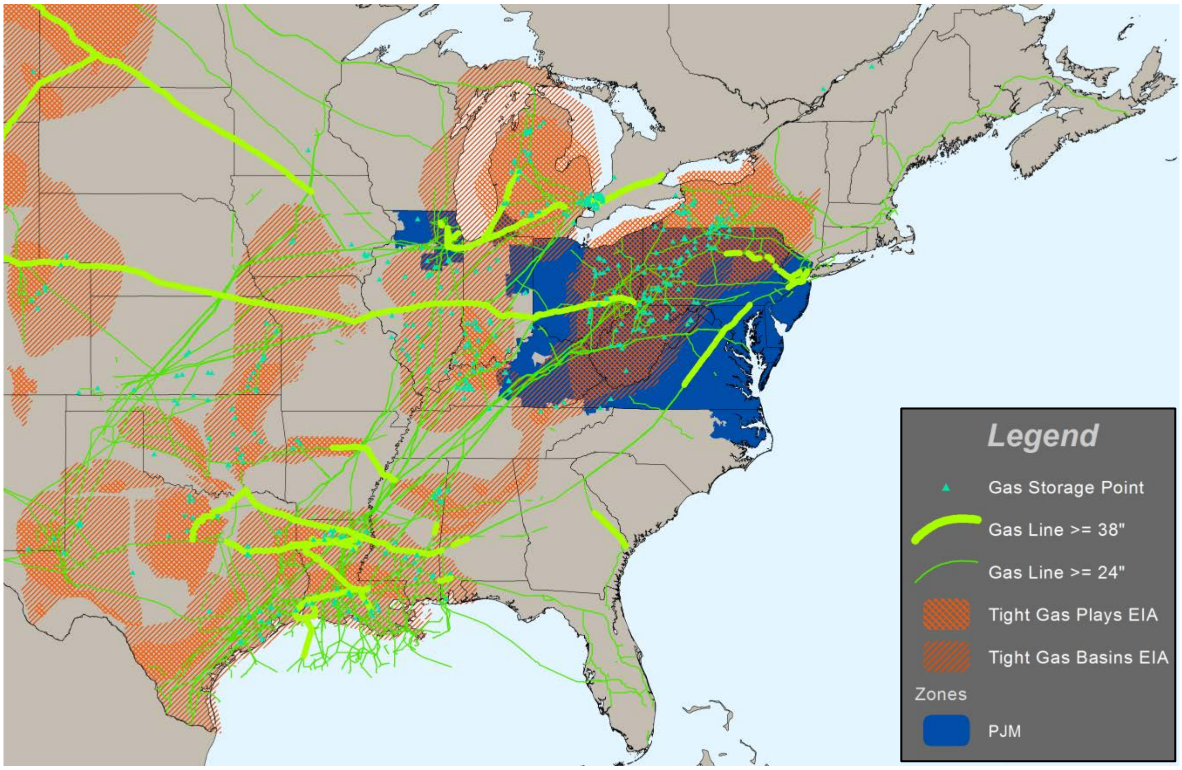
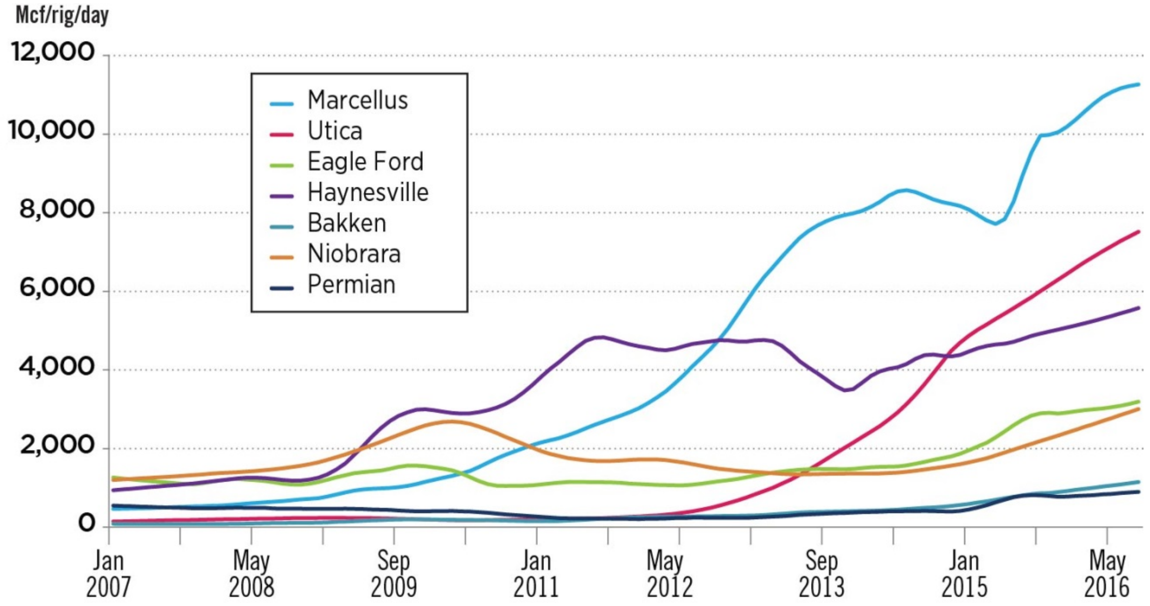


Figure 3. Rig Productivity[71]



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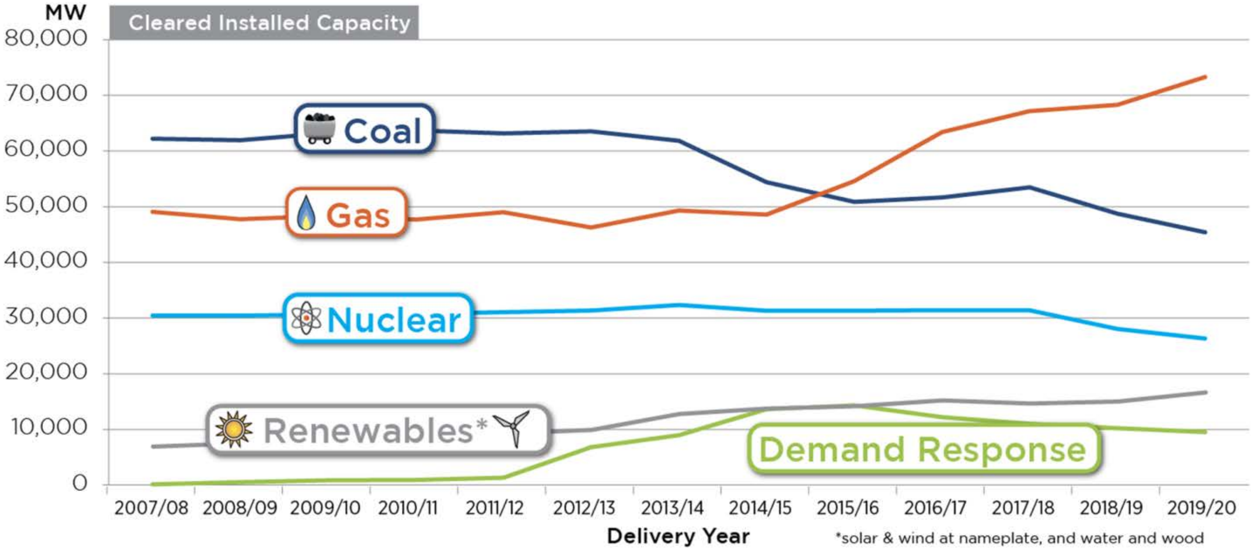
[71] Developed by PJM from information contained in U.S. Energy Information Administration Drilling Productivity Report: http://www.eia.gov/petroleum/drilling/.

Figure 4. Cleared Installed Capacity [72]



Federal Investment, Production Tax Credits and Utility-Scale Renewable Resources

Utility-scale renewables are an output of the long-term economic model and thus reflect the extension of the federal Investment Tax Credit (ITC) and Production Tax Credits (PTC). During development of the long-term economic model, the ITC was 30 percent of qualifying capital investment through the end of 2016, 10 percent of qualifying capital investment thereafter. In December 2015, the United States Senate extended the ITC; it will remain 30 percent of qualifying capital investment through 2019, then decline gradually for two years before falling to 10 percent of qualifying capital investment.[73]

Similar to the ITC, the PTC declines through 2019 to 40 percent of its 2016 value.[74] For both these credits, PJM based the credit value on an assumed start of construction and not the actual date on which the model brings the resource online, which is consistent with the IRS tax provisions. In the long-term model, the PTC is represented as a decrease in the capital investment required based on the present value of credit revenue associated with future energy production.

Unlike the ITC, the PTC can potentially impact system operations. In the short-term model, 10-years post-commencement of commercial operation, the PTC is reflected in wind units energy market bid prices. Generally, wind resources' bids have limited or no impact on market price formation, except in areas where there is severe

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[72] PJM Interconnection, LLC, *RPM Commitments by Fuel Type and Delivery Year.* Available electronically at http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/rpm-commitment-by-fuel-type-by-dy.ashx.

[73] *See* the *Database for State Incentives for Renewables & Efficiency* ("DSIRE") maintained by the North Carolina Clean Technology Center and their entry discussing the ITC available electronically at http://programs.dsireusa.org/system/program/detail/658. The extension for the ITC was done under the *Consolidated Appropriations Act, 2016,* December 15, 2015 available https://www.gpo.gov/fdsys/pkg/BILLS-114hr2029enr/pdf/BILLS-114hr2029enr.pdf.

[74] *See* DSIRE and their entry discussing the PTC available electronically at http://programs.dsireusa.org/system/program/detail/734. The extension for the PTC was done under the *Consolidated Appropriations Act, 2016,* December 15, 2015 as cited above.

transmission congestion or system conditions where there is insufficient load to accommodate the wind with other inflexible resources.

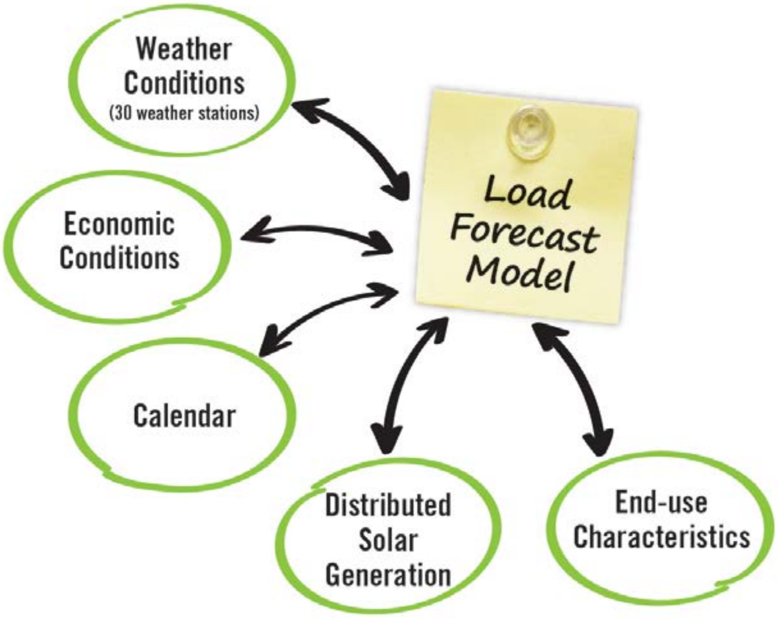
The technology cost assumption for utility scale renewable resources and all other technologies are based on a 2018 model year for consistency and because the wind and solar profiles are already aggressive when compared to the actual historical performance of these resources within PJM.[75]

Load Forecast Process

The PJM load forecast[76] starts with an econometric model that estimates the historical impact of load (peak and energy) from a range of different drivers including calendar effects, weather variables, economics, end-use characteristics (equipment/appliance saturation and efficiency), and distributed solar generation, shown in Figure 5.

Among other factors, PJM's load models capture evolving customer behaviors; which includes adoption of more efficient manufacturing equipment and home appliances and rooftop solar installations in both the commercial and residential sectors. Each year PJM's load forecast model produces a 15-year forecast assuming normal weather for each PJM zone and the RTO.

Figure 5. Load Forecast Model Variables



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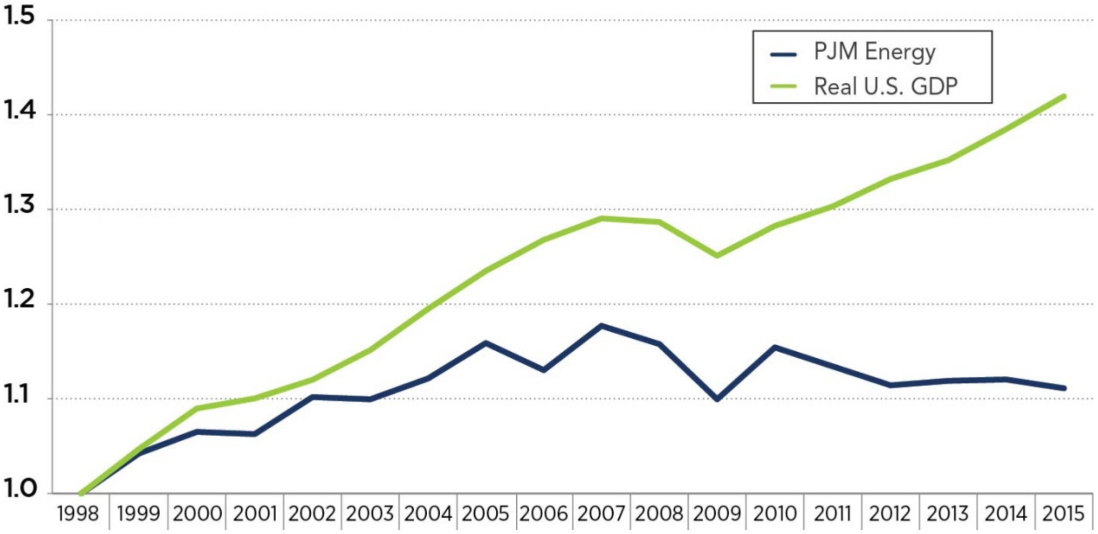
[75] NREL 2015 ATB.

76 Additional detail describing PJM's load forecasting process can be found in the following on-line documentation: Load Forecasting White Paper: available electronically at http://www.pjm.com/~/media/planning/res-adeq/load-forecast/2016-load-forecast-whitepaper.ashx and PJM Manual 19, "Load Forecasting and Analysis:" electronically available at http://www.pjm.com/~/media/documents/manuals/m19.ashx

Evolution of PJM's Total Energy Forecast

Explicit treatment of end-use characteristics and distributed solar generation were new additions to the load forecast model in 2016. Previously, these characteristics were captured only in the system metered load. The breakdown in the relationship of energy to economics drove this model change. The data in Figure 6 demonstrates how the relationship between economics and energy has become increasingly decoupled for several decades. Since 1998, the US economy is more than 40 percent larger, yet total energy consumption was approximately 17 percent larger in 2007, but has fallen back to only being a 10 percent increase in the past 17 years. In large part, this reflects the continued evolution to a more service-driven economy and, consequently, a less energy-intensive economy as exacerbated by the accelerated proliferation of more energy efficient electrical appliances and equipment.

Figure 6. Decoupling Energy from Economics[77]



End-use characteristics are captured through three distinct variables designed to capture the various ways in which electricity is used, both weather sensitive – heating and cooling – and non-weather sensitive. Each variable addresses a collection of different equipment types accounting over time for both the saturation of that equipment type as well as its respective efficiency. For instance, the cooling variable captures that central air conditioning units have become, and continue to be, more commonplace and increasingly efficient.

Energy Efficiency

The energy efficiency forecast is calculated through sensitivity work using the load forecast model. PJM does not explicitly forecast energy efficiency but instead captures within the load forecast model how energy efficiency reduces system load. Energy efficiency is the product of households and businesses employing increasingly efficient

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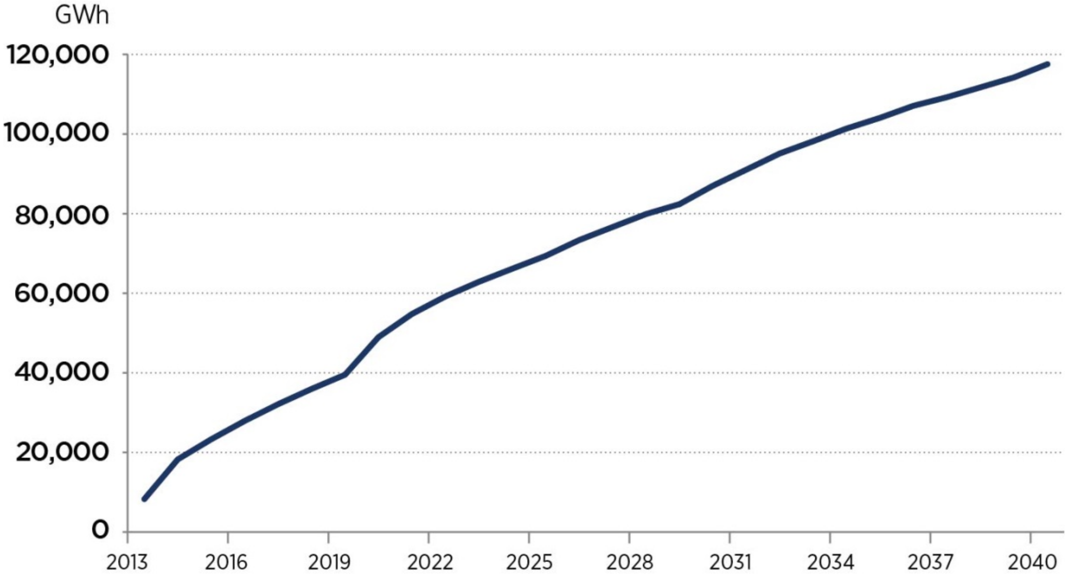
[77] Real GDP data annually from January 1, 1929 to January 1, 2015 can be obtained from the Federal Reserve Economic Data Base ("FRED") electronically at https://fred.stlouisfed.org/series/GDPCA and it shows that Real GDP is 42 percent higher in 2015 than in 1998. Total energy data through 2014 can be obtained from the 2016 Load Forecast Report, Table F-2 available electronically at http://pjm.com/~/media/documents/reports/2016-load-report.ashx and for 2015 can be found at http://pjm.com/pub/operations/hist-meter-load/2015-hourly-loads.xls.

appliances, equipment and processes. PJM's forecast model uses these trends as an input and reflects that energy efficiency activity will impact system load into the future.

While the load forecast model reflects future energy efficiency in its forecast, it is necessary for CPP analysis to know the magnitude of this reduction. The energy efficiency forecast shown in Figure 7 is derived using a two-step process described below:

1. The efficiency trends of all appliances and equipment used by the load forecast model are modified to be held at their 2012 levels. These series are then used to produce an alternate load forecast, one in which there are no improvements in efficiency post-2012.
2. This alternate load forecast is then compared with the baseline load forecast, with the delta being the amount attributable to efficiency improvements. This amount is the PJM energy efficiency forecast. By 2025, energy use is forecast to have been reduced slightly more than 7 percent and close to 11 percent by 2040 due to the natural turnover in appliance and equipment stock to more up-to-date and energy efficient replacements.

Figure 7. PJM Energy Efficiency Forecast



Behind-the-Meter Distributed Solar Generation

Distributed solar generation acts to lower load from what it otherwise would be. Recent years have witnessed a significant ramp-up in behind the PJM meter distributed solar resources: rising over 2,000 MW since 1998, with more than 90 percent of installations since 2010. And while the 2016 load forecast accounts for ever increasing amounts of distributed solar energy, it is only approximately 1/9 the impact of energy efficiency on the load forecast shown in Figure 7.[78]

Though not a large amount from an RTO perspective, the level of distributed solar is significant in certain areas of PJM and is expected to increase more in the years to come. Under PJM's model update, distributed solar generation impacts are reflected in the forecast using the following approach.[79]

1. First, PJM estimates the historical distributed solar generation hourly production. Estimates are developed using historical installed capacity, DC-to-AC conversion factors, solar insolation, cloud cover, solar panel efficiency degradation due to temperature, and panel tilt angle. These estimates are then combined with load history to produce a hypothetical forecast as if there was no distributed solar generation.

2. Second, PJM uses a vendor-supplied forecasted distribution of solar capacity additions over the next 15 years. The vendor forecast takes into consideration assumptions for federal and state policy, net energy metering policy, energy growth, solar photovoltaic capital costs, power prices and other factors. In order to have a long-term distributed solar forecast incorporated into the long-term load forecast the assumptions were frozen as of Nov. 30, 2015.

3. The resulting forecast is then discounted for expected panel degradation over time, and for expected production during PJM's peak given that peak solar production does not align with peak energy demand. This yields zonal distributed solar peak capacity forecasts. These values are subtracted from the hypothetical forecast discussed in the first step to produce final zonal and load distribution areas peak demand forecasts, as shown in Figure 8.

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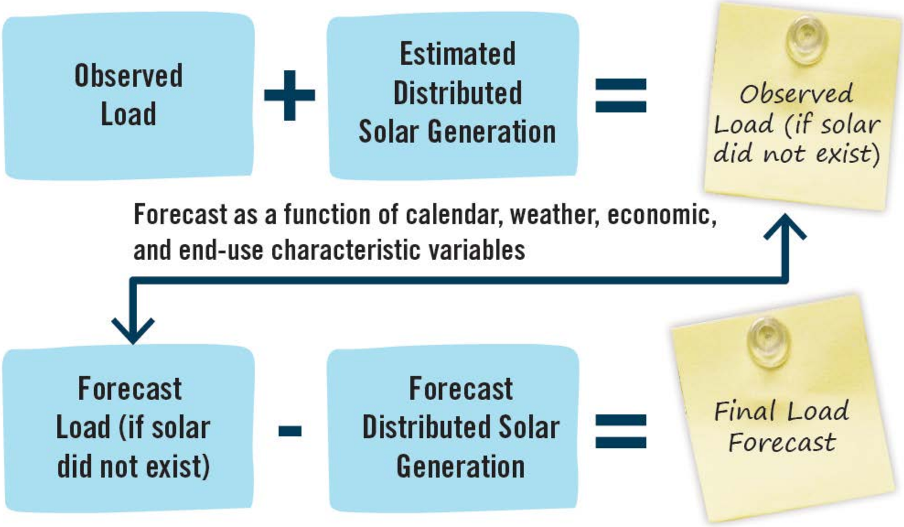
[78] *See* "2016 Distributed Solar Forecast Data" provided by the PJM Resource Adequacy Planning Department available electronically at http://pjm.com/~/media/planning/res-adeq/load-forecast/2016-solar-forecast-data.ashx.

[79] *See* "Manual 19 Changes: Distributed Solar Generation in the Long-Term Load Forecast", December 17, 2015 available electronically at http://pjm.com/~/media/planning/res-adeq/load-forecast/solar-forecast-presentation.ashx.

Figure 8. Accounting for Distributed Generation



During development of the load forecast assumptions, the Investment Tax Credit was 30 percent of qualifying capital investment through the end of 2016, 10 percent of qualifying capital investment thereafter. In December 2015, the United States Congress extended the ITC; it will remain 30 percent of qualifying capital investment through 2019, and then decline gradually for two years before falling to 10 percent of qualifying capital investment.[80]

Net metering policies currently in effect were assumed to remain in effect through the forecast period. The average annual rate of change for solar capital costs was assumed to be negative 4 percent.[81]

The annual retail power price escalation rate averaged over the forecast period was assumed to be 2.3 percent, and the annual wholesale power price available to solar escalation rate averaged over the forecast period was assumed to be 2.2 percent.[82]

Although the ITC extension is not assumed in the development of distributed solar, the combination of assumptions used to derive the distributed solar forecast provide a reasonable projection for use in the CPP Planning model. Given renewable portfolio standard policies effective during development of the model assumption, the growth in distributed solar in PJM states will cause solar renewable energy credits prices to trend lower in the model, which signifies supply and demand balance.

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[80] *See* DSIRE discussions at http://programs.dsireusa.org/system/program/detail/734 and http://programs.dsireusa.org/system/program/detail/658.

[81] For a summary of these assumptions see IHS Energy, "Solar PV Capacity Addition Forecast for PJM States: Summary report", November 30, 2015 at 5. Available electronically at http://pjm.com/~/media/committees-groups/subcommittees/las/20151130/20151130-item-04-ihs-pjm-pv-forecast-report.ashx.

[82] *Id.* at 6.

Renewable Portfolio Standards and Renewable Energy Credit Markets

While the majority of the PJM analysis of the CPP did not include renewable portfolio standards, PJM ran a set of sensitivities with RPS policies enforced. Moreover, the operation of ERC markets has many similar characteristics to renewable energy credits markets that are in operation to satisfy RPS mandates – should states in the PJM region opt for rate-based compliance and possibly rate-based trading regimes.

Status of Renewable Portfolio Standards Policies

According to a recent Renewable Portfolio Standards Status Report prepared by Lawrence Berkeley National Laboratory[83], nationwide achievement of RPS requirements has thus far been high, with states collectively meeting roughly 95 percent of their interim RPS targets in recent years[84]. In the PJM region states have fully met their interim non-solar RPS targets with the exception of Illinois, where alternative retail electric suppliers are required to meet 50 percent of RPS with alternative compliance payments (ACPs)[85]. With respect to solar targets, most PJM states fully achieved the targets over 2012-2014 with two exceptions. The District of Columbia faces inherent challenges of an exclusively urban market and, in Illinois, rules for alternative retail suppliers incentivize them to use ACPs for 100 percent of solar requirements[86].

Recent Developments in PJM States' Renewable Portfolio Standards Policies

Through the first two quarters of 2016, two jurisdictions in the PJM region have passed legislation updating renewable portfolio standards laws.

Maryland

On May 28, 2016, Maryland Governor Larry Hogan vetoed the Clean Energy Jobs – Renewable Energy Portfolio Standard Revisions bill (SB0921/HB1106) due to cost to ratepayers. The legislation would have increased the state's Renewable Portfolio Standard to 25 percent by 2020 – up from the current obligation of 20 percent by 2022, while the solar requirement would have increased to 2.5 percent by 2020 – up from the current obligation of 2.0 percent by 2022. The RPS bill passed in the House and the Senate earlier this year with veto-proof majorities, so there is potential for the bill to become law despite the Governor's veto. The veto override vote will not take place until January 2017 unless a special session is held before then.

District of Columbia

On June 29, 2016, the D.C. Council unanimously passed B21-0650, the Renewable Portfolio Standard Expansion Amendment Act of 2016, on its second reading. Mayor Muriel Bowser signed the bill on July 25 and it is now under

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[83] In addition to the references cited in this subsection, another good source of data on the status of RPS policies and their mechanics is the *Database for State Incentives for Renewables & Efficiency* ("DSIRE") maintained by the North Carolina Clean Technology Center at http://www.dsireusa.org/.

[84] "U.S. Renewables Portfolio Standards 2016 Annual Status Report", Galen Barbose, Lawrence Berkeley National Laboratory, April 2016, at 2. Available electronically at https://emp.lbl.gov/sites/all/files/lbnl-1005057.pdf.

[85] *Id.* at 24

[86] *Id.* at 25

Congressional review, with a projected enforcement date of November 2016. The RPS Expansion Amendment Act of 2016 will increase the RPS and solar carve-out requirements to 50 percent and 5 percent by the year 2032, respectively, and increase alternative compliance payments (financial penalties) for electricity suppliers who fail to comply with RPS requirements.

Renewable Energy Credit Markets and Clean Power Plan Compliance

Renewable portfolio standard programs are one of many possible compliance options states could rely upon to achieve emission targets under the CPP[87]. In states with mass-based plans, RPS policies can help the state reduce emissions indirectly by displacing emitting generation, although the emitting generation displaced may be in other parts of the PJM footprint. The total amount of emissions from all affected electric generating units is lower because the RPS helps bring more emission-free generation online[88]. A state that chooses to take a state-measures approach in a mass-based plan can have an RPS count directly toward CPP compliance, as long as the state proposes the RPS as one of the state measures in its plan. In this approach, a state would submit a plan that relies in whole or in part on an RPS to reduce emissions[89].

For rate-based plans, an RPS can help a state satisfy its CPP goals by producing more renewable energy that is eligible for ERCs. RPS resources can contribute to compliance with CPP emissions rate targets through the supply of ERCs to offset emissions from affected fossil-fired electric generating units[90]. Tracking systems developed to support verification of state RPS compliance could also help market participants track ownership of CPP compliance instruments and, ultimately, help states verify their CPP performance. The use of existing tracking system infrastructure is discussed in more detail below as it applies to states in the PJM region.

Leveraging Existing Renewable Energy Credit Tracking System Infrastructure

PJM Environmental Information Services, Inc. (PJM EIS) is a wholly-owned subsidiary of PJM Technologies, Inc. PJM EIS was formed to provide environmental and emissions attributes reporting and tracking services to its subscribers in support of renewable portfolio standards and other information disclosure requirements that may be implemented by government agencies. PJM EIS owns and administers the Generation Attribute Tracking System (GATS). PJM EIS's GATS exists to help states and load serving entities comply with renewable portfolio standard obligations as well as emissions and fuel mix disclosure requirements, both often imposed by the jurisdictional state agencies. The PJM EIS GATS system could be used to help the compliance entity in demonstrating they are in compliance with the EPA CPP, as well as help states address certain administrative aspects of the CPP[91].

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[87] Clean Energy States Alliance, "The EPA Clean Power Plan and State RPS Programs," Prepared for the RPS Collaborative by Ed Holt, President, Ed Holt & Associates, May 2016. Available electronically at http://cesa.org/assets/Uploads/CESA-RPS-CPP-report-May-2016.pdf.

[88] *Id.* at 7.

[89] *Id. at 7*.

[90] *Id. at* 6.

[91] Comments of PJM EIS on the EPA CPP Final Rule, January 22, 2016.

The functional design of the GATS was developed through considerable deliberation, beginning in 2001, of stakeholders from various state agencies in the PJM region (such as state public utility commissions, state environmental protection offices, state energy offices and consumer advocates) as well as PJM market participants, environmental advocates, other PJM stakeholders and PJM staff.

The GATS provides a central venue for renewable generators and distributed generators, such as homeowners with solar panels, to track their electricity output through the issuance of certificates. A certificate refers to an electronic record of generation data representing all of the attributes from one MWh of electricity generation from a generating unit registered in the GATS tracking system. A renewable energy credit is a certificate from a renewable energy source and is typically certified by at least one state. The system maintains a database of all certificates. Each certificate, with the environmental attributes it represents, can be bought, sold or transferred by electricity market participants and other parties, such as environmental groups. The system tracks the transfer of each renewable energy credit from owner to owner, from the time the credit is created until its retirement by the final purchaser.

The GATS and tracking systems like it provides a single, integrated regional system for state regulatory agencies and market participants that supports the emissions-disclosure requirements and renewable portfolio standards of states The GATS serves this function in the PJM region, covering all or part of 13 states and the District of Columbia. Eight states and the District of Columbia utilize GATS to verify compliance with their renewable energy mandates, providing GATS users with the capability to seamlessly and cost-effectively transfer RECs across state borders. It not only ensures accurate accounting and reporting of generation attributes but, through the use of RECs, provides the basis for a robust market for electricity from renewable sources. ERCs could follow a similar path as RECs with regard to the use of the GATS in the PJM region.

The GATS tracks all generation within the PJM region to support fuel mix and emissions disclosure for the PJM states. The GATS provides system mix reports with emission rates for sulfur dioxide, nitrogen oxides and carbon dioxide, and this reporting might be extended to an individual state basis. Emissions rates are calculated annually for each generator with the use of publicly available EPA data, which collects resource information and identifies the state where the resource is located, thereby enabling state-only compliance plans where desired. Account holders have the ability to enter actual generator emissions on a monthly basis, if desired.[92].

GATS can be modified to accommodate compliance with the CPP, particularly with regard to a rate-based state plan and the creation of the emission rate credits. Existing REC tracking systems likely have advantages over an EPA-administered system.

- EPA tracking systems are for ERCs and/or allowances only and not for renewable energy credits. States with a renewable portfolio standard (or electricity labeling policies that rely on certificate tracking) could leverage economies of scope and scale in having a "one stop shop" for a tracking system;

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[92] Historically, where a unit-specific emission rate is not available, the GATS will use a plant emission rate calculated by the EPA, or a fuel-type default emission rate. This works well for CO_2 emissions as the combustion method or other abatement technologies are not a factor in computing CO_2 emissions.

- Generation data need only be submitted and verified to, and accounts managed only on, one tracking system, the same system that will be issuing ERCs and RECs, reducing administrative burden for buyers and sellers.

Changes will be needed to be made within the existing tracking systems to create ERCs, but such changes would be minimal given the infrastructure exists. The existing systems would have to accommodate affected EGU plant efficiencies, gas-shift emission rate credits, incremental nuclear, energy efficiency, and any other ERC -eligible technologies. Additional modifications would be needed to allow for the transfer of ERCs to and from other EPA-approved emission rate credits tracking systems, including an EPA-administered ERC tracking system used to administer a federal plan.

Energy Efficiency Evaluation, Measurement & Verification

Although evaluation, measurement and verification (EM&V) standards do not play a direct role in the PJM analysis of the CPP (as energy efficiency is embedded in the load forecast as described both in this Appendix and in the body of the paper in the Key Inputs section), EM&V standards play a role in the sensitivity run where it is assumed 50 percent of the EE in the load forecast does not satisfy EM&V protocols and cannot create ERCs that can be used for compliance – although the EE still is assumed to reduce load. The discussion below centers on EM&V used by the states for their EE programs and in PJM for the capacity market as a way to achieve resource adequacy.

Current Status of EM&V

Several states in the PJM region have implemented EE programs in response to state legislative requirements or state commission policies.[93] These initiatives have included the development of EM&V standards. The purpose of EM&V is to quantify and verify the energy reductions achieved by the EE measures implemented at end-use sites, which could be one component of EM&V for rate-based compliance under the CPP.

State commissions use the measured impact of EE programs to judge the effectiveness of programs, to justify the recovery of program costs through customer rates, and to evaluate the performance of utilities. Congressional appropriations related to the American Recovery and Reinvestment Act of 2009 enabled many states to expand the EE programs offered by utilities, electric cooperatives and special purpose EE utilities.[94] Appropriations for the Act also funded U.S. Department of Energy work designed to overcome barriers to EE deployment and to improve and streamline EE programs, including EM&V.

The supportive state and federal EE policies described above provide context for EE participation in PJM's capacity market. Wholesale market rules designed to ensure resource adequacy for PJM's bulk power grid include provisions for competing generation, demand response and energy efficiency resources. The locational energy and capacity

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[93] *See Database for State Incentives for Renewables & Efficiency* ("DSIRE") maintained by the North Carolina Clean Technology Center at http://www.dsireusa.org/.

[94] *American Recovery and Reinvestment Act 2009,* January 6, 2009, Title IV. Available electronically at https://www.gpo.gov/fdsys/pkg/BILLS-111hr1enr/pdf/BILLS-111hr1enr.pdf.

market price signals inform the EE investment decisions of both EE providers (curtailment service providers) and end-use customers.

These transparent prices reveal the locations where EE investments will provide the greatest value to the grid and inform end-use customers' valuations of both energy and capacity. Three-year forward capacity auctions enable EE providers to make bids that are financially workable if cleared and then give EE providers three years to fulfill capacity commitments.

Qualified EE measures became eligible to participate in the PJM capacity market beginning with the 2011/2012 Delivery Year. Qualified EE resources must:

- Achieve a permanent, continuous reduction in electric energy consumption
- Not require of notice, dispatch or operator intervention
- Exceed then-current building codes, appliance standards or other relevant standards, at the time of installation, as known at the time of commitment as a capacity resource

Compliance of EE resources committed to ensure the capacity adequacy of the PJM region requires rigorous measurement and verification standards which can be found in the PJM *Manual 18B: Energy Efficiency Measurement & Verification.*[95] These standards include review and approval of a measurement and verification plan by PJM before offering the EE resource into the capacity auction as well as review and approval of a post-installation measurement and verification report by PJM each year the EE participates as a capacity resource.

The focus of measurement and verification standards for capacity market participation differs from the focus that applies to EE programs implemented by the states. The EM&V focus for state-sponsored EE programs is the total kilowatt-hour reduction achieved annually. The measurement and verification focus for EE resources participating in the capacity market is the kilowatt impact during the summer between 2 p.m. and 6 p.m.

The processes and procedures set forth in PJM Manual 18B leverage existing standards and provide for M&V plans before the CSP offers EE megawatts into the capacity market auction and post installation reports that confirm the availability of committed EE megawatts. The final CPP rule issued by the Environmental Protection Agency also leverages the "significant EM&V infrastructure in place … particularly with regard to the quantification and verification of energy savings resulting from utility-administered EE programs."[96] The requirement that "[r]ate-based state plans must require that eligible resources document in EM&V plans and M&V reports how all MWh saved and generated from eligible measures will be quantified and verified" aligns with the requirements imposed on EE measures committed as capacity resources in the PJM wholesale market.[97]

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[95] PJM Manual 18B: Energy Efficiency Measurement & Verification, Revision 02, 12/17/2015. Available electronically at http://pjm.com/~/media/documents/manuals/m18b.ashx.

[96] Clean Power Plan, Section VIII K 3. b. at 64909.

[97] *Id.*

Capacity market rules require offers to equal or exceed 100 kW or 0.1 MW. Market rules also allow aggregation of EE resources to achieve minimum offer requirements. EE resource participation in the capacity market has increased each year as shown in the Table 2.

Table 2. MW (UCAP) of Generation, Demand Resources and Energy Efficiency Offered and Cleared[98]

	Auction Results (all values in UCAP**)											
	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020
Generation Offered	131,165	132,614	132,125	136,068	134,873	147,189	144,109	157,691	168,716	166,205	166,910	172,071
DR Offered	716	937	968	1,652	9,848	12,953	15,546	19,956	14,507	11,294	11,676	11,818
EE Offered	-	-	-	-	653	757	832	940	1,157	1,340	1,306	1,650
Total Offered	131,881	133,551	133,093	137,720	145,373	160,898	160,486	178,588	184,380	178,839	179,891	185,540
Generation Cleared	129,061	131,339	131,252	130,857	128,527	142,782	135,034	148,806	155,634	154,690	154,506	155,443
DR Cleared	536	893	939	1,365	7,047	9,282	14,118	14,833	12,408	10,975	11,084	10,348
EE Cleared	0	0	0	0	569	679	822	923	1,117	1,339	1,247	1,515
Total Cleared	129,598	132,232	132,191	132,222	136,144	152,743	149,975	164,561	169,160	167,004	166,837	167,306
Uncleared	2,283	1,319	902	5,499	9,230	8,155	10,512	14,027	15,220	11,835	13,054	18,234

* RTO numbers include all LDAs ** UCAP calculated using sell offer EFORd for Generation Resources. DR and EE UCAP values include appropriate FPR and DR Factor.

Future Status of EM&V

PJM's rigorous measurement and verification standards can impose significant transactions costs for capacity market participation, depending on the EE measure. More rigorous requirements for capacity resources – known as Capacity Performance – will be effective June 1, 2020. These tougher Capacity Performance requirements expand the impact of EE measures on peak reductions beyond the summer period and may add additional transaction costs or foreclose direct participation for some EE measures that may not be available all year, but these do not prevent EE that is already in place and embedded in the load forecast to contribute toward emission reductions, nor do Capacity Performance EM&V requirements have a direct bearing on EM&V for energy savings that can create ERCs.

The American Recovery and Reinvestment Act of 2009 funded deployments of advanced metering infrastructure, together with two-way communication from the customer edge of the grid, are reducing transactions costs associated with measurement and verification for end-use customers. Meters capable of producing hourly or 15-minute interval

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[98] "2019/2020 RPM Base Residual Auction Results," PJM Interconnection LLC, May 24, 2016, at 21. Available electronically at http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2019-2020-base-residual-auction-report.ashx.

usage values enable customers who install EE measures to demonstrate impacts on usage and to obtain value in markets that provide proper price signals.

The application of other smart grid technologies, sometimes referred to as the digitalization of the grid, are providing customers and their utilities with timely information based on analysis of advanced metering infrastructure usage data and other variables like weather.

The convergence of locational marginal prices for energy and capacity with communications and computing technology innovations will significantly improve the tools customers can use to make investment and usage decisions as well as the tools state regulators and utilities can use to evaluate EE programs with less regulatory lag. Not only EE but also other distributed energy resources (including, but not limited to, demand response, storage and behind-the-meter generation) can take advantage of technology innovation. The convergence of market and technology trends will support state compliance for states opting for rate-based compliance measures under the Clean Power Plan.