PJM Interconnection Economic Analysis of the EPA Clean Power Plan Proposal

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Executive Summary

At the request of the Organization of PJM States, Inc., PJM Interconnection has analyzed potential economic impacts on electric power generation in the PJM footprint resulting from the U.S. Environmental Protection Agency's Clean Power Plan. The plan, proposed by EPA in June 2014, seeks a 30-percent reduction in carbon dioxide emissions from the electricity sector by 2030 (compared to 2005 levels). PJM does not take positions for or against pending regulations but does provide independent expert analysis on the potential economic and reliability impacts of proposed regulatory rules and legislation.

The Organization of PJM States, which represents state utility regulators in the region served by PJM, requested analyses of several scenarios including a comparison of regional compliance versus state-by-state compliance. PJM included additional scenarios with different assumptions in the analysis to provide modeled results covering a wide range of possible outcomes. In total PJM analyzed 17 distinct scenarios – each was evaluated with and without the implementation of the Clean Power Plan. The scenarios covered varying combinations and levels of renewable resources, energy efficiency, natural gas prices, nuclear generation and new entry of natural gas combined-cycle resources.

This report is the first of two PJM evaluations of the proposed Clean Power Plan. It presents an analysis of the Clean Power Plan's potential economic impacts, including the identification of fossil-fueled steam generation capacity thought to be "at risk" for retirement based only upon energy market simulation results. PJM has not attempted to simulate capacity market outcomes in conjunction with the energy market simulations. PJM will use the results of the economic analysis to conduct a reliability analysis to determine transmission needs resulting from potential generator retirements.

The results of PJM's analyses are not predictions of future outcomes; rather, they are assessments of possible impacts based on specific assumptions and tempered by uncertainties. Those uncertainties include future market conditions, the form of the final EPA rule and the manner in which states choose to comply. PJM's analyses offer insights into the complex interactions between wholesale electricity prices, generation at risk for retirement, changes in natural gas prices, energy efficiency, renewable resources, nuclear generation and compliance costs associated with the Clean Power Plan. This analysis attempts only to quantify the change in production costs as a cost of compliance with the Clean Power Plan. PJM did not attempt to quantify the capital costs of renewable resources, energy efficiency, or new combined-cycle generation that may be associated with complying with the Clean Power Plan because such decisions may be due to existing state policies or to otherwise-economic decisions for new entry independent of the Clean Power Plan.

High-level insights from the economic analysis include:

- Fossil steam unit retirements (coal, oil and gas) probably will occur gradually. As the CO_2 emission limits decline over time, the financial positions of high-emitting resources should become increasingly less favorable, with lower-emitting resources displacing them more often in the competitive energy market.

- Electricity production costs are likely to increase with compliance because larger amounts of higher-cost, cleaner generation will be used to meet emissions targets.
- The price of natural gas likely will be a primary driver of the cost of reducing CO_2 emissions if natural gas combined-cycle units become a significant source of replacement generation for coal and other fossil steam units.
- Adding more energy efficiency and renewable energy and retaining more nuclear generation would likely lead to lower CO_2 prices; this could result in fewer megawatts of fossil steam resources at risk of retirement because lower CO_2 prices may reduce the financial stress on fossil steam resources under this scenario.
- State-by-state compliance options, compared to regional compliance options, likely would result in higher compliance costs for most PJM states. This is because there are fewer low-cost options available within state boundaries than across the entire region. However, results will vary by state given differing state targets and generation mixes. PJM modeled regional versus individual state compliance only under a mass-based approach.
- State-by-state compliance options would increase the amount of capacity at risk for retirement because some states likely would face higher CO_2 prices in an individual compliance approach.

Introduction and Purpose

On June 2, 2014, the U.S. Environmental Protection Agency (EPA) released the Clean Power Plan, its proposed rule for reducing greenhouse gas emissions in the form of carbon dioxide (CO_2) from existing fossil-fueled electric generating units. On September 2, 2014, the Organization of PJM States, Inc., (OPSI) which represents state utility regulators in the PJM Interconnection footprint, requested PJM analyze some of the potential economic impacts of the proposed Clean Power Plan under a variety of scenarios. The OPSI-requested simulation outputs included: total emissions, emissions rates and resulting CO_2 prices, locational marginal price (LMP) effects, changes in energy market payments by load, percentage of generation by fuel type, generator net energy market revenue, and compliance costs. Furthermore, using generator net energy market revenues to conduct an assessment of fossil-steam generation at risk for retirement (primarily coal, but also oil and gas steam) was also of interest. Finally, OPSI also requested analysis of regional compliance options versus state-by-state compliance options under a limited set of scenarios and years.

In addition, PJM supplemented the OPSI-requested scenarios with eight additional scenarios related to different assumptions regarding natural gas prices, available energy efficiency, renewable energy resources, and available new entry of renewable energy and natural gas combined-cycle resources, plus three additional individual state compliance scenarios and an emissions rate based compliance scenario. PJM's choice of additional scenarios to model was designed to supplement the OPSI request and to provide model results under a wide range of possible outcomes.

In total, between the OPSI-requested and PJM additional scenarios there were 17 different assumption scenarios each run with and without the limits set forth in the Clean Power Plan proposal. The scenarios range from high penetration of renewable resources and energy efficiency and lower gas prices to limited new renewable resources and energy efficiency, high gas prices, reduction in nuclear generation, and limited new entry of combined-cycle resources.

This analysis is the first of two parts of PJM's evaluation of the effect of the EPA proposed Clean Power Plan on PJM's markets and on potential reliability implications. Our economic analysis seeks to provide potential impacts of the proposal to help inform decisions at the state and federal levels. As indicated, this analysis focusses on the economic impacts of the Clean Power Plan on PJM's energy market alone. The resulting identification of generation capacity "at risk" for retirement that will then be used in the subsequent PJM reliability analyses to determine the potential range of transmission reliability criteria violations that would require transmission upgrades. PJM's labeling of generation as being "at risk" for retirement does not mean that the resources will in fact retire due to the proposed Clean Power Plan because PJM has not simulated capacity market outcomes associated with the energy market results. Moreover, the PJM analysis attempts only to quantify the change in production costs as a cost of compliance with the Clean Power Plan. PJM did not quantify the capital costs of renewable resources, energy efficiency or new combined-cycle resources that may be associated with complying with the Clean Power Plan as such decisions may be due to existing state policies or to otherwise-economic decisions for new entry independent of the Clean Power Plan.

PJM as an Independent Source of Expert Information

PJM is an independent source of expert information. It does not advocate particular energy or environmental policies, nor is it forecasting market outcomes. PJM takes no position as to the wisdom or legality of the proposed Clean Power Plan as that is not PJM's area of expertise.[1] PJM's primary focus is on reliability, followed by the operation of efficient and non-discriminatory markets in which PJM is resource-, fuel-, age-, size-, and technology-neutral.

Focusing on the Qualitative Results

The outcomes of various scenarios were dependent upon the input assumptions and were designed to examine a wide range of potential states of the industry as they relate to demand, fuel prices, and energy efficiency and renewable energy penetration when the Clean Power Plan is in effect. PJM's choice of additional scenarios to model were designed to supplement the OPSI request and to provide model results under as wide a range of possible outcomes as possible.

Moreover, the Clean Power Plan has not been finalized and, even beyond that, state compliance plans will not be known for at least another year and a half, and could look very different from what has been reported in this paper. However, understanding the possible impacts early in the process is essential for PJM stakeholders and the PJM planning process in order to inform decision making and ensure grid reliability is maintained.

Additionally, there are a multitude of other pending, implemented or recently finalized environmental regulations that will interact with the Clean Power Plan. Any attempt to analyze the Clean Power Plan along with these other regulations would only complicate the analysis and would make it more difficult to derive useful insights regarding the Clean Power Plan. A summary of other environmental regulations and possible interactions with the Clean Power Plan is provided in Appendix 2.

While the modeling conducted for the analysis was very data intensive, and the results presented under various scenarios highlight specific changes to wholesale prices, load energy payments, net energy revenues for existing steam resources and compliance costs due to changes in resource dispatch, these numerical results are dependent on assumptions about industry conditions such as fuel costs, load growth, technological advancements and the form of state compliance plans in 2020, 2025 and 2029. Many things can change in the interim regarding industry conditions, as we have observed over the past eight years with a major recession, flat to declining demand, and the emergence of the gas production from the Marcellus shale.

Consequently, in light of this uncertainty, the directional changes of wholesale energy prices, compliance costs, generation at risk for retirement due to changes in the levels of natural gas prices, energy efficiency, renewable resources, nuclear generators in service, and available new entry provide the greatest insight regarding the impacts of the proposed Clean Power Plan.

[1] PJM's analysis does not address the legality of the EPA's proposed Clean Power Plan. The use of Clean Air Act Section 111(d) for beyond the fence-line carbon dioxide emissions reductions has faced a mixed reaction from states and industry within PJM's footprint. Indeed, PJM is concerned with the effects on the dispatch of electricity by a Regional Transmission Organization or Independent System Operator depending upon how states implement the Clean Power Plan.

Section 1 – Summary of EPA's Proposed Clean Power Plan

The proposed Clean Power Plan rule only applies to existing fossil-fueled generators, defined as fossil fuel generators in service or under construction as of January 8, 2014. The proposed Clean Power Plan sets emissions rate targets for each state, expressed as pounds of CO_2 per megawatt-hour (lbs/MWh). Power produced by renewable energy resources and verifiable energy savings from energy efficiency would count toward a reduction in a state's emission rate. Natural gas combined-cycle units and combustion turbines under construction after January 8, 2014, are considered new resources and are not automatically subject to the proposed Clean Power Plan; rather, they are subject to New Source Performance Standards (NSPS) under Section 111(b) of the Clean Air Act. The EPA has proposed, however, that states may opt to include new resources in their Section 111(d) compliance plans.

Compliance with the EPA's proposed Clean Power Plan is set to begin in 2020 with interim goals that decline over time until the final target is achieved by 2029. During this interim period states are allowed to average emissions over the years implying the ability to "bank" earlier emissions reductions to be used in later years of the interim period or "borrow" reductions that must be repaid in later years of the interim period. Final compliance is on a rolling three-year basis starting in 2030 where banking and borrowing can effectively take place during those three-year compliance periods.

Clean Power Plan Emissions Rate Targets

The EPA sets state-specific carbon reduction targets (composite CO_2 emission rates, lbs/MWh) based on each state's generation mix in 2012 and EPA's estimate of the state's ability to reduce its carbon dioxide intensity to create the Best System of Emissions Reduction[2]. These reduction targets were developed using four so-called "Building Blocks" as specified below:[3]

1. Generator heat rate improvements of 6 percent;
2. Re-dispatch from coal to natural gas combined-cycle generation that results in existing combined-cycle natural gas units operating up to a 70 percent capacity factor;
3. Renewable energy deployment to reach 13 percent of total energy output, retention of nuclear generation "at risk" for retirement, and nuclear generation under construction; and
4. End-use energy efficiency of 10.7 percent cumulative savings by 2030.

[2] Section 111(a)(1) provides that NSPS are to "reflect the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction and any non-air quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated."
See at: http://www.epa.gov/region9/air/listening/BackgroundEstablishingNewSourcePerformanceStds.pdf . While PJM takes no position with regard to the EPA's interpretation of BSER, BSER as defined in the Clean Power Plan encompasses not just the CO_2 emitting unit, but the entire electricity system.

[3] The EPA also proposed alternate targets that are less stringent but would also be put in place by 2025 rather than 2030. Under these alternative targets generator heat rate improvements would be only 4 percent, re-dispatch to combined-cycle natural gas would be only to a 65 percent capacity factor, renewable energy deployment would be only 9.4 percent of total energy, and energy efficiency would be a 5.2 percent cumulative savings per year.

While these four "building blocks" were used to determine the target emissions rates for each state, compliance plans for the proposed Clean Power Plan do not require these "building blocks" to be met. States may choose to utilize any combination of these options. Additionally, the EPA has noted in the proposed Clean Power Plan that states may propose other potential methods for reaching the proposed emissions rate targets that are not included in the four "building blocks" the EPA used to set the state emissions rate targets.

Clean Power Plan Implementation

The Clean Power Plan proposal puts forth guidelines and standards which the states must use to develop state-specific compliance plans. These state plans are federally-enforceable documents that detail how the state will meet the emission rate targets, or in the alternative, mass-based targets.

Where a state chooses to comply on a stand-alone basis, the default option under Section 111(d) of the Clean Air Act, the proposed Clean Power Plan indicates state compliance plans must be submitted for EPA approval by June 1, 2016. Should states indicate their intention to engage in regional compliance, as discussed below, the state compliance plan deadline would be extended to June 1, 2017, to allow for coordination among states.

The proposed Clean Power Plan envisions varied paths to achieve state-specific emission rate targets:

- States may choose to convert the emissions rate standard to a mass-based standard, effectively converting (lbs of CO_2)/MWh to total tons of CO_2;
- States are permitted to work together to comply with the proposed Clean Power Plan on a regional basis to take advantage of region-wide dispatch already in place under ISOs and RTOs and with multi-state utility systems. Examples of regional compliance include the Regional Greenhouse Gas Initiative (RGGI) for CO_2 emissions, the Title IV SO_2 Trading Program, and the Clean Air Interstate Rule for SO_2 and NO_x emissions;
- States may opt to bring new units subject to the NSPS into the 111(d) compliance plan to the extent they help the state achieve the emissions rate standard;
- State compliance plans may include, but are not limited to use of any combination of the aforementioned "building blocks" or any other emissions reduction strategy.

Ultimately states must meet the targets set by the EPA starting in 2020 and reaching the final target by 2029.[4] On average, the PJM States must reduce their system carbon emission rate 30 percent from 2005 levels. The proposed Clean Power Plan uses 2012 as a baseline for measuring emissions reductions.

[4] Under the EPA's proposed alternative compliance path, this would be by 2025. For 2030 and beyond compliance is based on a three year rolling average at the final target reached in 2029.

Section 2 – PJM Clean Power Plan Modeling Methodology

PJM largely employed the same production cost modeling approach it uses in the Market Efficiency analyses that are embedded in the Regional Transmission Expansion Plan (RTEP) process. However, PJM made certain computational adjustments in the analysis to model emissions compliance for each scenario; it also simplified the analysis to reduce computation times and permit easier interpretation of modeling results.

Production Cost Dispatch Model

PJM used PROMOD IV version 11.1 to conduct the analysis of the EPA's proposed Clean Power Plan. PROMOD is a production-cost simulation modeling platform that performs a security-constrained economic dispatch based on a weekly security-constrained unit commitment and hourly dispatch for user- defined chronological time periods. The granular dispatch enables more detailed and accurate generating unit representation, as well as representation of the transmission system on a nodal basis.

The results from PROMOD can be used to determine hourly, seasonal and annual electric energy/ancillary service market price trends, interchange patterns between different control regions, transmission congestion and emissions levels; they also can be used to perform economic valuations of generation resources. The results from PROMOD are sensitive to the fuel price forecasts used in the model, unit operating characteristics, resource mix, load levels and the power-flow model used to represent the transmission system.

To more accurately assess the potential operational impacts and costs of the Clean Power Plan policy, it is important to have a detailed representation of units observed over the compliance period. PROMOD is capable of dispatching the system based on unit bid and/or cost-based offers. For fossil resources, PROMOD can represent unit operating constraints such as ramp rates, reserve contribution, minimum up/down times, segmented heat rate curves and, perhaps most importantly, planned and forced outage rates. These operating constraints increase volatility in the model by limiting which set of least-cost resources can be committed and/or dispatched within specific periods to serve load.

For intermittent renewable resources, hourly profiles were added to the model to represent monthly and daily variability. Because the variable cost of renewable resources is below all other resources in both PROMOD and in PJM operations, they typically would not set price except during the lowest load hours, when they could also be curtailed for either economic or reliability reasons. The interaction of these intermittent renewable resources with load is very important because the level of coincidence with the peak and even off-peak load determines the types of fossil resources displaced, energy market price impacts and emissions levels measured over a Clean Power Plan compliance period.

Approach to Modeling the Clean Power Plan Scenarios

PJM, at the Organization of PJM States' request, ran five assumption scenarios under a regional mass-based approach for the years 2020, 2025 and 2029 to get a glimpse of compliance over the 10-year interim period. The years 2020, 2025 and 2029 were chosen to examine the effects of the Clean Power Plan at the start of the interim compliance period, a year halfway through the interim period and then the effects of reaching the final targets. Although the rule permits averaging emissions rates over the 2020-2029 period, PROMOD is not a suitable tool for modeling such dynamic compliance options. As a result, each model year assumes compliance with the stated emissions target. PJM also ran one of the five OPSI-requested scenarios under a state-by-state mass-based approach to provide a comparison under the same scenario assumptions between a regional and a state-by-state approach for the year 2020.

In addition, PJM ran eight other assumption scenarios under a regional mass-based approach in order to provide a wider range of possible future condition-scenarios that could occur for Clean Power Plan compliance and outcomes for the years 2020, 2025, and 2029. PJM then ran two of the eight scenarios under a state-by-state compliance approach to provide additional comparisons of state-by-state and regional approaches for the year 2020. PJM also used one of the eight scenarios to run an emission-rate-based regional approach to compare outcomes and glean insights into the differences between a mass-based approach and an emission-rate-based approach for the years 2025 and 2029.[5]

PJM's focus on running most assumption scenarios under a regional mass-based approach does not represent policy advocacy for broad compliance options. The ultimate decision on regional versus state-by-state or mass-based versus rate-based compliance rests with the states, which are responsible for Clean Power Plan implementation. The choice of modeling regional mass-based approaches was made to reduce computational complexity and simulation time.[6]

Modeling Emissions Compliance

Regardless of whether compliance is on a regional or state-by-state basis, the PJM market is modeled as operating the system by committing and dispatching the least-cost mix of resources to meet the PJM system load requirement and ensuring reliability while satisfying the regional or individual state emissions mass- or rate-based targets. Regional compliance modeling methodology results in a single price on CO_2 emissions, expressed in dollars per ton of CO_2 emissions ($/ton) that applies across the entire PJM footprint to all resources in all states. The CO_2 price determined within the PROMOD simulation represents the marginal cost of abatement for CO_2, driven by the difference in dispatch cost between lower-emitting resources, such as combined-cycle natural gas, and higher-emitting resources, such as coal, that results in reducing one more ton of CO_2 emissions.

There are two possible conceptual interpretations to the regional modeling performed by PJM, though PJM takes no position as to the policy implied by each interpretation. The first is that the price on CO_2 is akin to an emissions tax that is adjusted iteratively to ensure that the region served by PJM achieves the mass or rate target. The second is that

[5] As shown in the simulation discussion, there are differences in results from using a mass-based approach to compliance versus a rate-based approach. The difference are driven in part by the idea that new combined-cycle gas resources and combustion turbines with less than a 33 percent capacity factor are not automatically covered by the proposed Clean Power Plan, and, as such, PJM has modeled new combined-cycle gas and combustion turbines as not being subject to the Clean Power Plan.

[6] For each scenario/year combination it takes approximately six hours to run a single iteration. Regional solutions required four to six iterations to converge to a solution with each scenario/year combination requiring 24 to 36 hours of computational time to complete. With 39 scenario/year combinations being run for the regional mass-based approach, up to two months of computational clock time were required to run the Clean Power Plan policy cases. There also were 42 non-Clean Power Plan cases to run for comparison purposes, and, although no iterative approach was needed in these cases, completing these runs could take up to 10 additional days of computational clock time. Fortunately, scenario/year combinations are independent so that simulations could be run simultaneously, in parallel. State-by-state cases took up to 10 iterations to converge due to widely varying resource mixes across the PJM states. The state-by-state cases also required additional programming algorithms to reduce the number of iterations. Each state-by-state case took 60 hours of computational clock time. The regional emission-rate cases converge more slowly than the regional mass-based cases, on average in seven iterations.

emissions (or emissions reductions) can be exchanged between affected resources and across states at the CO_2 price, so long as on balance the emissions target (rate or mass) is ultimately achieved across the footprint[7]. In either case, the cost of CO_2 emissions is treated as an input cost to production just like any other variable input such as fuel or operations and maintenance costs.

Individual state compliance modeling results in a CO_2 price for each state with affected resources (11 states in the PJM simulations), so that, rather than one CO_2 price for the region, there are 11 different CO_2 prices, one for each state.[8] CO_2 costs are treated as generation input costs as in the regional case. And, just as in regional compliance, the same two conceptual interpretations apply, but only within the state boundaries, rather than across the entire PJM footprint.

PJM first ran the model to determine whether the assumptions in the scenario would result in exceeding the PJM-calculated regional or state-by-state emissions target. If that target was exceeded, then PJM determined a CO_2 emissions price (or 11 prices in a state-by-state run) to be applied to each fossil fuel-fired generator that would cause lower-emitting or emission-free generation to replace the higher-emitting generation to achieve the regional or state-by-state mass or rate target. At the end of each iteration, PJM determined whether the emission target was met. If emissions still exceeded the target, the CO_2 price would increase in the next iteration, and conversely, if emissions were below the target, the CO_2 price would decrease in the next iteration. This iterative process continued until the emissions target was met within +/- 0.5 percent.

Clean Power Plan Modeling Approach in the Context of the RTEP Process

Each year PJM develops the Regional Transmission Expansion Plan (RTEP) that looks out 15 years, incorporating the most recent load forecasts and expectations about future generation supply, to identify transmission upgrades required to maintain deliverability of firm resources and meet zonal loads. The 2019 RTEP model was incorporated into PROMOD to facilitate running energy market simulations. By using PROMOD, complementary results can be obtained for use in future reliability analyses to determine transmission upgrades. For example, flows on the transmission system can be evaluated hourly for binding transmission facilities and the economic cost (congestion) associated with mitigating potential transmission facility overloads can be assessed.

The ability to run weekly security constrained unit commitment and hourly security-constrained economic dispatch with detailed generator characteristics and transmission topology is important, given that the Clean Power Plan “building blocks” include significant levels of renewable energy development, energy efficiency deployment and redispatch from coal to natural gas.

Finally, unlike PJM’s market efficiency or interregional planning models used in the RTEP process, where economic interchange is represented between PJM and its neighbors, this analysis is focused only on PJM’s dispatch. First, the proposed Clean Power Plan will likely have very different economic and reliability impacts on PJM’s neighbors because

[7] PJM understands that the states will decide how to comply with the Clean Power Plan. To model effects, PJM must adjust resource dispatch in order to ensure the resources that are operating do not produce emissions that exceed the target. To affect dispatch, PJM models different levels of CO_2 prices until the dispatch results achieve the emissions target.

[8] The PJM portion of Michigan has resources that are well below the emissions reduction targets and by extension, the state carbon dioxide price from a PJM perspective will be zero.

of differing resource mixes, regulatory frameworks and stakeholder processes. Second, earlier environmental policies such as the Mercury and Air Toxics Standards (MATS) have reinforced market trends away from coal to natural gas. Most regions within the Eastern Interconnection will continue to undergo significant transformation with or without the Clean Power Plan. As a consequence, modeling economic energy transfers between PJM and other regions would only add uncertainty and complexity in interpreting the results. Thus, PJM elected to dispatch only its own resources to serve load within the RTO footprint in the modeling.[9]

[9] Historically, PJM has alternated between being a net export versus net import region. Recently PJM has undergone an expansion of its footprint by integrating of additional transmission and load zones. Because of significant resource and load diversity within PJM, economic interchange represents a fraction of the total load served within the RTO.

Section 3 – Overview of Data Inputs and Simulated Scenarios

Rather than developing a reference case to compare against the various compliance scenarios, PJM used the 2014 Market Efficiency case (2014 transmission planning case), for comparison. The studied compliance scenarios varied the level of natural gas prices, renewable resources, nuclear generation in service, energy efficiency and the quantity of available new entry combined-cycle resources. Below are a description of key data inputs and a summary of the compliance scenarios studied.

Generation Resource Mix and Demand Growth

PJM does not run a capacity expansion model in order to meet future installed reserve margin (IRM) target levels nor does it assume that renewable portfolio standards (RPS) will be met in its transmission planning models. Rather, PJM used generation in the PJM generation interconnection queues with an executed Facilities Study Agreement (FSA) or Interconnection Service Agreement (ISA) to determine the level of new generation to include in its transmission planning model. For the Clean Power Plan analysis, PJM used the 2014 transmission planning model for 2019. After accounting for resources that have submitted a deactivation notice to PJM, the FSA and ISA incremental capacity expected to be in service by 2019 is still in excess of PJM's target IRM of 15.7 percent.

PJM does not retire existing resources from its planning model based on end-of-useful life or unfavorable resource economics because this would compromise PJM's independence by effectively taking a position on the commercial viability of existing resources.

In addition, PJM notes that combined-cycle natural gas resources make up the majority of new installed capacity represented in the model, followed by wind units[10]. This has important implications for evaluating the potential impacts of the Clean Power Plan. Even with the announced generation retirements, and the expected mix of new resources being built, PJM has already seen declining CO_2 intensity due to existing environmental policies and lower natural gas prices, an effect that may well be accelerated by the Clean Power Plan.

On the demand side, energy efficiency and demand response resources that clear the PJM Capacity Market reduce the load obligation used in the PJM reserve requirement calculation. Within PROMOD and therefore within PJM's Clean Power Plan analysis, however, these resources have different treatments.[11] Because PJM does not separately identify energy efficiency in its base load forecast that is used in PROMOD, energy efficiency is modeled as a load modifier and is assumed to have the same shape as firm load. This assumption is critical in assessing the results of scenarios with higher penetrations of energy efficiency. Energy efficiency tends to be very diverse within the PJM footprint, and its availability during the peak versus off-peak hours will affect its ability to displace CO_2 emissions. Additionally, demand

[10] In PJM, wind units are only initially allowed to request capacity interconnection rights (CIR) up to 13 percent or 20 percent based on when they entered the interconnection queue. Once in operation, they can request additional CIRs after satisfying performance criteria.

[11] Following from the actual behavior of demand response resources in the PJM energy market, demand resources in the modeling were not considered to be a compliance option and are only dispatched when prices approach the energy market offer cap. This price is significantly higher than the price impacts of the Clean Power Plan compliance scenarios. Consequently, demand resources are not a significant source of emission reductions in the modeling.

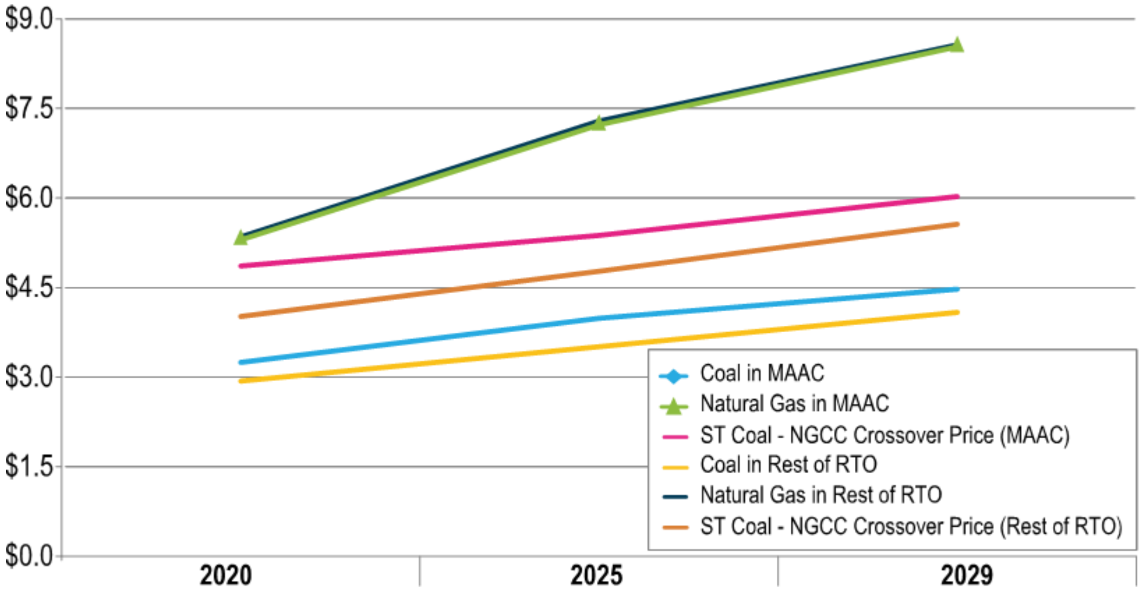
response in PJM predominantly is used only in system emergencies and used less frequently as a consumption reducer on a real-time basis in the energy market.[12]

Fuel Costs Assumptions

For this analysis, PJM used fuel and non-Clean Power Plan CO_2 emissions price forecasts[13] provided by Ventyx, an ABB Company, from its 2014 Spring NERC 9.7 data release. For the analysis time frame of 2020-2029, Ventyx provides an independent annual economic price forecast for each coal resource inclusive of commodity costs and transportation. On the gas side, the U.S. is split into different market regions where a monthly basis adder/decrement is applied by market area to a monthly forecasted Henry Hub natural gas price based on differing demand and supply constraints during the cooling and heating season across PJM. The gas market areas are defined based on major natural gas pipeline/infrastructure serving the region. Each unit in the model is represented with a start-fuel and can also be modeled with secondary or tertiary fuel sources to enable fuel switching.

Figure 1 shows the average coal and natural gas prices calculated using dispatch data taken from the 2014 transmission planning case. Based on the average heat rates and variable operations and maintenance (VOM) costs of combined-cycle natural gas resource and steam turbine coal dispatched in the scenario, the cross-over natural gas price, or the natural gas price at which a combined-cycle natural gas resource becomes lower cost to dispatch than coal resources, is also shown. At the coal and natural gas prices shown in Figure 1, the marginal cost of reducing CO_2 emissions through redispatch is greater than zero, implying a positive price on CO_2 emissions to facilitate that redispatch unless there are sufficient generator retirements, renewable energy developments and energy efficiency measures to achieve the emissions rate or mass targets absent redispatch.

Figure 1. PJM Planning Model Average Delivered Natural Gas and Coal Prices



[12] Demand response as a capacity resource is modeled in this analysis as being dispatched only at the energy market offer cap when needed and, thus, does not contribute meaningfully to reducing total energy reductions.

[13] These would be prices on CO_2 emissions from the Regional Greenhouse Gas Initiative (RGGI), in which Maryland and Delaware participate.

Non-Clean Power Plan Emissions Costs Assumption

The SO_2 prices from the Clean Air Interstate Rule (CAIR) in are set to $0 per short ton reflecting the excess allowances available within the CAIR program at the time the forecast was developed. And even under the Cross State Air Pollution Rule (CSAPR), EPA has projected SO_2 prices to be zero once MATS is implemented. At the same time, seasonal and annual NO_x prices under CAIR or CSAPR are positive in the model, but they are low enough not to have a meaningful impact on the economic dispatch.

Two PJM states, Maryland and Delaware, participate in the Regional Greenhouse Gas Initiative program. The RGGI CO_2 prices in the model grow over time as the number of CO_2 allowances budgeted within the program were reduced in order to incent further reductions in emissions. Maryland and Delaware are net importers of energy within PJM; therefore, the additional costs of RGGI included in the cost-based offers of resources within these states do not impose significant additional economic cost to PJM load. That said, in all scenarios evaluated except the 2014 transmission planning case, the RGGI CO_2 prices are set to zero in order to determine the impact of the Clean Power Plan within a regional or state-by-state compliance framework for PJM.

Deriving the PJM Regional CO_2 Emissions Rate

The EPA provided the following CO_2 emission rate (lbs/MWh) target equation to illustrate how each state's goal is calculated:

$$\frac{2012\ Affected\ EGU\ Emssions\ (\mathrm{lbs})}{2012\ \text{Affected EGU MWh} + \text{Renewable MWh} + 5.8\%\ \text{Existing Nuclear MWh} + \text{New EE MWh}}$$

On a national basis, the calculation of the emissions rate is based on reaching a 10.7 percent cumulative energy efficiency savings by 2030 relative to 2012 load and an assumption that renewable energy would satisfy 13 percent of the total energy demand from 2030 forward relative to 2012 load. EPA's 2012 affected electric generating unit (EGU) emissions were based upon an assumed heat rate improvement of six percent for coal-fired resources and a redispatch from coal generation to natural-gas combined-cycle generation that would result in natural-gas combined-cycle units running up to a ceiling of a 70 percent capacity factor.

For the PJM footprint as a whole, the resulting emissions rates are shown in Table 1. In large measure, growth in energy efficiency and renewable resources is driving the goal rates and grow at a near constant rate as a percentage of load. As a result, the average target rate between 2020 and 2029 is between the 2024 and 2025 target rates shown in Table 1. Additional explanation of the calculation of emissions rates may be found in Appendix 4.

Table 1. PJM Target CO_2 Emissions Rate Simulated

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Average	Final
1,398	1,372	1,346	1,319	1,292	1,264	1,237	1,212	1,187	1,163	1,279	1,163

Developing the PJM and State Mass Targets Used in the Analysis

On Nov. 6, 2014, the EPA provided two alternative methods for states to perform the rate-to-mass conversion. The first method is intended to calculate a mass target for existing sources and does not account for incremental load growth, while the second option includes new sources, assuming that all new load growth would be met by new sources. PJM's analysis summarized in this report employs the first option as described below:

Target CO2 Rate x [Max (2012 Affected EGU MWh-Incremental Renewable Energy-Incremental Energy Efficiency-New Nuclear, 0)+Total Renewable Energy+5.8 percent Nuclear +Incremental energy efficiency]

For states within PJM, this equation can be reduced to the following: Target CO_2 Rate x [2012 Affected EGU MWh + 2012 renewable energy + 5.8 percent Nuclear]

The November 6 guidance used by PJM in the analysis results in declining mass targets through 2029. Effectively the November 6 guidance does not provide credit for new energy efficiency and renewable energy resources. Instead, efficiency and renewable resources are assumed to displace existing generation. The rate-to-mass conversion results are shown in Table 2 for the November 6 guidance. Additional discussion of various rate-to-mass conversion issues can be found in Appendix 5.

Table 2. Rate-to-Mass Conversion – CO_2 Emission Target (Millions of Short Tons)

	2020	2025	2029
November 6 Rate-to-Mass Equation	387	354	327

Scenario Summaries Descriptions

In analyzing the scenarios, PJM's intention was not to determine the relative effectiveness or implementation costs of each so-called "building block," as the relative effectiveness will depend on other scenario assumptions and model inputs. However, organizing the analysis around isolating how changes in the building blocks or other compliance pathways from one scenario to another change the simulation outputs permits, meaningful qualitative observations to be made about the effects of changing different building blocks or compliance pathways. Further, while PJM modeled publicly announced fuel conversions from coal to gas steam or coal to combined-cycle gas, PJM did not model generator heat rate improvements (Building Block #1) since it is assumed that the gains from heat rate improvements have already been achieved due to the competitive pressure to reduce costs and maximize profits in the PJM-operated wholesale power market.

OPSI-Requested Scenarios

Table 3. Definition and Assumptions of the OPSI Requested Scenarios

<table>
<tr><th>OPSI Scenarios</th><th>Fossil & Nuclear Resources</th><th>Renewables</th><th>Energy Efficiency</th></tr>
<tr><td>OPSI 2a</td><td>Existing and Planned Resources (ISA and FSA only)</td><td>PJM RPS Requirement</td><td rowspan="2">100% EPA EE</td></tr>
<tr><td>OPSI 2b.1</td><td colspan="2">Existing and Planned Resources (Non-Renewable: ISA and FSA only,
*Wind/Solar – FSA, ISA, SIS and FEAS</td></tr>
<tr><td>OPSI 2b.2</td><td>Existing and Planned Resources (ISA and FSA only)</td><td rowspan="3">PJM RPS Requirement</td><td>50% EPA EE Goals</td></tr>
<tr><td>OPSI 2b.3</td><td>Existing and Planned Resources (ISA and FSA only)
Increase Natural Gas Price by 50%</td><td rowspan="2">100% EPA EE</td></tr>
<tr><td>OPSI 2b.4</td><td>Existing and Planned Resources (ISA and FSA only)
50 % Reduction in Nuclear Capacity</td></tr>
<tr><td>OPSI 2c</td><td colspan="3">Same as OPSI 2a – but state-by-state compliance</td></tr>
</table>

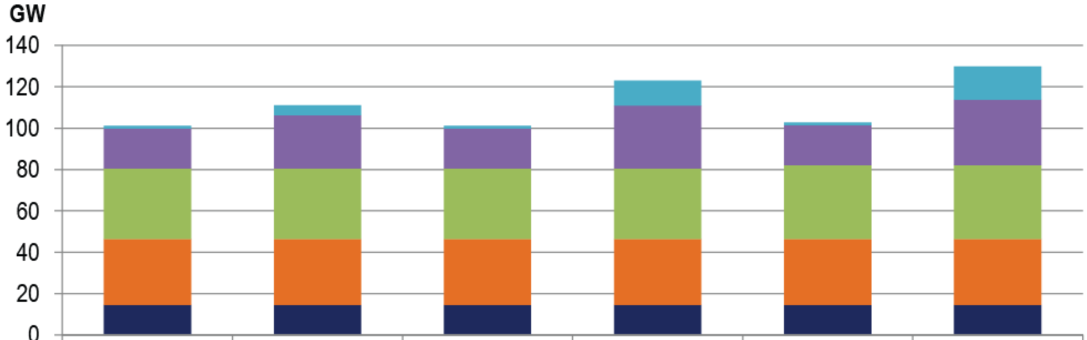
The OPSI-requested scenarios described in Table 3 can be viewed through the lens of starting with the OPSI 2a case, in which the PJM planning assumptions on new resources remain in place, all the RPS requirements on the books in the PJM footprint are met and the EPA energy efficiency expectations are achieved. The remaining scenarios are evaluated relative to the OPSI 2a case.

OPSI 2b.1 is very similar to the OPSI 2a case but for using only wind and solar resources in all stages in the queue without regard to meeting in aggregate all the RPS requirements in PJM as described in Table 3. OPSI 2b.2 is an energy-efficiency sensitivity that examines the impact of reducing the amount of energy efficiency to 50 percent of the EPA goals in the building blocks. OPSI 2b.3 is a natural gas price sensitivity examining the effect of increasing natural gas prices by 50 percent. OPSI 2b.4 is an extreme case examining the effect of reducing in-service nuclear capacity by 50 percent. OPSI 2c is a state-by-state compliance case that runs under the same assumptions as OPSI 2a, but compliance by state is based only on emissions within the state.

Further details on the OPSI-requested scenarios can be found in Appendix 3.

In order to provide a sense of the difference between the PJM planning case used in the Regional Transmission Expansion Plan (labeled below as RTEP) and OPSI 2a over the simulation years 2020, 2025 and 2029 by resource mix, Figure 2 shows how similar the OPSI 2a case is to the PJM planning case.

Figure 2. Comparison of the Resource Mix in the PJM Planning Case and the OPSI Scenario Satisfying RPS Requirement in PJM States and EPA Target Levels of Energy Efficiency



	2020 RTEP	2020 OPSI 2a	2025 RTEP	2025 OPSI 2a	2029 RTEP	2029 OPSI 2a
Energy Efficiency	1.3	4.9	1.3	12.2	1.3	16.2
Wind & Solar	19.4	25.7	19.4	30.4	19.4	31.6
All Nuclear	34.1	34.1	34.1	34.1	35.7	35.7
111(d) NGCC	31.9	31.9	31.9	31.9	31.9	31.9
111(b) NGCC	14.5	14.5	14.5	14.5	14.5	14.5

The significant difference seen here is in level of energy efficiency and renewable generation in the form of wind and solar resources. The differences in energy efficiency, renewables and nuclear can be discerned to consider the relative effects of each scenario on PJM's markets.

PJM Cases

The PJM-defined scenarios shown in Table 4 were developed to supplement the OPSI-requested scenarios with different combinations of renewable resources, energy efficiency, new entry combined-cycle gas and nuclear capacity in service.

For example, the effects of different levels of energy efficiency can be isolated by comparing the outcomes in scenarios PJM 2 and PJM 3 shown in Table 4. The effects of reducing the amount of new entry combined-cycle gas through the consideration of commercial probabilities can be isolated by comparing the outcomes from scenarios PJM 4 and PJM 5, while reducing new entry to only meet the installed reserve margin can be examined by comparing scenarios PJM 4 and PJM 7 shown in Table 4.

The impact of reduced nuclear resources by only 10 percent, as opposed to the 50 percent examined in scenario OPSI 2b.4, can be seen by comparing simulation outcomes in scenarios PJM 5 and PJM 6 shown in Table 4. The effect of 50 percent higher natural gas prices with lower new entry and lower renewable resources and energy efficiency can be seen by comparing the outcomes of PJM 7 and PJM 8 shown in Table 4.

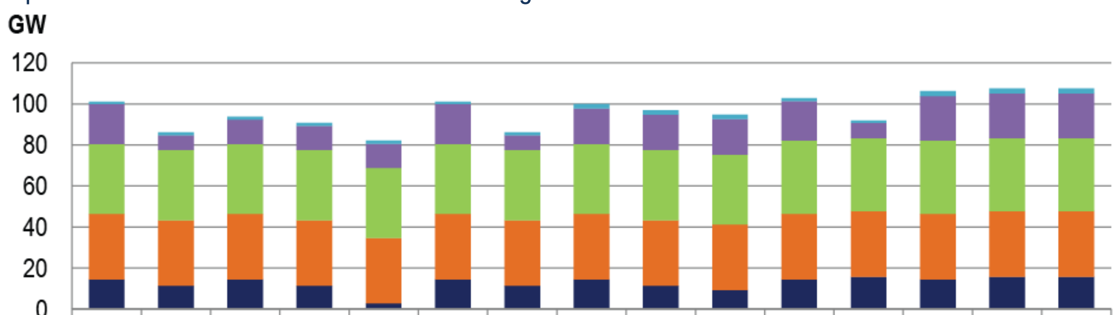
State-by-state compliance relative to regional compliance under a mass-based approach can be examined by comparing scenario PJM 4 to PJM 9 and PJM 7 to PJM 11. PJM also examined the difference between regional mass-based and rate-based compliance in PJM 4 and PJM 10.

Further details on the PJM scenarios can be found in Appendix 3.

Table 4. Definition and Assumptions of the PJM Developed Scenarios

	Fossil Resources	Nuclear	Renewables	Energy Efficiency
PJM 1	Existing and Planned Resources (ISA and FSA only)		EPA Expected Renewables	50% EPA EE
PJM 2	Existing and Planned Resources (ISA and FSA only) Adjust planned natural gas capacity based on historic commercial probability		Existing Wind & Solar	17/18 BRA Cleared
PJM 3			Existing Wind & Solar	100% EPA EE
PJM 4	Existing and Planned Resources (ISA and FSA only)		Trend Wind/Solar and Energy Efficiency Based on historic growth rates: Wind and Solar – In Service, Under Construction Energy Efficiency - PJM BRA Cleared MW	
PJM 5	Existing and Planned Resources (ISA and FSA only) Adjust planned natural gas capacity based on historic commercial probability			
PJM 6	Existing and Planned Resources (ISA and FSA only) Adjust planned natural gas capacity based on historic commercial probability 10% Nuclear Retirement			
PJM 7	Same as PJM 5 except reduce new combined-cycle natural gas resource capacity to not exceed IRM target			
PJM 8	Same as PJM 7 with Henry Hub gas price set to 50% higher			
PJM 9	Same as PJM 4 Scenario but simulated for state-by-state compliance			
PJM 10	Same as PJM 4 Scenario but simulated to achieve regional rate target			
PJM11	Same as PJM 7 Scenario but simulated for state-by-state compliance			

Figure 3. Comparison of the Resource Mix in the PJM Planning Case and Various PJM Scenarios



	RTEP	PJM 2	PJM 4	PJM 5	PJM 7	RTEP	PJM 2	PJM 4	PJM 5	PJM 7	RTEP	PJM 2	PJM 4	PJM 5	PJM 7
	2020					2025					2029				
Energy Efficiency	1.3	1.3	1.5	1.5	1.5	1.3	1.3	2.1	2.1	2.1	1.3	1.3	2.5	2.5	2.5
Wind & Solar	19.4	7.3	11.8	11.8	11.8	19.4	7.3	17.3	17.3	17.3	19.4	7.3	21.7	21.7	21.7
All Nuclear	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1	35.7	35.7	35.7	35.7	35.7
111(d) NGCC	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9
111(b) NGCC	14.5	11.4	14.5	11.4	2.8	14.5	11.4	14.5	11.4	9.3	14.5	15.7	14.5	15.7	15.7

[1] In 2029 two additional NGCC resources are added to PJM 2, 5, and 7

PJM 2 uses a commercial probability for new fossil resources in the queue, existing renewable resources, and existing energy efficiency, PJM 4 uses the ISA/FSA planning assumptions for planned gas resources, and trends renewable resources and energy efficiency based on historic growth rates, PJM 5 is the same as PJM 4 but assigns commercial probabilities to planned gas resources in the queue, PJM 7 reduced new entry combined cycle so that the installed reserve margin is not exceeded.

Figure 3 provides a sense of the difference between the 2014 transmission planning case (listed as RTEP) and scenarios PJM 2, PJM, 4, PJM 5 and PJM 7. The major difference between the planning case and the PJM scenarios are with respect to the quantity of renewables (lower in the PJM cases), new entry combined-cycle gas (lower, and drastically so in PJM 7) and slightly higher energy efficiency values, but far below what EPA has targeted in setting the target CO_2 emissions rates, or even only 50 percent of the EPA level.

Section 4 – Economic Results from Regional Mass-Based Simulation Comparisons

Following the comparisons outlined in the previous section, simulation results are presented here by changes in the main drivers of Clean Power Plan compliance: natural gas prices that drive redispatch and ultimately the price on CO_2 emissions; renewable energy; energy efficiency; nuclear capacity in service; and the level of potential new entry in the model.

From a dispatch and modeling perspective, placing a price on CO_2 emissions represents CO_2 emissions as an input to producing energy in exactly the same way that generators face prices for fuel and face variable operations and maintenance expenses for each megawatt-hour of output. So, in the case of a mass-based target, higher-emitting resources face a larger increase in running costs than lower-emitting resources.

For example, coal units emit CO_2 at a rate of approximately 2,000 lbs/MWh (or 1 short ton/MWh) and new combined-cycle gas units emit CO_2 at a rate of approximately 700-800 lbs/MWh (or 0.35-0.40 tons/MWh). At a CO_2 price of $20/ton, a coal unit's running cost will increase by about $20/MWh. In contrast, a combined-cycle unit's running costs will increase by only $7-$8/MWh. As CO_2 prices increase, higher-emitting resources become more expensive to operate relative to lower- emitting resources and are dispatched less in order to meet the mass-based target. At the same time, lower-emitting resources will be dispatched more so that power demand can be met in all hours.

Energy efficiency, renewable resources and nuclear resources have a CO_2 emissions rate of zero. As additional zero-emitting resources are added to meet the target and avoid the need for redispatch of coal to combined-cycle natural gas resources, the price of CO_2 emissions is reduced.

The remainder of this section will examine the relevant changes in drivers and how this affects: 1) total MWh of that driver; 2) the effects on resource redispatch; 3) the price of CO_2 emissions that comes out of the model; 4) changes in load energy payments; 5) compliance costs due to redispatch alone, which are measured as the change in total fuel and variable operations and maintenance production costs; and 6) identifying how much fossil steam capacity (coal, oil and gas) is at risk for retirement.

With respect to compliance costs, PJM has chosen to focus on detailed examination of compliance costs due to redispatch since deployment of renewable resources and energy efficiency, while capital intensive, may be driven by policies other than the Clean Power Plan. PJM is not in a position to make the subjective determination of what renewable resource and energy efficiency capital costs are related to compliance with the Clean Power Plan or with other state or federal policies.

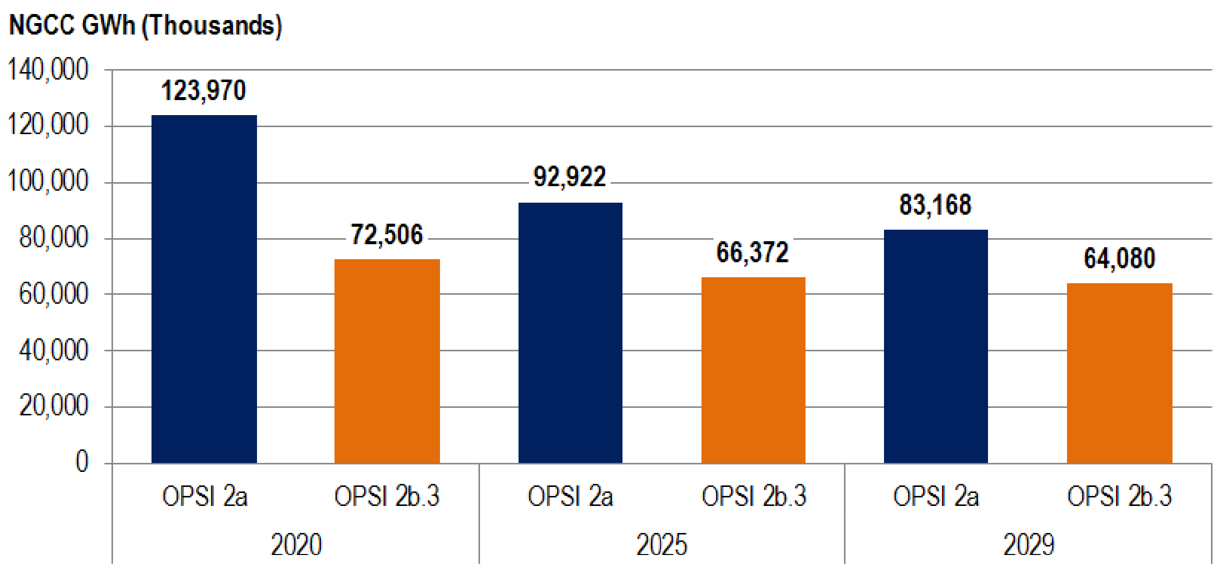
Units at risk for retirement are defined as those that require an additional amount of money, beyond the net energy market revenues for them to remain financially viable and in commercial operation. In this analysis, the needed amount is some fraction of the Net Cost of New Entry (Net CONE) of a natural gas combustion turbine defined as the reference resource in the PJM Reliability Pricing Model (RPM) capacity market. PJM has chosen, consistent with its study on the effects of the Mercury and Air Toxics Standards and Cross State Air Pollution Rule) in 2011, a benchmark of 0.5 Net CONE as defining being at risk for retirement. However, simply because a unit is considered at risk for retirement in this analysis does not mean that the unit would actually retire. That unit may still be committed in the capacity market and receive capacity revenue that, combined with its energy market revenue, assures its financial viability.

In addition, the Net CONE values to which PJM is benchmarking the steam units to be at risk for retirement are not the same Net CONE values used to define the Variable Resource Requirement Curve that signifies the demand for capacity. Instead, these Net CONE values use the Gross CONE value, adjusted for inflation to the simulation year (2020, 2025 and 2029), and the Net Energy Market Revenues that are derived for the combustion turbine directly from the simulations. PJM believes such a benchmark is appropriate to compare the realized Net CONE of the natural gas combustion turbine with the realized need for capacity revenues coming out of the simulation Given the different assumptions in each simulation scenario, it should not be surprising that the Net CONE values can change significantly and affect the quantity of fossil steam capacity considered at risk for retirement.

Changes in Natural Gas Prices

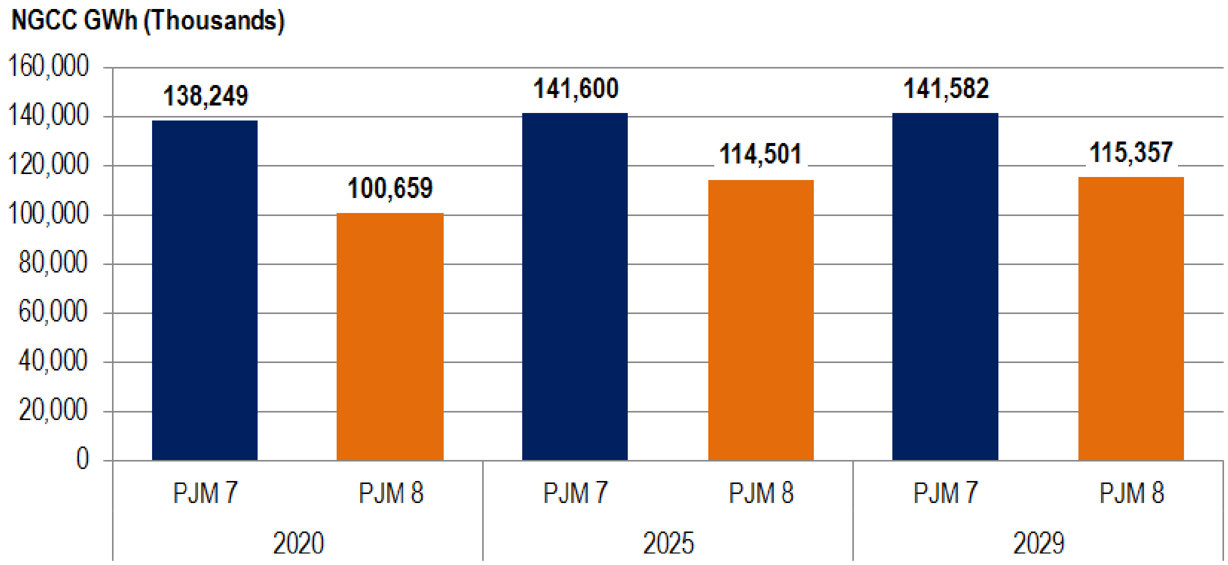
OPSI-requested scenarios 2a and 2b.3 and PJM-developed scenarios PJM 7 and PJM 8 can be examined to see the effects of increasing natural gas prices. The effects on total combined-cycle natural gas dispatch for these scenarios can be seen in Figure 4 for the OPSI scenarios and**Error! Reference source not found.**for the PJM scenarios. Increasing the gas price by 50 percent reduces combined-cycle gas dispatch in the absence of the Clean Power Plan. Figure 4 and Figure 5 also show the effect on the amount of gas generation of reducing the level of renewable resources and energy efficiency. Figure 4 shows gas generation with states in PJM meeting their RPS goals and the EPA energy efficiency target, which avoids the need for as much gas-fired generation. In contrast, Figure 5 shows much higher levels of gas-fired generation, in some cases even with higher gas prices, as the additional gas-fired generation will be required to serve load with lower levels of renewable resources and energy efficiency.

Figure 4. Total Natural Gas Generation in OPSI Scenarios with Different Gas Prices Absent the Clean Power Plan



OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

Figure 5. Total Natural Gas Generation in PJM Scenarios with Different Gas Prices Absent the Clean Power Plan



PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

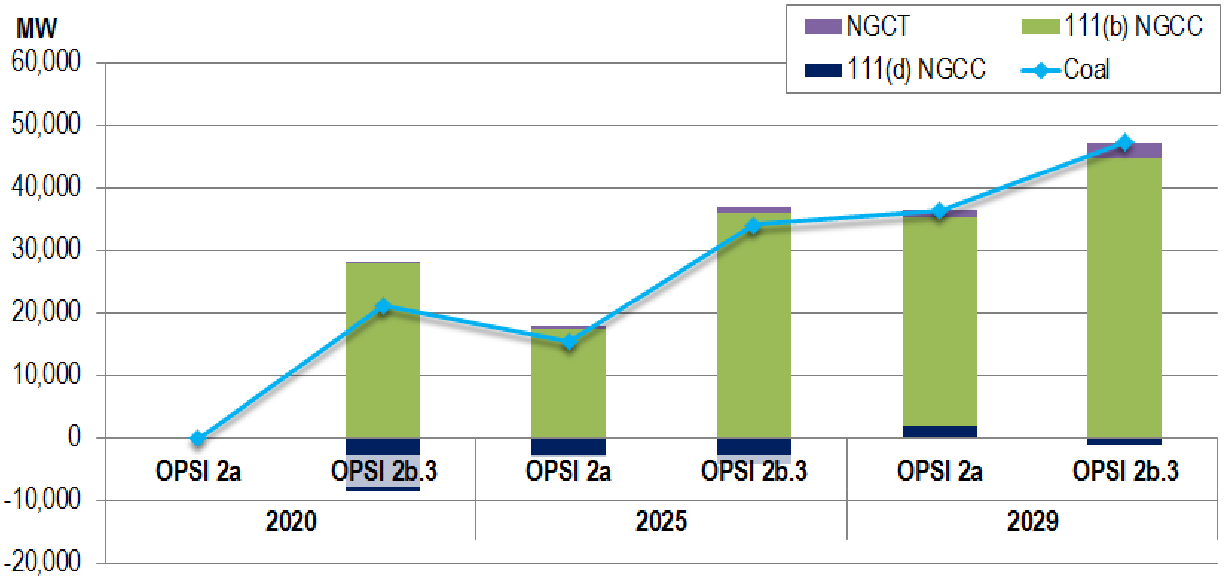
Effect on Resource Redispatch

Any increase in the natural gas prices affects CO_2 prices. The implication is that both coal resources and existing combined-cycle natural gas resources subject to the Clean Power Plan are much less attractive within the economic dispatch than new entry combined-cycle natural gas resources that are subject to 111(b) New Source Performance Standards (NSPS) and not subject to the Clean Power Plan as PJM has modeled it. Most of the redispatch occurs from coal to new entry natural gas, where the emissions do not count against meeting the mass-based target. This is clearly shown in the OPSI scenarios in Figure 6 where the dispatch of existing combined-cycle resources actually declines relative to not having the Clean Power Plan at all in 2020 and 2025. By 2029, as the mass-based targets decline and CO_2 prices rise, existing combined-cycle units become more competitive, but still do not participate significantly in redispatch. Because of the high levels of energy efficiency and renewables, there is also very little production from combustion turbines and less overall redispatch is required compared to the PJM scenarios, which are characterized by lower growth in renewables and energy efficiency and are discussed below. New entry combined-cycle natural gas resources, already operating at lower capacity factors absent the Clean Power Plan, are able to easily ramp up to take on the redispatch burden.

In the PJM scenarios in Figure 7, where the levels of available renewable resources and energy efficiency are lower and new entry combined cycle is limited, a greater redispatch of existing combined-cycle resources subject to the Clean Power Plan is observed. This is because the ability to use new entry combined cycle subject to 111(b) NSPS and not modeled as subject to the Clean Power Plan, is limited in 2020 and 2025. But as more new combined-cycle resources come on line, the amount of new combined-cycle gas dispatched increases and eventually overtakes the redispatch of existing combined-cycle gas units. Moreover, simple-cycle combustion turbines that also are not subject to the Clean

Power Plan as modeled, will ramp up output because they are relatively less expensive than existing combined-cycle resources, and there are not sufficient new entry combined-cycle units to displace coal units. [14]

Figure 6. Changes in Coal and Natural Gas Resource Dispatch due to Increasing Natural Gas Prices on in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources

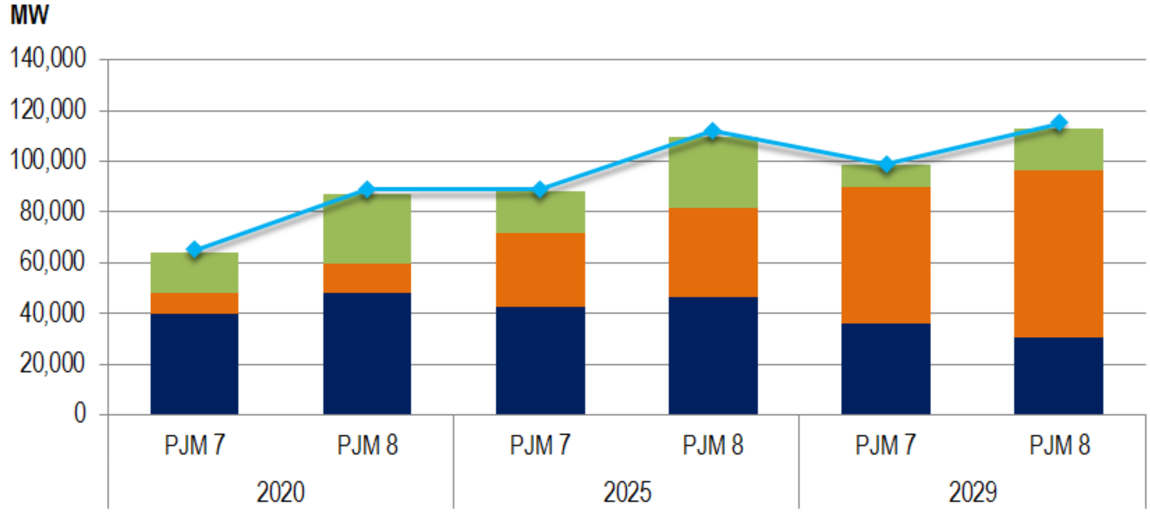


OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher. A positive value for coal indicates a reduction in coal generation.

A comparison of Figure 6 and Figure 7 shows that, even at the same gas prices, reducing the availabiliy of renewable resources, energy efficiency and new combined-cycle entry (OPSI 2a vs. PJM 7) substantially increases the amount of coal generation displaced under the Clean Power Plan. The reason is that renewable resources, energy efficiency and new entry combined-cycle gas resources all displace existing coal and existing gas-fired generation to some extent and offer emissions reductions without the need to redispatch from coal to existing combined-cycle gas.

[14] PJM has not assessed whether in the simulations the combustion turbines would run above a 33 percent capacity factor and therefore subject to the Clean Power Plan.

Figure 7. Changes in Coal and Natural Gas Resource Dispatch due to Increasing Natural Gas Prices in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources

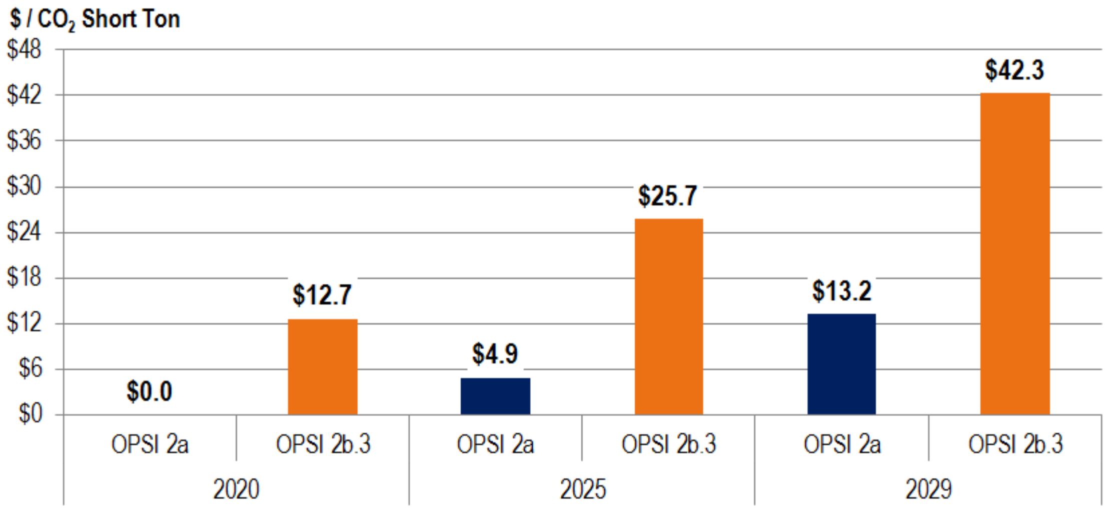


PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher. A positive value for coal indicates a reduction in coal generation.

Effect on CO_2 Prices

All things being equal, an increase in natural gas prices also results in a higher CO_2 emissions price since the marginal cost of reducing emissions through redispatch is higher due to the higher natural gas prices. For the OPSI-requested scenarios 2a and 2b.3, this can be seen in Figure 8 and for the PJM-developed scenarios PJM 7 and PJM 8 this can be seen in Figure 9.

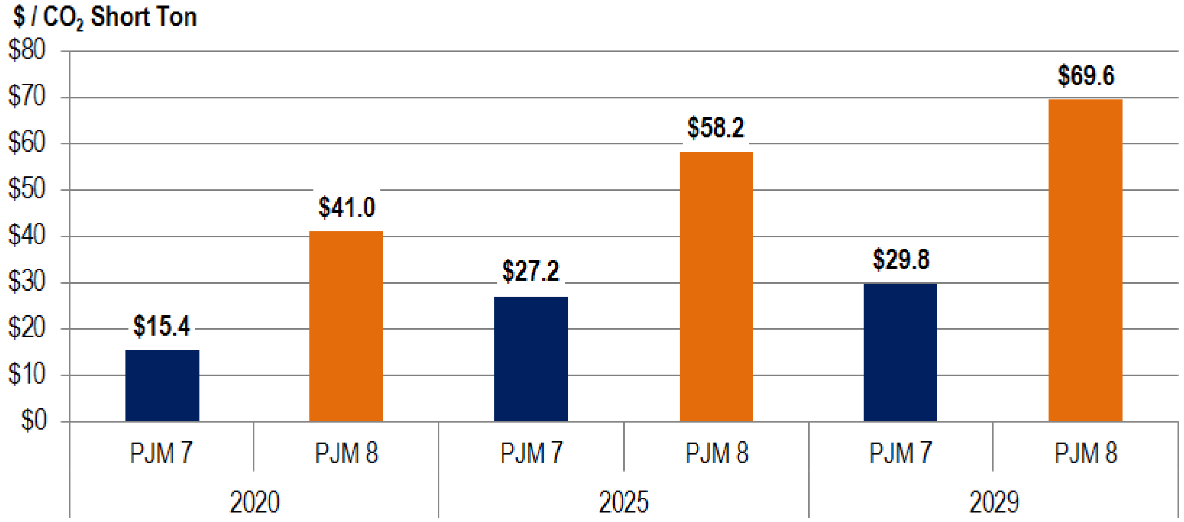
Figure 8. Effects of Increasing Natural Gas Prices on CO_2 Prices in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

The two differences between the OPSI-requested scenarios in Figure 8 and PJM-developed scenarios in Figure 9 are that the level of renewables and energy efficiency are lower in the PJM scenarios, as is the availability of potential new entry combined-cycle gas in the PJM scenarios. Since, these resources are treated as zero-emitting for existing resource compliance, greater redispatch of existing combined-cycle gas resources is required in the PJM scenarios, as shown in the previous subsection.

Figure 9. Effects of Increasing Natural Gas Prices on CO_2 Prices in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources

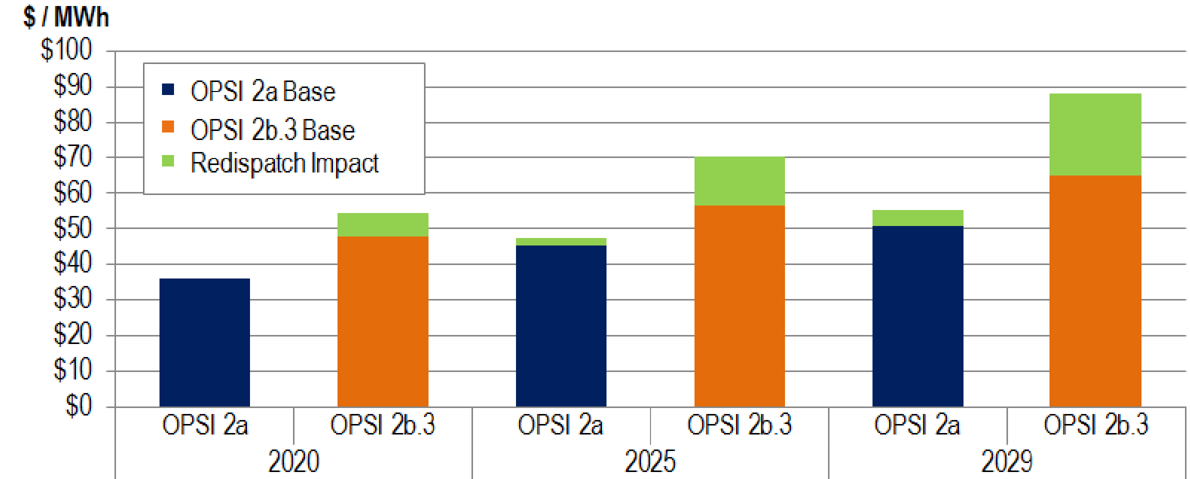


PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

Effects on Locational Marginal Prices (LMP)

Clearly, introducing a price on CO_2 emissions will increase wholesale market energy prices as represented by the Locational Marginal Price (LMP). And, the higher the price is on CO_2 emissions, the greater will be the increase in LMP. But, the change in LMP due to a change in CO_2 price is not a direct, one-to-one relationship, as shown in Figure 10 and Figure 11 for the OPSI and PJM scenarios, respectively. For these scenarios, in fact, the effect is that only about 50 to 60 percent of the CO_2 price is transmitted through to LMP. The reason is that there will be many periods where combined-cycle gas is on the margin, with emissions less than one-half ton of CO_2/MWh, and others where coal is on the margin, emitting about one ton of CO_2. It makes intuitive sense that the effect on LMP will be between the emissions rates of a combined-cycle gas resource and a coal resource.

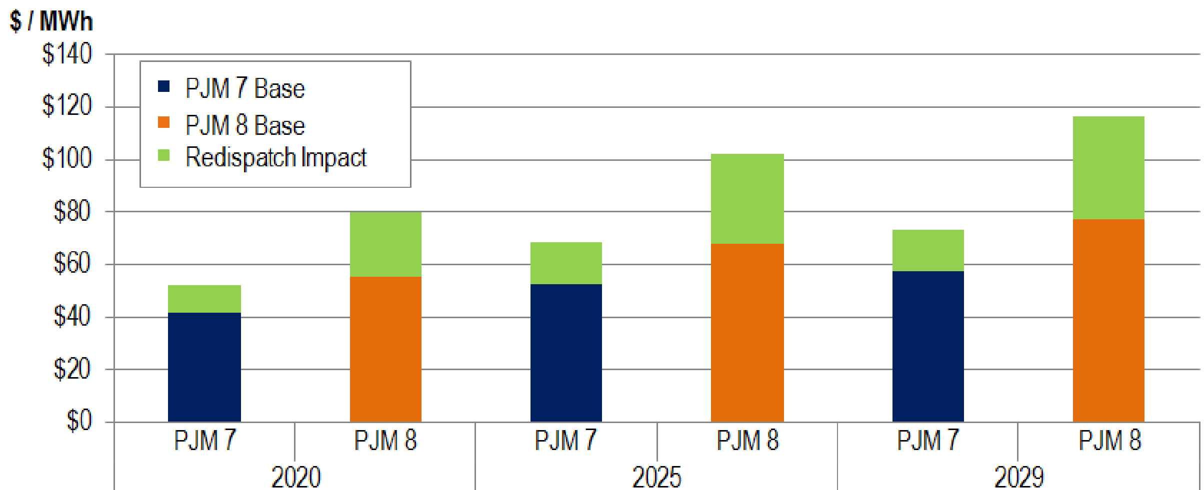
Figure 10. Effect of CO_2 Prices on Load-weighted Average LMP in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.3	2025 OPSI 2a	2025 OPSI 2b.3	2029 OPSI 2a	2029 OPSI 2b.3
111(d)	$0.0	$6.8	$1.9	$14.0	$4.6	$23.2
LMP Base	$35.9	$47.7	$45.4	$56.6	$50.6	$64.9

OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

Figure 11. Effect of CO_2 Prices on Load-weighted Average LMP in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



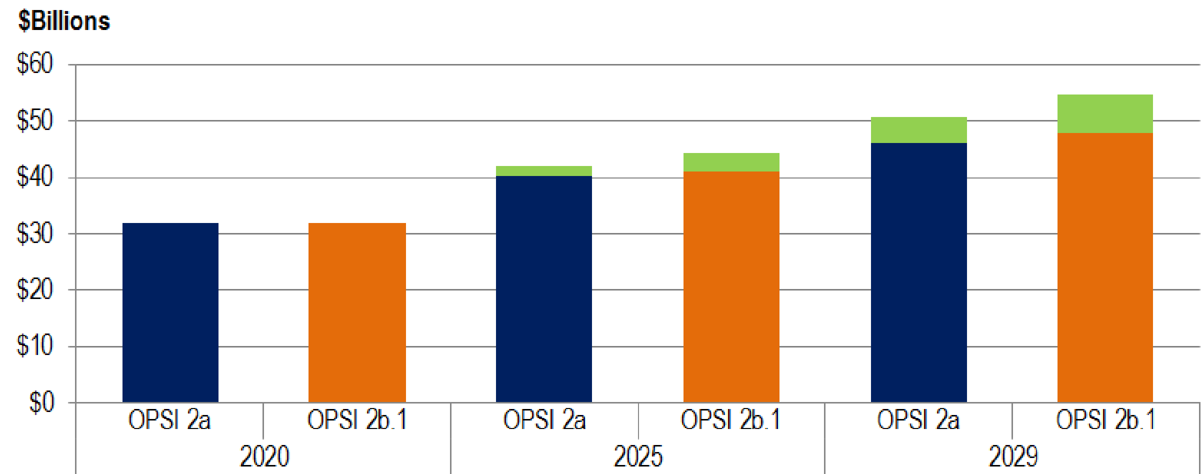
	2020 PJM 7	2020 PJM 8	2025 PJM 7	2025 PJM 8	2029 PJM 7	2029 PJM 8
111(d)	$10.3	$24.6	$16.1	$34.5	$15.6	$39.4
LMP Base	$41.7	$55.1	$52.5	$67.6	$57.7	$77.3

PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

Effect on Load Energy Payments

Not surprisingly, the effect on load energy payments will be an increase due to the higher LMP, and larger changes in CO_2 prices will lead to larger increases in load energy payments, while smaller changes in CO_2 prices lead to more muted increases in load energy payments. The changes for the OPSI-requested and PJM-developed scenarios are presented in Figure 12 and Figure 13, respectively.

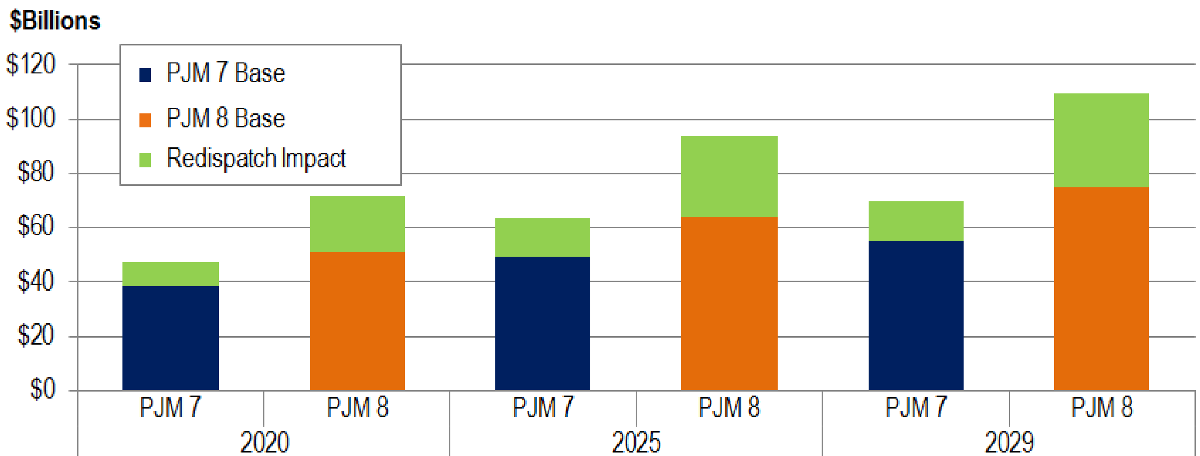
Figure 12. Effect of CO_2 Prices on Load Energy Payments in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.1	2025 OPSI 2a	2025 OPSI 2b.1	2029 OPSI 2a	2029 OPSI 2b.1
111(d)	$0.0	$0.0	$1.8	$3.4	$4.5	$6.9
Base	$31.9	$31.9	$40.2	$41.0	$46.1	$47.8

OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

Figure 13. Effect of CO_2 Prices on Load-weighted Average LMP in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



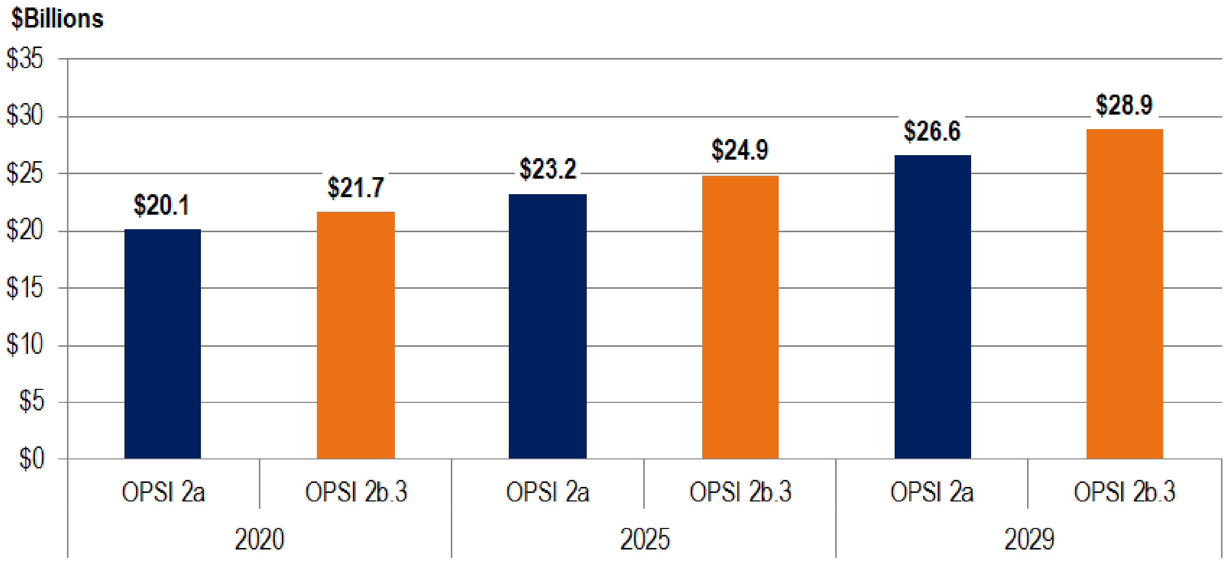
	2020 PJM 7	2020 PJM 8	2025 PJM 7	2025 PJM 8	2029 PJM 7	2029 PJM 8
111(d)	$8.9	$20.7	$14.5	$29.8	$14.8	$34.7
Base	$38.2	$50.9	$49.1	$63.9	$55.2	$74.9

PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

Effects on Compliance Costs as Measured Through Changes in Production Costs

Total fuel and operations and maintenance production costs for the OPSI-requested scenarios is presented in Figure 14, and the change in production costs due to redispatch to comply with the Clean Power Plan (compliance costs) is shown in Figure 15. The same simulation outputs for the PJM scenarios are presented in Figure 16 and Figure 17, respectively. In all cases, any associated production costs due directly to the price of CO_2 emissions are removed as such discussion then get into wealth distribution issues between generation, load, and state governments that is beyond the scope of this analysis..[15]

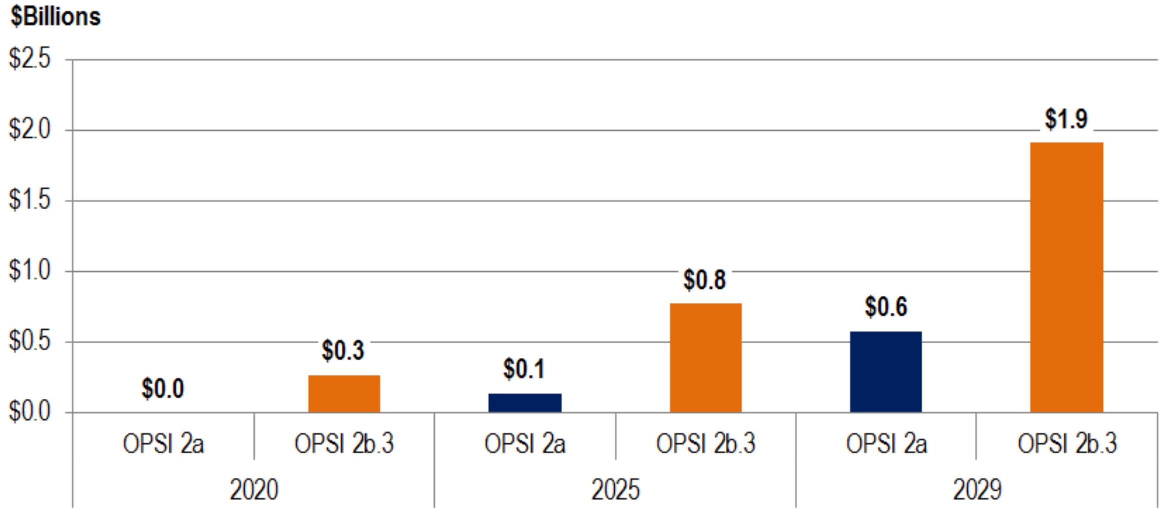
Figure 14. Total Fuel and Variable O&M Production Costs in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

15 The effects of the CO_2 price is balanced out in aggregate as some or all resources would need to pay for CO_2 emissions, other resources may be able to sell emissions reductions, any revenue streams from CO_2 emissions prices may revert to state governments of loads. In all cases the direct cost of emissions, CO_2 price multiplied by total emissions paid for, must equal the revenue accruing to some party (or parties) and so balance out as revenues equal costs.

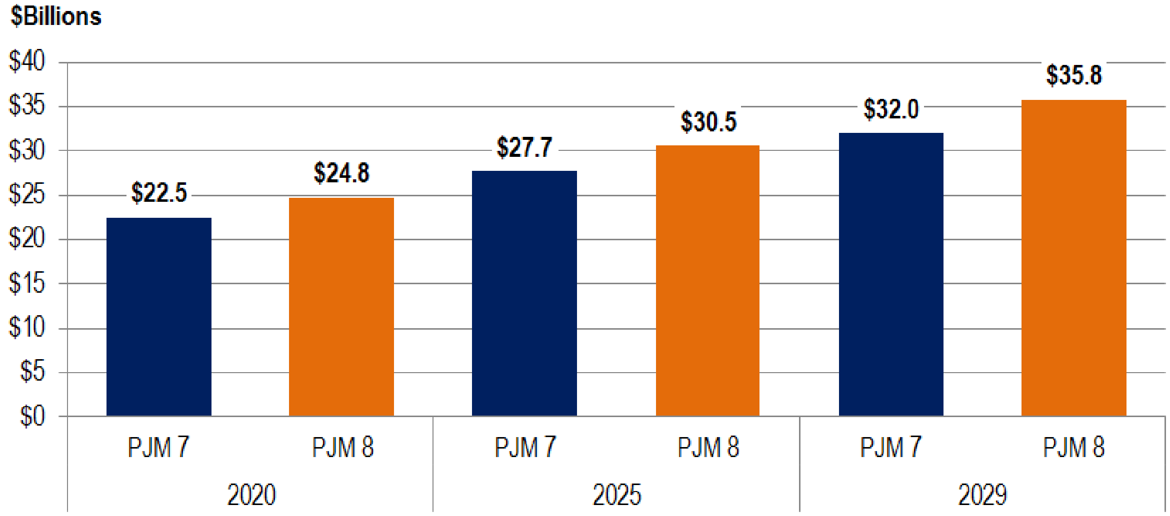
Figure 15. Total Fuel and Variable O&M Compliance Costs due to Redispatch in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

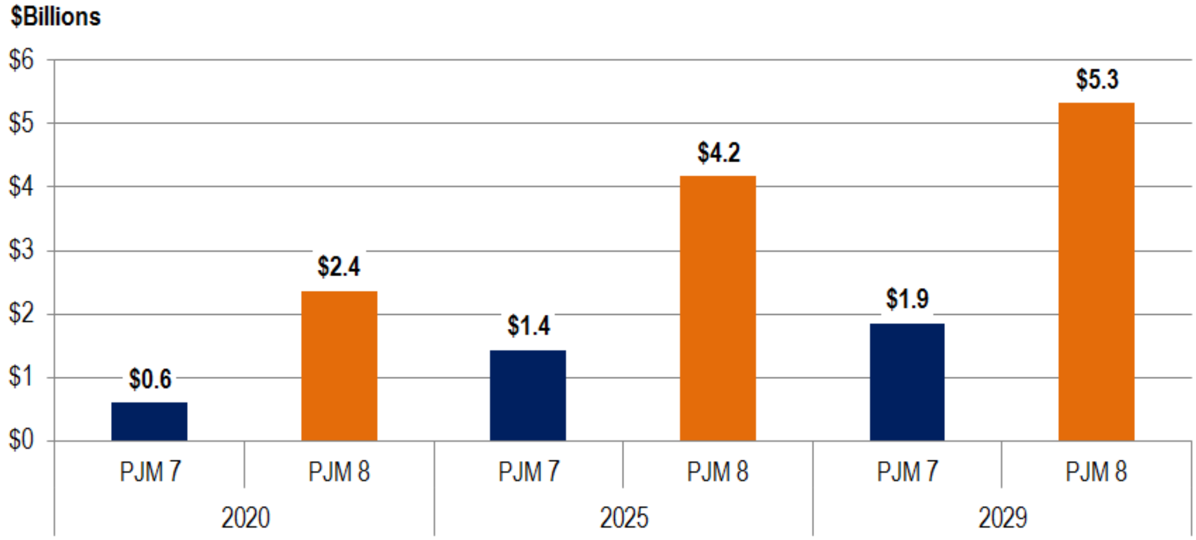
For the OPSI-requested scenarios, the fuel and operation and maintenance compliance costs are at most 6.5 percent of total fuel and operation and maintenance production costs comparing the values in Figure 14 and Figure 15. In large measure this is due to the lower need for redispatch because of the high levels of energy efficiency, renewable resources and new entry assumed in the OPSI-requested scenarios. In contrast, in the PJM-developed scenarios, an increase in gas prices results in compliance costs that are as high as 15 percent of total fuel operation and maintenance costs comparing values in Figure 16 and Figure 17 because of the need to increase redispatch as the levels of efficiency, renewables and new entry are lower than in the OPSI scenarios.

Figure 16. Total Fuel and Variable O&M Production Costs in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

Figure 17. Total Fuel and Variable O&M Compliance Costs due to Redispatch in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

Fossil Steam Capacity at Risk for Retirement

Assessing the quantity of fossil steam capacity at risk for retirement requires knowing the amount of money fossil steam resources require in order to cover their going-forward or avoidable costs, such as fixed operations and maintenance costs, fixed labor costs and other associated overhead. However, a benchmark comparison is needed because knowing the amount of money required to go forward in isolation does not provide sufficient information regarding whether a resource may be at risk for retirement. As discussed at the beginning of the results section, PJM has chosen 0.5 Net CONE as the benchmark revenue to determine at-risk resources in the absence of running any capacity market simulations that would determine whether resources would clear in PJM's capacity market. The use of the 0.5 Net CONE benchmark should not be taken as a prediction or indication of any future capacity market prices as they are a function of both supply (examined here) and the demand for capacity, which is not analyzed in this work.

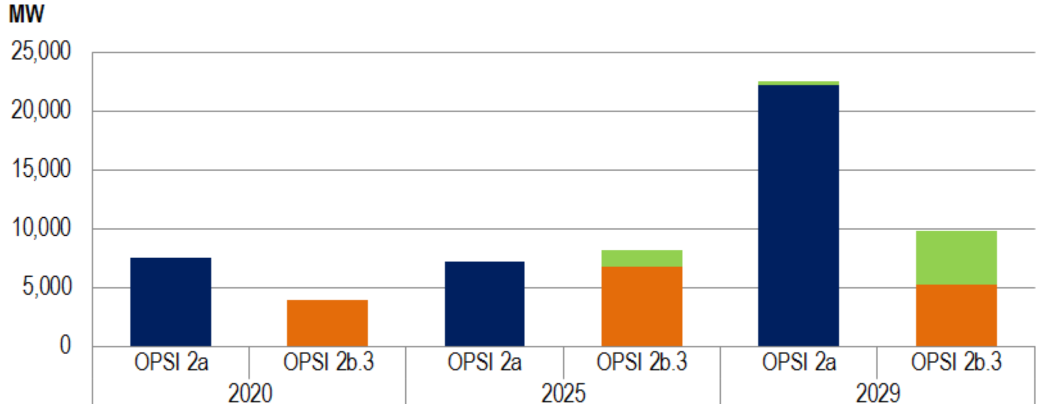
Table 5 and Table 6 show the Gross CONE and Net CONE benchmark values for each OPSI and PJM scenario and year. The Net Energy and Ancillary Service (EAS) revenues for combustion turbines are determined within each scenario/year run and differ by each scenario/year as shown in Table 5 and Table 6. Figure 18 and Figure 19 show the fossil steam capacity at risk for retirement based on the 0.5 Net CONE benchmark for the simulation years 2020, 2025 and 2029 for the OPSI and PJM scenarios respectively.

Table 5. Combustion Turbine CONE Values for OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	OPSI 2a	$414.5	$4.3	$410.2
	OPSI 2b.3	$415.7	$5.6	$410.1
2025	OPSI 2a	$464.6	$9.3	$455.3
	OPSI 2b.3	$464.6	$13.6	$451.0
2029	OPSI 2a	$506.8	$19.1	$487.6
	OPSI 2b.3	$507.9	$32.8	$475.1

OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

Figure 18. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.3	2025 OPSI 2a	2025 OPSI 2b.3	2029 OPSI 2a	2029 OPSI 2b.3
0.6 - 0.75 Net Cone				1,355	318	4,625
0.5 - 0.6 Net Cone	7,521	4,004	7,275	6,814	22,269	5,250

OPSI 2a assumes all planned resources with ISA/FSA are in service, all state RPS requirements in PJM are met, and the EPA energy efficiency target is achieved. OPSI 2b.3 is the same as OPSI 2a except natural gas prices are 50 percent higher.

Multiple, offsetting effects go into determining the differences in fossil steam capacity at risk for retirement under the Clean Power Plan given a 50 percent increase in price. With respect to fossil steam (primarily coal) net energy market revenues the following effects must be considered:

- All else equal, the higher gas price results in a higher price on CO_2, which would reduce fossil steam net energy market revenues as the higher CO_2 price increases fossil steam running costs.
- But, higher gas prices also increase wholesale energy market prices and, all else equal, increases the net energy market revenues of fossil steam units.
- All else equal, reduced generation output due to the need to redispatch reduces net energy market revenues.

For fossil steam units, if the increase in wholesale energy prices dominates the reduced generation output and higher running costs, then net energy market revenues increase. Otherwise, fossil steam units will observe a reduction in energy market revenues.

The change in the benchmark Net CONE also can be a relevant factor. If Net CONE falls, all else equal, the combustion turbines start appearing more attractive as resources relative to existing fossil steam resources. Conversely, if Net CONE rises, all else equal, combustion turbines appear less attractive relative to the existing fossil steam resources.

There does not appear to be a consistent relationship between fossil steam capacity at risk for retirement as shown in Figure 18 for the OPSI scenarios or Figure 19 for the PJM scenarios. While the Net CONE benchmark decreases in all scenarios with an increase in gas prices, this effect is more pronounced in the PJM scenarios with lower levels of renewable resources, energy efficiency and new combined-cycle resources.

For the OPSI scenarios, it appears that in 2020 and 2029 the increase in the wholesale energy market effect dominates all the other effects that would increase capacity at risk as shown in Figure 18. In contrast in the PJM scenarios the increasing wholesale energy market revenue only dominates in 2029 as shown in Figure 19, otherwise it appears the capacity at risk for retirement increases with gas prices in other years.

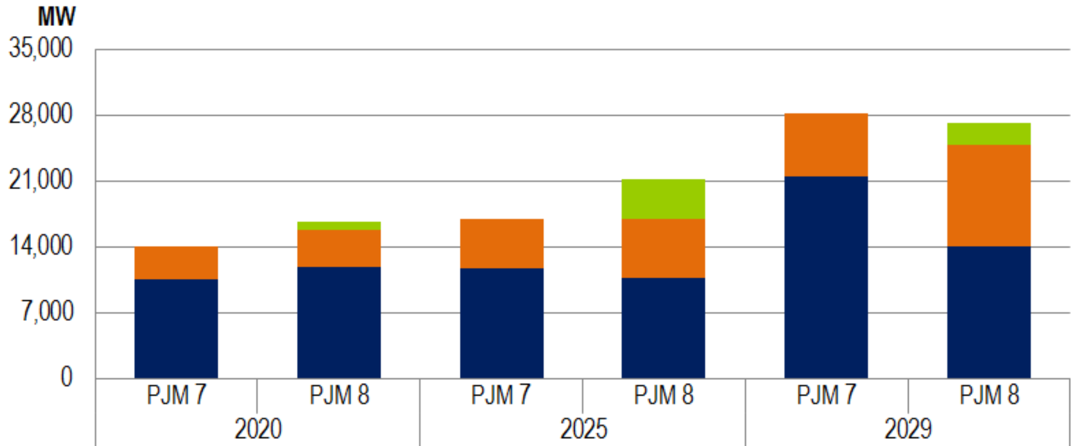
One final observation, comparing the total capacity at risk for retirement in the OPSI scenarios with high levels of renewable resources, energy efficiency, and new combined-cycle resources leads to less fossil steam capacity at risk in Figure 18 relative to reduced levels of renewable resources, energy efficiency and new combined-cycle resources in the PJM scenarios in Figure 19. So, while there was no definitive pattern observed with respect to changing gas prices, the side-by-side examination of the OPSI and PJM scenarios does show that an increase in zero-emitting resources (from a Clean Power Plan compliance perspective) reduces fossil steam capacity at risk for retirement. The reason for this effect is that the reduction in Net CONE, which makes combustion turbines relatively more attractive, is greater when there are less renewable resources, energy efficiency, and new combined-cycle resources. Combustion turbines run more often and at higher prices leading to greater net energy market revenues, which is the main driver of this result because this effect dominates the effect of coal and other fossil steam resources running more often and at higher prices.

Table 6. Combustion Turbine CONE Values for PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	PJM 7	$415.7	$65.6	$350.1
	PJM 8	$415.7	$96.9	$318.8
2025	PJM 7	$464.1	$76.4	$387.7
	PJM 8	$463.9	$126.3	$337.7
2029	PJM 7	$507.6	$55.0	$452.5
	PJM 8	$507.0	$97.1	$409.9

PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

Figure 19. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



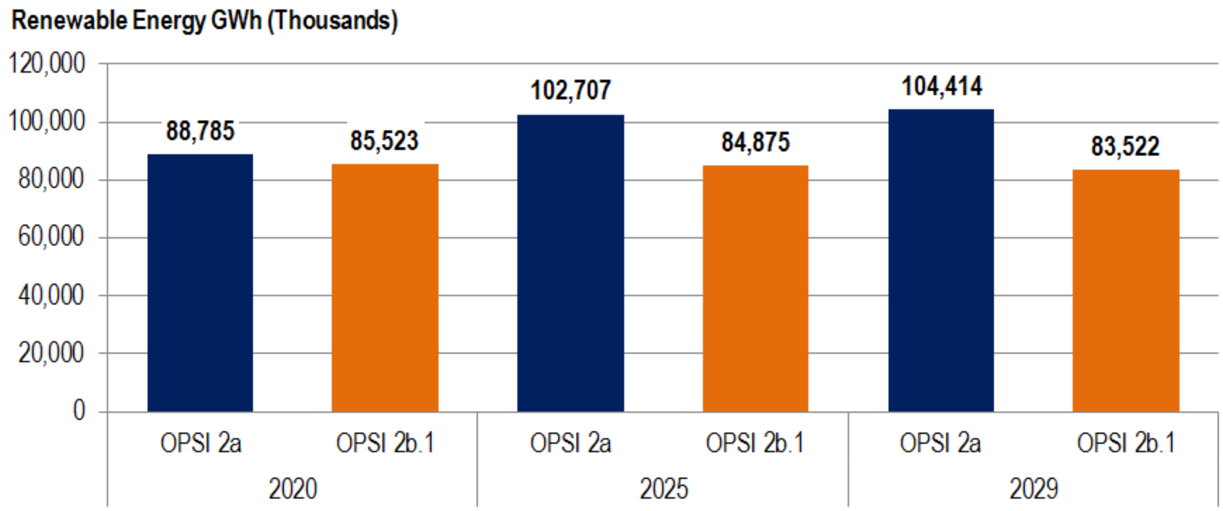
	2020 PJM 7	2020 PJM 8	2025 PJM 7	2025 PJM 8	2029 PJM 7	2029 PJM 8
0.75 - 1.0 Net Cone		896		4,250		2,309
0.6 - 0.75 Net Cone	3,614	3,930	5,331	6,269	6,785	10,784
0.5 - 0.6 Net Cone	10,500	11,824	11,700	10,628	21,417	14,017

PJM 7 limits new combined-cycle gas entry to just meeting the installed reserve margin target, and renewable resource and energy efficiency levels are grow at historic growth rates from current levels. PJM 8 is the same as PJM 7 except natural gas prices are 50 percent higher.

Changes in Available Renewable Resources

OPSI-requested scenarios 2a and 2b.1 can be examined to see the effects of changing the availability of renewable energy resources in isolation. The OPSI scenarios changed the amount of renewables from meeting all RPS requirements in PJM to only using the available renewable resources in the PJM queue. The changes in total renewable energy output are shown in Figure 20. At the beginning of the compliance period there is little difference, but the difference grows over time.

Figure 20. Renewable Energy Resource Generation in OPSI Scenarios with Differing Levels of Renewable Resources

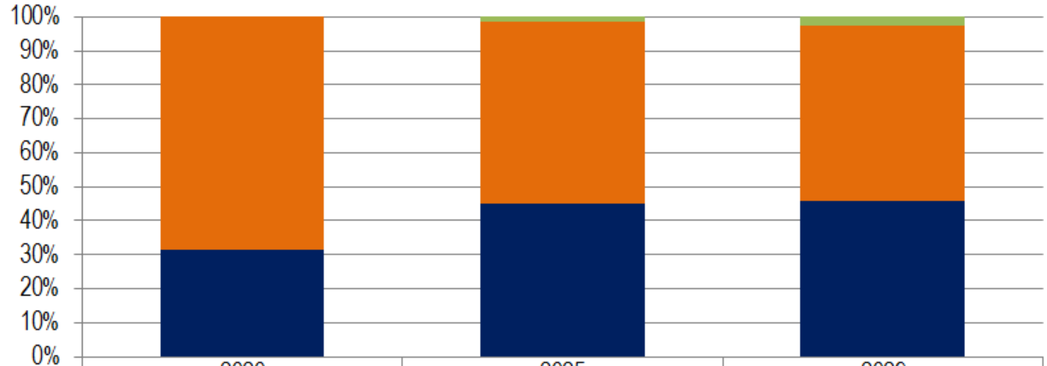


OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.

Effect on Resource Redispatch

In the absence of the Clean Power Plan, as shown in the Figure 21, an increase in renewable energy would primarily displace natural gas generation, but as gas prices rise between 2020 and 2029, the ratio of natural gas versus coal displacement would decline from 2.2 to 1 down to 1.12 to 1. When natural gas prices are low, combined-cycle natural gas resources operate at much higher capacity factors and can displace coal in both on-peak and off-peak hours. However, as the natural gas price rises, gas is more limited to peak hours and, because wind energy is concentrated during off-peak hours, its value in displacing CO_2 emissions goes up. Renewables displace either coal or gas energy on a 1-for-1 basis. However, each megawatt-hour of displaced natural gas generation has a lower value in reducing CO_2 emissions relative to the reduction that can be achieved through displacing coal resources.

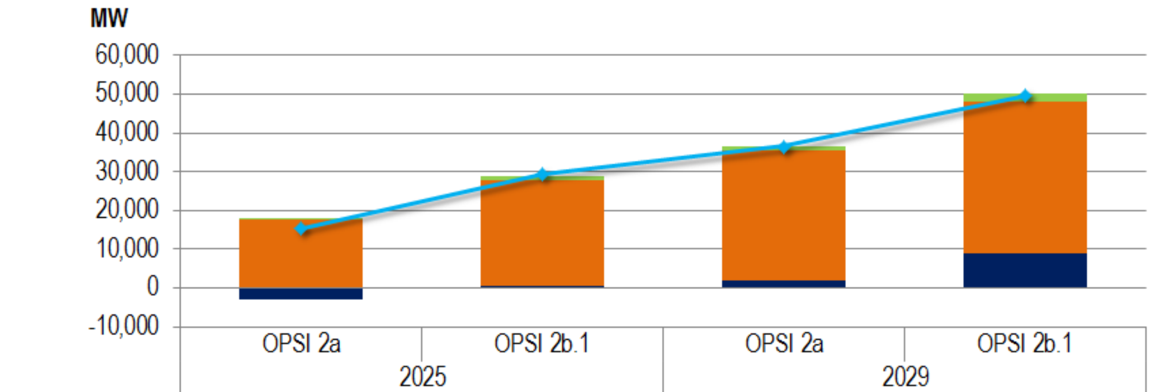
Figure 21. Percentage Displacement of Fossil Resources by Renewable Energy Resource Generation in OPSI Scenario 2a with PJM States Achieving RPS Standards



	2020	2025	2029
Other	0.0%	1.3%	2.5%
Natural Gas	68.7%	53.8%	51.6%
Coal	31.3%	44.9%	45.9%

In 2020, neither of the scenarios bind on the CO_2 emissions target. Therefore, no incremental redispatch is required to achieve the emissions target. By 2025 and 2029, however, to achieve the emissions reduction on a mass basis, as shown in 0, coal must be redispatched to lower-emitting resources. Similar to other scenarios, on a megawatt basis, new entry combined-cycle natural gas resources under 111(b) NSPS, which are not subject to Clean Power Plan compliance as PJM has modeled it, provide most of the energy that would have been provided by the coal resources that are dispatched down. The amount of existing combined-cycle redispatch is minimal in both 2025 and 2029. Resources not subject to the Clean Power Plan, like new entry combined-cycle gas under 111(b) NSPS and simple-cycle combustion turbines that are not subject to the Clean Power Plan unless they exceed a 33 percent capacity factor, account for the bulk of the redispatch based on total energy output. The 111(b) combined-cycle natural gas resources represent only about 45 percent of the total installed capacity (ICAP) value of 111(d) combined-cycle natural gas resources, which is indicative of their being the cheapest alternative for reducing emissions from covered sources because their emissions do not count against compliance.

Figure 22. Changes in Coal and Natural Gas Dispatch in OPSI Scenarios with Differing levels of Renewable Resources



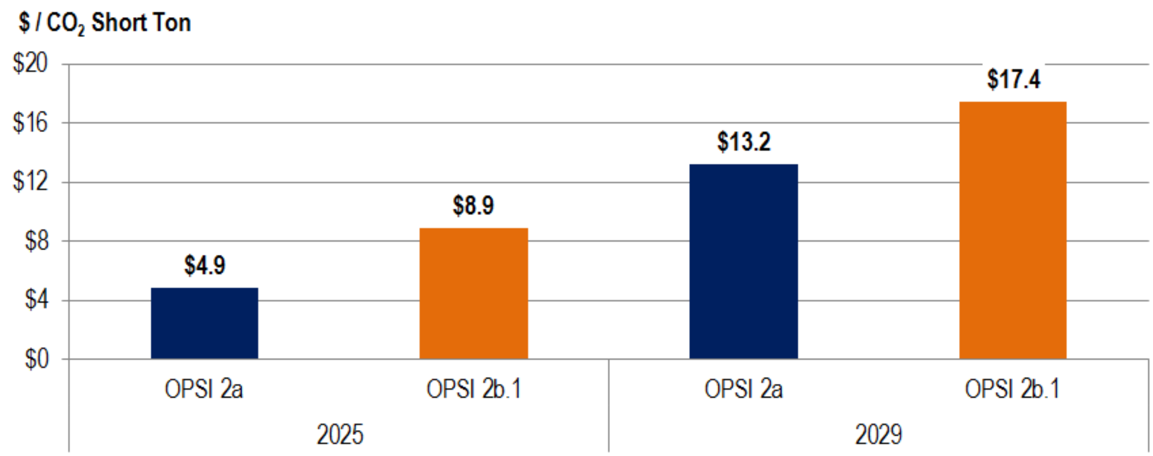
	2025 OPSI 2a	2025 OPSI 2b.1	2029 OPSI 2a	2029 OPSI 2b.1
NGCT	372	968	1,112	2,086
111(b) NGCC	17,605	27,274	33,451	39,010
111(d) NGCC	-2,890	611	2,004	8,979
Coal	15,468	29,317	36,387	49,670

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue. A positive value for coal indicates a reduction in coal generation.

Effect on CO_2 Prices

A reduction in available renewable resources and renewable resource output increases the need for natural gas combined-cycle redispatch, which results in a higher CO_2 emissions price. This reflects the fact that the marginal cost of reducing emissions through redispatch is higher due to the need to dispatch less efficient combined-cycle resources. For the OPSI-requested scenarios 2a and 2b.1, this can be seen in Figure 23. Figure 23 only shows 2025 and 2029 since the CO_2 price is zero in both scenarios in 2020.

Figure 23. CO_2 Prices in OPSI Scenarios with Differing Levels of Renewable Resources

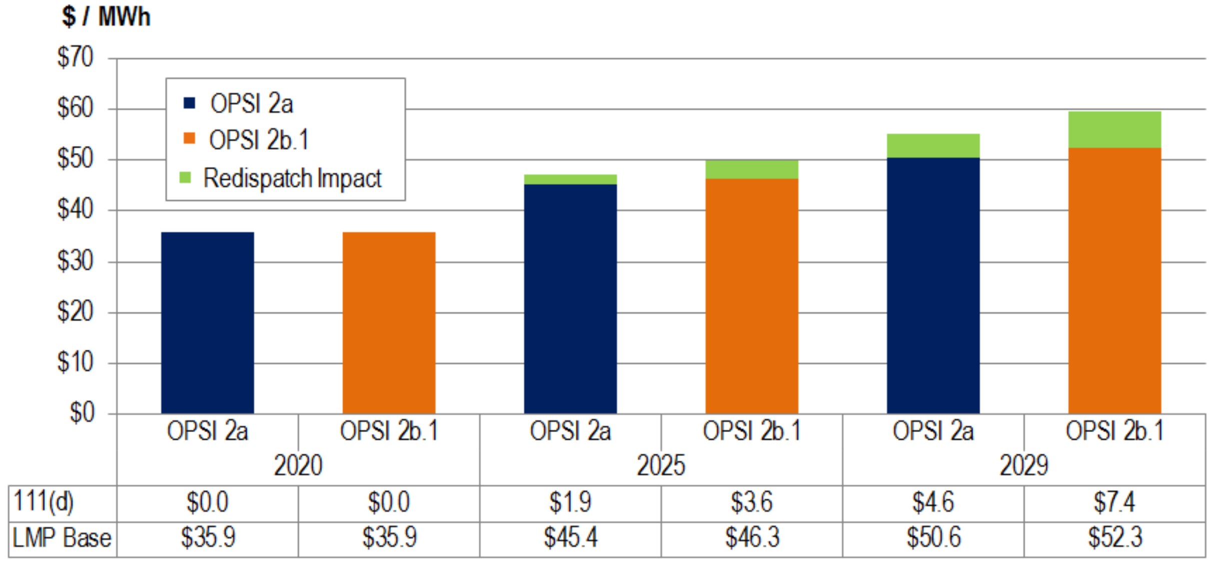


OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.

Effects on Locational Marginal Prices

As opposed to the case where natural gas prices have gone up 50 percent, the translation of CO_2 prices into LMP is much more muted as shown in Figure 24. Because of the availability of new combined-cycle gas not subject to the Clean Power Plan as PJM has modeled it, and because of the relatively small change in renewables, at most only 42 percent of the CO_2 price gets moved into LMP in 2029. In fact, the price translation is between 37 percent and 42 percent in all cases, which indicates the prevalence of existing combined-cycle gas resources on the margin in all years.

Figure 24. Effects of CO_2 Prices on Load-weighted Average Wholesale Energy Market Prices in OPSI Scenarios with Differing levels of Renewable Resources

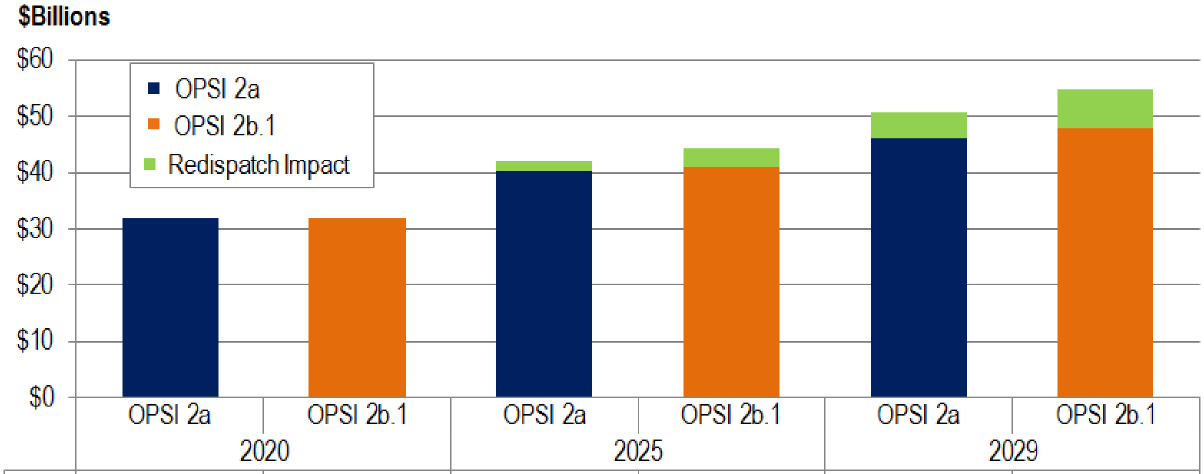


OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.

Effect on Load Energy Payments

Given the lower CO_2 prices and the smaller changes in CO_2 prices, the increases in load energy payments are far less pronounced than in the case where gas prices rise 50 percent. The changes for the OPSI-requested scenarios are presented in Figure 25.

Figure 25. Effects of CO_2 Prices on Load Energy Payments in OPSI Scenarios with Differing Levels of Renewable Resources



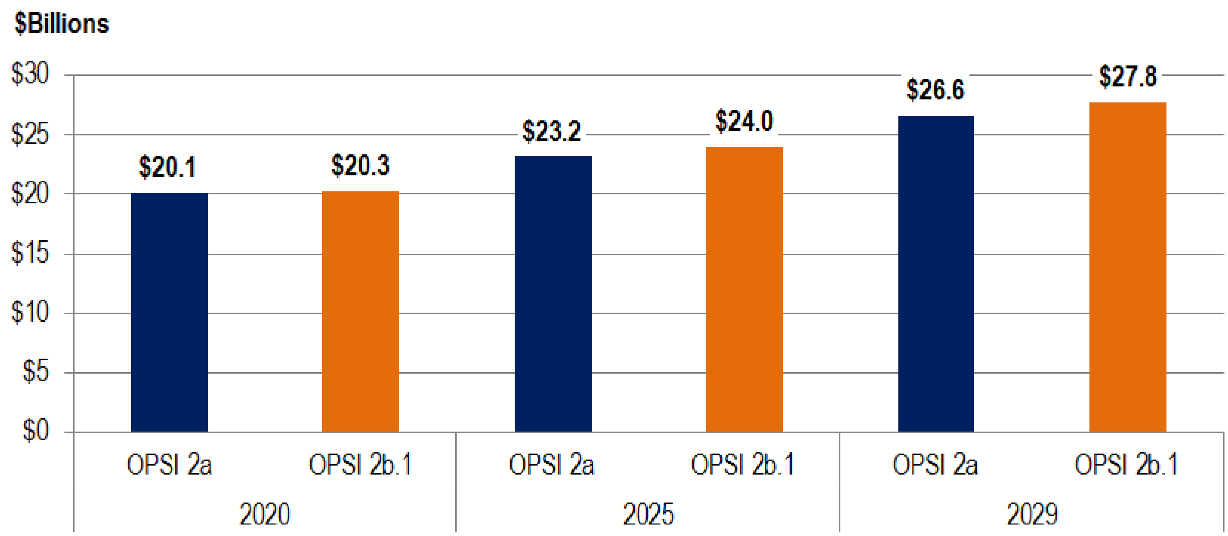
	OPSI 2a 2020	OPSI 2b.1 2020	OPSI 2a 2025	OPSI 2b.1 2025	OPSI 2a 2029	OPSI 2b.1 2029
111(d)	$0.0	$0.0	$1.8	$3.4	$4.5	$6.9
Base	$31.9	$31.9	$40.2	$41.0	$46.1	$47.8

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.

Effects on Compliance Costs as Measured Through Changes in Production Costs

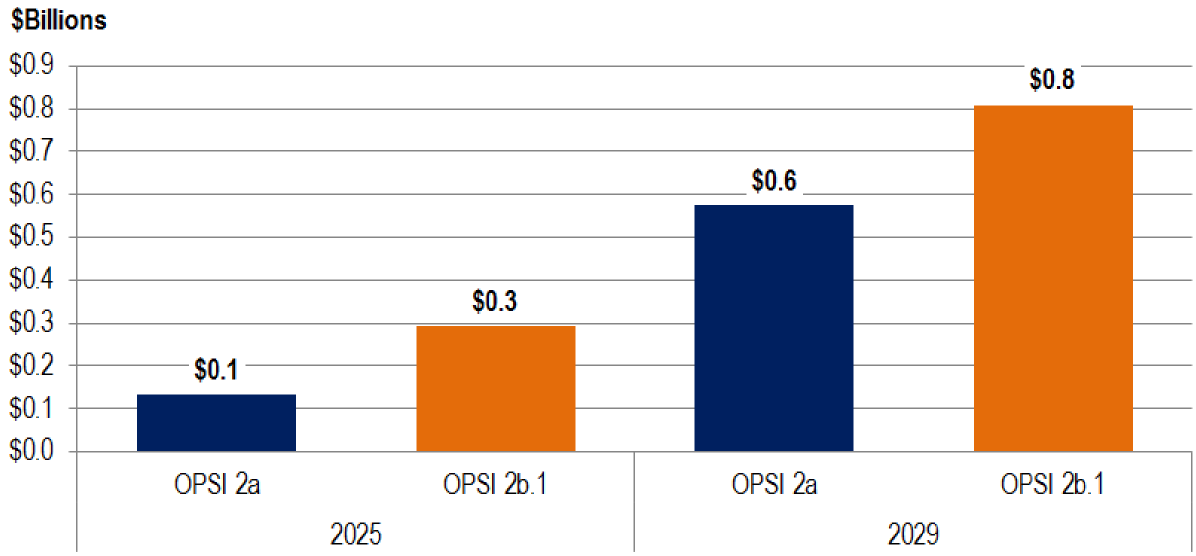
Total fuel and operations and maintenance production costs for the OPSI 2a and 2b.1 scenarios are presented in Figure 26 and the change in production costs due to redispatch (compliance costs) is shown in Figure 27 below.

Figure 26. Total Fuel and Variable O&M Production Costs in OPSI Scenarios with Differing Levels of Renewable Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.

Figure 27. Total Fuel and Variable O&M Compliance Costs in OPSI Scenarios with Differing levels of Renewable Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.

For these OPSI-requested scenarios, the fuel and operation and maintenance compliance costs are at most 2.9 percent of total fuel and operation and maintenance production costs and in OPSI 2a are as low as 0.5 percent. In large measure this is due to the lower need for redispatch because of the high levels of energy efficiency, renewable resources and new entry assumed in the OPSI-requested scenarios. So, while available renewables declined, the reduction was not as sharp as the increase in gas prices examined above.

Fossil Steam Capacity at Risk for Retirement

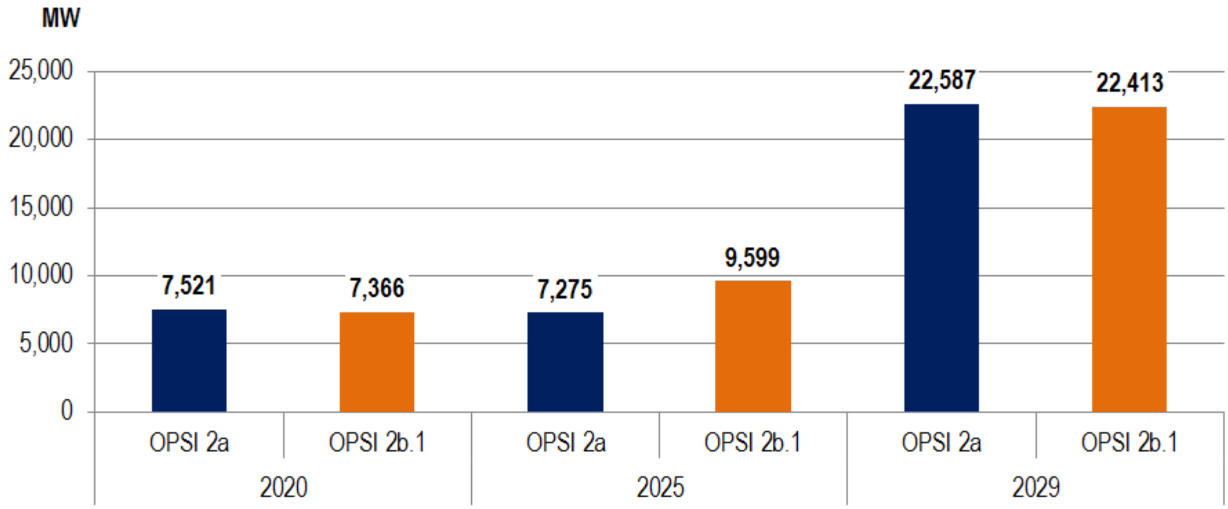
Table 7 and Figure 28 show the Net CONE benchmarks and the fossil steam capacity at risk for retirement, respectively, for the simulation years 2020, 2025 and 2029 for the OPSI scenarios.

Table 7. Combustion Turbine CONE Values for OPSI Scenarios with Differing Levels of Renewable Resources

Year	Scenario	CT Gross Cone ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	OPSI 2a	$414.5	$4.3	$410.2
	OPSI 2b.1	$415.7	$4.7	$411.0
2025	OPSI 2a	$464.6	$9.3	$455.3
	OPSI 2b.1	$463.2	$13.2	$450.0
2029	OPSI 2a	$506.8	$19.1	$487.6
	OPSI 2b.1	$507.9	$34.4	$473.5

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into *commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.*

Figure 28. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for OPSI Scenarios with Differing Levels of Renewable Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.1 reduces the renewable energy resources to be equal to only those resources currently in service or in the interconnection queue.

There are multiple, offsetting effects that go into determining the differences in fossil steam capacity at risk for retirement under the Clean Power Plan given a reduction in available renewable resources. With respect to fossil steam (primarily coal) net energy market revenues the following effect must be considered:

- All else equal the lower levels of renewable generation results in a higher price on CO_2 which would reduce fossil steam net energy market revenues as the higher CO_2 price increases fossil steam running costs;
- But lower levels of renewable generation also increase wholesale energy market prices, and all else equal, increases the net energy market revenues of fossil steam units;
- And lower levels of renewable resources implies high fossil steam output, all else equal, leading to higher net energy market revenues;
- Yet, there may also be reduced generation output due to the need to re-dispatch, which all else equal, reduces net energy market revenues.

For fossil steam units, if the increase in wholesale energy prices dominates the reduced generation output and higher running costs, then net energy market revenues increase. Otherwise, fossil steam units will observe a reduction in energy market revenues.

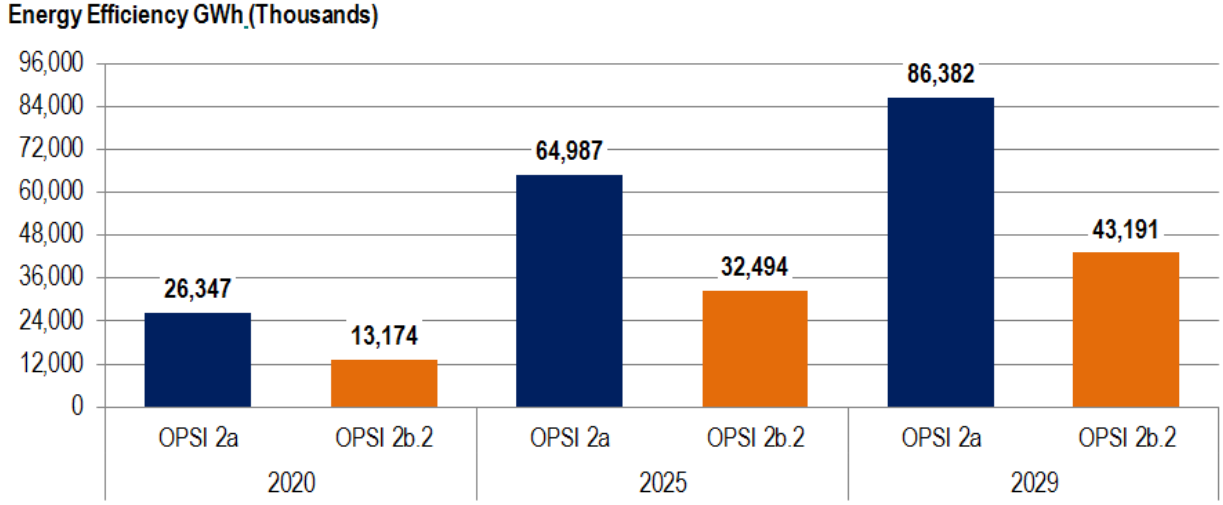
The change in the benchmark Net CONE can also be a relevant factor. If Net CONE falls, all else equal, the combustion turbine starts appearing more attractive as a resource relative to existing fossil steam resources. Conversely, if Net CONE rises, all else equal, the combustion turbine appears less attractive relative to the existing fossil steam resources.

For these scenario simulations, there does not appear to be a consistent relationship between fossil steam capacity at risk for retirement as shown in Figure 18 for the OPSI scenarios. While the Net CONE benchmark decreases in all scenarios with a decrease in renewable output as combustion turbines run slightly more often and at higher prices, it appears that the price and increase output effects of reduced renewable dominate the Net CONE and revenue reducing effects in 2020 and 2029. Only in 2025 do reduced renewable resources result in more fossil steam capacity at risk for retirement.

Changes in Energy Efficiency

Energy efficiency as PJM has modeled it in PROMOD results in a reduction both in both peak demand (megawatts) and total energy demand (megawatt-hours) over the year. OPSI-requested scenarios 2a and 2b.2 and PJM-developed scenarios PJM 2 and PJM 3 can be examined to see the effects of decreasing available energy efficiency. OPSI 2b.2 reduces the available energy efficiency by 50 percent from OPSI 2a, which assumes 100 percent of the EPA energy efficiency target. Figure 29 below shows the difference in energy efficiency levels across the compliance years simulated.

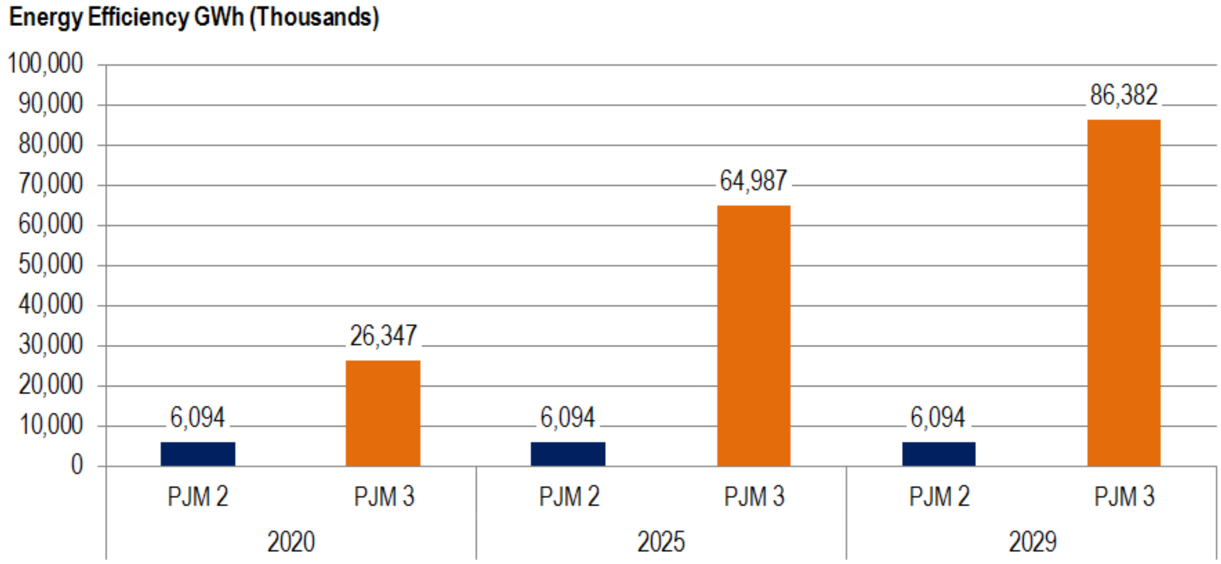
Figure 29. Total Energy Efficiency Reductions in OPSI Scenarios with High Levels of Renewable and New Combined-Cycle Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

PJM 2 assumes only the amount of energy efficiency that has cleared in the 2017/2018 RPM Base Residual Auction will be available over the compliance horizon, while PJM 3 assumes meeting 100 percent of the EPA targeted energy efficiency levels over the 2020 to 2029 period. This is shown in Figure 30.

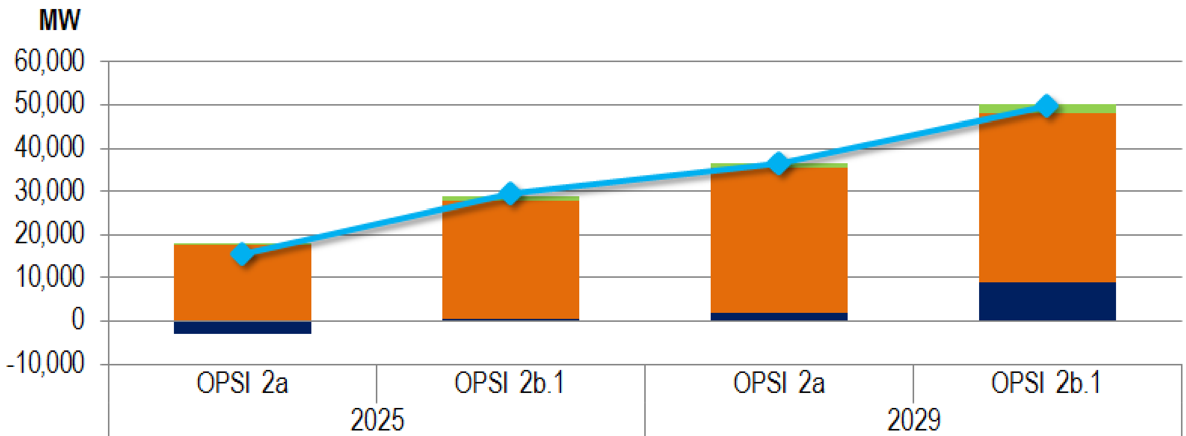
Figure 30. Total Energy Efficiency Reductions in PJM Scenarios with Reduced Levels of Renewable and New Combined-Cycle Resources



PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Effect on Resource Redispatch

Figure 31. Changes in Coal and Natural Gas Generation at Differing Levels of Energy Efficiency in OPSI Scenarios with High Levels of Renewable and New Combined-Cycle Resources



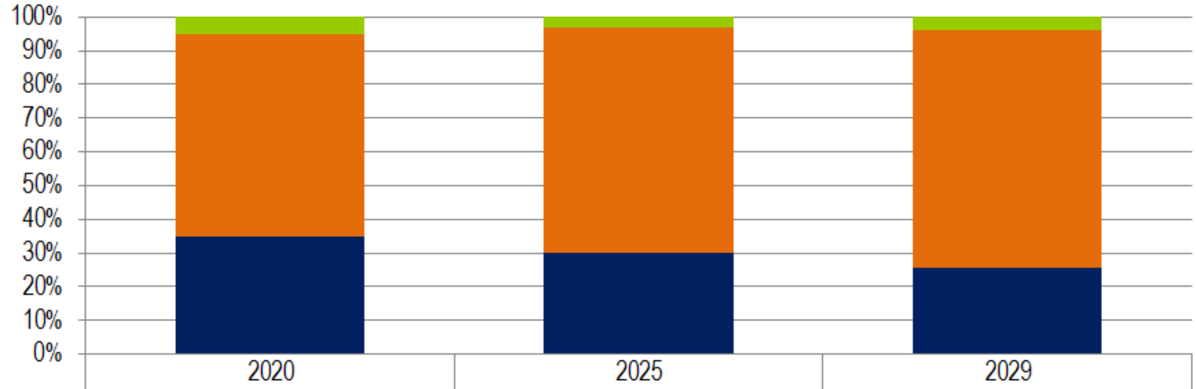
	2025 OPSI 2a	2025 OPSI 2b.1	2029 OPSI 2a	2029 OPSI 2b.1
NGCT	372	968	1,112	2,086
111(b) NGCC	17,605	27,274	33,451	39,010
111(d) NGCC	-2,890	611	2,004	8,979
Coal	15,468	29,317	36,387	49,670

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

Figure 31 shows the redispatch in the OPSI scenarios. Neither of the OPSI scenarios bind on the CO_2 emission target in 2020, so there is no redispatch required. In other words, the OPSI scenarios result in emissions below the target. Reducing the level of energy efficiency affects both coal and natural gas resources. In the absence of the Clean Power Plan, coal output would make up for 56 percent of the lost energy efficiency in 2025 and 52 percent in 2029. However, with the Clean Power Plan in place, coal output is reduced, as shown in Figure 31, and is replaced primarily with new entry combined-cycle gas subject to 111(b) NSPS and not modeled as part of the Clean Power Plan. With the reduced level of energy efficiency, only in 2029 is there a ramp up in existing combined-cycle redispatch.

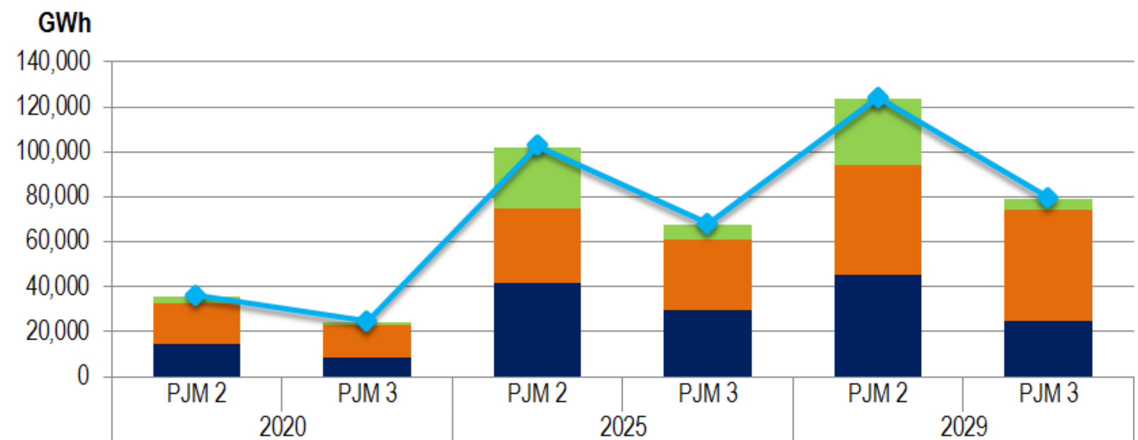
Figure 32 shows how energy efficiency would displace generation resources in the absence of the Clean Power Plan. An increase in energy efficiency would primarily impact natural gas generation by nearly a 2.2 to 1.0 ratio to coal generation. Because natural gas resources emit far less CO_2 than coal resources, each megawatt-hour of energy efficiency does not displace emissions one-for-one; instead, the tons removed of CO_2 are a fraction of the energy efficiency added. For example, a combined-cycle natural gas resource with a heat rate of 6.8 mmbtu/MWh and an emissions rate of 118 lbs/mmbtu will only reduce 0.4 tons of CO_2 for each megawatt-hour displaced, whereas a coal unit with a heat rate of 9.5 mmbtu/MWh and an emissions rate of 205 lbs/mbbtu will reduce CO_2 emissions at a rate of 97.4 percent of each megawatt-hour displaced. For less-efficient coal resources, it is possible to achieve an even greater reduction in CO_2 emissions than the corresponding energy displaced.

Figure 32. Percentage Displacement of Fossil Resources by Energy Efficiency in OPSI Scenario 2a in the Absence of the Clean Power Plan



	2020	2025	2029
Other	5.2%	3.1%	4.0%
NGCC	60.0%	66.9%	70.2%
Coal	34.8%	30.1%	25.8%

Figure 33. Changes in Coal and Natural Gas Generation at Differing Levels of Energy Efficiency in PJM Scenarios with Reduced Levels of Renewable and New Combined-Cycle Resources



	2020 PJM 2	2020 PJM 3	2025 PJM 2	2025 PJM 3	2029 PJM 2	2029 PJM 3
NGCT	2,865	1,520	26,963	6,540	29,321	5,103
111(b) NGCC	18,524	14,718	33,362	31,144	48,848	49,322
111(d) NGCC	14,345	8,186	41,609	29,702	45,449	24,596
Coal	36,163	24,650	102,739	68,131	124,177	79,315

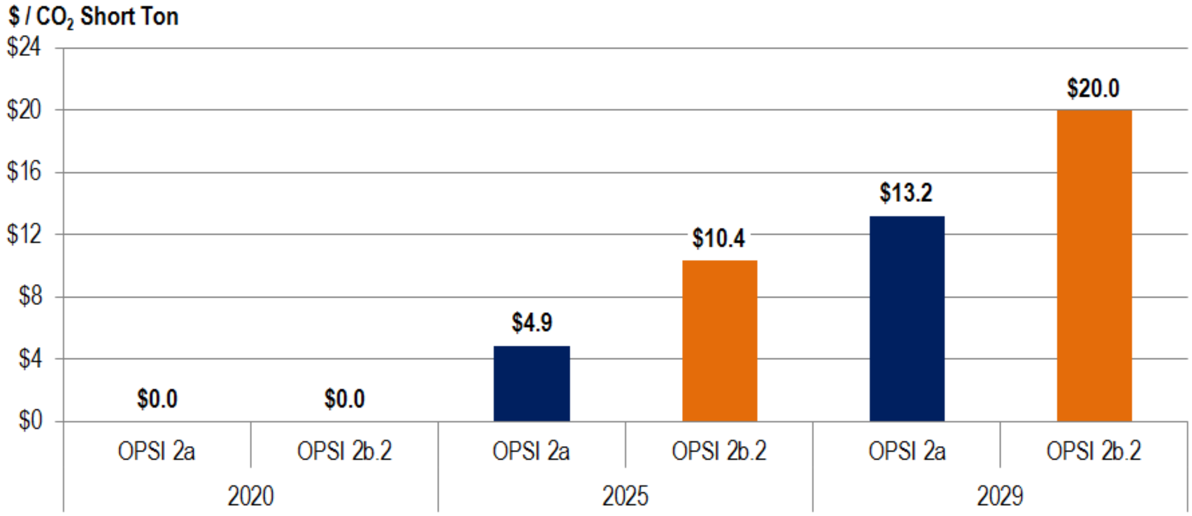
PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Figure 33 shows the redispatch that occurs in the PJM scenarios. Increasing energy efficiency reduces the need for coal to existing natural gas re-dispatch and reduces the dispatch of simple-cycle combustion turbines not subject to the Clean Power Plan. But what remains largely unchanged is the redispatch of new entry combined-cycle resources subject to 111(b) NSPS and not modeled as subject to the Clean Power Plan. Because these resources contribute zero emissions to Clean Power Plan compliance, they are already running as much as possible so the increase in energy efficiency does not appreciably affect their dispatch.

Effect on CO_2 Prices

All things being equal, a reduction in available energy efficiency results in a higher CO_2 emissions price since the marginal cost of reducing emissions through redispatch is higher. This is because of the need to redispatch additional and less efficient combined-cycle gas resources to achieve compliance with the regional mass-based target. For the OPSI-requested scenarios 2a and 2b.2, this can be seen in Figure 34 and for the PJM-developed scenarios PJM 2 and PJM 3 this can be seen in Figure 35.

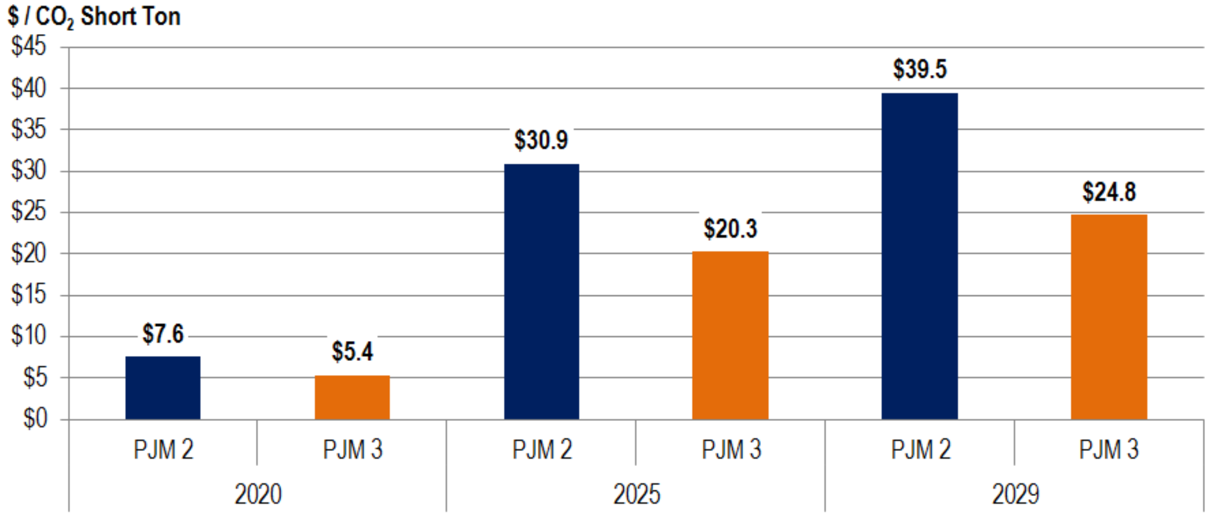
Figure 34. CO_2 Prices with Differing Levels of Energy Efficiency in OPSI Scenarios with High Levels of Renewable and New Combined-Cycle Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

In the OPSI-requested scenarios in 2020, there are only small differences in total GWh as shown in 0, and with sufficient renewable capacity the CO_2 price remains zero in both scenarios. In the PJM scenarios, PJM 2 shows a larger increase in CO_2 prices since the level of energy efficiency is well below the 50 percent threshold examined in the OPSI scenarios. This reinforces the idea that reducing the levels of energy efficiency results in higher CO_2 prices. The two differences between the OPSI-requested scenarios in Figure 34 and the PJM developed scenarios in Figure 35 are that both the level of renewables and the availability of potential new entry combined-cycle gas are lower in the PJM scenarios. This results in CO_2 prices being higher due to greater redispatch from coal to existing combined-cycle natural gas resources and possibly even natural gas combustion turbines, with a lower level of zero-emitting resources from a compliance perspective.

Figure 35. CO_2 Prices with Differing Levels of Energy Efficiency in PJM Scenarios with Reduced Levels of Renewable and New Combined-Cycle Resources

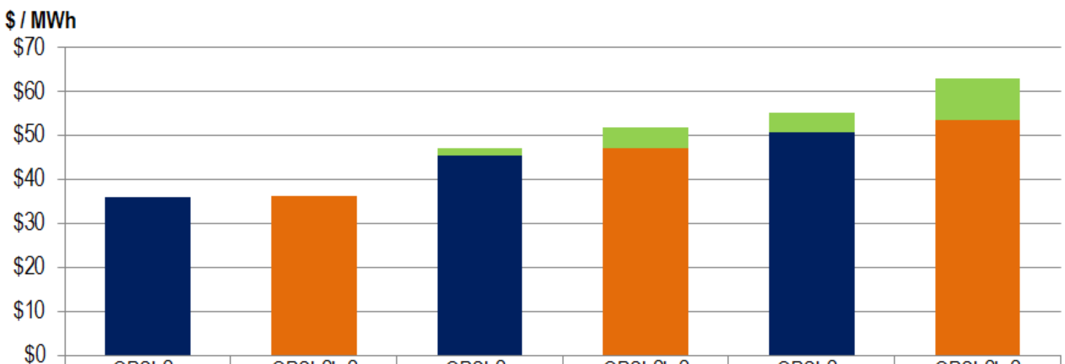


PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Effects on Locational Marginal Prices

Since it increases the price of CO_2 emissions, reducing energy efficiency will increase wholesale market energy prices as represented by the Locational Marginal Price. This is shown for the OPSI scenarios in Figure 36 and for the PJM scenarios in Figure 37. Again, the translation of CO_2 price into the LMP is less than 50 percent, implying that it is primarily existing combined-cycle resources that are on the margin in the energy market, rather than coal resources.

Figure 36. Effects of CO_2 Prices on Load-weighted Average Wholesale Energy Market Prices in OPSI Scenarios with Differing Levels of Energy Efficiency and High Levels of Renewable and New Combined-Cycle Resources

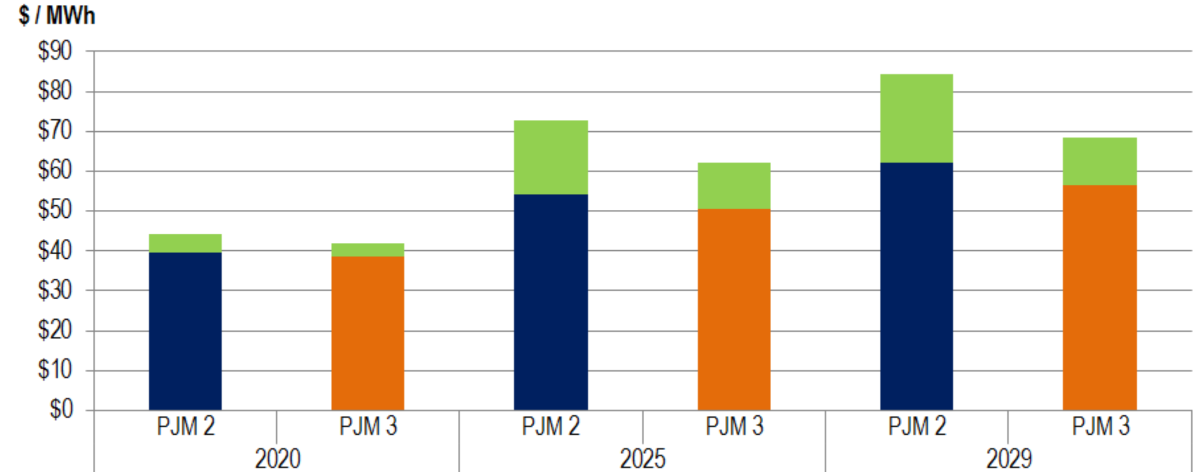


	2020		2025		2029	
	OPSI 2a	OPSI 2b.2	OPSI 2a	OPSI 2b.2	OPSI 2a	OPSI 2b.2
111(d)	$0.0	$0.0	$1.9	$4.6	$4.6	$9.4
LMP Base	$35.9	$36.4	$45.4	$47.1	$50.6	$53.5

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

In the PJM scenarios, in contrast, the effect of CO_2 prices on LMP is between 50 and 60 percent, indicating a greater need for redispatch of resources, and the increased redispatch of combustion turbines as shown in Figure 33. This also suggests there would be more times when coal is on the margin due to the lower levels of energy efficiency, coupled with lower availability of renewables and new entry combined-cycle that is not subject to the Clean Power Plan as PJM has modeled it.

Figure 37. Effects of CO_2 Prices on Load-weighted Average Wholesale Energy Market Prices in PJM Scenarios with Differing Levels of Energy Efficiency and Reduced Levels of Renewable and New Combined-Cycle Resources



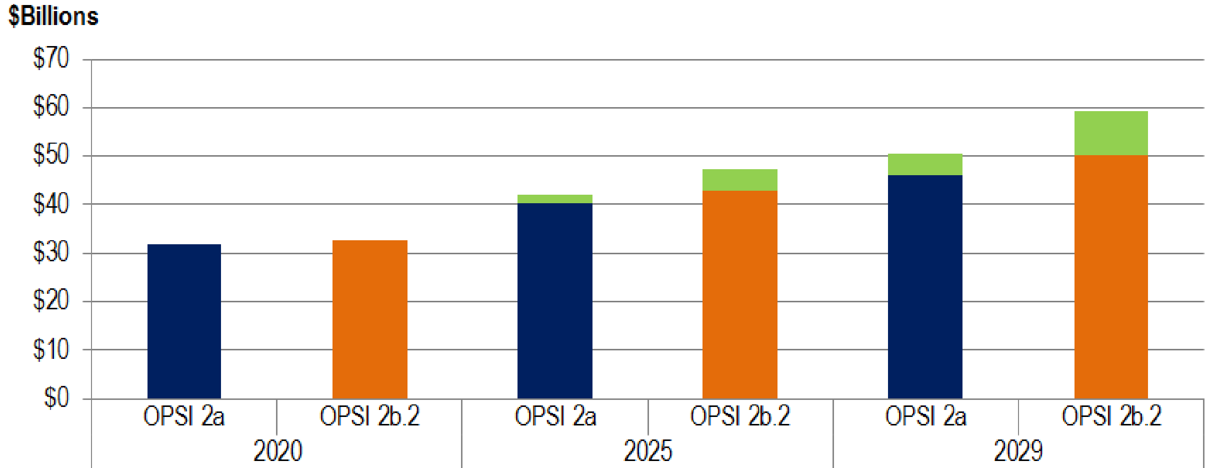
	PJM 2 2020	PJM 3 2020	PJM 2 2025	PJM 3 2025	PJM 2 2029	PJM 3 2029
111(d)	$4.9	$3.3	$18.6	$11.4	$22.4	$12.1
LMP Base	$39.5	$38.7	$54.2	$50.6	$62.1	$56.3

PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Effect on Load Energy Payments

Stemming from the changes in LMP, the effect on load energy payments from a decrease in energy efficiency will be an increase due to the higher LMP and a higher level of energy consumption because efficiency has been reduced. Figure 38 for the OPSI scenarios and Figure 39 for the PJM scenarios shows this clearly as the changes in energy efficiency alone, absent redispatch, lead to higher load payments.

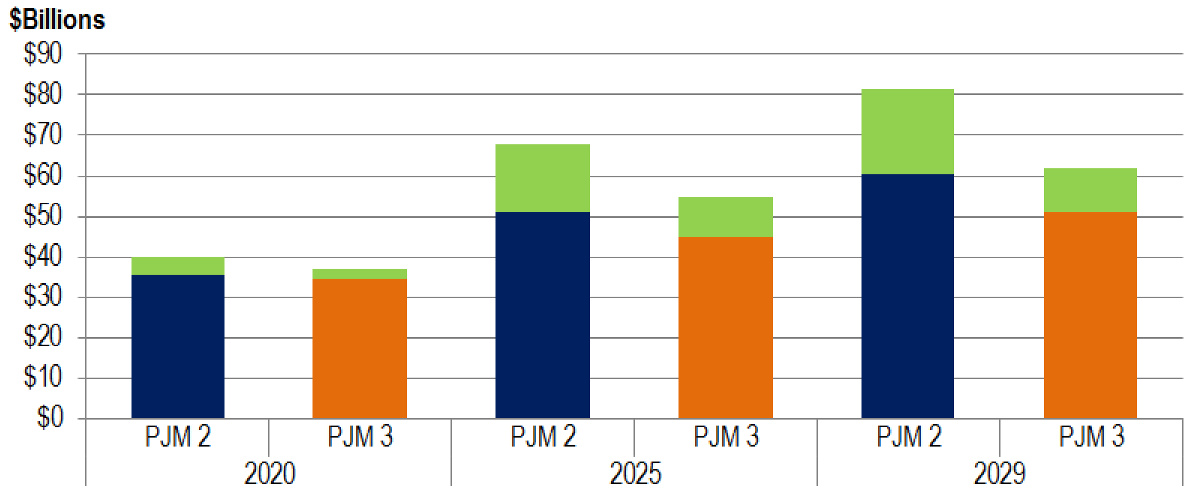
Figure 38. Effects of CO_2 Prices on Load Energy Payments in OPSI Scenarios with Differing Levels of Energy Efficiency and High Levels of Renewable and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.2	2025 OPSI 2a	2025 OPSI 2b.2	2029 OPSI 2a	2029 OPSI 2b.2
111(d)	$0.0	$0.0	$1.8	$4.4	$4.5	$8.8
Base	$31.9	$32.7	$40.2	$43.0	$46.1	$50.3

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

Figure 39. Effects of CO_2 Prices on Load Energy Market Payments in PJM Scenarios with Differing Levels of Energy Efficiency and Reduced Levels of Renewable and New Combined-Cycle Resources



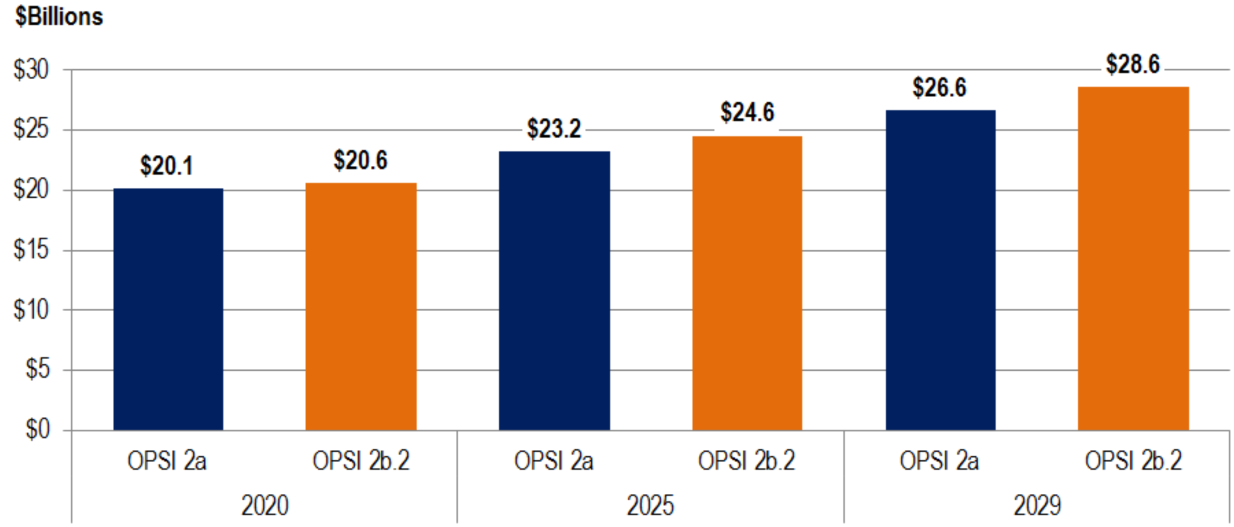
	2020 PJM 2	2020 PJM 3	2025 PJM 2	2025 PJM 3	2029 PJM 2	2029 PJM 3
111(d)	$4.2	$2.8	$16.8	$9.9	$21.1	$10.7
Base	$35.8	$34.3	$51.1	$45.0	$60.3	$51.2

PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Effects on Compliance Costs as Measured Through Changes in Production Costs

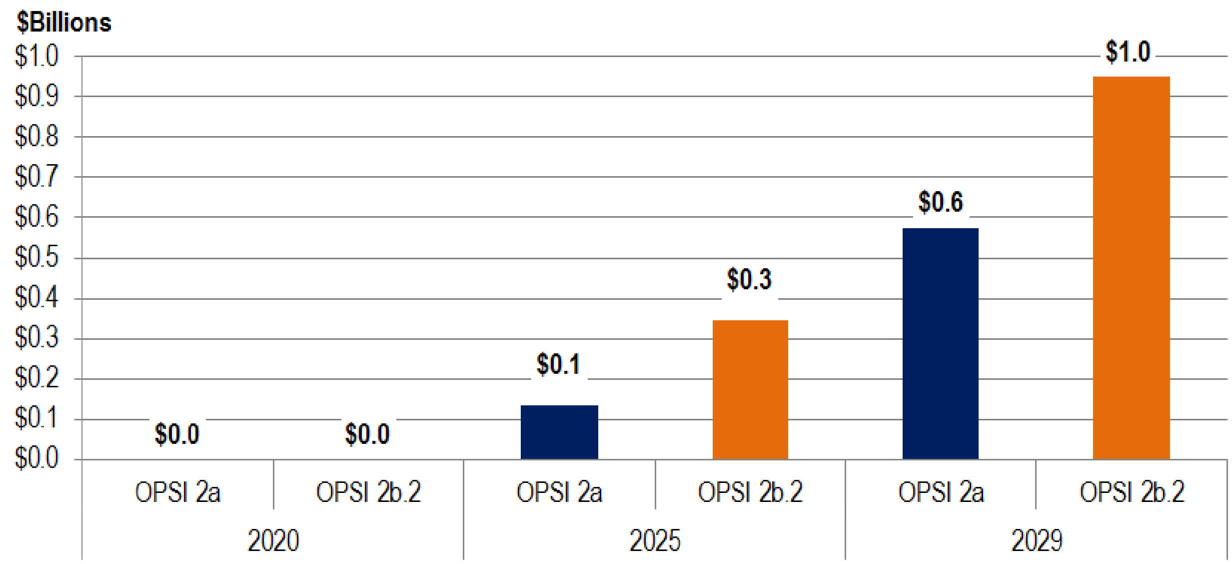
Total fuel and operations and maintenance production costs for the OPSI-requested scenarios are presented in Figure 40 and the changes in production costs due to redispatch (compliance costs) are shown in Figure 41. The same simulation outputs for the PJM scenarios are presented in Figure 42 and Figure 43, respectively.

Figure 40. Total Fuel and Variable O&M Production Costs in OPSI Scenarios with Differing Levels of Energy Efficiency and High Levels of Renewable and New Combined-Cycle Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

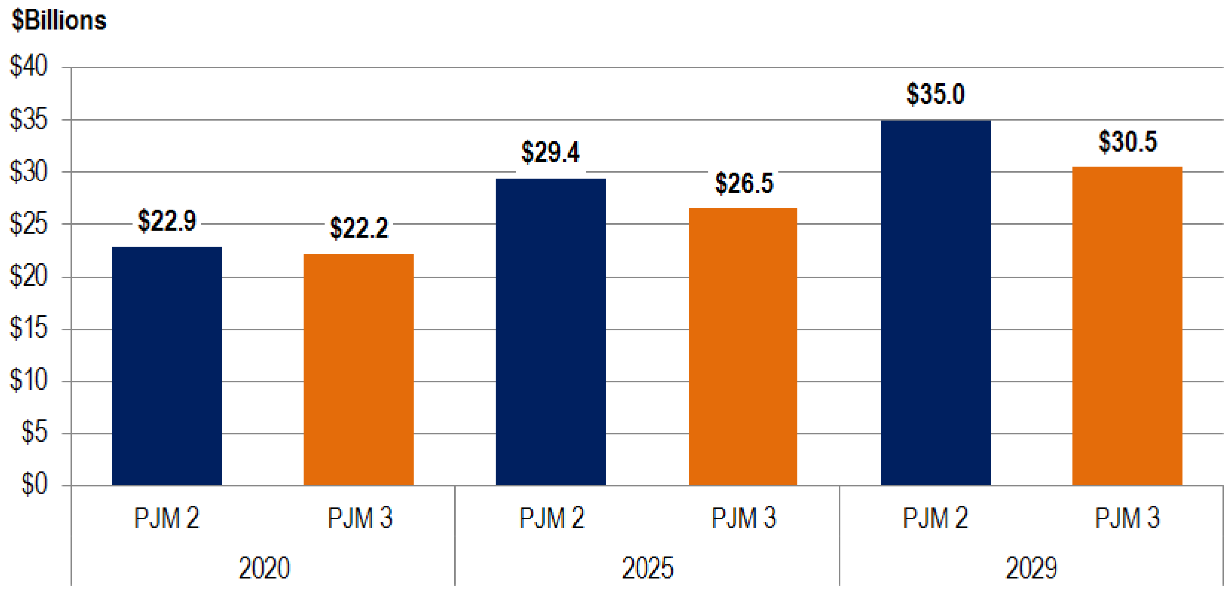
Figure 41. Total Fuel and Variable O&M Compliance Costs in OPSI Scenarios with Differing Levels of Energy Efficiency and High Levels of Renewable and New Combined-Cycle Resources



OPSI 2a assumes PJM states meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

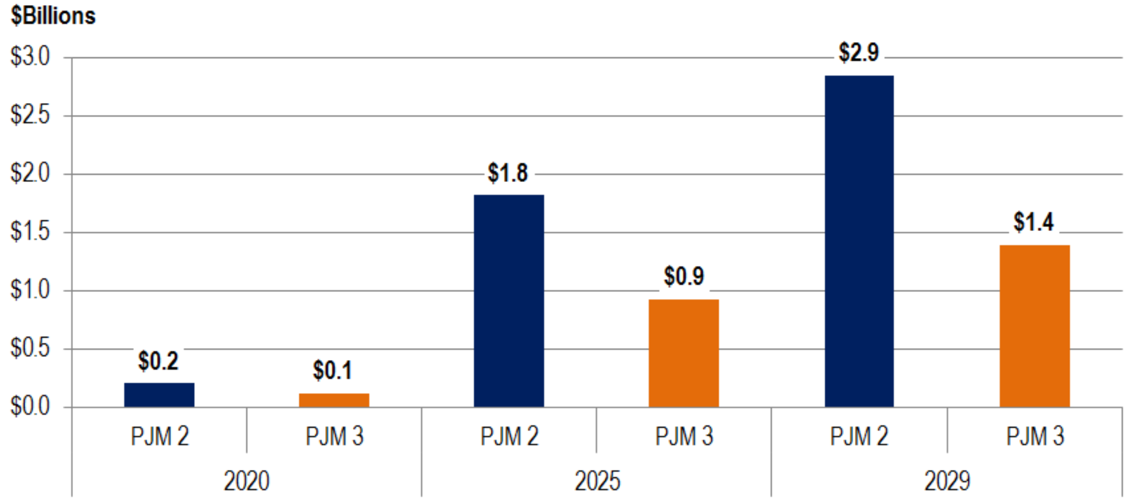
For the OPSI-requested scenarios, the fuel and operation and maintenance compliance costs are at most 3.5 percent of total fuel and operation and maintenance production costs, and that is with energy efficiency reduced by 50 percent in 2029. In large measure, this is due to the reduced need for redispatch because of the high levels of renewable resources and new entry assumed in the OPSI-requested scenarios. In the PJM-developed scenarios, in contrast, a decrease in energy efficiency to current levels throughout the compliance period results in compliance costs that are as high as 8.3 percent of total fuel and operation and maintenance costs due to the need to increase redispatch as the levels of efficiency, renewables and new entry are reduced compared to the OPSI scenarios.

Figure 42. Total Fuel and Variable O&M Production Costs in PJM Scenarios with Differing Levels of Energy Efficiency and Reduced Levels of Renewable and New Combined-Cycle Resources



PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Figure 43. Total Fuel and Variable O&M Compliance Costs in PJM Scenarios with Differing Levels of Energy Efficiency and Reduced Levels of Renewable and New Combined-Cycle Resources



PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Fossil Steam Capacity at Risk for Retirement

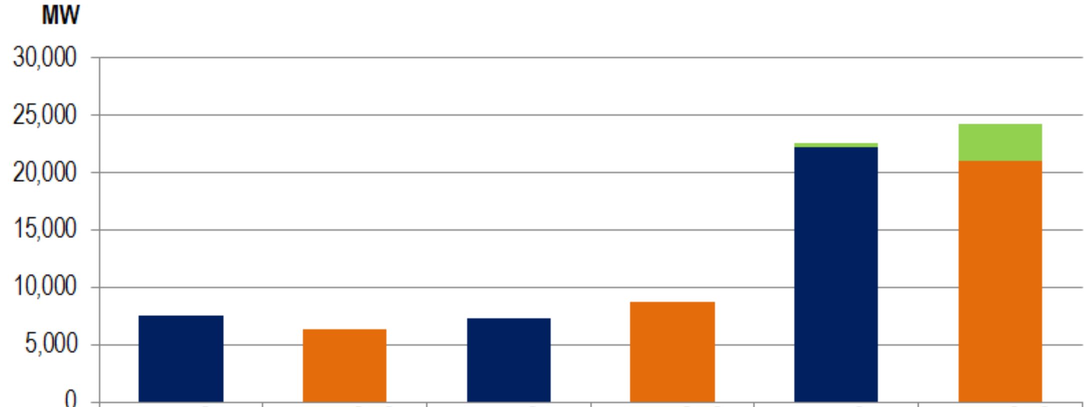
Table 8 and Figure 44 show the Net CONE benchmarks and the fossil steam capacity at risk for retirement, respectively, for the simulation years 2020, 2025 and 2029 for the OPSI scenarios.

Table 8. Combustion Turbine CONE Values for OPSI Scenarios with Differing Levels of Energy Efficiency and High Levels of Renewable and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	OPSI 2a	$414.5	$4.3	$410.2
	OPSI 2b.2	$415.7	$4.4	$411.3
2025	OPSI 2a	$464.6	$9.3	$455.3
	OPSI 2b.2	$464.6	$13.5	$451.1
2029	OPSI 2a	$506.8	$19.1	$487.6
	OPSI 2b.2	$507.9	$35.8	$472.0

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

Figure 44. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for OPSI Scenarios with Differing Levels of Energy Efficiency and High Levels of Renewable and New Combined-Cycle Resources



	OPSI 2a	OPSI 2b.2	OPSI 2a	OPSI 2b.2	OPSI 2a	OPSI 2b.2
	2020		2025		2029	
0.6 - 0.75 Net Cone					318	3,267
0.5 - 0.6 Net Cone	7,521	6,374	7,275	8,770	22,269	20,981

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.2 reduces energy efficiency to 50 percent of the EPA target levels.

Multiple, offsetting effects due to changes in energy efficiency levels go into determining the differences in fossil steam capacity at risk for retirement under the Clean Power Plan. With respect to fossil steam (primarily coal) net energy market revenues the following effect must be considered:

- All else equal, the higher levels of energy efficiency result in a lower price on CO_2, which would increase fossil steam net energy market revenues as the lower CO_2 price reduces fossil steam running costs.
- But, higher levels of energy efficiency also decrease wholesale energy market prices and, all else equal, decreases the net energy market revenues of fossil steam units.
- All else equal, higher levels of energy efficiency imply lower fossil steam output, leading to lower net energy market revenues.
- Yet, there also may be increased generation output due to the reduction in redispatch, which, all else equal, increases net energy market revenues.

For fossil steam units, if the decrease in running costs and reduced redispatch dominates the reduced generation output due to energy efficiency and lower energy prices, then net energy market revenues increase. Otherwise, fossil steam units will observe a reduction in energy market revenues.

The change in the benchmark Net CONE is likely the most relevant factor with respect to energy efficiency. Increasing energy efficiency results in an increase in Net CONE, which, all else equal, makes combustion turbines appear less attractive as resources relative to existing fossil steam resources since energy efficiency also reduces peak loads and peak power prices. This effect is clearly seen in Table 8 and Table 9.

In the OPSI scenarios, reducing the amount of energy efficiency alone seems to result in a slight decrease in fossil steam capacity at risk when there are positive CO_2 prices in 2025 and 2029. But in 2020, when the CO_2 price is zero in both scenarios, reducing energy efficiency improves fossil steam net energy revenues and slightly reduces the amount of capacity at risk for retirement. In 2025 and 2029, the Net CONE values for the combustion turbine are lower with less energy efficiency and would lead to more capacity at risk. This conclusion is reinforced by the relative changes in CO_2 prices being greater than the change in LMPs so that fossil steam net revenues are not enhanced.

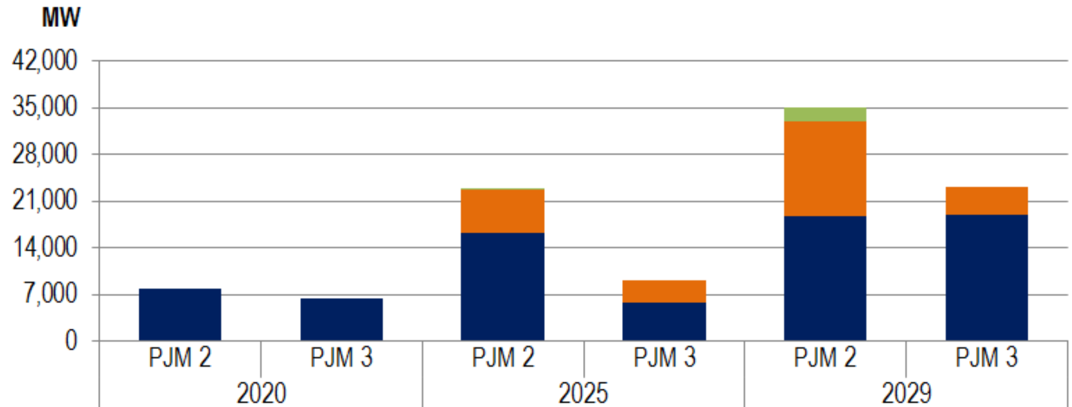
Table 9 and Figure 45 show the Net CONE benchmarks and capacity at risk for retirement, respectively, for the simulation years 2020, 2025 and 2029 for the PJM scenarios.

Table 9. Combustion Turbine CONE Values for PJM Scenarios with Differing Levels of Energy Efficiency and Reduced Levels of Renewable and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	PJM 2	$415.4	$20.9	$394.4
	PJM 3	$415.4	$16.3	$399.0
2025	PJM 2	$464.6	$105.7	$358.9
	PJM 3	$464.6	$54.6	$410.0
2029	PJM 2	$507.9	$130.9	$377.0
	PJM 3	$507.9	$62.5	$445.4

PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Figure 45. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for PJM Scenarios with Differing Levels of Energy Efficiency and Reduced Levels of Renewable and New Combined-Cycle Resources



	2020 PJM 2	2020 PJM 3	2025 PJM 2	2025 PJM 3	2029 PJM 2	2029 PJM 3
0.75 - 1.0 Net CONE			185		2,064	
0.6 - 0.75 Net CONE			6,484	3,419	14,097	4,255
0.5 - 0.6 Net CONE	8,001	6,554	16,227	5,755	18,831	18,965

PJM 2 assumes renewable resources at the current existing levels for all years, energy efficiency levels at the amount of energy efficiency cleared in the 2017/2018 BRA, and combined-cycle natural gas new entry based on historic commercial probabilities. PJM 3 is identical to PJM 2 except energy efficiency levels are increased to be at the EPA target energy efficiency levels.

Unlike the OPSI scenarios, the PJM scenarios have less available renewable resources and new entry combined- cycle gas. Increasing energy efficiency shows a clear trend in reducing the amount of fossil steam capacity at risk under the Clean Power Plan. And, with CO_2 prices relatively higher than in the OPSI scenarios, this effect becomes even more pronounced. The reason for less capacity at risk can be seen through the Net CONE values in Table 9 where increasing energy efficiency increases the Net CONE of the combustion turbine because there is less need for peaking resources. The increase in Net CONE should reduce capacity at risk as combustion turbines become a less attractive alternative relative to retaining existing fossil resources. The reductions in CO_2 prices in Figure 35 are approximately equal to the reduction in LMPs in Figure 37, so that the net energy market revenues on average would only be affected by selling less energy, but this effect is dominated by the Net CONE increase.

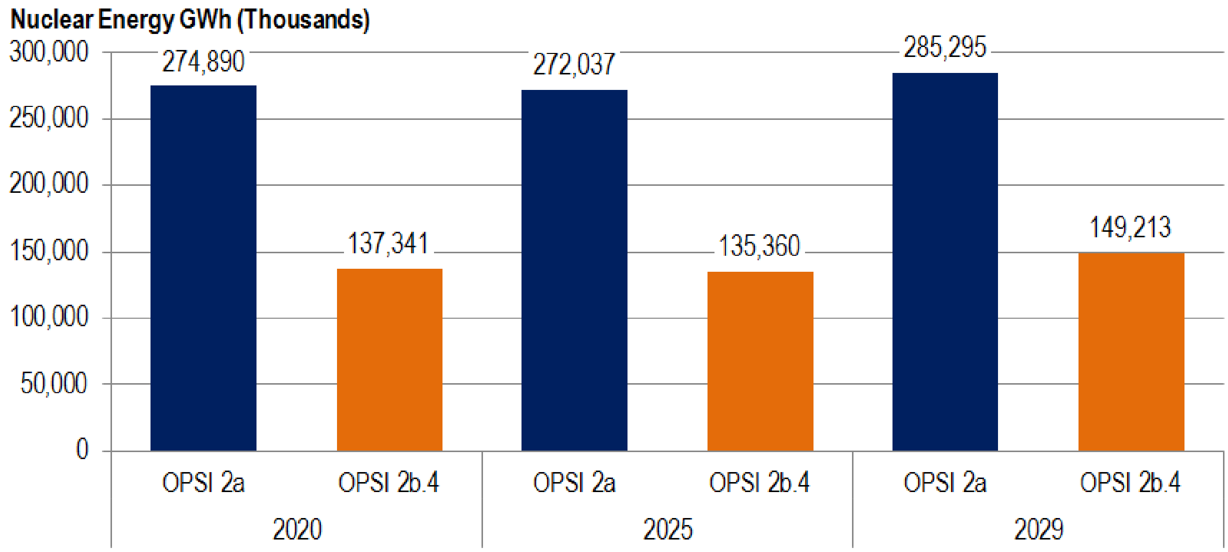
Finally, in comparing capacity at risk for retirement across the OPSI scenarios and the PJM scenarios, one can draw the conclusion that with the Clean Power Plan for the scenarios shown, increasing amounts of energy efficiency reduce the capacity at risk for retirement quite substantially, and this effect seems to be greater at higher CO_2 prices.

Changes in Nuclear Capacity in Service

OPSI-requested scenarios 2a and 2b.4, which reduces nuclear capacity by 50 percent, and PJM-developed scenarios PJM 4 and PJM 6, which reduces nuclear capacity by only 10 percent, can be examined to see the effects of decreasing nuclear capacity with respect to the Clean Power Plan.

Figure 46 and Figure 47 show the change in nuclear energy output.[16]

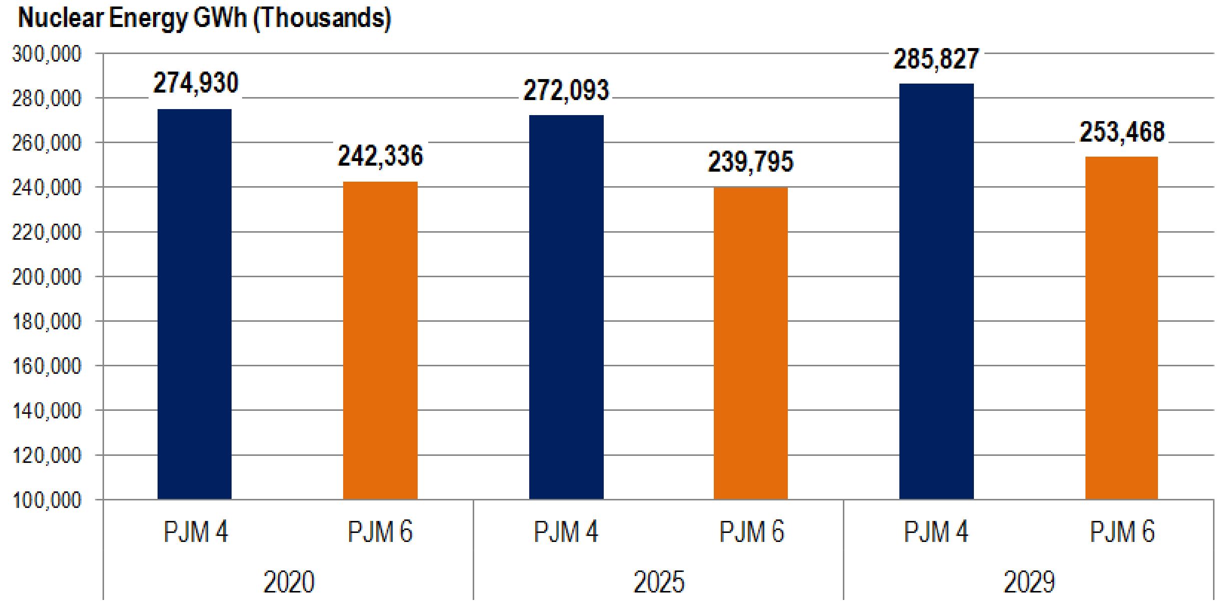
Figure 46. Total Nuclear Generation Reductions in the OPSI Scenarios Reducing Nuclear Generation 50 Percent



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

[16] Retirements are modeled as proportionate across the PJM footprint. North Anna 3 is added to the model in 2028.

Figure 47. Total Nuclear Generation Reductions in the PJM Scenarios Reducing Nuclear Generation 10 Percent

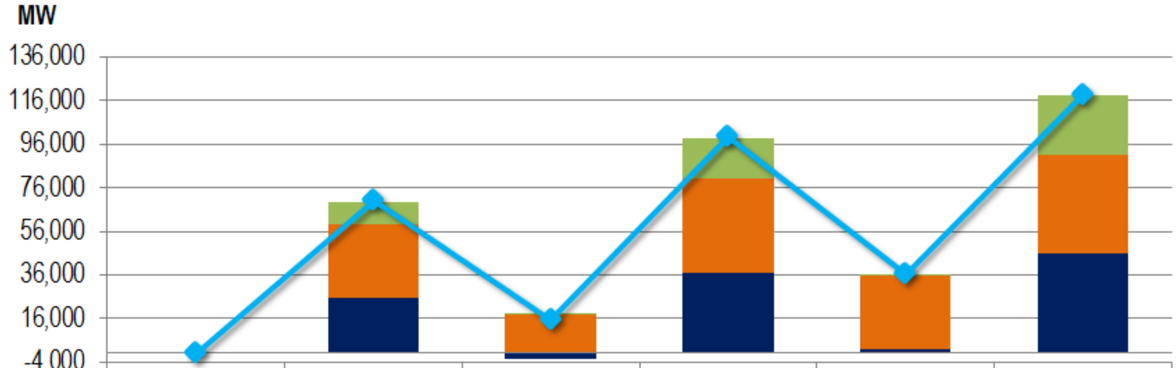


PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Effect on Resource Redispatch

In Figure 48, the retirement of 50 percent of the nuclear fleet in the OPSI scenarios has a significant impact on the amount of redispatch required to achieve the CO_2 emission targets. As the targets decline and load and natural gas prices increase through 2029, the amount of energy due to redispatch from simple-cycle combustion turbine resources not subject to the Clean Power Plan increases nearly three times (2.7) between 2020 and 2029. At high enough CO_2 prices, the least efficient existing combined-cycle resources subject to the Clean Power Plan become more expensive than the most efficient combustion turbines that do not face a price on CO_2 emissions. Moreover, the decline in nuclear resources causes a much greater redispatch of coal resources downward, as well as the ramp up of existing combined-cycle resources.

Figure 48. Changes in Coal and Natural Gas Generation with a 50 Percent Reduction in Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources

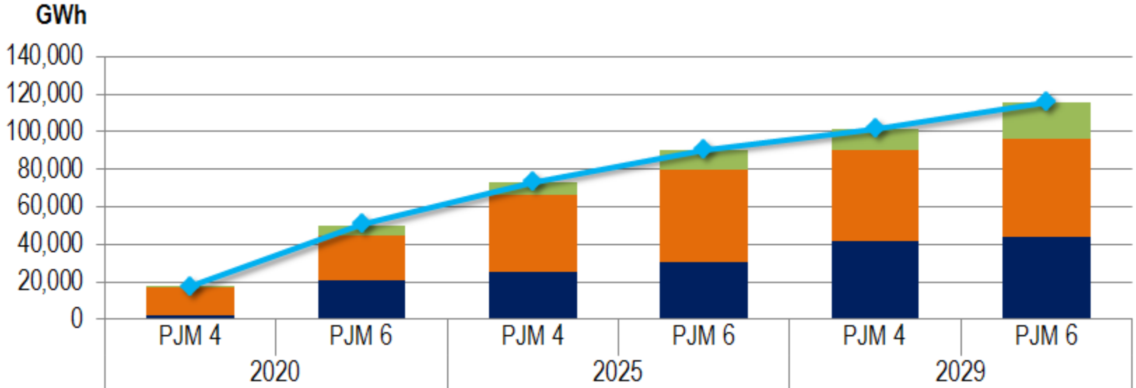


	2020 OPSI 2a	2020 OPSI 2b.4	2025 OPSI 2a	2025 OPSI 2b.4	2029 OPSI 2a	2029 OPSI 2b.4
NGCT	0	10,057	372	18,569	1,112	27,355
111(b) NGCC	0	33,874	17,605	43,503	33,451	45,082
111(d) NGCC	0	25,352	-2,890	36,703	2,004	46,109
Coal	0	70,154	15,468	99,434	36,387	118,686

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

Figure 49 the PJM scenarios with the loss of 10 percent of the nuclear fleet. Relative to the OPSI scenarios, the PJM scenarios show the same directional changes, but they are not nearly as pronounced. The major difference between the PJM scenarios and the OPSI scenarios is the reduction in available energy efficiency and renewable resources and limited new-entry combined cycle. This forces more redispatch of existing combined-cycle natural gas than in the OPSI scenarios absent the reduction in nuclear output. Another reason for the increase in existing combined-cycle resource output is the new entry combined-cycle units subject to 111(b) NSPS operating closer to their limits in all hours, leaving existing combined-cycle units to run more often as they are also not subject to the Clean Power Plan as modeled.

Figure 49. Changes in Coal and Natural Gas Generation with a 10 Percent Reduction in Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



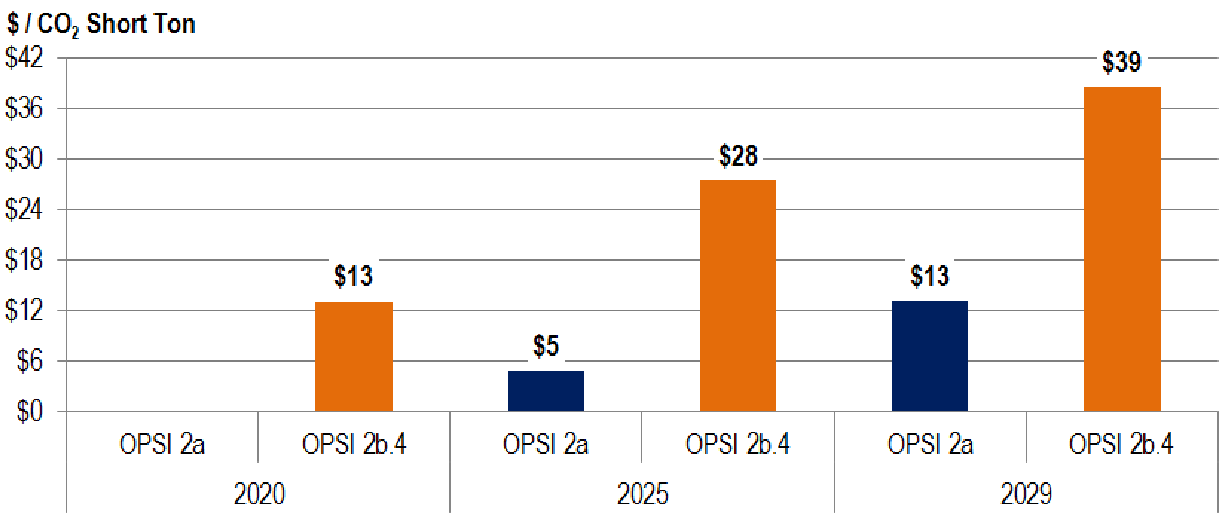
	PJM 4 (2020)	PJM 6 (2020)	PJM 4 (2025)	PJM 6 (2025)	PJM 4 (2029)	PJM 6 (2029)
NGCT	795	5,148	6,356	10,933	11,416	19,230
111(b) NGCC	14,568	23,921	41,170	48,995	48,230	51,999
111(d) NGCC	2,220	21,032	25,327	30,415	41,860	44,276
Coal	17,667	50,721	73,329	90,917	101,901	115,922

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Effect on CO_2 Prices

All things being equal, a decrease in nuclear generation also results in a higher CO_2 emissions price since the marginal cost of reducing emissions through redispatch is higher because of the higher natural gas prices. For the OPSI-requested scenarios 2a and 2b.4, this can be seen in Figure 50. For the PJM-developed scenarios PJM 4 and PJM 6, this can be seen in Figure 51.

Figure 50. CO_2 Prices with a 50 Percent Reduction of Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources

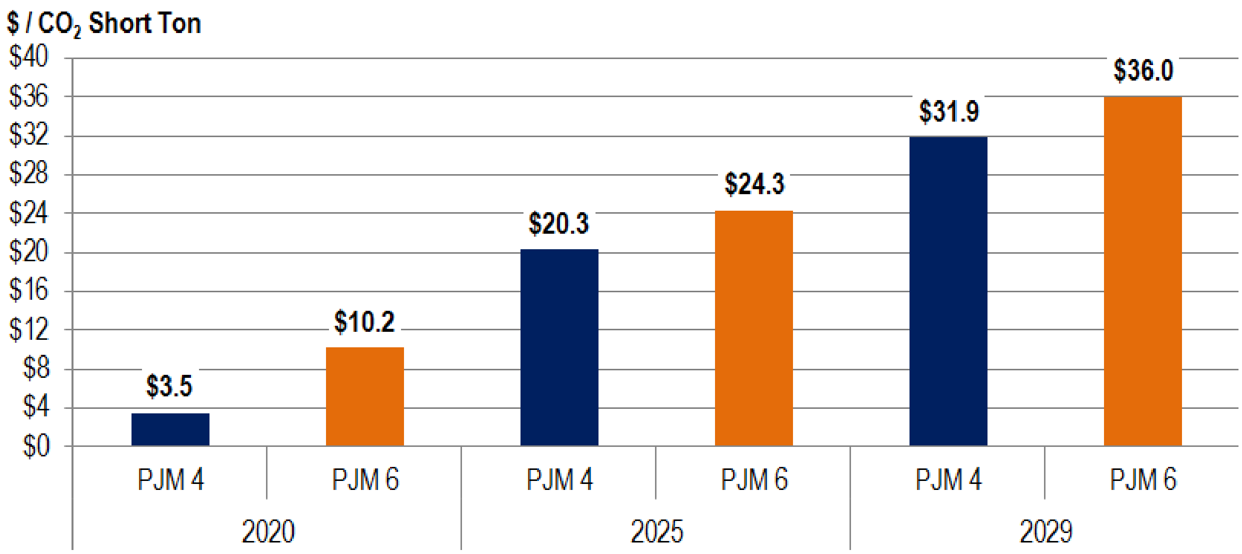


OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

Figure 50 shows the dramatic increase in CO_2 prices caused by a loss of 50 percent of the nuclear output. Compared to holding energy efficiency at current levels versus the EPA 100 percent target, the loss in zero-emitting gigawatt-hours is nearly two times greater in 2029. This effect also is true when compared to reducing renewable resources and energy efficiency to historic growth rates. Therefore, the CO_2 price impact of nuclear output reduction would be larger even assuming the PJM states' RPS and 100 percent of the EPA efficiency target are met since the loss of nuclear will need to be replaced by the remaining existing resources and require even more redispatch of existing combined-cycle gas resources.

Figure 51 shows a much more muted impact of losing only 10 percent of nuclear output. The two differences between the OPSI-requested scenarios in Figure 52 and the PJM-developed scenarios in Figure 51 are that the levels of renewables and energy efficiency are lower in the PJM scenarios and the availability of potential new entry combined-cycle gas also is lower in the PJM 6 scenario. From a compliance perspective, these resources are treated as zero emitting for existing resource compliance, so greater redispatch of existing combined- cycle gas resources is required in the PJM scenarios. Only all of those changes combined in PJM 6 get close to the CO_2 price impacts of losing 50 percent of nuclear capacity alone.

Figure 51. CO_2 Prices with a 10 Percent Reduction of Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



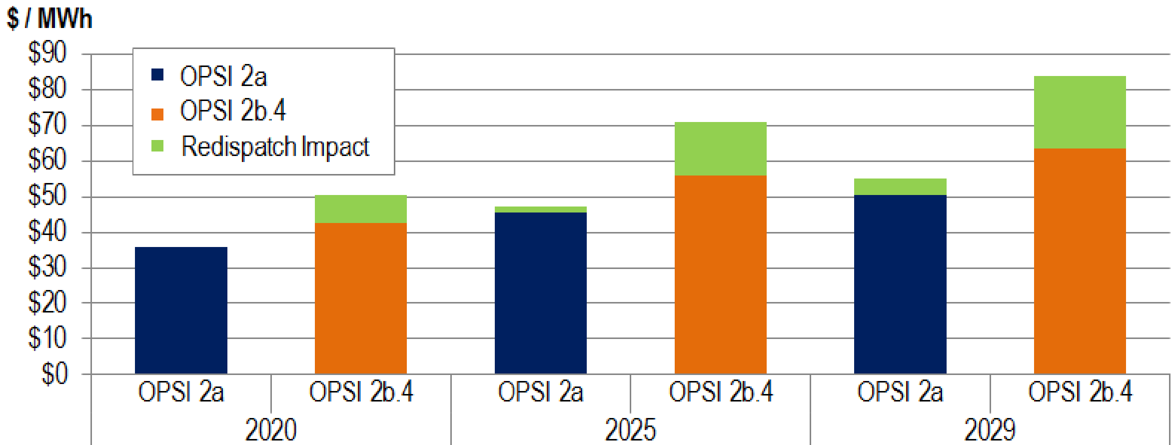
PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Effects on Locational Marginal Prices

Figure 52 and Figure 53 show the changes in LMP for the OPSI and PJM scenarios, respectively. For the OPSI 2b.4 scenario, in which 50 percent of the nuclear capacity is assumed to retire, only about 52 percent of the CO_2 price gets transmitted through LMP, indicating that existing combined-cycle gas is on the margin in the energy market a large percentage of the time rather than coal resources.

For the PJM-developed scenarios, about 55 percent of the CO_2 price gets passed through to LMP, indicating coal and existing combined-cycle resources are on the margin slightly more often than in the in the OPSI case. This also reflects the fact that in PJM 6 there is also slightly less new entry combined cycle available for dispatch, causing a slightly higher level of existing resource dispatch.

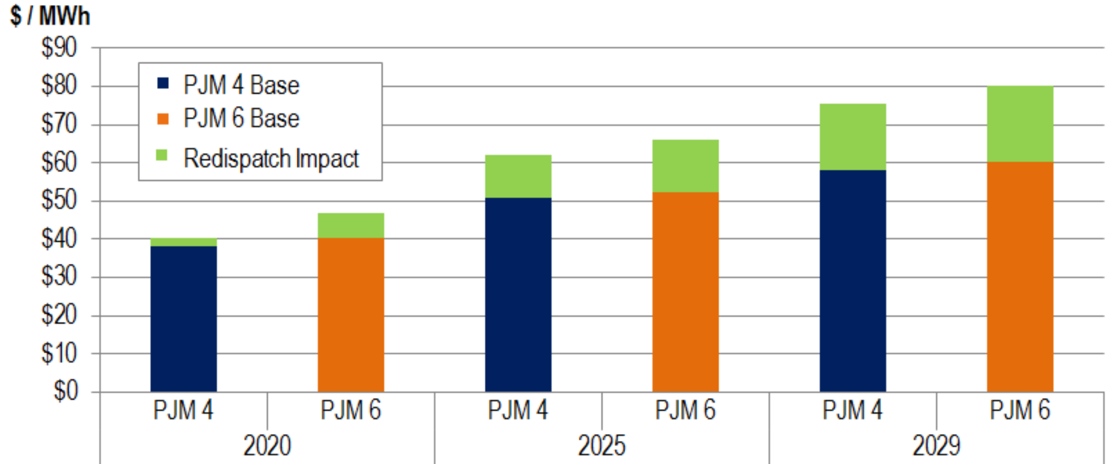
Figure 52. Effects of CO_2 Prices on Load-Weighted Average Wholesale Energy Market Prices with a 50 Percent Reduction of Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.4	2025 OPSI 2a	2025 OPSI 2b.4	2029 OPSI 2a	2029 OPSI 2b.4
111(d)	$0.0	$7.9	$1.9	$15.2	$4.6	$20.5
LMP Base	$35.9	$42.6	$45.4	$55.8	$50.6	$63.4

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

Figure 53. Effects of CO_2 Prices on Load-Weighted Average Wholesale Energy Market Prices with a 10 Percent Reduction in Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



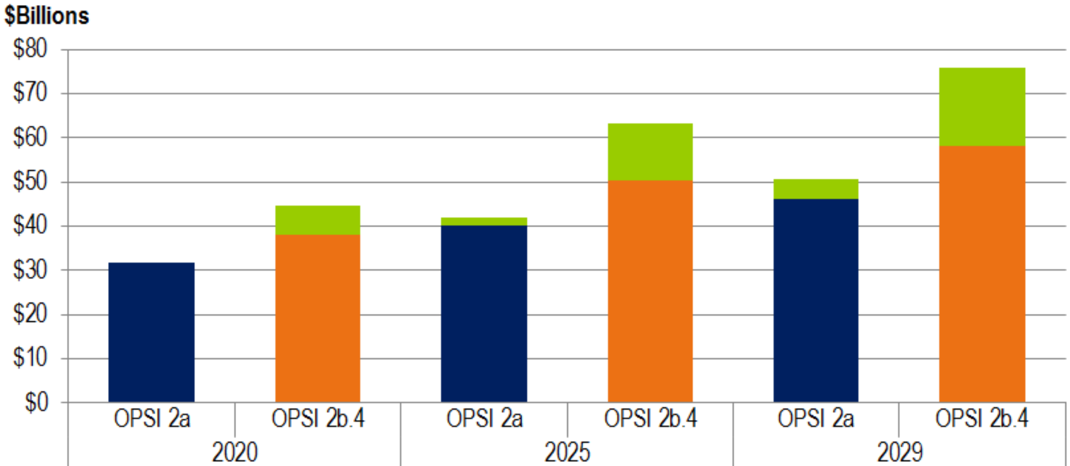
	PJM 4 (2020)	PJM 6 (2020)	PJM 4 (2025)	PJM 6 (2025)	PJM 4 (2029)	PJM 6 (2029)
111(d)	$2.1	$6.4	$11.4	$13.6	$17.3	$19.9
LMP Base	$38.3	$40.4	$50.7	$52.4	$58.1	$60.3

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Effect on Load Energy Payments

The changes for the OPSI-requested and PJM-developed scenarios are presented in Figure 54 and Figure 55, respectively. Not surprisingly, the incremental change in load energy payments from losing 50 percent of nuclear capacity is much greater than losing only 10 percent of nuclear capacity. However, the total cost changes in load energy payments between PJM 6 and OPSI 2b.4 are quite similar since in both cases, there is a significant reduction in zero-emitting resources from a compliance perspective.

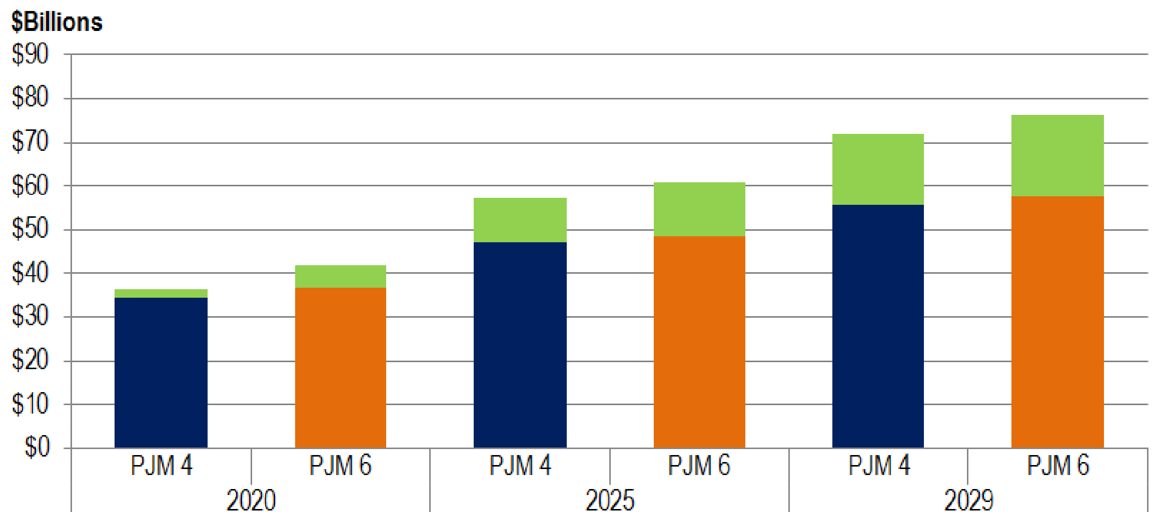
Figure 54. Effects of CO_2 Prices on Load Energy Payments with a 50 Percent Reduction of Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.4	2025 OPSI 2a	2025 OPSI 2b.4	2029 OPSI 2a	2029 OPSI 2b.4
111(d)	$0.0	$6.7	$1.8	$12.9	$4.5	$18.0
Base	$31.9	$38.1	$40.2	$50.3	$46.1	$58.0

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

Figure 55. Effects of CO_2 Prices on Load Energy Payments with a 10 Percent Reduction in Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



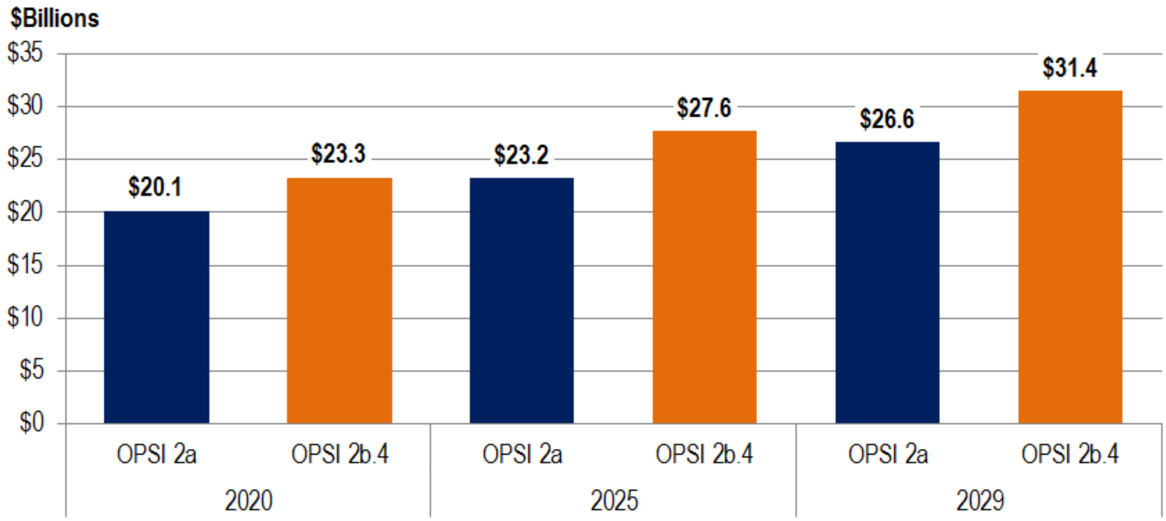
	2020 PJM 4	2020 PJM 6	2025 PJM 4	2025 PJM 6	2029 PJM 4	2029 PJM 6
111(d)	$1.8	$5.5	$10.3	$12.3	$16.2	$18.6
Base	$34.4	$36.6	$47.0	$48.6	$55.7	$57.7

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Effects on Compliance Costs as Measured Through Changes in Production Costs

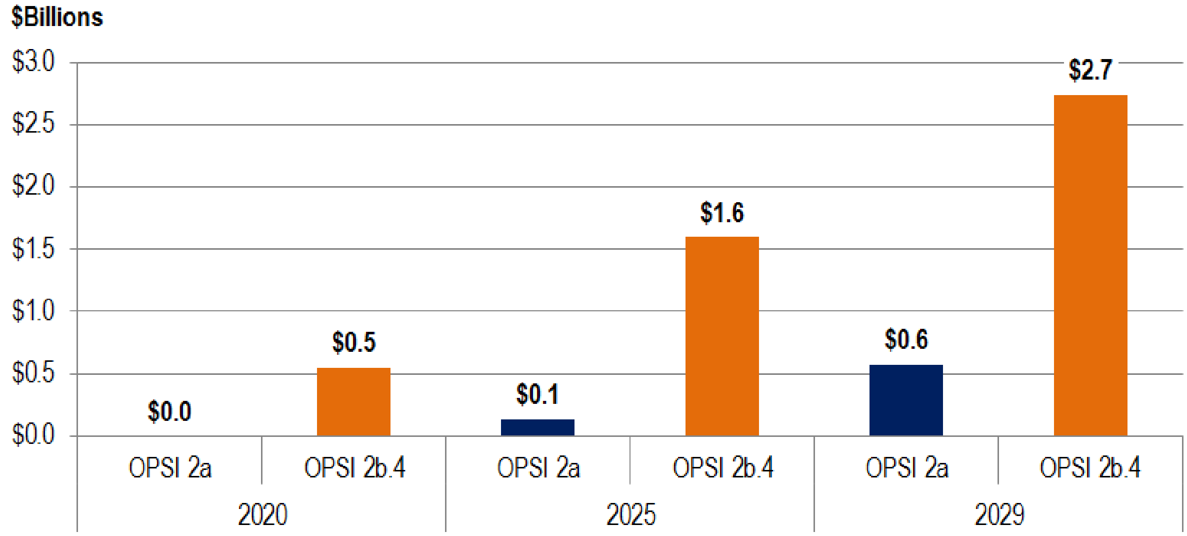
Total fuel and operations and maintenance production costs for the OPSI-requested scenarios are presented in Figure 56, and the change in production costs due to redispatch (compliance costs) are shown Figure 57. The same simulation outputs for the PJM scenarios are presented in Figure 58 and Figure 59, respectively.

Figure 56. Total Fuel and Variable O&M Production Costs with a 50 Percent Reduction of Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

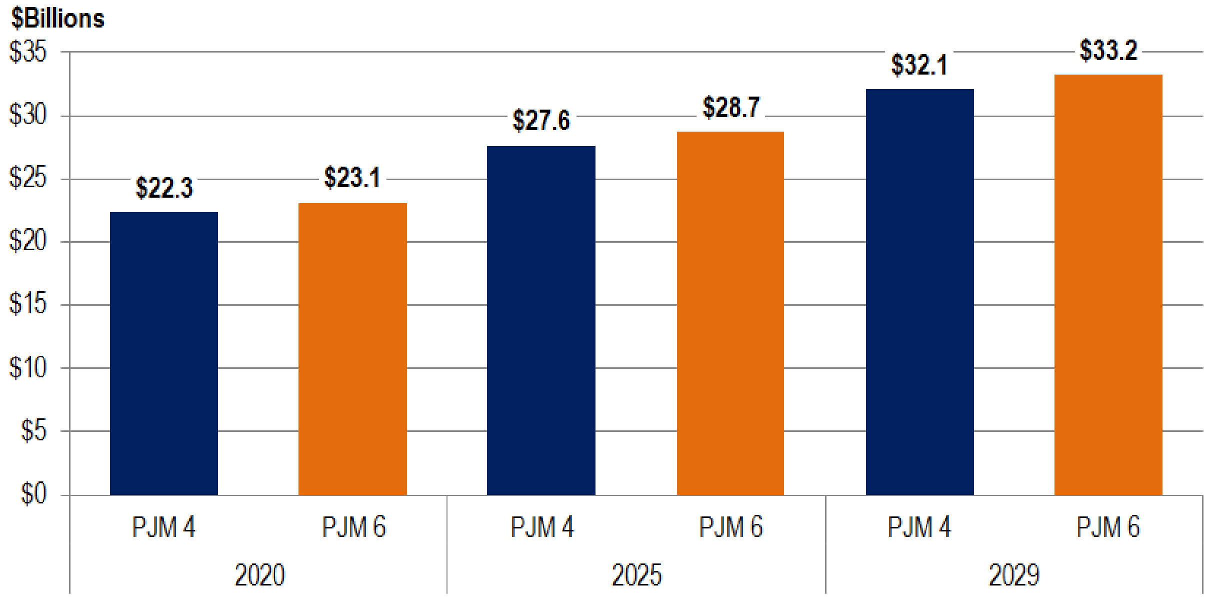
Figure 57. Total Fuel and Variable O&M Compliance Costs with a 50 Percent Reduction of Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

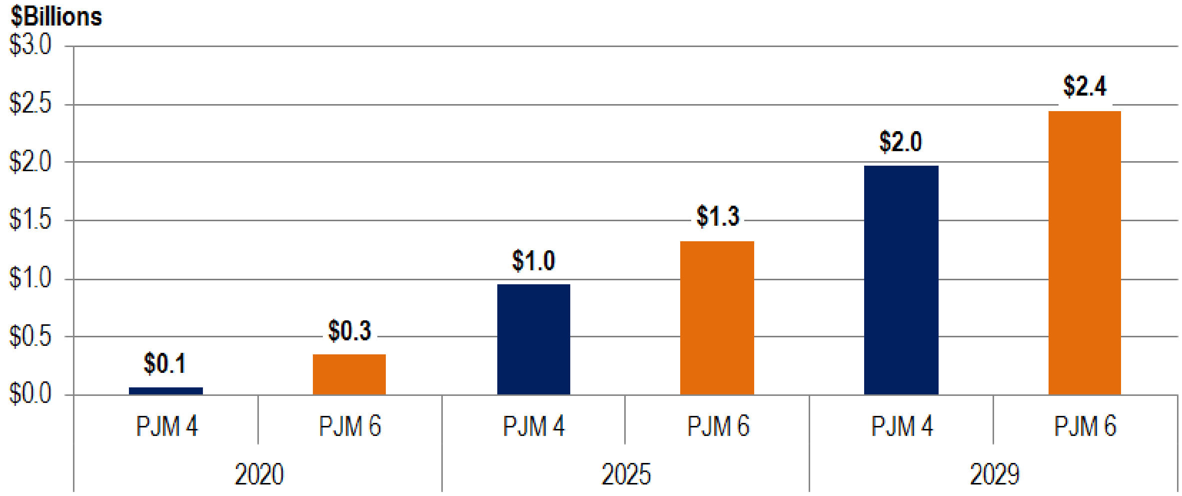
For OPSI 2b.4, the fuel and operation and maintenance compliance costs are at most 8.6 percent of total fuel and operation and maintenance production costs in 2029 due to the increasing need for redispatch of existing combined-cycle gas resources over time. This percentage is much lower in the early years of compliance, when there are still sufficient energy efficiency, renewable resources and new entry to help achieve compliance. In contrast, a decrease in nuclear capacity in the PJM-developed scenarios does result in high compliance costs, but these only reach as much as 7.2 percent of total fuel operation and maintenance costs in PJM 6 in 2029. On average, the compliance costs as a percentage of total fuel and operation and maintenance production costs are higher than in the OPSI scenarios because the level of efficiency, renewables and new entry are reduced compared to the OPSI scenarios.

Figure 58. Total Fuel and Variable O&M Production Costs with a 10 Percent Reduction in Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Figure 59. Total Fuel and Variable O&M Compliance Costs with a 10 Percent Reduction in Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Fossil Steam Capacity at Risk for Retirement

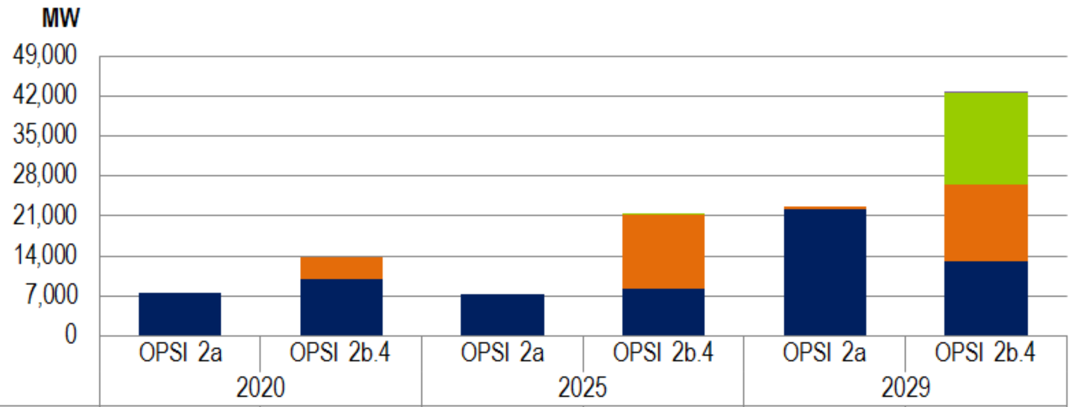
Table 10 and Figure 60 show the Net CONE benchmarks and the fossil steam capacity at risk for retirement, respectively, for the simulation years 2020, 2025 and 2029 for the OPSI scenarios.

Table 10. Combustion Turbine CONE Values for with a 50 Percent Reduction of Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	OPSI 2a	$414.5	$4.3	$410.2
	OPSI 2b.4	$415.7	$70.8	$344.9
2025	OPSI 2a	$464.6	$9.3	$455.3
	OPSI 2b.4	$464.6	$144.6	$320.0
2029	OPSI 2a	$506.8	$19.1	$487.6
	OPSI 2b.4	$507.9	$196.3	$311.6

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

Figure 60. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs with a 50 Percent Reduction of Nuclear Generation in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.4	2025 OPSI 2a	2025 OPSI 2b.4	2029 OPSI 2a	2029 OPSI 2b.4
1.0 - 1.5 Net Cone						268
0.75 - 1.0 Net Cone				268		16,178
0.6 - 0.75 Net Cone		3,852		12,972	318	13,375
0.5 - 0.6 Net Cone	7,521	9,856	7,275	8,243	22,269	13,062

OPSI 2a assumes PJM state meet their RPS requirements, the EPA energy efficiency target, and all generations with FSA/ISA are come into commercial operation. OPSI 2b.4 reduces nuclear generation by 50 percent.

As with other sensitivities analyzed, there are multiple, offsetting effects due to changes in nuclear generation levels that go into determining the differences in fossil steam capacity at risk for retirement under the Clean Power Plan. With respect to fossil steam (primarily coal) net energy market revenues the following effect must be considered:

- All else equal the lower levels of nuclear generation results in a higher price on CO_2 which would decrease fossil steam net energy market revenues as the higher CO_2 price raises fossil steam running costs;
- But lower levels of nuclear generation also increase wholesale energy market prices, and all else equal, increases the net energy market revenues of fossil steam units;
- And lower levels of nuclear generation implies higher fossil steam output, all else equal, leading to higher net energy market revenues;
- Yet, there may also be decreased generation output due to the increased need for re-dispatch, which all else equal, decreases net energy market revenues.

For fossil steam units, if the increase in running costs and increased redispatch dominates the increased generation output and higher energy prices due to reduced nuclear generation, then net energy market revenues increase. Otherwise, fossil steam units will observe a reduction in energy market revenues.

In the OPSI scenarios CO_2 price increases are slightly less than LMP increases overall between scenarios, as shown in Figure 50 and Figure 52, perhaps indicating a slight increase in net energy market revenues for fossil steam resources.

However, the change in the benchmark Net CONE is likely the most relevant factor with respect to reduced nuclear generation. Decreasing nuclear output results in a decrease in Net CONE as combustion turbines run more often and at higher energy prices. All else equal, the combustion turbine appears more attractive as a resource relative to existing fossil steam resources. This effect is clearly seen in Table 10 and Table 11.

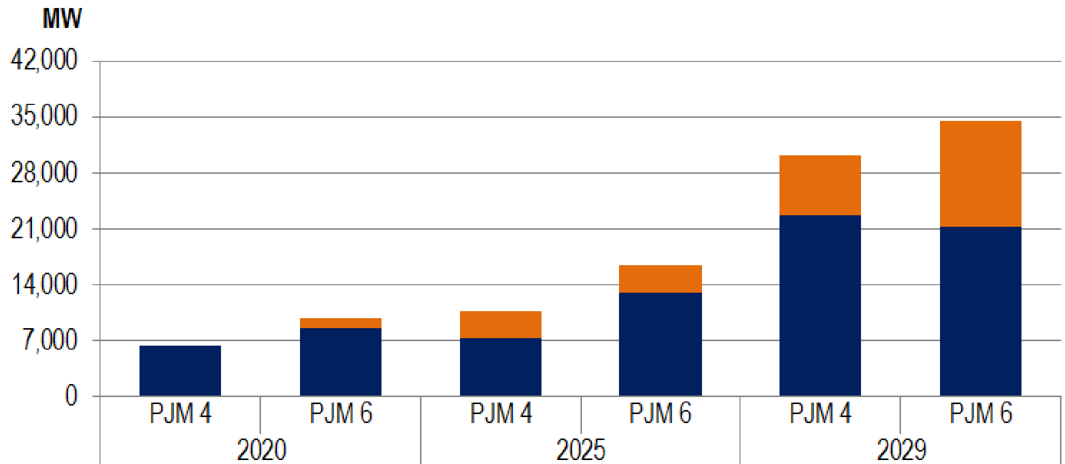
Table 11 and Figure 61 show the Net CONE benchmarks and capacity at risk for retirement, respectively, for the simulation years 2020, 2025 and 2029 for the PJM scenarios.

Table 11. Combustion Turbine CONE Values with a 10 Percent Reduction in Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	PJM 4	$414.8	$10.5	$404.3
	PJM 6	$415.7	$32.2	$383.5
2025	PJM 4	$464.6	$38.2	$426.4
	PJM 6	$464.6	$55.9	$408.7
2029	PJM 4	$507.9	$64.4	$443.5
	PJM 6	$507.9	$90.6	$417.2

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Figure 61. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs with a 10 Percent Reduction in Nuclear Generation in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



	2020 PJM 4	2020 PJM 6	2025 PJM 4	2025 PJM 6	2029 PJM 4	2029 PJM 6
0.6 - 0.75 Net CONE		1,337	3,419	3,419	7,511	13,367
0.5 - 0.6 Net CONE	6,407	8,580	7,390	12,992	22,789	21,252

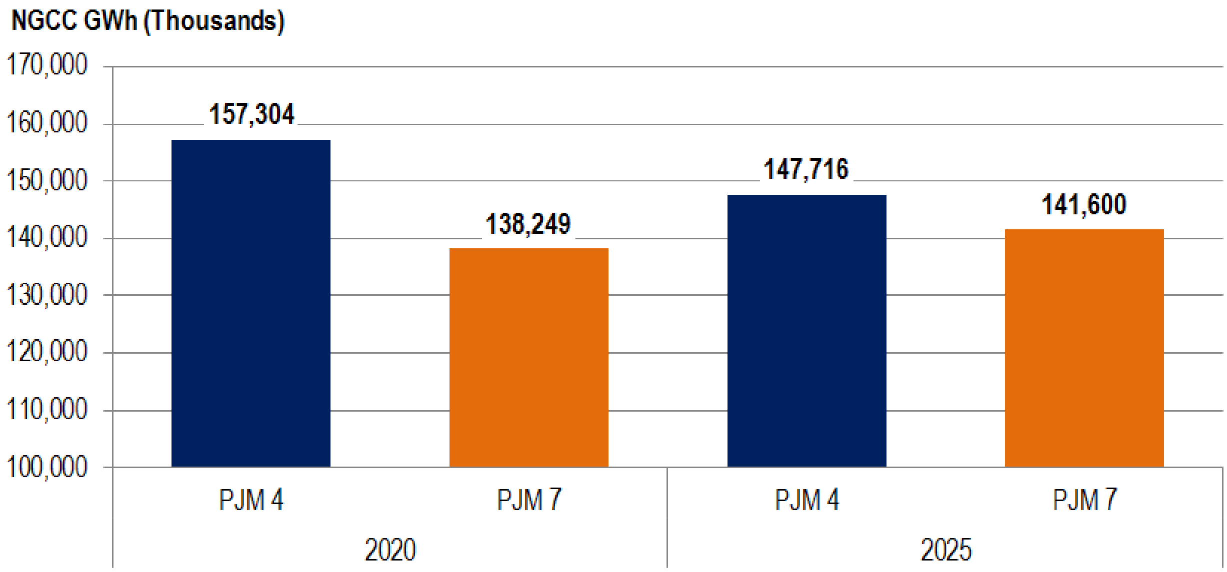
PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 6 is identical to PJM 4 except nuclear generation is reduced 10 percent and new gas resources are reduced based on historic commercial probability.

Just as in the OPSI scenarios, the reduction in nuclear capacity, though smaller, increases the amount of fossil steam capacity at risk for retirement. The mechanisms are the same as described for the OPSI scenarios where the Net CONE decline dominates the slight increase in net energy market revenues for steam resources.

Changes in Available New Entry Natural Gas Combined Cycle

As new entry natural gas combined-cycle resources are not required to be brought under the Clean Power Plan, and PJM has modeled it as such, reducing the availability of new entry combined-cycle gas should have the same directional effect as reducing nuclear capacity, energy efficiency or renewable resources. PJM-developed scenarios PJM 4 and PJM 7 show the impact of reducing new gas capacity to achieve only the installed reserve margin target of 15.7 percent. Figure 63 shows the reduction in new combined-cycle output that is assumed between the two PJM scenarios.[17]

Figure 62. Total Changes in New Combined-Cycle Output due to Reducing Available New Entry in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency



PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

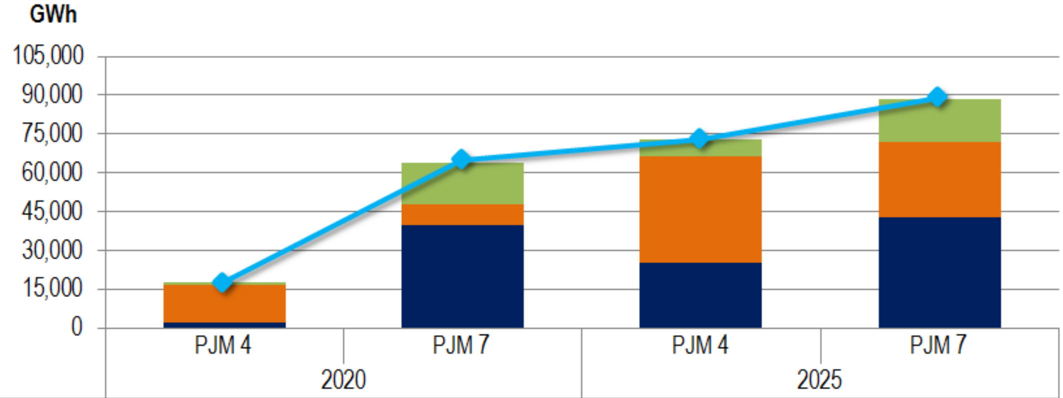
Effect on Resource Redispatch

Given the reduction in new entry combined cycle subject to 111(b) NSPS, it is intuitive that the redispatch of existing combined-cycle resources subject to the Clean Power Plan will need to increase, as shown in Figure 63. But, simple-cycle combustion turbine dispatch also increases because of the reduction in new entry combined-cycle resources, and these simple-cycle resources are also not subject to the Clean Power Plan. The amount of coal redispatch also

[17] This restriction is only binding in 2020 and 2025 as in 2029 additional resources were added in both scenarios to meet the installed reserve margin target.

increases as new entry combined-cycle resources decline, likely due to the increasing CO_2 price resulting from the increase in existing natural gas redispatch.

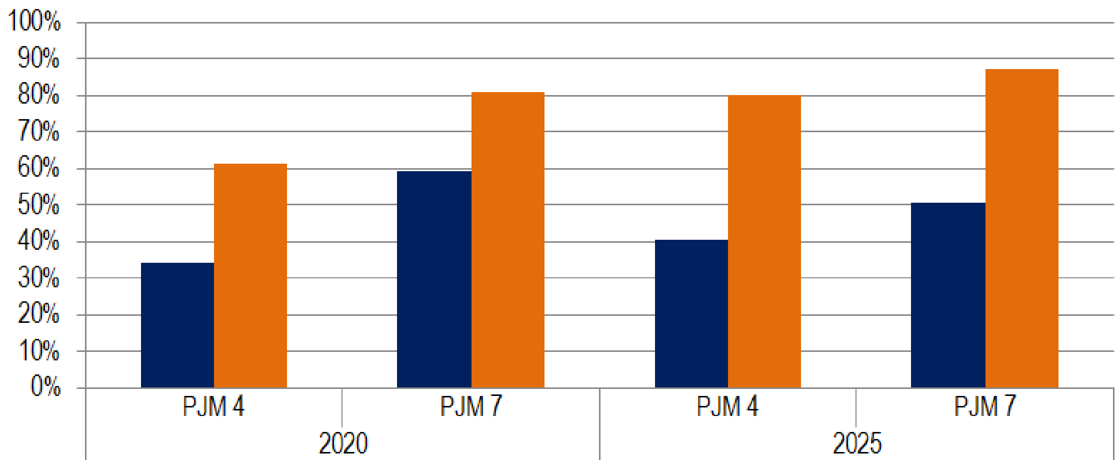
Figure 63. Changes in Coal and Natural Gas Generation at Differing Levels of New Combined-Cycle Gas in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency



	2020 PJM 4	2020 PJM 7	2025 PJM 4	2025 PJM 7
NGCT	795	16,054	6,356	16,621
111(b) NGCC	14,568	8,014	41,170	29,074
111(d) NGCC	2,220	39,947	25,327	42,734
Coal	17,667	65,099	73,329	89,179

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Figure 64. Capacity Factors of New and Existing Combined-Cycle Resources with Lower Levels of New Combined-Cycle Resources in PJM Scenarios with Lower Levels of Renewable Resources and Energy Efficiency



	2020 PJM 4	2020 PJM 7	2025 PJM 4	2025 PJM 7
111(d) NGCC	34.3%	59.4%	40.3%	50.9%
111(b) NGCC	61.3%	80.9%	80.0%	87.1%

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

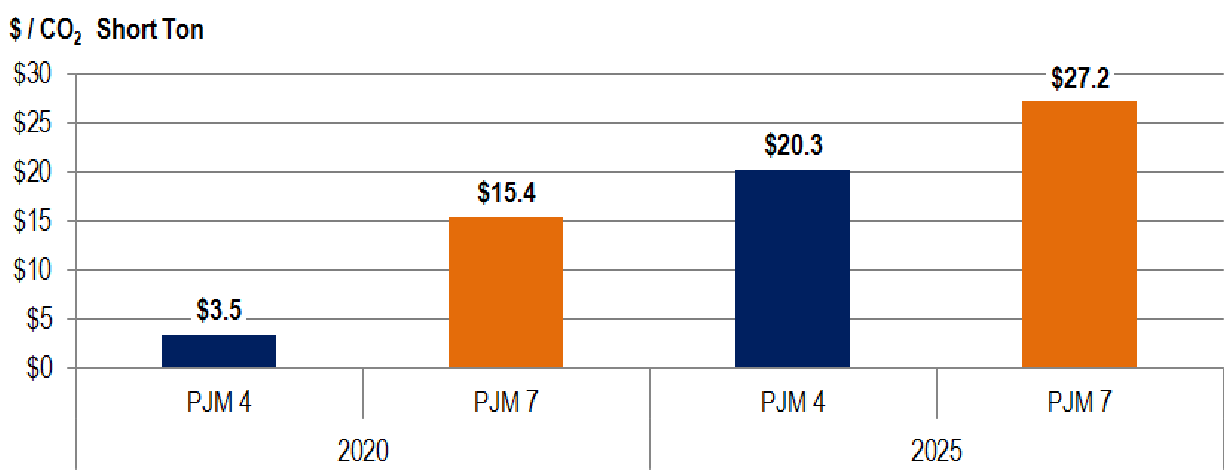
Even though the difference in the amount of new entry combined-cycle natural gas resources in the two scenarios explains much of the resulting redispatch, it also helps to understand the capacity factors of new entry combined-cycle units subject to 111(b) NSPS versus existing combined-cycle units subject to the Clean Power Plan, as shown in Figure 64.

The capacity factor of new entry combined-cycle resources is approaching the availability factor for this type of resource. While the PJM 7 scenario shows lower output from new entry combined-cycle resources than for existing combined-cycle resources in Figure 63, this result is simply due to new entry combined-cycle resources in this scenario having reached their limits for energy production. By limiting the new entry of combined-cycle natural gas resources, more total redispatch is required from coal to existing natural gas combined cycle resources, and more expensive resources must contribute to the redispatch needed by the system to achieve the CO_2 targets, as shown in Figure 63.

Effect on CO_2 Prices

With reduced output from new entry combined-cycle resources, there is a greater need to redispatch existing combined-cycle gas resources in order to achieve compliance with the regional mass-based targets. This leads to higher CO_2 prices as less efficient combined-cycle units are dispatched to make up for the loss of the new entry combined-cycle resources. This can be seen in Figure 65, with the greatest impact being early in the compliance period, with reduced new entry having the greatest effect in 2020.

Figure 65. CO_2 Prices with Differing Levels of Available New Combined-Cycle Resources in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency

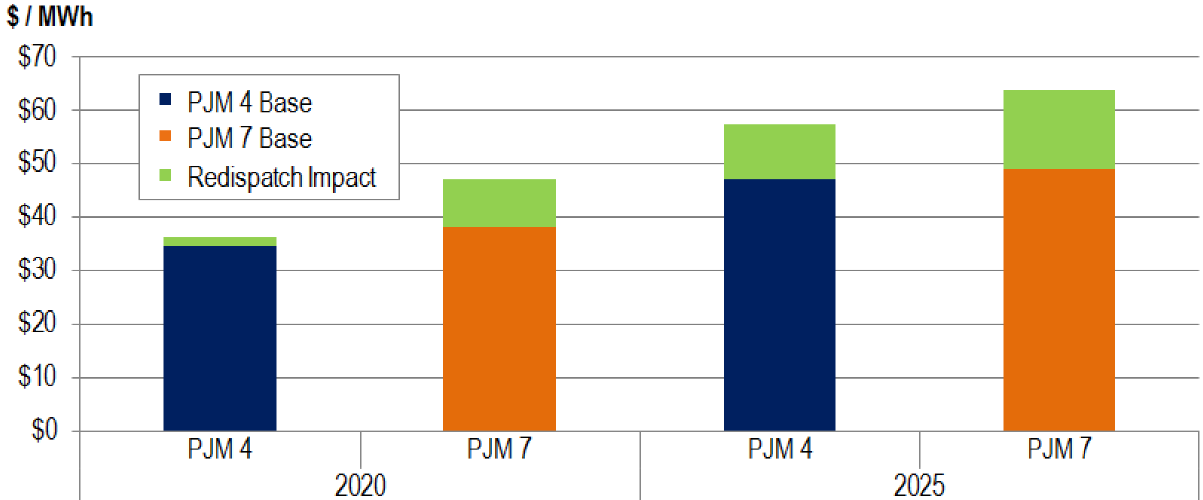


PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Effects on Locational Marginal Prices

Figure 66 shows that about 53 percent to 58 percent of the CO_2 price gets transmitted through to LMP as more and less efficient combined-cycle units and some coal and combustion turbines are likely on the margin to make up for the lost new entry combined-cycle units in the energy market and drive up LMPs. Because the new entry constraint becomes less binding over time, the LMP impact is declining.

Figure 66. Effects of CO_2 Prices on Load-weighted Average Wholesale Energy Market Prices with Differing Levels of New Combined-Cycle Resources in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency



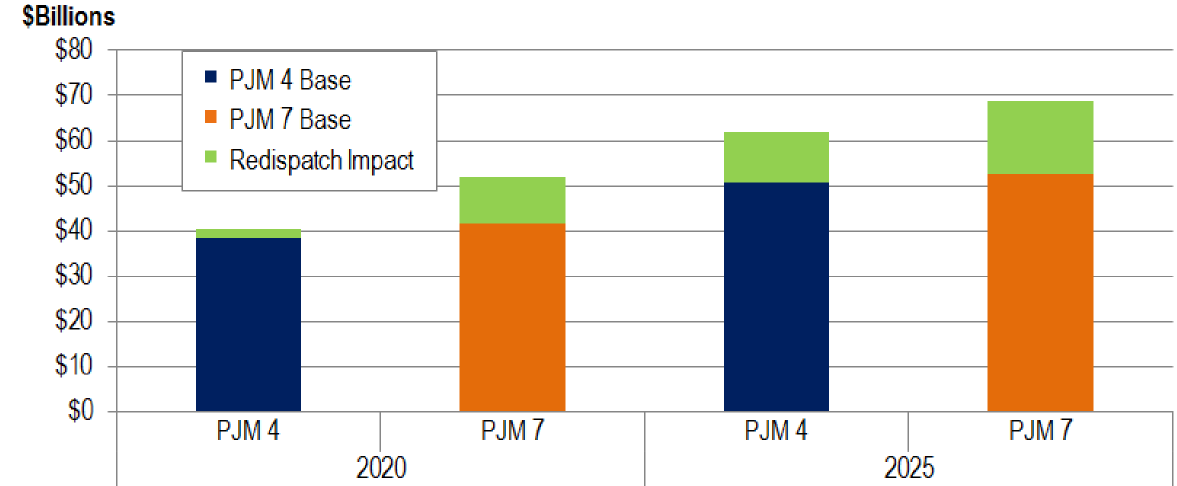
	2020 PJM 4	2020 PJM 7	2025 PJM 4	2025 PJM 7
111(d)	$1.8	$8.9	$10.3	$14.5
Base	$34.4	$38.2	$47.0	$49.1

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Effect on Load Energy Payments

The reduction of new entry combined cycle has two effects on load energy payments as shown in Figure 67. The first is the effect of losing more efficient combined-cycle resources and replacing them with less efficient existing combined-cycle units. This effect is small. The effect of the reduction in costs due to redispatch from the Clean Power Plan is 2.5 times greater than the first effect since the new entry combined cycle is effectively a zero-cost resource for compliance purposes, and the cost of redispatch now increases from using more existing combined-cycle redispatch and emission compliance.

Figure 67. Effects of CO_2 Prices on Load Energy Payments with Differing Levels of New Combined-Cycle Resources in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency



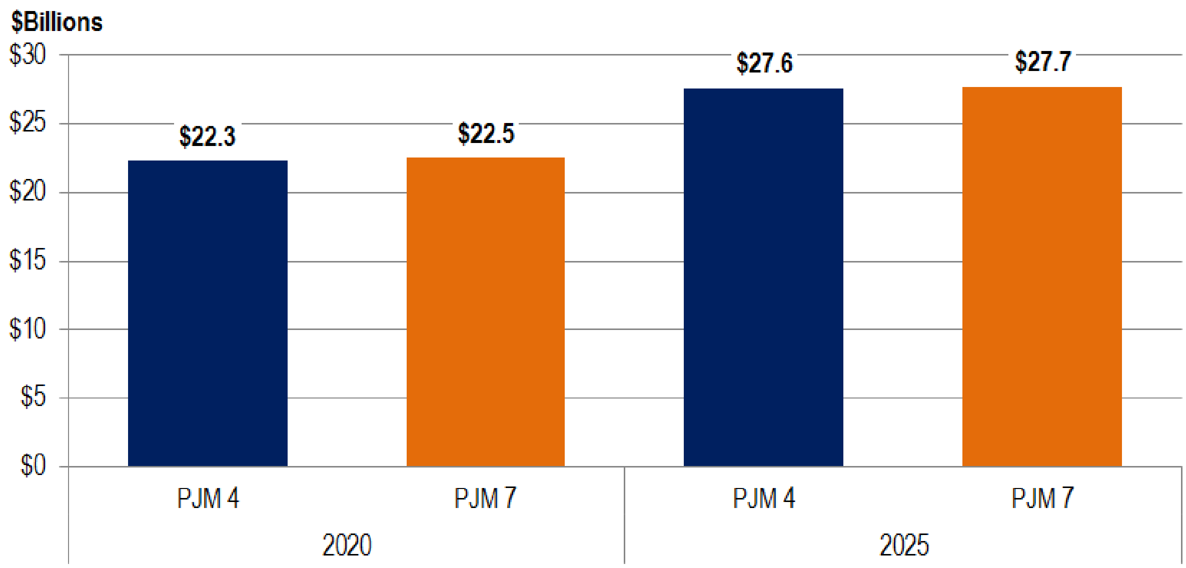
	2020 PJM 4	2020 PJM 7	2025 PJM 4	2025 PJM 7
111(d)	$2.1	$10.3	$11.4	$16.1
LMP Base	$38.3	$41.7	$50.7	$52.5

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Effects on Compliance Costs as Measured Through Changes in Production Costs

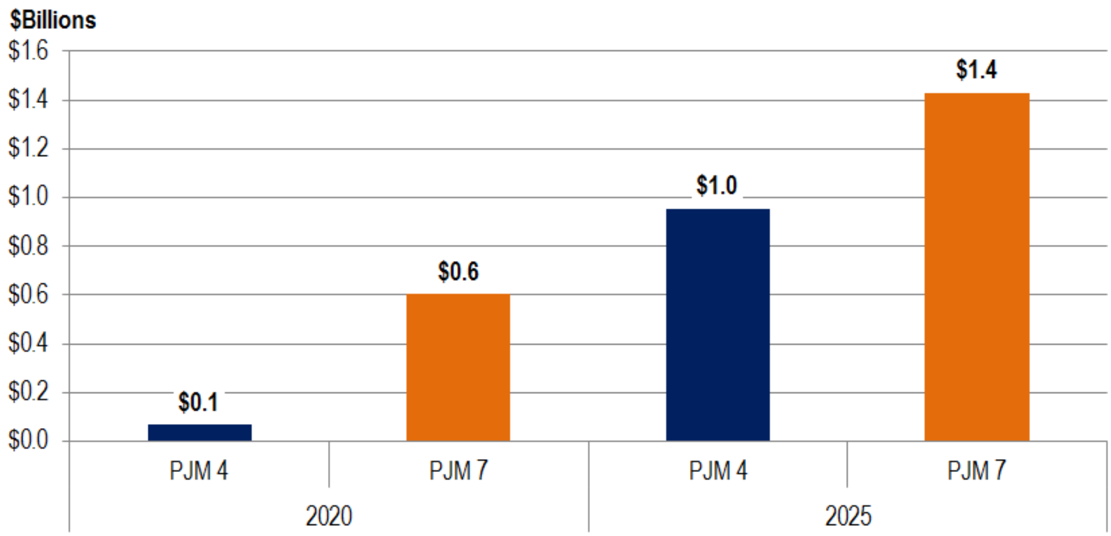
Total fuel and operations and maintenance production costs are presented in Figure 68, and the change in production costs due to redispatch (compliance costs) is shown in Figure 69. The fuel and operation and maintenance compliance costs are at most 5 percent of total fuel and operation and maintenance production costs, and that is for PJM 7 in 2025.

Figure 68. Total Fuel and Variable O&M Production Costs in PJM Scenarios with Differing Levels of New Combined-Cycle Resources in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency



PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Figure 69. Total Fuel and Variable O&M Compliance Costs in PJM Scenarios with Differing Levels of New Combined-Cycle Resources in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency



PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Fossil Steam Capacity at Risk for Retirement

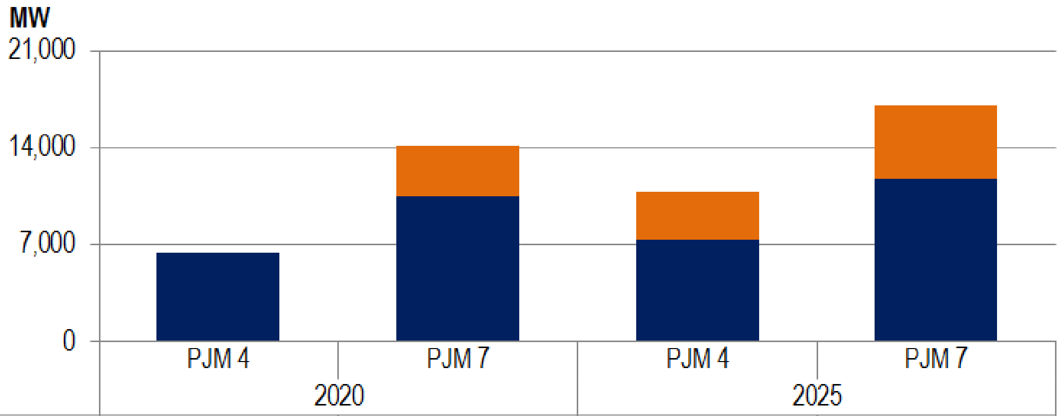
Table 12 and Figure 70 show the Net CONE benchmarks and the fossil steam capacity at risk for retirement, respectively, for the simulation years 2020 and 2025 for the PJM 4 and PJM 7 scenarios.

Table 12. Combustion Turbine CONE Values for Differing Levels of New Combined-Cycle Resources in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	PJM 4	$414.8	$10.5	$404.3
	PJM 7	$415.7	$65.6	$350.1
2025	PJM 4	$464.6	$38.2	$426.4
	PJM 7	$464.1	$76.4	$387.7

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Figure 70. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for Differing Levels of New Combined-Cycle Resources in PJM Scenarios with Reduced Levels of Renewable Resources and Energy Efficiency



	2020 PJM 4	2020 PJM 7	2025 PJM 4	2025 PJM 7
0.6 - 0.75 Net CONE		3614	3419	5331
0.5 - 0.6 Net CONE	6407	10500	7390	11700

PJM 4 assumes renewable resources and energy efficiency grow at historic growth rates and all planned ISA/FSA gas resources in the queue are in commercial operation. PJM 7 is identical to PJM 4 except new gas resources are reduced so that the target installed reserve margin is not exceeded.

Reducing the amount of available new entry combined-cycle gas has the same effect, qualitatively, as reducing available nuclear generation or energy efficiency as discussed. Reducing new entry combined-cycle resources leads to a decline in the Net CONE, as shown in Table 12, as combustion turbines are needed to meet peak loads more often and at higher LMPs. In 2025, steam resources would see their net energy revenues increase, but not enough to offset the reduced Net CONE value, as was observed with the reduction in nuclear capability.

Section 5 – Economic Results Comparing Regional Versus Individual State Compliance with Mass-Based Targets

The one modeling commonality between regional and state-by-state compliance is the PJM regional dispatch across the footprint. The major difference between regional compliance and state-by-state compliance is that regional compliance has a single CO_2 price across the PJM footprint corresponding to a single, aggregate mass-based limit on emissions. In contrast, state-by-state compliance means there is a CO_2 price in every affected state (District of Columbia is not affected by 111(d) and Tennessee has no generation in PJM) corresponding to an individual state-based emissions limit.

In a state-by-state approach, CO_2 prices in each state will differ, perhaps significantly, from the single, regional CO_2 price due to the available abatement options and resource mix within a state. For example, a state with very little renewable energy or natural gas combined-cycle resources will likely find it much more expensive to redispatch resources and likely could face a much higher CO_2 price than the regional price. Conversely, a state with a large amount of low cost natural gas combined-cycle and a lot of energy efficiency may face a lower CO_2 price since the energy efficiency reduces emissions at zero marginal cost (albeit at some level of capital expense), and the low-cost natural gas combined-cycle resources result in low marginal costs of emissions abatement.

Under regional compliance, the two aforementioned states in the example would benefit from having the low-cost state reduce emissions below its target limit, and sell those reductions to the high-cost state (the purchase price of those emissions reductions would be below the in-state cost of reducing emissions). In other words, regional compliance provides more “degrees of freedom” in available abatement options across a wider area. This is the same idea behind ISO/RTO wholesale power markets and the benefits all parties receive from buying and selling power. Those with low-cost power are net exporters and those with high-cost power are net importers.

PJM analyzed three different scenarios to compare regional compliance versus state-by-state compliance. For the OPSI-requested scenarios, PJM ran OPSI 2a on a state-by-state compliance basis (OPSI 2c). PJM then ran two PJM-developed scenarios on a state-by-state compliance basis, PJM 4 (PJM 9 is the state-by-state version) and PJM 7 (PJM 11 is the state-by-state version). Due to the computational burden and time to solve the state-by-state scenarios, PJM only solved these for the first interim compliance year of 2020.

Table 13 shows the different assumptions under each of the comparisons. The OPSI scenarios achieve the Renewable Portfolio Standards with the PJM states and achieve the EPA energy efficiency target. The PJM 4/PJM 9 scenarios significantly limit renewable resource and energy efficiency availability, and provide a contrast to the OPSI scenarios. PJM 7/PJM11 scenarios are even more limiting due to reducing available new entry natural gas combined-cycle resources.

Table 13. Regional versus State-by-State Compliance Scenario Descriptions

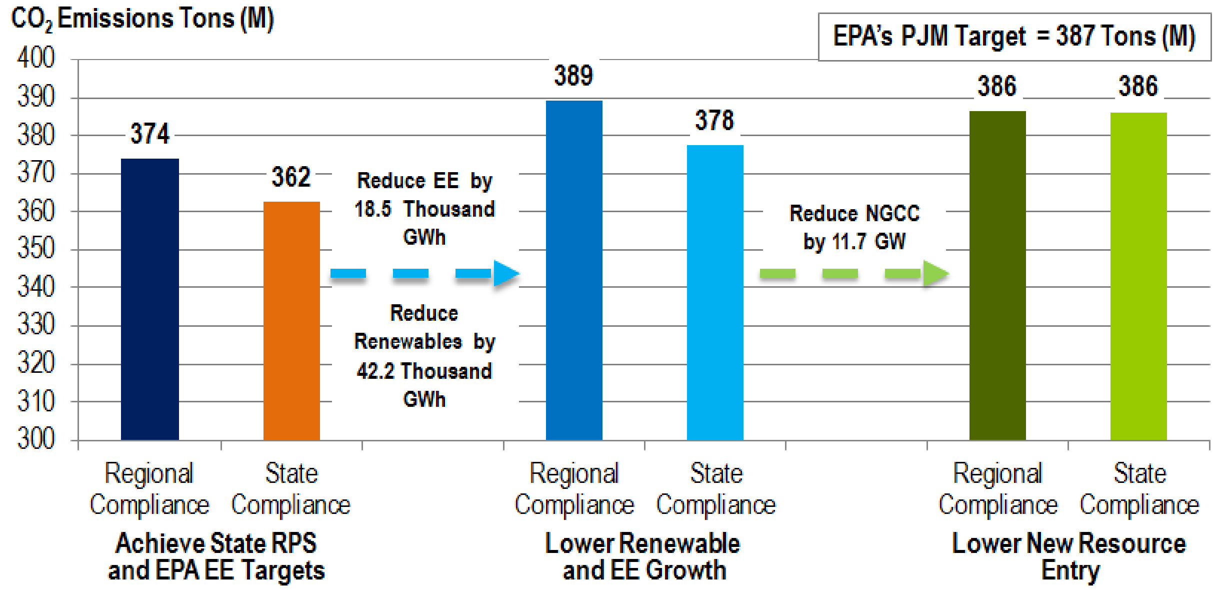
Driver	OPSI 2a/2c	PJM 4/9	PJM 7/11
Renewables	81.9 GWh	50.2 GWh	50.2 GWh
111(b) NGCC	14.5 GW	14.5 GW	2.8 GW
Nuclear	33.4 GW	33.4 GW	33.4 GW
Gas Price	Economic Forecast	Economic Forecast	Economic Forecast
Energy Efficiency Credit	23.3 GWh	9.2 GWh	9.2 GWh
Description	Achieve State RPS and EPA EE Targets	Low Growth in Renewables and EE	Limited New Resources

Differences in Emissions Levels

The PJM region-wide 2020 mass-based target for emissions is 387 million tons. In PJM's simulation methods to save computational time, PJM did not model to achieve the precise emissions target, but the final results are very close. Overall, it is easier to achieve the PJM regional target when all resources across the region can be utilized to meet the target than it is to comply on a state-by-state basis when only resources within a state can be used to achieve the emissions target. Hitting each state target individually may result in "over-complying" on a regional basis.

Figure 71 shows this is the case as state-by-state emissions levels are lower than on a regional level.

Figure 71. Target and Realized Emissions Levels in Regional versus State-by-State Compliance Simulations

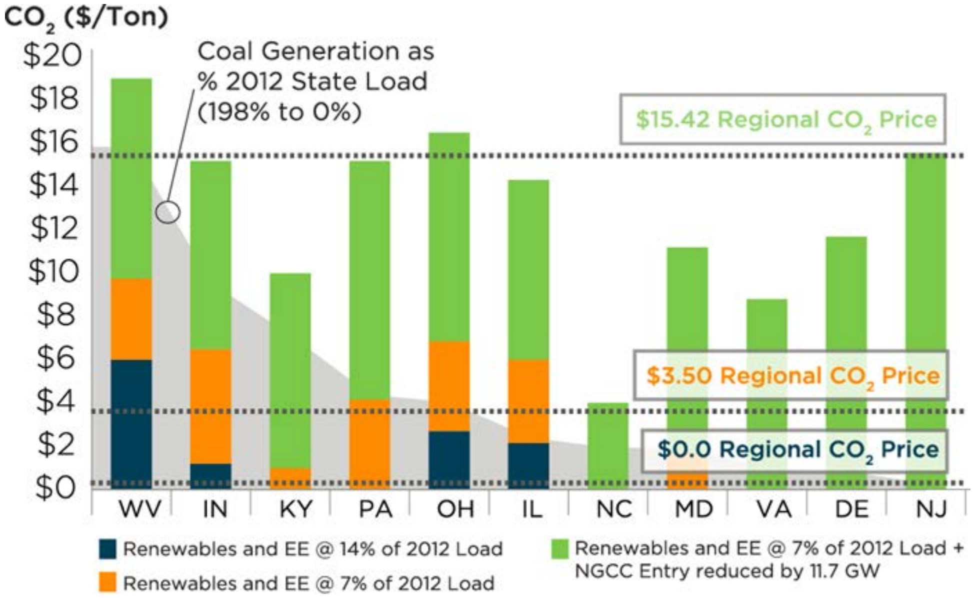


State-by-state compliance options, compared to regional compliance options, likely would result in higher compliance costs for most PJM states. This is because there are fewer low-cost options available within state boundaries than across the entire region. However, results will vary by state given differing state targets and generation mixes.

Differences in CO_2 Price

Under state-by-state compliance some states will realize CO_2 prices below the regional price and some states will realize CO_2 prices above the regional price. Figure 72 shows the various state prices and regional prices for the three simulated scenarios in 2020[18].

Figure 72. Regional versus State-by-State CO_2 Prices



The prices for each set of regional versus state-by-state comparisons are read in the following way. For the higher renewable and energy efficiency scenarios, the regional; price is $0/ton and the state prices are the blue bars. For the lower renewable and energy efficiency scenarios in orange, the CO_2 prices are the combination of the blue and orange bars stacked. For the reduced combined-cycle scenarios, the CO_2 prices are the combination of the blue, orange, and green bars.

For the OPSI scenarios 2a (regional compliance) and 2c (state-by-state compliance) the regional CO_2 price is zero due to the availability of renewable resources, energy efficiency and new entry combined-cycle gas not subject to the Clean Power Plan as PJM has modeled it. The state-by-state prices are shown with the blue bars in Figure 72. Note that states that are coal-dominated are the states with positive prices (Indiana, Illinois, Ohio and West Virginia) while the remaining states have a CO_2 price of zero.

For the PJM 4/PJM 9 cases where renewables and energy efficiency are much more limited, the regional CO_2 price as shown in Figure 72 is $3.50/ton. The prices in each state are shown as the sum of the blue and orange bars in Figure 72. In these scenarios, for example, the CO_2 price in West Virginia spans $6/ton to $9.70/ton and the CO_2 price in Ohio increases from $2.70/ton to $6.90/ton. The main conclusion is that as the available compliance options become more limited, regional and state-by-state CO_2 prices increase.

[18] The price in Michigan is always zero since the PJM portion of Michigan includes only nuclear and existing natural gas combined-cycle resources. The existing combined-cycle gas emissions rate (and mass tonnage) is below the target rate or mass figure. This does not reflect what the state price might be given that the majority of resources subject to the Clean Power Plan are MISO resources.

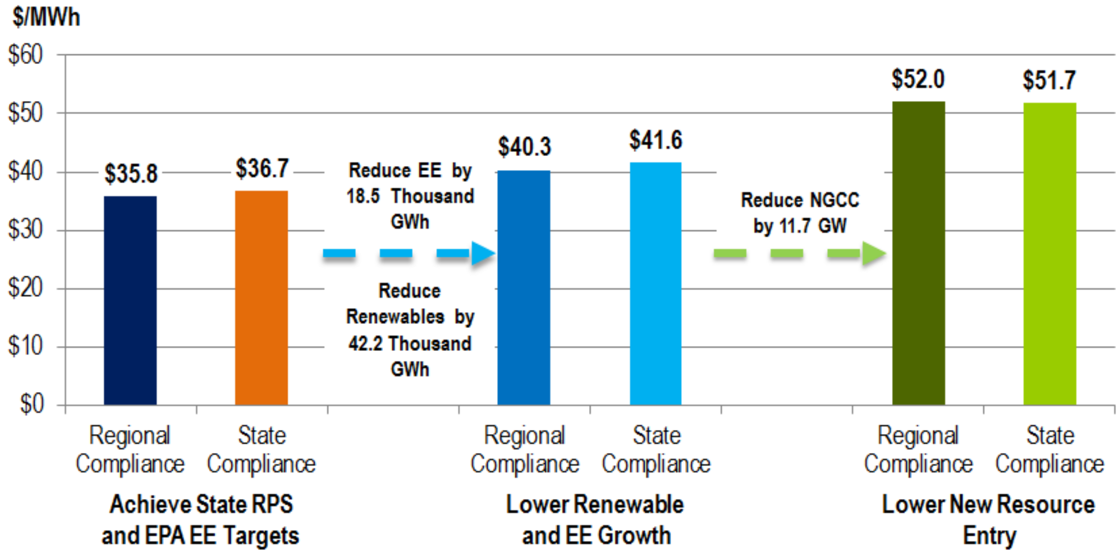
Finally, for the PJM 7/PJM 11 scenarios where natural gas combined-cycle new entry is also limited, the regional CO_2 price increases to $15.42/ton. In these scenarios, there are three states that have prices above the regional price: New Jersey at $15.60/ton, West Virginia at $18.90/ton and Ohio at $16.50/ton. Other states see substantial increases in their state CO_2 prices due to limiting new entry combined-cycle gas resources. Two states, Indiana and Pennsylvania, have CO_2 prices very near the regional price, but just below it at $15.20/ton and $15.10/ton respectively.

Effects on Locational Marginal Prices and Load Energy Payments

Figure 73 shows the incremental effect on the LMPs across the PJM footprint of moving from regional compliance to state-by-state compliance. Intuitively, because there are fewer options for re-dispatch under state-by-state compliance, the costs of compliance should be higher, and by extension, this should be reflected in the LMPs across PJM.

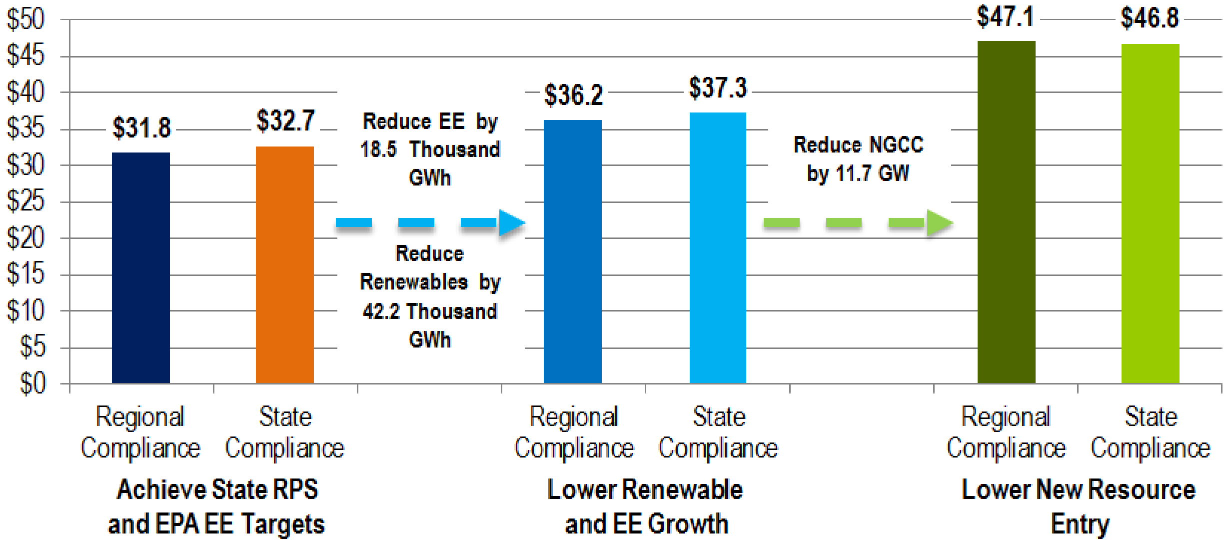
However, there is one exception as shown in Figure 73. In the scenario with reduced new natural gas combined-cycle entry, LMP's are $0.30 higher in the regional dispatch than in the state-by-state. The reason for this is most of the new entry would take place in the eastern portion of PJM thus reducing congestion and LMPs overall. But also, much of the existing natural gas combined-cycle resources are in the eastern part of PJM, so when states comply individually, more of these existing combined-cycle resources are running and reducing congestion on the system relative to the regional scenario.

Figure 73. Regional versus State-by-State Compliance Effects of CO_2 Prices on Load-weighted Average Wholesale Energy Market Prices



As the average LMPs rise, so do the load energy payments in aggregate across the PJM footprint as shown in Figure 74.

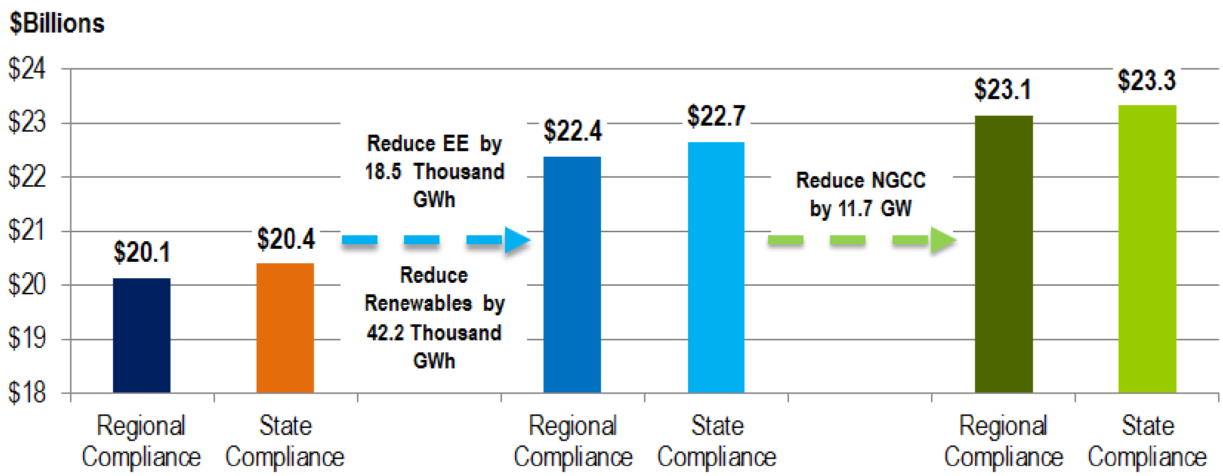
Figure 74. Regional versus State-by-State Compliance Effects of CO_2 Prices on Load Energy Payments



Effects on Production Costs and Compliance Costs due to Re-Dispatch

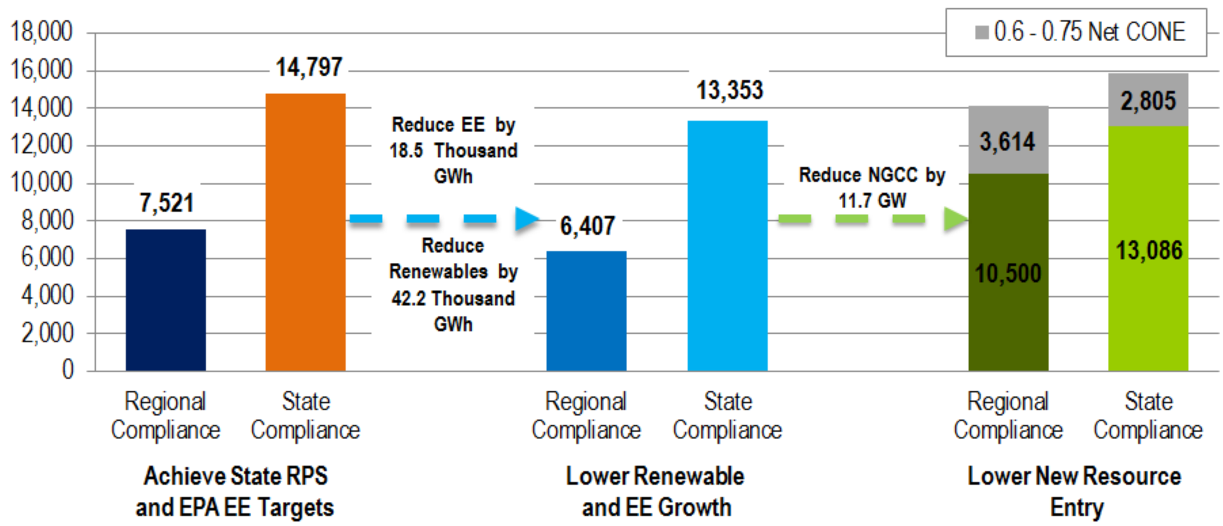
State-by-state compliance with fewer compliance or redispatch options available leads to an increase in production costs and therefore, by extension, an increase in overall compliance costs across the region. Figure 75 shows the difference in total fuel and variable Operating and Maintenance production costs in moving from regional compliance to state-by-state compliance. The difference in production costs between regional and state-by-state compliance is the incremental, additional compliance cost associated with going to state-by-state compliance. Figure 75 shows that the incremental change in compliance cost is about $300 million in 2020 as a result of going with state-by-state compliance.

Figure 75. Regional versus State-by-State Compliance Total Fuel and Variable O&M Production and Implied Changes in Compliance Costs



Effects on Generation Capacity at Risk for Retirement

Figure 76. Regional versus State-by-State Compliance Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs



The shift from regional to state-by-state compliance results in more capacity being at risk for retirement due to the Clean Power Plan Figure 76 shows generation at risk for retirement based on the metric of requiring at least 0.5 Net CONE for a combustion turbine. Moving toward state-by-state compliance approximately doubles the amount of capacity at risk for retirement in two of the three scenarios studied.

Table 14. Combustion Turbine CONE Values for Regional versus State-by-State Compliance

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
Achieve State RPS and EPA EE Targets	OPSI 2a	$414.5	$4.3	$410.2
	OPSI 2c	$414.4	$5.2	$409.1
Lower Renewable and EE growth	PJM 4	$414.8	$10.5	$404.3
	PJM 9	$415.1	$12.2	$403.0
Remove 11.7 GW of NGCC	PJM 7	$415.7	$65.6	$350.1
	PJM 11	$415.7	$61.9	$353.8

In moving toward state-by-state compliance, the Net CONE values of combustion turbines shown in Table 14 do not change appreciably. However, it seems that in states dominated by coal resources, the CO_2 prices increase. When this happens, it erodes net energy market revenues because RTO-wide LMPs change very little while coal and other fossil steam running costs increase in states with higher CO_2 prices than the regional price leading to the sharp increase in fossil steam capacity at risk for retirement.

By the time all resources that are zero-emitting resources, from a compliance perspective, have declined as shown in Table 13, there will be a lot more capacity at risk for retirement as shown in Figure 76. This would occur even under regional compliance as there are no more "low-cost" abatement alternatives available to keep CO_2 prices lower anywhere across the region. This would mean that the incremental additional at risk generation will be much smaller moving to state-by-state compliance.

The reason for this is straightforward in the context of state-by-state CO_2 prices relative to CO_2 prices under regional compliance. The states that reflect the greatest impact of moving toward state-by-state compliance are heavily reliant on coal in their resource mix. And, as CO_2 prices increase, it places greater financial strain on higher emitting steam resources such as coal as net energy market revenues are eroded due to the higher CO_2 prices. This effect leads to an increase in capacity at risk for retirement, and this will be seen in states that already have a high concentration of coal in their resource mix.

Section 6 – Economic Results Comparing Rate-based versus Mass-Based Regional Compliance

PJM ran a scenario to compare emissions rate-based compliance to mass-based compliance on a regional basis. PJM chose to do this comparison only on a regional basis because in some scenarios, the simulations would not converge quickly – if at all – due to feasibility constraints, computational time requirements and complexity. PJM believes the qualitative insights in examining state-by-state rate-based compliance can be deduced from the state-by-state mass-based comparisons and the regional rate-based comparison.

PJM ran the rate-based scenario based on PJM 4, with the rate-based case defined as scenario PJM 10. The PJM 4 scenario limits renewable resource and energy efficiency availability as discussed previously.

Modeling Differences between Rate-Based and Mass-Based Compliance

Rate-based compliance requires that the target emissions rate, rather than a target on total tonnage implied by a mass-based standard be met. On a regional basis, similar to a mass-based compliance paradigm, resources with emissions rates below the target emissions rate are in effect selling emissions reductions to resources with an emissions rate that is above the rate-based target.

Reflecting the Cost of CO_2 Emission in Energy Market Offers

The practical implication of an emissions rate-based compliance paradigm is that resources with emissions rates higher than the target rate will pay for the difference between the target rate and their emissions rate at the going price of CO_2 emissions. This results in an increase in the running cost of these higher emitting resources. In contrast, resources with emissions rates lower than the target rate effectively receive a credit for being below the emission rate target and thereby *reduce* the running cost of the lower emitting resources. A regional emissions rate mechanism thus has the effect of uniformly reducing energy market offers given a price on CO_2 emissions.

For example, suppose the target emissions rate is 1,200 lbs/MWh (.6 tons/MWh) and a combined-cycle unit has an emission rate of 800 lbs/MWh and a wind resource has 0 lbs/MWh. For a price of CO_2 of $20/ton, the combined-cycle unit gets a credit (reduction in running cost) of $4/MWh [(1200 – 800 lbs/MWh = .2 tons/MWh) * $20/ton]. The wind resource gets a credit of $12/MWh [(1200 – 0 lbs/MWh = 0.6 tons) *$20/MWh]. In contrast, a coal unit that emits 2000 lbs/MWh is charged (observes an increase in its running cost) of $8/MWh [(2000 – 1200 lbs/MWh = 0.8 tons) *$20/MWh].

In contrast, under a mass-based system, the coal unit, at the same CO_2 price of $20/ton would realize an increase in running cost of $20/MWh, the natural gas combined-cycle unit an increase, rather than a decrease, in running cost of $8/MWh, and the wind resources rather than seeing an effective decrease in its running cost would see no change in its running cost of zero. If the CO_2 price is the same under both mass-based and rate-based compliance, the price difference between lower emitting and higher emitting resources will be the same, but will have very different effects on LMP as shown below.

Modeling Emission Rate Compliance in PROMOD

The emissions rate for each affected electric generating unit must first be adjusted to reflect its performance relative to the benchmark or target rate as discussed above. Within PROMOD IV, this is implemented by using a “bid adder” which can be positive- or negative-denominated in $/MWh and is added to the unit’s cost-based offer during the real-time security-constrained economic dispatch. The bid adder is not included in the production cost of the unit, however represents the cost of emissions (positive or negative) to the resource the unit receives outside of the market simulation.

Because the benchmark emissions rate is measured PJM wide, from a modeling perspective the only difference in evaluating whether the rate or mass target achieved is that the mass-based emissions are a direct output from the simulation, where the emissions rate is calculated based upon the level of delivered energy from covered sources and renewables[19], assumed energy efficiency credit[20] and an assumption that 5.8 percent of PJM’s nuclear output would be credited within the rate compliance equation. In each iteration the below equation is applied to determine the mass and energy from 111(d) Affected EGU’s that will force the simulated CO_2 emission rate to be equal to the target CO_2 emission rate.

$$CO2\ Emissions\ Rate\ (\frac{lbs}{MWh}):$$

$$= \frac{111(d)\ Affected\ EGU\ Emssions\ (\text{lbs})}{\text{111(d)Affected EGU MWh} + \text{Renewable MWh} + \text{5.8\% Existing Nuclear MWh} + \text{New EE MWh}}$$

Because incremental energy efficiency is modeled as an offset to each transmission zone’s forecasted annual energy, the contribution level within the rate compliance equation does not change by scenario. The credit for avoided nuclear retirements also does not change as this is fixed at 5.8 percent of nuclear output. In general, the level of renewables is consistent with the assumed forecast input into the simulation; however, due to curtailment that may occur due to transmission constraints, the actual level may vary slightly. Consequently, it is the generation from fossil-based resources that drive the outputs from the simulations comparing rate-based to mass-based compliance.

Effect on Combined-Cycle Gas Operation: New Versus Existing Resources

Under a mass-based compliance regime, new-entry combined-cycle resources have the same effect as energy efficiency and renewable resources in that they are treated as zero-emitting resources for the purpose of compliance, because they are not modeled as subject to the Clean Power Plan and 111(d). Effectively, new-entry combined-cycle resources enjoy a cost advantage over existing natural gas combined-cycle resources since they do not face a price on CO_2 emissions that must be factored into their energy offers. As a consequence, new entry combined-cycle resources

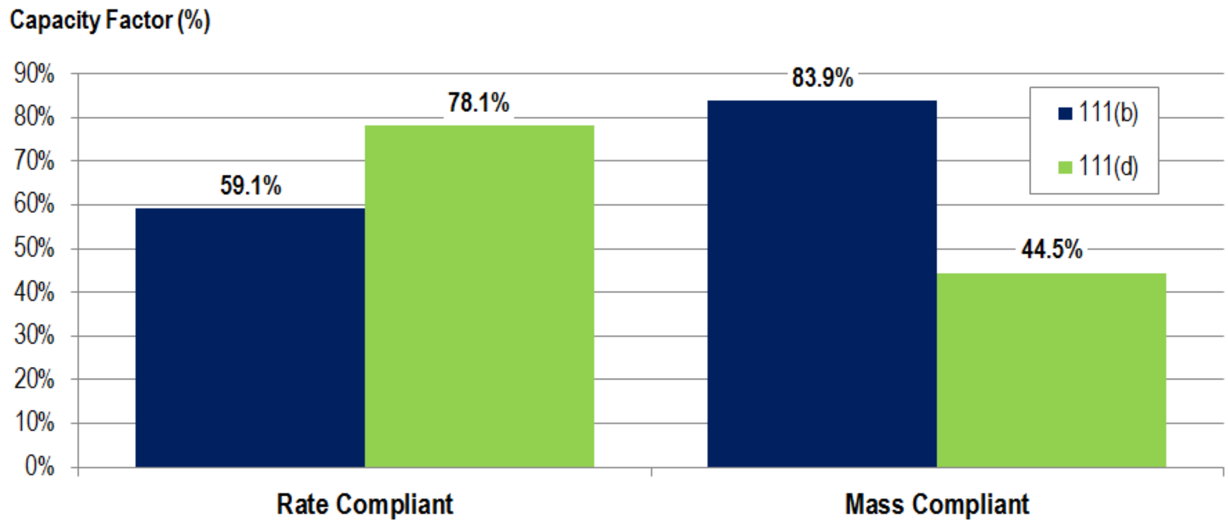
[19] Non-existing hydroelectric power, and only the amount that is deliverable or not curtailed in the simulation. The full amount of renewables input into the model may not be delivered because of transmission congestion.

[20] As an additional consideration, within the EPA formulation, states are only credited up-to 100 percent of their energy efficiency based upon the ratio of in-state generation to load. For a net-importing state, this means that less than 100 percent of the energy efficiency would be credited. For this analysis, PJM did not adjust the percent of energy efficiency credited by scenario based upon changes in the level of in-state generation; however, this additional variable must be considered when comparing rate versus mass-based compliance frameworks. Also, another feature of the policy for consideration within a regional compliance framework is whether the weighted mass or rate target should have an adjustment to reflect that the region may be a net-exporter whereas any individual state within it is a net-importer.

will run much more intensely, as represented by running at high capacity factors as shown in Figure 77 under mass-based compliance. In fact, new-entry combined-cycle resources run at nearly an 84 percent capacity factor while existing combined-cycle units only run at a 44.5 percent capacity factor.

However, under rate-based compliance, this result is the reverse. Existing combined-cycle resources effectively receive a credit when they run. However, the new combined-cycle resources do not, thereby providing a cost advantage to the existing combined-cycle resources, leading them to run at a higher capacity factor (78 percent) than the new combined-cycle resources (59 percent) as shown in Figure 77.

Figure 77. Rate- versus Mass-Based New and Existing Combined-Cycle Capacity Factors



Emissions Rate and Total CO_2 Tons

Figure 78. Rate- versus Mass-Based CO_2 Emissions Rates and Total Tons

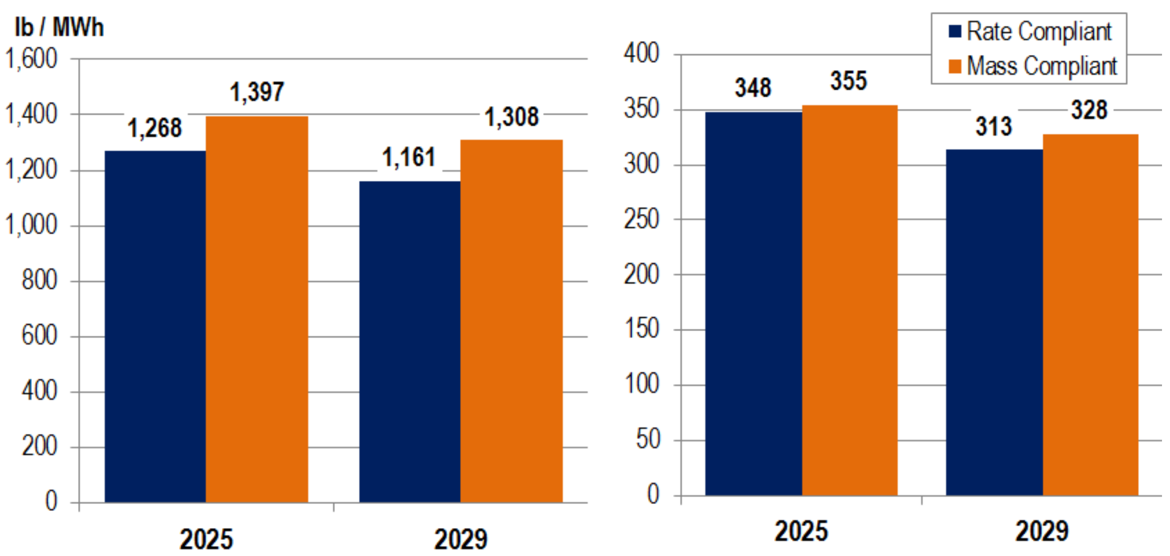


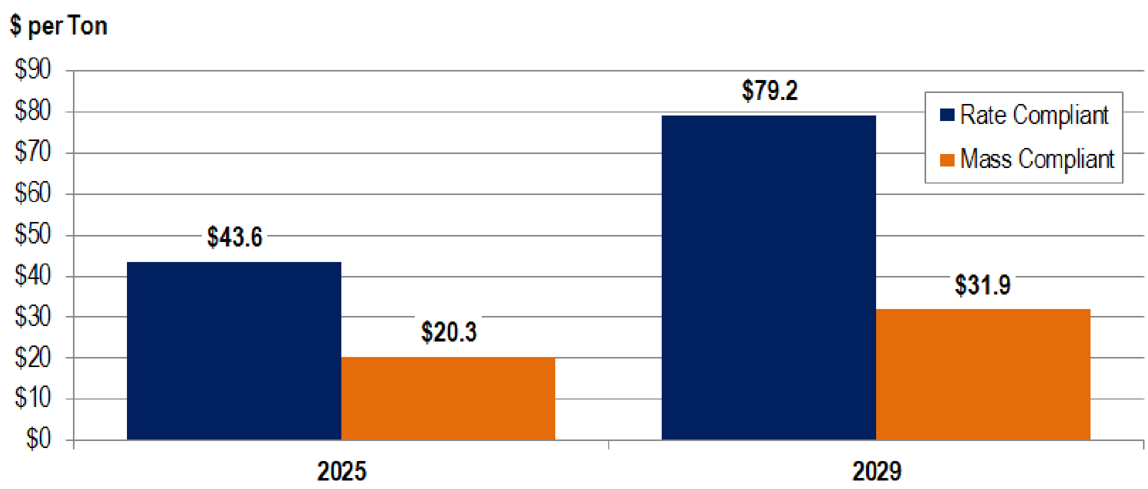
Figure 78 shows the differences in total emissions (right panel) and emissions rates (left panel) between rate- and mass-based compliance. To achieve the target emissions rate, greater redispatch of existing combined-cycle natural gas is required, which results in lower total emissions as can be seen in Figure 78. In part the results of this scenario could be due to the underlying assumptions where renewable resources and energy efficiency are only growing at historic growth rates and are below the RPS requirements of PJM states and EPA target energy efficiency levels. From a mass-based perspective, new combined-cycle gas and all combustion turbines can help achieve the mass target if they are treated as zero-emitting resources from a compliance perspective as modeled for this study. From a rate-based perspective, reduced energy efficiency and renewable resources must be replaced by existing combined-cycle resources to achieve the rate as new combined-cycle resources cannot help achieve the rate target in spite of having lower emissions rates than the target rate.

CO_2 Price Differences

Figure 79 shows the prices of CO_2 emissions for both the rate-based and mass-based compliance options. Figure 79 clearly shows that the price of CO_2 emissions is much higher under a rate-based regime than under a mass-based regime. First, as discussed above, rate-based compliance drives much more re-dispatch of existing combined- cycle resources to meet the emissions rate standard.

Second, because new combined-cycle resources are not included, they do not provide any credit for reducing the emissions rate to the target level, driving the need for more existing natural gas re-dispatch. In contrast, under a mass-based regime, new combined-cycle resources could be run at high capacity factors because they provide credit against the mass-based target, reducing the need for re-dispatch and by extension, the price of CO_2 emissions.

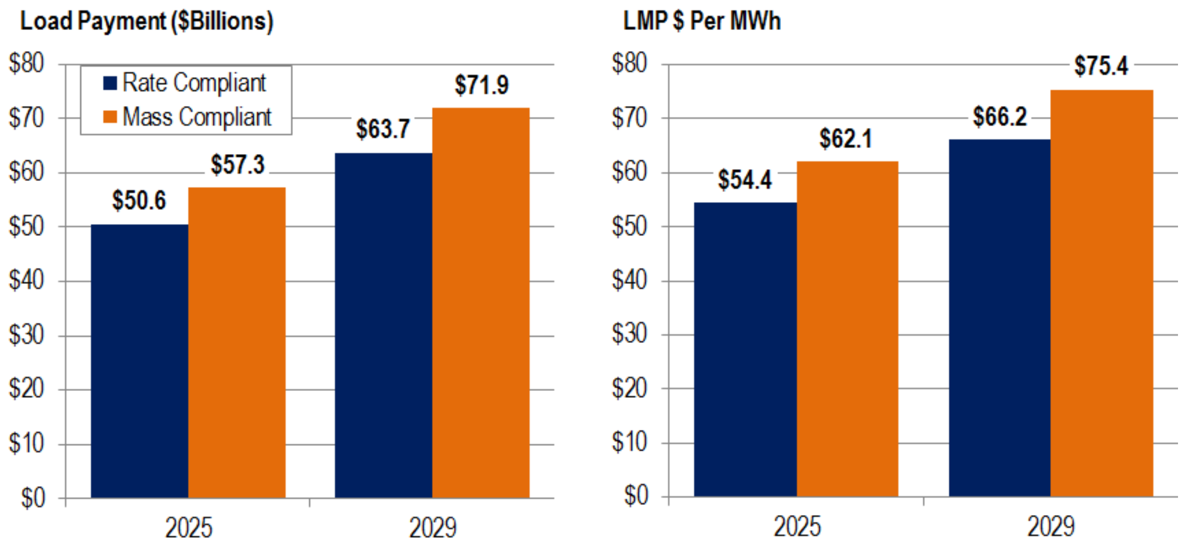
Figure 79. Rate- versus Mass-Based CO_2 Prices



LMP and Load Energy Payment Differences

As discussed above, units with emissions rates below the target rate receive a credit to their running costs, units with emission rates above the target rate do not face the full cost of CO_2 emissions in their offers and renewable resources effectively receive a credit that reduces their running cost below zero. As a consequence, LMPs will be lower than they would be under a mass-based program since unit offers are uniformly lower than under a mass-based approach for any given CO_2 price as shown in the right panel of Figure 80. Given the target emissions rates are approximately 1,260 lbs/MWh in 2025 and 1,160 lbs/MWh in 2029, implied credit to existing combined cycle gas in 2025 and 2029 are roughly $8/MWh and $16/MWh respectively with the implication that existing combined cycle will rarely be on the margin. Running costs for coal resources increase by $16/MWh and $32/MWh respectively, similar to the amount under a mass-based approach. New-entry combined-cycle resources will be on the margin most often and at a lower cost than existing combined- cycle resources under a mass-based approach, which would lead to lower LMPs.

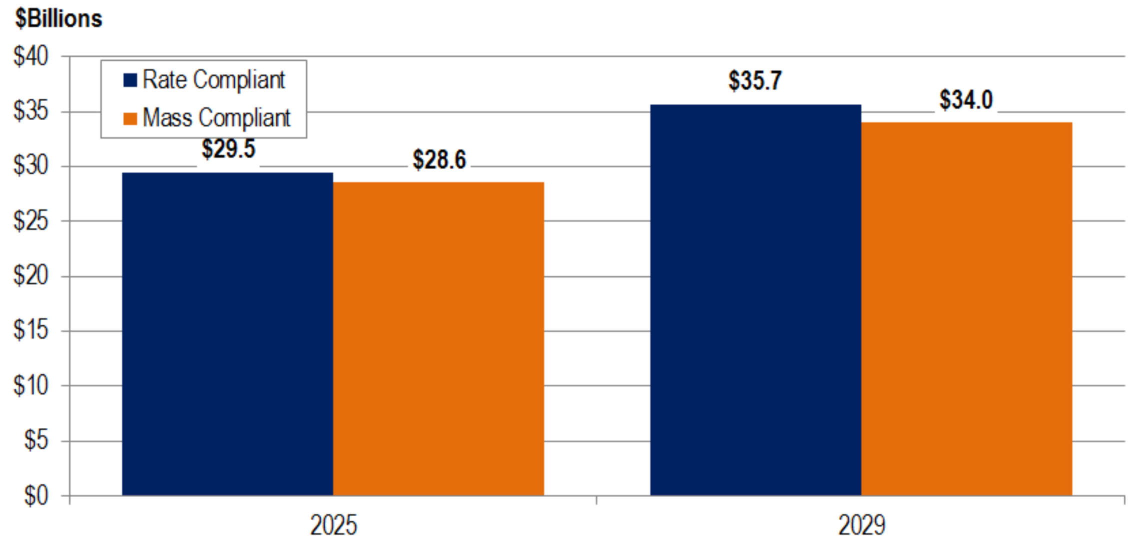
Figure 80. Rate- versus Mass-Based Compliance Effects of CO_2 Prices on Load-Weighted Average Wholesale Energy Market Prices and Load Energy Payments



Since LMPs are lower, load energy payments are also lower as shown in Figure 80 left panel.

Production Cost and Redispatch Compliance Cost Comparisons

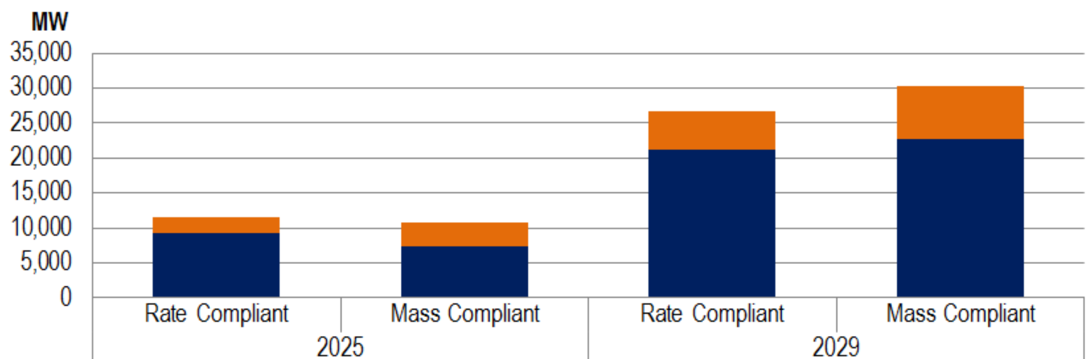
Figure 81. Rate- versus Mass-Based Compliance Total Fuel and Variable O&M Production and Implied Changes in Compliance Costs



Since achieving the emissions rate target requires more redispatch to existing combined-cycle natural gas, total fuel and operation and maintenance production costs – and by extension compliance costs – are higher under a rate-based regime than under the mass-based regime as shown in Figure 81. However, this result should be taken in the context of the assumptions of the scenarios that were used (lower levels of renewables and energy efficiency) and the fact that new combined-cycle resources and combustion turbines were not modeled as being affected resources under the Clean Power Plan.

Comparison of Units at Risk for Retirement

Figure 82. Rate- versus Mass-Based Compliance Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs



	2025 Rate Compliant	2025 Mass Compliant	2029 Rate Compliant	2029 Mass Compliant
0.6 - 0.75 Net Cone	2,352	3,419	5,473	7,511
0.5 - 0.6 Net Cone	9,169	7,390	21,173	22,789

Understanding the differences in fossil steam capacity at risk for retirement already has many offsetting drivers, and comparing rate- versus mass-based approaches to compliance has other moving parts; so the discussion will concentrate just on this scenario under these assumptions. Table 15 shows that the Net CONE is slightly higher in the emissions rate regime, which would, with everything else equal, lead to a decline in the fossil steam capacity, evident in 2029 but not in 2025. However, the differences are very small and probably are not the main effect in this scenario.

There are multiple considerations that have offsetting effects for fossil steam units as outlined below.

- Assuming the same price on CO_2 emissions, the rate-based regime results in a smaller increase in running costs for fossil steam units (by construction) than under a mass-based regime and, all else equal, would increase net energy market revenues.
- As new combined cycle gas does not count toward meeting the emission-rate target, fossil steam output may rise in the rate regime since it still may appear more economic than new combined cycle gas given the nature of how CO_2 prices affect running costs increasing net energy market revenues.
- But, in these scenario, CO_2 prices are much higher than under a mass-based regime and so this could offset the reduction in running costs.
- Under an emissions rate regime, LMPs are lower in this scenario so that, all else equal, net energy market revenues should decline for fossil steam units.
- Also, there may be decreased generation output due to the increased need for redispatch under an emissions rate regime, which decreases net energy market revenues.
- Finally, for fossil steam units, if the decrease in running costs and possible increase in output dominates all the other factors, then there may be less fossil steam capacity at risk under an emission-rate regime. Otherwise, fossil steam units will observe a reduction in energy market revenues.

Figure 82 shows that for the scenarios run there is no discernable pattern regarding fossil steam capacity at risk for retirement as in 2025 mass-based compliance leads to less capacity at risk while in 2029 there is slightly more capacity at risk.

Table 15. Combustion Turbine CONE Values for Rate- versus Mass-Based Compliance

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2025	PJM 10	$463.3	$30.5	$432.9
	PJM 4	$464.6	$38.2	$426.4
2029	PJM 10	$507.9	$57.0	$450.9
	PJM 4	$507.9	$64.4	$443.5

Section 7 – Summarizing Fossil Steam Capacity at Risk for Retirement for Use in Transmission Reliability Studies

In the previous section on the economic results, the capacity value of fossil steam units which are at risk for retirement varied greatly by the set of assumptions used to run the scenarios for the simulation years 2020, 2025 and 2029. For every scenario, the capacity at risk for retirement increases over time. Thus, any potential retirements would be expected to happen over time rather than at the same time.

Criteria for Identifying the Capacity at Risk for Retirement

However, PJM also needs to identify a set of units that are potentially at risk for retirement by simulation year and groups of scenarios.

Compliance Year for Identifying Capacity at Risk for Retirement

PJM uses the 2025 simulation year based on the idea that it is in the middle of the initial compliance period. But, there are also other reasons for choosing 2025. First, units opting to retire by 2025 likely would have made that decision prior to the Base Residual Auctions held in 2021 or 2022 for the 2024/2025 or 2025/2026 delivery years given PJM's experience with the Mercury and Air Toxics Standards. Given the timing of the Base Residual Auctions for resources to make decisions to retire by 2025, the actual retirement decisions would be made after one or two years' experience with the Clean Power Plan and state compliance plans but not actually occur until halfway through the initial compliance period.[21]

The year 2020 would not have been a good year to examine since, in many scenarios, CO_2 prices were zero and more information would be needed for fossil steam capacity to make retirement decisions. Moreover, to retire by 2020, those decisions would likely be made at the time the base residual auctions would be held in 2016 or 2017 for the 2019/2020 and 2020/2021 delivery years and at a time when state compliance plans would not likely be known by generation owners.

Groupings of Compliance Scenarios for Identifying Capacity at Risk

After choosing the year 2025, PJM grouped capacity at risk by scenarios, but not including the state-by-state or the emissions rate scenarios: 1) All scenarios; 2) At least 50 percent of scenarios; 3) High renewable resources and energy efficiency; 4) Lower renewables and energy efficiency; and 5) Worst-case scenarios where the most extreme of events occur that would lead to the greatest need for redispatch, highest fuel and variable operation and maintenance compliance costs and highest CO_2 prices. These groupings are enumerated in 0.

[21] Even given the recent experience, the PJM Tariff still permits resources to retire with only 90 days' notice. But, in that case, resources with capacity commitments then would need to buy their way out of those commitments or face penalties for non-delivery.

Table 16. Definitions of "At-Risk" Scenario Groupings

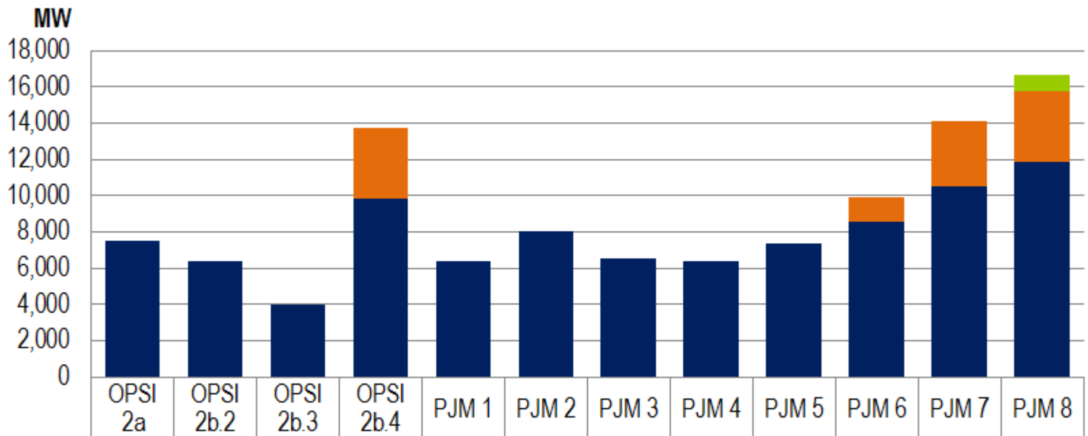
Scenario Group	Criteria
All Scenarios in all years	Generator fails to meet the 0.5 Net CONE Criteria in all scenarios for all years
50% of Scenarios	Generator fails to meet the 0.5 Net CONE Criteria in greater than 50% of the scenarios
Worst Case Scenarios	Generator fails to meet the 0.5 Net CONE criteria for each of the worst case scenarios (OPSI 2b.4, PJM 2, PJM 8)
High Renewable/EE	Generator fails to meet the 0.5 Net CONE criteria for each of the high renewable scenarios (OPSI 2a, OPSI 2b.1, OPSI 2b.2, PJM 1)
Low Renewable/EE	Generator fails to meet the 0.5 Net CONE criteria for each of the low renewable scenarios (PJM 4, PJM 5, PJM 6 & PJM 7)

Rather than focusing on scenarios that seem too pessimistic or optimistic in 0, PJM opted to focus its attention on units that are identified in at least 50 percent of all scenarios as this encompasses the all-scenario category, and does not necessarily take a position on the likelihood of industry conditions that would materialize under the other scenario groupings. However, in order to provide a range of results, PJM will also then examine the worst-case scenario with the greatest amount of capacity at risk and all scenarios that will have the lowest capacity value at risk.

Identified Capacity at Risk for Retirement Based on a Combustion Turbine

Figure 83 shows the value of the capacity at risk for retirement across all of the scenarios in 2025 based on the Net CONE of a combustion turbine resource.

Figure 83. Fossil Steam Capacity at Risk for Retirement using a the Combustion Turbine Net CONE as the Benchmark across all Regional, Mass-based Scenarios



	OPSI 2a	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
0.75 - 1.0 Net Cone												896
0.6 - 0.75 Net Cone				3,852						1,337	3,614	3,930
0.5 - 0.6 Net Cone	7,521	6,374	4,004	9,856	6,374	8,001	6,554	6,407	7,356	8,580	10,500	11,824

Figure 84 shows the identification of capacity at risk for retirement grouped as shown in 0 for 2025.

Figure 84. Fossil Steam Capacity at Risk for Retirement using a the Combustion Turbine Net CONE as the Benchmark by Scenario Groupings

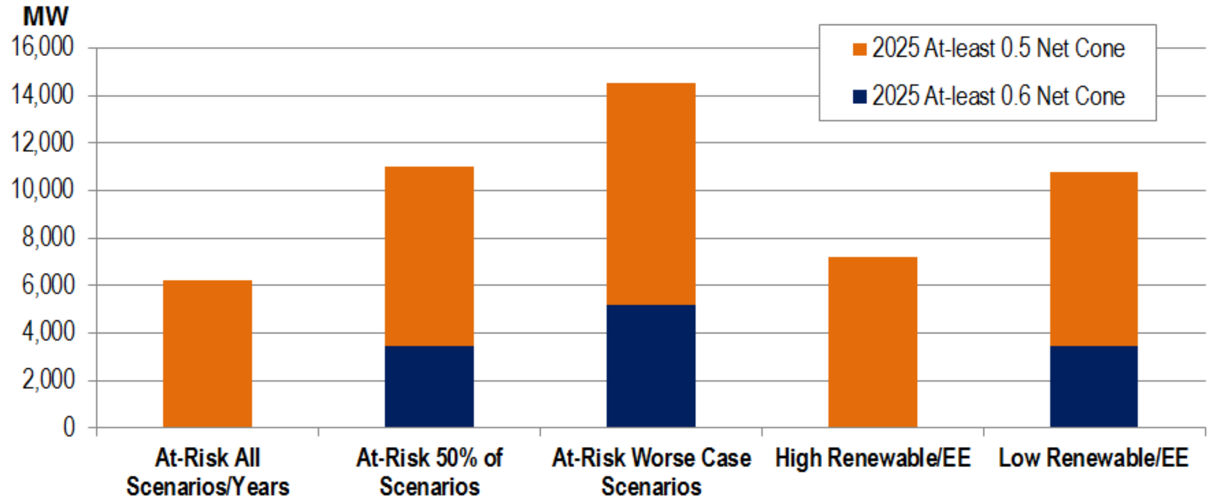
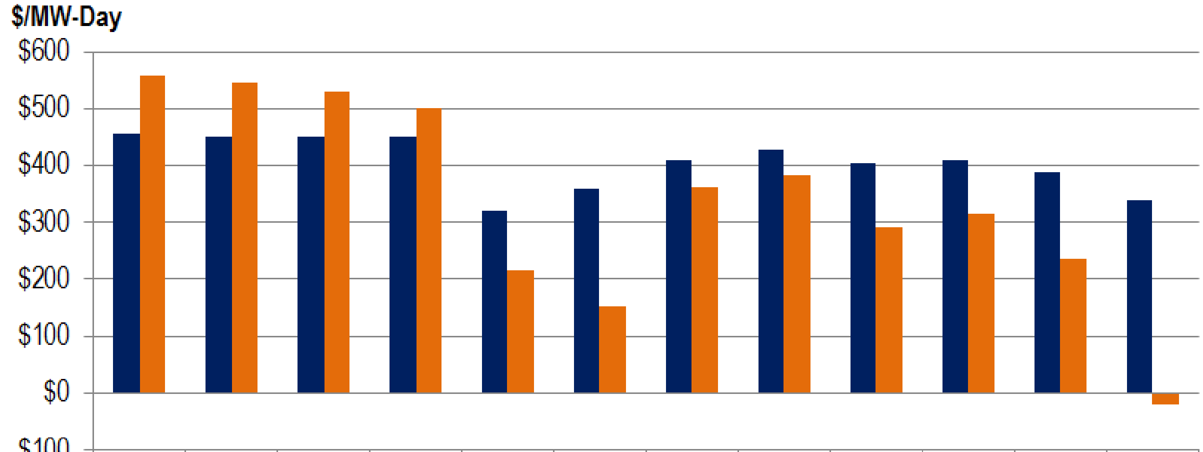


Figure 84 shows that nearly 11,000 MW of capacity are considered at risk for retirement in at least half the scenarios, about 14,500 MW in the worst-case scenario, and only about 6,200 MW at risk in all scenarios.

Identified Capacity at Risk for Retirement Based on the Lowest-Cost Resource

In addition to examining the risk of retirement benchmarked against the Net CONE of a combustion turbine, which represents the reference resource in the RPM capacity market for setting the demand for capacity, PJM also benchmarked for a natural gas combined-cycle resource. Figure 85 shows the Net CONE values for the combustion turbine and a combined-cycle resource for each scenario in 2025. In some scenarios the combustion turbine Net CONE is lower, and in some scenarios the combined-cycle resource Net CONE is lower. The combined-cycle resource net CONE becomes appreciably lower in all the more dramatic scenarios where renewables, energy efficiency and nuclear are limited.

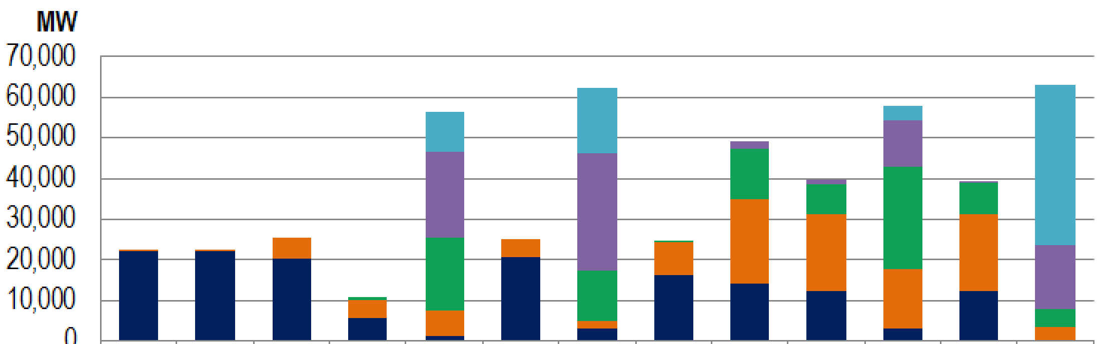
Figure 85. Combustion Turbine and Combined-Cycle Net CONE across all Regional, Mass-Based Scenarios



	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
SCGT	$455	$450	$451	$451	$320	$359	$410	$426	$405	$409	$388	$338
NGCC	$558	$545	$530	$501	$216	$154	$363	$383	$293	$315	$236	-$20

Figure 86 shows the value of capacity at risk, relative to the lowest cost resource, in all scenarios.

Figure 86. Fossil Steam Capacity at Risk for Retirement using a the Combustion Turbine Net CONE as the Benchmark across all Regional, Mass-based Scenarios

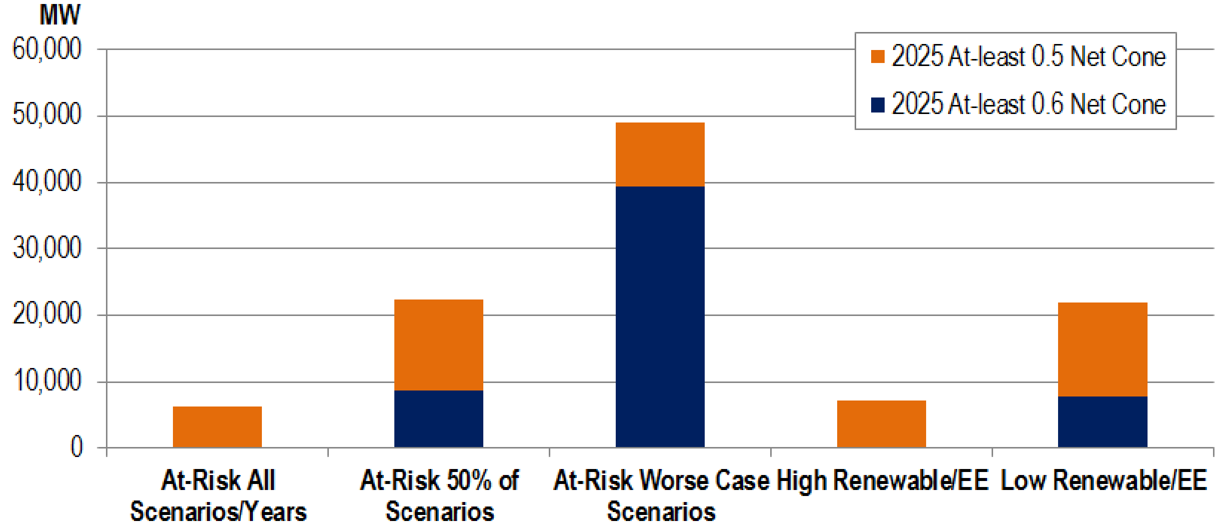


	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
>1.5 Net Cone					9,986		15,900				3,347		39,344
1.0 - 1.5 Net Cone					21,102		29,059		2,114	948	11,631	308	15,732
0.75 - 1.0 Net Cone				641	17,790		12,211	308	12,409	7,206	25,025	7,846	4,293
0.6 - 0.75 Net Cone	318	368	5,072	4,505	6,405	4,623	1,934	7,912	20,536	19,070	14,752	18,865	3,554
0.5 - 0.6 Net Cone	22,269	22,045	20,408	5,683	1,261	20,499	3,116	16,232	14,209	12,284	3,028	12,194	

One can easily observe that the cases where the combined-cycle Net CONE is dramatically lower, the value of capacity at risk for retirement increases. This increase is not due to a change in the fossil steam net energy revenues, but rather completely related to the change in benchmark chosen to identify capacity at risk for retirement. Figure 87 shows the average value of the capacity at risk by scenario grouping.

Figure 87 shows that capacity at risk in all scenarios to be around 6,200 MW, capacity at risk in at least half the scenarios is about 22,400 MW, and capacity at risk in the worst-case scenarios tops 48,900 MW.

Figure 87. Fossil Steam Capacity at Risk for Retirement using the Least-Cost Net CONE as the Benchmark by Scenario Groupings



Capacity at Risk for Transmission Reliability Studies

PJM took the simple average of capacity at risk in 2025 across the groupings for the combustion turbine and the least-cost resource:

- Capacity at risk in all scenarios: about 6,200 MW
- Capacity at risk in at least 50 percent of scenarios: approximately 16,700 MW
- Capacity at risk in the worst case scenarios: approximately 31,700 MW

The manner and ordering in which new entry and retirements occur is a dynamic process whereby capacity that retires or newly enters, changes the market dynamics in future years for capacity that remains in service. These dynamics may lead some capacity resources, considered to be at risk, to remain in commercial operation while their economic prospects improve. At the same time others not yet identified could find themselves at risk for retirement.

Conclusions

The results of PJM's analyses are not predictions of future outcomes; they are assessments of possible impacts based on specific assumptions and tempered by uncertainties, including future market conditions, the form of the final EPA rule and the manner in which states choose to comply. Although this report presents specific results under various scenarios that highlight changes to wholesale prices, load energy payments, net energy revenues for existing steam resources and compliance costs due to changes in resource dispatch, these numerical results depend on assumptions about industry conditions such as fuel costs, load growth, technological advancements and the form of state compliance plans in 2020, 2025 and 2029. Many things can change in the interim regarding industry conditions.

Significant qualitative results of PJM's analysis of the proposed Clean Power Plan include:

- Fossil steam unit retirements (coal, oil and gas) probably will occur gradually. As the CO_2 emission limits decline over time, the financial positions of high-emitting resources should become increasingly less favorable with lower-emitting resources displacing them more often in the competitive energy market.
- Electricity production costs and prices are likely to increase with compliance because larger amounts of higher-cost, cleaner generation will be used to meet emissions targets.
- The price of natural gas likely will be a primary driver of the cost of reducing CO_2 emissions if natural gas combined-cycle units become a significant source of replacement generation for coal and other fossil steam units.
- Adding more energy efficiency and renewable energy and retaining more nuclear generation likely would lead to lower CO_2 prices and could result in fewer megawatts of fossil steam resources at risk of retirement because lower CO_2 prices may reduce the financial stress on fossil steam resources under this scenario relative to new entry alternatives.
- State-by-state compliance options – compared to regional compliance options – likely would result in higher compliance costs for most PJM states because there are fewer low-cost options available within state boundaries than across the entire region. However, results will vary by state given differing state targets and generation mixes. PJM modeled regional versus individual state compliance only under a mass-based approach.
- State-by-state compliance options would increase the amount of capacity at risk for retirement because some states would likely face higher CO_2 prices in an individual compliance approach.

While all simulation analyses of policies or regulations like the Clean Power Plan involve making assumptions, some modeling assumptions regarding how compliance takes place seem critical such as: (1) the exclusion or inclusion of new natural gas resources and combustion turbines operating below a 33-percent capacity factor under Clean Power Plan compliance and (2) whether state plans choose a rate- or mass-based approach to compliance. Additional analysis examining inclusion of new natural gas resources and combustion turbines into Clean Power Plan compliance as well as additional simulations to explore the differences between rate- and mass-based compliance may be desirable.

In this analysis PJM has identified fossil steam generation capacity thought to be "at risk" for retirement based only upon energy market simulation results and comparing them to a Net CONE benchmark as PJM did in its analysis of the Mercury and Air Toxics Standards in 2011. For subsequent reliability analyses, however, it may be necessary to simulate capacity market outcomes (using the energy market simulation results as inputs) to further refine the identification of generation at risk for retirement.

Given that PJM simulated only energy market outcomes, PJM quantified the change in fuel and variable operation and maintenance production costs related to redispatch from higher-emitting to lower-emitting resources solely as a cost of compliance with the Clean Power Plan. PJM did not attempt to quantify the capital costs of renewable resources, energy efficiency, or new combined-cycle resources that may be associated with complying with the Clean Power Plan because such decisions may be made in accordance with existing state or federal policies or may otherwise be a result of economic decisions for new entry independent of the Clean Power Plan. Still, a better understanding of trade-offs between capital-intensive and redispatch compliance options is necessary to gauge the full range of long-term impacts on PJMs markets.

As the Clean Power Plan is finalized and state plans take shape, a number of additional environmental regulations will interact with the Clean Power Plan in ways that cannot be foreseen and may only be fully known as these other regulations take shape and are finalized in some cases. As information about the Clean Power Plan, state compliance plans and future industry conditions comes into sharper focus, PJM will refine this initial analysis to ascertain potential reliability effects and will continue to serve as a source of independent technical information on potential market implications to the PJM stakeholder community.

Appendix 1: Detailed Data Inputs and Outputs

Table 17. Key Modeling Variables (Delivered Energy) and Resulting Emissions

Year	Scenario ID	Renewable (GWh)	EE (GWh)	Nuclear (GWh)	111(b) Combined-Cycle Natural Gas Resource (MW)	111(b) Combined-Cycle Natural Gas Resource (GWh)	111(d) CO_2 Tons (millions)	Total CO_2 Tons (millions)
2020	OPSI 2a	88,359	26,347	274,890	14,470	51,046	374	397
	OPSI 2b.1	85,096	26,347	274,890	14,470	51,977	375	399
	OPSI 2b.2	88,540	13,174	274,906	14,470	53,716	381	406
	OPSI 2b.3	88,746	26,347	274,926	14,470	31,747	415	431
	OPSI 2b.4	88,771	26,347	137,341	14,470	76,425	448	485
	PJM 1	44,918	13,174	274,930	14,470	63,045	406	435
	PJM 2	34,363	7,893	274,930	11,445	54,118	421	447
	PJM 3	34,324	26,347	274,930	11,445	51,118	410	435
	PJM 4	46,107	7,893	274,930	14,470	63,292	407	436
	PJM 5	46,118	7,893	274,930	11,445	52,113	414	439
	PJM 6	46,169	7,893	242,336	11,445	56,777	432	460
	PJM 7	46,184	7,893	274,931	2,786	11,776	438	448
	PJM 8	46,210	7,893	274,931	2,786	9,272	463	473
2025	OPSI 2a	102,269	64,987	272,037	14,470	37,606	372	391
	OPSI 2b.1	84,438	64,987	272,080	14,470	42,194	382	403
	OPSI 2b.2	106,144	32,494	272,053	14,470	44,674	387	409
	OPSI 2b.3	102,087	64,987	272,043	14,470	28,607	394	409
	OPSI 2b.4	103,075	64,987	135,360	14,470	67,762	440	475
	PJM 1	62,634	32,494	272,092	14,470	56,742	411	439
	PJM 2	34,265	11,056	272,094	11,445	55,917	442	470
	PJM 3	34,210	64,987	272,088	11,445	45,672	412	436
	PJM 4	61,081	11,056	272,093	14,470	60,274	420	449
	PJM 5	61,086	11,056	272,093	11,445	50,213	426	451
	PJM 6	61,093	11,056	239,795	15,737	70,242	434	467
	PJM 7	61,087	11,056	272,093	9,333	42,140	430	452
	PJM 8	61,085	11,056	272,094	9,333	37,193	450	471
2029	OPSI 2a	103,977	86,382	285,295	14,470	33,793	363	381
	OPSI 2b.1	83,082	86,382	285,643	14,470	38,621	375	395
	OPSI 2b.2	109,693	43,191	285,662	14,470	42,813	384	405
	OPSI 2b.3	103,671	86,382	285,442	14,470	27,922	379	394
	OPSI 2b.4	106,535	86,382	149,213	14,470	64,031	429	462
	PJM 1	101,181	43,191	285,675	14,470	46,494	391	414
	PJM 2	34,197	13,624	285,830	15,737	72,658	435	470
	PJM 3	33,782	86,382	285,668	15,737	51,990	400	426
	PJM 4	73,634	13,624	285,827	14,470	58,108	415	443

Year	Scenario ID	Renewable (GWh)	EE (GWh)	Nuclear (GWh)	111(b) Combined-Cycle Natural Gas Resource (MW)	111(b) Combined-Cycle Natural Gas Resource (GWh)	111(d) CO_2 Tons (millions)	Total CO_2 Tons (millions)
	PJM 5	73,629	13,624	285,828	15,737	60,802	414	443
	PJM 6	73,869	13,624	253,468	15,737	68,240	428	461
	PJM 7	73,629	13,624	285,828	15,737	60,802	414	443
	PJM 8	73,556	13,624	285,830	15,737	53,163	434	460

Table 18. Generation before Clean Power Plan and Generation with Clean Power Plan Regional Mass-Based Compliance

		2020		2025		2029	
Scenario ID	Type	Gas Generation (MWh)	Coal Generation (MWh)	Gas Generation (MWh)	Coal Generation (MWh)	Gas Generation (MWh)	Coal Generation (MWh)
BAU	Base	155,705,279	349,046,844	159,234,413	371,375,819	163,717,507	371,652,766
BAU RPS	Base	150,014,293	346,770,401	138,467,129	360,607,938	140,369,870	360,410,769
OPSI 2a	Base	126,704,699	341,315,739	96,249,688	345,791,357	86,496,089	338,468,681
	111(d)	126,279,012	341,753,562	111,275,223	330,323,046	122,963,425	302,082,030
OPSI 2b.1	Base	128,959,187	342,344,129	105,847,653	353,794,603	97,278,310	348,058,915
	111(d)	129,480,203	341,820,493	134,595,789	324,477,824	147,193,480	298,389,396
OPSI 2b.2	Base	133,699,205	347,247,586	113,026,734	357,182,863	106,426,251	354,958,897
	111(d)	133,699,205	347,247,586	146,308,203	323,516,022	165,035,853	295,904,162
OPSI 2b.3	Base	74,848,088	394,593,668	69,580,326	373,377,903	67,278,292	358,320,017
	111(d)	94,442,241	373,404,264	102,255,107	339,231,100	113,276,033	310,861,519
OPSI 2b.4	Base	212,855,868	392,067,520	183,978,592	392,307,749	173,502,477	382,761,032
	111(d)	281,804,916	321,913,200	282,199,069	292,873,585	291,500,086	264,074,688
PJM 1	Base	160,217,926	365,626,654	142,530,019	375,029,560	115,308,204	360,829,395
	111(d)	177,176,126	348,534,468	203,291,547	313,505,589	182,586,031	292,958,495
PJM 2	Base	167,406,109	373,726,331	174,093,887	392,220,305	182,591,242	388,452,158
	111(d)	202,982,927	337,562,923	275,501,575	289,480,881	305,740,516	264,275,042
PJM 3	Base	155,261,770	366,680,485	134,710,978	374,522,010	126,231,647	367,752,395
	111(d)	179,577,043	342,030,978	201,803,013	306,391,077	205,019,684	288,437,512
PJM 4	Base	161,119,516	365,989,768	152,613,019	380,939,094	145,396,587	377,585,230
	111(d)	178,637,369	348,323,101	225,184,948	307,609,746	246,587,478	275,684,727
PJM 5	Base	157,507,718	369,642,396	150,015,161	383,664,442	146,004,876	376,966,940
	111(d)	185,969,508	340,819,289	233,143,385	299,505,460	244,713,881	277,633,041
PJM 6	Base	178,396,480	381,257,160	175,997,100	389,551,241	169,256,608	385,403,764
	111(d)	228,268,123	330,536,575	266,013,420	298,633,900	284,381,648	269,481,667
PJM 7	Base	146,375,174	380,866,344	148,341,263	385,382,376	146,004,876	376,966,940
	111(d)	209,956,678	315,767,017	236,348,564	296,203,644	244,432,479	277,934,631

		2020		2025		2029	
Scenario ID	Type	Gas Generation (MWh)	Coal Generation (MWh)	Gas Generation (MWh)	Coal Generation (MWh)	Gas Generation (MWh)	Coal Generation (MWh)
PJM 8	Base	107,723,016	420,608,916	120,865,534	413,782,323	119,594,149	404,224,205
	111(d)	193,793,475	331,672,074	229,852,552	301,975,212	231,751,891	289,142,978

Table 19. Clean Power Plan Regional Mass-Based Compliance-Related Costs

		Δ **Fuel and O&M** ($ billions)			CO_2 Allowance Price ($/Ton)			Allowance Value ($ billions)		
Scenario ID	Type	2020	2025	2029	2020	2025	2029	2020	2025	2029
OPSI 2a	Base	$0.00	$0.13	$0.58	$0.00	$4.88	$13.22	$0.00	$1.73	$4.31
OPSI 2b.1	Base	$0.00	$0.29	$0.81	$0.00	$8.92	$17.43	$0.00	$3.13	$5.70
OPSI 2b.2	Base	$0.00	$0.35	$0.95	$0.00	$10.35	$19.95	$0.00	$3.65	$6.54
OPSI 2b.3	Base	$0.27	$0.77	$1.91	$12.66	$25.72	$42.28	$4.92	$9.12	$13.82
OPSI 2b.4	Base	$0.55	$1.60	$2.74	$13.07	$27.50	$38.60	$5.06	$9.74	$12.61
PJM 1	Base	$0.07	$0.75	$1.13	$3.33	$17.80	$22.42	$1.30	$6.32	$7.38
PJM 2	Base	$0.21	$1.82	$2.85	$7.57	$30.94	$39.49	$2.95	$10.92	$12.90
PJM 3	Base	$0.12	$0.93	$1.39	$5.35	$20.33	$24.76	$2.07	$7.20	$8.15
PJM 4	Base	$0.07	$0.95	$1.97	$3.50	$20.31	$31.89	$1.36	$7.20	$10.46
PJM 5	Base	$0.16	$1.27	$1.86	$6.05	$24.68	$29.85	$2.35	$8.74	$9.76
PJM 6	Base	$0.35	$1.32	$2.45	$10.17	$24.34	$36.04	$3.95	$8.60	$11.83
PJM 7	Base	$0.60	$1.43	$1.85	$15.42	$27.18	$29.77	$5.96	$9.67	$9.74
PJM 8	Base	$2.37	$4.18	$5.32	$41.00	$58.19	$69.56	$15.91	$20.45	$22.73

Table 20. Demand Cost Variables before and after Compliance with the Clean Power Plan

	TDC ($Billions)			Δ **TDC ($Billions)**			LMP ($/MWh)			Δ **LMP ($/MWh)**		
Scenario ID	2020	2025	2029	2020	2025	2029	2020	2025	2029	2020	2025	2029
OPSI 2a	$31.87	$40.22	$46.06	$0.00	$1.77	$4.53	$35.91	$45.36	$50.59	$0.00	$1.89	$4.56
OPSI 2b.1	$31.87	$41.00	$47.77	$0.00	$3.38	$6.87	$35.89	$46.33	$52.33	$0.00	$3.57	$7.36
OPSI 2b.2	$32.68	$42.97	$50.30	$0.00	$4.38	$8.82	$36.41	$47.13	$53.54	$0.00	$4.65	$9.37
OPSI 2b.3	$42.54	$50.97	$60.11	$5.55	$11.45	$19.36	$47.72	$56.59	$64.85	$6.82	$14.01	$23.17
OPSI 2b.4	$38.08	$50.26	$58.04	$6.69	$12.87	$17.98	$42.56	$55.76	$63.44	$7.94	$15.23	$20.55
PJM 1	$34.30	$45.71	$51.55	$1.75	$8.70	$10.34	$38.23	$50.00	$54.65	$2.00	$9.74	$11.03
PJM 2	$35.79	$51.10	$60.31	$4.17	$16.78	$21.07	$39.52	$54.15	$62.11	$4.85	$18.58	$22.37
PJM 3	$34.34	$44.98	$51.21	$2.77	$9.87	$10.71	$38.66	$50.63	$56.35	$3.29	$11.40	$12.10
PJM 4	$34.43	$47.04	$55.66	$1.81	$10.26	$16.25	$38.27	$50.73	$58.10	$2.06	$11.36	$17.26
PJM 5	$35.07	$48.22	$55.15	$3.30	$12.89	$14.86	$38.85	$51.80	$57.75	$3.86	$14.18	$15.70
PJM 6	$36.56	$48.59	$57.71	$5.52	$12.28	$18.62	$40.43	$52.41	$60.31	$6.42	$13.59	$19.91
PJM 7	$38.17	$49.14	$55.15	$8.92	$14.54	$14.80	$41.71	$52.55	$57.75	$10.29	$16.09	$15.64
PJM 8	$50.86	$63.89	$74.93	$20.70	$29.80	$34.65	$55.13	$67.64	$77.26	$24.62	$34.50	$39.36

Appendix 2

Other Rules That May Interact with the Clean Power Plan

MATS

The Mercury and Air Toxics Standards (MATS) rule requires coal-fired generators to meet a specific emission rate for mercury. PJM analyzed the MATS rule proposal[22] and determined that 11,000 MW – 25,000 MW of coal-fired capacity would be at risk for retirement. To date, approximately 18,500 MW of coal capacity have either retired or notified PJM of their planned retirement. These retirements are rapidly altering the capacity resource mix in PJM with the bulk of the new capacity consisting of natural gas combined-cycle units. These retirements also necessitated approximately $4 billion of transmission upgrades in PJM to maintain reliability.

CSAPR

The EPA's Cross State Air Pollution Rule seeks to reduce emissions of nitrogen oxides and sulfur dioxide through a cap and trade program. Following a 2014 U.S. Supreme Court decision, Phase I emission caps (budgets) are scheduled to apply in 2015 and 2016, and Phase 2 budgets apply in 2017 and beyond.

National Ambient Air Quality Standards

Ozone

The EPA recently proposed that the current primary and secondary National Ambient Air Quality Standards for ozone be revised to 0.065 – 0.070 parts per million (ppm) down from the current level of 0.075 ppm. Additionally, the EPA proposed to increase the time period in which ozone is monitored from the current five-month period to an eight-month period in all 13 states in PJM, as well as the District of Columbia. The new standard could impact the ability to site new generation in PJM at a time when the Clean Power Plan could drive the need for more new generation in PJM.

Sulfur Dioxide

The one-hour sulfur-dioxide National Ambient Air Quality Standard, which became effective August 2010, set the standard at 75 ppm. Although compliance or attainment normally is monitored with ambient air monitors, due to a lack of sulfur dioxide monitors, the EPA suggested the use of dispersion modeling. The final Data Requirement Rule that will determine what process is used to measure attainment was due in December 2014 but has been pushed back. The states will submit nonattainment designations in 2017, and the EPA will finalize them later that year. The states will then have until 2019 to develop and submit their plans to bring all areas into attainment with the new standard. Like the ozone standard, this standard could limit the ability to site new generation at a critical time.

[22] Coal Capacity at Risk for Retirement in PJM http://www.pjm.com/~/media/documents/reports/20110826-coal-capacity-at-risk-for-retirement.ashx

Clean Water Act Section 316(b)

In order to reduce harm to aquatic organisms, the EPA issued final regulations for cooling water intake structures at existing power plants under section 316(b) of the Clean Water Act in May 2014. The rule applies to the location, design, construction and capacity of cooling water intake structures based on “best technology available” at facilities that use at least 2 million gallons per day. Facilities will need to address these requirements as their National Pollutant Discharge Elimination System permits are renewed – with most renewals occurring 2018 through 2022. A longer compliance schedule can be employed if justified by appropriate factors such as measures needed to maintain adequate energy reliability.

Coal Combustion Residuals

In December 2014 the EPA finalized rules for the storage of coal ash and scrubber waste under Subtitle D of the Resource Conservation and Recovery Act. The rule regulates the materials as non-hazardous waste, continuing to allow beneficial reuse. Additionally, the rule sets out requirements for structural integrity, location, groundwater monitoring and the closing of existing surface impoundments, and the design and operating parameters for new facilities. These rules will be implemented in the 2015-2017 timeframe.

Steam Electric Effluent Limitation Guidelines

The EPA proposal to regulate toxic metal contaminants in water discharges from electric generators is expected to be finalized by September 2015. Facilities, particularly coal units, may need to upgrade wastewater treatment processes.

Appendix 3

OPSI-Requested Scenarios

OPSI 2a

In this scenario, PJM used all of the assumptions in its 2014 transmission planning case except regarding the level of energy efficiency, load and renewable energy. PJM assumed the state targets were met for energy efficiency identified in the EPA's June 2, 2014, goal computation technical support document. Similar to the planning case, PJM reduced the projected load forecast by the amount of energy efficiency. The high level of energy efficiency in this scenario, especially by 2029, produces very high reserve levels. As a result, many new thermal resources would not be required, but, because they are expected to be in service prior to 2020, PJM retained them in this scenario.

Using the reduced load forecast, PJM calculated an adjusted megawatt-hour renewable energy requirement for each PJM state based on its respective voluntary or mandatory RPS target percentages and added wind and solar resources to the base planning model to achieve the RPS targets. Initially resources were added from the PJM generation interconnection queues, but by 2025 and 2029 additional resources were required. Solar power was added first to account for solar carve-outs in specific states, and the remainder of the aggregated renewable requirement was modeled as on-shore wind resources. The location of wind resources was based upon the energy distribution of existing and planned renewable resources already sited within each PJM state. For example, a state that provides 10 percent of the total renewable energy within the PJM footprint would be allocated 10 percent of the remaining PJM target requirement. The allocation then was distributed proportionately to discrete resources within the state. This method reflects approaches that use technical feasibility as criteria for building out renewables and recognizes that some states have had more encouraging policies for development of renewables than others. The aggregate amount of renewable energy assumed in this scenario is significantly higher than the amount calculated by the EPA because the growth rate is based on individual states and is not a regional average as the EPA used.

OPSI 2b.1

In this scenario, the energy efficiency levels were modeled at 100 percent of the targets used in the EPA's target rate goal computation, and the PJM forecasted load reflects an adjustment for energy efficiency. However, the amount of renewable energy assumed within the model was based on all active renewable resources within the PJM generation interconnection queue. Additional wind and solar resources that are in the System Impact Study and Feasibility Study[23] phases of the PJM interconnection process were included in the model. Additional renewable resources still would be required to meet the PJM states' RPS requirements.

[23] See Generation Interconnection fact sheet for a brief explanation of the phases of the PJM generation interconnection process http://www.pjm.com/~/media/about-pjm/newsroom/fact-sheets/generation-interconnection-fact-sheet.ashx.

OPSI 2b.2

This scenario is the same as the OPSI 2a scenario except the level of energy efficiency was reduced by 50 percent and the renewable energy requirement was adjusted to reflect the higher load resulting from the reduction in the amount of energy efficiency.

OPSI 2b.3

This scenario is the same as the OPSI 2a scenario except that the natural gas price was increased by 50 percent in 2020. The forecasted price for the remaining years was based on applying the trend observed in the original forecast to the assumed higher 2020 price. The model already included assumptions about resources that would enter or exit the market in response to a significant increase in the price of natural gas.

OPSI 2b.4

This scenario is the same as the OPSI 2a scenario except that the amount of nuclear installed capacity was reduced by 50 percent. To mitigate local transmission impacts and because none of these resources are actually at-risk in the model by 2020, the nuclear capacity was reduced proportionately based on each resource's installed capacity value[24].

OPSI 2b.c

This scenario is the same as the OPSI 2a scenario but is simulated for state-by-state compliance as opposed to regional compliance. All of the resource and economic assumptions are the same. However, each state was modeled with an individual CO_2 emission constraint based on its EPA proposed mass target. This scenario is simulated only for 2020.

PJM-Developed Scenarios

PJM 1

Beginning with the 2014 transmission planning case, the amount of renewable energy was modified to reflect the levels provided by the EPA for each of the interim compliance years. The energy at the modeled sites was scaled proportionally using the method described for the OPSI 2a case. In addition the energy efficiency level was reduced by 50 percent similar to the OPSI 2b.3 scenario.

After making an adjustment for the energy efficiency, this scenario can be used to compare the levels of re-dispatch assumed in the EPA's goal computation to the levels required to comply with the mass-target in the PJM simulation.

[24] The installed capacity of a generator is based the summer net dependable rating of the unit as determined in accordance with PJM's rules and procedures of the determination of generating capacity.

PJM 2

Beginning with the 2014 transmission planning case, renewable energy amounts were reduced to include only resources already installed or under-construction. In addition, the level of energy efficiency assumed in the model is limited to the amount which cleared in the PJM Base Residual Auction for the 2017/2018 delivery year (1,339 MW). The respective commercial probability[25] for units with a signed Feasibility Study Agreement (13 percent), System Impact Study Agreement (25 percent), Facilities Study Agreement (53 percent) or Interconnection Service Agreement (60 percent)[26] was applied to all of the combined-cycle natural gas resource units in the PJM generation interconnection queues. Applying these factors reduced the amount of modeled combined-cycle natural gas resource capacity by 3 GW in 2020 and 2025. Discrete units were ranked based on both whether they were in a historically constrained Locational Deliverability Areas and transmission network upgrade costs. By 2029, as reserve margins become tighter, an additional 1,267 MW of combined-cycle natural gas resource capacity from the PJM generation interconnection queues was added to the scenario. Although this scenario is highly unlikely, it sets an upper bound on the economic impacts of the Clean Power Plan if there is very little development in renewable energy and or energy efficiency.

PJM 3

This scenario is the same as PJM 2 except that energy efficiency was grown at a rate consistent with the EPA's proposed goals. This scenario is intended to show whether energy efficiency as modeled within the scenario would be able to compensate for the lack of development in renewables. By depressing energy market prices, high amounts of renewables make energy efficiency programs less valuable as most of the economic benefit of these programs comes from the avoided energy costs through reducing consumption.

PJM 4

Beginning with the 2014 transmission planning case, a linear regression function was used to estimate the build-out (in megawatts) of wind and solar resources through the end of the interim compliance period. Units identified as existing, partially in-service or under-construction from the PJM generation interconnection queues were used in the regression function. In addition, rather than using the energy production assumed for the latest wind turbine technology, the energy output of the wind resources was reduced to better approximate historic average capacity factors observed within PJM. In 2020, the level of renewable energy assumed in this scenario was comparable to the PJM 1 scenario. However, renewable growth through 2029 was not as fast. Energy efficiency (in megawatts) also was trended based on the results of the last six PJM Base Residual Auctions to determine a level of energy efficiency expected to be available during the interim compliance period. The energy reduction was calculated based on the historic PJM load factor.

[25] See 2013 PJM Reserve Requirement Study for average commercial probabilities applied to planned units.

[26] See PJM Manual 14A: Generation and Transmission Interconnection Process for information about the agreements http://www.pjm.com/~/media/documents/manuals/m14a.ashx.

This scenario is intended to provide a view of growth in these resources that is more consistent with historic trends. Rather than assuming all of the existing queued renewable resources will be built before the compliance period, this scenario gradually increases the amount of renewables and energy efficiency within the PJM footprint. As the targets become stricter over time, growth in renewables is expected to grow as an important component in complying with the policy.

PJM 5

This scenario is the same as the PJM 4 scenario but reduces the combined-cycle natural gas resource capacity by 3 GW in 2020 and 2025. The 3 GW are identified and removed using the same procedure based on commercial probability described in scenario 2. By 2029, as reserves become tighter, PJM 4 and PJM 5 scenarios are nearly identical except for the additional 1,267 MW of new combined-cycle natural gas resources added to the PJM 5 scenario.

PJM 6

This scenario is equivalent to the PJM 5 scenario but reduced the available nuclear capacity by 10 percent. Similar to the OPSI 2b.4 scenario, the reduction is applied proportionally across the PJM footprint based on each individual resource's installed capacity. By the compliance period, natural gas prices would rise enough such that nuclear resources would earn significantly higher revenues than they have for the last several years, a period in which natural gas prices were historically low. Because natural gas prices are forecasted to rise within the model, the risk of nuclear units retiring based on economics is greater before the start of the compliance period, than it is during the compliance period. Although a significant influx of renewables could diminish profits earned by nuclear resources, with the Clean Power Plan, the modeled re-dispatch would cause an upward trend in energy market prices.

PJM 7

This scenario is the same as the PJM 5 scenario except combined-cycle natural gas resource capacity is reduced such that the total resources modeled within PJM do not exceed the installed reserve margin target. Because of low natural gas prices and gains in the efficiency of new combined-cycle natural gas units, new units that entered the market could earn significant energy market revenues in recent years. In some regions, combined-cycle natural gas resources have had a lower Net Cost of Entry than even combustion-turbine units. Consequently, within many capacity expansion models, the dominant unit type selected for meeting reserve margin targets would be combined-cycle natural gas resources. Within a typical capacity expansion plan new resources would enter only until the installed reserve margin target is achieved. Because new combined-cycle natural gas resources are not 111(d)-affected sources, overstating them within the model has consequences both within a rate-based or mass-based compliance framework. Under both a rate-based and mass-based framework, because new sources regulated under 111(b) are not modeled with a CO_2 price, they represent a cheap form of compliance where emissions are simply shifted from existing combined-cycle natural gas resource to the new sources. Under a rate-based framework, however, their exclusion from the compliance formula can negatively impact compliance because they reduce the contribution of lower-emitting sources within the compliance equation. Within a mass-based framework, the same incentive for including these resources does not exist as the fewer resources covered by the policy, the lower the total emissions. This scenario is intended to isolate the impacts of these resources by including only enough additional combined-cycle natural gas resource to meet the IRM targets. By 2029, there is no difference between this scenario and PJM 5.

PJM 8

This scenario is the same as the PJM 8 scenario except that the natural gas price forecast was increased by 50 percent in 2020.

PJM 9

This scenario is the same as the PJM 4 scenario but was simulated for state-by-state compliance as opposed to regional compliance where a single CO_2 price is determined for the region. This scenario was simulated only for 2020.

PJM 10

This scenario is the same as the PJM 4 scenario but, rather than modeling an emissions budgeting program for the region similar to the Regional Greenhouse Gas Initiative, PJM simulated an emissions rate performance trading program to achieve the target PJM rate. This scenario is simulated only for 2025 and 2029.

PJM 11

This scenario is the same as the PJM 7 scenario but simulated for state-by-state compliance.

Appendix 4: Calculating Target CO_2 Emission Rates for PJM States

On June 2, 2014, the EPA provided proposed goal CO_2 emission rates for each state under two options. Under the proposed option 1, states can comply with the policy over an interim period of 2020-2029 with the final target rate in 2030 based on the 2029 rate. Option 2 has a shorter interim compliance period defined as 2020 through 2024 and achieves final target compliance by 2025. PJM evaluated the Clean Power Plan using Option 1; while Option 1 has a more stringent final target, it also has a longer lead-time for states to implement the building blocks. To determine the target rates, the EPA used four building blocks, which it considered to be the "Best System of Emissions Reductions." When submitting their implementation plans, states do not have to adhere to the EPA's building blocks, but for the purposes of compliance and modeling the Clean Power Plan, the building blocks (Option 1) are required to determine the target rates.

Building Block 1: Reducing the carbon intensity of generation at individual affected electric generating units through a 6 percent improvement to coal-unit heat-rates

Building Block 2: Reducing emissions from the most carbon-intensive affected electric generating units in the amount that results from substituting generation at those electric generating units with generation from less carbon intensive affected electric generating units (including combined-cycle natural gas resource units under construction); the EPA assumed a ceiling of 70 percent on capacity factors for combined-cycle natural gas resources.

Building Block 3: Reducing emissions from affected electric generating units in the amount that results from substituting generation at those electric generating units with expanded low- or zero-carbon generation. Nationally, the EPA assumed renewable energy would serve 13 percent of 2012 load by the start of 2030; 5.8 percent of at-risk nuclear is assumed to be retained through incremental investment.

Building Block 4: Reducing emissions from affected electric generating units in the amount that results from the use of demand-side energy efficiency that reduces the amount of generation required to serve load. Nationally, the EPA assumed energy efficiency would produce cumulative savings of 10.7 percent of 2012 load by the start of 2030.

The EPA provided the following CO_2 emission rate (lbs/MWh) compliance equation to illustrate how each state's goal is calculated:

$$\frac{2012\ Affected\ EGU\ Emssions\ (\mathrm{lbs})}{2012\ \mathrm{Affected\ EGU\ MWh}\ +\ \mathrm{Renewable\ MWh}\ +5.8\%\ \mathrm{Existing\ Nuclear\ MWh}\ +\ \mathrm{New\ EE\ MWh}}$$

The level of energy efficiency and renewable energy is the primary driver of the CO_2 emission rate goals within the Clean Power Plan. Building blocks 1 and 2 as well as the nuclear assumption all were based on 2012 baseline generation and do not change from year to year when calculating the target rates. For determining the CO_2 emission rate goals for the PJM footprint, the EPA's 2012 thermal output of affected electric generating units within each state was adjusted based only on the generation operated within the PJM balancing authority. Likewise, the renewable energy and energy efficiency megawatt-hour values were re-calculated based only on the portion of state-load served within the PJM footprint. The renewable targets for the entire PJM footprint, as a percentage of the 2014 PJM Load Forecast's annual energy projection, increase from 3.8 percent in 2020 to 11.4 percent in 2029. This increase is lower than the Renewable Portfolio Standards calculated for PJM states based on the applicable states' voluntary or mandatory RPS. Of the states with load served by PJM, all of them except for Tennessee and Kentucky have either voluntary or mandatory RPS policies. Although Indiana has an RPS, under the existing goals, no incremental generation would be required to meet its RPS. Based on the methodology applied to earlier studies, such as the Renewable Integration Study, the amount of renewable energy required to meet the RPS grows from just under 10 percent in 2020 to 13.4 percent of PJM's forecasted load by 2029[27]. The EPA-projected values are lower because the growth of renewables within a given state was limited by the annual average growth rate for the EPA-defined region in which the state is located. If instead, renewable energy within the PJM footprint grows at a rate consistent with each state's RPS, building block 3 would offset the amount states have to do under any other building blocks.

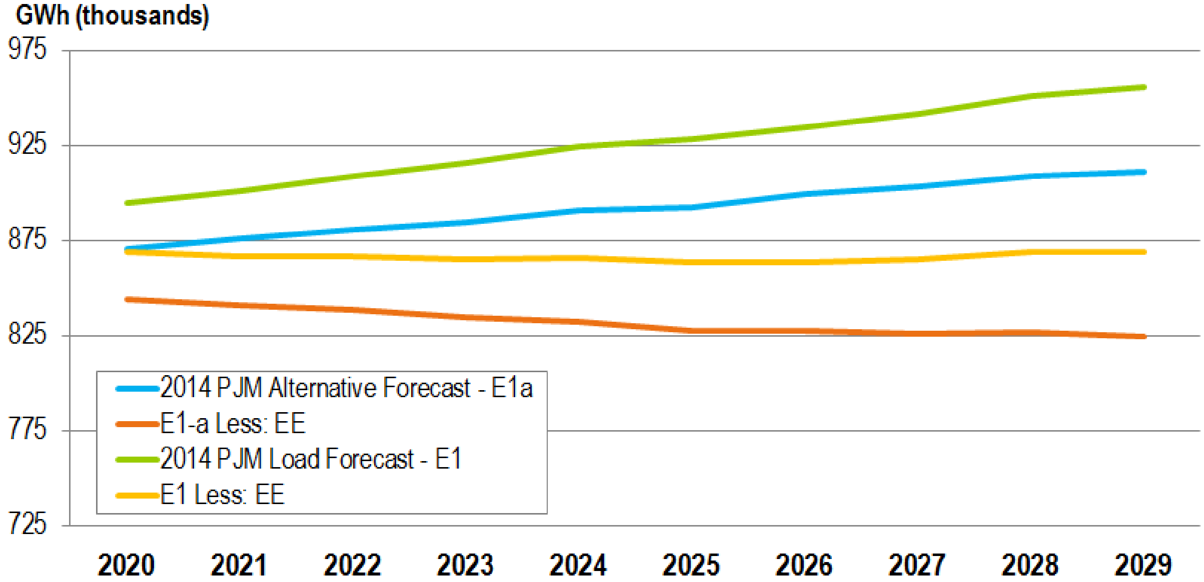
Energy efficiency growth as a percentage of 2012 PJM wholesale load represents about 3.3 percent cumulative savings by 2020 and 11 percent by 2029. When each state's energy efficiency is adjusted for the percent of in-state generation to serve load, the savings which would be credited within the compliance equation drop to 2.9 percent in 2020 growing to 9.1 percent by 2029. This growth in energy efficiency is significant as the PJM 2014 load forecast projects only 0.51 percent load growth between 2020 and 2029, indicating a downward trend from the 0.76 percent load growth forecasted for the entire 2012 through 2029 period.

Recognizing that historically the PJM forecast has overstated realized load, in 2014 PJM provided an alternative approach in which the economic forecast was adjusted based upon trending historic load factors in the PJM footprint. While energy efficiency likely has had an impact on the historic load factors, at this time it was not possible to determine the exact amount of energy efficiency embedded in the either of the PJM forecasts. For the purpose of receiving PJM capacity market revenues, energy efficiency resources are eligible only to participate in PJM's RPM auction for four consecutive years. During measurement and verification, energy efficiency must achieve a permanent, continuous reduction in electric energy consumption at the End Use Customer's retail site (during the defined energy efficiency Performance Hours[28]) that is not reflected in the peak load forecast. Consequently, for PJM's analysis of the Clean Power Plan, the energy efficiency targets provided by the EPA in its technical support document are assumed to be incremental. If the levels of energy efficiency included in the EPA proposal are achieved, PJM would have either negative or at-best flat load growth over the interim compliance period. However, if energy efficiency is overstated in the simulation because a significant amount does not participate in the PJM Capacity Market but already is represented in the load forecast, downward adjustment would lead only to greater re-dispatch, CO_2 prices and compliance cost.

[27] The renewable energy requirement for PJM states is calculated based on wholesale load (retail load + T&D losses), and adjustment for fossil-fuel based resources and credit multipliers, which reduce the megawatt-hours needed from renewables for RPS compliance.

[28] EE Performance Hours are between the hour ending 15:00 Eastern Prevailing Time (EPT) and the hour ending 18:00 EPT during all days from June 1 through August 31, inclusive, of such Delivery Year, that is not a weekend or federal holiday. Source: PJM Manual 18 –PJM Capacity Market.

Figure 88. 2014 PJM Load Forecast Adjusted for Energy Efficiency



In calculating the rate target for PJM as a whole, the energy efficiency credit is based on the individual states as opposed to the region's generation-to-load ratio. This can lead to different results than assuming all of the energy efficiency for the region is credited in the compliance equation. The result of applying the compliance equation to the PJM footprint is shown in the table below. Because energy efficiency and renewable energy are driving the goal rates and grow at a near constant rate as a percentage of load, the average target rate is between the 2024 and 2025 target rates.

Table 21. PJM Target CO_2 Rate Simulated

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Average	Final
1,398	1,372	1,346	1,319	1,292	1,264	1,237	1,212	1,187	1,163	1,279	1,163

Appendix 5: Calculating a Mass Target for the PJM Footprint

The EPA guidance on June 2, 2014, did not provide an explicit formula for the rate-to-mass conversion. However, within the accompanying technical support document titled "Projecting EGU CO_2 Emissions Performance in State Plans," the EPA provided a method for converting the rate-based emission performance goal to a mass-based goal. In the technical support document, the EPA states that "A mass-based CO_2 emission performance goal is calculated by projecting the tons of CO_2 that would be emitted during a state plan performance period (e.g., 2020-2029, 2030-2032) by affected EGUs in the state if they hypothetically were meeting the state rate-based CO_2 emission performance goal for affected EGUs established in the emission guidelines."[29] In performing the projection of electric generating unit generation and CO_2 emissions, a reference case must be developed that excludes qualifying state programs and measures contained in the state plan. The EPA provides the following variables for inclusion in the reference case scenario:

- Electricity load growth projections (energy and peak demand)
- Fuel supply, delivery, and pricing assumptions
- Cost and performance of electric generating technologies
- EGU firm builds and retirements (e.g., those scheduled with a regional transmission organization or independent system operator)
- Transmission capability and ISO/RTO transmission expansion plans
- Applicable federal regulations (other than the EPA emission guidelines)
- Applicable state regulations and programs (other than those that are included in the state-plan)

The EPA requirement that already "on-the-books" measures to mitigate CO_2 emissions must be excluded from the state plan primarily impacts the amount of credit that can be applied for energy efficiency programs. The EPA allows crediting within a state plan only for emissions reductions from existing state programs if the installation of the energy efficiency measure occurs after June 2, 2014, the date when the emissions guidelines were proposed as part of the Clean Power Plan. Renewable resources do not have this limitation, and the full amount of installed [30] and proposed renewables can be credited within the rate-compliance equation. In the footnotes to the technical support document, the EPA suggests that renewables already part of an existing RPS obligation be included in the reference case, whereas increases to state RPS post June, 2, 2014, be excluded. The amount of energy efficiency and renewable energy assumed when developing a reference case is important to establishing the amount of emissions that would occur in the absence of the policy. For example, energy efficiency installed before June 2, 2014, should be subtracted from the load forecast used in the reference case, whereas energy efficiency installed after this date would be included in the state plan. Similarly, the amount of renewables assumed within the simulation will displace a mixture of existing and new generation resulting in lower projected total thermal output.

[29] EPA Docket ID No. EPA-HQ-OAR-2013-0602 - Projecting EGU CO_2 Emission Performance in State Plans
[30] Excludes existing hydro

Using the criteria described above to project thermal output from affected electric generating units and after crediting for building blocks 3 and 4, the total energy then would be multiplied by the target rate to achieve a mass-based equivalent CO_2 emissions level. Of note, within the technical support document, the EPA does not mention crediting for already announced generation retirements or fuel conversions. The already-announced generation retirements within PJM accounted for nearly 50 million tons of CO_2 in 2012. All of the planned retirements are expected to occur in advance of the compliance period, and most were included in the goal computation. In addition, the projection of thermal output is very sensitive to the inputs in the model, namely fuel prices as well as assumptions about load growth. Also, resources within the PJM generation interconnection queue are not static, as historically there is a high drop-out rate for new interconnection requests. Variation in the aforementioned variables can cause different outcomes in the proxy mass limit calculated. Rather than using this approach, PJM used the November 6, 2014, EPA guidance on rate-to-mass conversion in the latest analysis evaluating the impacts to PJM load and generation of the Clean Power Plan.

On November 6, 2014, the EPA provided two alternative methods for states to perform the rate-to-mass conversion. The first method is intended to calculate a mass target for existing sources and does not account for incremental load growth; the second option includes new sources, assuming that all new load growth would be met by new sources. In PJM's latest analysis, the first option was studied. The rate-to-mass conversion is described by the following displacement equation:

Target CO_2 Rate x [Max (2012 Affected EGU MWh-Incremental Renewable Energy-Incremental Energy Efficiency-New Nuclear, 0)+Total Renewable Energy+5.8 percent Nuclear +Incremental Energy Efficiency]

For states within PJM, this equation can be reduced to the following: Target CO_2 Rate x [2012 Affected EGU MWh + 2012 Renewable Energy + 5.8 percent Nuclear]

The most significant difference from the June 2, 2014, guidance is the absence of crediting for incremental energy efficiency and renewable energy. Instead they are assumed to displace existing generation. The rate-to-mass conversion results are shown below for each of the PJM base-case[31] scenarios using the November 6, 2014, guidance versus the mass-target that would have been calculated using the projection procedure described in the June 2, 2014, technical support document.

[31] Base case – No re-dispatch to achieve compliance with the Clean Power Plan

Table 22. Rate-to-Mass Conversion – CO_2 Emission Target (Millions of Short Tons)

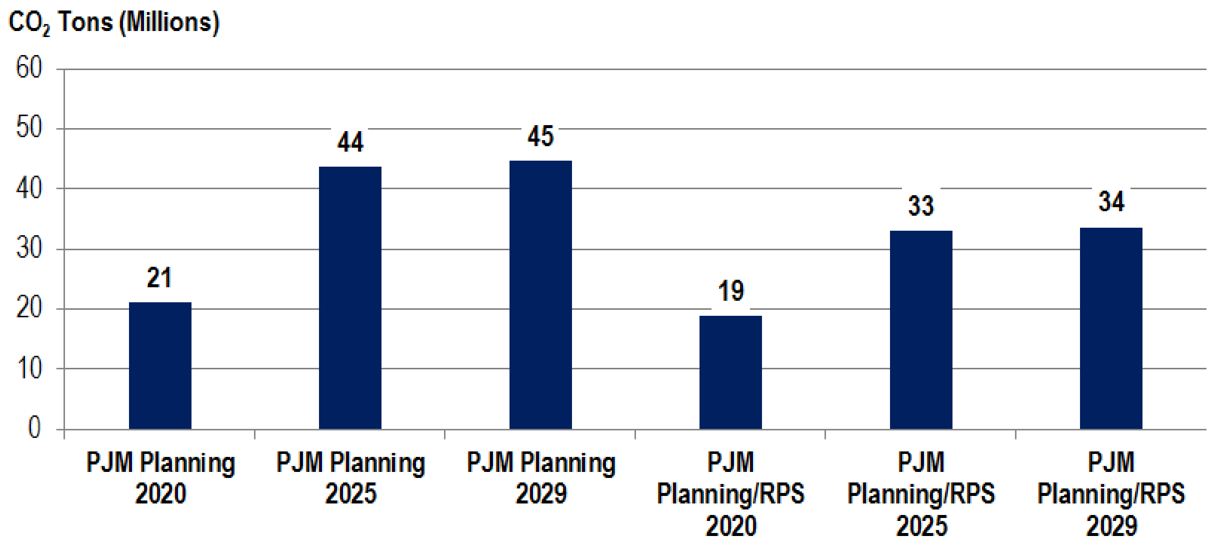
Scenario	2020	2025	2029
PJM Planning Model	378	356	329
PJM Planning Model Meet RPS	380	362	335
Nov 6 Rate-to-Mass Equation	387	354	327
Sensitivity Scenarios utilized in the evaluation of compliance with the Clean Power Plan			
OPSI 2a	378	363	337
OPSI 2b.1	378	360	334
OPSI 2b.2	378	361	333
OPSI 2b.3	393	369	341
OPSI 2b.4	442	416	386
PJM 1	371	355	337
PJM 2	377	357	323
PJM 3	377	356	325
PJM 4	370	352	327
PJM 5	378	357	326
PJM 6	386	355	331
PJM 7	404	362	326
PJM 8	407	366	331

PJM did not attempt to build a reference case that comported exactly with the method described in the June 2, 2014, technical support document. Of the scenarios simulated, the closest representation of a reference case is the PJM Planning Model and the variation of the Planning Model that meets the existing state-based RPS requirements. When enforcing compliance with the Clean Power Plan, PJM determined the CO_2 prices for each scenario within 1 percent of the regional target and 2.5 percent for each state under state-by-state compliance. Comparing the mass-target result from the November 6 rate-to-mass equation to the mass target result from projecting emissions in the PJM Planning Model, the largest difference is 9 million short tons in 2020, which is just over 2 percent. Because, in the simulation, natural gas prices are lowest in 2020, the economic impact of non-compliance is lower in 2020 than in later years. By 2025 and 2029, the two methods provided by the EPA yield nearly identical targets, as the difference shrinks to just 2 million tons.

The equation-based approach includes the output of the coal resources (operating in 2012) expected to either retire or convert to natural gas before the compliance period; the projection method has all of these resources either removed from the simulation or modified to reflect the conversion to natural gas. The resources slated to retire or to convert to gas-fired steam units before the start of the interim compliance period accounted for nearly 56 million CO_2

short tons[32]. Most of the expected retirements on a megawatt basis, were announced prior to the June 2, 2014, guidance for the Clean Power Plan and are associated with the MATS rule. Consistent with the criteria that "on-the-books" measures be excluded from the state plans, the EPA did not provide explicit credit for the MATS retirements in the rate compliance formulation. However, because of the rise in natural gas prices and load in the projection scenario relative to 2012, the remaining coal resources experience an increase in their output and their CO_2 emissions that is included in the June 2, 2014, rate-to-mass conversion. The figure below shows the difference in emissions between the PJM Planning Case and historic 2012 baseline emissions for resources burning coal as their primary fuel in 2012 that have note already submitted retirement notices.

Figure 89. Rise in CO_2 Emissions in PJM Planning Model Relative to 2012



Between 2020 through 2029, as natural gas prices rise relative to coal prices, existing coal resources serve both a larger share of the load growth and the unserved load created by already announced retirements. When the coal-natural gas price spread widens, the gap in emissions targets based on the two methodologies tightens. Therefore, using the projection method, an implicit credit is awarded for the announced retirements as a function of load growth and natural gas prices. While achieving the existing state RPS reduces the projection of coal output, the difference gets transferred into the credit awarded to renewables in the rate-compliance equation. These results depend heavily on the natural gas prices. If prices stay flat or decline, there would be no implied credit, and the June 2 methodology potentially would lead to significantly lower targets depending on the magnitude of combined-cycle natural gas resources added to the "reference case." Because the regional and state emission rate targets are lower than the emissions reductions from retiring coal, there is not a full credit; however, the target rate applied to the affected electric generating unit's energy (megawatt-hours) is the same whether using the projection method described in the June 2, 2014, technical support document or the displacement equation provided on November 6, 2014.

[32] Announced Resource Retirements accounted for nearly 50 million CO_2 short tons and resources expected to undergo fuel conversion accounted for another 5.9 million CO_2 short tons.

While some of the sensitivity scenarios above never would be considered a reference case, if states were to use the June 2, 2014, guidance, it may be difficult to ensure consistent interpretation of the rate-to-mass conversion. The results of the rate-to-mass conversions for the various sensitivity scenarios used for compliance modeling show that the assumptions built into the reference case will have an influence on the resulting mass target calculated. The variables that appear to have the most significant impact on the mass conversion are a change in the level of nuclear capacity by 50 percent (OPSI 2b.4) or an increase in the natural gas price of 50 percent. (A significant change in the available nuclear capacity would cause all lower-ranked resources in the dispatch to make up the energy difference.) The value of additional lower- or zero- emitting resources in displacing CO_2 emissions changes with the coal-natural gas price spread. Because of the range of drivers that can influence which units are generating and the level of emissions, states would face the risk that the mass-targets they include in their implementation plans would not be accepted by the EPA. For that reason, PJM utilized the rate-to-mass conversion guidance issued on November 6, 2014, for its simulations of the Clean Power Plan.