PJM Phase 1 Long-Term Economic Analysis of the EPA's Final Clean Power Plan Rule

Introduction and Purpose

On August 3, 2015, the U.S. Environmental Protection Agency released its final Clean Power Plan rule for reducing greenhouse gas emissions in the form of carbon dioxide from existing fossil-fueled electric generating units. On October 16, 2015, the Organization of PJM States, which represents state utility regulators in the region served by PJM Interconnection, requested that PJM analyze the potential economic impacts of the final rule. PJM will use the outputs from the economic analysis to examine any potential reliability impacts of the Clean Power Plan.

PJM's role in performing analysis on the final Clean Power Plan is as an independent source of expert electric power industry information. PJM's primary focus is on reliability and efficient and non-discriminatory markets; PJM is neutral concerning the fuel-type, age, size and technology used by resources to provide energy and reliability services. PJM does not advocate particular energy or environmental policies and is not forecasting market outcomes in this analysis. The outcomes of the scenarios/sensitivities are dependent upon the underlying assumptions and are designed to examine a potential state of the PJM market driven by fuel price assumptions, federal and state policy assumptions and resource capital costs.

In the analysis of the Proposed Clean Power Plan Rule, completed last year, PJM performed scenario-based analysis to understand the impacts of fuel prices and changes in the generation fuel mix due to compliance with some rate-based[1], but primarily mass-based[2], compliance paths. For the final rule, OPSI requested that PJM develop an economic baseline (reference case) representing PJM market outcomes absent the Clean Power Plan followed by evaluation of the various compliance pathways articulated by the EPA in the final rule. PJM adopted a modeling plan to conduct analysis of the compliance pathways in three phases.

The Phase 1 analysis is intended to develop potential regional resource mixes and market outcomes driven by the choice of compliance pathway. In the second and third phases of analysis, PJM will conduct more detailed operational analysis of the compliance pathways in discrete years and provide state specific results.

Executive Summary

PJM developed a comprehensive model representing markets for energy, capacity, renewable energy credits, and carbon dioxide in order to analyze the potential impacts of EPA's Clean Power Plan for the Organization of PJM States. Key observations from the modeling are:

- Trade-ready/regional compliance leads to lower compliance costs.
- Mass-based compliance provides more certainty in emissions levels than rate-based.

[1] A rate-based goal is measured in pounds of CO_2 per megawatt-hour. Rate-based compliance requires reporting low or zero-emitting source generation, and energy efficiency savings in addition to generation and stack CO_2 emissions from affected sources.
[2] A mass-based goal is measured in total short tons of CO_2 emissions. Under mass-based compliance, emission reductions are accounted for directly by reduced stack CO_2 emissions from affected sources.

- Rate-based compliance can lead to fewer retirements than mass-based compliance but is very sensitive to the level of output from zero-emitting resources that can be converted to emission rate credits.
- Rate-based compliance reduces wholesale energy market prices relative to mass-based compliance which can negatively impact zero-emitting resources.
- Because of PJM's regional economic operations, comparable resources in neighboring states can be dispatched independent of the chosen compliance pathway.
- Because of PJM's regional economic operations, interstate or intrastate trading of emissions allowances and credits affects wholesale prices only when they change the marginal resource in energy or capacity markets.

Compliance Modeling Approach

To more accurately model the Clean Power Plan, PJM captured the primary market-based revenue opportunities for generators. To do this, PJM developed a representation of the renewable energy credit markets (REC), emissions markets at a state or regional level, and a representation of PJM's Capacity Market on a regional basis. This facilitated the economic entry and exit of generation, which heavily influences compliance, specifically in the case of the Clean Power Plan, which, because of a lack of direct control options, is dependent on generation re-dispatch, generator retirements and new entry.

Mass-Based Compliance

Mass-based compliance results in an explicit cap on the emissions from affected sources. PJM's modeling reflects an auction framework in which generators are able to purchase allowances through either an intrastate or multi-state framework, depending on the compliance pathway being assessed. The clearing price in the model represents the marginal costs of abatement required to not exceed the emissions limitation and is in theory equivalent to the price that would result when emissions allowances are allocated to the generators. For additional information on the allowances available in the PJM region, see the EPA's technical support document on unit-level allowance allocations[3] by step compliance period.

In PJM, generators reflect the cost of allowances in their energy market bids. Thus, in general, mass-based compliance with the Clean Power Plan should lead to higher costs than a future without the Clean Power Plan. However, timing of new entry and different resources attracted to the market over a long horizon may reduce the differences in total costs.

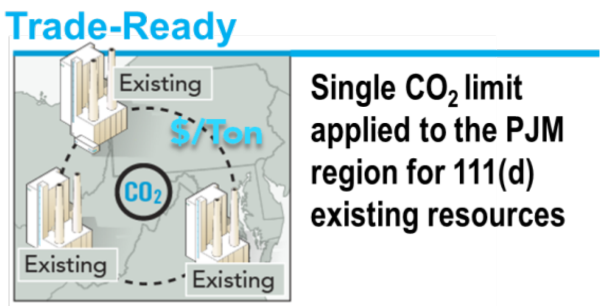
During Phase 1 of PJM's compliance analysis, PJM evaluated both the existing source targets and existing source targets with new source complement[4] for both intrastate and trade-ready[5] compliance. PJM's approach to modeling the mass-based compliance pathways is described below:

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

[4] The new source complements represent the EPA's estimated emissions from new sources needed to satisfy incremental electricity demand from 2012.

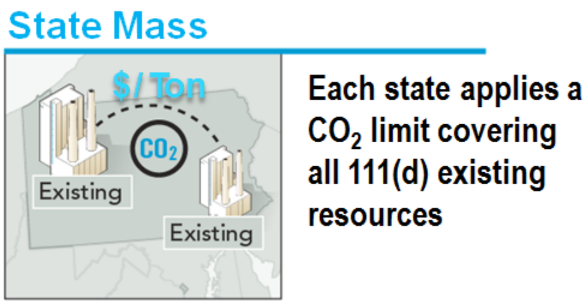
a. Trade-Ready Existing Source Emissions Limitation – *States enforce EPA's emissions limits on existing sources only.*

This option carries regulatory risks because it is not presumptively approvable by the EPA. The example shown on the right represents Trade-Ready or Regional Compliance in which allowance trading can occur across state lines.



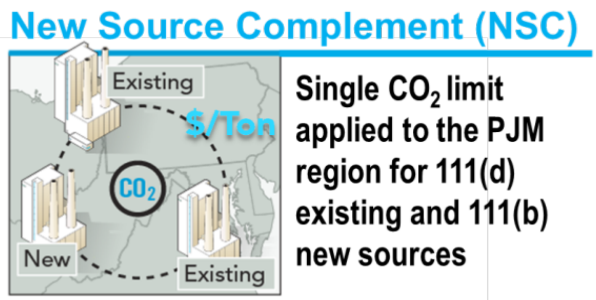
b. State Existing Source Emissions Limitation – *States enforce EPA's emissions limits on existing sources only.*

This option carries regulatory risks because it not presumptively approvable by the EPA. The example shown on the right represents intrastate compliance in which allowance trading is limited to each state's borders.



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

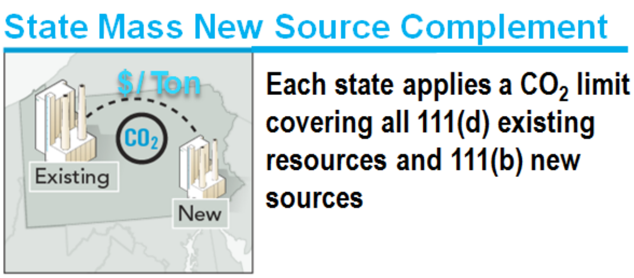
EPA developed this approach to prevent shifting of emissions from regulated to unregulated sources. This compliance pathway would be presumptively approvable for states that adopt it. PJM modeled this compliance pathway based on the mass goal adjustments provided in the EPA technical support document "New Source Complements to Mass Goals."[6]



[5] Sources in one state can trade with other affected sources in any other state implementing similar approaches (e.g., emissions-rate state with other emissions-rate states or mass-based state with other mass-based states) as long as those states meet certain minimum requirements, such as an EPA-approved or administered tracking system, and the state performance standard reflects the emission performance rates in the guidelines.

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

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



EPA developed this approach to prevent shifting of emissions from regulated to unregulated sources within states. This compliance pathway would be presumptively approvable for states that adopt it. While state enforcement of the New Source Complement reduces shifting of emissions from existing resources to new resources within the enforcing states, it does not prevent shifting to resources outside of the state.

Rate-Based Compliance Pathway

A rate-based compliance pathway utilizes emission rate credits (ERCs) as the tradeable commodity to help achieve compliance. ERCs are by default modeled within a market framework in which a clearing price is determined based on producers and buyers of ERCs. Consequently, there is not an explicit cap on emissions but an implied one based upon the total amount of ERCs supplied to the market during any compliance period. In other words, the supply must at-least match demand for ERCs but there is no cap on total emissions. Similar to mass-based compliance, the clearing price for ERCs reflects the level of additional revenue needed to comply, which in the case of this rule, is to incentivize re-dispatch to lower emitting resources or for economic entry of new resources.

Similar to mass-based, under rate-based compliance generators reflect the value of ERCs within their energy market offers. However, rate-based trading results in ERC producers reflecting a negative bid-adder in their energy market offer and buyers of ERCs reflecting a positive bid adder to recover their out-of-market costs. The negative bid-adder can result in lower wholesale energy costs when the affected resource is marginal. Similar to mass-based compliance, rate-based compliance leads to a different set of resources and timing for their entry relative to a future without the Clean Power Plan. Over a long-horizon, the longer-term benefits of adding these resources earlier may outweigh the higher short-term costs.

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

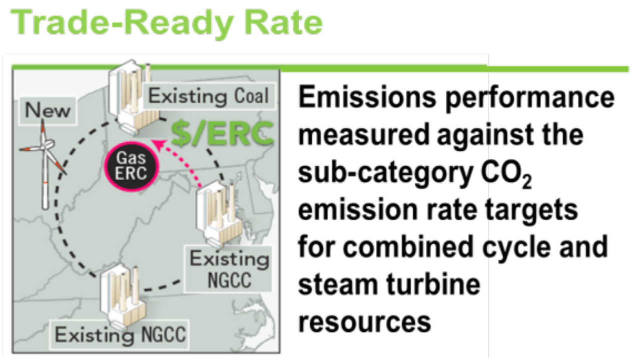
a. All Rate-Based Compliance Pathways

An advantage of state rate-based compliance over state mass-based compliance is that zero-emitting resources are able to apply for ERCs in states for which the resource is not physically located. The only limitation on selling renewable resources' ERCs is the requirement that ERCs produced in a mass-based state have a power purchase or similar agreement with the purchasing rate-based state. [7]To reduce modeling complexity, energy efficiency embedded in the load forecast was modeled

[7] Only renewable resources qualify for this exception in mass-based states.

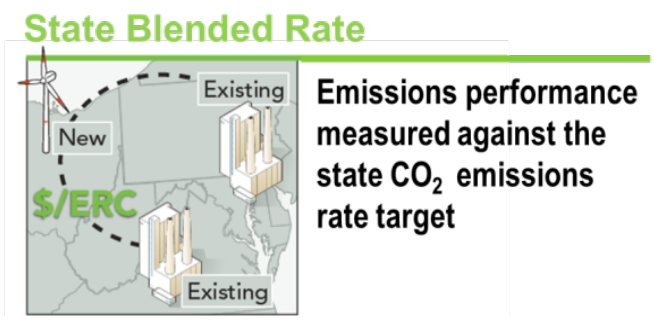
as a reduction in the demand for ERCs in the state(s) in which the load reductions occur. However, all other zero-emitting ERCs are able to be sold throughout the broader market region to resources in the state or region with the highest ERC price.

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



PJM studied the proposed method described in the federal plan[8], which balances demand for ERCs with two types of ERCs, gas-shift ERC produced by existing natural gas combined cycles and ERCs produced by all qualifying sources.[4] Covered thermal resources consume or produce ERCs based on the applicable combined-cycle natural gas rate target or fossil steam targets. PJM utilized the methodology described in the EPA's technical support document to assign a GS-ERC production rate to all covered natural gas combined cycles in the PJM footprint. Given the size of the PJM footprint, PJM did not model EPA's proposed limitation on combined-cycle gas units utilizing GS-ERCs for compliance. This assumption is reasonable for the PJM region given the level of coal demand for ERCs far exceeds the amount of GS-ERCs that can be produced, and once the ERCs are produced they have the same compliance value to fossil steam resources.

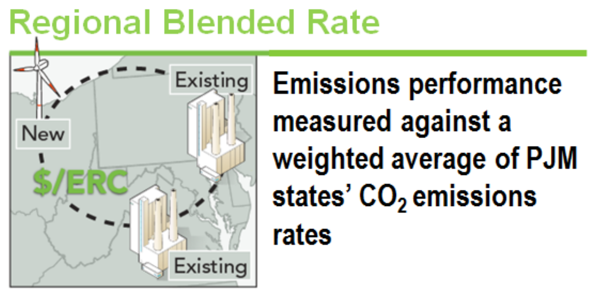
c. Blended Rate – Individual States enforce the weighted average rate target EPA calculated based on 2012 generation.



Thermal resources are able to produce or consume emissions rate credits, but are not able to sell emissions rate credits outside of the state. Under intrastate compliance, PJM's modeling enforced the geographic restriction on the sale of ERCs produced by thermal resources, but allowed these resources to buy ERCs from any zero-emitting resource in the footprint. The rate targets are defined in the EPA technical support document "Goal Computation Appendix"[9].

[8] Proposed Federal Plan, Section IV. Rate-Based Implementation Approach
[9] Data File: Goal Computation Appendix 1-5 (XLSX)
https://www.epa.gov/sites/production/files/2015-11/tsd-cpp-emission-performance-rate-goal-computation-appendix-1-5.xlsx

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



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

Key Takeaways from the Phase 1 Clean Power Plan Compliance Analysis

Mass-Based Versus Rate-Based Emissions Compliance

Because rate-based compliance does not result in an explicit cap on emissions, it is difficult to make direct "apples-to-apples" comparisons regarding effects on wholesale market energy and capacity prices, resources' entry and exit, and even compliance costs with mass-based trading programs since the environmental outcomes (emissions levels) can be quite different.

Any form of rate-based compliance has the potential to have CO_2 rebound effects when the rate targets stop declining but the supply of ERCs increases. Trade-ready rate-based compliance has a cost advantage over the other rate-based compliance methods because it only requires fossil steam turbine units to purchase ERCs based on emissions performance relative to the fossil steam target. The fossil steam target is a higher rate target than either the regional or state blended rate target. While natural gas combined cycle resources generate fewer credits against their own target, the gap in demand versus supply of ERCs is smaller than it is under the other rate-based compliance pathways for the PJM region.

Ultimately, total mass emissions rebound effects are present for all rate-based compliance methods because the goal is an emission rate, not total mass. This effect reduces retirements relative to mass-based compliance since the long-term trajectory of total mass emissions can rise as additional energy efficiency and/or renewable resources enter the market economically. Lower retirements and more zero-emitting resources in general implies higher investment and going-forward costs but lower production costs than mass-based compliance.

Energy Market Supply Curve

Regional Economic Dispatch Remains in Place for both State and Regional Compliance Pathways when a Price is the Mechanism for Achieving Compliance

Due to regional economic dispatch, economic substitution among resources can occur efficiently within and between states, and every generator in PJM is dispatched for the benefit of load in the region. Moreover, entry and exit of resources, regardless of location, provides resource adequacy for the entire region and a new set of options for dispatch in the regional energy market. Consequently, regional dispatch of resources in the Energy Market and the ability for entry and exit to occur based on the relative economics of resources effectively blurs the line between individual state compliance and broader regional compliance with the emissions targets. The reason for this is that state compliance can still exploit cost-effective redispatch and resource substitution opportunities in exactly the same way as would be the case in broader regional compliance schemes. Since the Clean Power Plan is premised almost exclusively on entry and exit and redispatch as the primary compliance options, the differences between state and regional compliance on price and cost impacts will be muted.

New Entry Combined Cycles Flatten the Energy Market Supply Curve

In most scenarios, fossil steam (mostly coal) resources that are retired are replaced by new combined-cycle gas resources . With this changing configuration of the generation resources regardless of state or regional compliance, the supply curve is much flatter, which means changing units at the margin results in little if any change in energy market prices. This phenomenon already exists in ISO-New England, without any consideration of the Clean Power Plan, as a large portion of the supply curve is comprised of combined-cycle gas resources.

In the Energy Market, as the relative costs of generators changes, substitution occurs within a state or across the broader region. When substitution occurs, it does not necessarily result in an increase in the price paid by load if the marginal resource on the system setting price does not change or if the cost of the marginal resource does not change. For example, if the next increment of load is 120 GW, but the substitution occurs for resources that are economic in the range of the first 50 – 119 GW of load, then there will be no impact on wholesale prices. However, if the substitution causes PJM to replace the generator serving the 120th increment of load (GW), then there will be an increase or decrease in wholesale prices if the replacement resource has different costs, or not change at all if the replacement resource has the same cost.

Flatness of the Supply Curve and Zero-emitting Resource Deployment

Given the assumed trajectory of natural gas prices and the simulated amount of economic combined-cycle new entry, the resulting PJM Energy Market supply curve is relatively flat over a large range of supply quantities. Consequently, the addition of zero-emitting resources into the market does not result in steep market price declines.

Energy Market Prices

Energy Market Prices under Intrastate Compliance Can Be Either Higher or Lower than Trade-Ready Compliance

In many years and on average over time, energy market prices for the entire region do not vary significantly for intrastate compliance than under regional compliance. This result may seem counterintuitive at first given that overall production costs are higher in the intra-state mass-based compliance pathway. However, an increase in overall production costs does not always mean that the cost of the marginal resources has changed.

Because intrastate compliance can lead to some states having a lower CO_2 price than the CO_2 price derived from interstate trade-ready compliance, the resulting market price can be lower when generators in less CO_2-constrained states set the market price. For the PJM model runs, many of the states that are less constrained on emissions have historically experienced higher wholesale prices due to congestion. If the marginal resource were located in a state with a higher state CO_2 price than the trade-ready price, then wholesale costs would increase for intrastate compliance. The economic stacking of resources within a broad region is based primarily on fuel price dynamics and unit operating characteristics.

Rate-based Trading Compliance Pathways Lead to Lower LMP Impacts than Mass-based Trading Compliance Pathways

The driver for this result is the manner in which ERCs used for rate-based compliance affect generator energy market offers. For low or zero-emitting resources, the ERC value reduces running costs, as it looks like a production incentive similar to the Production Tax Credit. In contrast, under mass-based compliance all regulated CO_2 emitting resources reflect a cost of CO_2 allowances in their energy market offers.

Rate-based Trading Price Effects under Scenario-based Analysis Versus Entry/Exit-based Analysis

In the proposed rule analysis, both rate-based compliance and mass-based compliance led to higher market prices than the reference model. However, under the final rule analysis, rate-based compliance leads to lower market prices than a future without the Clean Power Plan. This result is due to market-based entry and exit in the current model compared to the previous scenario-based analysis, which means that the generating resources were held constant for evaluation with and without enforcement of the Clean Power Plan. Rate-based compliance leads to more new entry of zero-emitting resources. Combined with the fact that thermal resources supplying emissions rate-credits can bid a lower energy market offer, energy market prices should be lower or at-least not increase during many hours in the year. Under the scenario-based analysis, the ERC price was due only to re-dispatch from higher emitting resources to lower-emitting resources, consequently the resulting market prices could increase relative to the reference model.

Combustion Turbines Not Regulated

The Clean Power Plan does not regulate combustion turbines. When energy prices are highest in the summer or winter period, combustion turbines operate the most. Whenever combustion turbines set market prices, the wholesale market-clearing price will not reflect the state's choice of compliance. Furthermore on a load-weighted basis, prices at peak, all else equal, are counted more heavily in this average than are off-peak or shoulder period prices. As a result, peak prices in the state or regional compliance framework should be approximately the same.

Economic Retirement Considerations

Zero-emitting Resources and the Amount of Coal Retirements

Under the Clean Power Plan renewable and energy-efficiency resources receive one emission rate credit for every MWh of production regardless of the level of CO_2 emitted from resources that they displace. ERCs provide an additional cash flow to these resources in much the same way as does the Production Tax Credit and the Investment Tax Credit. In addition to the utility-scale zero-emitting resources that enter the model economically, qualifying[10] energy efficiency and behind-the-meter solar resources embedded in the PJM Load Forecast earn ERCs.

[10] Must be deployed after 2012

The combination of zero-emitting options reduces coal retirements under a trade-ready approach by half versus mass-based compliance pathways. This result is very similar to the finding in the PJM Analysis of the Proposed Rule in which renewable resources and energy efficiency also reduced the amount of coal-fired capacity at risk for retirement. PJM found that the reduction in compliance costs was more significant than the reduction in net energy market revenues when zero-emitting resources were added to the system. Furthermore, rate-based compliance reduces economic incentives for natural gas combined cycle resources to enter the market. Less new-entry diminishes competition in the long-run between natural gas and coal resources, preserves coal resources' energy market revenues and thus lowers their retirement risk.

Differences in Coal Retirements for Intra-state versus Trade-ready Compliance

In the analysis of the proposed rule, the general result was that more generation would be at risk for retirement under state compliance than under regional compliance. This does not hold in the analysis of the final rule, which modeled the dynamics of new entry and exit. Instead, retirements are very dependent upon individual state emissions constraints and resource mixes.

For some states that are relatively less constrained on emissions, intrastate compliance reduces the compliance costs associated with net sales of allowances or ERCs to generators. Conversely, in states that are more emissions constrained, compliance costs associated with net purchases of allowances or ERCs increases compliance costs for generators. Consequently, interstate trade-ready compliance does not necessarily decrease or increase the retirement risks across the PJM footprint relative to intrastate compliance, but it may change the "distribution of resources" at risk for retirement. However, by imposing the same CO_2 price on all resources, interstate trade-ready compliance enables emissions reductions to come from the least efficient and/or highest-emitting resources in PJM. In states with more stringent CO_2 targets but relatively lower-cost coal resources, state compliance can lead to earlier retirements than would occur in an interstate trade-ready framework.

Compliance Cost

Trading Leads to Lower Combined Production, Going-forward and Investment Costs

Regardless of the rate-based or mass-based trading path, multi-state trading leads to lower overall costs than relying on more restrictive state-based trading regimes. Regional compliance provides the largest set of options for compliance, and any in-state restriction is bound to lead to fewer options and higher costs overall.

Trade-Ready Mass-based Compliance Leads to Lower Production Costs

Trade-ready mass-based compliance compared to intra-state mass-based compliance leads to production cost savings of about $356 million[11] per year. The overall cost results hold as well although there may be variances among going-forward or capital investment costs.

[11] Before adjustments for inflation

State Blended Rate Compared to Regional Blended Rate Compliance Leads to Lower Production Costs, but Higher Overall Costs

This result is not immediately intuitive. However, considering that state-rate-based compliance restricts ERCs produced from thermal resources to in-state trading, state-rate-based compliance creates additional demand for zero-emitting resources, which have fewer geographic boundaries[12] than do their fossil counterparts. As more zero-emitting resources are added to the system, the production costs decrease, but investment costs increase.

Secondary Takeaways from the Phase 1 Analysis

- Due to the extension of federal tax credits, renewable resources are developed earlier in the study horizon for both mass and rate-based compliance pathways. However, future participation in the Capacity Market may influence the timing and quantity of renewable investments in the PJM footprint. If these projects cannot achieve under-construction status before the federal tax credits either expire (i.e. Production Tax Credit) or sunset (i.e. Investment Tax Credit) or their costs do not maintain the current trajectory, rate-based compliance will appear much more expensive than the model results suggest.

- Mass-based compliance tends to provide greater market incentives than rate-based compliance for new natural gas with or without the new source complement because of higher wholesale market prices and no direct incentives provided to renewable resources.

- Provided distributed resources and energy efficiency embedded in the load forecast show up and are accounted for through state measurement and verification programs, PJM participants are able to avoid additional investments in new resources to generate ERCs and/or reduce emissions.

- Regulating new resources under the mass-based new source complement pathway results in the lowest CO_2 emissions but also increases wholesale electric costs relative to other compliance options. Higher compliance costs associated with more expensive allowances results in greater retirements for states adopting this compliance pathway regardless of the choice of intrastate or trade-ready compliance.

- Under the capacity market representation adopted for the simulation, resource adequacy is maintained under all compliance pathways.

Analysis Going Forward

Going forward, PJM will perform a short-term analysis evaluating all the Clean Power Plan compliance pathways for state and regional compliance. In the second and third phases of analysis, PJM will conduct more detailed operational analysis on the compliance pathways in discrete years and provide state-specific results. The analyses will include various sensitivity studies to better understand the Clean Power Plan's impacts on both the reliable and economic operation of the PJM power system. This analysis is expected to be completed in June 2016 and will be accompanied by a more detailed compliance assessment report.

[12] Only renewable resources in mass-based states can apply for emissions rate credits in rate-based states. A power purchase or similar agreement is required to provide evidence that the resource is not being double counted.

Appendix

PJM Entry/Exit Modeling

Generation entry/exit decisions are affected by many factors including public policy, regulations and market drivers such as fuel prices, demand growth, and technology costs and efficiencies. Most long-term modeling tools are designed to perform integrated resource planning-type analysis in a regulated, vertically integrated utility environment where a portfolio of assets is optimized to minimize overall costs, subject to reserve margin constraints.

As an independent entity and operator of wholesale power markets, it is inappropriate and unnecessary for PJM to perform integrated resource planning studies. However, in its role in providing reliability and non-discriminatory open access to transmission, PJM does study and coordinate resource retirements and new generation interconnection requests to participate in the PJM wholesale market. With over 60,000 megawatts of gas-fired generation, 15,000 MW of wind generation, and 3,600 MW of solar currently in the interconnection queue[13], performing an economic or reliability study can be challenging because of the probability of a significant amount of projects cancelling or delaying in-service dates. Moreover, future retirements are often unknown as the PJM Tariff only requires that resources provide a 90-day notice prior to deactivation. Therefore, when studying the future transmission needs of the system, PJM's planning process uses established criteria for deactivating existing resources, such as known deactivation notices, and including resources within the models based on "steel in the ground" and interconnection queue study status.

To evaluate a period longer than five years in a policy study exercise can be challenging because of the difficulty of determining which existing resources will retire and which new resources to add to maintain resource adequacy. The challenge lies in the uncertainty of which existing resources will eventually retire and which resources in the interconnection queue will eventually go into commercial operation as such decisions are related to future policies and market conditions.

To address these uncertainties from a competitive, wholesale market standpoint for the purposes of modeling, PJM utilized Plexos (R) Integrated Energy Model to perform a 20-year, simultaneous optimization of the energy market, capacity and renewable energy credit markets. While PJM does not administer the renewable energy credit markets, it was important to evaluate them within the simulation given they are key drivers of renewable interconnections and a key component of EPA's articulated "Best System of Emissions Reductions" in the final Clean Power Plan. There are other factors that will influence generation development including out-of-market bilateral contracts, but the energy market, capacity and renewable energy credit markets provide the primary market signals that drive utility-scale generation development within the PJM region.

[13] State of the Market Report, Table 12-5 Queue Capacity by LDA, control zone and fuel (MW): At December 31,2015 http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2015/2015-som-pjm-volume2-sec12.pdf

Energy Market

Like all optimization models, Plexos' objective is to minimize overall costs to serve energy. Because of the long-term study horizon, the approach to dispatching resources is different from chronological, security constrained unit commitment and economic dispatch approach applied in more detailed operational analysis, in which discrete study years are evaluated in daily or weekly steps.

For the longer term evaluated for PJM's entry/exit analysis, PJM is dispatching resources based on a load duration curve approach. This approach isolates segments of the annual load curve then economically stacks resources to serve the system's energy needs. Given PJM's size, and the number of resource decisions over the study horizon (2018-2037), this is a necessary simplification given current computing capabilities both at PJM and in the industry. PJM selected a minimum number of segments for all years to satisfy several objectives: (1) minimize the error in representing the hourly load shape, (2) produce similar market prices and dispatch as would be developed through chronological dispatch, and (3) reduce computational run time. Plexos does not perform resource aggregation or use "representative resources" to represent a class of resource types for existing or new resources. Each specific and unique resource is modeled and dispatched based on its own fuel, variable operations and maintenance, and emissions costs which can be location specific. As PJM continues to work through the remainder of the analysis – the evaluation of the compliance pathways – improvements to this approach may become apparent.

Capacity Market

PJM also is using Plexos to simultaneously clear the Reliability Pricing Model Capacity Market over 20 years using the same variable resource requirement curve parameters as used in the Reliability Pricing Model Base Residual Auction. This is a feature that PJM has worked with the vendor to develop specifically for PJM. In the model, the decision to enter or exit the market for thermal resources, is based on a long-term expectation of clearing the capacity market and earning enough revenues in the energy market to cover the variable production costs to produce energy plus going-forward costs inclusive of pre-specified hurdle rate of return on capital investment. New resources must also be able to cover their annual build costs based on a capital recovery factor. PJM recognizes that its member, generation-owning companies have different risk profiles, hurdle rates of return, and timing considerations for generation investment and retirement decisions. However, in the model, the near term viewpoint carries greater weight for all generators simply based on discounting future cash flows. At any time in the study horizon (2018-2037) resources can enter/exit the market. In the reference model, because there are no price or cost-based fluctuations due to new regulations or fuel prices, most of the unit retirements occur in the beginning of the study period, whereas new entry is volatile over the study horizon as a function of capacity and energy demand and prices.

Transmission

Transmission is a key factor in deciding to bring in new generation resources and also to retire them. Existing resources in constrained delivery areas can extend their economic and reliability value until new transmission is built. The period of time it takes to build new transmission upgrades can also bridge to a future in which fundamental market conditions are more favorable for their continued operation.

Transmission limitations are not represented in the 20-year model because PJM assumes that the Regional Transmission Planning process will mitigate them. Therefore, the additional energy market revenues earned due to providing relief of congested transmission facilities are not reflected. Conversely, congestion costs imposed on resources contributing to congested transmission facilities are not reflected.

Renewable Energy Credit Market

While PJM does not administer the trading markets for Renewable Energy Certificates, developing a modeling representation for these markets was fundamental to studying the state Renewable Energy Portfolio Standards. Some states (Maryland, District of Columbia, Delaware, New Jersey, Pennsylvania, Ohio and Illinois) have mandatory RPS targets enforceable through alternative compliance payment penalties. The alternative compliance payment effectively establishes a ceiling on the clearing price of RECs in those states.

Within the aforementioned states, there are also specific requirements for solar resources. Because of the requirements, PJM needed to study individual state Solar Renewable Energy Credit markets in addition to a single REC market in which all renewable portfolio standard qualifying resources can participate in trading. By having a state SREC price, the model will build solar resources in state. The SREC prices reported in the PJM reference case and sensitivities are therefore the weighted average prices of SRECs across all states with solar carve-outs.

The model assumes that it is not necessary to build non-solar resources within a state to meet a state's RPS requirement because of their broad geographic eligibility requirements. Therefore, the model assumes only a PJM-wide REC trading market to capture price signals. By assuming trading, the alternative compliance payments established by one state may not lead to a sudden change in the total renewable energy added to the system. The level of the alternative compliance penalties will impact resource investment decisions in the model because in some instances, it could be cheaper to pay the penalty than to invest in new resources. The price of RECs reported by PJM in the reference case and sensitivities is the PJM region-wide REC price based on the regional demand for RECs and varying levels of alternative compliance penalties.

PJM is modeling the economic fundamentals of renewable energy credit trading markets, but similar to its representation of the capacity market, PJM is not attempting to represent the various strategies that participants within REC markets may adopt which can create volatility and even decouple the link between investment and price signals.

Emissions Market

The PJM region includes all or parts of 13 states and the District of Columbia. While PJM's energy and capacity markets allow external participation today, the choice of compliance pathway states take could significantly influence the ability of resources in those states to participate within the PJM market. Consequently, PJM's modeling only represents energy and capacity resources that are physically within the PJM region. The size of the emissions market represented in the PJM analysis is also based on these resources. Depending on whether the region is evaluated for intrastate or interstate, trade-ready compliance, the modeling reflects one or multiple emissions markets.

From a modeling perspective, the key difference between interstate, trade-ready and intrastate compliance, is the generator's ability to trade allowances or credits with resources in other states. For both state-by-state and trade-ready, the model will identify the cost per ton of CO_2 or cost per ERC at which the emissions market(s) would clear while simultaneously clearing the energy, capacity markets and in sensitivity analysis REC markets.

Enforcing compliance via a CO_2 price in $/ton or $/ERC is the most efficient mechanism from an economic dispatch perspective. The regional economic dispatch model is clearing the market given complete information about the fuels, load, resource availability and resource operating characteristics. In practice, for states adopting intrastate compliance, it might be difficult to establish an in-state price that is effective in achieving the state targets.

Clean Power Plan in Historic Context

Since 1970 with the original Clean Air Act, emissions reduction policies have evolved from what are known as "command and control" policies toward "market-based" or emissions trading policies.

Command and Control

Command-and-control policies mandate that a specific control technology be installed or an emissions-rate standard be achieved. Such policies provide either no flexibility (installing a pre-determined technology) or limited flexibility because there is no possibility of looking outside the confines of the emissions source (e.g., the generation unit or plant) for more cost-effective reduction options. For reducing power plant emissions, command-and-control policies dominated the 1970 Clean Air Act and the 1977 Clean Air Act Amendments. More recently, the Mercury and Air Toxics Standards (MATS) issued in 2011 is a traditional command-and-control regulation mandating that generating units achieve the defined emissions rate standards whether they run for one hour or every hour of the year.

Market-based Options: Bubbles and Offsets

Market-based options evolved in some states from what were called "bubble and offset" programs in which some states, to comply with National Ambient Air Quality Standards (NAAQS), adopted an EPA idea to allow for marketable emission permits to allow for new emissions sources or expansion of existing sources in areas that were designated as being in "non-attainment" with the NAAQS. These programs work by allowing emissions sources to buy reductions from other sources in the same area (at lower cost) in order to keep emissions at a certain ambient level but effectively functioned as a cap on emissions in a local area.

Market-based Options: Cap and Trade

Market-based options expanded to the cap-and-trade programs with the 1990 Clean Air Act Amendments. The key programs are the Title IV Sulfur Dioxide Trading Program, the NO_x Budget Program, Clean Air Interstate Rule and, most recently, the Cross State Air Pollution Rule. All are cap-and-trade programs that provide flexibility and multiple options for resources to achieve overall emissions-reduction goals whether through changing resource dispatch, switching generation fuels, installing control technologies or buying/selling emissions allowances. Such flexibility leads to lower overall costs of compliance.

The Clean Power Plan: Elements of Trading and Command and Control

The Clean Power Plan is a blend of both a command-and-control and market-based mechanism for existing resources. Existing resources must achieve an emissions rate standard, which looks like a command-and-control mandate. Yet, EPA explicitly allows existing sources affected under this rule to buy emissions reduction credits (ERCs) from other lower emitting resources to achieve the standard because there is no emission control technology that could be installed that would allow affected generation resources to meet the standard and because fuel-switching options are limited.

In the alternative, states responsible for the rule could elect to convert the emission-rate standard into an emissions cap and implement the rule as a more traditional cap-and-trade program that the power industry has become familiar with over the past two decades.

The Clean Power Plan: Limited Options and Not All Emissions Sources are Included

Section 111(d) for existing sources does not regulate new natural gas combined-cycle gas facilities. The New Source Performance Standards, Section 111(b), already regulates these resources. Moreover, EPA has elected not to force combustion turbines (seen as peaking resources) into the program. The suite of available compliance options under the Clean Power Plan is more limited than the options for compliance available in previous programs. Unlike the cap-and-trade programs for sulfur dioxide and nitrogen oxides, there are limited fuel-switching options due to technology or infrastructure limitations and no post-combustion emission-control technologies that can be employed. The main driver of emissions reductions under the Clean Power Plan will be through the re-dispatch of the power system toward lower-emitting resources and/or the entry of low or zero-emitting resources along with retirement of higher-emitting resources.

Finally, another unique feature of the Clean Power Plan – relative to other market-based programs affecting the power industry – is the ability for states to choose different compliance pathways by which states can choose to comply in isolation or be part of a broader trading area for ERCs (under an emission rate standard) or allowances (under a mass-based standard). Intuitively, the broader is the trading area, the more options will be available for compliance and the lower the overall costs of compliance should be.

PJM's Work on the Clean Power Plan in the Context of the Academic Literature

The academic literature shows both theoretically and empirically that to achieve the same outcome market-based mechanisms for emissions reductions, in particular emission-trading regimes, are more cost-effective than command-and-control regimes. The increasing available options for environmental compliance should reduce the cost of compliance.

Known Distortions Affecting Emissions Trading Programs

In the context of the cap-and-trade programs for both sulfur dioxide and nitrogen oxides, state public utility commission cost recovery treatment of various compliance options, such as fuel switching, installation of controls and buying or selling allowances, potentially could distort the emissions-trading market distortions. The theoretical literature clearly showed how state utility regulation could bias these choices and lead to increased costs. Empirical literature confirmed this finding.

Later, with the advent of organized power markets and the move toward "deregulated generation," empirical work showed once again that generation resources operating in market environments were choosing lower-cost options relative to their regulated counterparts.

Other Interactions with Emissions Trading Not Yet Well Understood

However, the academic literature has not assessed the impact of individual state compliance versus broader regional compliance that has come up with the use of Section 111(d) as the mechanism to develop the Clean Power Plan. Work has started in this area, but it is more simulation work than theoretical empirical analysis. Intuitively, regional compliance should lead to lower cost since it provides more options for compliance than state level compliance. Also, most of the literature in this area, but for simulation work, has not considered broader regional dispatch of resources and how this interacts with emissions trading regimes. There is a hole in the literature that explicitly examines the impact of entry and exit on emissions compliance. To add to the complexity, entry and exit decisions are influenced by factors beyond the emissions trading program such as other "incentives" provides by subsidies in the form of tax credits, or other policies driving the deployment of renewable resources such as renewable portfolio standards. Finally, the Clean Power Plan poses a unique situation in which emissions sources that are part of the economic dispatch are not subject to the rule unless they are brought in by the states in their plans.