PJM Economic Analysis of Generation Retirement Potential due to the EPA's Clean Power Plan Proposal

Introduction and Purpose

On June 2, 2014 the U.S. Environmental Protection Agency released its proposed rule, known as the Clean Power Plan, 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 that PJM analyze some of the potential economic impacts of the proposed Clean Power Plan under a variety of scenarios. Outputs from the analysis include CO_2 prices and their corresponding impacts on energy market prices, load energy payment, and compliance costs. Furthermore, generator net energy market revenues and an assessment of fossil-steam generation at risk for retirement (primarily coal-fired, but also oil and gas-fired steam) based on net energy market revenues was also of interest. Finally, OPSI requested analysis of regional compliance options versus state-by-state compliance options under a limited set of scenarios and years.

In addition to the OPSI-requested scenarios, PJM supplemented the OPSI request with eight additional scenarios related to different assumptions regarding natural gas prices, available energy efficiency, renewable energy resources, and available new entry of renewable resources and natural gas combined cycle resources, plus an additional state-by-state compliance scenario and an emissions rate based compliance scenario. In total, between the OPSI-requested and additional PJM scenarios, there are 16 different assumption scenarios each run with and without the Clean Power Plan.

PJM is an independent source of expert electric power industry information. It does not advocate particular energy or environmental policies and is not forecasting market outcomes. The outcomes of the scenarios are dependent upon the underlying assumptions and are 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. Moreover, PJM's primary focus is on reliability, followed by the operation of efficient and non-discriminatory markets, in which PJM is neutral concerning resources, fuels, age, size, and technology subject to ensuring the primary reliability objective.

Along with responding to the OPSI request, PJM's economic analysis assesses coal, oil and gas steam generation "at risk" for retirement due to the proposed EPA 111(d) greenhouse gas rule and soon-to-be-finalized 111(b) New Source Performance Standards, and then uses this information as an input into transmission reliability studies. Determining a generating unit to be "at risk" does not mean that the resource actually will retire due to the proposed Clean Power Plan; however, the determination allows PJM to prepare for that possibility

The economic analysis discerns varying degrees of "at risk" generation by examining additional revenues required beyond net energy market revenues, expressed as a percentage of Net Cost of New Entry for both natural gas combustion turbines and natural gas combined cycle units. In other words, how much additional capacity market revenue would a generating unit need to go forward and remain in commercial operation? Levels of "at risk" generation will depend upon different assumptions regarding levels of energy efficiency, renewable energy, natural gas prices, nuclear unit retirements, and the level of emissions reductions that are to be achieved.

The identified units "at risk" for retirement will be studied by the PJM Planning Department to evaluate whether any transmission reliability criteria violations would result from their retirements and what transmission upgrades or additions would be necessary to ensure reliable operations going forward.

EPA's Proposed Rule

The proposed Clean Power Plan rule only applies to existing fossil-fueled generators, defined those in service or under construction as of January 8, 2014. The proposed Plan sets emissions rate standards expressed as pounds of CO_2 per megawatt-hour (lbs/MWh) for each state. 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 and combustion turbines under construction after January 8, 2014 are considered new resources and are not automatically subject to the proposed Clean Power Plan, but rather are subject to New Source Performance Standards under Section 111(b) of the Clean Air Act.

State-by-state compliance with an emissions rate standard, as proposed, is the default compliance metric as the states are individually responsible for developing compliance plans and implementing the Federal rule. However, the proposed Clean Power Plan left open the possibility that states could choose to convert the emissions rate standard to a mass-based standard, effectively converting lbs of CO_2 per MWh to total tons of CO_2, or to bring new units subject to the New Source Performance Standards into the 111(d) compliance plan to the extent they can help the state achieve the emissions rate standard. Moreover, the proposed Clean Power Plan allows states to work together to comply with the proposed Plan on a regional basis.

Compliance with the EPA's proposed Clean Power Plan is set to begin with interim goals beginning in 2020 with emissions rate targets declining over time until the final target is achieved by 2029. During the 2020-2029 period, states are allowed to average emissions during a "glide path" to full compliance, which implies the ability to "bank" earlier emissions reductions to be used in later years and/ or "borrow" reductions that must be repaid in later years of the "glide path." Final compliance is on a rolling three-year basis starting in 2030 when banking and borrowing effectively can take place during the three-year compliance period.

PJM Dispatch Modeling Methodology

PJM utilized PROMOD IV version 11.1 to conduct the analysis of the EPA's proposed Plan. PROMOD performs a security constrained economic dispatch based upon weekly security constrained unit commitment and hourly dispatch for user-defined chronological time periods. The granular dispatch enables more detailed and accurate unit representation, as well as representation of the transmission system on a nodal basis. Although emissions compliance under the policy is enforced over a multi-year horizon, the results from PROMOD can be used to determine hourly and seasonal electric energy/ancillary service market price trends, interchange patterns between different control regions, transmission congestion risks, emissions levels and to perform resource economic valuations. These results are sensitive to the fuel price forecasts used in the model, unit operating characteristics, as well as the power-flow model used to represent the transmission system.

For this analysis, PJM utilized a fuel forecast provided by Ventyx, an ABB Company, from their 2014 Spring NERC 9.7 data release. For the time-frame, 2020-2029, evaluated within the PJM analysis, Ventyx provides an independent annual economic price forecast for each coal resource, including commodity costs and transportation. On the gas side, the US 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. The gas market areas are defined based upon major natural gas pipeline/infrastructure serving the region. Each unit in the model is represented with a start-up fuel, and can also be modeled with secondary or tertiary fuel sources to enable fuel-switching.

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 within the compliance period. PROMOD is capable of dispatching the system based on unit bid and/or cost-based offers. For fossil resources, PROMOD provides the ability to 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 constraining which set of least-cost resources can be committed and/or dispatched within specific periods to serve load. For intermittent resources, hourly profiles were added to the model to represent monthly and daily variability. Because their variable cost is below all other resources, within both PROMOD and in PJM operations, they typically would not set price except during the lowest load hours when they could be curtailed for either economic or reliability reasons. The interaction of these intermittent resources with load is very important as the level of coincidence with the peak and even off-peak load determines the types of fossil resources displaced, energy market price impacts, as well as emissions levels measured over a Clean Power Plan compliance period.

PJM Modeling Methodology in the Context of the RTEP Process

Each year PJM develops the Regional Transmission Expansion Plan (RTEP) that looks five years out incorporating the most recent load forecasts, as well as expectations about future generation supply to identify transmission upgrades required to maintain deliverability of firm resources and zonal loads. The 2019 RTEP model was incorporated into PROMOD to facilitate running a security constrained economic dispatch simulation. By using PROMOD, complementary results can be obtained for use in further reliability analysis to determine transmission upgrades. Namely, flows on the transmission system can be evaluated hourly for binding transmission facilities and the economic cost (congestion) associated with mitigating overloads can be assessed. The ability to do this was important given the policy building blocks which include significant levels of renewable energy development and energy efficiency deployment, and most importantly re-dispatch from coal to natural gas in modeled scenarios.

PJM Clean Power Plan Modeling Approach

PJM, at OPSI's request, ran 5 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 glide path period. PJM also ran one of the 5 scenarios under a state-by-state, mass-based approach to provide a comparison under the same scenario assumptions between a regional and state-by-state approach, but only 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 states-of-the-industry that could occur for Clean Power Plan compliance and, by extension, provide a wider range of outcomes for the years 2020, 2025, and 2029. PJM then ran one of the eight scenarios under a state-by-state compliance approach to provide another comparison of state-by-state to a regional approach for the year 2020. PJM also took one of the eight scenarios and ran 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.

PJM performed limited state-by-state compliance and rate-based analyses due to the computational time associated with such complex analysis. PJM expresses no preference for how the policy should be implemented. 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.

Modeling Emissions Compliance

Regardless of whether compliance is on a regional or state-by-state basis, PJM modeled the full PJM region, operating the system by committing and dispatching the least-cost mix of resources to meet the PJM load requirement while satisfying the regional or individual state emissions mass or rate targets and ensuring reliability. 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 footprint to all resources in all states. State-by-state compliance modeling results in a CO_2 price for each state with affected resources (which includes12 states in the PJM Region).

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 mass or rate target. If that target was exceeded, then PJM determined a CO_2 emissions price (or 12 prices in a state-by-state run) to be applied to each fossil fuel-fired generator to 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. For each iteration, PJM determined whether or not the emission target was met. If emissions still exceeded the target, the CO_2 price would increase in the next iteration; 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% for regional cases.

In the case of a mass-based target, higher-emitting resources would face a larger increase in running costs than lower-emitting resources as the price on CO_2 emissions is treated exactly the same as a fuel cost from an energy market offer and dispatch perspective. For example, if the price of CO_2 is $20/ton, a coal unit that emits 2000 lbs/MWh (1 ton) will see its running cost increase by $20/MWh. In contrast, a combined cycle unit that emits 800 lbs/MWh (0.4 tons) will only see its running costs increase by $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 often, so that power demand can be met in all hours.

In the case of the regional emissions rate-based target analysis, PJM modeled the price of CO_2 emissions in resources' energy offers differently than that for the mass-based target analysis. For resources that have emissions rates below the target, the running cost reflected in the energy offer is reduced by the difference between the resource's emission rate and the target emissions rate. For example, suppose the target emissions rate is 1,200 lbs/MWh (0.6 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 reflected in the energy offer) of $4/MWh [(1200 – 800 lbs/MWh = 0.2 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 reflected in the energy offer) of $8/MWh [(2000 – 1200 lbs/MWh = 0.8tons) *$20/MWh].

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 Locational Marginal Prices.

Summary of PJM Simulation Results

The quantitative simulation results presented in the accompanying presentation must be viewed from the perspective that they reflect scenario assumptions on fuel prices, demand, renewable energy and energy efficiency penetration, new natural gas combined cycle entry, retention of nuclear resources, and the form of the compliance (state-by-state or regional and rate-based or mass-based).

Given the uncertainty about future market conditions, the form of the final rule, and the form of state compliance plans, it is best to focus on the qualitative results, which show the direction of wholesale power prices, units "at risk" for retirement, CO_2 prices, and similar metrics given the directional changes in some of the assumptions.

A summary of the key qualitative observations from the PJM simulation runs are as follows.

1. As mass-based emissions targets decline over time and/or natural gas prices increase:
    a. CO_2 prices rise because emissions become more restricted and the cost to re-dispatch resources to achieve the required emissions reductions increases
    b. Compliance costs in the form of increased production costs from re-dispatch increase because more and costlier re-dispatch to meet the emissions target is needed
    c. The megawatt value of capacity "at risk" for retirement incrementally increases over time. Not all potential coal, oil and gas steam unit retirements will happen at once. This observation follows from the idea that the decline over time of emissions rate- and mass-based targets lead to increasing CO_2 prices and, by extension, to increasingly more difficult financial positions for high-emitting resources.

2. Increasing energy efficiencyand renewable energy:
    a. Reduces CO_2 prices and compliance costs due to re-dispatch. In the extreme under a mass-based or rate-based approach, it is possible to add enough energy efficiency and renewable energy so that re-dispatch is not needed since there will be sufficient zero-emitting resources to avoid re-dispatch; and
    b. Results in fewer coal, oil, and gas steam megawatts "at-risk" for retirement. Although this seems counter-intuitive, under the proposed Clean Power Plan, more energy efficiency and renewable energy means lower CO_2 prices, which implies that the financial stress on higher emitting resources is reduced.

3. Excluding new resources subject to New Source Performance Standards under 111(b) from 111(d) compliance
    a) New natural gas combined cycle would have the same effect as renewable energy and energy efficiency from a compliance perspective under a mass-based approach. These resources appear to be zero-emitting from a compliance perspective and have the effect of reducing 111(d)-related re-dispatch compliance costs.

b) Under an emissions rate-based approach excluding new natural gas combined cycle may lead to higher CO_2 prices and compliance costs since these low-emitting resources could help reduce the emissions rate but are not available to do so
c) Results in higher capacity factors for new natural gas combined cycle relative to existing natural gas combined cycle under a mass-based approach since new natural gas combined cycle do not face a CO_2 price adder in energy market offers and running costs
d) Under an emission rate-based approach, existing natural gas combined cycle capacity factors are higher than new natural gas combined cycle capacity factors since the existing natural gas combined cycle receive a credit for being below the emissions target making them lower cost to run than new natural gas combined cycle.

4. Compared to regional compliance, state-by-state compliance results in
    a) Higher CO_2 prices on average and higher compliance costs as there are fewer low cost options for re-dispatch when states are restricted to resources within their state boundaries rather than on a region-wide basis; and
    b) An increase in the megawatts of capacity "at risk" for retirement, since higher-emitting resources will face higher CO_2 prices that result in greater challenges for earning revenues to cover their going forward costs.

5. Compared to mass-based compliance, emission rate-based compliance results in
    a) Higher CO_2 prices when new natural gas combined cycle resources subject to 111(b) are excluded because it requires more existing natural gas combined cycle re-dispatch to meet the emissions rate target; and
    b) Complicated interactions that make changes in coal, oil and gas steam megawatts "at-risk" for retirement less clear

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