Clean Power Plan Analysis
PJM Modeling Plan

PJM Interconnection
February 8, 2016

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Introduction

On Aug. 3, 2015, the U.S. Environmental Protection Agency (EPA) released its final Clean Power Plan (CPP) rule to regulate carbon dioxide (CO_2) emissions under section 111(d) of the Clean Air Act. The rule applies to existing and under-construction fossil resources satisfying EPA's eligibility criteria. Similar to the draft rule, the EPA developed what it considers to be the "best system of emissions reductions" to develop interim and final compliance rate-based performance standards to be achieved by states and/or affected generating units within those states. The EPA has also provided state-level mass targets intended to represent an equivalent amount of emissions reductions as anticipated under the rate-based standard.

Nationwide, the regulation intends to reduce total CO_2 emissions from eligible sources by 32 percent relative to 2005 levels. For the PJM region, by 2030 the regulation would result in a 36 percent decrease in CO_2 emissions from 2005 levels, and a 23 percent reduction from 2012 CO_2 emissions levels, the year for which the emissions baseline was established.

In addition to section 111(d) of the Clean Air Act, the EPA established performance standards for new, modified and reconstructed sources (new source performance standards) under section 111(b) of the Clean Air Act. The standards are based on emissions performance achievable by individual generating units. The combination of 111(d) and the standards will shift the way energy is produced and delivered within the PJM system, and influence future investments in generation sources. PJM's role as a regional transmission organization is to ensure cost-effective delivery of generation over the bulk transmission system. PJM does not engage in integrated resource planning but does have a responsibility to ensure operational reliability through its Day-Ahead and Real-Time Energy Markets, resource adequacy through the capacity market, and long-term transmission security through the Regional Transmission Expansion Plan (RTEP) process.

Similar to its analysis of the proposed rule, PJM plans to study various future states of the electric system to assess economic and reliability impacts. This initial analysis will not be used to inform specific transmission upgrades to be included a future Regional Transmission Expansion Plan, nor is it definitive on what resource owners and resource developers may do in the future. Rather, this analysis should be used to assess potential implications of various future states – to identify potential economic, operational, resource adequacy and transmission usage implications.

This modeling document is informed by input PJM received from the Organization of PJM States, Inc. (OPSI), [1] state environmental agencies, and interested stakeholders since its initial release in the fall of 2015.

PJM Economic and Reliability Modeling Framework

Reference Scenario (Starting Point)

For analysis of the final CPP regulation, PJM will develop a reference model as a starting point for evaluation of the CPP compliance scenarios. Since this model will simulate the PJM market both before and after the start of the compliance period, but assumes no compliance with the CPP, this model is intended for measurement of the CPP's incremental power system impacts.

[1] http://www.pjm.com/~/media/about-pjm/who-we-are/public-disclosures/20151019-opsi-letter-regarding-modeling-economic-impacts.ashx

The following describes the criteria PJM will use to develop its reference model

- PJM will utilize the Reliability Pricing Model Base Case for both its initial transmission and generation representation. This model is a look-ahead power flow and generation model used to develop the PJM capacity market's auction parameters. This model captures existing resources and resources with an executed interconnection service agreement[2] as of November 2016.

- PJM will also evaluate the historic commercial probability[3] of resources that have either achieved an Interconnection Service Agreement or executed a Facilities Study Agreement against the increased economic benefit created by the extension of the Federal Production and Investment Tax Credit to determine an initial renewable resource assumption in the 2019/2020 timeframe.

Compliance Scenarios

Each of the compliance pathways is likely to yield different economic and reliability results for the PJM region over the interim (2022-2029) and final (2030 and beyond) compliance periods. The key difference in compliance will be the choice of rate- or mass-based compliance and the level of trading at which states enable generators to engage.

Trading Ready within the PJM Analysis

PJM intends only to model energy and capacity resources that both participate in the PJM energy market and are located within a PJM state. The PJM region includes all or parts of 13 states and the District of Columbia. Therefore, PJM will evaluate trading ready similar to how it evaluated multi-state compliance under the proposed rule. PJM will assume that generating units purchase allowances or Emission Rate Credits (ERC) through a multi-state auction framework and will reflect the full cost of allowances or ERC value within their bid prices. Furthermore, PJM will model the ability to purchase allowances or credits from other states that choose a similar compliance pathway – mass-based or rate-based.

An annual emissions limit (mass-based) is enforced within the model to identify the costs per ton of CO_2 allowances. ERC can also be assumed to be traded within a market. The supply of ERC and/or Gas-Shift ERC must be greater than or equal to total demand for ERCs. PLEXOS will identify the cost per ton of CO_2 or cost per ERC value at which the market would clear while simultaneously clearing the energy and ancillary services markets for the PJM region.

PJM does not operate its market in isolation from other balancing authorities. Instead, every hour of the day PJM transacts energy with its neighbors subject to contractual agreements, transmission limitations and economic opportunity. Unlike electrical energy or fuels, emissions markets are not limited by any physical constraints; generators may be able to transact allowances or ERCs beyond the PJM region. Energy interchange within the PJM region is a fraction of total energy served within the RTO, and is not a significant driver of total emissions. In order to have a more detailed view on the operational and reliability impacts associated with the CPP within PJM, the analysis

[2] PJM's Interconnection Projects department will review the construction and permitting status of large thermal units to validate these units' inclusion in the model.

[3] For average commercial probabilities by interconnection queue study phase, see PJM's 2015 Reserve Requirement Study http://pjm.com/~/media/planning/res-adeq/2015-pjm-reserve-requirement-study.ashx

will not model other balancing regions. In future coordinated analyses, PJM will evaluate both energy market interchange and broader emissions trading.

Mass-Based Compliance

Mass-based compliance will be evaluated by enforcing demand for CO_2 allowances below the CO_2 limits imposed by the EPA. Each of the mass-based compliance scenarios will be studied for both intrastate and trade-ready compliance.

- *States enforce EPA's emissions limits on existing sources on new sources.* This is known as the New Source Complement approach and, according to EPA, would be presumptively approvable.
- States enforce EPA's emissions limits on existing sources and establish a production based set-aside for renewable energy and existing natural gas combined cycles. While the EPA has stated this approach would be presumptively approvable, the size of the set-asides is uncertain and will be informed by the model rule(s) when it is finalized. In EPA's regulatory impact assessment, the rate-based compliance and mass-based compliance scenario achieved the same total emissions. To assess the risks associated with this compliance pathway, PJM intends to limit total emissions from existing and new sources to the same level of emissions observed in the equivalent (trading or no trading) rate-based scenario – consistent with the observation of EPA's regulatory impact assessment results.
- *States enforce EPA's emissions limits on existing sources only*. This option carries regulatory risks because it is not presumptively approvable. However, because some PJM states' fuel mix is homogenous from a compliance perspective, and because of uncertainty in the size of the final set-asides, it is important to consider whether any states may achieve compliance with the targets without including the new source complement or set-asides.

Rate-Based Compliance Pathway

Rate-based compliance will be evaluated by enforcing the supply of ERC to be at-least equal to demand for ERC during the compliance period.

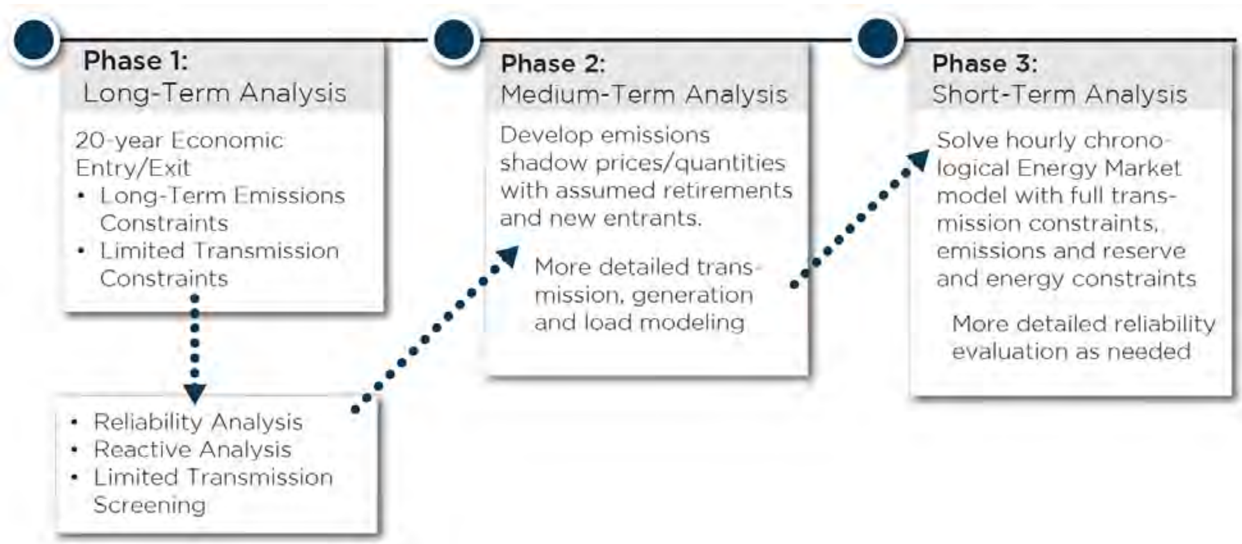
- *States enforce sub-category rate targets for fossil steam and natural gas combined cycle resources*. The EPA is still evaluating both the ERC allocation methodology for this compliance path and whether to maintain subcategory rates or a single uniform rate standard. PJM will study the proposed method, which balances two types of ERCs, Gas-Shift ERC produced by existing natural gas combined cycles and ERC produced/consumed by all qualifying sources.[4] PJM will study this option for trade-ready compliance only.
- Individual states or a group of states chooses to enforce the weighted average rate target EPA calculated based on 2012 generation. Generators cannot trade outside of the state or group of states when choosing this option. PJM will study the intrastate approach as well as the multi-state joint goal approach.

[4] The EPA defines the calculation method for Gas-Shift Emission Rate Credits in the proposed Federal Plan, and took comments during the comment period.

Approach to Evaluating Reference and Compliance Scenarios

PJM's modeling approach is designed to provide states with answers on how compliance with the CPP will drive market outcomes and the need for additional investment in the electric system. The analyses are being performed in phases to support a thorough evaluation of generation and transmission impacts. The approach illustrated in Figure 1 should not only synchronize the reliability and market analyses but also facilitate ease in comparing the various compliance pathways.

Figure 1. Compliance Pathway Evaluation Approach



Long-Term Modeling

This simulation will evaluate continued economic viability of existing resources and opportunities for entry of new resources. Using the reference scenario, PJM will run a 20-year economic entry/exit and resource adequacy assessment subject to the following objectives:

- Capacity and energy resources will enter the market when both short- and long-run market signals are sufficient to enable new entry.
- Over a long-term horizon, the model will determine whether the expected capacity and energy market revenues are sufficient to cover variable and going-forward (avoidable) costs of existing units. [5]
- Emissions limitations will be modeled based on the compliance periods provided in the final emissions guidelines (2022–2024, 2025-2027, 2028-2029, two-year compliance periods thereafter)

[5] PJM will not have the ability to perform the capacity emergency transfer limit (CETL) and capacity emergency transfer objective (CETO) analyses to support identification of constrained locational deliverability area regions (i.e., those regions as defined in the RPM capacity market) as part of a long-term generation entry/exit model. PJM is pursuing using a nodal representation for the long-term model construct, which will create locational pricing differentials for resources based on selected regional constraints.

Siting New Entrant Generators for Nodal Analysis

The economic entry/exit model will determine the level of new entrants and the type of resources entering or exiting the market. To maintain efficiency in modeling, but also to preserve the reasonableness of running a detailed Security Constrained Economic Dispatch model, PJM will add new entrants to the model according to the following criteria:

- PJM will assign locational cost factors to resources based upon PJM locational deliverability areas (LDA)
    - Within the LDA, PJM will initially use its interconnection queue in order of study status and network upgrade costs to identify nodal locations to site the resources.
    - When the queue is no longer sufficient, resources will be located within the LDA based upon the most viable interconnection locations according to limited generation deliverability analysis.
- Technical potential will be used to limit the concentration of resources within a specific state
- PJM will account for state policies/regulations/legislation[6] reasonably expected to influence specific technologies' market potential within individual states or across the PJM footprint.
- Nuclear resources that are not presently at an advance stage of the interconnection queue process (i.e., at the ISA stage) will not be allowed to enter the market during the interim compliance period and not before 2025.
- The Clean Air Act 111(b) new source performance standards require partial carbon capture and sequestration for even super-critical coal resources; consequently, we do not expect new coal resources to be economic, except in a high gas scenario.

Medium- and Short-Term Modeling

PJM will study both the reference model and compliance scenarios in 2023, 2026, 2028 and 2030 under security constrained economic dispatch in the following sequence:

1. The generation model resulting from the long-term analysis will be studied by PJM's Transmission Planning Department for reactive interface analysis and selected transmission flowgate screening analysis for either 2025 or 2026.
2. The generation model resulting from the long-term analysis will be passed to PLEXOS' mid-term analysis tool to refine the emissions prices, based on more detailed unit and transmission modeling. The main purpose of this model is to decompose annual or multi-year emissions constraints into discrete quantities for study in more detailed chronological simulation.
3. The resulting emissions limitations will next be passed to a security constrained economic dispatch engine, which will clear the ancillary services market and energy market for 8,760 simulation hours within each study year.

[6] E.g., Solar carve-outs in state renewable portfolio standards or specific resources identified in integrated resource plans for entry in a particular year

Both the medium- and short-term simulation will use the average emissions limitation for the three- and or two-year compliance period.[7] To not overstate transmission congestion in localized pockets of the system, in which less significant transmission upgrades would likely be constructed independent of the CPP, PJM will use discretion in the level of detail for transmission modeling in later years.

Key Expected Deliverables

The analyses results will include by state and/or RTO region for each simulation year:

- Carbon dioxide emissions by fuel and prime mover, and by regulatory status[8]
- ERC and gas-shift ERC produced and consumed
- Emissions allowance price,[9] ERC price, and gas shift ERC price[10]
- Locational marginal prices, and energy market load payments
- Aggregate facility level transmission congestion by voltage level
- Monthly peak hour wholesale electric sector natural gas demand
- Percentage of generation by prime mover and fuel type
- Generating capacity retired and added
- Fuel and variable operation and maintenance production cost
- Resource entry capital cost for replacement generation and load growth and for CPP compliance

Clean Power Plan Analysis Timeline

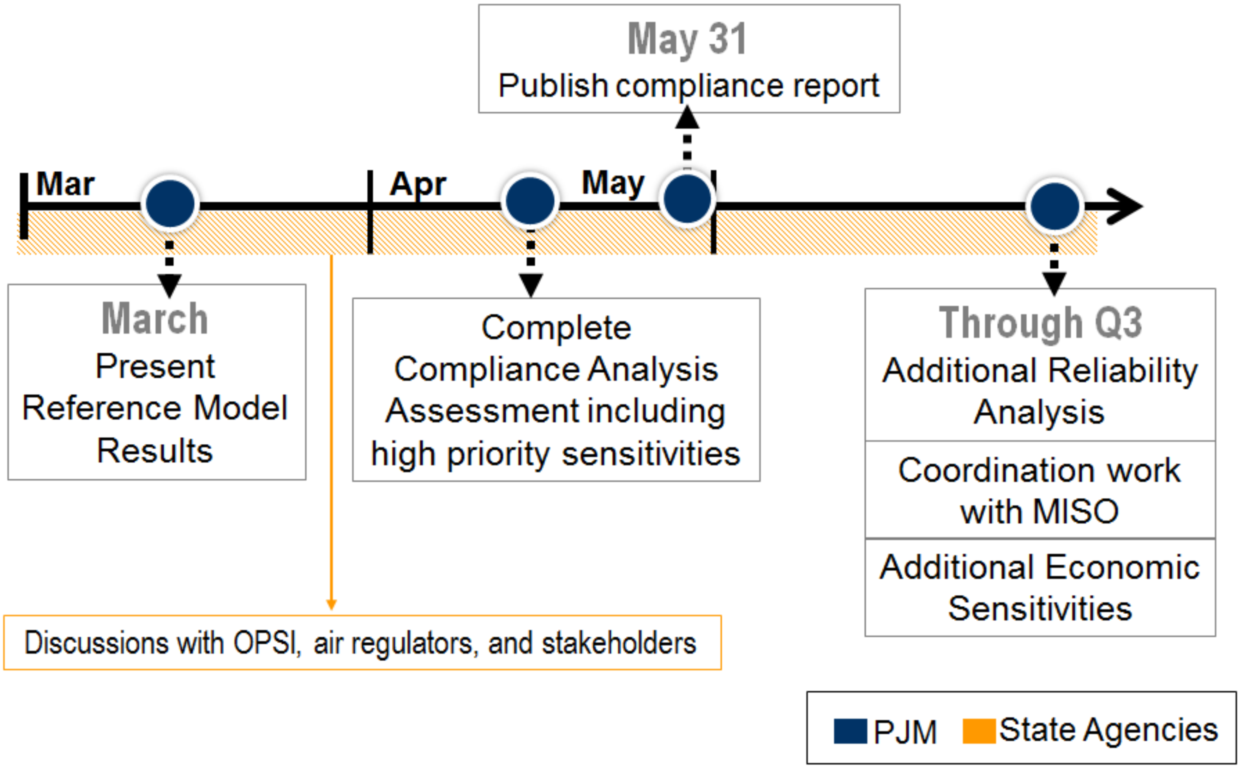
The economic and reliability analyses of the final rule should be completed in a timely fashion to be incorporated into compliance option discussions of state agencies, air regulators and members in the spring of 2016.

[7] Banking of CO_2 emissions is allowed under the final emissions guidelines, but will not be modeled in the analysis, except for excess allowances available in an earlier compliance period in which the emissions price is $0 per ton. Consistent with the final emissions guidelines for states, borrowing between compliance periods will not be modeled.

[8] 111(d) and 111(b) resource emissions will be identified separately.

[9] PJM recognizes that states can also directly allocate allowances to generating units, or could distribute potential auction market revenues. Assuming a liquid trading market, these options should lead to a similar market value for the allowances, but will affect the cash flows for individual generating units. PJM is not proposing to model the impacts of different allocation approaches in the main body of analysis PJM is proposing to complete in the spring of 2016, but should the states prioritize an analyses of different allocation approaches as a sensitivity and offer input into the allocation method, PJM will perform the analysis thereafter.

Figure 2. PJM Clean Power Plan Analysis Timeline



In order to accommodate state's data needs, PJM may provide preliminary results earlier than the dates described above. PJM's Compliance Pathways Assessment report will contain key observations and results from the final analyses.

Scenario and Sensitivity Analyses

PJM cautions that the results of simulations should not be viewed as forecasts for future electric market outcomes. To the contrary, PJM recognizes that future states of the electric system and upstream fuels markets may be different from the inputs assumed in PJM's reference model. PJM values both scenario and sensitivity analyses; such analyses recognize that markets are dynamic. The scenario and sensitivity analyses allow for the evaluation of uncertainty.

For the CPP analysis, key drivers of compliance results will be natural gas prices and state renewable portfolio standards. These have the potential to affect power sector-wide economic outcomes and incremental CPP compliance cost perhaps more than any other driver. Consequently, PJM will study each of the compliance pathways and the reference case with, and without the renewable portfolio standards and for a high and low natural gas price forecast.

Table 1. Planned Scenarios for Reference and Compliance Scenarios

Sensitivity	Implementation	Modeling Reasoning
Natural Gas Price Forecast	IHS CERA Monthly Gas Price Outlook and Fall 2016 ABB Natural Gas Price Forecast	These forecasts are significantly different and will change economic competitiveness of all resources in the model
Renewable Portfolio Standard	PJM will model a minimum requirement for renewable resource development within PJM. Utilities can comply or pay alternative compliance payments.	Will impact revenues earned by existing resources and lower overall production and allowance costs

PJM will conduct sensitivity analyses by exogenously changing key input assumptions while holding all other variables constant. PJM has sought input from OPSI and the state air regulators in prioritizing the sensitivity analyses in order to best support the states' consideration of compliance options. Based on the states' direction, PJM will evaluate the sensitivities upon completion of the initial compliance analysis studied under base model assumptions.

Table 2. Optional Sensitivities for Select Scenarios

Sensitivity	Implementation	Modeling Reasoning
Capital and Financing Costs Assumptions	Increase overnight capital costs and the costs of capital	Will impact ability of new resources to recover their long run investment costs
EPA Environmental Regulations	Enforce compliance with other environmental regulations by including environmental retrofit costs in resource fixed costs.	Increases revenue requirements for existing resources and makes new resource entry more attractive
Federal Incentives	Assume continuation of the Federal Production and Investment Tax Credit Programs.	Will lead to additional investment in renewable resources to support state Renewable Portfolio Standards
High-Load growth	Develop a high load forecast based on PJM's Load Forecasting parameters.[11]	A high load forecast will drive new entry to meet the reserve margin targets but also put pressure on existing resources to run more
Rate- and Mass-Based Standard	PJM will study some states as rate-based and others as mass-based within the same simulation.	To show interactions between resources dispatched within the same economic region, but that are located in states with different compliance strategies.

Sensitivity	Implementation	Modeling Reasoning
High Energy Efficiency or Low-Load Forecast	Apply EPA's projections for energy efficiency used in its Regulatory Impact Analysis	Lowers load growth, which in turn reduces compliance costs and reduces the need to add supply side resources
Nuclear Relicensing	A number of nuclear units must undergo re-licensing during the compliance period.	Nuclear resources provide base-load zero emissions energy. Retirements can affect compliance costs for the region as a whole.
Allowance Allocation	PJM will evaluate various allowance allocation strategies states potentially will take.	States may decide to allocate allowances as opposed to auctioning them, or they could choose to provide allowances to non-emitting resources.
Clean Energy Incentive Program	Matching credits provided to energy efficiency and qualifying renewable energy providers	May increase level of renewable and/or energy efficiency before the start of compliance

OPSI Special Modeling Requests

In practice, because states operating within the Regional Greenhouse Gas Initiative[12] are not electrically isolated from other states, the auctions may need to account for potential differences in CO_2 prices with the broader electric dispatch region. Disparate pricing can affect both generating units' economic competitiveness and their ability to achieve emissions reductions in response to the assumed clearing price. Specifically, the CO_2 allowance budget for Maryland and Delaware represents about 25 percent of their RGGI CO_2 base allowance budget in 2015.[13] Consequently, significant changes in allowance demand due to market prices in the PJM region can influence future RGGI auctions. As part of the initial compliance pathway assessment, OPSI requested that PJM study Maryland and Delaware only for mass-based compliance and applying the new source complement.

Mass-Based Trade-Ready Analysis

- The CO_2 allowance allocation within these states is tradeable and, thus has economic value to resources beyond Maryland and Delaware's border.
- The market-clearing price for CO_2 allowances will be the same for Maryland and Delaware and other Trade Ready states whose resources are dispatched within the model.
- New thermal resources and simple cycle combustion turbine resources located in Maryland and Delaware will include the CO_2 price determined by the analyses in their energy market bids, consistent with their treatment in the current RGGI framework.

[12] RGGI applies to CO_2 emitting units whose nameplate capacity is greater than 25 MW located in MD, DE, New York, and New England States.

[13] https://www.rggi.org/docs/CO2AuctionsTrackingOffsets/Allocation/2015_Allowance-Allocation.xls

Rate-Based Analysis and Mass-Based (Intrastate trading)

- PJM will study Maryland and Delaware's thermal resources with a RGGI CO_2 price forecast[14] in which the CPP is not enforced.
- Imposing a CO_2 price will affect generation dispatch throughout the PJM footprint, but may not limit the CO_2 emissions from resources in Maryland and Delaware to remain below the CPP or RGGI limits.
- When the 2016 RGGI program review results are available, PJM will update its results to include the updated RGGI forecast prices.

Power Flow Analyses – Scope and Procedure

According to EPA's final emissions guidelines, states must consider reliability implications when establishing standards of performance for compliance with the CPP. Consistent with Figure 1, PJM plans to perform reliability analyses on the various compliance pathways available to states. PJM's final rule analysis is based on a feedback loop between economic and reliability analyses.

The economic study results will provide the generation portfolios, including resource retirements and new entrants for study using the 2019/2020 Reliability Pricing Model Base Case. The purpose of the analysis is to compare transmission needs observed in a reference case or sensitivity case with and without the CPP.

PJM will perform load and generator deliverability analyses (See Appendix B: PJM Reliability Test Descriptions for more detail) focused on monitored facilities at 230 kV and higher in an effort to identify the broader regional implications of the final CPP. A cluster of conductor limit-based overloads into or within an area – as revealed by deliverability studies — would be indicative of a need for new transmission into the area. PJM will not attempt to identify reliability criteria violations below 230 kV, given the highly localized nature of the required upgrades in those instances.

In addition, studies will not focus on reliability criteria violations limited by terminal equipment. PJM's experience suggests that such limiting equipment could likely be upgraded within three years at nominal cost. By contrast, if larger scope upgrades — such as conductor replacements or new transmission lines — would be required, they would likely take more time to complete at much higher cost. The latter types of upgrades are of greater consequence in assessing whether a given compliance path will lead to reliability issues.

Consistent with PJM's established RTEP process, PJM will conduct studies to assess compliance with NERC and regional planning criteria. The RTEP process rigorously applies NERC Planning Standards through the application of a wide range of reliability analyses, including load and generation deliverability tests. PJM's methodology will include:

- Power flow case development for each scenario
- Identification of critical LDA to run based on the at-risk generation profile in each zone
- Capacity emergency transfer objective value calculations for identified critical zones

[14] ABB's NERC Fall 2015 Model RGGI price forecast

- Load deliverability study tests to determine capacity emergency transfer limit values for critical LDA
- A system-wide generator deliverability test for single contingencies and a common mode outage study test for tower contingencies.

RTEP analyses assess system compliance with the thermal, voltage (reactive), stability and short circuit standards specified by NERC and made mandatory by FERC.

Appendix A: Simulation Tool and Key Model Inputs

PJM will use Energy Exemplar's PLEXOS ® Integrated Energy Model (PLEXOS) to perform its analysis of both the reference model and CPP compliance scenarios. Compared to other commercial power systems analysis software, PLEXOS is an open platform that enables the user to develop customized constraints for co-optimization within unit commitment and dispatch.

After careful evaluation of simulation tools, PJM determined that PLEXOS provides the greatest capability to meet the specific modeling challenges for CPP analysis within reasonable timeframes. Below is a subset of PLEXOS capabilities that PJM plans to use for its analysis:

- Minimization of short- and long-run (20-year) capital, fixed, and production costs associated with generation, and transmission[15] investments
- Chronological dispatch of generating resources subject to transmission constraints (security constrained economic dispatch)
- Environmental limits analysis over long- and short-time horizons for simultaneous evaluation of rate (lb/MWh) and mass-based (tons) emissions limits
- Detailed hourly renewable generation modeling[16]

Table 3. Key Inputs to Economic and Reliability Analysis

Input	Primary Source for Data
Load Forecast	2016 PJM load forecast[17] – Energy Efficiency and behind-the-meter assumptions will be aggregated with renewables for ERC analysis
Transmission Model	Reliability Pricing Model Base Case for 2019/2020 auction – historic constrained flowgates and new transmission limitations based on screening analysis
Forecast Fuel Prices	ABB NERC Fall 2016 database and IHS CERA monthly natural gas briefing
Unit Capital and Fixed Operations and Maintenance Cost	National Renewable Energy Laboratory annual technology baseline supplemented with assumptions from the EIA, the PJM Tariff and EPA Base case v5.13
Unit-Level Operating Characteristics	ABB Simulation-Ready database[18]

15 The initial compliance analysis described in this document will not be used to evaluate transmission investment options.

17 http://www.pjm.com/~/media/documents/reports/2016-load-report.ashx

18 PJM will use Velocity Suite, internal data and SNL online datasets to review key unit operating parameters.

Input	Primary Source for Data
Unit Entry/Exit	PLEXOS ® will determine economic resources based on long-term optimization
Siting of New Entrants	PJM interconnection queue by study status, network upgrade and LDA region
Solar and Wind 8760 Shapes	National Renewable Energy Laboratory[19]

[19] NREL updated hourly shapes wind shapes based on the PJM Renewable Integration Study completed in 2013

Appendix B: PJM Reliability Test Descriptions

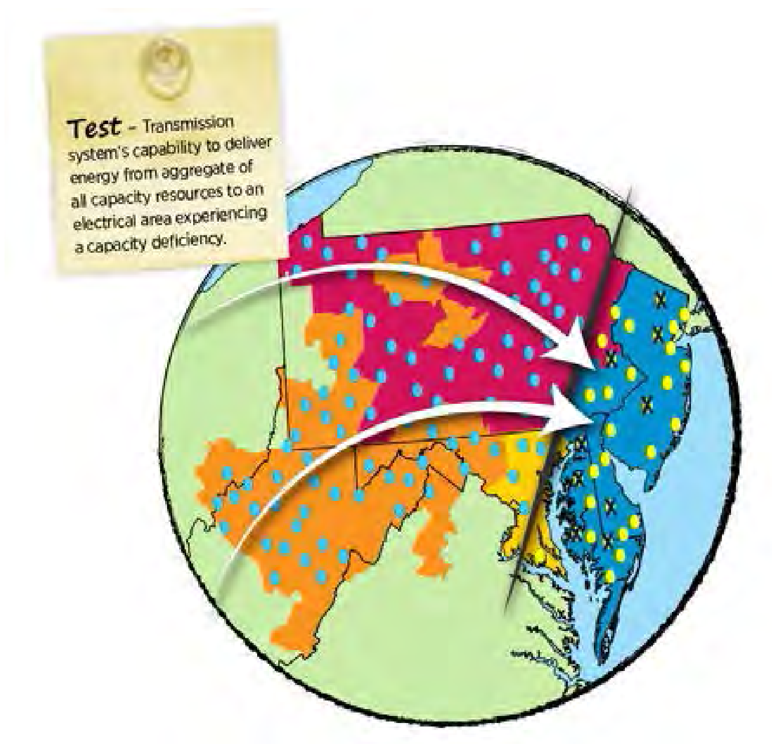
Load Deliverability Test

When an area cannot meet its load-serving requirement from internally generated power – whether an individual RPM capacity market locational deliverability area (LDA) or the PJM area as a whole – it must import power. Transmission lines become more heavily loaded to the degree that generation is removed from an area and not replaced with the same quantity megawatts at the same location. If either or both location and quantity differ from what was originally there, transmission flows are altered. That is essentially the nature of deliverability tests from a transmission planning perspective.

PJM's load deliverability test requires that the transmission system must be robust enough to deliver energy from an aggregate of all capacity resources to an LDA experiencing a capacity deficiency, shown conceptually in Figure 3. The test ensures that load inside an LDA can be served by generating resources outside that LDA. If sufficient generating capacity cannot be delivered to load as a result of one or more limiting transmission constraints, the LDA fails the load deliverability test. The methodology requires that each LDA under test be modeled at a higher than normal load level – 10 percent probability of occurring – with higher levels of unavailable generation than normal.

Load deliverability studies test the transmission system's capability to import sufficient energy to meet a defined capacity emergency transfer objective.

Figure 3. Load Deliverability Test Concept



The capacity emergency transfer objective (CETO) calculated for the load deliverability test is the import capability required for the area to meet a loss-of-load expectation risk level of one event in 25 years. The risk refers to the probability that an LDA would need to shed load due solely to its inability to import needed capacity assistance during a capacity emergency (i.e., the transmission system is not robust enough to import sufficient power during a capacity emergency). PJM calculates a CETO value for each of the LDAs using a realistic probable model of the load and capacity located within each LDA. The model recognizes, among other factors, historical load variability, load forecast error, generating unit maintenance requirements and generating unit forced outage rates. A number of factors drive CETO value increases, including the following:

- LDA peak load increase
- LDA capacity resource decreases including generation, demand resource programs and energy efficiency
- LDA capacity resources

CETO values calculated for the CPP analyses took into account the deactivation of at-risk generation within each LDA. Under PJM's RTEP process, load deliverability power flow analysis results identify the capacity emergency transfer limit (CETL) for each LDA. This value represents the maximum megawatts that an LDA can import under specified peak-load test conditions.

Transmission system topology changes, including the addition (or removal) of transmission facilities and changes in the load distribution profile within a zone, impact CETL levels, as do the addition and retirement of generation facilities. Each LDA is tested for its expected import capability up to established transmission facility limits, indicating how much an area can actually be expected to import. If the CETL value is less than CETO, the test fails, indicating the need for additional transmission capability. Transmission limits are defined in terms of facility thermal ratings and voltage limits.

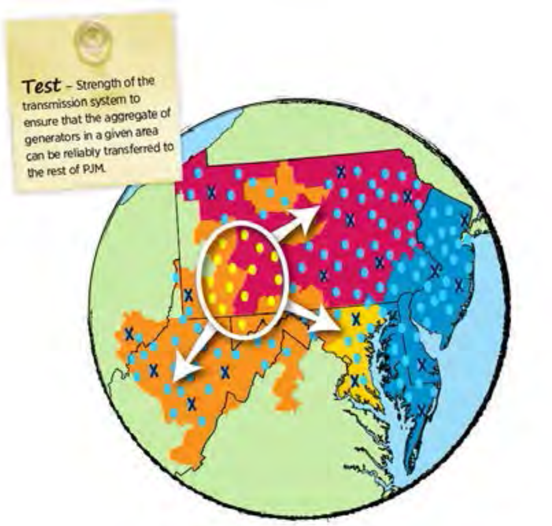
Figure 4. Locational Deliverability Areas

Generation Deliverability and Common Mode Analyses

Generator deliverability testing ensures that the transmission system will not limit delivery of capacity resources, so that generation is not “bottled” when needed. The test considers both the ramping impact of generators that are electrically close to a particular flowgate and the ramping impact of queued generation that is electrically further away. Generator deliverability testing ensures sufficient transmission capability to export generation capacity in excess of forecasted peak load from an area to the aggregate of PJM load. Specifically, the scope of generator deliverability tests the strength of the transmission system to ensure that the excess capacity of an aggregate of generators in a given area can be reliably transferred to the rest of PJM, as shown in Figure 5. Generator deliverability testing is used to assess Category A and B contingencies as part of baseline analysis, and as part of queued interconnection request studies.

PJM analysis also included Category C common mode contingencies. Common mode contingency studies determine the impact of losing multiple facilities that share a common element or system protection arrangement. These include bus faults, breaker failures, double circuit tower line outages and stuck breaker events.

Figure 5. Generation Deliverability Test



Transmission Limits

Transmission limits are defined in terms of facility thermal ratings and voltage limits. From a planning perspective, a thermal overload occurs on a bulk electric system facility if flow on that facility exceeds 100 percent of one of the following:

- The facility’s normal rating with all facilities in service (NERC Category A)
- The facility’s emergency rating following the loss of a single facility (NERC Category B)

Likewise, voltages are also monitored for compliance with existing voltage limits specified in terms of permissible bus voltage level and contingency voltage drop, as specified by PJM Operations. Consistent with deliverability studies for thermal criteria violations, PJM’s load deliverability testing methodology also evaluates compliance with reliability voltage criteria.