Carbon Price Senior Task Force
Base Case Review

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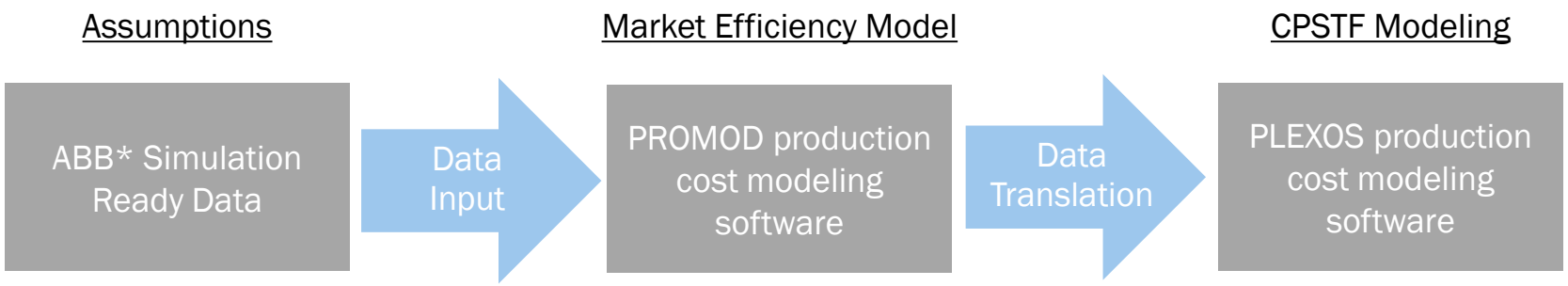
Summary

- Uneven carbon pricing results in emissions leakage. Leakage mitigation can improve the efficacy of carbon pricing programs
- Exelon reviewed several cases from the PJM modeling that were subsequently used to test the impact of leakage mitigation using PJM's one-way and two-way border adjustment methodology
- Exelon observed that certain model outputs appear inconsistent with observable market data and historical experience, suggesting shortcomings in the modeling that have important policy implications
- Exelon examined various model inputs and market data
  - Market Efficiency Case assumptions
  - Updated CPSTF assumptions
  - Historical and forward energy prices
  - Historical generation dispatch
- Exelon also examined several model outputs for consistency with expected results
  - Capacity factors by technology
  - Generation dispatch
  - Energy prices and price spreads
- There are apparent shortcomings in PJM's underlying modeling yielding outputs that do not align with market observations and undermine the leakage mitigation results PJM has presented
- We request that PJM review its model for errors and supplement the data available for stakeholders to review the PJM model and its inputs

PJM's modeling is not yet a valid way to evaluate the effectiveness of leakage mitigation

PJM's Market Model Development

- The foundation of the CPSTF modeling is the PJM Market Efficiency Case from 2018-2019
- The Market Efficiency Case is essentially a snapshot of the PJM transmission system. It is used in the RTO Regional Transmission Planning Process (RTEP) to identify the reliability and economic benefits of potential and planned transmission upgrades.



- Generating unit characteristics
- Fuel and emissions costs
- Load
- Transmission topology
- Power flow case (PJM changes the power flow case to make it more appropriate for RTEP Market Efficiency Evaluation)

- Simulates hourly commitment and dispatch of generation to meet load
- This is the information available to market participants with a PROMOD license, the wherewithal to work with the model, and certification to access sensitive data

- Has additional features and flexibility to support carbon price modeling
- Supports the border adjustment constraints used in the various scenarios
- CPSTF updated important inputs including but not limited to fuel prices, demand, and supply. These updates are not available to all market participants

Note: ABB is a data, analysis, and technology/software vendor

PJM began with Market Efficiency case, but changed both platform and inputs for the CPSTF

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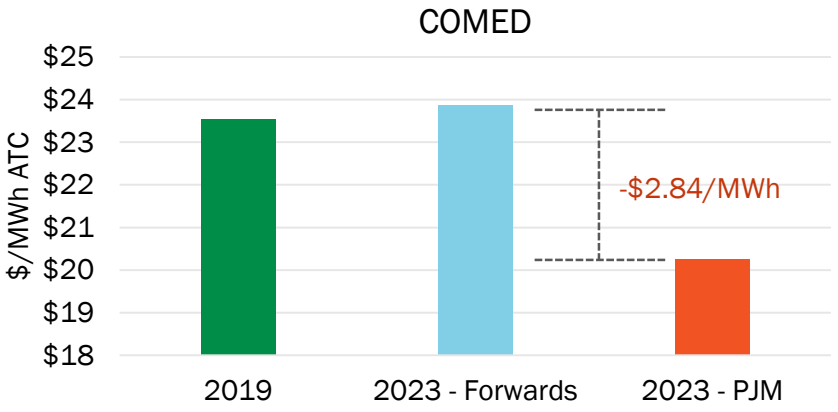
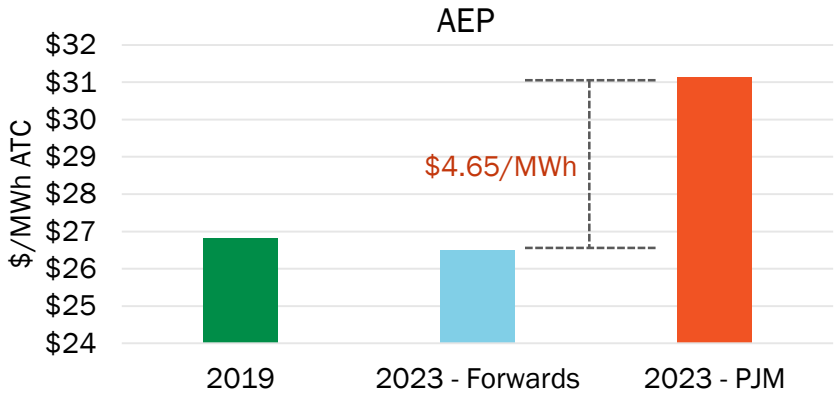
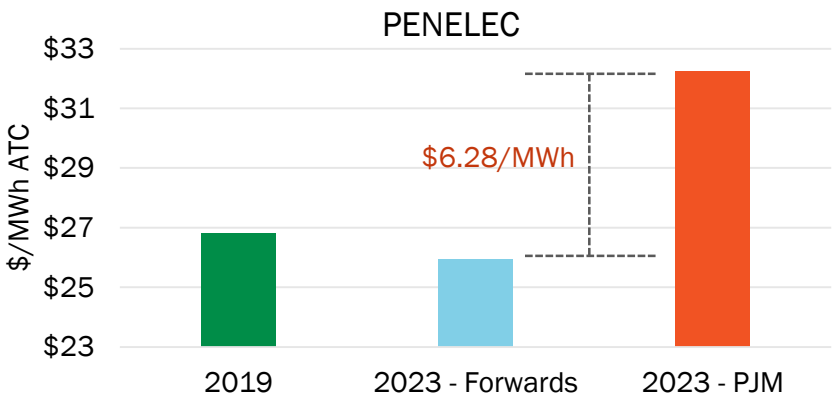
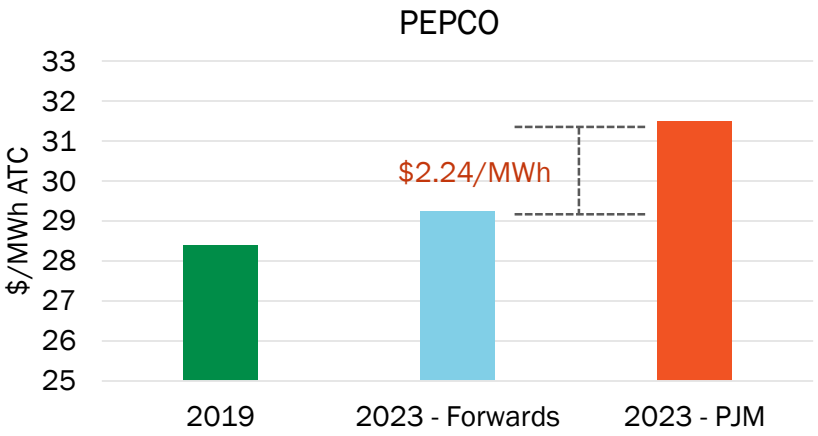
PJM's Power Price Outputs Vary Widely from Market Prices









Note: Forwards data from OTC Global Holdings. Values represent the average of 2023 forwards from 11/1/2019 until 10/1/2020, roughly the term of CPSTF workflow. PJM results are average monthly LMPs from scenario 4-0W.

PJM's model produces ComEd prices well below forward prices and eastern prices well above forward prices

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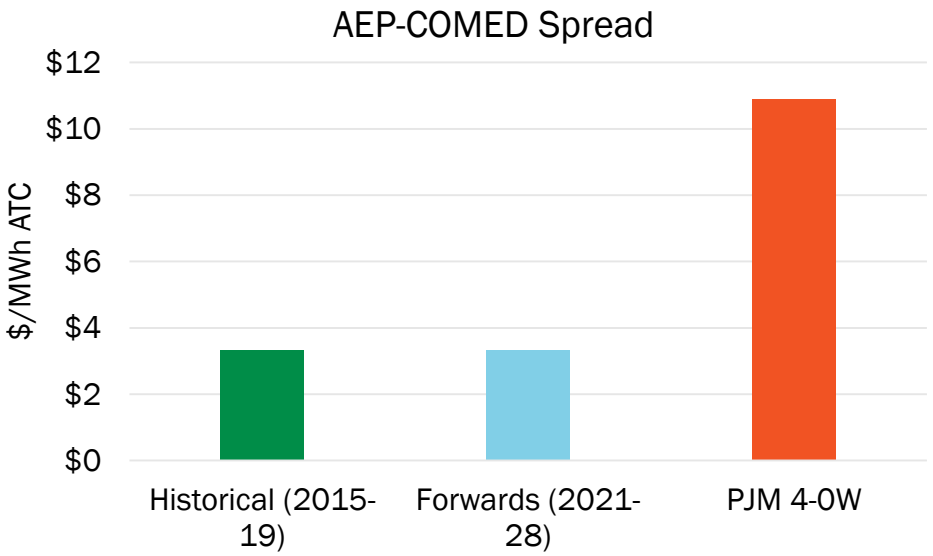
PJM's Model Yields an AEP-COMED Spread 3x Observed Values

- PJM's model produces price spreads of over $10/MWh, much greater than both historical and forward-looking spreads
- The outsized price spread between ComEd and the rest of the RTO in PJM's modeling suggests that ComEd fossil units will continue running and exporting to the east even with a carbon price added to dispatch costs
- If the model produced spreads consistent with observed values, ComEd fossil units would be less competitive after incorporating a carbon price.



Note: Historical values reflect annual average day-ahead prices. Forwards data from OTC Global Holdings; values represent the average of 2023 forwards from 11/1/2019 until 10/1/2020, roughly the term of CPSTF workflow.

Simplified Example

If IL has a $6 carbon price, an IL coal unit would have ~$6/MWh adder to its dispatch cost. Since the carbon adder is less than the spread to AEP, the unit might be dispatched to meet load in the east despite the carbon cost. However, in a model with a spread closer to historical levels, those coal units would not run economically, and the emissions impact of a carbon price in IL would be stronger.

Inaccurate price spreads mute the effect of a carbon price

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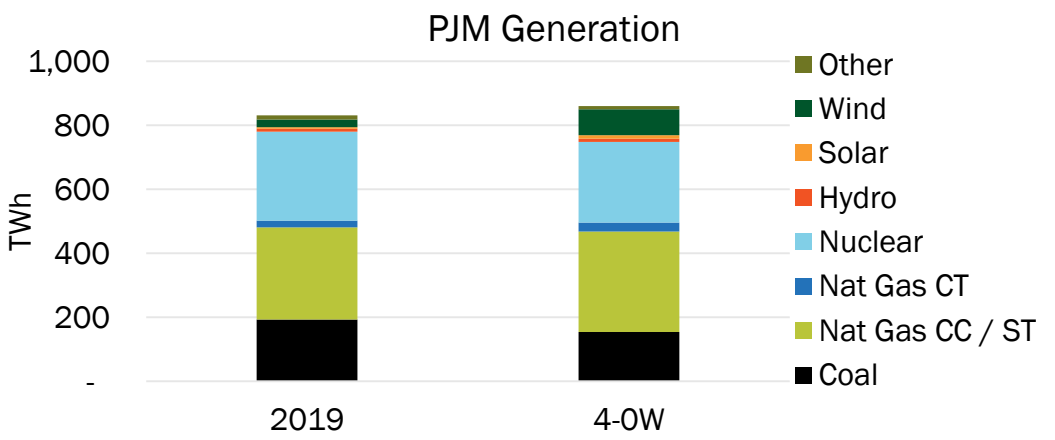
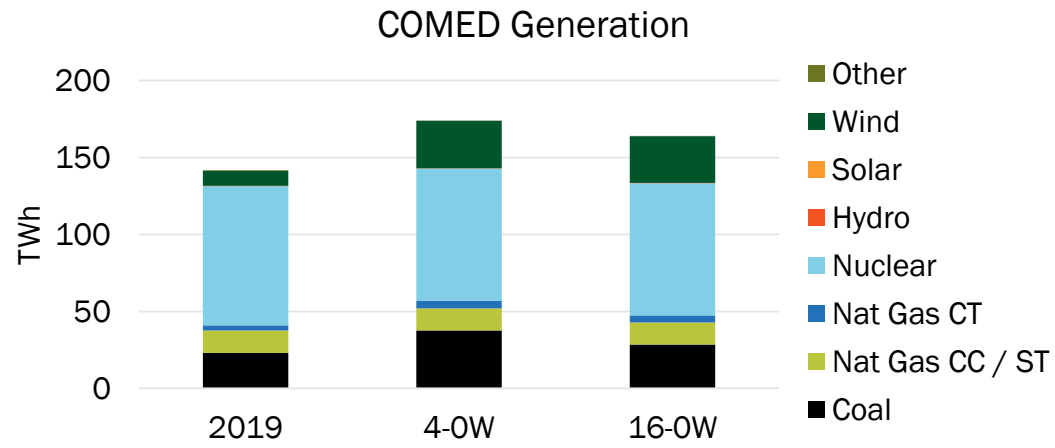
PJM's Model Yields Counterintuitive Generation Dispatch in IL

- Dispatch in PJM's modeling suggests Illinois generation output, especially coal, would *increase* relative to historical levels with a carbon adder
- Conversely, PJM's modeling shows RTO-wide generation outputs that are generally consistent with history
- The PJM modeling disparities occur even after updating the Market Efficiency Case stack assumptions, including coal retirements, new gas builds, and lower nuclear capacity



Note: 2019 generation data from EIA



Note: 2019 generation data from EIA

PJM modeling suggests that Illinois coal generation output would *increase* relative to recent history *even with a carbon price*

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PJM's Modeling Potentially Yields Inaccurate Capacity Factors

- PJM's input data and results suggest unachievable capacity factors for wind and solar
- Capacity factors are calculated using the total generation values reported for each scenario and the two versions of the total installed capacity information
  - Market Efficiency Case stack
  - Total PJM capacity figures included in the PLEXOS data supplement
- We do not believe these capacity factors, particularly the values for wind and solar, are representative of how these resources are actually modeled in PLEXOS, but we can't make more accurate calculations without more data and clear guidance on PLEXOS inputs.

PJM Annual Capacity Factor by Resource Type, Case 4-0W

Resource Type	Updated CPSTF Model Stack	Mkt. Efficiency Model Stack
Coal	33%	37%
Nat Gas CC / ST	58%	63%
Nat Gas CT	12%	13%
Nuclear*	100%	100%
Hydro	13%	14%
Solar	55%	92%
Wind	92%	109%
Other	12%	12%

*Nuclear capacity is quoted at different levels; the lower (~28GW) level is used here.

Takeaways

- Apparent shortcomings in PJM's modeling yield outputs that do not align with market observations
- The modeling done thus far should not form the basis of conclusions about that value of border adjustments or other policy options
- In other words, initial conclusions about various policy options, like PJM's one-way or two-way border adjustments, may be driven by modeling shortcomings rather than by the policy efficacy

An accurate and representative base case is necessary to analyze stakeholders' policy questions, including the degree of leakage in PJM and the benefits of various leakage mitigation options.

Next Steps

We request additional detail on PJM's PLEXOS model:

- What were the changes made to the model inputs during the translation from PROMOD to PLEXOS?
- What changes, if any, to the representation of external regions were made during the move from PROMOD to PLEXOS?
- We would expect the PROMOD Market Efficiency model results to roughly align with the results of a PLEXOS run using the same inputs and assumptions. Is this the case? If not, why?

We request additional data from CPSTF studies:

- Regional detail on capacity inputs: Capacity by type and by state, zone, and/or carbon region
- Transfer capability or limits in/out of PJM by zone, state, and/or carbon region, along with the interchange at the same borders
- Wind availability profile used in PLEXOS
- Average carbon impact on unit dispatch cost, by unit type
- Nuclear capacity: there appears to be a discrepancy between nuclear capacity extracted via published slides and "PJM Study of Carbon Pricing and Potential Leakage Mitigation Mechanisms" document (Carbon Assumptions – Stakeholder Version.docx)

We request additional model detail and data to better evaluate the existing CPSTF studies and that PJM review its modeling and report back to the CPSTF at its next meeting