Advancing Zero Emissions Objectives Through PJM’s Wholesale Electricity Markets

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PJM Interconnection
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PJM as Part of the Eastern Interconnection

Key Statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member companies</td>
<td>1,000+</td>
</tr>
<tr>
<td>Millions of people served</td>
<td>65</td>
</tr>
<tr>
<td>Peak load in megawatts</td>
<td>165,492</td>
</tr>
<tr>
<td>MW of generating capacity</td>
<td>176,569</td>
</tr>
<tr>
<td>Miles of transmission lines</td>
<td>82,546</td>
</tr>
<tr>
<td>2016 GWh of annual energy</td>
<td>792,314</td>
</tr>
<tr>
<td>Generation sources</td>
<td>1,304</td>
</tr>
<tr>
<td>Square miles of territory</td>
<td>243,417</td>
</tr>
<tr>
<td>States served</td>
<td>13 + DC</td>
</tr>
</tbody>
</table>

- 27% of generation in Eastern Interconnection
- 28% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection

As of 2/2017
Cleared Installed Capacity

- **Coal**
- **Gas**
- **Nuclear**
- **Renewables**

Delivery Year:
- Since 2007
- 2008/2009
- 2010/2011
- 2012/2013
- 2014/2015
- 2016/2017
- 2018/2019
- 2020/2021

*includes solar & wind at nameplate, hydro and wood
Harmonizing Public Policy & Market Design

Accommodate
Capacity Market Repricing

Advance
Carbon Pricing
Motivation

• Several states in the PJM footprint have a desire to subsidize supply resources to meet carbon-reduction initiatives (i.e. Illinois Zero Emission Credits)

• PJM believes market design can advance state policy initiatives and adapt to changing conditions to ensure the PJM region continues to reap the benefits of competitive markets
Carbon Pricing Overview

• A system-wide carbon price across PJM is the most efficient and cost effective implementation
  – Energy market is already designed to handle additional emissions costs through energy offers
  – When cost of emissions increase, largest emitters costs increase the most, they are dispatched less, and prices likely increase for non-emitters

• However, all states are unlikely to agree on a carbon-price
  – Second-best option is to implement a carbon-price for a subregion of PJM
RGGI vs. PJM Carbon Pricing Framework

**RGGI**
- Participating states issue allowances
- Allowances are pooled and auctioned quarterly
- Clearing prices set the “price for carbon”
- Costs may be included in resource offers
- “Price for carbon” may impact non-participating states
- Regional impact

**PJM Framework**
- Focused on reducing emissions through market-based incentives
- “Price for carbon” may be a tax or from a cap and trade mechanism (i.e. RGGI)
- Costs may be included in resource offers
- Price impacts predominantly limited to participating states
- Import MW carbon compliance costs accounted for in carbon price subregion
- Requires participating states to adopt the same carbon policy
- Similar to RGGI when applied across the entire footprint
Sub-regional Implementation Approaches

- Sub-regional implementation models CAISO approach

- Simpler, “One-pass” Approach
  - Resources inside carbon region submit offers including carbon costs
  - Resources outside carbon region submit two offers: one with and one without carbon costs
  - Single-pass optimization that includes carbon costs for resources outside the carbon region only when serving load inside the carbon region
One Pass Optimization

- **Non-Carbon Price Subregion**
  - LMP = $7/MWh
  - 50 MW

- **Carbon Price Subregion**
  - LMP = $15/MWh
  - LMP_{carbon} = $8/MWh
  - 100 MW

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### Power Plant Performance

<table>
<thead>
<tr>
<th>Type</th>
<th>EcoMax</th>
<th>Offer</th>
<th>Carbon Cost</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>100 MW</td>
<td>$7/MWh</td>
<td>$10/MWh</td>
<td>10 tons/MWh</td>
</tr>
<tr>
<td>Nuclear</td>
<td>100 MW</td>
<td>$0/MWh</td>
<td>$0/MWh</td>
<td>0 tons/MWh</td>
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<tr>
<td>Natural Gas</td>
<td>200 MW</td>
<td>$15/MWh</td>
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Second Potential Implementation Approach

- Two-pass approach
  - Same offers as one-pass approach
  - Solve first pass with no imports into carbon region
  - Fix resource outputs with respect to serving non-carbon region load
  - Only allow imports into carbon region from resources in non-carbon region in excess of first-pass output
What Does the Two-Pass Framework Do?

- Identify “base” dispatch for the non-carbon price subregion with no imports into the carbon price subregion
- Perform “final” dispatch allowing imports into the carbon price subregion
- Identify units in the non-carbon price subregion that are importing power to the carbon price subregion and the associated MW amounts
- Carbon component of the LMP is based on the marginal cost of carbon compliance to serve load in the carbon price subregion
Two-Node Subregion System Example

- **Non-Carbon Price Subregion**
  - 50 MW
  - EcoMax: 100 MW, Offer: $7/MWh, Carbon Cost: $10/MWh, Emissions: 10 tons/MWh

- **Carbon Price Subregion**
  - 100 MW
  - EcoMax: 100 MW, Offer: $0/MWh, Carbon Cost: $0/MWh, Emissions: 0 tons/MWh

- **Natural Gas**
  - 200 MW, Offer: $15/MWh, Emissions: 5 tons/MWh
Two Pass Optimization – Second Pass

Non-Carbon Price Subregion
LMP = $7/MWh

Carbon Price Subregion
LMP = $15/MWh
LMP_{carbon} = $8/MWh

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Ongoing Debate

- Concerns with two-pass approach
  - Discriminatory against non-carbon emitting resources in the non-carbon region
  - Incentives for non-emitting resources in the non-carbon region to offer above their actual cost to avoid dispatch in the first pass
  - Inefficient as overall transfers are not economically maximized
- Proposed alternative is to use the one-pass approach, but charge a carbon fee to imports into the carbon region equal to the difference between a hypothetical, single, marginal cost of carbon and the actual marginal cost of carbon in the carbon region
• Further investigation and modeling are needed to refine approaches, but state interest is required for PJM to undertake
  – Day-Ahead Market has additional complexity that may require minor modifications
• PJM welcomes discussion with interested states
  – PJM has met with interested entities from DE, MD, PA and VA
• Reaching a common policy will be difficult