PJM Generation Dispatch, Resource Mix, and Emissions

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PJM Interconnection

PA DEP Air Quality Technical Advisory Committee
Oct. 15, 2020
### Key Statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member companies</td>
<td>1,040+</td>
</tr>
<tr>
<td>Millions of people served</td>
<td>65</td>
</tr>
<tr>
<td>Peak load in megawatts</td>
<td>165,563</td>
</tr>
<tr>
<td>Megawatts of generating capacity</td>
<td>186,788</td>
</tr>
<tr>
<td>Miles of transmission lines</td>
<td>84,236</td>
</tr>
<tr>
<td>2019 gigawatt hours of annual energy</td>
<td>787,307</td>
</tr>
<tr>
<td>Generation sources</td>
<td>1,446</td>
</tr>
<tr>
<td>Square miles of territory</td>
<td>369,089</td>
</tr>
<tr>
<td>States served</td>
<td>13 + DC</td>
</tr>
</tbody>
</table>

- 27% of generation in Eastern Interconnection
- 26% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection

As of 2/2020
PJM – Primary Focus

1. Reliability
   - Grid operations
   - Supply/demand balance
   - Transmission monitoring

2. Market Operation
   - Energy
   - Capacity
   - Ancillary services

3. Regional Planning
   - 15-year outlook
Day-Ahead Energy Market Details

☑ Day-Ahead Market
  ✓ develop day-ahead schedule using least-cost security constrained unit commitment and security constrained economic dispatch programs that simultaneously optimize energy and reserves;
  ✓ calculate hourly LMPs for next Operating Day using generation offers, demand bids, and bilateral transaction schedules;

☑ Day-Ahead Market Settlement
  ✓ Based on scheduled hourly quantities and day-ahead hourly prices;
Real Time Market Operations Functions

• Support the Real-Time Market Clearing/Dispatch Engines
  – Security Constrained Economic Dispatch (SCED)
    • Intermediate Term – ITSCED
    • Real-Time – RTSCED
  – Ancillary Services Optimizer (ASO)

• Support the Locational Pricing Calculator Engine (LPC)
  – Calculates 5-minute clearing prices for energy, regulation, and reserves (then aggregates to hourly values)
  – Posts LMPs for more than 11,000 pricing nodes (including the Energy, Loss and Congestion components)

• Perform the daily real-time price verification process
  – Validate all prices prior to posting hourly Energy LMPs and Regulation and Reserve market clearing prices (MCPs)

• Support Market-to-Market coordination process with MISO and NYISO
  – Prices are exchanged with neighboring ISO/RTOs and used in our clearing engines.
**PJM Markets Timeline**

### 0800-1100
**Data Hand-off Ops. ➔ Mkts**
- **Ops. Technical Analysis**
  - 0800 - 1100

**Market Participant Bid/Offer Period**
- Before 1100
  - Market participants enter bids and offers.

### 1100-1330
**Data Hand-off Ops. ➔ Mkts**
- Day - Ahead Results Posted & Balancing
  - 1100 - 1330
- Process all the markets requests from day-ahead bids
- Post Day-Ahead Market results by 1330

### 1200-1415
**Data Hand-off Ops. ➔ Mkts**
- Re-bid Period
  - After day-ahead results are available -1415
  - Make adjustments based on the clearing results.

### 1415-2400
**Real-Time Operations and Monitoring**
- Balancing Market Bid Period Closes
  - 1415 - Midnight

**Commitments Second**
- Reliability analysis includes:
  - Updated offers
  - Unit availabilities
  - PJM load forecast info

**Supplemental**
- Reliability performed as needed
- Minimize start-up and cost to run

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ACE Graph
Generation Dispatch Operations

- Maintain System Control
  - Generation / Demand balance
- Maintain Adequate Reserves
  - Operate on contingency basis
- Implement Emergency Procedures
  - To keep the lights on!
- Synchronized Reserve/Regulation Market
  - Clear Market
  - Administer real-time optimization
Cleared Installed Capacity

MW Cleared Installed Capacity

- **Coal**
- **Gas**
- **Nuclear**
- **Renewables**
- **Demand Response**

*includes solar & wind at nameplate, hydro and wood*

Delivery Year

- 2007/2008
- 2009/2010
- 2011/2012
- 2013/2014
- 2015/2016
- 2017/2018
- 2019/2020
- 2021/2022

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Pennsylvania – Existing Installed Capacity
(CIRs – as of Dec. 31, 2019)

- Coal, 10,046 MW
- Natural Gas, 18,575 MW
- Wind, 188 MW
- Hydro, 2,408 MW
- Solar, 7 MW
- Oil, 4,160 MW
- Nuclear, 9,069 MW
- Waste, 252 MW

PA: 44,705 MW
Carbon Price Modeling – 2023 Generation Analysis

As the carbon price increases, generation:
- **Decreases** in carbon-price sub-region*
- **Increases** in the rest of the RTO

* There may also be shifts in generation within the carbon-price sub-region, as the carbon price is only applied to RGGI generators.

Legend:
- Other
- Wind & Solar
- Hydro
- Nuclear
- Natural Gas CT
- Natural Gas CC / Steam
- Coal

**Carbon-Price Sub-Region**
DE, MD, NJ, PA

**Rest of RTO**

<table>
<thead>
<tr>
<th>Case 1-0W</th>
<th>Case 8-0W</th>
<th>Case 9-0W</th>
<th>Case 1-0W</th>
<th>Case 8-0W</th>
<th>Case 9-0W</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 / ton</td>
<td>$6.87 / ton</td>
<td>$14.88 / ton</td>
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<td>$14.88 / ton</td>
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</tbody>
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Carbon Price Modeling - 2023 Total CO₂ Emissions

Generation shift from increasing carbon price results in CO₂:
- *Decrease* in carbon-price sub-region
- *Increase* in rest of RTO (no carbon price)
- *Net decrease* across the RTO

**Note:**
- Emissions are for PJM only and do not account for changes in external regions
- Shifts in RTO generation and external interchange between cases are driving changes in emissions
Carbon Price Modeling - 2023 Average Yearly LMPs*

On average, LMPs increase in both sub-regions with an increasing carbon price.

*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.
Carbon Price Modeling - 2023 RTO Generation and External Interchange

Total Generation Production (GWh)

Case 1-0W: $0 / ton
Case 8-0W: $6.87/ton
Case 9-0W: $14.88/ton

7,190 GWh decrease
17,266 GWh decrease

Net External Interchange (GWh)

Net Imports
Net Exports

Case 9-0W
Case 8-0W
Case 1-0W
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