PJM Market Efficiency Long Term Window Overview

September 2, 2016
Agenda

- Overall Objectives
- PJM Market Efficiency Roadmap
- PJM Market Efficiency Objectives & Model
- Market Efficiency Cycle
- Market Efficiency Work Flow
- Market Efficiency Process
- Future Discussion Topics
- Appendix – Numerical Example & References
Overall Objective

• Discuss PJM’s Market Efficiency Construct
  – Concepts
  – General Process for the long term window

• Discuss future education topics
Market Efficiency Goals and Model

• Goals
  – Assess future energy and capacity market congestion
  – Solicit and approve projects to relieve congestion
  – Strategic multi driver project development
    • Address both reliability and congestion
  – Accelerate beneficial reliability projects

• PJM Model
  – Sponsorship model
Market Efficiency Road Map

Inception of ME in RTEP

RTEP Drivers:
- Reliability
- Market Efficiency
- Operational Performance
- Public Policy

Order 1000

Reforms:
- Cost Allocation
- Non incumbent Development

1st Window

Impacts:
- Formal
- Competitive
- Long term
## Market Efficiency Cycle Timeline

**12 month**
- Acceleration

**24 month Cycle**
- Input assumptions
- Base case development
- Develop target congestion
- Proposal submission
- Evaluation
- Approval
# Market Efficiency Statistics

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Proposed Projects</th>
<th>Analyzed Projects</th>
<th>Approved Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to 14/15</td>
<td>25 projects (2010, 2011)</td>
<td>25+ projects (with combinations)</td>
<td>2010, 2011 – 1 project approved</td>
</tr>
<tr>
<td></td>
<td>17 projects (2012)</td>
<td>17 projects (2012)</td>
<td>2012 - No project approved</td>
</tr>
<tr>
<td></td>
<td>17 projects (2013)</td>
<td>17 projects (2013)</td>
<td>2013 – 1 project approved</td>
</tr>
<tr>
<td>2014/15 Window</td>
<td>93 projects</td>
<td>110+ projects (with combinations)</td>
<td>14 projects</td>
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<tr>
<td></td>
<td></td>
<td>2400+ PROMOD runs, 50,000+ runtime hrs.</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Prior to 14/15 includes projects from 2010 to 2013.
- 2014/15 Window includes projects from 2014 to 2015.
- 2010, 2011 – 1 project approved
- 2012 - No project approved
- 2013 – 1 project approved
- 2014 – 14 projects
- 2400+ PROMOD runs
- 50,000+ runtime hrs.
Market Efficiency Work Flow

- PROMOD NERC Data Annual Release
- RTEP Power Flow Update
- External Model Updates (MISO and others): load, gen, flowgates

1. Assumptions Analysis
2. Bus to Load Zone mapping
3. Flowgate model
4. ME Base Case
5. PJM Load Forecast Update
6. PJM Generation Queue Update
7. Reactive limits (PV Analysis)

- Analysis
- Re tooling
- Approval and Communication
Market Efficiency Analytical Software

**Inputs**
- Generation data
- Demand & energy
- Fuel forecasts
- Environmental costs
- Power flow case
- Monitored flowgates
- Other information: reserve requirement, market territory, etc.

**Outputs**
- Hourly LMP of buses and hubs, include energy, loss and congestion components
- Hourly unit generation and production cost
- Hourly binding constraints and shadow prices
- Hourly line flows
- Hourly company purchase/sale
- Environmental emissions
- Fuel consumption
# PROMOD SCED Simulation

- **Generation Expansion Plan (ISA/FSA)**
- **Intermittent resource hourly shapes**
- **Fuel Price Forecast:** Natural Gas, Coal, Oil-H, Oil-L
- **Emissions Price Forecast:** CO2 (National, RGGI), SO2, Nox (seasonal, annual)
- **Demand Forecast:** Annual Peak Load and Energy, Hourly shapes

# Market Efficiency Inputs – Overview Base Case Inputs

- **Demand Response Forecast**
- **Transmission Topology (As-Is, RTEP)**
- **Topology Mapping:** Bus-Area, BusLoad-Demand, Gen-Bus (As-Is, RTEP)
- **Reactive Interface PV Analysis**
- **Monitored lines and contingencies, interfaces and nomograms, PARs**

# Interregional Inputs

**MISO and NY Updates:** GenExp, load forecast, wind profiles, major upgrades, flowgates, transactions with SPP/MRO, imports Canada

**Pool Interaction Modeling:** M2M flowgates, pseudo-ties, DC schedules, hurdle rates, import/export limits, inactive pools

# Reporting Inputs

- **RTO Weighted Average Cost of Capital**
- **RTO Fixed Carrying Charge Rate**
- **ARR Source Sink Paths and Cleared MW**
- **Project Cost and ISD**
Market Efficiency – PJM Inputs

- Generation Modeling
- Load Forecast
- Fuel
- Emissions
- Transmission Topology
- Thermal and Reactive Flowgates
Market Efficiency Inputs – PJM Generation Modeling

- Forecasted generation includes
  - In-service generation
  - Active queue generation with Interconnection Service (ISA) and Facility Service (FSA) agreements
  - Expected future deactivations

- Modeled inputs:
  - Operational: summer/winter capacity, heat rate, min runtime/downtime, must run status, emission rates
  - Cost: startup cost, variable O&M, curtailment price
Market Efficiency Inputs – PJM Load Forecast

- **PJM Load Forecast Report**
  - Peak Load and Annual Energy adjusted by Energy Efficiency cleared in RPM Auction
  - Load forecast mapped to PROMOD Areas

- **ABB synthetic demand shapes**
  - Based on the average of several years of load shapes
  - Hourly load shapes merged to match PJM load zones

- **Demand Response**
  - Modeled as discrete units
  - Amount based on the level cleared in the RPM BRA auction
Market Efficiency Inputs – PJM Fuel Forecast

• Forecast prices developed by the ABB fuels group
  – Gas and Oil
    • Prices derived from NYMEX and the EIA Annual Energy Forecast.
  – ABB’s coal forecasting model:
    • Mining costs, emission price forecasts, transportation routes and pricing, coal quality

• PJM checks
  – Fuel to Unit mapping
  – Primary and Start-up fuel mapping
Market Efficiency Inputs - Emissions Forecast

• Emissions prices developed by ABB
  – Three major effluents modeled: SO2, NOx, and CO2.
  – Effluents (by trading program) assigned to generators based on location and release rates
  – Sources:
    • EPA CEMS data.
    • ABB’s proprietary Emission Forecast Model (EFM).

• PJM checks
  – Consistency with expected emissions legislation affecting PJM Generators
  – Mapping of generating units to emissions price
  – Validate installation of emissions reduction equipment and removal rates for generating units (if necessary)
Market Efficiency Inputs - Transmission Topology

• Same topology used for all study years
• RTEP system topology
  – All approved baseline upgrades
  – All FSA network and direct interconnection upgrades
• External world topology
  – Derived from Eastern Interconnection Reliability Assessment Group (ERAG) Multi-Regional Modeling Working Group (MMWG) Series
Market Efficiency Inputs - Flowgates

• Thermal Flowgates
  – Historical market constraints
  – NERC Book of Flow-gates
  – Removed constraints with very low likelihood of binding in any future year simulation
  – Added constraints with increasing likelihood of binding

• Transmission Ratings Modeling
  – Summer 95 degree day-time rating for Normal and Long-term Emergency
  – Winter 32 degree day-time rating for Normal and Long-term Emergency

• Reactive Limits
  – PV Analysis to develop summer and winter MW transfer limits for commercially significant interfaces in PJM
  – Modeled interfaces: AEP-DOM, AP South, BCPEP, Black Oak Bedington, 5004/5005, Central Interface, Cleveland, COMED, Eastern Interface, Western Interface
Market Efficiency Process – Congestion Drivers

- PROMOD simulations will be analyzed for congestion drivers

- PJM solicits projects for congestion drivers
Market Efficiency Process – Proposal Analysis

• Each valid proposal is tested for Benefits/Cost >1.25
  – Total Benefits = Energy Benefits + RPM Benefits
  – Energy Benefits
    • Regional Projects: 50% Change in Production Costs + 50% Change in Net Load Payments*
    • Lower Voltage Projects: 100% change in net load payments*
  – Reliability Pricing Model (RPM) Benefits
    • RPM Regional: 50% Change in Total System Capacity Cost + 50% Change in Load Capacity Payments
    • RPM for Lower Voltage Projects: 100% Change in Load Capacity Payments

• Candidates passing B/C tests:
  – Congestion driver reductions
  – Other factors: overall PJM congestion changes, PJM Load Payments, PJM Production Costs
  – Perform Sensitivities
    • Gas Sensitivity
    • Load Sensitivity
    • Other sensitivities as needed (Examples: gen exp, renewable penetration, carbon tax, imports/exports, etc.)

* Only zones with decrease in net load payments
Market Efficiency Process – Other Analyses

- **Reliability Analysis**
  - Additional reliability upgrades

- **Independent Cost Analysis**
  - Projects exceeding $50M Independent cost analysis

- **Constructability Analysis**
  - Verification of proposed schedule duration
  - Other risks to both cost and schedule

- **Project Combinations**
  - Combination of components of multiple projects
  - Incremental or multiple projects
Market Efficiency Project Selection – Single Proposal per Congestion Driver

Start

Review proposals → Perform B/C → Does project pass B/C?

Yes →

Does project reduce or fix congestion driver?

Yes →

Does project cause additional unacceptable congestion?

Yes →

Project Not Recommended

No →

Sensitivity Analysis Other Factors considered*

Yes →

Project Not Recommended

No →

Project Not Recommended

No → Does project require additional upgrades?

Yes →

Does Reliability and Constructability Analysis (if necessary) require additional changes?

Yes →

No →

Project Recommended

No →

Finish

* Other factors considered such as PJM Overall Production Cost, load Payments, and congestion
Market Efficiency Project Selection – Multiple Proposals per Congestion Driver

Start

Review proposals

Perform B/C

Does project pass B/C?

Yes

No

Project Not Recommended

Does project reduce or fix congestion driver?

Yes

No

Project Not Recommended

Does project cause additional unacceptable congestion?

Yes

No

Project Not Recommended

Sensitivity Analysis

Other Factors considered*

Yes

No

No

No

Project Not Recommended

Does project require additional upgrades?

Yes

No

No

Finish

Project Recommended

Is the project competitive?

Yes

No

No

Project Not Recommended

Does Reliability and Constructability Analysis (if necessary) require additional changes?

Yes

No

No

* Other factors considered such as PJM Overall Production Cost, load Payments, and congestion
Market Efficiency Process – Approval & Communication

• Selected projects require PJM board approval

• Approved projects are communicated at TEAC meetings

• Letter from PJM notifying construction responsibility
Future Discussion Topics

• Hypothetical Scenarios
• Project Selections
• Guidelines
Appendix 1 - Example B/C Ratio Calculation
## Project Benefits for Non-Simulated Years

**Regional Transmission Expansion Plan Model year:** 2021  
**Project In-service Year:** 2021  
**Promod IV Simulation Years:** 2017, 2021, 2024 & 2027

<table>
<thead>
<tr>
<th>Year</th>
<th>Period 1</th>
<th>2021</th>
<th>Period 2</th>
<th>2024</th>
<th>Period 3</th>
<th>2027</th>
<th>Period 4</th>
</tr>
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<tbody>
<tr>
<td>2017</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2017 Benefit + ( \frac{(2021 Benefit - 2017 Benefit)}{2021 - 2017} \times (\text{year} - 2017) )</td>
<td></td>
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<td></td>
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<tr>
<td>2021 Benefit + ( \frac{(2024 Benefit - 2021 Benefit)}{2024 - 2021} \times (\text{year} - 2021) )</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024 Benefit + ( \frac{(2027 Benefit - 2024 Benefit)}{2027 - 2024} \times (\text{year} - 2024) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Excel Formula:** trend (known y-values, known x-values, new x’s)  
e.g. trend ( [2017, 2021, 2024, 2027 Energy Market Benefits], [2017, 2021, 2024, 2027 years], 2028)

- Period 1 benefits  
  2018 - 2020
- Period 2 benefits  
  2022 - 2023
- Period 3 benefits  
  2025 - 2026
- Period 4 benefits
Determining Revenue Requirement

**Project Voltage:** 500 kV or 230 kV  **Project Cost:** $110 Million Dollars  **Project Benefit Period:** 15 yrs

**PJM Fixed Carrying Charge Rate** = 15.3%  **PJM Discount Rate** = 7.4%

**Project Annual Revenue Requirement** =  Project Cost x Fixed Carrying Charge Rate  
= $110 Million x 15.3% = $16.83 Million Annually

**Excel Formula:**  \( pv \) (rate, # periods, payment per period)

**Net Present Value of Project Costs** =  \( pv(7.4\%, 15, -16.83) = $149 Million \)
Selecting Zones Based on Net Load Payment

The Project is not in-service until 2021. Therefore the benefits are evaluated between 2021 and 2035, the first 15 years of in-service life.

Zones 1, 2 and 4 all have Net Load Payment benefits with an NPV > 0 for the 15 year analysis period. These zones will be included in the total system benefit.

The Net Present Value of Net Load Payment Benefits in Zone 3 do not exceed zero for the 15 year analysis period. This zone will be excluded from the total system benefit calculation.

Low Voltage Project Net Load Payment Benefit
Zone 1 + Zone 2 + Zone 4 = $223.85 Million

Regional Project Net Load Payment Benefit
50% ( Zone 1 + Zone 2 + Zone 4 ) = $111.92 Million

<table>
<thead>
<tr>
<th>Year</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
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<tbody>
<tr>
<td>2017</td>
<td>$8.00</td>
<td>$3.00</td>
<td>$0.50</td>
<td>$5.00</td>
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<td>2018</td>
<td>$9.00</td>
<td>$2.50</td>
<td>$0.40</td>
<td>$5.30</td>
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<tr>
<td>2019</td>
<td>$10.00</td>
<td>$2.00</td>
<td>$0.30</td>
<td>$5.50</td>
</tr>
<tr>
<td>2020</td>
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<td>$1.50</td>
<td>$0.20</td>
<td>$5.80</td>
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<tr>
<td>2021</td>
<td>$12.00</td>
<td>$1.00</td>
<td>$0.10</td>
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<td>2022</td>
<td>$12.30</td>
<td>$1.30</td>
<td>($0.30)</td>
<td>$6.70</td>
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<tr>
<td>2023</td>
<td>$12.70</td>
<td>$1.70</td>
<td>($0.60)</td>
<td>$7.30</td>
</tr>
<tr>
<td>2024</td>
<td>$13.00</td>
<td>$2.00</td>
<td>($1.00)</td>
<td>$8.00</td>
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<tr>
<td>2025</td>
<td>$14.00</td>
<td>$2.20</td>
<td>($1.70)</td>
<td>$7.70</td>
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<tr>
<td>2026</td>
<td>$15.00</td>
<td>$2.30</td>
<td>($2.30)</td>
<td>$7.30</td>
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<tr>
<td>2027</td>
<td>$16.00</td>
<td>$2.50</td>
<td>($3.00)</td>
<td>$7.00</td>
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<tr>
<td>2028</td>
<td>$16.60</td>
<td>$2.00</td>
<td>($2.80)</td>
<td>$7.90</td>
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<td>2029</td>
<td>$17.40</td>
<td>$1.90</td>
<td>($3.20)</td>
<td>$8.20</td>
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<td>2030</td>
<td>$18.20</td>
<td>$1.90</td>
<td>($3.50)</td>
<td>$8.40</td>
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<tr>
<td>2031</td>
<td>$18.90</td>
<td>$1.90</td>
<td>($3.80)</td>
<td>$8.70</td>
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<tr>
<td>2032</td>
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<td>($4.19)</td>
<td>$8.90</td>
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<td>($4.53)</td>
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<td>$1.78</td>
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<td>2035</td>
<td>$21.97</td>
<td>$1.75</td>
<td>($5.22)</td>
<td>$9.64</td>
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NPV (Millions) $138.97 $16.17 ($19.77) $68.71
System Adjusted Production Cost Benefits

- The Project is not in-service until 2021. Therefore the benefits are evaluated between 2021 and 2035.

- NPV Adjusted Production Cost Benefit = NPV(7.4%, Adjusted Production Cost Savings)

- Regional Adjusted Production Cost Benefits = 50% x $121.2 Million

<table>
<thead>
<tr>
<th>Year</th>
<th>Net Adjusted Production Cost Benefit</th>
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<tbody>
<tr>
<td>2017</td>
<td>$8.00</td>
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<td>2018</td>
<td>$8.50</td>
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<td>$18.08</td>
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<td>2035</td>
<td>$18.68</td>
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NPV (Millions) $121.2
Does Project Pass Criteria

• REGIONAL METHOD
  – Total Energy Market Benefits = Load Payment Benefit x 50% + Production Cost Benefit x 50%
  – Total Benefits = $112 Million + $60.6 Million = $172.51 Million
  – Does the Project Pass: Benefits / Costs = $172.51 / $149 = 1.15 > PROJECT FAILS

• Low Voltage Method
  – Total Benefits = 100% Load Payment Benefit = $223.85 Million
  – Does the Project Pass: Benefits / Costs = $223.85 / $149 = 1.49 > PROJECT PASSES
Appendix 2 – Operating Agreement & Manual References
References

• Scope, PJM requirements & Member requirements
  http://www.pjm.com/about-pjm/member-services.aspx

• PJM Manual 14B, Section 2.6:
  http://www.pjm.com/~/media/documents/manuals/m14b.ashx

• PJM Operating Agreement, Schedule 6, Section 1.5.7:

• PJM Market Efficiency Practices