# PJM Market Efficiency Long Term Window Overview

September 2, 2016




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# 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

| 2006 | 2011 | 2014 |
|---|---|---|

## Inception of ME in RTEP

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

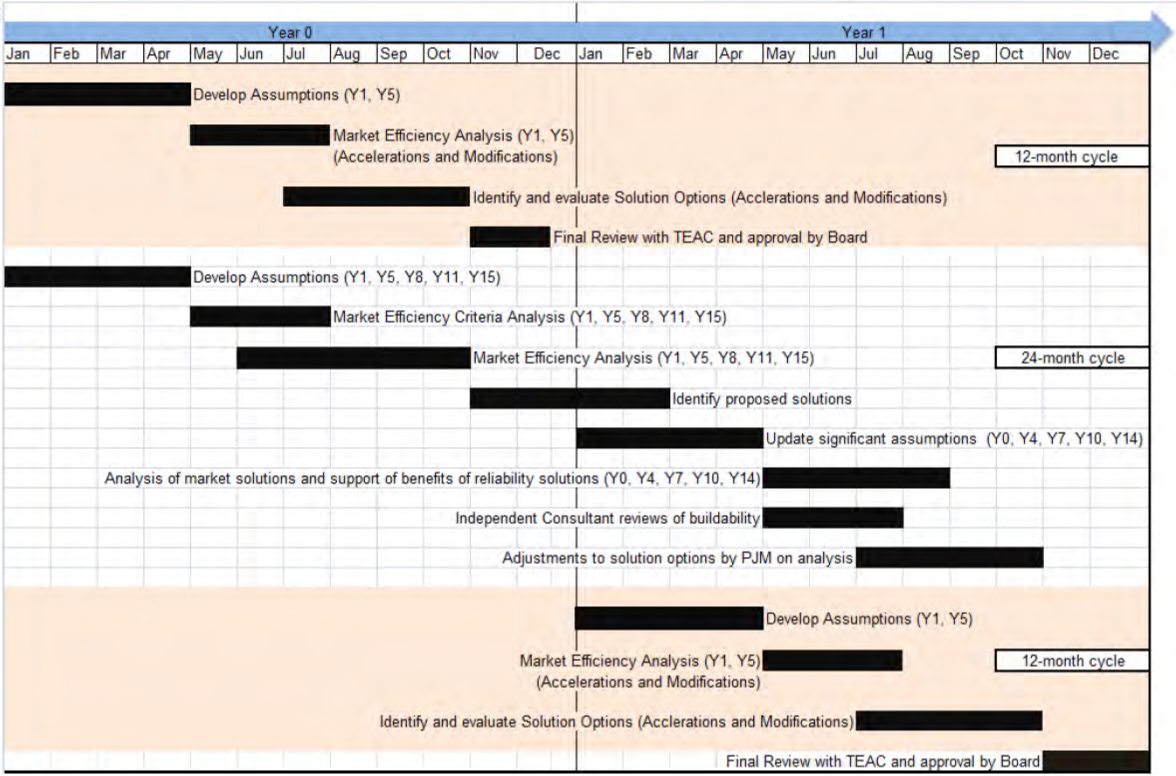
## Order 1000

Reforms:
- Cost Allocation
- Non incumbent Development

## 1st Window

Impacts:
- Formal
- Competitive
- Long term

# Market Efficiency Cycle Timeline

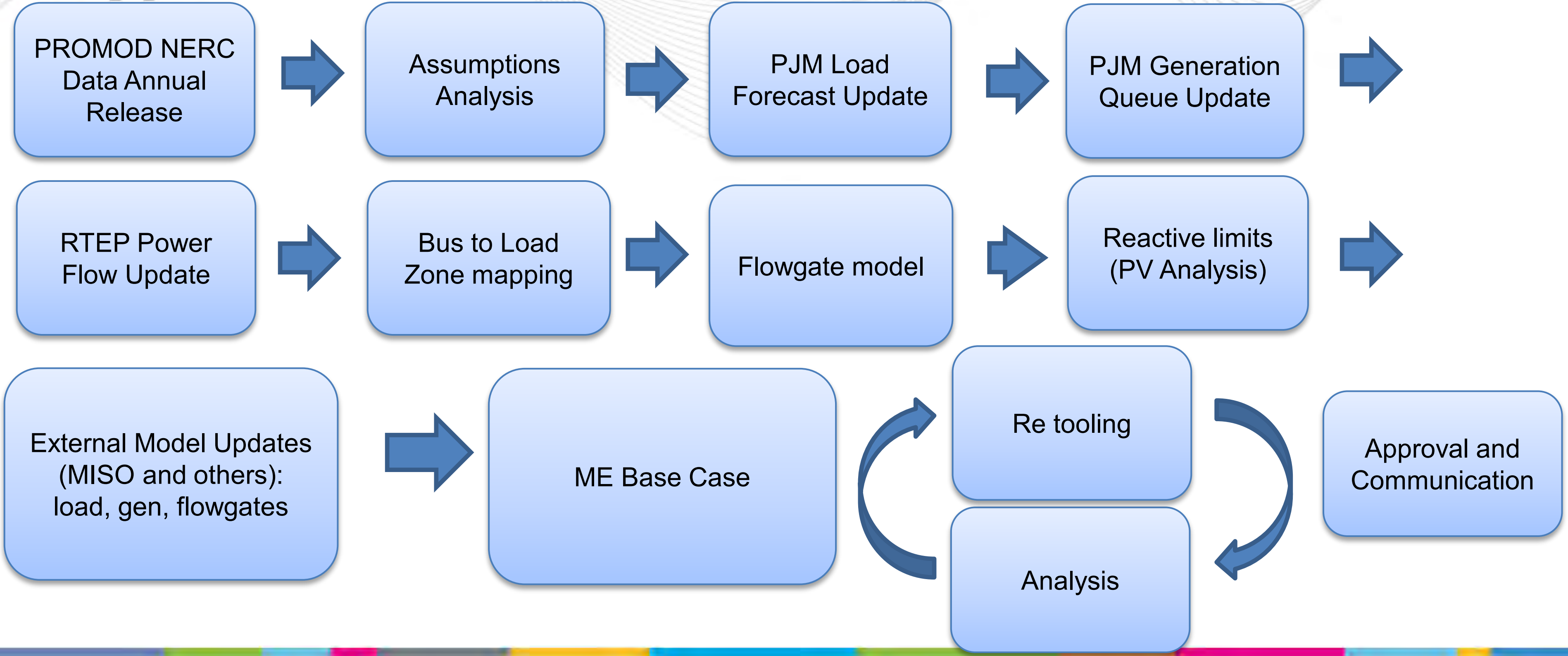



- 12 month
  - Acceleration
- 24 month Cycle
  - Input assumptions
  - Base case development
  - Develop target congestion
  - Proposal submission
  - Evaluation
  - Approval

# Market Efficiency Statistics

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

# Market Efficiency Work Flow



# 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.

→ **PROMOD** →

## 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



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# Market Efficiency Inputs – Overview Base Case Inputs

## PROMOD SCED Simulation

- Generation Expansion Plan (ISA/FSA)
- Demand Response Forecast
- Intermittent resource hourly shapes
- Transmission Topology (As-Is, RTEP)
- Fuel Price Forecast: Natural Gas,Coal, Oil-H, Oil-L
- Topology Mapping: Bus-Area, BusLoad-Demand, Gen-Bus (As-Is, RTEP)
- Emissions Price Forecast: CO2 (National, RGGI), SO2, Nox (seasonal,annual)
- Reactive Interface PV Analysis
- Demand Forecast: Annual Peak Load and Energy, Hourly shapes
- 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: $SO_2$, $NO_x$, and $CO_2$.
  - 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

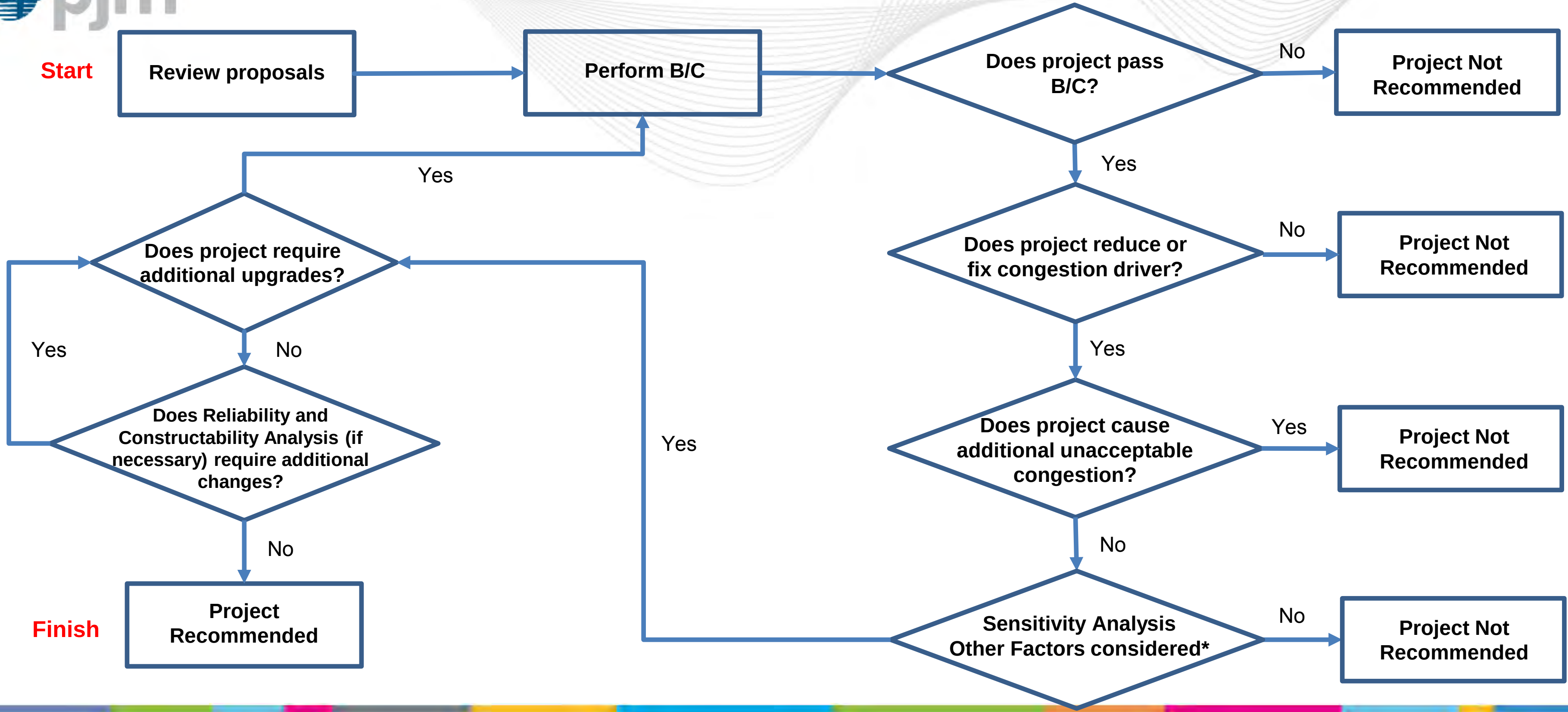
- Candidates passing B/C tests:
  - Congestion driver reductions
  - Other factors: overall PJM congestion changes, PJM Load Payments, PJM Production Costs
  - Perform Sensitivities
    - Gas Sensitivity
    - Load Sensitivity
    - Other sensitivities as needed (Examples: gen exp, renewable penetration,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

* Only zones with decrease in net load payments

# Market Efficiency Process – Other Analyses

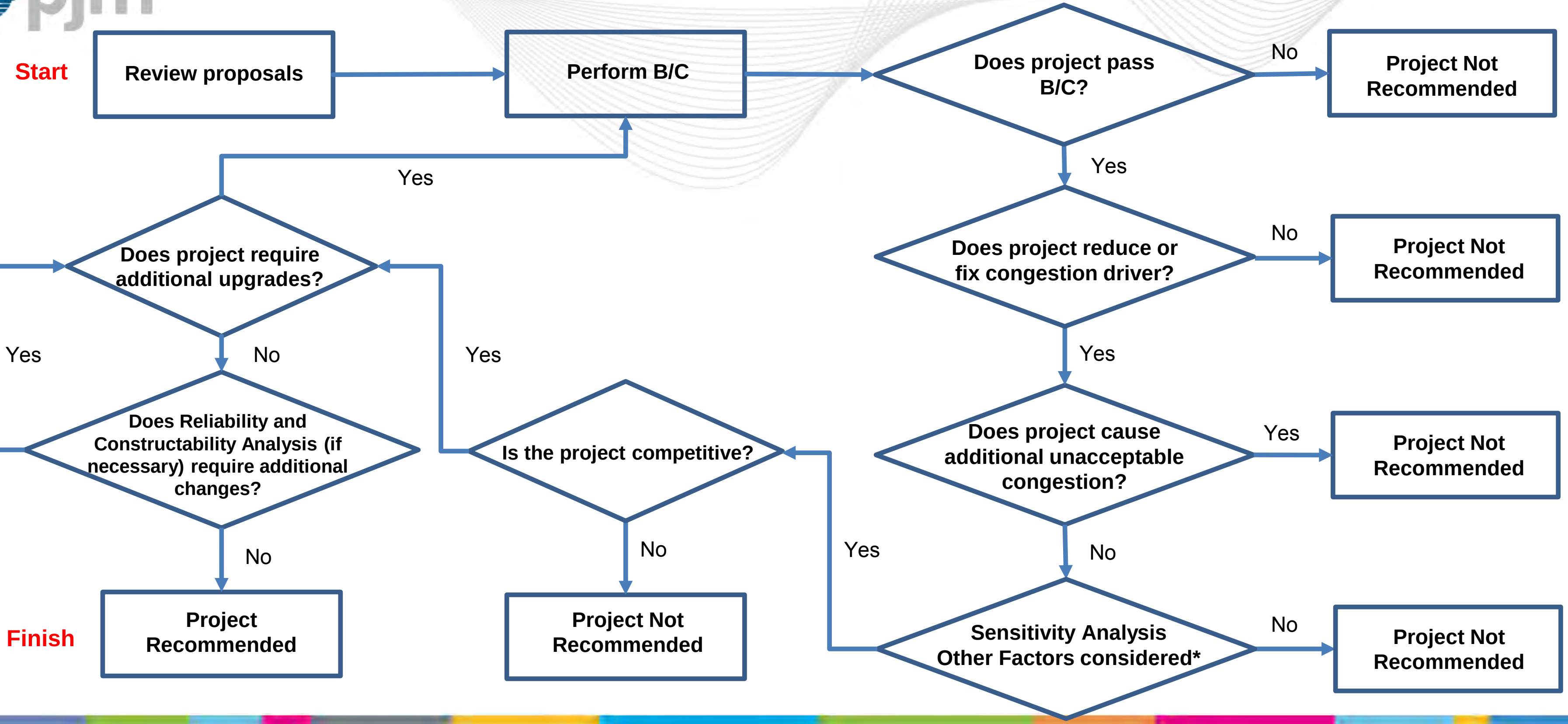
- Reliability Analysis
  - Additional reliability upgrades
- Independent Cost Analysis
  - Projects exceeding $50M Independent cost analysis
- Constructability Analysis
  - Verification of proposed schedule duration
  - Other risks to both cost and schedule
- Project Combinations
  - Combination of components of multiple projects
  - Incremental or multiple projects

# Market Efficiency Project Selection – Single Proposal per Congestion Driver




* Other factors considered such as PJM Overall Production Cost, load Payments, and congestion

# Market Efficiency Project Selection – Multiple Proposals per Congestion Driver

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# 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*

| 2017 | Period 1 | 2021 | Period 2 | 2024 | Period 3 | 2027 | Period 4 |
|---|---|---|---|---|---|---|---|

Period 1 benefits
2018 - 2020

$$2017\,Benefit + \frac{(2021\,Benefit - 2017\,Benefit)}{2021 - 2017}\,x\,(year - 2017)$$

Period 2 benefits
2022 - 2023

$$2021\,Benefit + \frac{(2024\,Benefit - 2021\,Benefit)}{2024 - 2021}\,x\,(year - 2021)$$

Period 3 benefits
2025 - 2026

$$2024\,Benefit + \frac{(2027\,Benefit - 2024\,Benefit)}{2027 - 2024}\,x\,(year - 2024)$$

Period 4 benefits

**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)

# 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*



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# 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.

<u>Low Voltage Project Net Load Payment Benefit</u>

Zone 1 + Zone 2 + Zone 4 = $223.85 Million

<u>Regional Project Net Load Payment Benefit</u>

50% ( Zone 1 + Zone 2 + Zone 4 ) = $111.92 Million

ISD

| Year | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
|---|---|---|---|---|
| 2017 | $8.00 | $3.00 | $0.50 | $5.00 |
| 2018 | $9.00 | $2.50 | $0.40 | $5.30 |
| 2019 | $10.00 | $2.00 | $0.30 | $5.50 |
| 2020 | $11.00 | $1.50 | $0.20 | $5.80 |
| 2021 | $12.00 | $1.00 | $0.10 | $6.00 |
| 2022 | $12.30 | $1.30 | ($0.30) | $6.70 |
| 2023 | $12.70 | $1.70 | ($0.60) | $7.30 |
| 2024 | $13.00 | $2.00 | ($1.00) | $8.00 |
| 2025 | $14.00 | $2.20 | ($1.70) | $7.70 |
| 2026 | $15.00 | $2.30 | ($2.30) | $7.30 |
| 2027 | $16.00 | $2.50 | ($3.00) | $7.00 |
| 2028 | $16.60 | $2.00 | ($2.80) | $7.90 |
| 2029 | $17.40 | $1.90 | ($3.20) | $8.20 |
| 2030 | $18.20 | $1.90 | ($3.50) | $8.40 |
| 2031 | $18.90 | $1.90 | ($3.80) | $8.70 |
| 2032 | $19.68 | $1.84 | ($4.19) | $8.90 |
| 2033 | $20.45 | $1.81 | ($4.53) | $9.15 |
| 2034 | $21.21 | $1.78 | ($4.87) | $9.40 |
| 2035 | $21.97 | $1.75 | ($5.22) | $9.64 |
| **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

| | Year | Net Adjusted Production Cost Benefit |
|---|---|---|
| | 2017 | $8.00 |
| | 2018 | $8.50 |
| | 2019 | $9.00 |
| | 2020 | $9.50 |
| ISD | 2021 | $10.00 |
| | 2022 | $10.70 |
| | 2023 | $11.30 |
| | 2024 | $12.00 |
| | 2025 | $12.70 |
| | 2026 | $13.30 |
| | 2027 | $14.00 |
| | 2028 | $14.50 |
| | 2029 | $15.10 |
| | 2030 | $15.70 |
| | 2031 | $16.30 |
| | 2032 | $16.88 |
| | 2033 | $17.48 |
| | 2034 | $18.08 |
| | 2035 | $18.68 |
| | **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

- 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: http://www.pjm.com/media/documents/merged-tariffs/oa.pdf

- PJM Market Efficiency Practices http://www.pjm.com/~/media/planning/rtep-dev/market-efficiency/pjm-market-efficiency-modeling-practices.ashx