PJM Market Efficiency Benefits Calculation

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- Market Efficiency Projects may address:
  - Energy market constraints (drivers)
  - Capacity market constraints (drivers)

- Market Efficiency Projects may generate:
  - Energy market benefits
  - Capacity market benefits (RPM Benefits)

- Total Benefits = Energy Benefits + RPM Benefits

PJM Market Efficiency Benefits Calculation - Energy

Energy Benefits Simulation

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

Energy Benefits Calculation

- Regional Projects: 50% Change in Total Energy Production Cost + 50% Change in Load Energy Payment

- Lower Voltage Projects: 100% change in Load Energy Payment

* Only zones with decrease in net load payments

Energy Benefits Calculation (con’t)

- Change in Total Energy Production Cost
  - Calculated for the PJM Region
  - Adjusted for interchange with neighboring pools

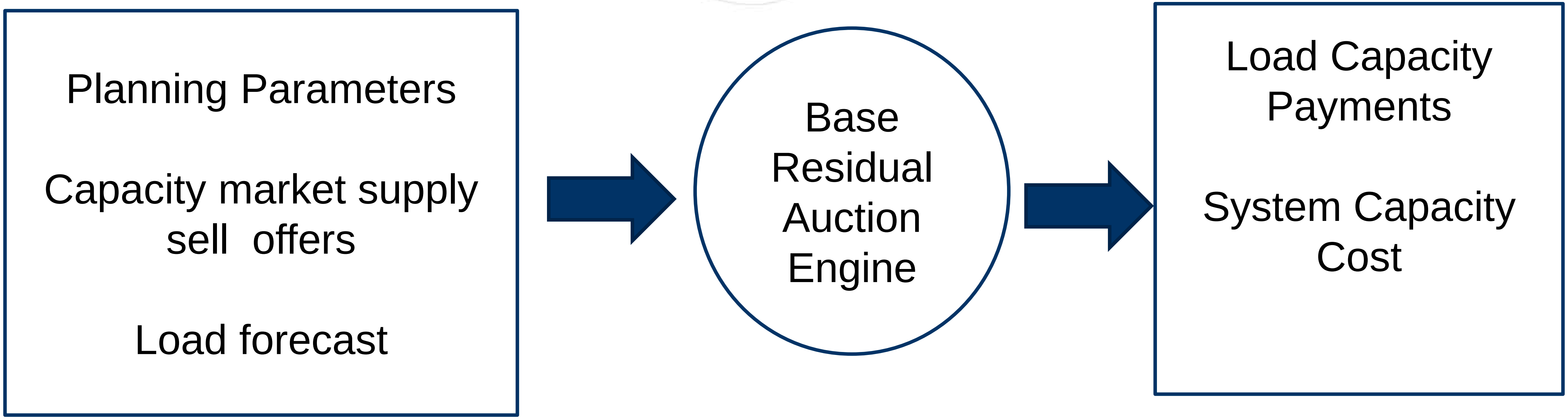
- Change in Load Energy Payments
  - Calculated for each transmission zone
  - Only zones that show a LMP decrease will be considered

Energy Benefits Details

Item	Production Cost Benefits	Load Payment Benefits
Granularity	PJM region	Benefitting Transmission Zones
Simulated years	Four years (RTEP - 4, RTEP, RTEP+3, RTEP+6)	
Trend	Interpolated between the simulated years & Extrapolated after the last simulated years	
Benefits horizon	Calculated for 15 years starting with the project in-service date (Net Present Value)	

PJM Market Efficiency Benefits Calculation - Capacity

Capacity Benefits Simulation



Capacity Benefits Calculation

- Regional Projects: 50% Change in System Capacity Cost + 50% Change in Load Capacity Payment

- Lower Voltage Projects: 100% change in Load Capacity Payment

* Only zones with decrease in net load payments

Capacity Benefits Calculation (con't)

- Change in Total System Capacity Cost
  - Calculated for the PJM Region
- Change in Load Capacity Payment
  - Calculated for each transmission zone
  - Only zones that show a LMP decrease in capacity payment will be considered

Capacity Benefits Details

Item	Capacity Cost Benefits	Load Capacity Payment Benefits
Granularity	PJM region	Benefitting Transmission Zones
Simulated years	Three years (RTEP, RTEP+3, RTEP+6)	
Trend	Interpolated between the simulated years & Extrapolated after the last simulated years	
Benefits horizon	Calculated for 15 years starting with the project in-service date (Net Present Value)	

Example B/C Ratio Calculation

Hypothetical Example

- Hypothetical project will be considered
- Energy benefits are calculated
- Both regional and low voltage benefits are determined

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)

Selecting Zones Based on Net Load Payment

- Project in-service date is 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

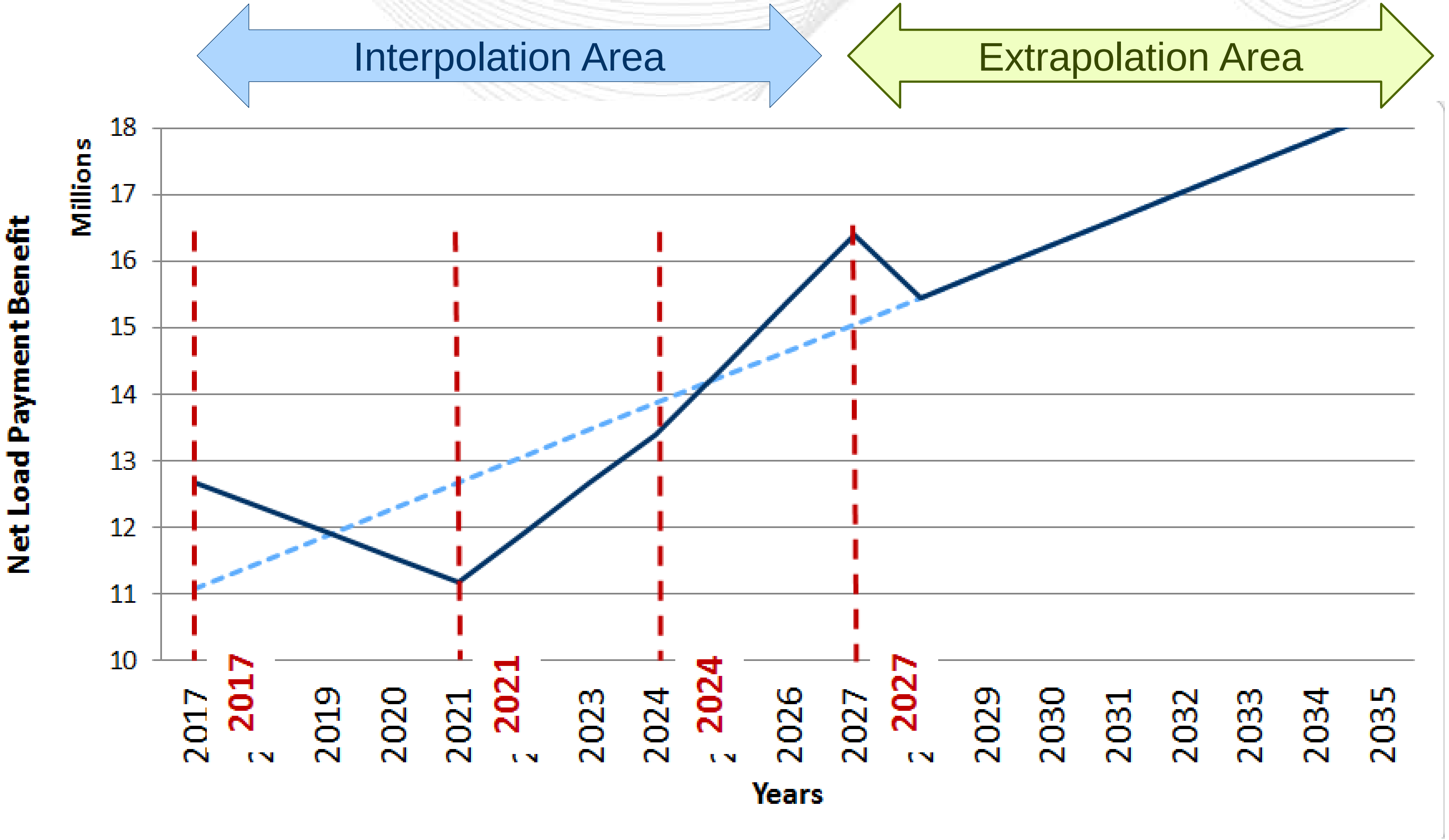
Zone 1 + Zone 2 + Zone 4 = $223.85 Million

Regional Project Net Load Payment Benefit

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

	Year	Zone 1	Zone 2	Zone 3	Zone 4
	2017	$12.67	$3.00	$0.50	$5.00
	2018	$12.29	$2.50	$0.40	$5.30
	2019	$11.92	$2.00	$0.30	$5.50
	2020	$11.55	$1.50	$0.20	$5.80
ISD	2021	$11.18	$1.00	$0.10	$6.00
	2022	$11.92	$1.30	($0.30)	$6.70
	2023	$12.67	$1.70	($0.60)	$7.30
	2024	$13.41	$2.00	($1.00)	$8.00
	2025	$14.40	$2.20	($1.70)	$7.70
	2026	$15.40	$2.30	($2.30)	$7.30
	2027	$16.39	$2.50	($3.00)	$7.00
	2028	$15.46	$2.00	($2.80)	$7.90
	2029	$15.85	$1.90	($3.20)	$8.20
	2030	$16.25	$1.90	($3.50)	$8.40
	2031	$16.65	$1.90	($3.80)	$8.70
	2032	$17.05	$1.84	($4.19)	$8.90
	2033	$17.44	$1.81	($4.53)	$9.15
	2034	$17.84	$1.78	($4.87)	$9.40
	2035	$18.24	$1.75	($5.22)	$9.64
	NPV (Millions)	**$138.97**	**$16.17**	**($19.77)**	**$68.71**

Example Zonal Net Load Payment Benefits



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**

- **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
- **Low Voltage Method**
  - Total Benefits = 100% Load Payment Benefit = $223.85 Million

Energy Benefits Challenges

- Mismatch between RTEP topology and generation expansion for the 1st simulated year

- Fuel and load forecasts driving uncertainties in the benefits calculation for the 4th simulated year and trending beyond.

- Benefits metric is more strict for regional projects than for lower voltage projects

Capacity Benefits Challenges

- Planning parameters applicable for capacity market driver cannot be calculated beyond RTEP year

- Capacity market benefits are calculated assuming most recent capacity market offers

Appendix A - Glossary

Glossary – Adjusted Production Cost (APC)

- Calculated as total annual fuel costs, variable O&M costs, and emissions costs of the dispatched resources in the PJM Region, adjusted for the interchange with the neighboring pools
  - Purchases valued at the Load Weighted LMP
  - Sales valued at the Generation Weighted LMP

$$APC \quad = \sum_{Units}^{Base\ Case} \Big[(Fuel\ Costs + Emission\ Costs + Variable\ O\&M) + \begin{pmatrix} PJM\ Purchase \times PJM\ Load\ Weighted\ LMP \\ -PJM\ Sale \times PJM\ Gen\ Weighted\ LMP \end{pmatrix} \Big]$$

Glossary – Net Load Payment (NLP)

- Calculated as the annual sum of the hourly estimated zonal load megawatts for each PJM transmission zone multiplied by the hourly estimated zonal Locational Marginal Price for each PJM transmission zone minus the value of Transmission Rights for each PJM transmission zone.

$$NLP = \sum_{Hours} \sum_{Zones} (Hourly\ Bus\ Load \times Hourly\ Bus\ LMP)$$

$$-8760 \times \sum_{Zones} ARR\ Patch\ Cleared\ MW \times (Annual\ Sink\ Node\ CLMP$$

$$\times\ Annual\ Source\ Node\ CLMP)$$

Glossary - Energy Benefits

- Change in Total Adjusted Energy Production Cost
  - Calculated as difference in total Adjusted Production Costs without and with the enhancement or expansion.

- Change in Load Energy Payment
  - Calculated as difference between the Net Load Payments without and with the economic-based enhancement or expansion.
  - Only zones that show a decrease will be considered in determining the Change in Load Energy Payments.

Glossary - Reliability Pricing Model (RPM) Benefits

- Change in Total System Capacity Cost
  - Calculated as the difference between the sum of the megawatts that are estimated to be cleared in the Base Residual Auction under PJM's Reliability Pricing Model capacity construct times the prices that are estimated to be contained in the offers for each such cleared megawatt (times the number of days in the study year) without and with the economic-based enhancement or expansion.

- Change in Load Capacity Payment
  - Calculated as the sum of the estimated zonal load megawatts in each PJM transmission zone times the estimated Final Zonal Capacity Prices (payments paid by load in each transmission zone) for capacity under the Reliability Pricing Model construct (times the number of days in the study year) minus the value of Capacity Transfer Rights for each PJM transmission zone without and with the economic-based enhancement or expansion.
  - Only PJM transmission zones that show a decrease will be considered in determining the Change in Load Capacity Payment.