EPA's Clean Power Plan Proposal
Review of PJM Analyses Preliminary Results

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PJM has been tasked with assessing potential impacts of the EPA Clean Power Plan Proposal on PJM states; however, as an RTO, PJM:

- Maintains neutrality on carbon policy
- Acts as an independent source of information on carbon policy implications
- Does ***not*** forecast market outcomes but rather models outcomes based on a specific set of assumptions

Overview of PJM Analyses

Analysis	Emissions Target Utilized
Regional Economic Modeling	Mass target using June 2 EPA guidance for conversion from rate based targets
	Mass target using November 6 EPA guidance for conversion from rate based
	Rate based target
State by State Economic Modeling	Mass target using November 6 EPA guidance for mass conversion from rate based targets
Reliability Analysis (to be completed)	Power flow analyses modeling retirement of “at-risk” units identified from the regional economic modeling

Section I: Modeling Approach

Overview of Regional Compliance Modeling Approach Using Mass-Based Emissions Targets

Used PROMOD for simulation modeling

- PROMOD models hourly security constrained economic generation commitment and dispatch
- Assumptions consistent with 2014 RTEP Market Efficiency Analysis
- 14 scenarios adjusted new generation, energy efficiency, renewable energy, nuclear retirements, and gas price assumptions. (PJM is not modeling each EPA Building Block independently)

Convert to mass-based emissions targets

- Converted rate-based emissions targets to mass-based targets for the states / portion of states within PJM; aggregated to represent the emissions target for PJM region
- Input CO_2 price to re-dispatch generation until emissions target achieved

Assume new gas units are regulated under 111(b), not 111(d)

- Emissions from new gas units are ***not*** counted toward the emissions target

Overview of Regional Compliance Modeling Approach Using Rate-Based Emissions Targets

Used PROMOD for simulation modeling

- PROMOD models hourly security constrained economic generation commitment and dispatch
- Assumptions consistent with 2014 RTEP Market Efficiency Analysis
- 14 scenarios adjusted new generation, energy efficiency, renewable energy, nuclear retirements, and gas price assumptions. (PJM is not modeling each EPA Building Block independently)

Used rate-based emissions targets

- Calculate performance credit and penalty for each 111(d) covered source based on unit emissions rate and EPA provided benchmark target rate
- Model CO_2 performance credit / penalty as a bid adder/decrement to the simulation until emissions rate target is achieved

Assume new gas units are regulated under 111(b), not 111(d)

- Emissions from new gas units are ***not*** counted toward the emissions target

Existing Source vs. New Source Performance Standards Proposals

	111(d)	111(b)
Relevant dates	Interim compliance 2020-2029. Final compliance 2030 and beyond	Scheduled promulgation January 2015
Units impacted	Existing and Under-construction: ST Coal, NGCC, ST Gas/Oil, High-utilization CT Gas/Oil, IGCC and some CHP	New Gas-Fired CT, fossil-fired utility boilers and IGCC units

Standard	State-based compliance with a CO_2 emissions rate target or converted to a mass-based target	Federal compliance (NSPS):
		• Large CT - 1,000 lbs/MWh
		• Steam Turbine and IGCC:
		  • 1,100 lbs/MWh (12 mos.)
		  • 1,000-1,050 lbs/MWh (84 mos.)

Impact on units	Reduced net energy market revenues Potentially CO_2 allowance price or restrictions on unit operation	New gas/dual fuel CCs meet limit New coal units require partial carbon capture and sequestration or similar to meet limits

Calculating Costs

- **Production cost –** resulting incremental variable cost due to re-dispatch from one higher emitting resource to another lower emitting resource until the mass-based emissions target is achieved
- **Carbon Price –** Price on emissions for 111(d) covered sources that is derived from re-dispatching lower variable cost/ higher emitting sources to higher variable cost/lower emitting sources
- **Load energy payment –** energy costs borne by load; Through simulation implementing a CO_2 price will increase the marginal cost of energy, thus increasing load energy payments (congestion and marginal losses may also change but were not separately identified)

Incremental production cost is a 111(d) compliance cost

Calculating Costs

- **Capital cost –** estimated total new investment associated with addition of new generation (PJM Interconnection Queue and State based RPS) and Energy Efficiency
  - Based on generic overnight capital costs in 2012 dollars

- **Transmission cost**
  - Based on transmission upgrades made necessary as a result of generation retirements

Incremental investments in new generation, energy efficiency programs and transmission upgrades also may be 111(d) compliance costs

Model Years

- Clean Power Plan "Glide Path"
  - interim goal allows averaging emissions compliance from 2020-2029
- PROMOD is not capable of dynamically modeling a “glidepath”
- Similar to EPA’s modeling approach, PJM modeled individual years
- OPSI requested PJM analyze three years: 2020, 2025 and 2029
- PJM’s modeling, therefore, should not be interpreted to suggest that compliance must be achieved by 2020, 2025 or 2029.

Section II: Mass-based and Emission Rate Targets

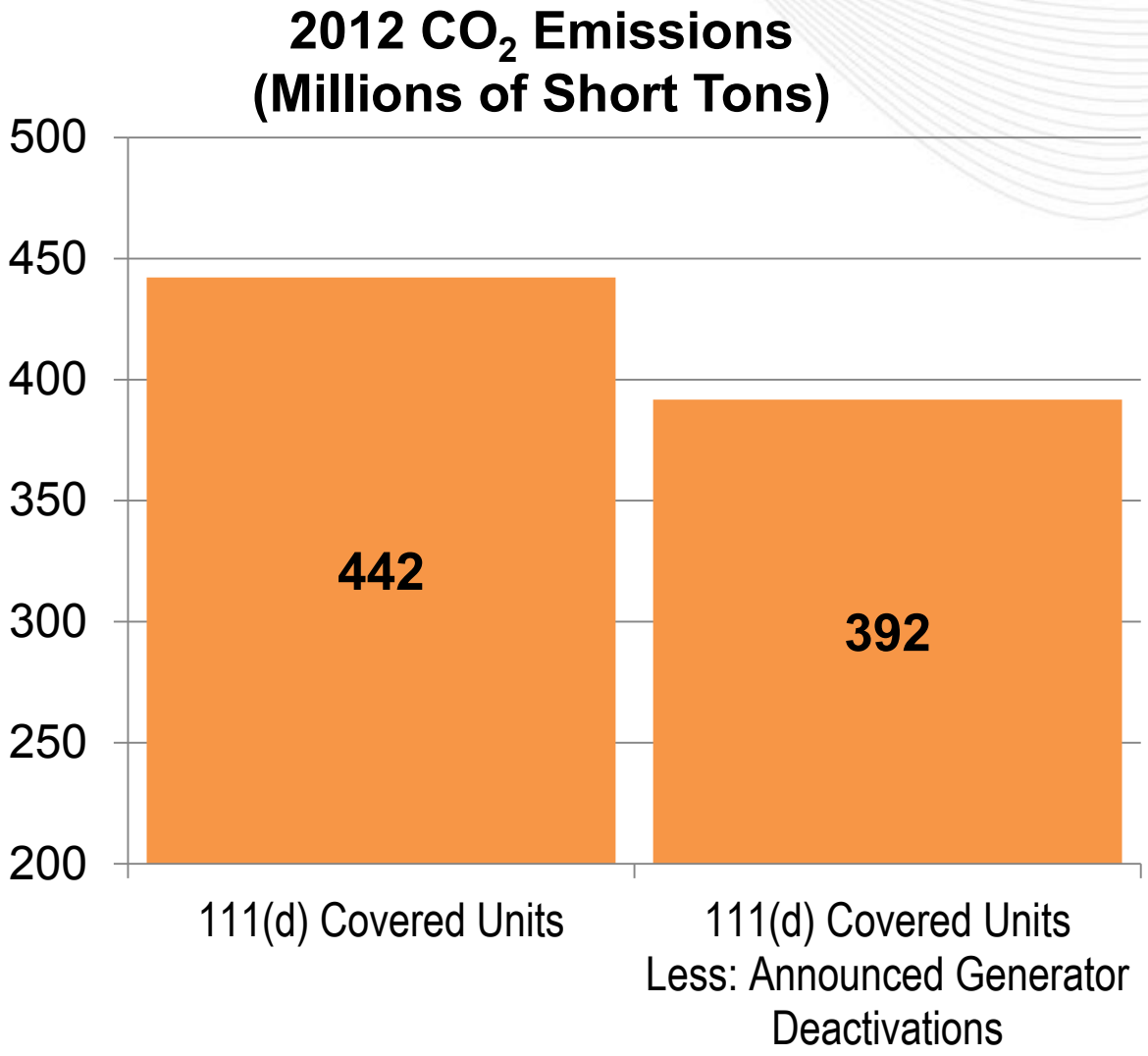
Historic Trends and Policies Affecting CO_2 Mass Reduction Pre-2020

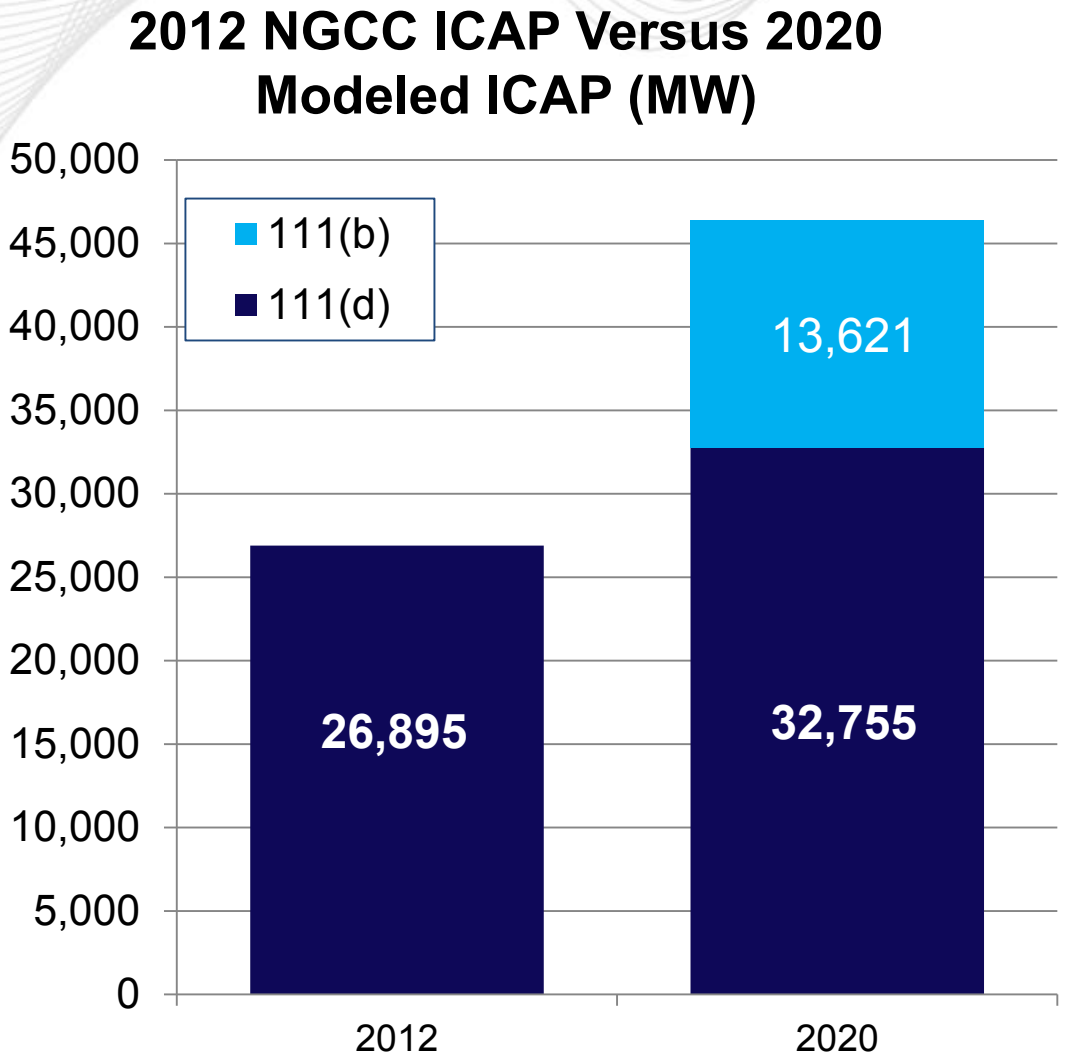
MATS compliance has led to many announced coal steam retirements by 2016 and is independent of 111(d) policy

Sustained low natural gas prices combined with sluggish load growth exert economic pressure on less efficient coal units to retire independent of 111(d) policy

PJM announced deactivation's mitigate impacts of 2020 emissions target and provide some margin for output increases consistent with load growth

Impact of Retirements and New Resources Relative to 2012 Baseline: Mass Basis





EPA Eq.1 - Implied in June 2 TSD

Mass Target =State Rate x (2012 Covered Sources + Renewables + Nuclear$_{,ar\text{-}new}$ + Incremental EE)

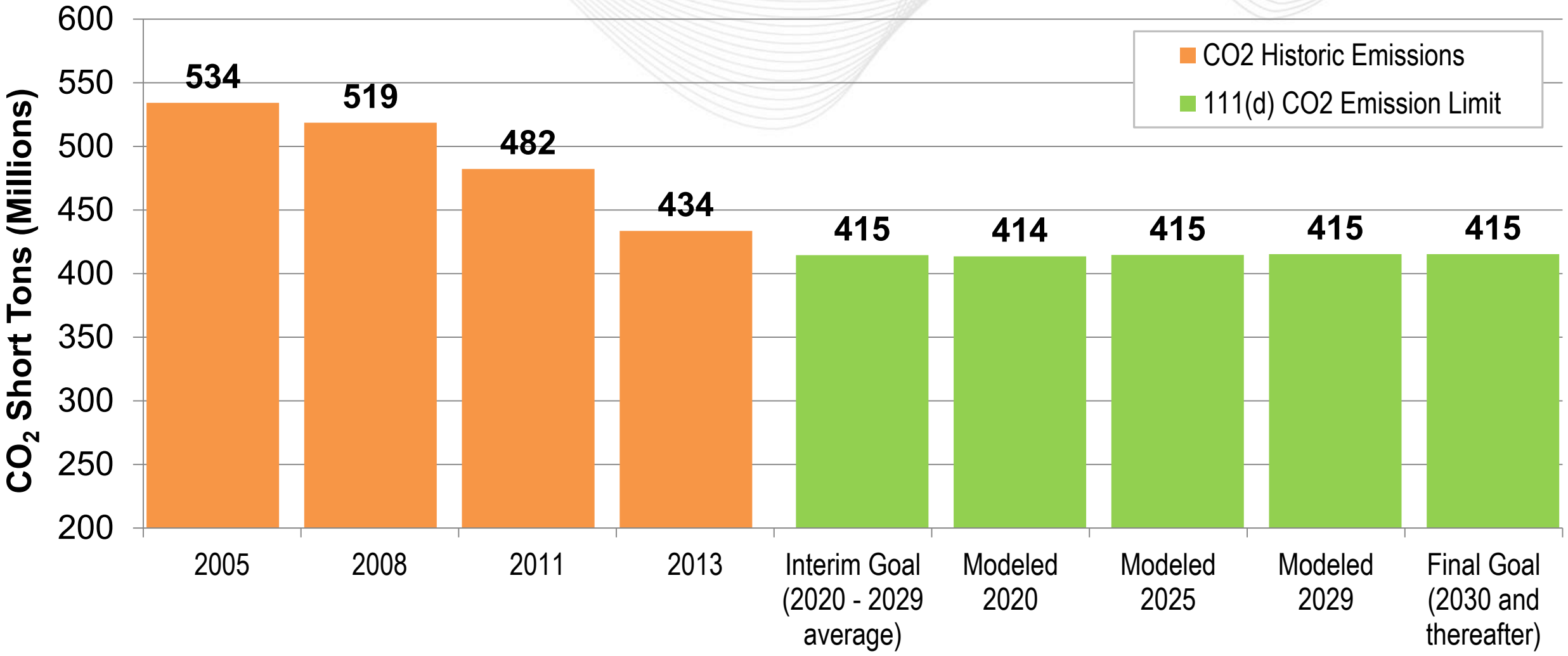
- State with higher EE and RPS targets has higher mass limit
- Constant mass target as EE and RPS are only variable to change as rate declines

EPA Eq. 2 - Implied in November 6 TSD

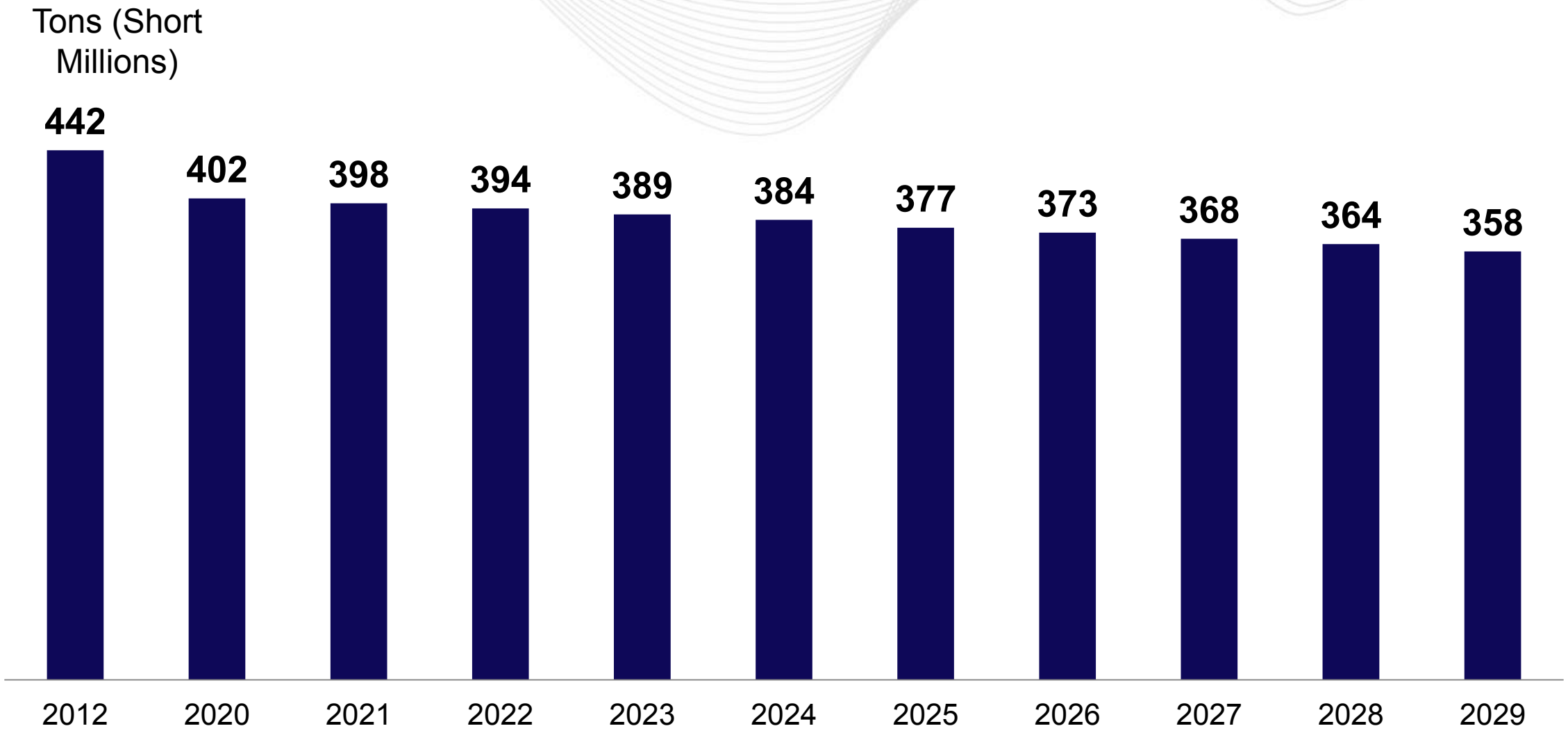
Mass Target = State Rate x (2012 Covered Source + 2012 Renewable + Nuclear$_{,ar\text{-}new}$ + Net New Load growth)

- No crediting for new renewables and incremental EE
- Declining mass target over interim compliance period

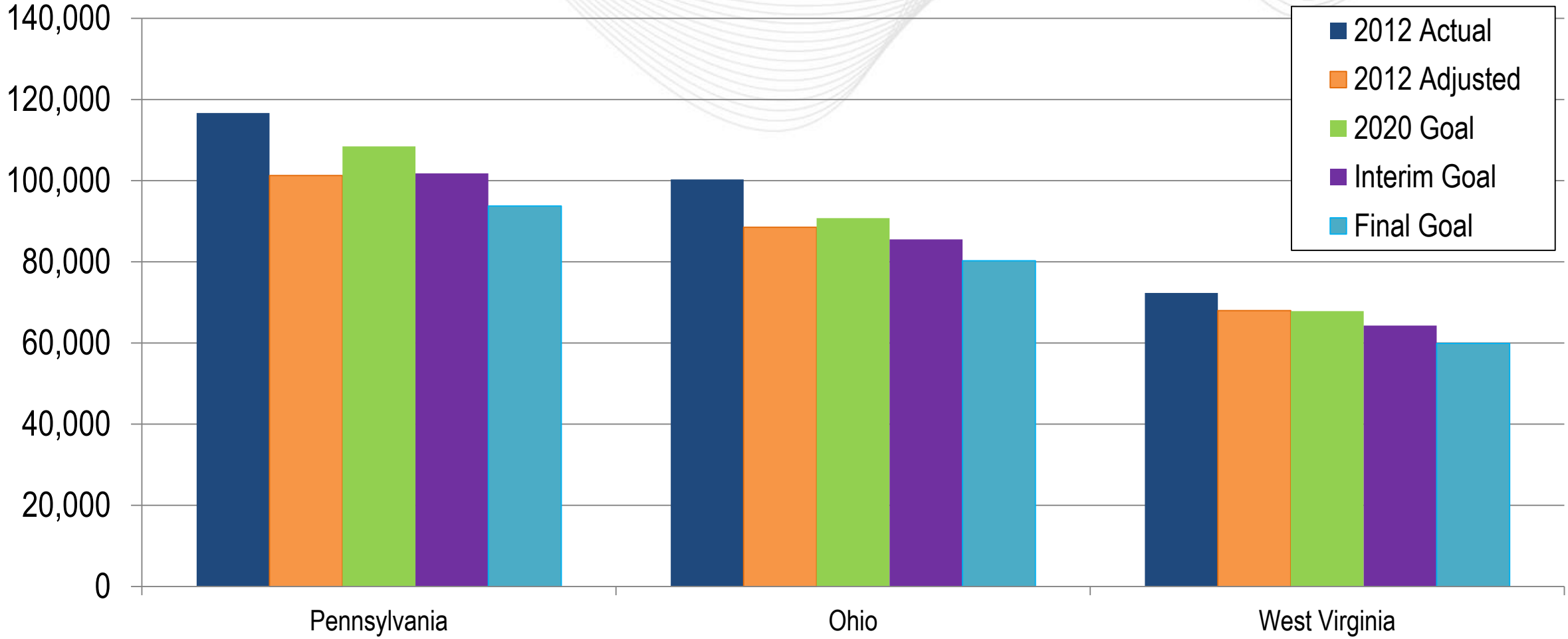
PJM Historic Emissions vs 111(d) Mass-Based Limits
June 2nd TSD



PJM Region Carbon Emissions Target Mass Limits: November 6 Guidance



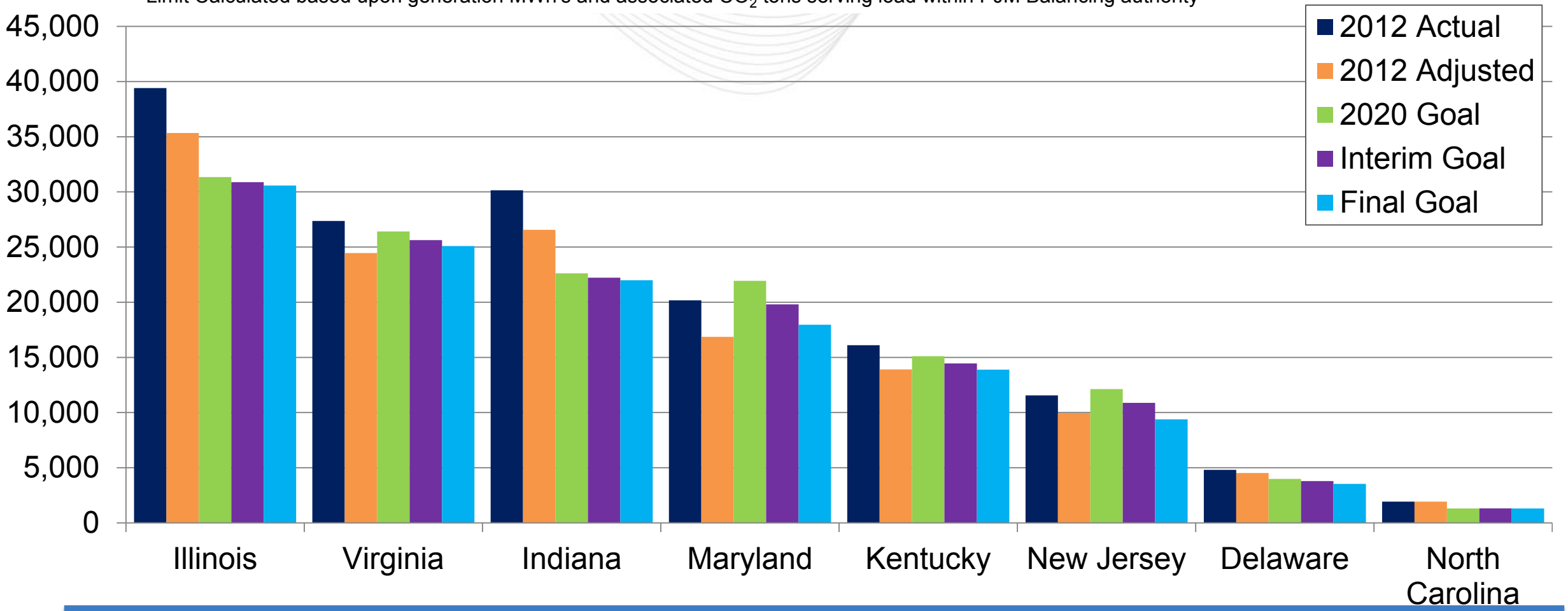
State-Wide CO_2 Mass Limits (Nov. 6 EPA Guidance) PA, OH and WV



2012 Adjusted = 2012 Total CO_2 Emissions ***Less***: 2012 Emissions From PJM Announced Unit Deactivations

State-Wide CO_2 Mass Limits (Nov. 6 EPA Guidance)
IL*, VA, IN*, MD, KY*, NJ, DE and NC*

*Limit Calculated based upon generation MWh's and associated CO_2 tons serving load within PJM Balancing authority



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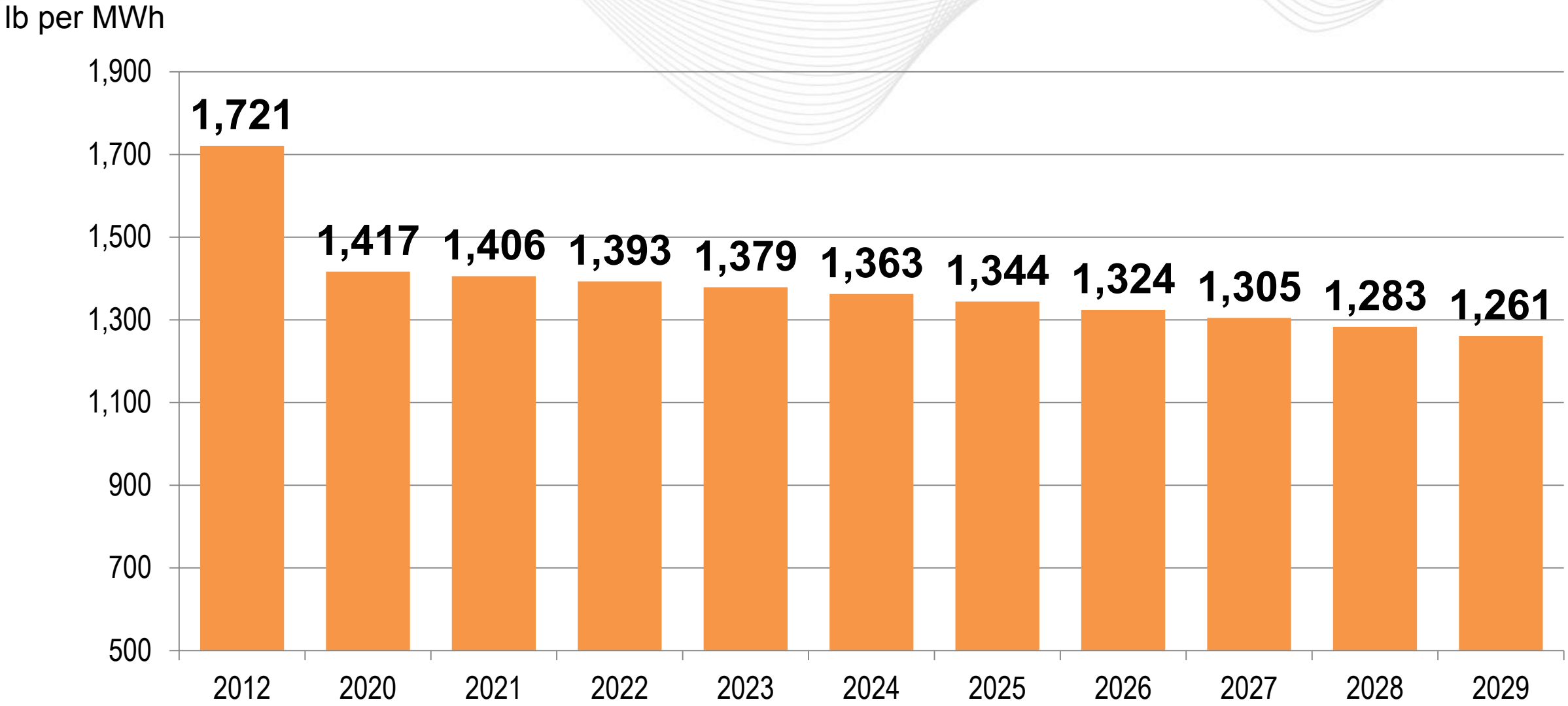
PJM Region Carbon Emissions Target Rates



Section III: Scenario Descriptions

Planning Model Resource Capacity

- The PJM Planning model already consists of a significant amount of renewables due to the inclusion of interconnection queue projects with an Interconnection Service Agreement and or Facilities Study agreement
  - Commercial Likelihood of ISA projects > 70%
  - Commercial Likelihood of Completion for FSA Projects > 50%
- Resources from the interconnection queue are modeled at their full energy resource value
  - Most resources have an in-service date prior to the start of the interim compliance period
- Base planning model meets PJM IRM Target in all years

OPSI Compliance Alternatives Evaluated

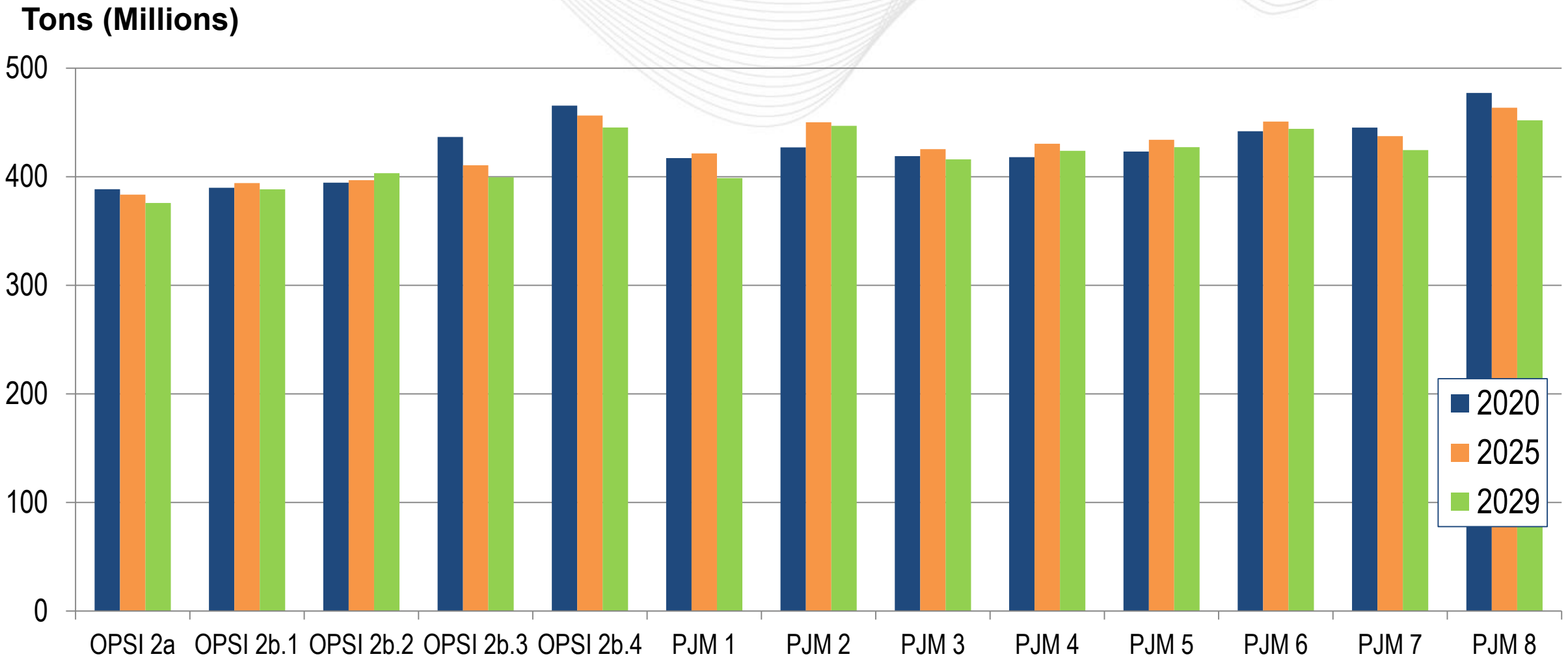
OPSI Scenarios	Fossil & Nuclear Resources	Renewables	Energy Efficiency (EE)
OPSI 2a	Existing and Planned Resources (ISA and FSA only)	PJM RPS Requirement	100% EPA EE
OPSI 2b.1	Existing and Planned Resources (Non-Renewable: ISA and FSA only, *Wind/Solar – FSA, ISA, SIS and FEAS		
OPSI 2b.2	Existing and Planned Resources (ISA and FSA only)	PJM RPS Requirement	50% EPA EE Goals
OPSI 2b.3	Existing and Planned Resources (ISA and FSA only) Increase Natural Gas Price by 50%		100% EPA EE
OPSI 2b.4	Existing and Planned Resources (ISA and FSA only) 50 % Reduction in Nuclear Capacity		
OPSI 2c	Same as OPSI 2a – but state-by-state compliance		

PJM Compliance Alternatives Evaluated

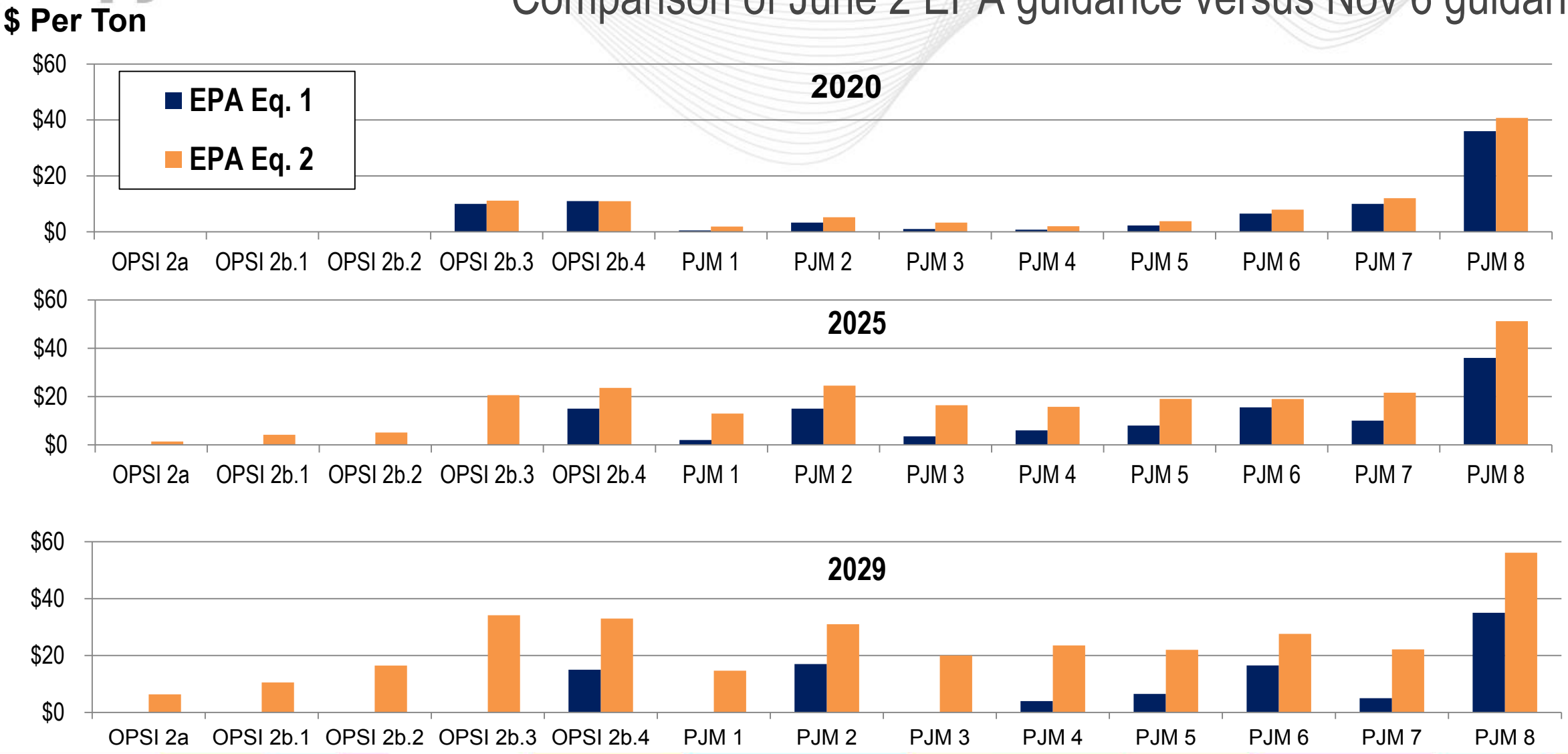
	Fossil Resources	Nuclear	Renewables	Energy Efficiency (EE)
PJM 1	Existing and Planned Resources (ISA and FSA only)		EPA Expected Renewables	50% EPA EE
PJM 2	Existing and Planned Resources (ISA and FSA only) Adjust planned natural gas capacity based on historic commercial probability		Existing Wind & Solar	17/18 BRA Cleared
PJM 3			Existing Wind & Solar	100% EPA EE
PJM 4	Existing and Planned Resources (ISA and FSA only)		Trend Wind/Solar and Energy Efficiency Based on historic growth Rates: Wind and Solar – IS, UC Energy Efficiency - PJM BRA Cleared MW	
PJM 5	Existing and Planned Resources (ISA and FSA only) Adjust planned natural gas capacity based on historic commercial probability			
PJM 6	Existing and Planned Resources (ISA and FSA only) Adjust planned natural gas capacity based on historic commercial probability 10% Nuclear Retirement			
PJM 7	Same as PJM 5 except Reduce new NGCC capacity to not exceed IRM Target			
PJM 8	Same as PJM 7 with Henry Hub gas price set to 50% higher			
PJM 9	Same as PJM 4 Scenario – but simulated for state-by-state compliance			
PJM 10	Same as PJM 4 Scenario – but simulated to achieve regional mass target			

Section IV: Regional Compliance Mass Target Emissions and Price Comparisons

CO_2 Emissions With no Carbon Price



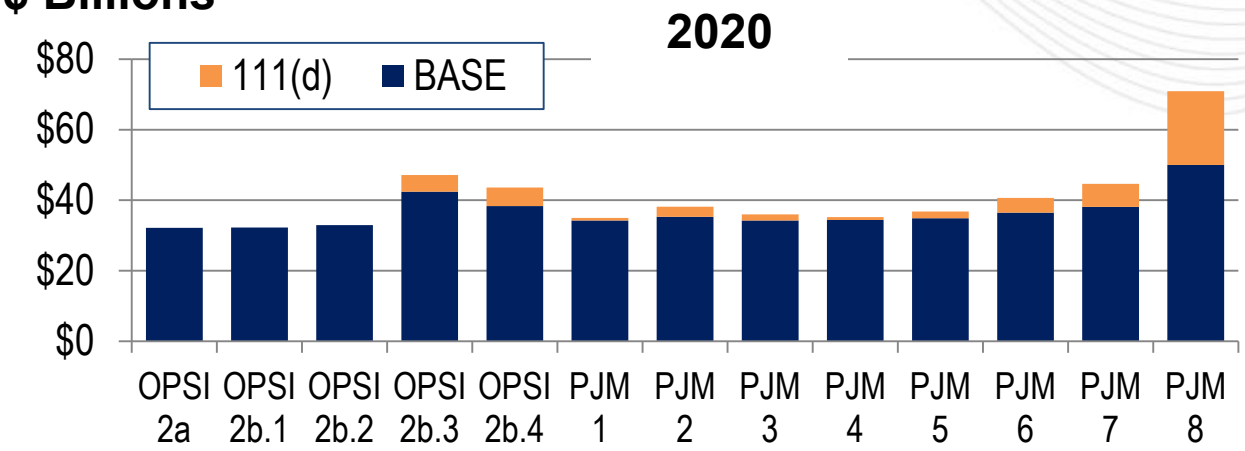
Implied Carbon (CO_2) Price in 2020, 2025 and 2029
Comparison of June 2 EPA guidance versus Nov 6 guidance

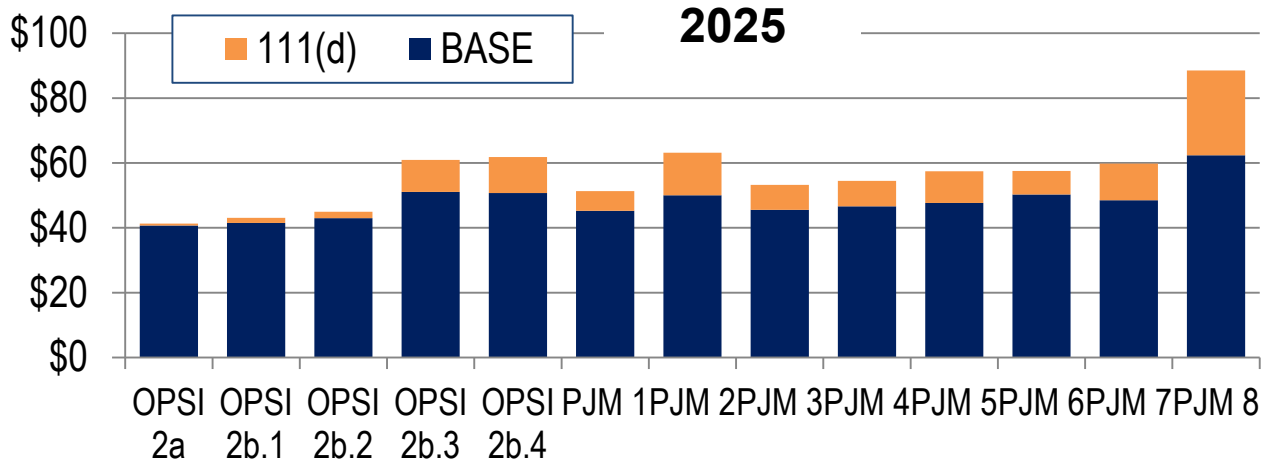


2020 & 2025 Load Energy Payment
Comparison of June 2 EPA guidance versus Nov 6 guidance

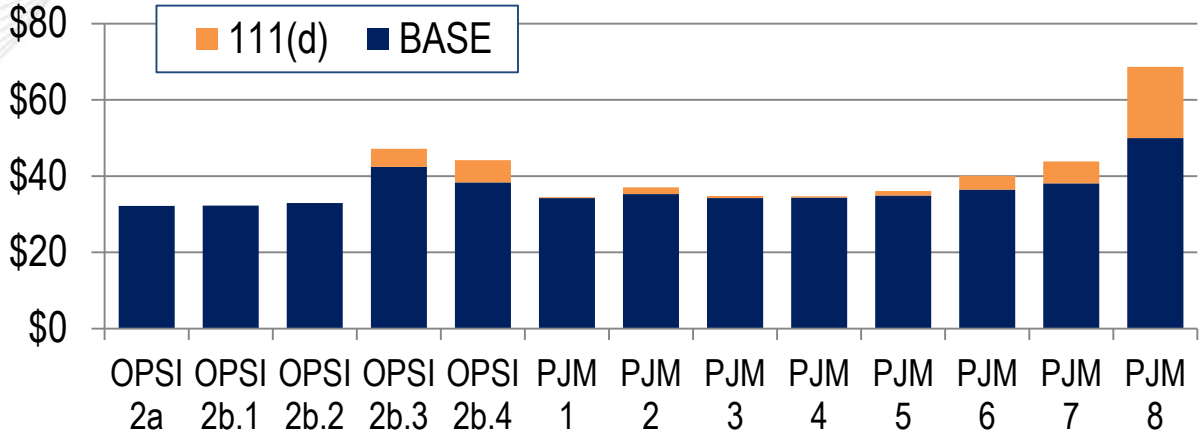
EPA Eq. 2

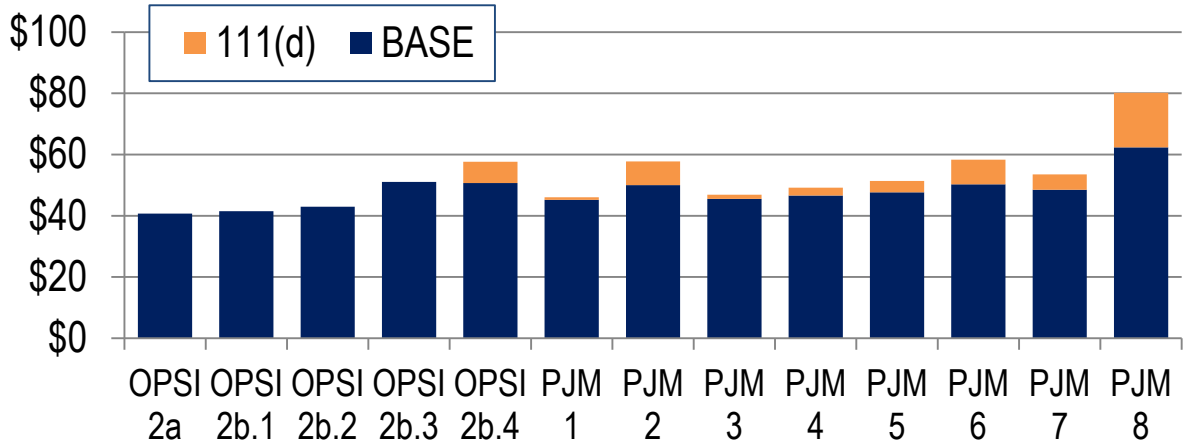
$ Billions





EPA Eq. 1

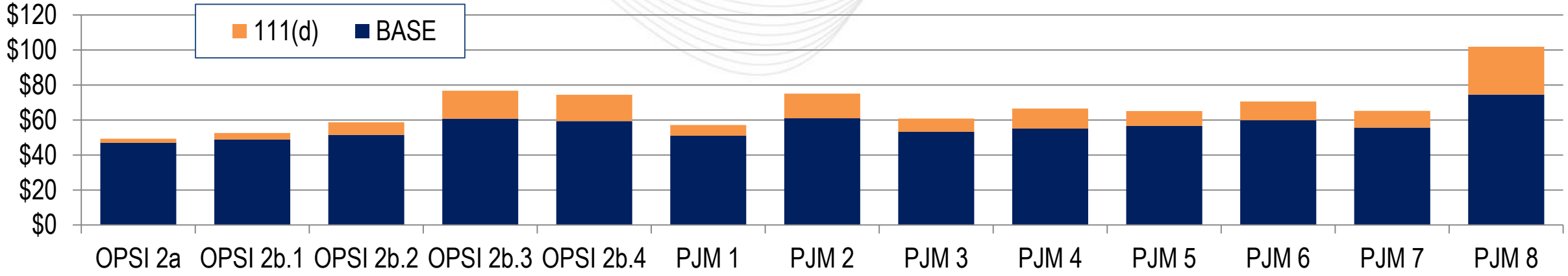




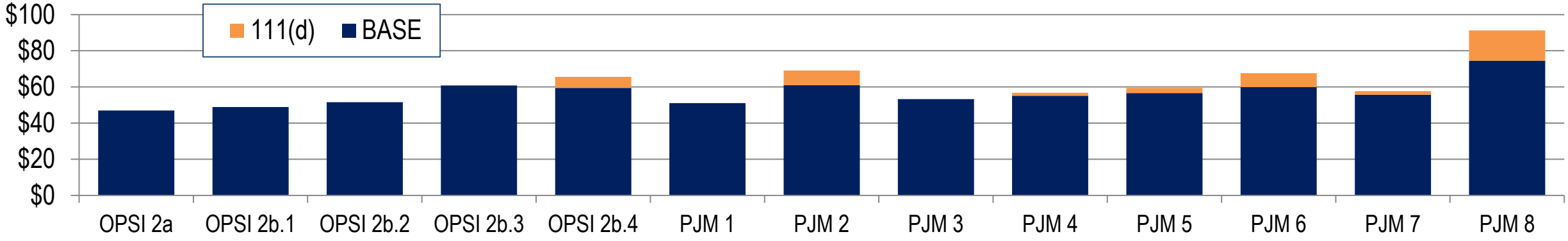
2029 Load Energy Payment
Comparison of June 2nd EPA guidance versus Nov 6th guidance

$ Billions

EPA Eq. 2

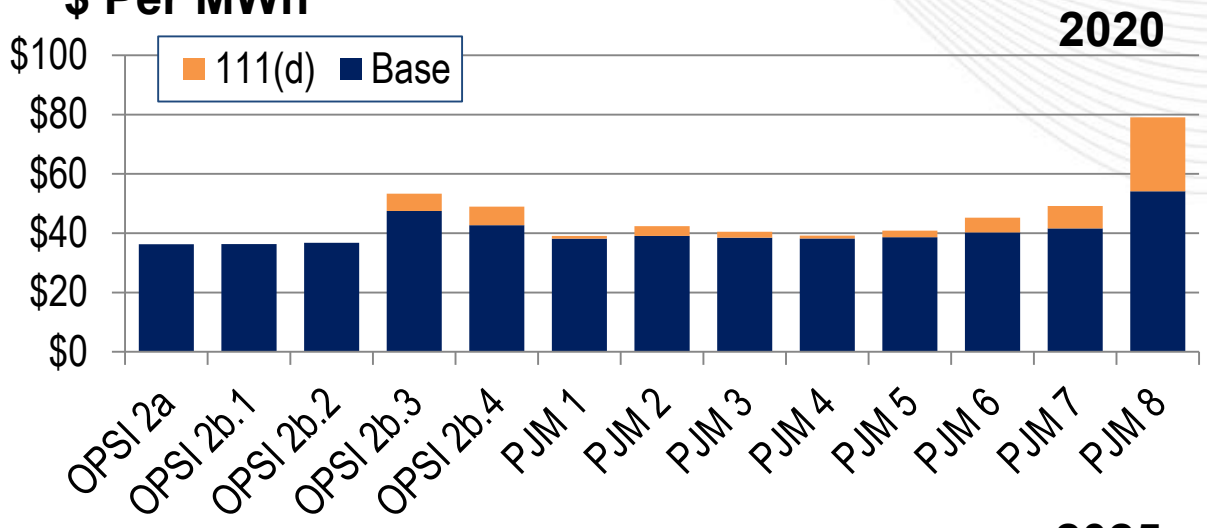


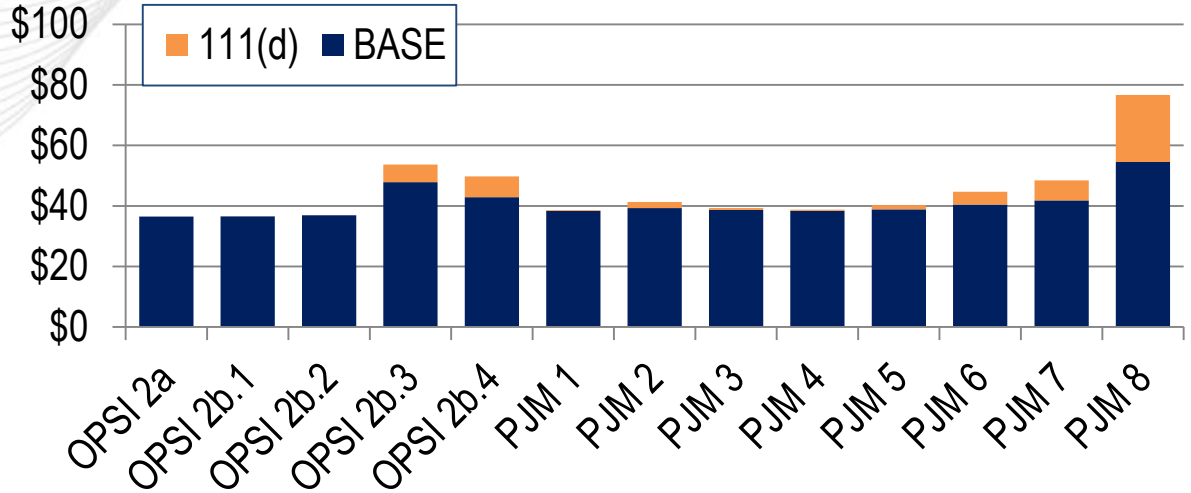
EPA Eq. 1

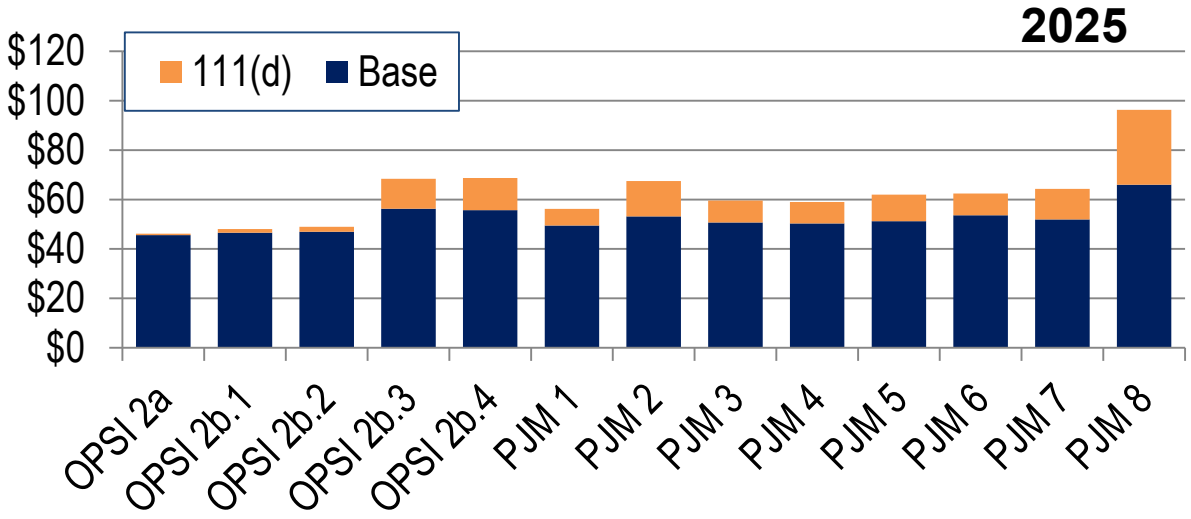


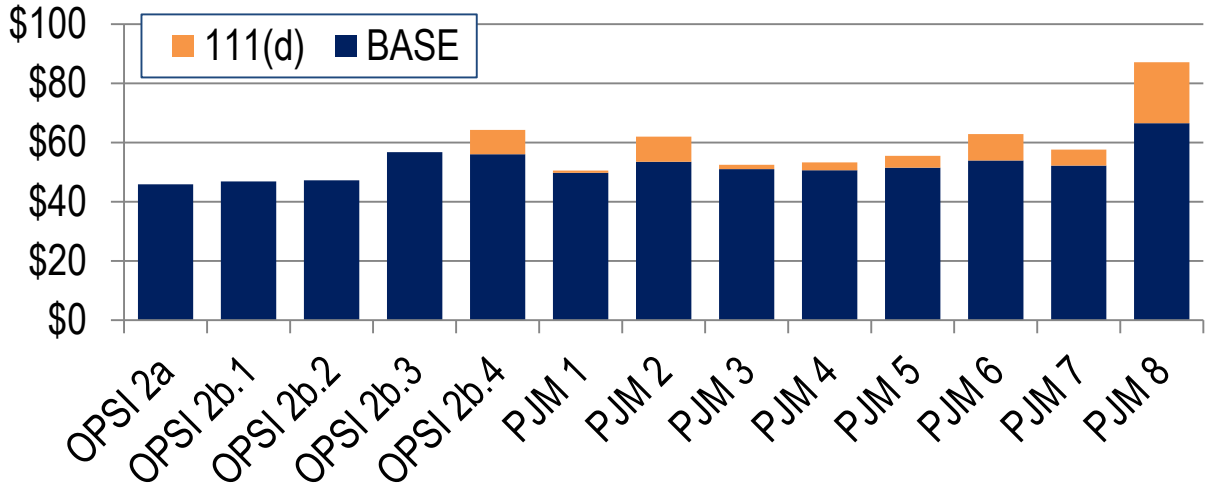
2020 & 2025 PJM Average Locational Marginal Price
Comparison of June 2 EPA guidance versus Nov 6 guidance

$ Per MWh

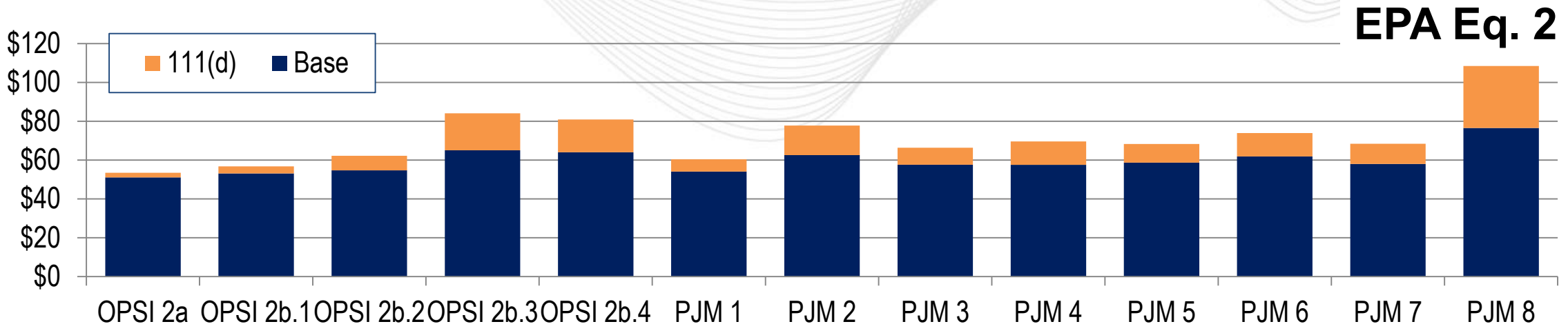


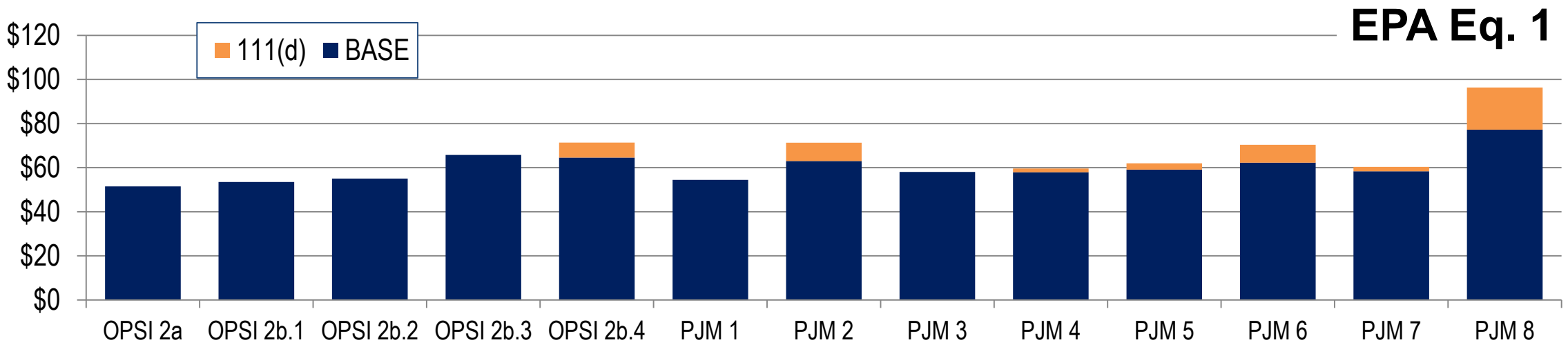






2029 PJM Average Locational Marginal Price
Comparison of June 2 EPA guidance versus Nov 6 guidance

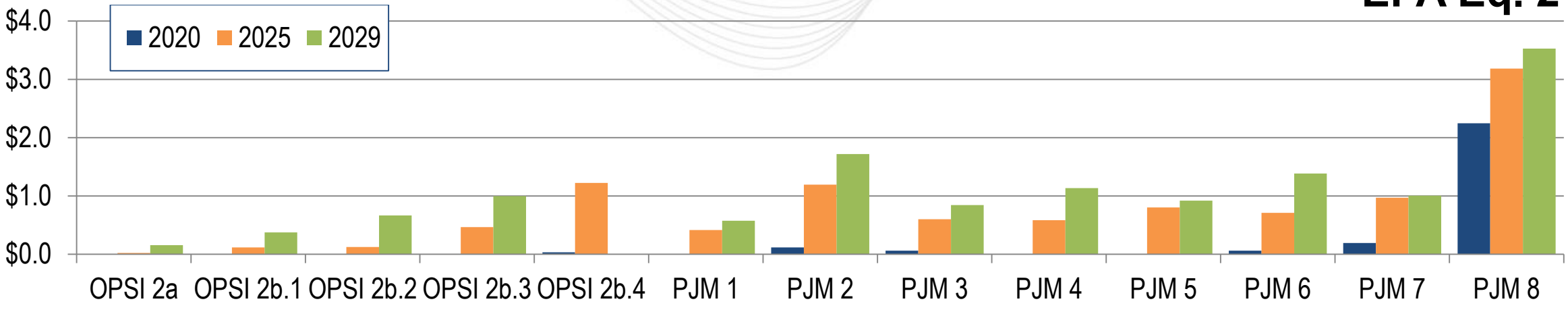




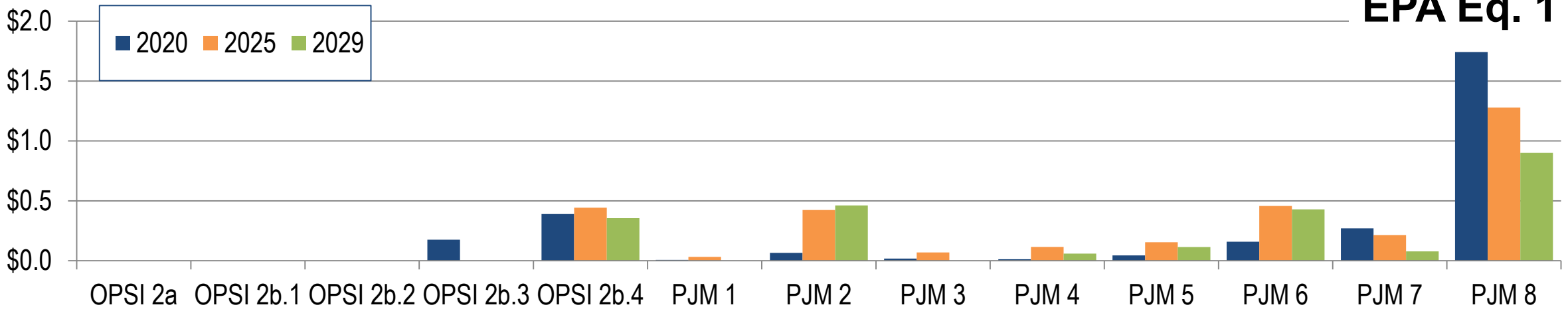
Variable Compliance Costs (Implied CO_2 Allowance Value Not Included)
Δ in Fuel and Variable O&M Costs due to 111(d) Policy

$ Billions

EPA Eq. 2



EPA Eq. 1



Section V: State Versus Regional Compliance

Notes:

Unless otherwise noted All results are based on November 6th guidance, EPA Equation #2

Regional vs. State Compliance Modeling

Regional Approach

- A single price on CO_2 is applied to all carbon emitting resources across PJM.
- This in turn raises the costs of carbon intensive resources, impacting dispatch, which is done on a lowest cost basis.
- The approach results in satisfying the emissions target with the least cost mix of resources to meet PJM load requirements.

State by State Approach

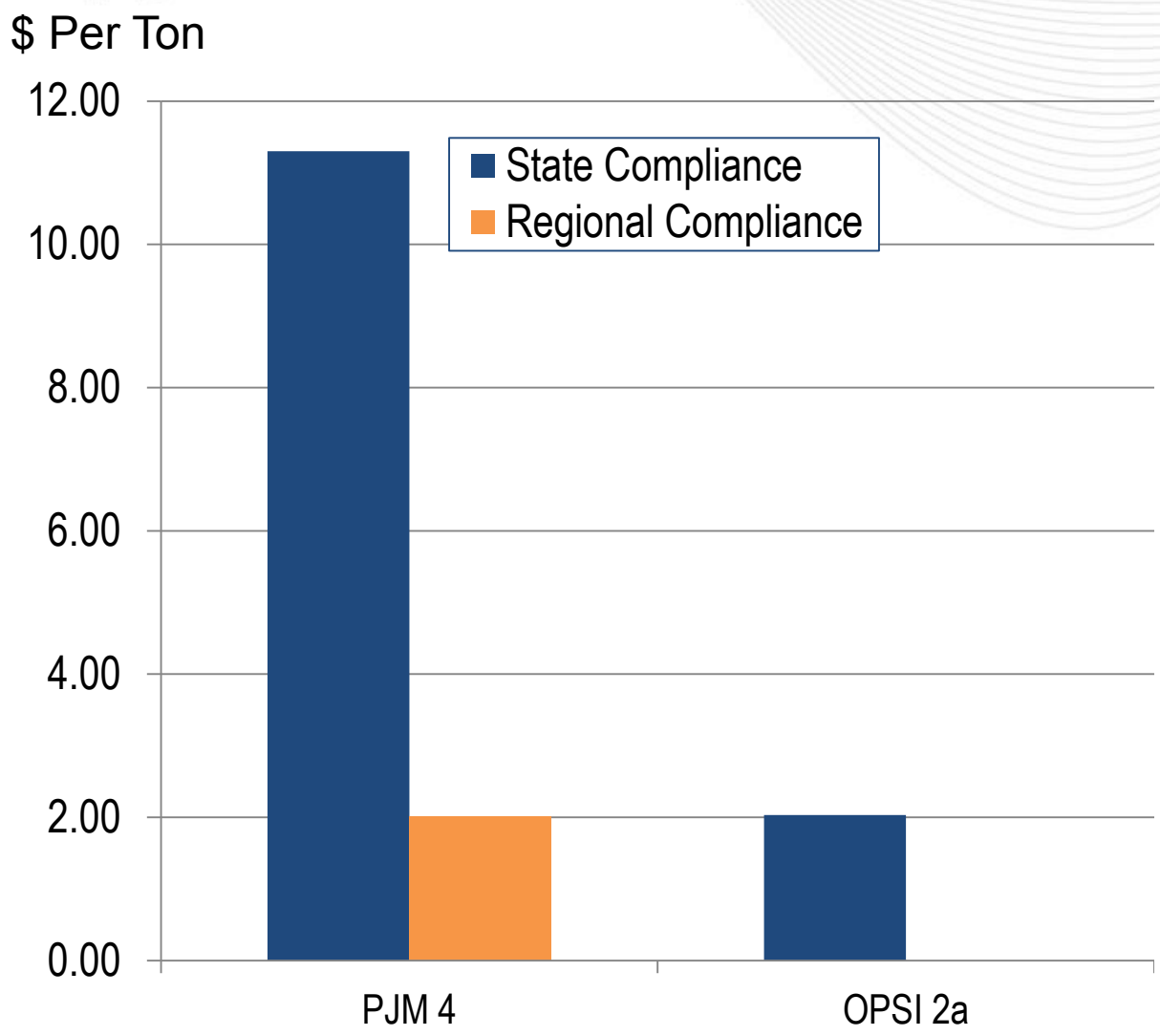
- Each state has an individually determined price on CO_2 applied to the carbon emitting resources located within it to ensure satisfaction of emissions target.
- Those prices are applied, and PJM dispatches the resources across the region to determine the least cost mix to meet the total PJM load requirements.
- The approach results in each state satisfying its emissions target and the resource mix being the least-cost combination, as influenced by disparate CO_2 prices, to meet the PJM load requirements.

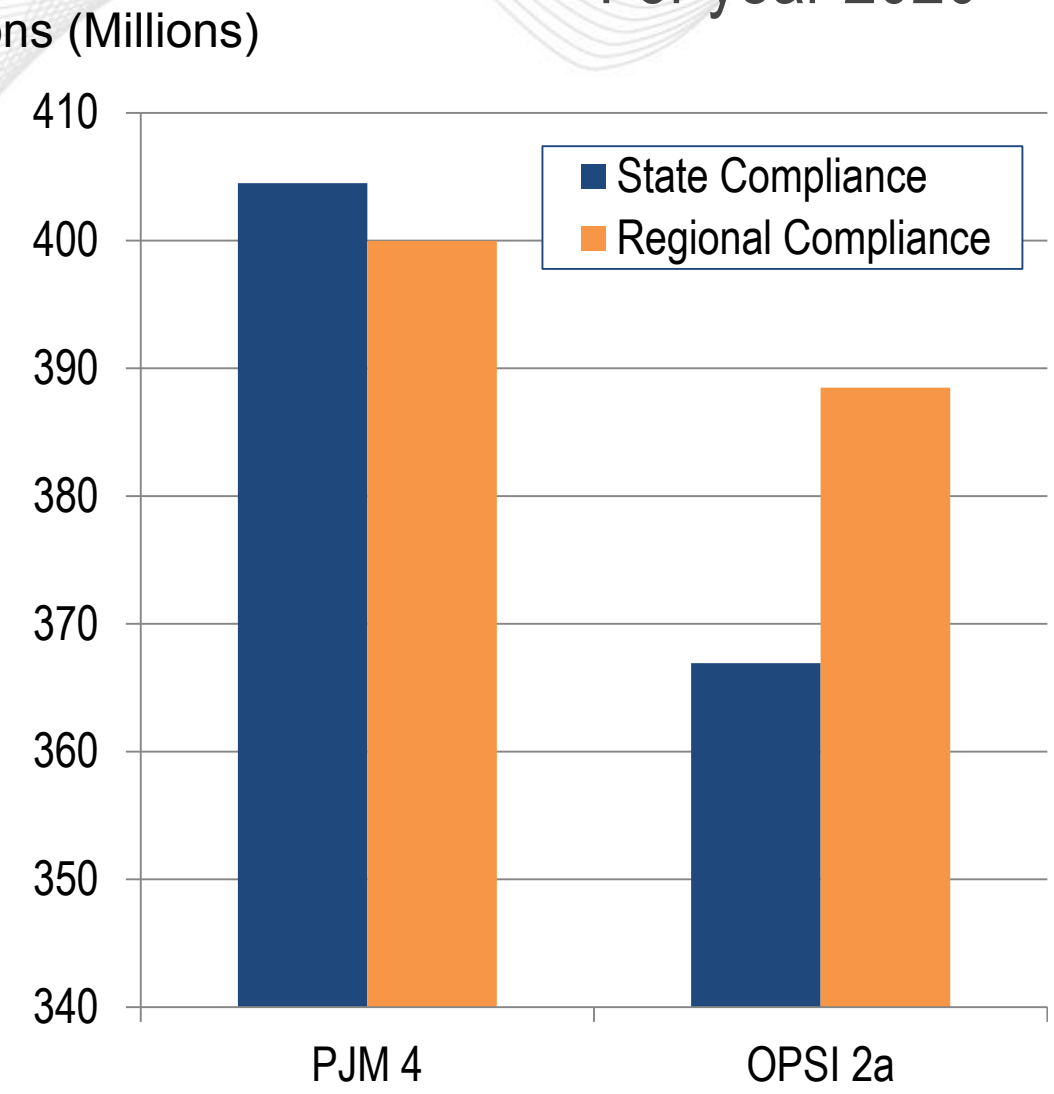
Description of Scenarios Evaluated For State Analysis

Driver	OPSI 2a	PJM 4
Renewables	81.9 GWH	50.2 GWH
New NGCC	19 GW	19 GW
Nuclear	33.4 GW	33.4 GW
Gas Price	Economic Forecast	Economic Forecast
Energy Efficiency	23.3 GWh	9.2 GWh

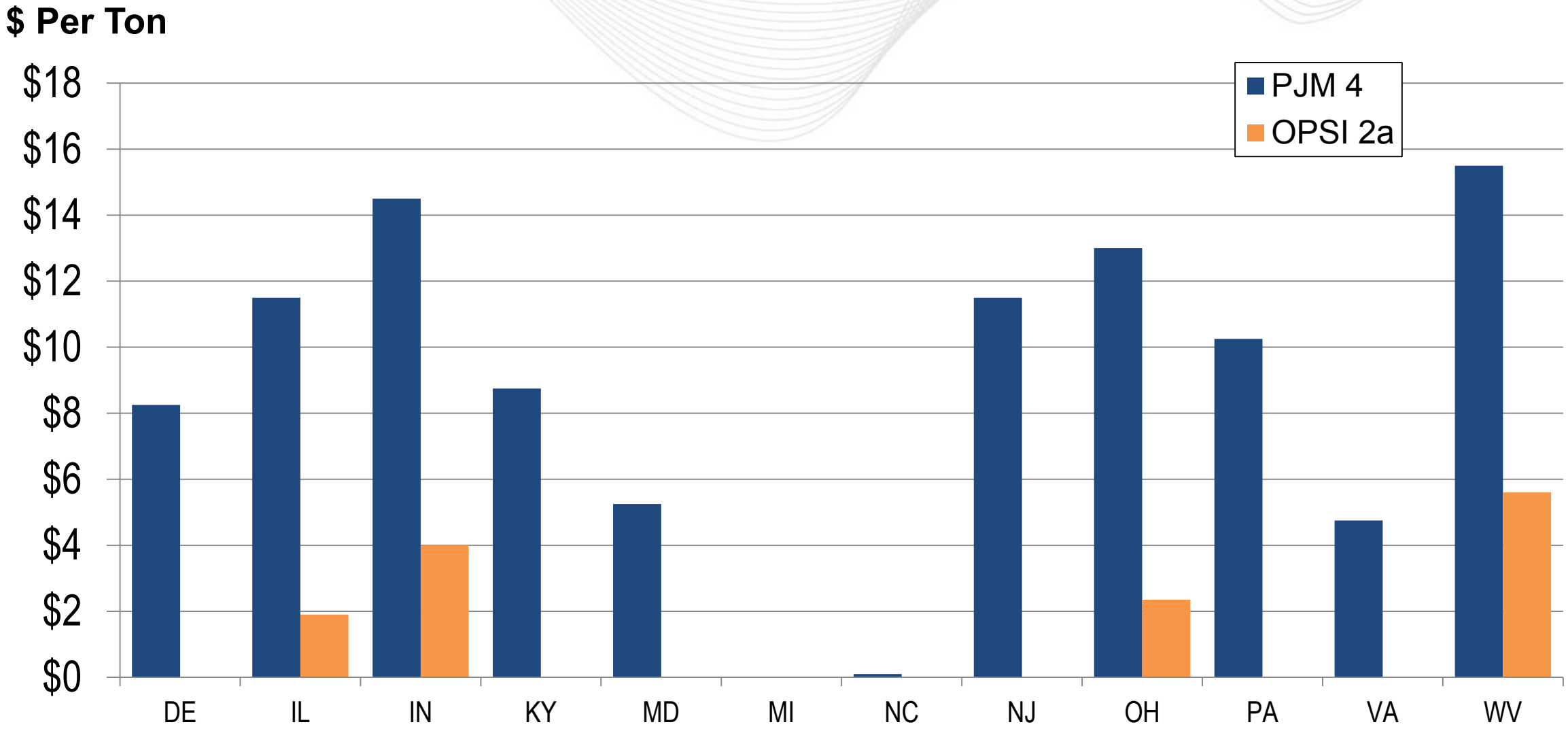
States only evaluated for compliance with 2020 interim target

Carbon Price under State Compliance Versus Regional Compliance For year 2020

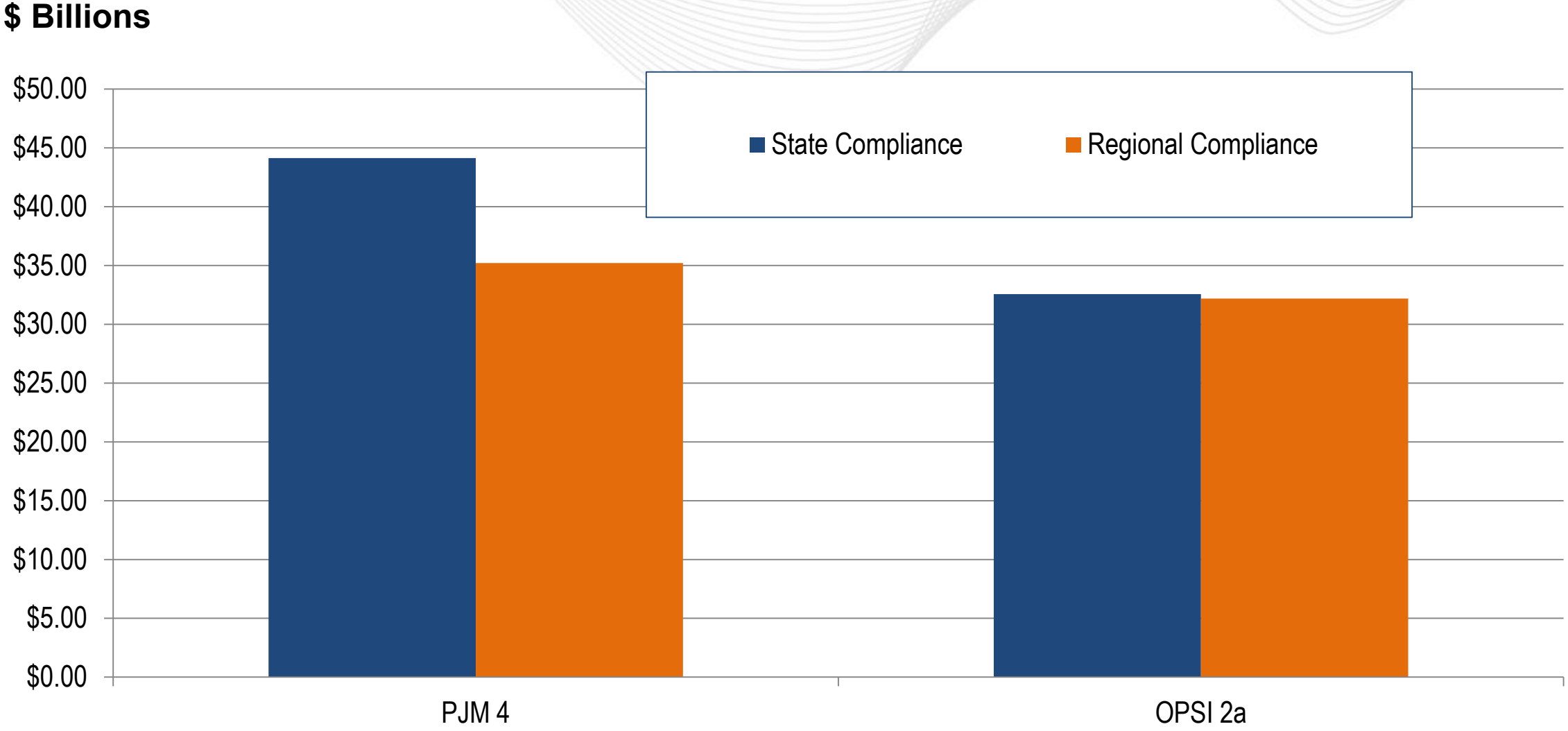




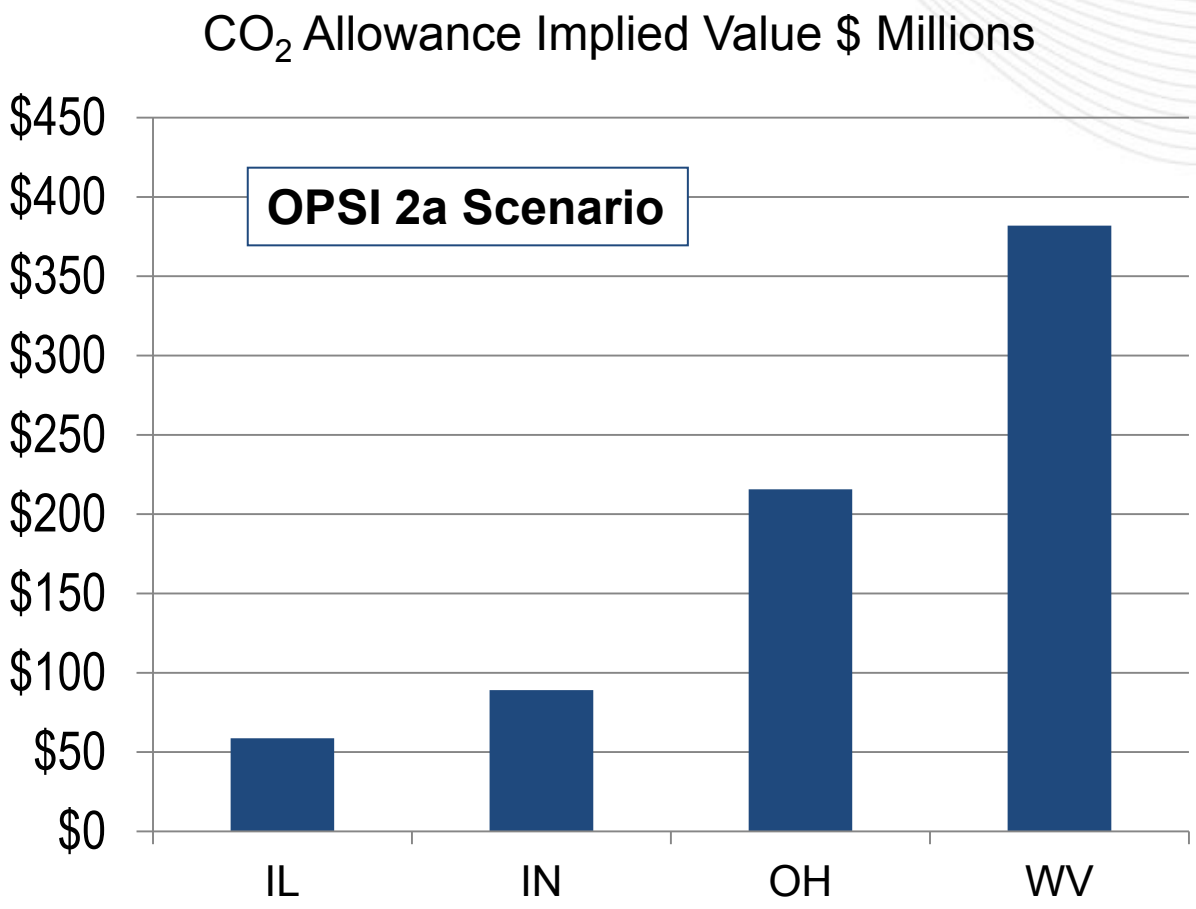
Individual State Implied Carbon (CO_2) Prices For year 2020

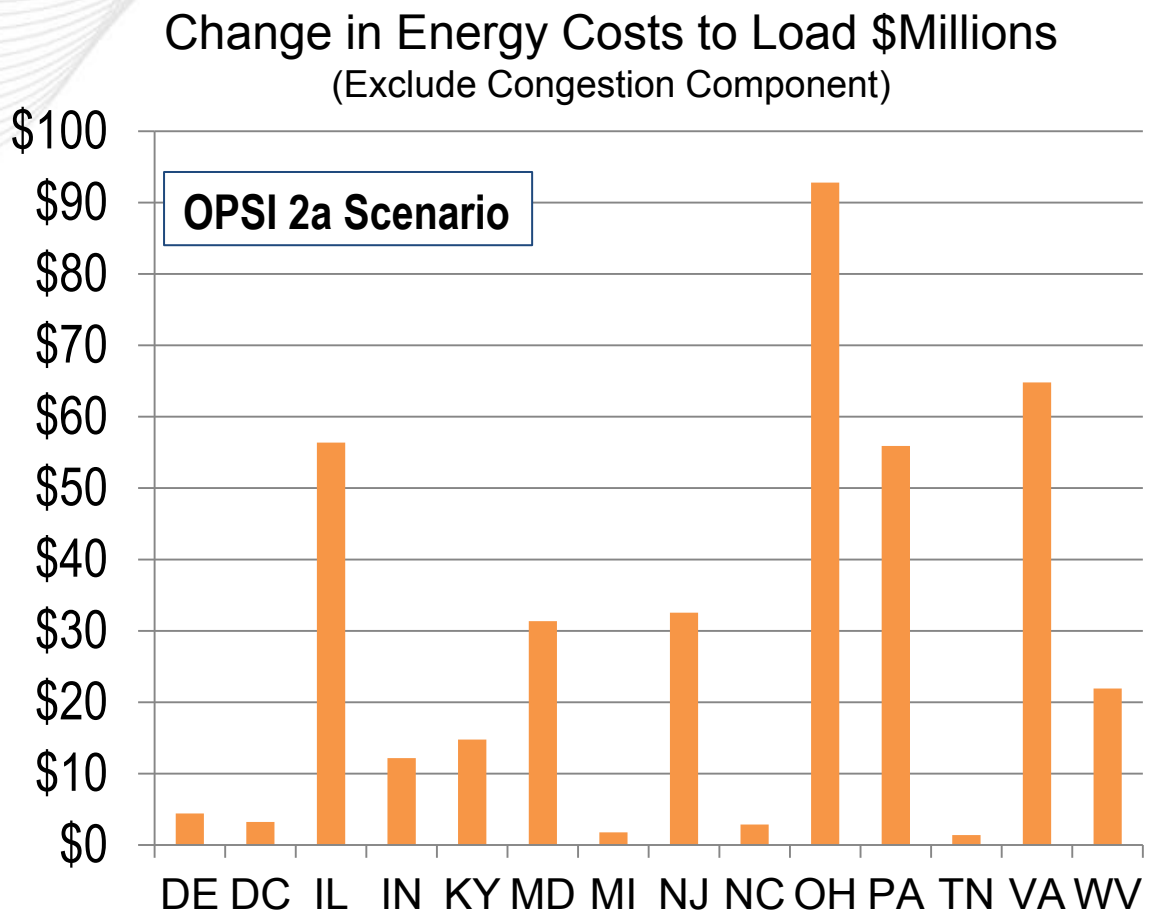


PJM Total Load Payment
State Versus Regional Compliance For Year 2020



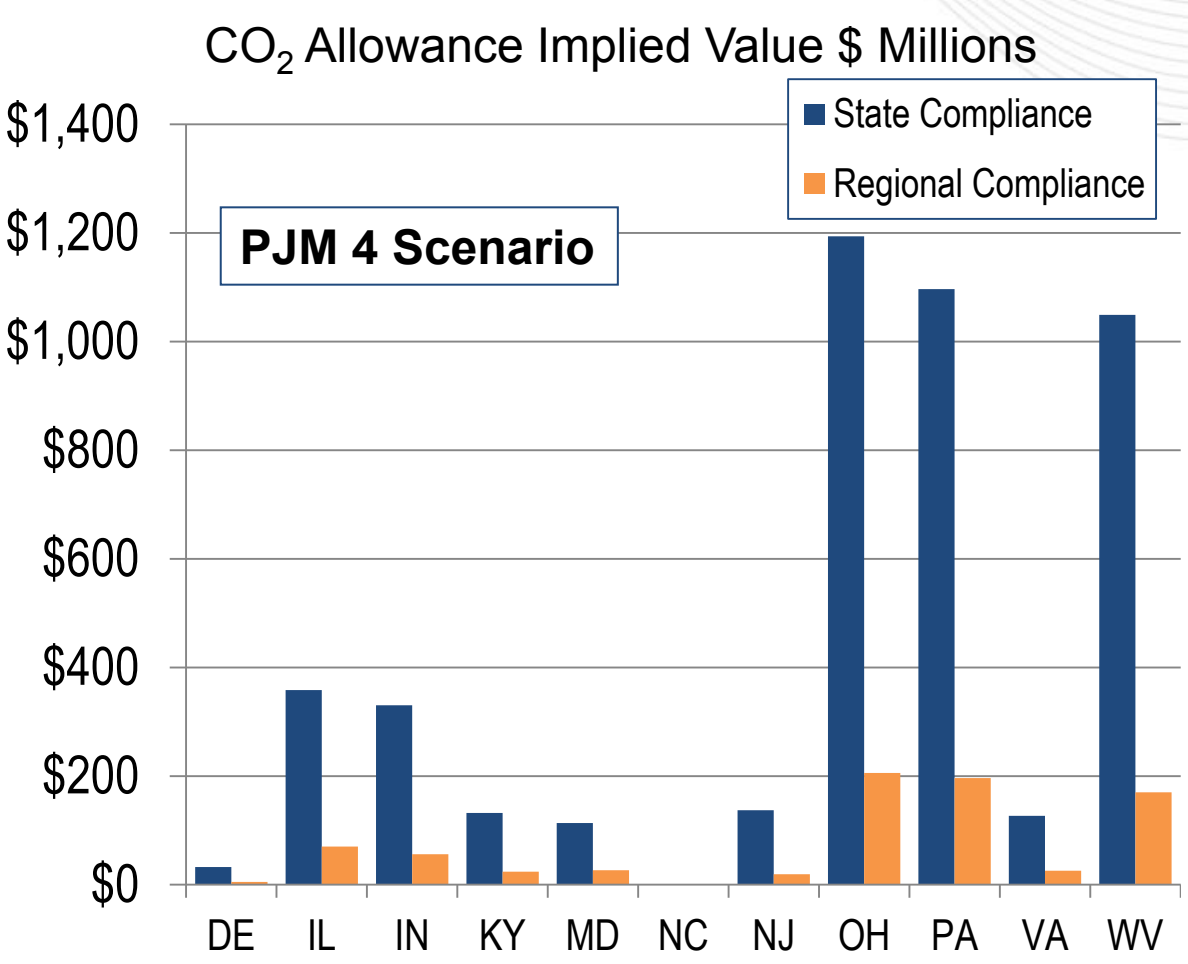
Implied CO_2 Allowance Cost Comparison and State Energy Cost Impact of Individual State Compliance Versus Regional Compliance For 2020

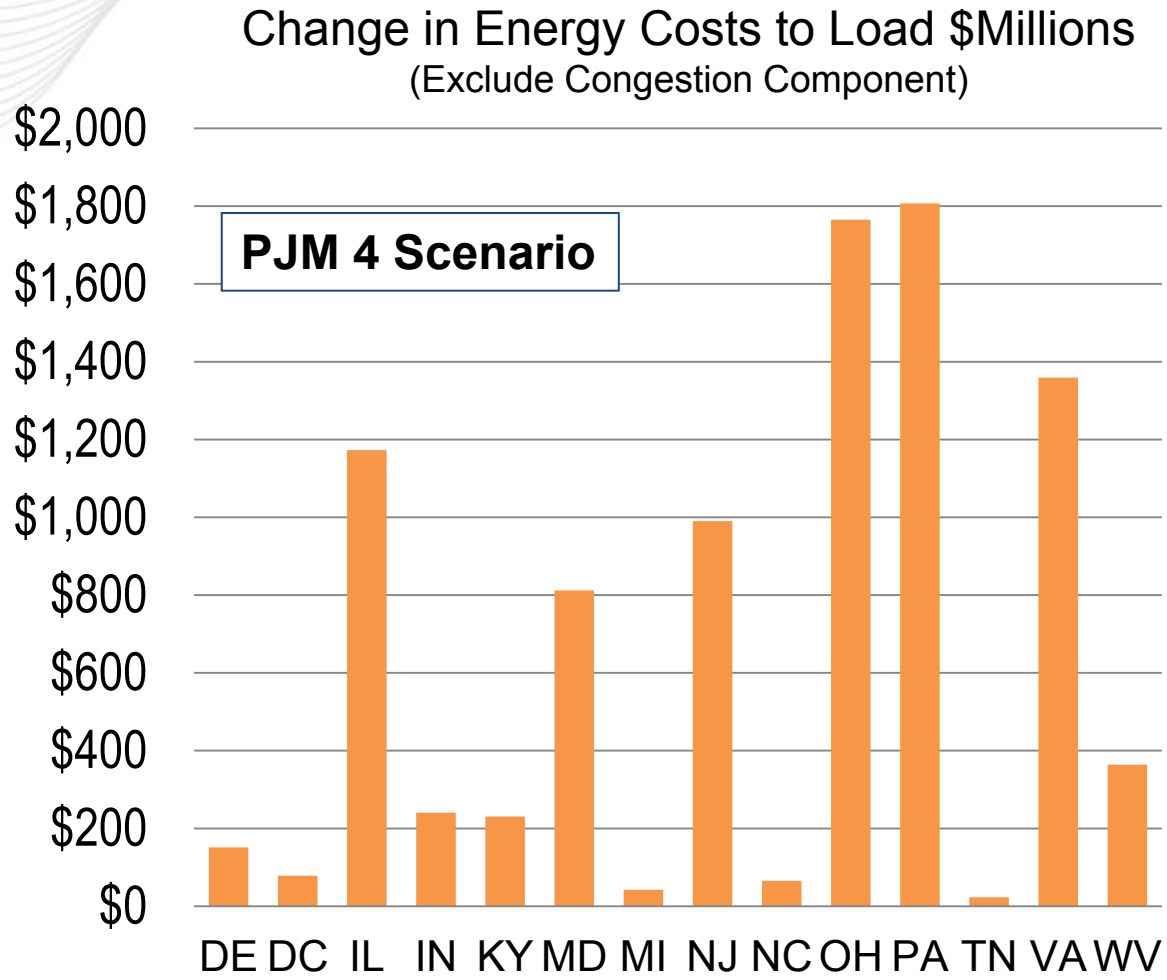




Regional Compliance Case did not result in redispatch – Consequently, there is no additional compliance costs

Implied CO_2 Allowance Cost Comparison and State Energy Cost Impact of Individual State Compliance Versus Regional Compliance For 2020





Section VI: Rate Based Versus Mass-Based Compliance

Notes:

Rate Based Compliance Impacts were measured using the PJM #4 Scenario for 2025 and 2029

2025 CO_2 rate target is equivalent to the interim (average) target for 2020 through 2029

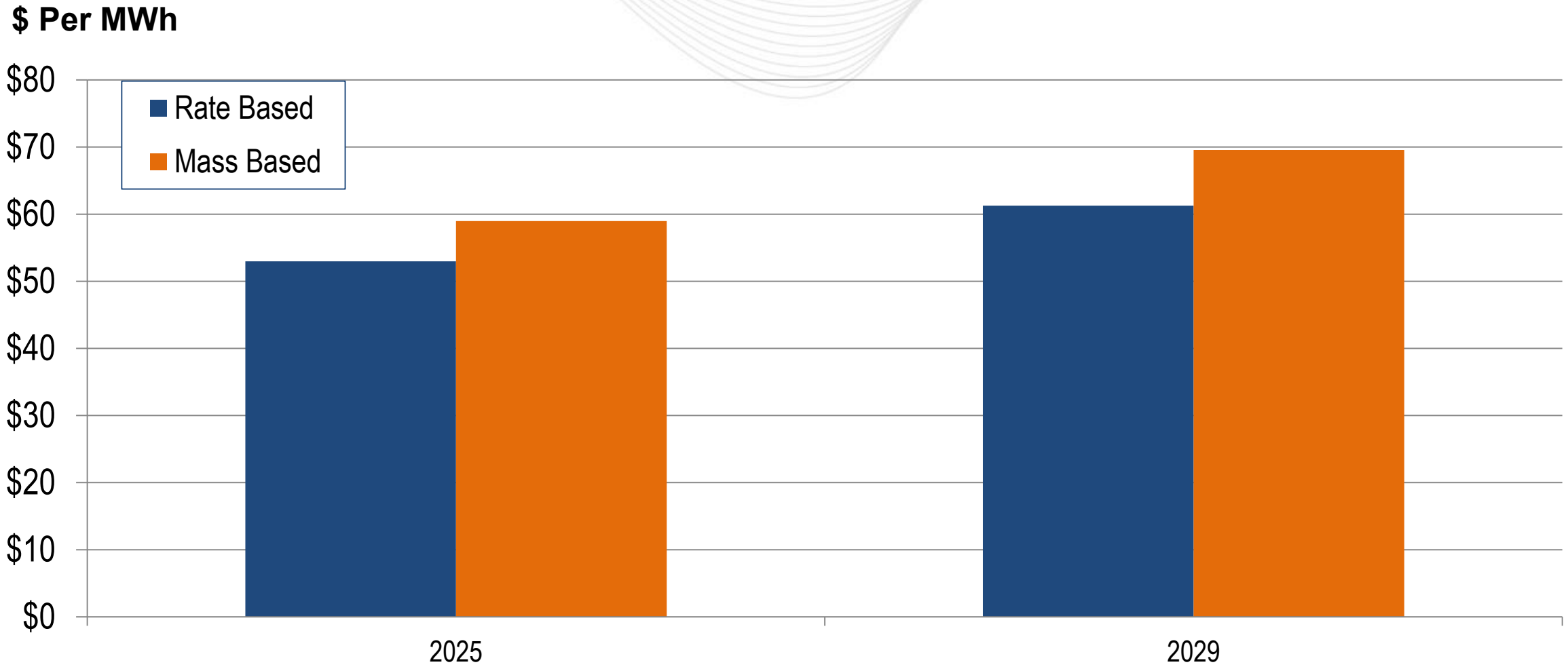
All results are based on November 6th guidance, EPA Equation #2

Implementation of Rate-Based Method

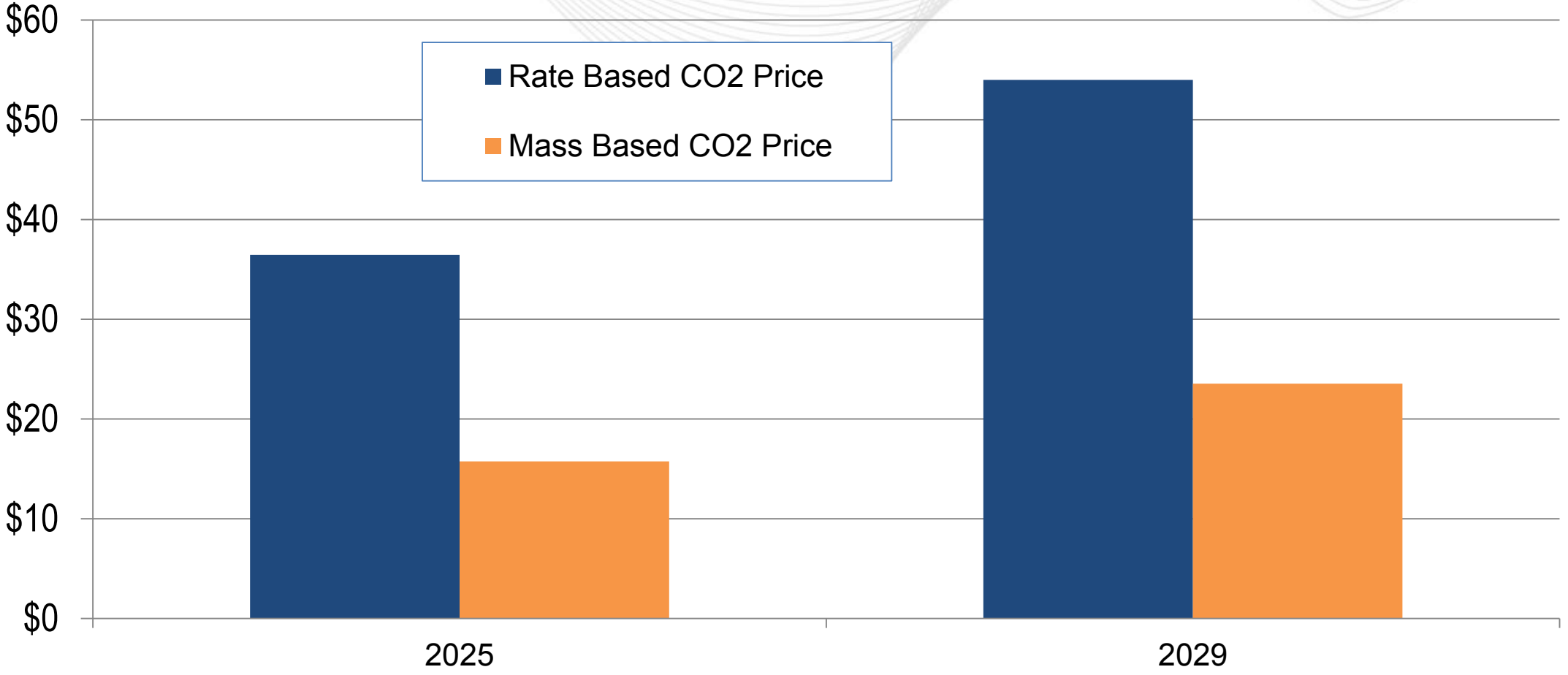
- Individual Resource Price adder to be applied to all covered units
  - Unit Price Adder = Heat Rate x (Emissions Rate – Target Rate) x CO_2 price
  - Emissions Rate < Target Rate yields production credit
  - Emissions Rate > Target Rate yields transfer payment
- Unit's bid price reflects either production credit or penalty as a function of performance

$$\text{System } CO_2 \text{ Target Rate} = \frac{\text{lbs of } CO_2 \text{ from affected Sources}}{\text{Nuclear}_{,\,ar} + \text{Renewables} + \text{Incremental EE} + \text{Affected Source MWh's}}$$

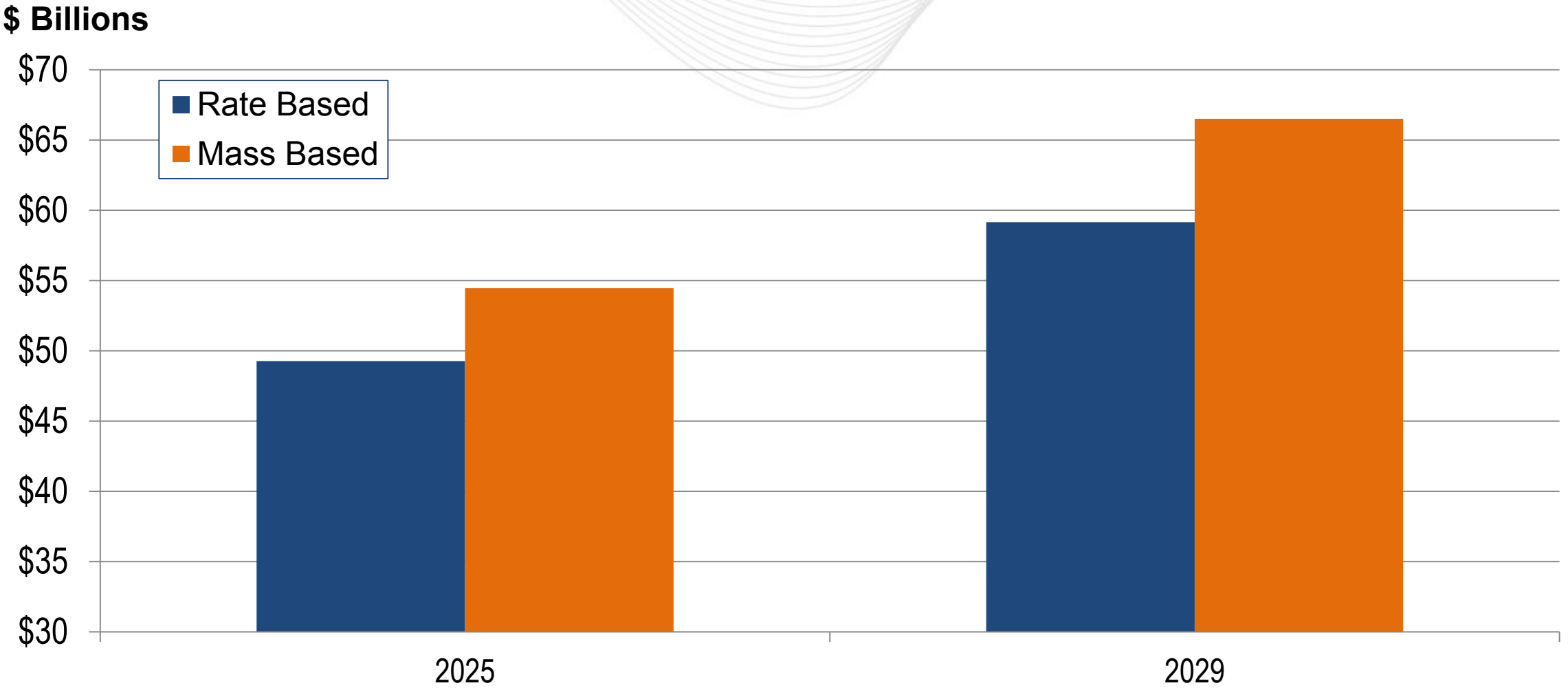
PJM Locational Marginal Price: PJM 4
Rate Based (Performance) Versus Mass-Based Regional Compliance



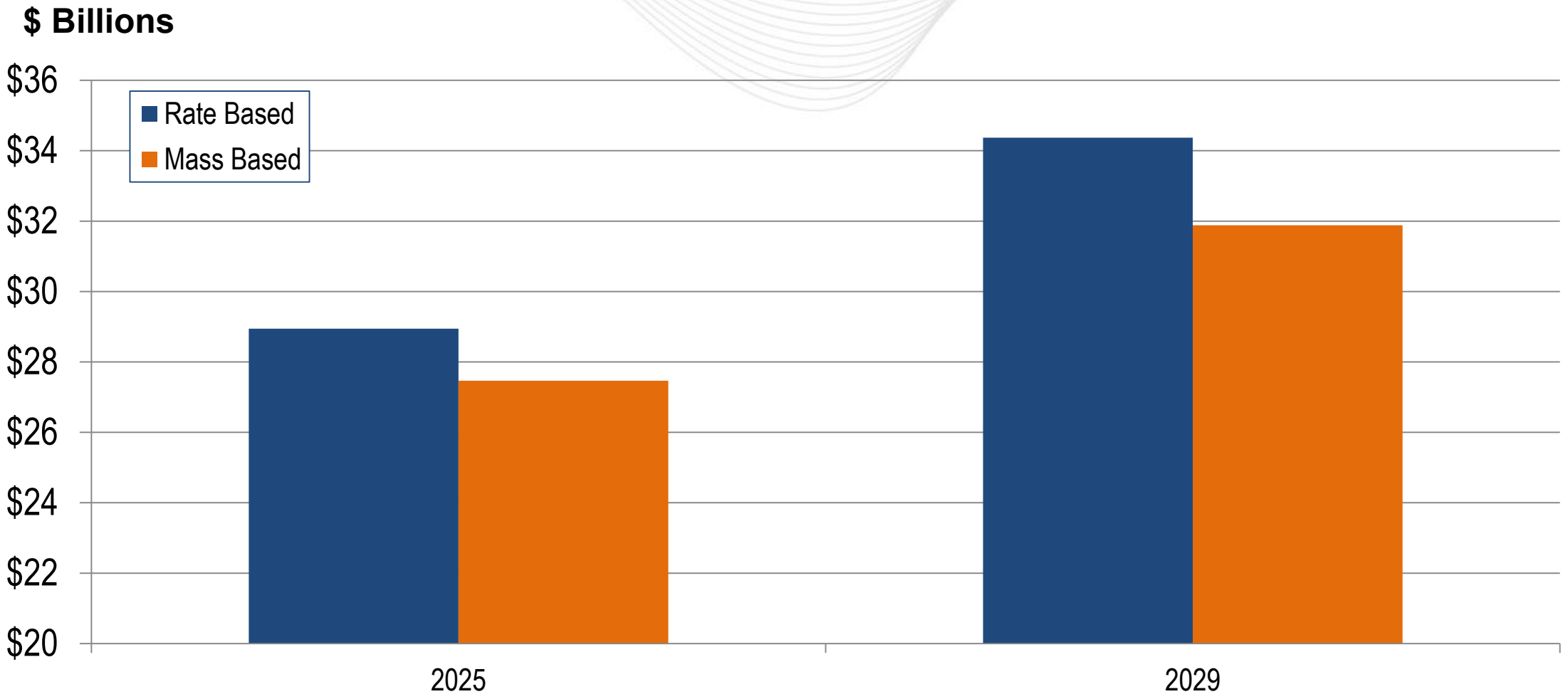
PJM Implied Carbon (CO_2) Price: PJM 4 Under Rate Based (Performance) Versus Mass Based Compliance



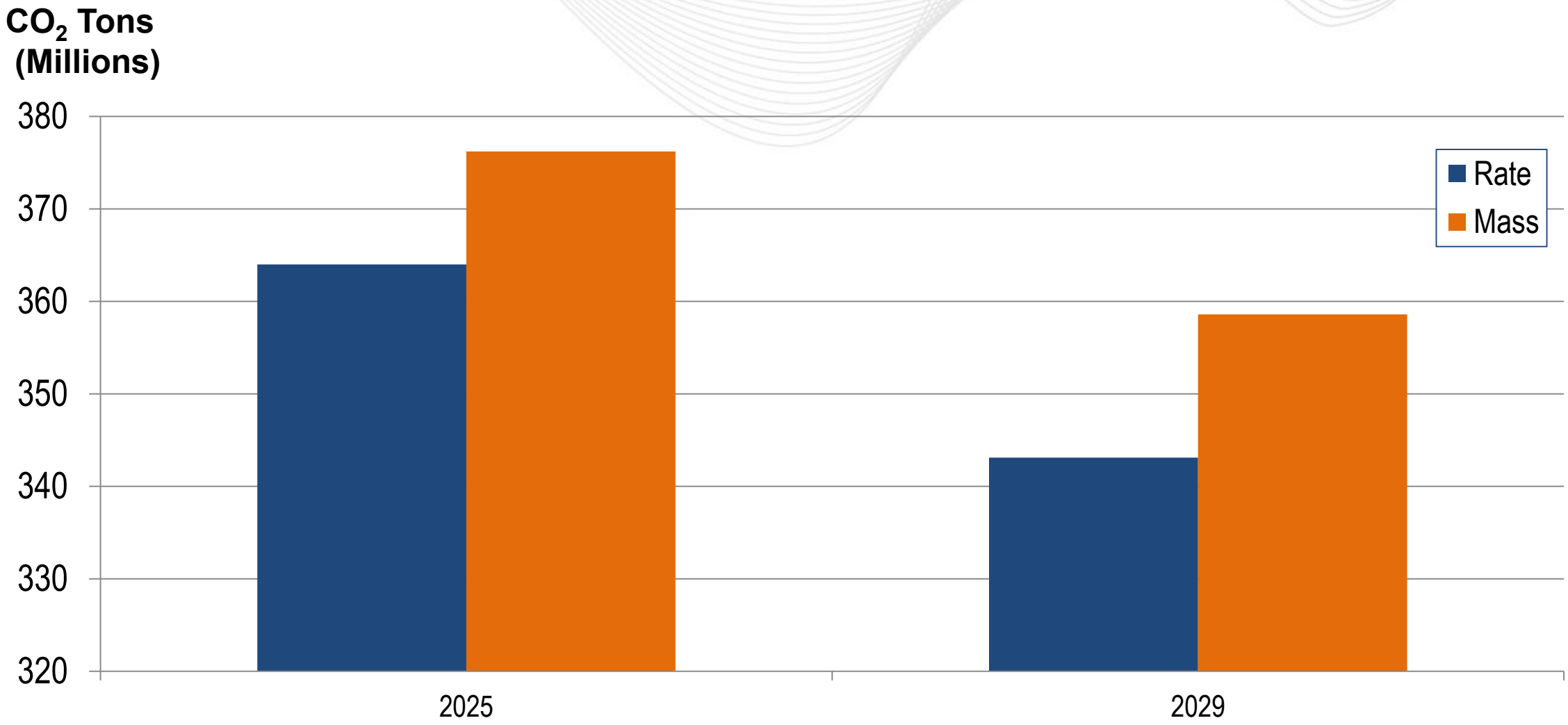
Total PJM Load Payment: PJM 4
Rate Based (Performance) Versus Mass-based Compliance



Total PJM Production Costs Comparison: PJM 4 Rate Based (Performance) Standard Versus Mass Based Standard



Total PJM CO_2 Simulated Emissions: PJM 4 Rate Based "Performance" Versus Mass Based Standard



Section VII: Economic Analysis of Steam Turbine Retirement Risk

Note:

units that have already announced deactivation are not included in this analysis; the analysis focused on "incremental" retirement risk

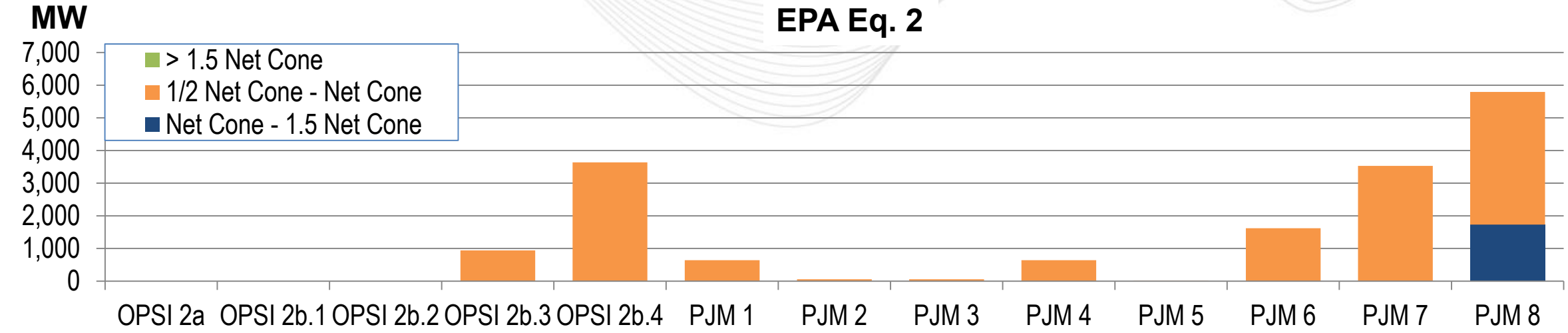
Economic Retirement Risk Analysis Key Variables

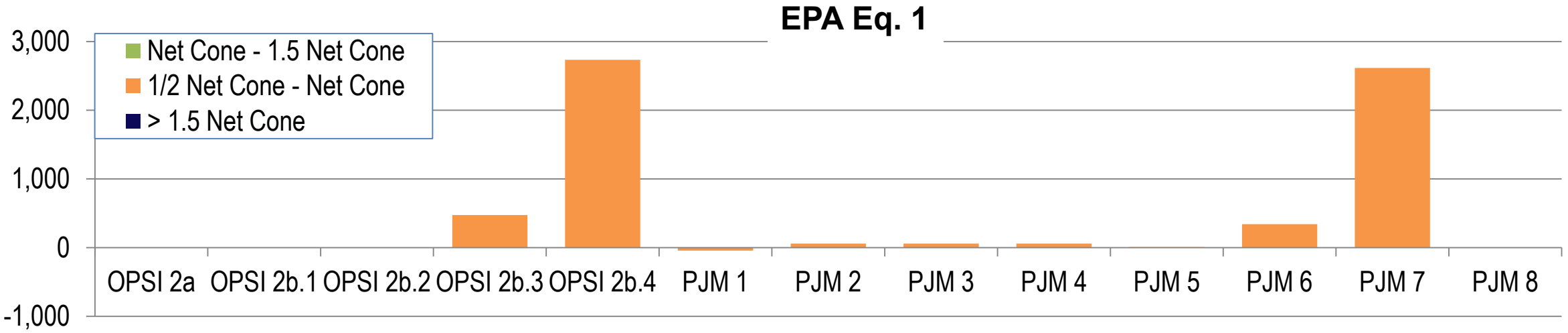
- Technology type and Avoidable Cost Rates (ACR) Determines annual avoidable costs used in calculating Market Seller Offer Caps in RPM
- Net Energy Market Revenues are based on simulation and exclude ancillary service revenue
- In the RPM Capacity Market, the price of capacity, and the quantity of capacity resources are determined within the auction framework
- Net Cost of New Entry (Combustion Turbine) is the benchmark price at which resource adequacy is achieved at the Reliability Requirement.
  - For a regulated utility, this would be a reasonable benchmark for making the decision to retain an existing unit, or retiring the unit and building a natural gas CT

Economic Risks is assessed based on Energy Market Revenues Net of Fixed (ACR) and Variable Operating Costs benchmarked against the following criteria:

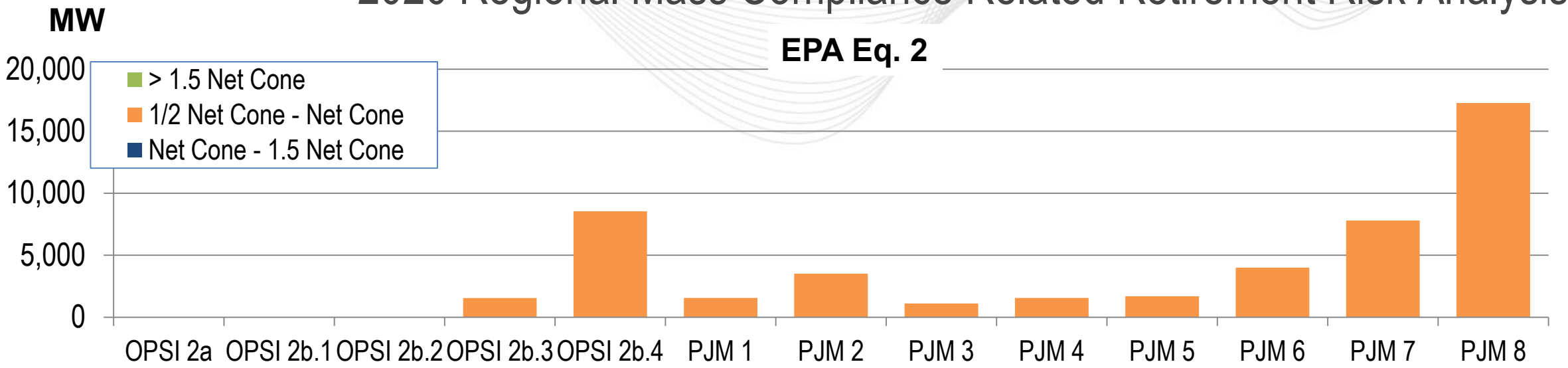
	> 1.5 Net CONE	Net CONE – 1.5 Net CONE	½ Net CONE – Net CONE	< ½ Net CONE
Financial Viability	Above max RPM LDA price	Above the cost of new entry gas CT	Would clear before new entry gas CT	Likely to clear Assuming no additional capital costs
Risk	"Very High" or "Most at Risk"	"High"	"at Risk" or "at some Risk"	"Low"

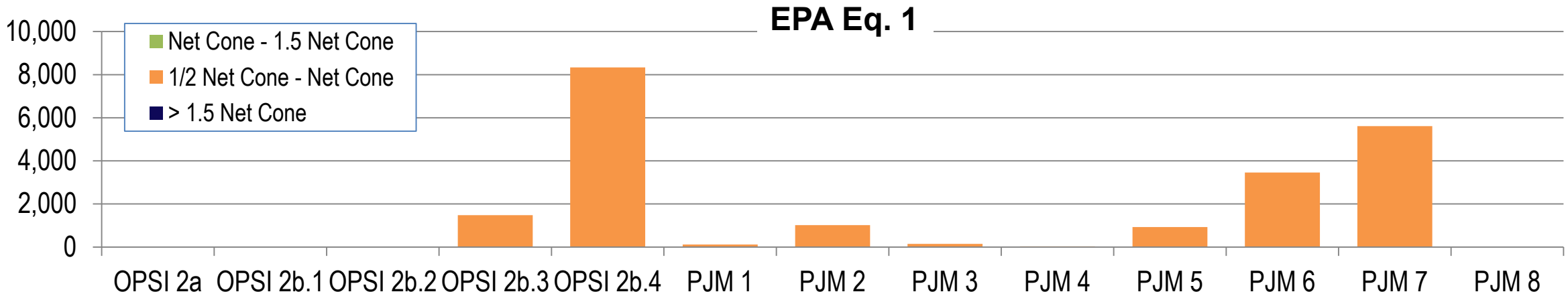
MAAC Region Steam Turbine
2020 Regional Mass Compliance Related Retirement Risk Analysis



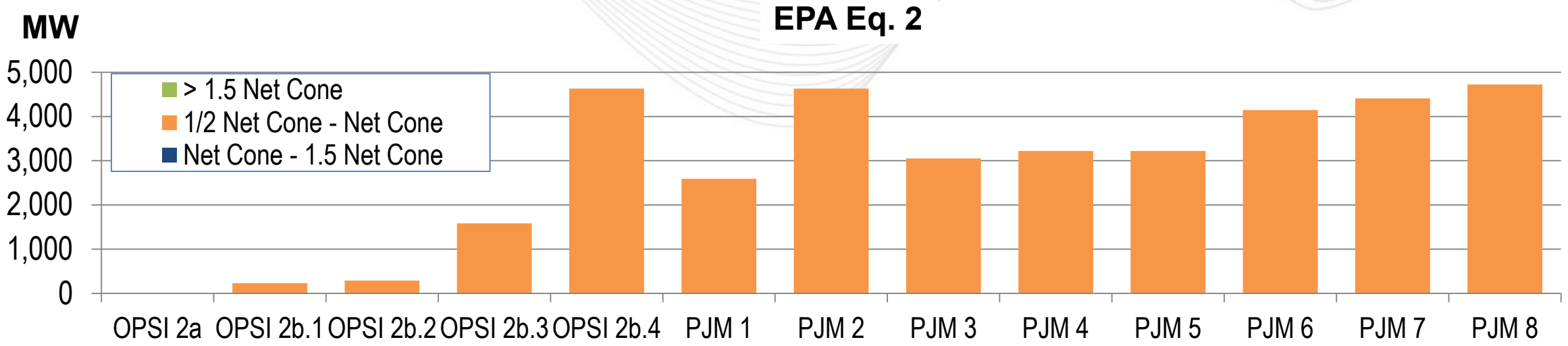


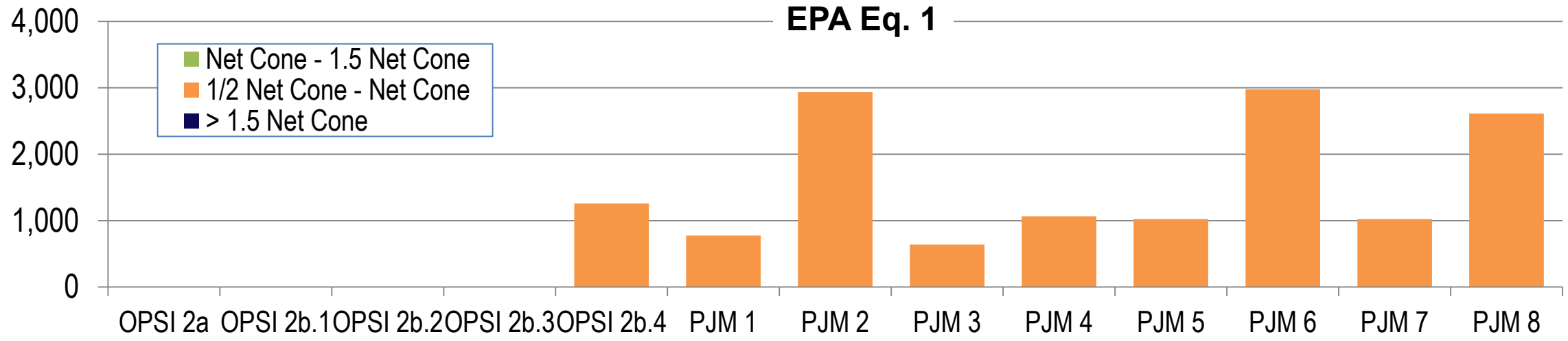
Rest of RTO Region Steam Turbine
2020 Regional Mass Compliance Related Retirement Risk Analysis



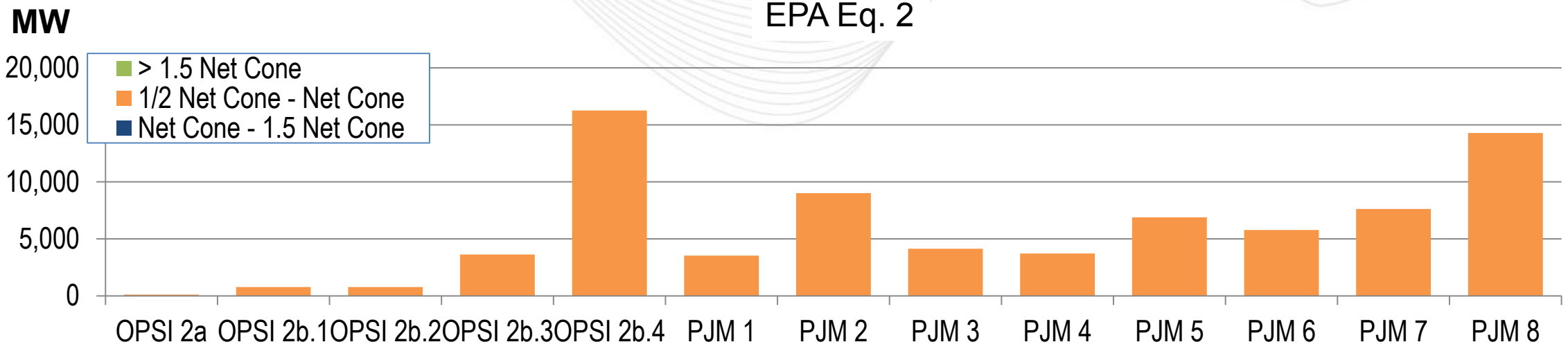


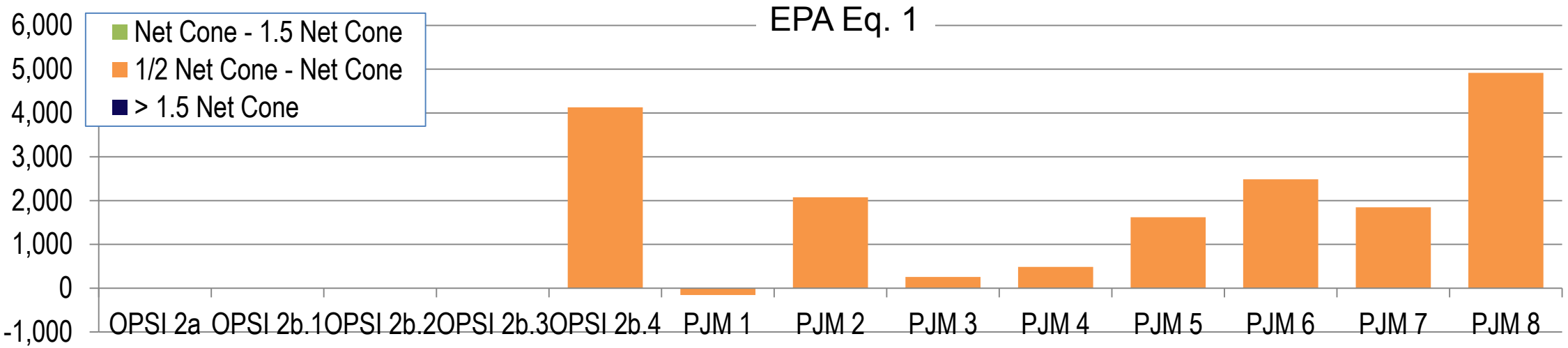
MAAC Region Steam Turbine
2025 Regional Mass Compliance Related Retirement Risk Analysis



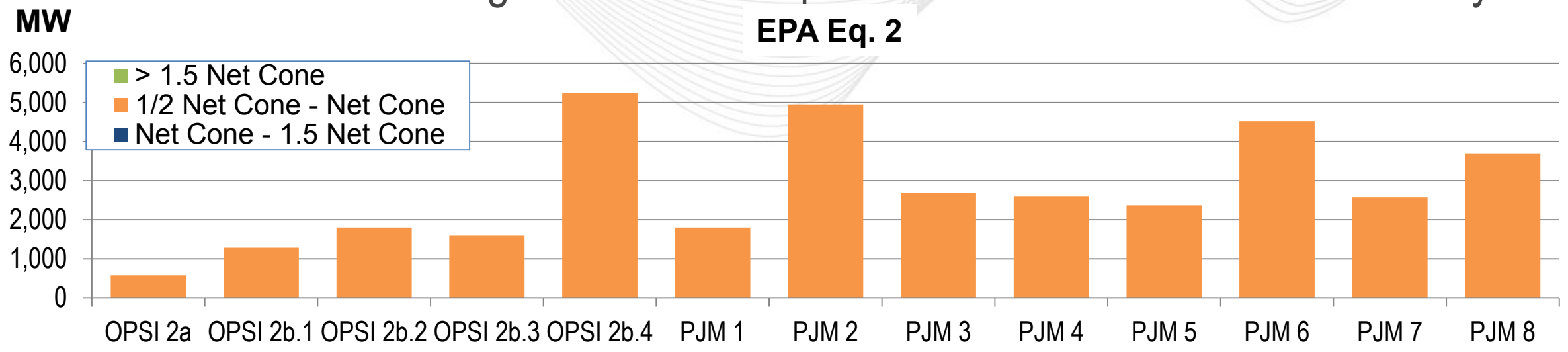


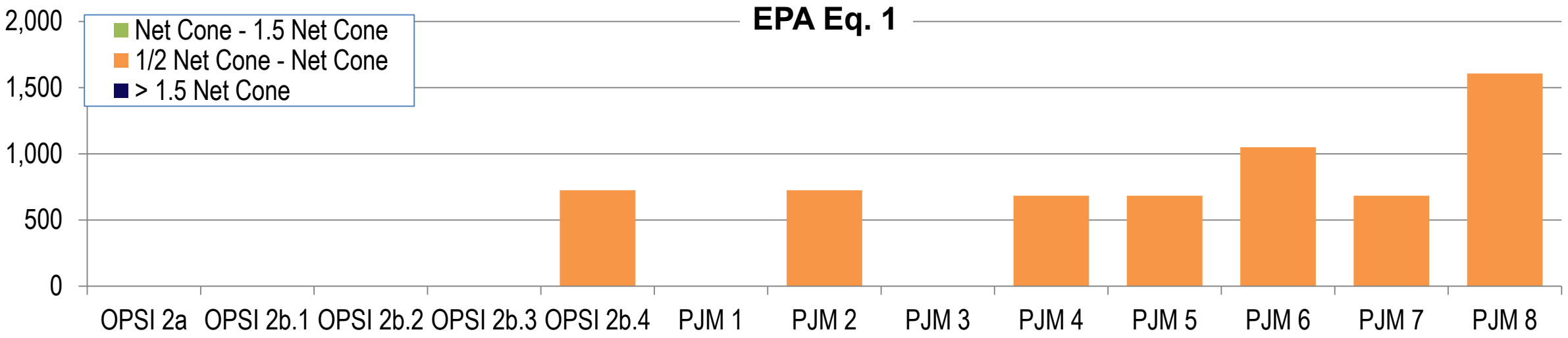
Rest of RTO Region Steam Turbine
2025 Regional Mass Compliance Related Retirement Risk Analysis



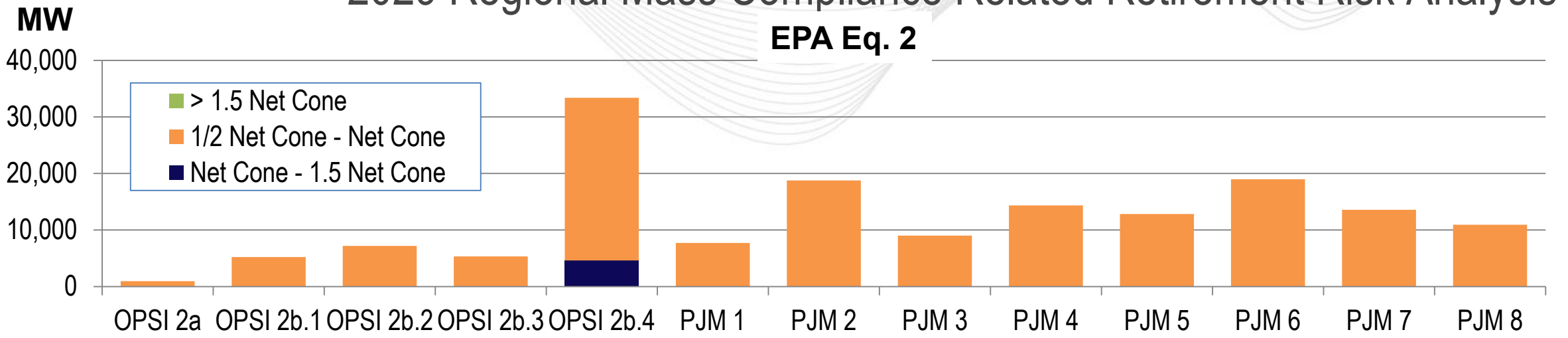


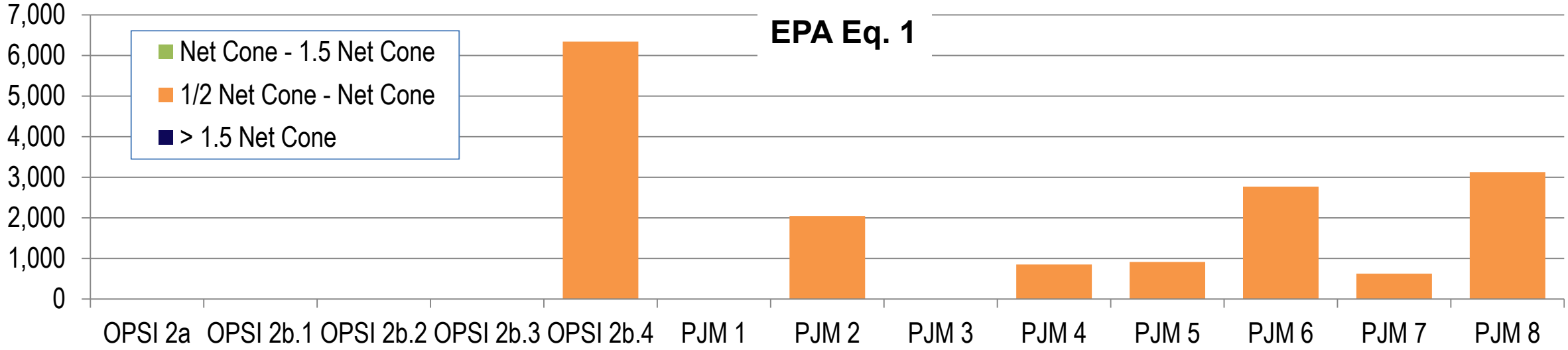
MAAC Region Steam Turbine
2029 Regional Mass Compliance Related Retirement Risk Analysis



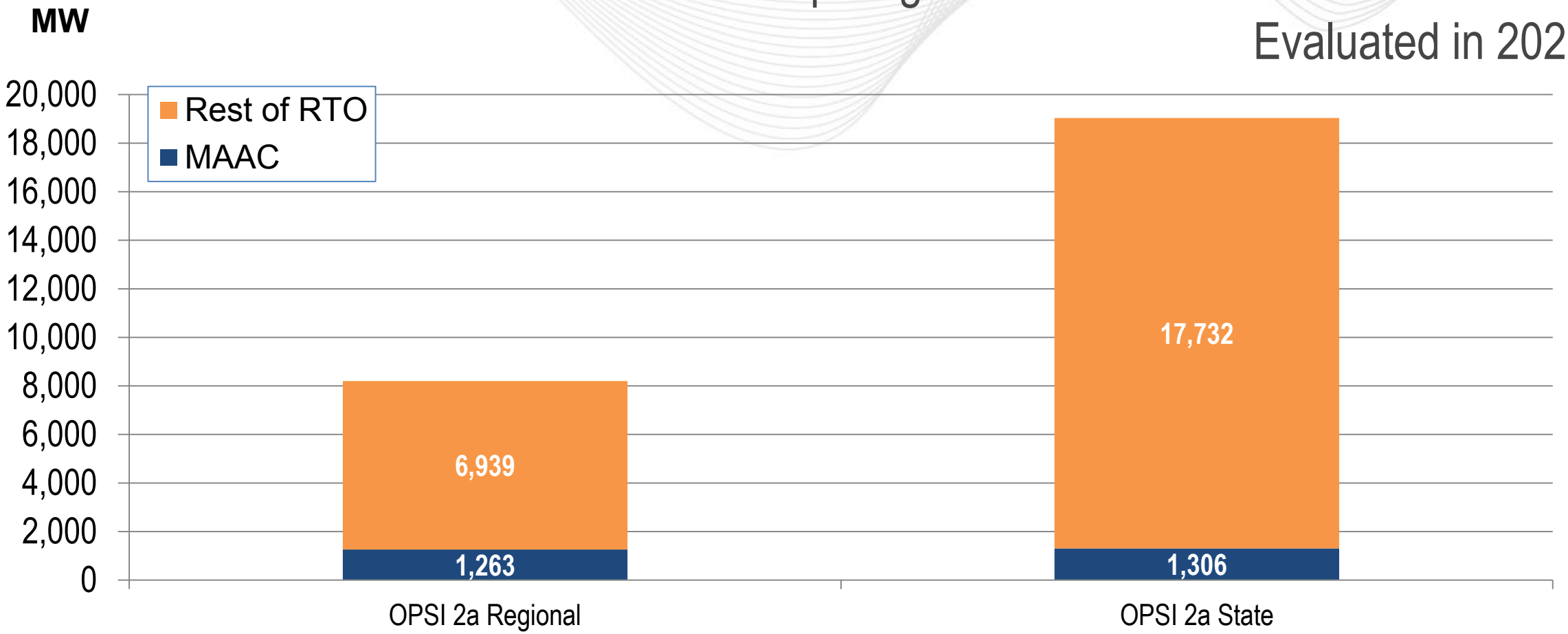


Rest of RTO Region Steam Turbine
2029 Regional Mass Compliance Related Retirement Risk Analysis



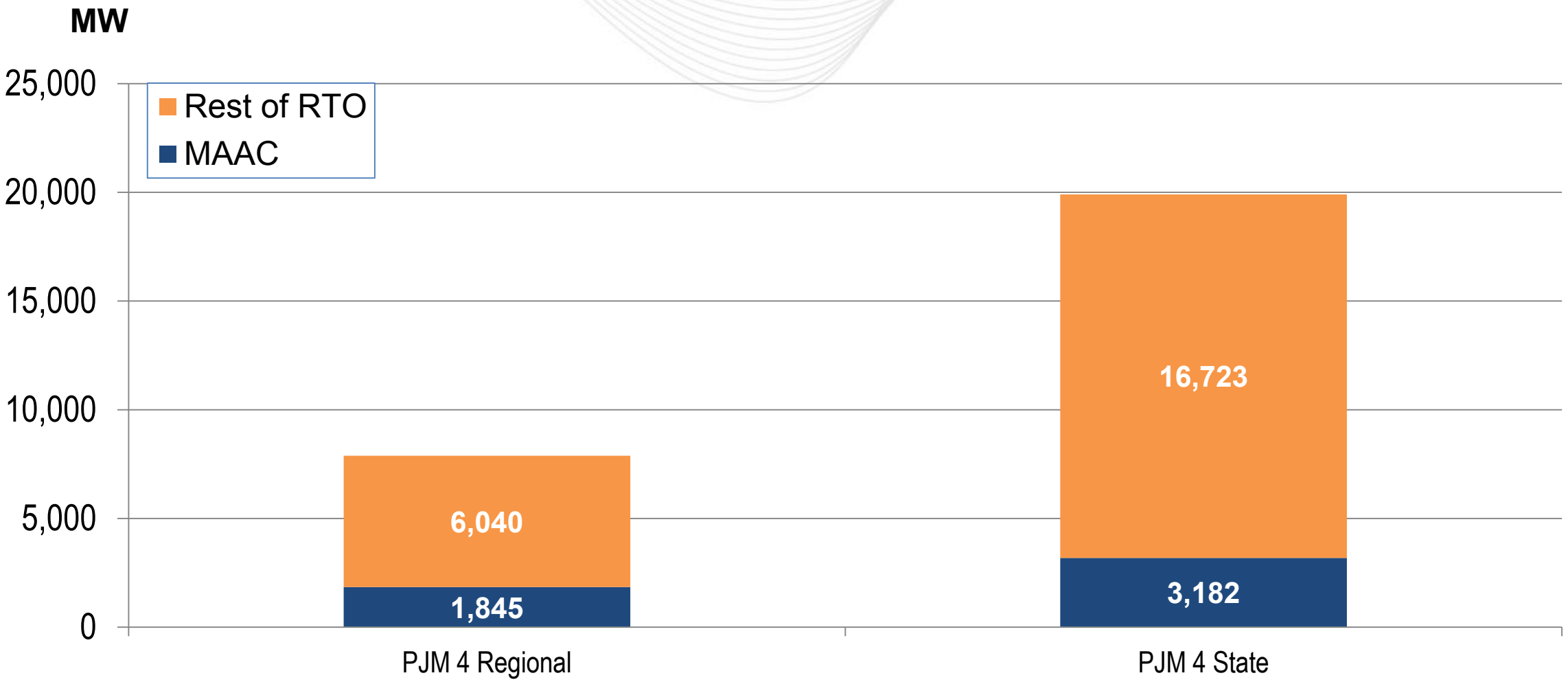


State By State Versus Regional Mass Based Compliance
Steam Turbine Units Requiring > ½ Net Cone to cover Fixed Costs Evaluated in 2020

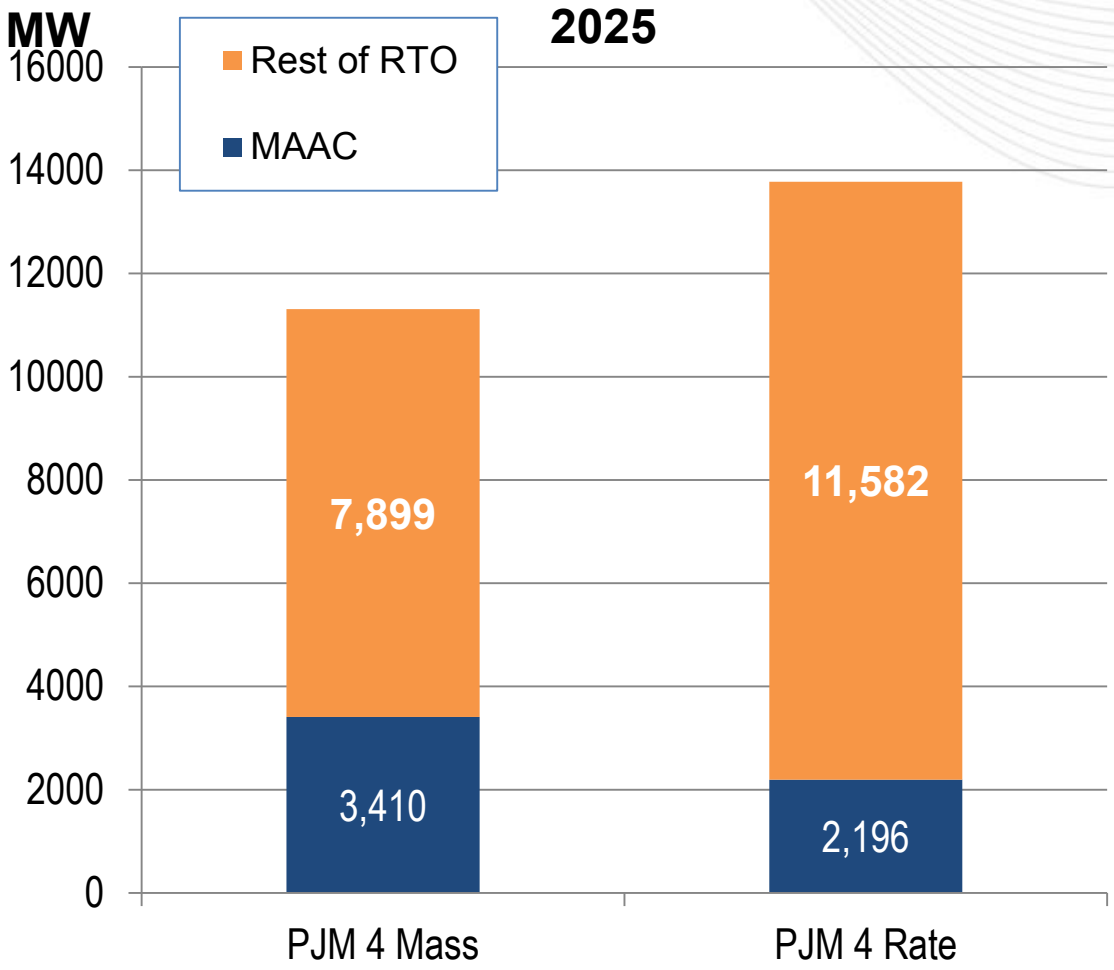


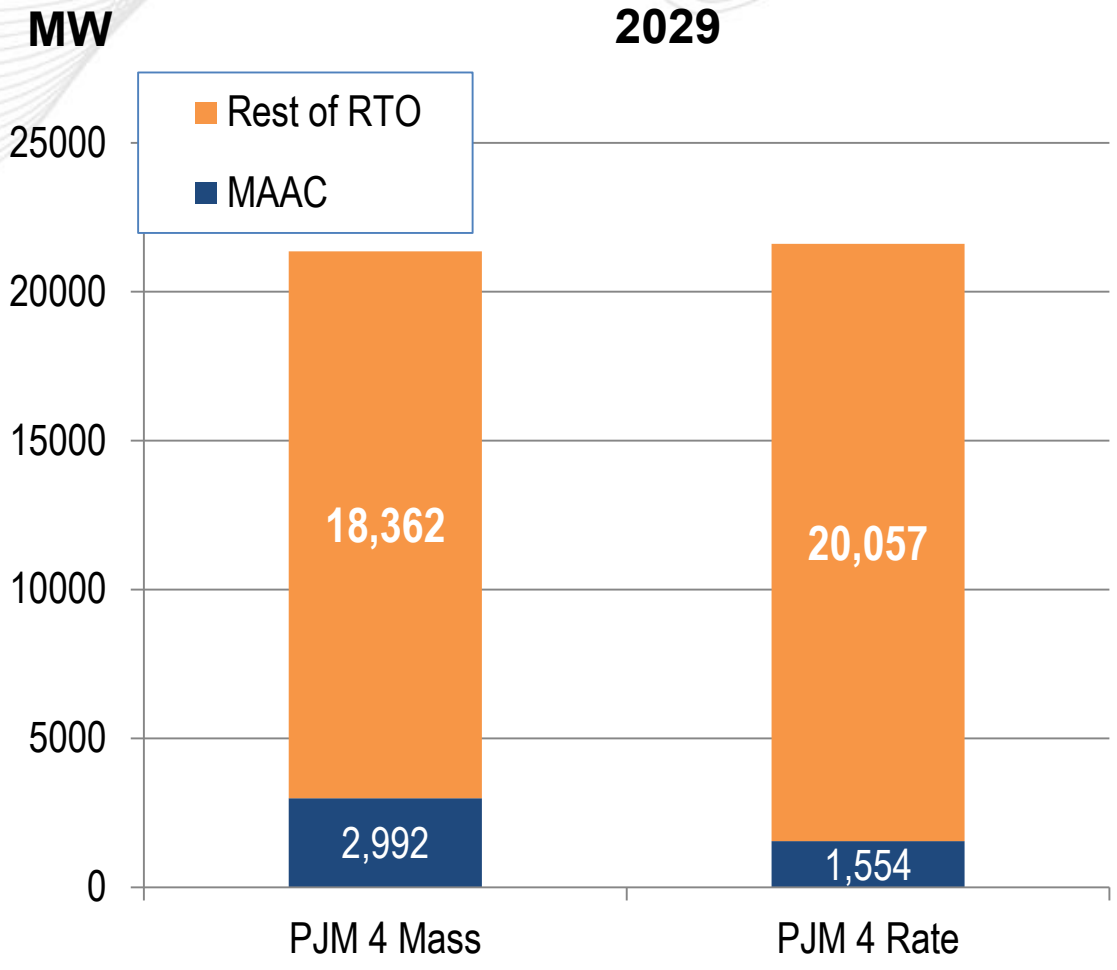
OPSI 2a (Regional) – High Renewables and High EE Case does not require re-dispatch of resources consequently there are no new retirements due to regional policy implementation

State By State Versus Regional Mass Based Compliance
Steam Turbine Units Requiring > ½ Net Cone to cover Fixed Costs
Evaluated in 2020



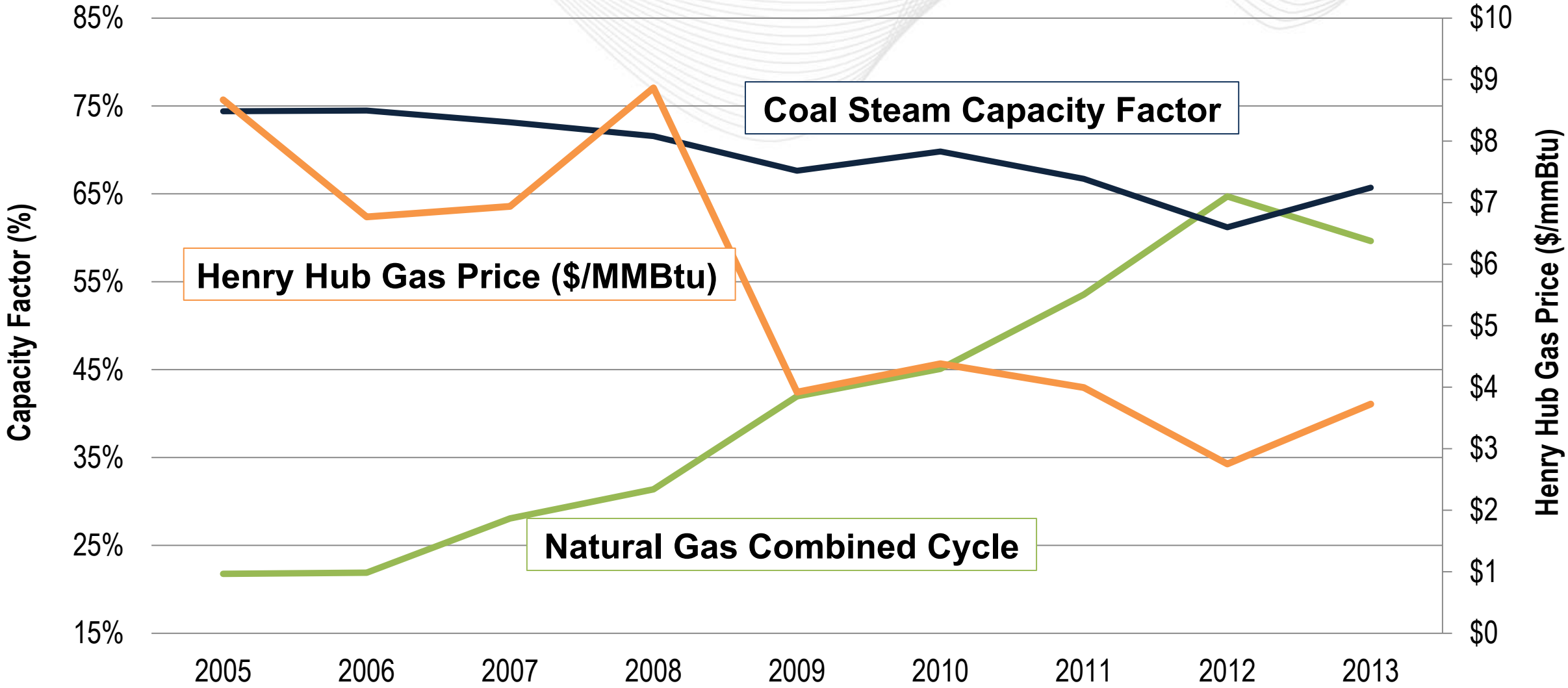
Rate Versus Mass Based Compliance (PJM 4)
Steam Turbine Units Requiring > ½ Net Cone to Cover Fixed Costs



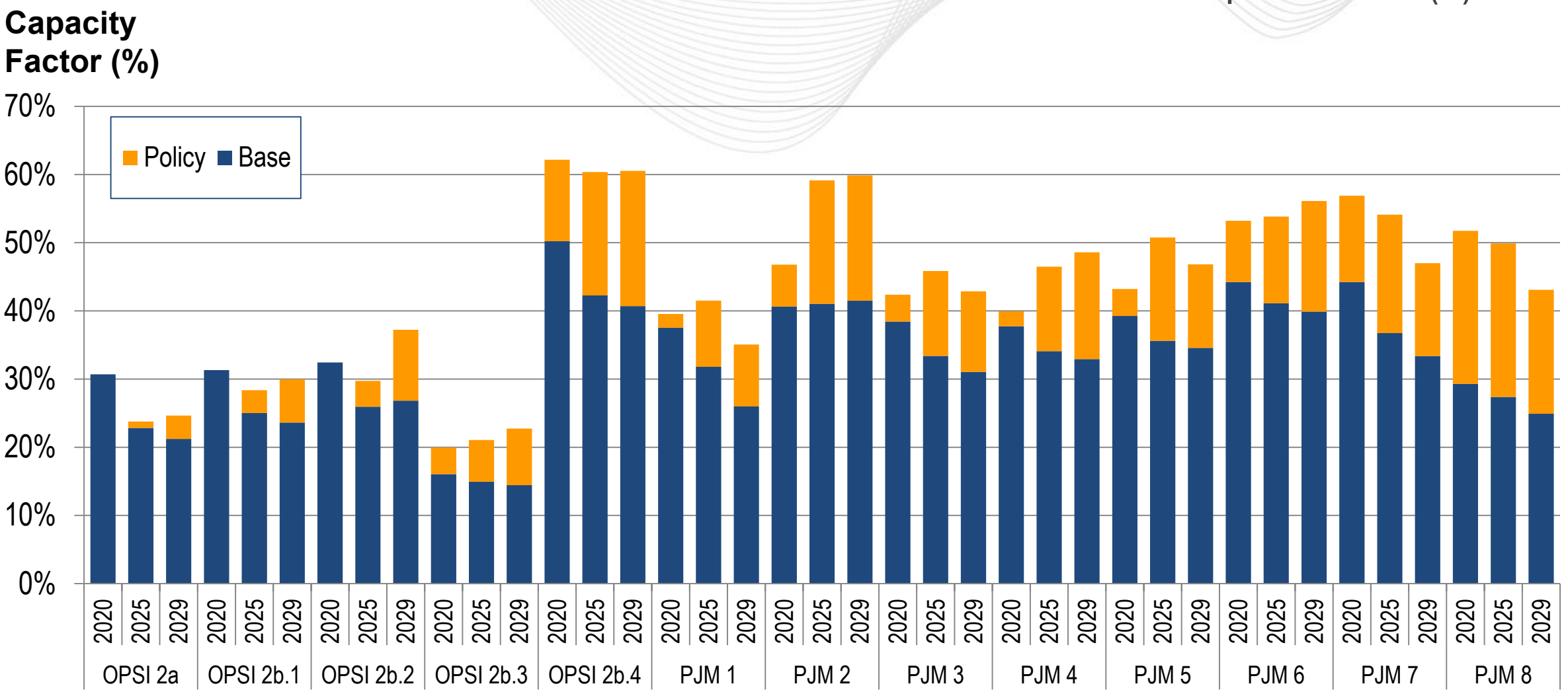


Section VIII: Natural Gas Combine Cycle Operational Analysis

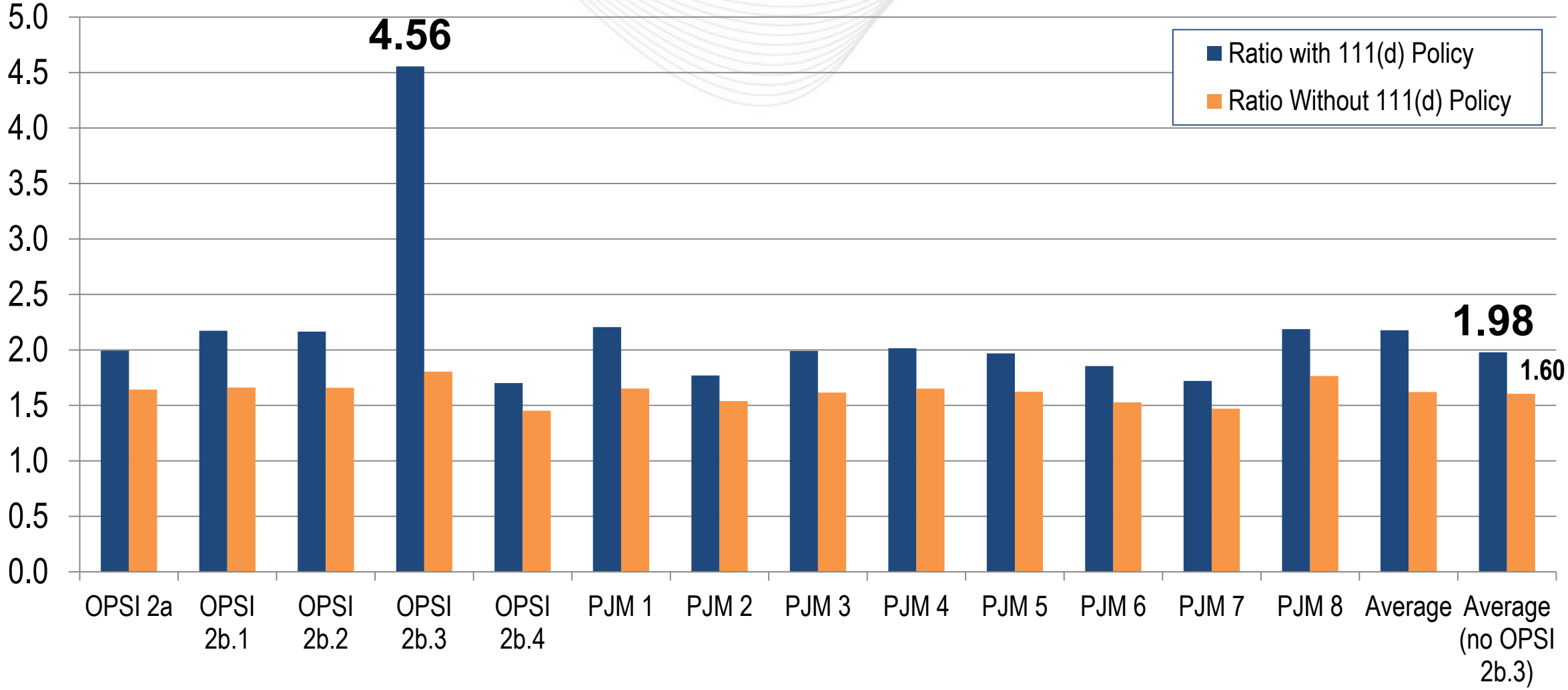
PJM Historic Capacity Factors vs Gas Price



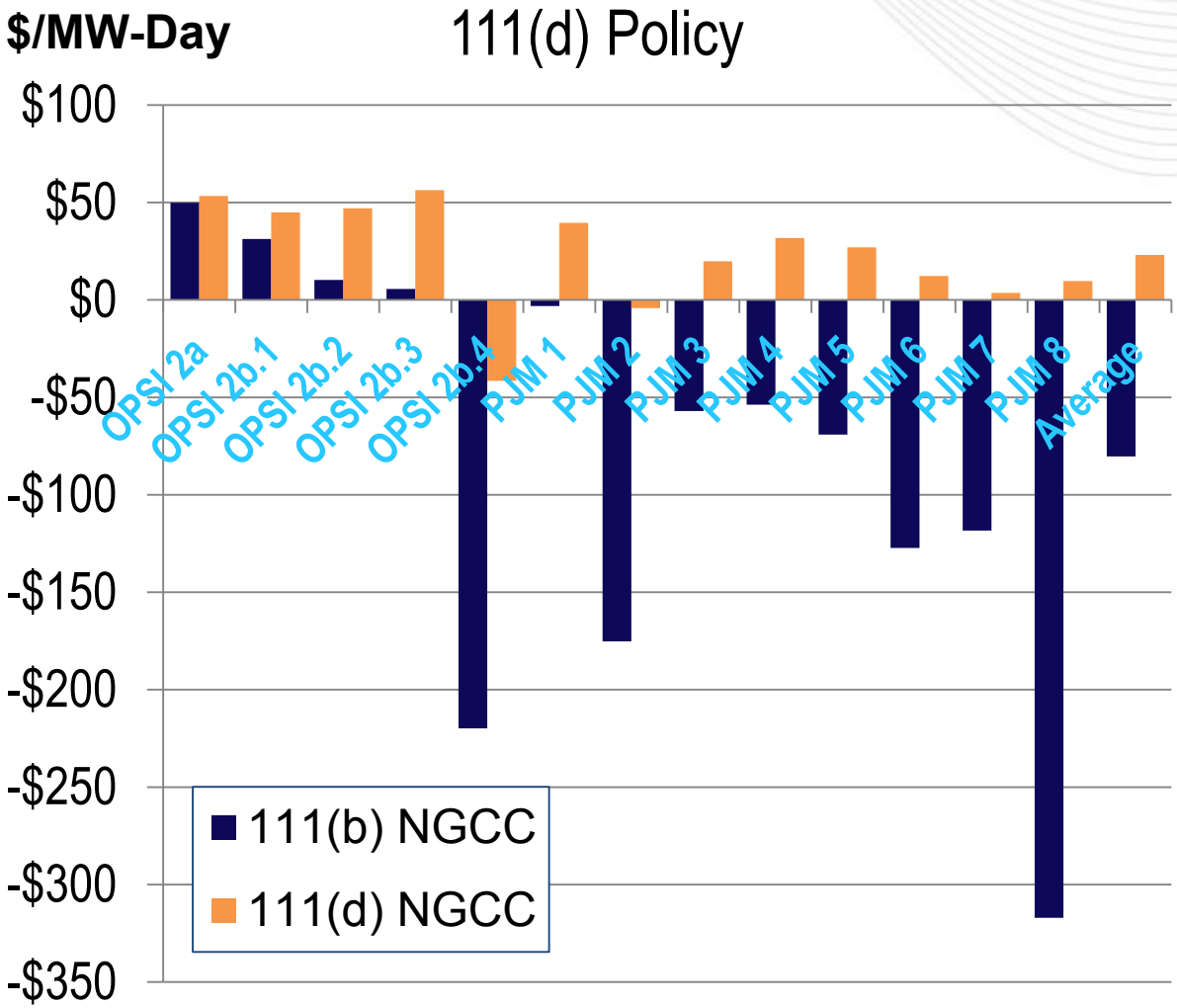
2020 NGCC Capacity Factors by Scenario
Impact of 111(d) Policy

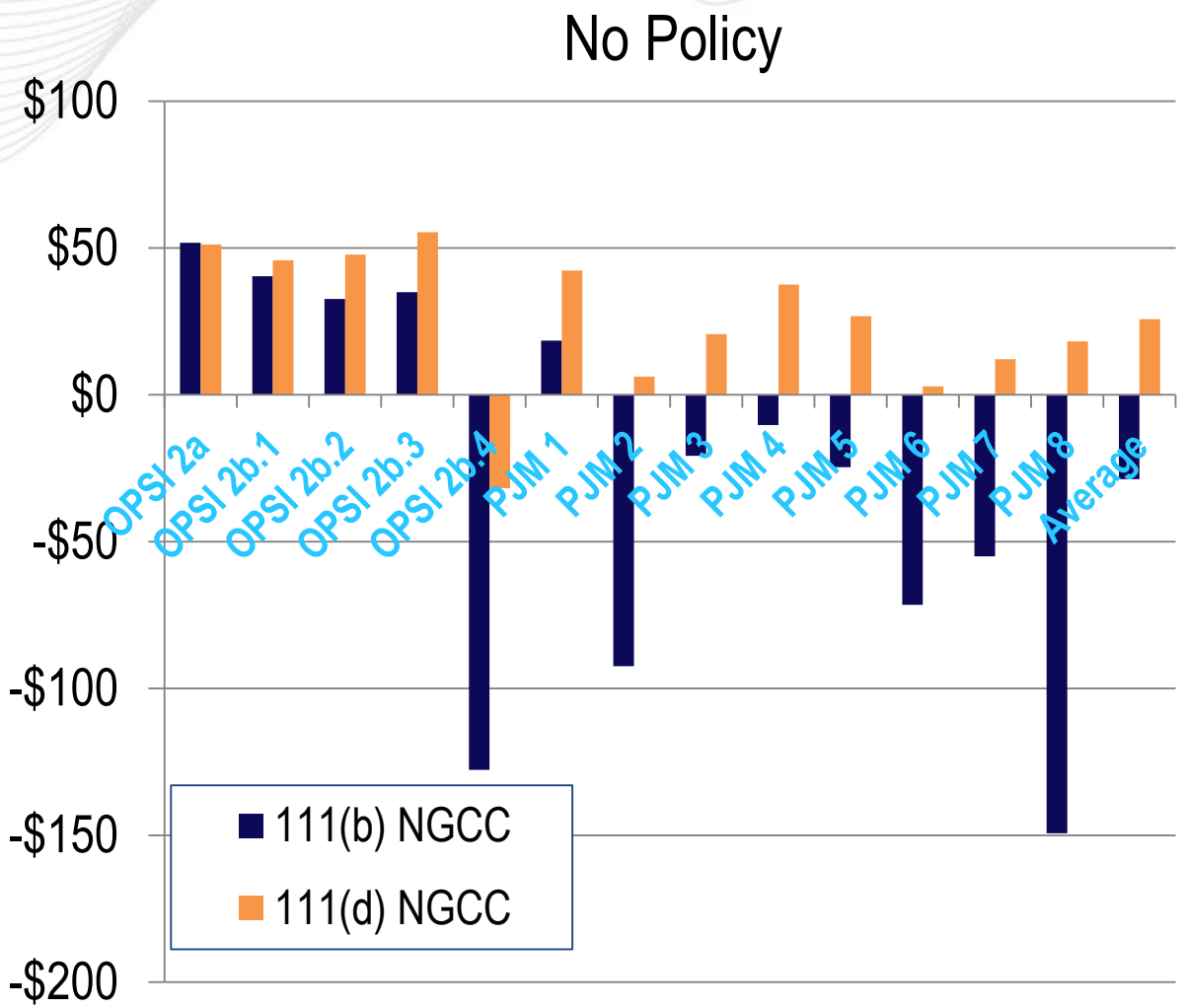


Capacity Factor Impacts Policy
CF (%) Ratio of Resources under 111(b) Versus Under 111(d)



NGCC Average Revenue Requirement 2020,2025 & 2029 With and Without 111(d) Policy



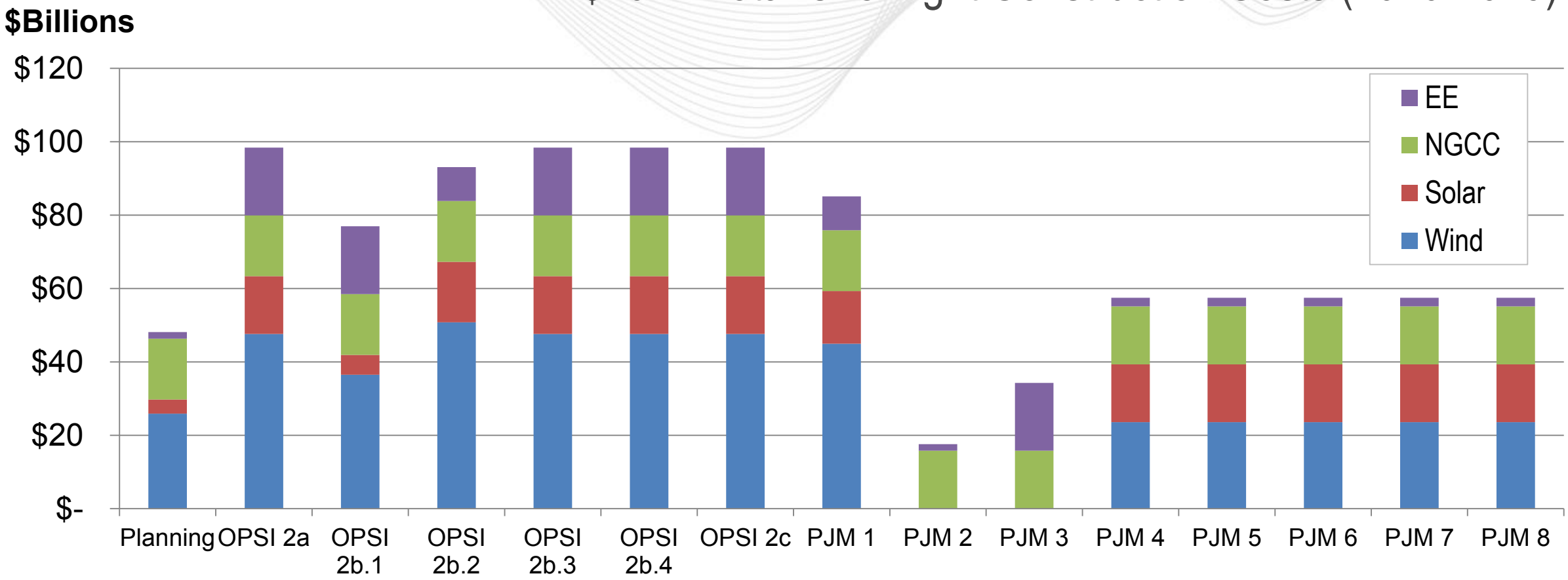


Section IX: Appendix

- PJM expects to have initiated the reliability analysis and have preliminary results for some of the reliability criteria tests by the end of November
  - Using the mass based and rate based economic modeling of regional compliance, identify potential retirements
  - Through power flow analysis using the 2022 RTEP case, identify potential reliability criteria violations that would result due to the potential retirements
  - Estimate potential transmission infrastructure costs based:
    - Generally, on the level of transmission upgrades required for the recent Mercury Air Toxics Standard (MATS) related generation retirements, and
    - Specifically, on the average cost to upgrade identified limiting transmission facilities
  - Reliability criteria testing will continue beyond the end of November and be reviewed with stakeholders at the TEAC

Actual transmission costs may vary (significantly) depending on whether upgrades to existing facilities or new green field transmission projects are needed.

Generic Capital Investment Costs By Scenario
$2012 Total Overnight Construction Costs (2020-2029)



These costs are generic total build costs and should not be misinterpreted as resulting from compliance with the Clean Power Plan. These costs may be incurred before, during or after the interim compliance period for 111(d).

Sources for Generic Capital Cost Assumptions

- Lazard's Levelized Cost of Energy Analysis version 7.0 (referred to as the Lazard Report)
- United States Energy Information Administration Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants, April 2013 (referred to as the EIA report)
- National Renewable Energy Laboratory Distributed Generation Energy Technology Capital Costs (referred to as the NREL report)