Transmission Expansion Advisory Committee

January 7, 2015

PJM's Economic and Reliability Analysis of the EPA's Clean Power Plan (CPP)

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 CO_2 policy
- Acts as an independent source of information on CO_2 policy implications
- Does *not* forecast market outcomes but rather models outcomes based on a specific set of assumptions

To assess coal, oil and gas steam generation "at risk" for retirement due to the EPA 111(d) GHG proposed rule and recently finalized 111(b) New Source Performance Standards:

- "At risk" means that generating resources will face varying financial challenges from the 111(d) rule; it does not mean that resources will necessarily retire
- Varying degrees of "at risk" generation must look at additional revenues beyond net energy market revenues expressed as percentages of the Net Cost of New Entry for both natural gas CT and CC units
- Simply put, this is the amount of additional revenue needed from the capacity market for the resource to go forward

“At-risk” resources identified by the economic analysis are an input into the reliability analysis that is forthcoming and currently in process

- Perform power flow analyses to determine transmission needs resulting from potential resource retirements
  - Generator Deliverability Analysis
  - Load Deliverability Analysis
- Evaluate transmission reliability criteria violations due to the retirements of different levels of “at-risk” resources
- Identify necessary transmission upgrades assuming “at-risk” resources retire

Caveats and Cautions…Qualitative Results are Key

- PJM studied 16 different scenarios designed to encompass the range of possible states of the industry heading into CPP compliance:
  - 13 mass-based regional compliance scenarios (2020, 2025, 2029)
  - 2 state-by-state mass-based compliance scenarios (2020 only)
  - 1 emission rate based regional compliance scenario (2025 and 2029)
- Each scenario is based on assumptions, such as:
  - Types of new generation resources
  - Amounts of energy efficiency and load growth
  - Gas prices

Caveats and Cautions…Qualitative Observations are Key

- Quantitative results from the simulations depend crucially on assumptions regarding renewables, efficiency, gas prices, nuclear retirements, pace of new entry
- But over the wide range of scenarios PJM simulated , there are consistent qualitative observations
- Actual results will depend upon several variables, including:
  - The final EPA rule
  - How states choose to implement the rule
  - Actual load growth and fuel prices

Key Qualitative Observations from the PJM Analysis

- As the emission mass targets decline over time and/or natural gas prices increase:
  - CO_2 prices rise
  - Compliance costs in the form increased production costs from re-dispatch increase
  - The MW value of capacity "at risk" for retirement incrementally increases over time…that is there not all potential coal, oil and gas steam unit retirements will happen at once
- Increasing energy efficiency (EE) and renewable energy (RE)
  - Reduces CO_2 prices and compliance costs due to re-dispatch
  - Results in fewer coal, oil, and gas steam MW "at-risk" for retirement

Key Qualitative Observations from the PJM Analysis

- Excluding new resources under 111(b) from 111(d) compliance
  - Makes new NGCC have the same effect as RE and EE from a compliance perspective under a massed-based approach
  - Does not help as much under a emissions rate-based approach
- Compared to regional compliance, state-by-state compliance results in
  - Higher CO_2 prices on average and higher compliance costs
  - Increase in the MW value of capacity “at risk” for retirement
- Compared to mass-based compliance, emission rate based compliance
  - Higher CO_2 prices
  - Complicated interactions that make changes in coal, oil and gas steam MW “at-risk” for retirement less clear

Key Qualitative Observations from the PJM Analysis: Regional Mass-based Compliance

With 111(d)

- Higher gas prices increase re-dispatch costs and further disadvantage all 111(d) covered sources relative to new sources
- Higher energy market prices will incent significant new entry from renewable and gas sources
- Renewables/EE reduce risk to coal resources by mitigating CO_2 prices and new NGCC entry
- New NGCC are dispatched before many coal resources and all existing NGCC.
- NGCC are cheapest capacity option for meeting reliability target (LOLE criteria) in many scenarios

Without 111(d)

- Higher gas prices increase revenues for coal and nuclear resources and reduce retirement risk for units with high fixed cost
- Flat load and energy market price growth reduces incentives new investment
- Renewables/EE reduce energy market prices making it more difficult for coal and other steam resources to recover their fixed cost
- New NGCC would be dispatched after most coal as coal-to-gas spreads grow over time
- In response to higher gas prices and EE and RE penetration, CTs are the cheapest capacity option for meeting reliability target (LOLE criteria)

Economic Risks is assessed based on Energy Market Revenues Net of Fixed Costs (ACR) 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 expenditures required
Risk	"Very High" or "Most at Risk"	"High"	"at Risk" or "at some Risk"	"Low"

Section I: Modeling Approach

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 • Units under 111(b) not subject to 111(d) but could be included at a state's discretion	• New Gas-Fired CT, fossil-fired utility boilers and IGCC units • CTs running under a 33% capacity factor are exempt

Standard	• State-based compliance with a CO_2 emissions rate target or converted to a mass-based target
	• Options for regional compliance
		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

Overview of 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
- 15 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

- Adjusted EPA's 2012 thermal resource data, under-construction NGCC, projected renewables and energy efficiency to only include the contribution from resources within the PJM footprint
- Re-calculated the emission rate target for each PJM state (primarily impacts border states)
- Converted each state's rate-based emissions targets to a mass-based target
- Aggregated state mass-based emissions targets to represent the mass-based emissions target for the PJM region

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

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

Regional vs. State-by-State 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
- Region-wide dispatch is used in both approaches
- Only looked at 2 scenarios adjusted new generation, energy efficiency, renewable energy, nuclear retirements, and gas price assumptions. (PJM is not modeling each EPA Building Block independently)

Regional Compliance

- Use aggregated state mass-based emissions targets to represent the mass-based emissions target for the PJM region
- No one state needs to comply in isolation, but in aggregate the mass-based targets must be achieved
- Iterate on a single, PJM-wide CO_2 price to converge to achieving the aggregate mass-based target

State-by-State Compliance

- Each state has its own emission mass-target it must achieve alone
- Each state (12 states in the simulation) has its own unique CO_2 price
- Iterate on each of the state prices until each state meets its mass target

Model Years

- Clean Power Plan "Glide Path"
  - interim goal allows averaging emissions compliance from 2020-2029
  - Implies “banking” or “borrowing” emissions in any particular year so long as the 10 year average is achieved

- PROMOD is not capable of dynamically modeling a “glide path”
  - 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: Scenario Descriptions

Capacity Resources in the Planning Model

- 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 or exceeds 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 rate target			

Key Terms and Definitions

- Base - Scenario that is simulated in absence of a CO_2 price to effect re-dispatch from higher emitting to lower emitting sources
- 111(d) – Scenario that is simulated with the intent of reducing emissions consistent with the EPA's Clean Power Plan section 111(d) proposed goals
- Steam Turbine Resource – Gas, Oil and Coal fired resources whose prime mover is a steam turbine. Does not include combine cycle resources.
- Avoidable Cost Rates (ACR) - Annual avoidable costs used in calculating Market Seller Offer Caps in RPM
- Net Energy Market Revenues - Based on simulation and exclude ancillary service revenue
- Net Cost of New Entry (Net Cone) - Benchmark price at which resource adequacy is achieved at the Reliability Requirement.

Economic Analysis of Steam Turbine Retirement Risk

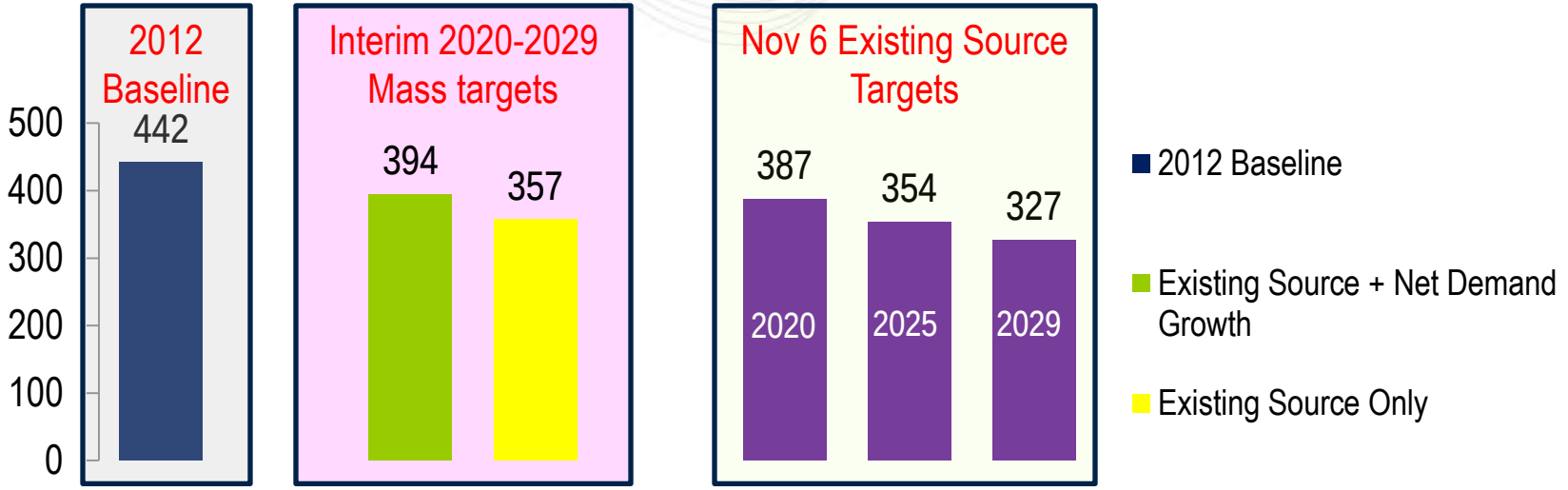
Note:

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

EPA Rate-to-Mass Conversion for Stricter (Existing Source) November 6 Guidance

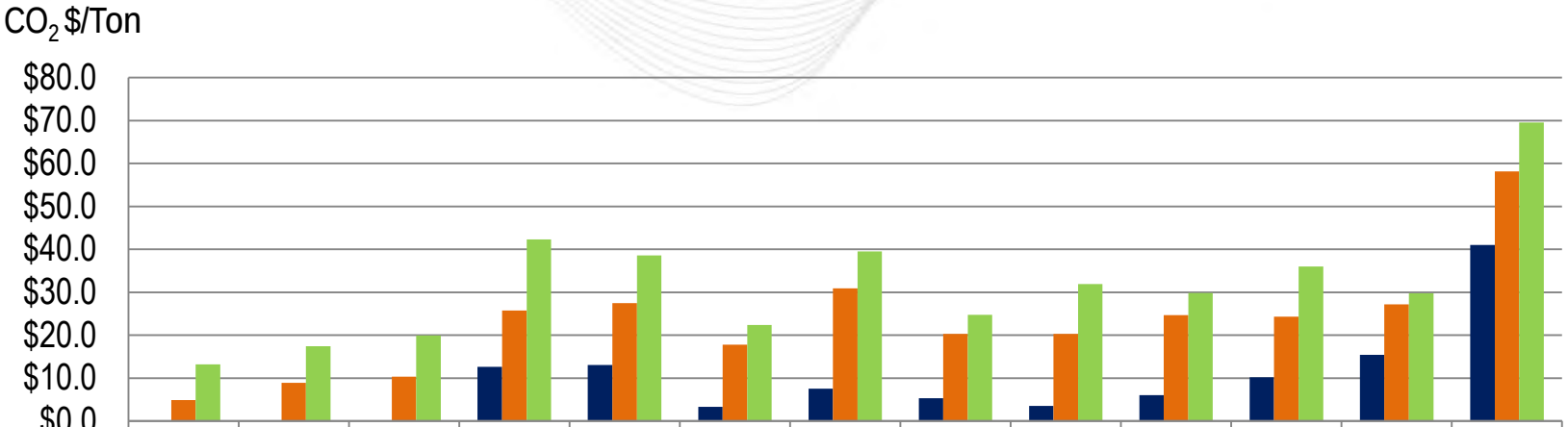
November 6 Existing Source Equation: Used in economic analysis to assess generator performance

State Mass Target = State rate x (2012 Covered Sources MWh + 2012 Renewables + Nuclear$_{,at\text{-}risk}$)



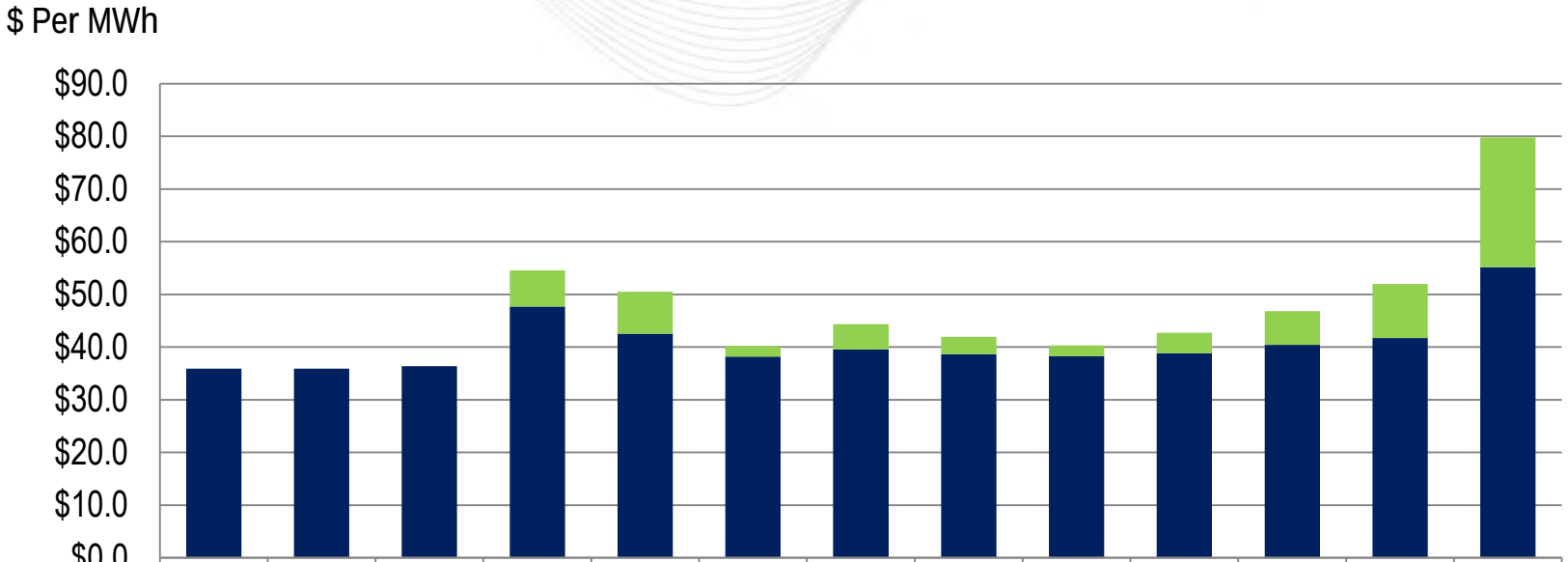
- 2012 baseline emissions include emissions from units that have already announced deactivations
- Already announced retirements accounted for nearly 50 million short tons of CO_2 in 2012. Load previously served by these resources will be met by a mixture of remaining and/or new resources.

111(d) Implied CO_2 Price for Mass-Based Regional Compliance



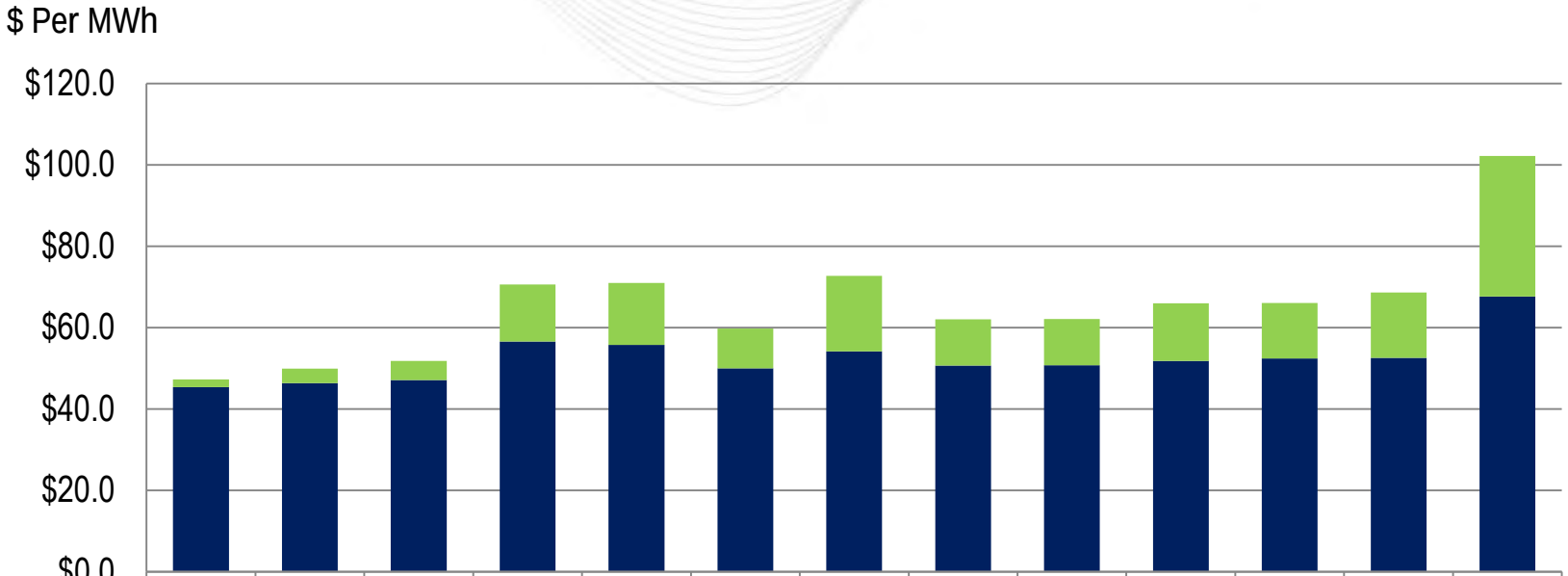
	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
2020	$0.0	$0.0	$0.0	$12.7	$13.1	$3.3	$7.6	$5.4	$3.5	$6.1	$10.2	$15.4	$41.0
2025	$4.9	$8.9	$10.4	$25.7	$27.5	$17.8	$30.9	$20.3	$20.3	$24.7	$24.3	$27.2	$58.2
2029	$13.2	$17.4	$20.0	$42.3	$38.6	$22.4	$39.5	$24.8	$31.9	$29.9	$36.0	$29.8	$69.6

111(d) Impact to PJM Average Locational Marginal Price in 2020: Mass-Based Regional Compliance



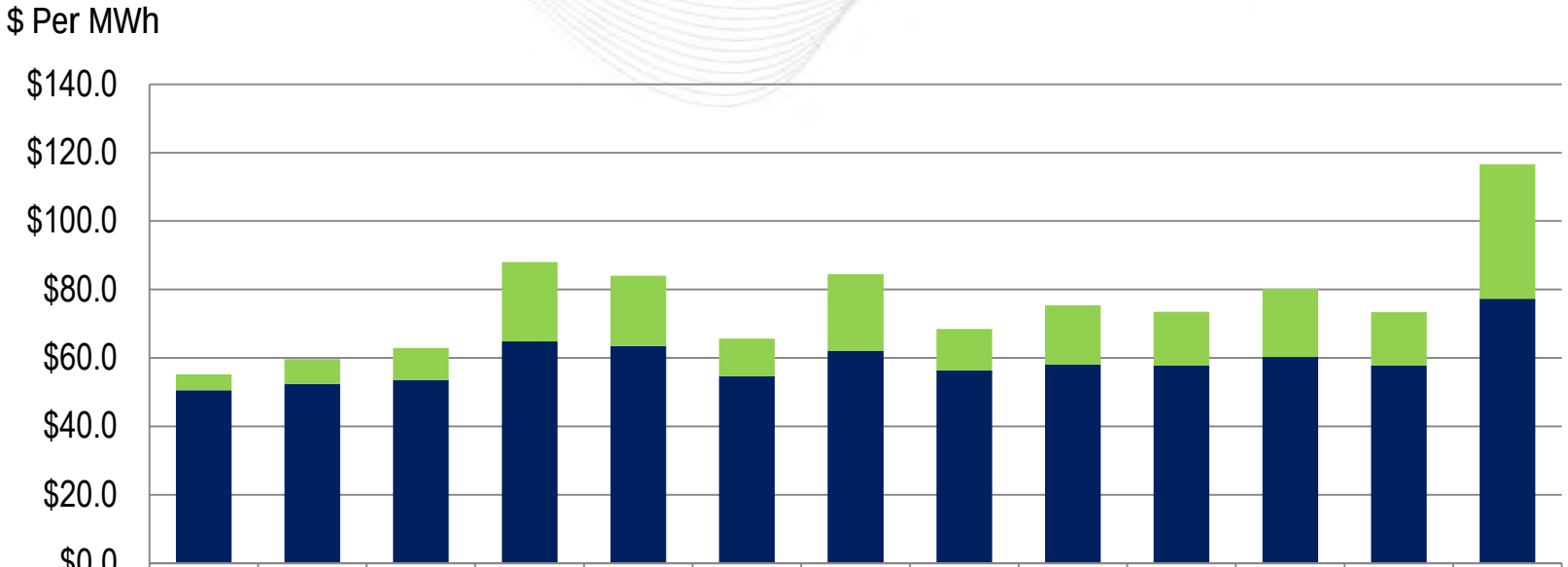
	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
Δ LMP 111(d)	$0.0	$0.0	$0.0	$6.8	$7.9	$2.0	$4.9	$3.3	$2.1	$3.9	$6.4	$10.3	$24.6
LMP Base	$35.9	$35.9	$36.4	$47.7	$42.6	$38.2	$39.5	$38.7	$38.3	$38.9	$40.4	$41.7	$55.1

111(d) Impact to PJM Average Locational Marginal Price in 2025: Mass-Based Regional Compliance



	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
Δ LMP 111(d)	$1.9	$3.6	$4.6	$14.0	$15.2	$9.7	$18.6	$11.4	$11.4	$14.2	$13.6	$16.1	$34.5
LMP Base	$45.4	$46.3	$47.1	$56.6	$55.8	$50.0	$54.2	$50.6	$50.7	$51.8	$52.4	$52.5	$67.6

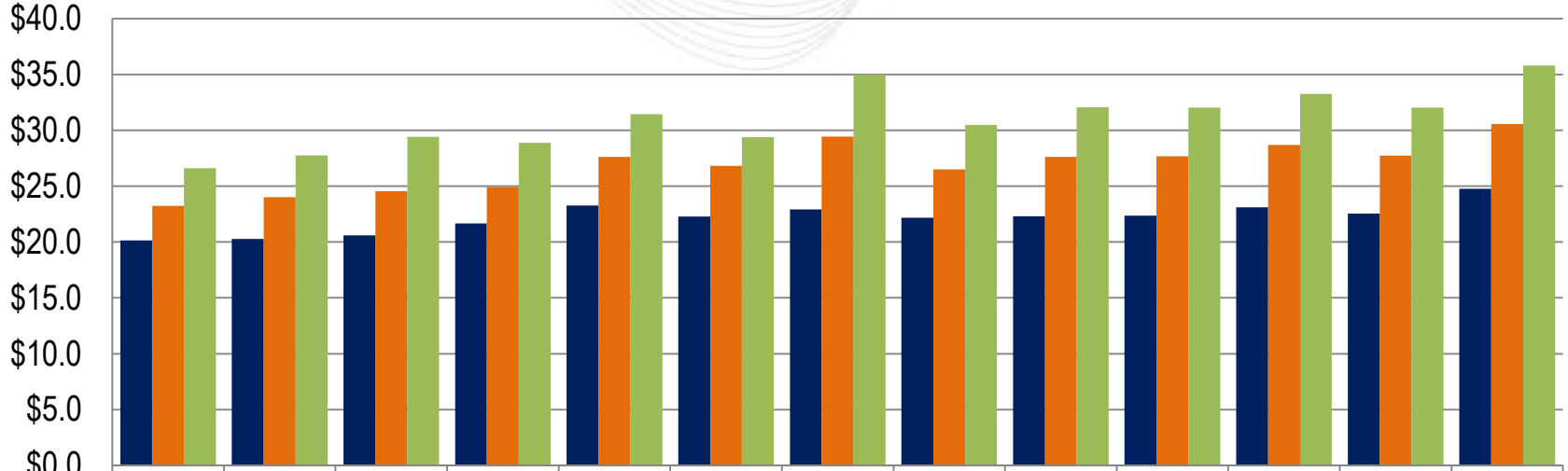
111(d) Impact to PJM Average Locational Marginal Price in 2029: Mass-Based Regional Compliance



	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
Δ LMP 111(d)	$4.6	$7.4	$9.4	$23.2	$20.5	$11.0	$22.4	$12.1	$17.3	$15.7	$19.9	$15.6	$39.4
LMP Base	$50.6	$52.3	$53.5	$64.9	$63.4	$54.7	$62.1	$56.3	$58.1	$57.7	$60.3	$57.7	$77.3

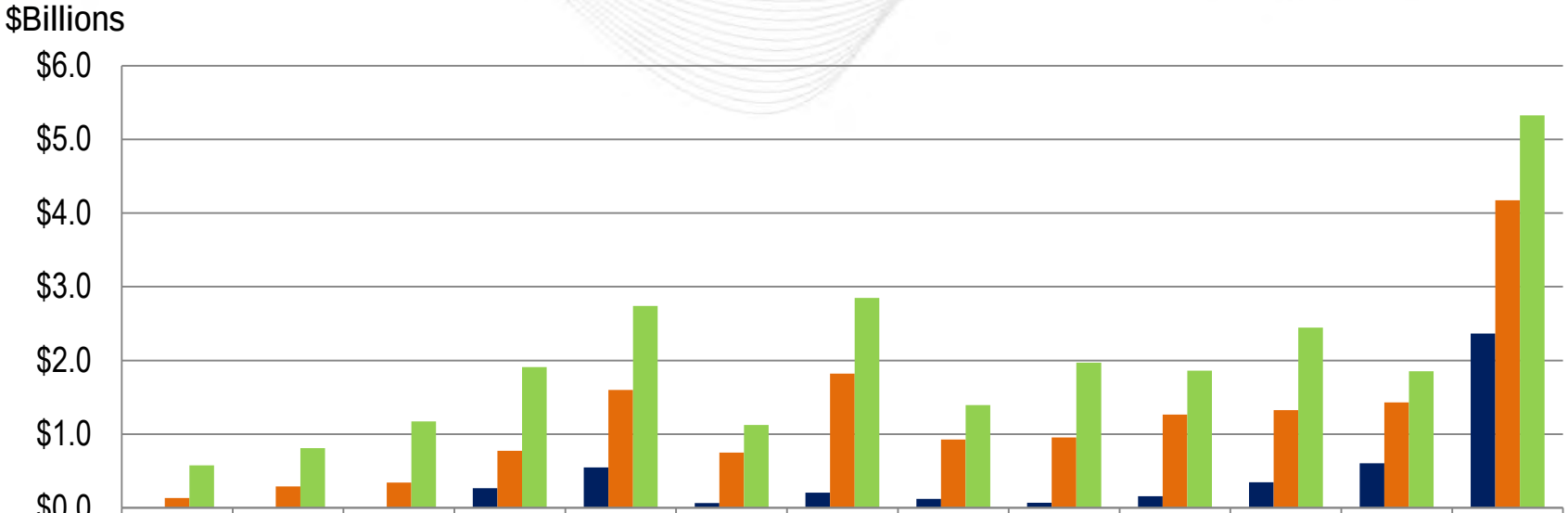
Measuring Compliance Cost due to Re-Dispatch: Fuel and O&M Expense Before 111(d)

$Billions



	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
2020	$20.1	$20.3	$20.6	$21.7	$23.3	$22.3	$22.9	$22.2	$22.3	$22.4	$23.1	$22.5	$24.8
2025	$23.2	$24.0	$24.6	$24.9	$27.6	$26.8	$29.4	$26.5	$27.6	$27.7	$28.7	$27.7	$30.5
2029	$26.6	$27.8	$29.4	$28.9	$31.4	$29.4	$35.0	$30.5	$32.1	$32.0	$33.2	$32.0	$35.8

Measuring Compliance Costs due to Re-Dispatch: Change in Fuel and O&M Expense due to 111(d)



	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
2020	$0.0	$0.0	$0.0	$0.3	$0.5	$0.1	$0.2	$0.1	$0.1	$0.2	$0.3	$0.6	$2.4
2025	$0.1	$0.3	$0.3	$0.8	$1.6	$0.7	$1.8	$0.9	$1.0	$1.3	$1.3	$1.4	$4.2
2029	$0.6	$0.8	$1.2	$1.9	$2.7	$1.1	$2.9	$1.4	$2.0	$1.9	$2.4	$1.9	$5.3

PJM Base Residual Auction 2014
Reference Resource for Development of the VRR Curve

"Reference Resource" shall mean a combustion turbine generating station, configured with two General Electric Frame 7FA turbines with inlet air cooling to 50 degrees, Selective Catalytic Reduction technology in CONE Areas 1, 2, 3, and 4, dual fuel capability, and a heat rate of 10.096 Mmbtu/ MWh."

- PJM Tariff Attachment DD, pg. 513 Docket #: ER14-822-002

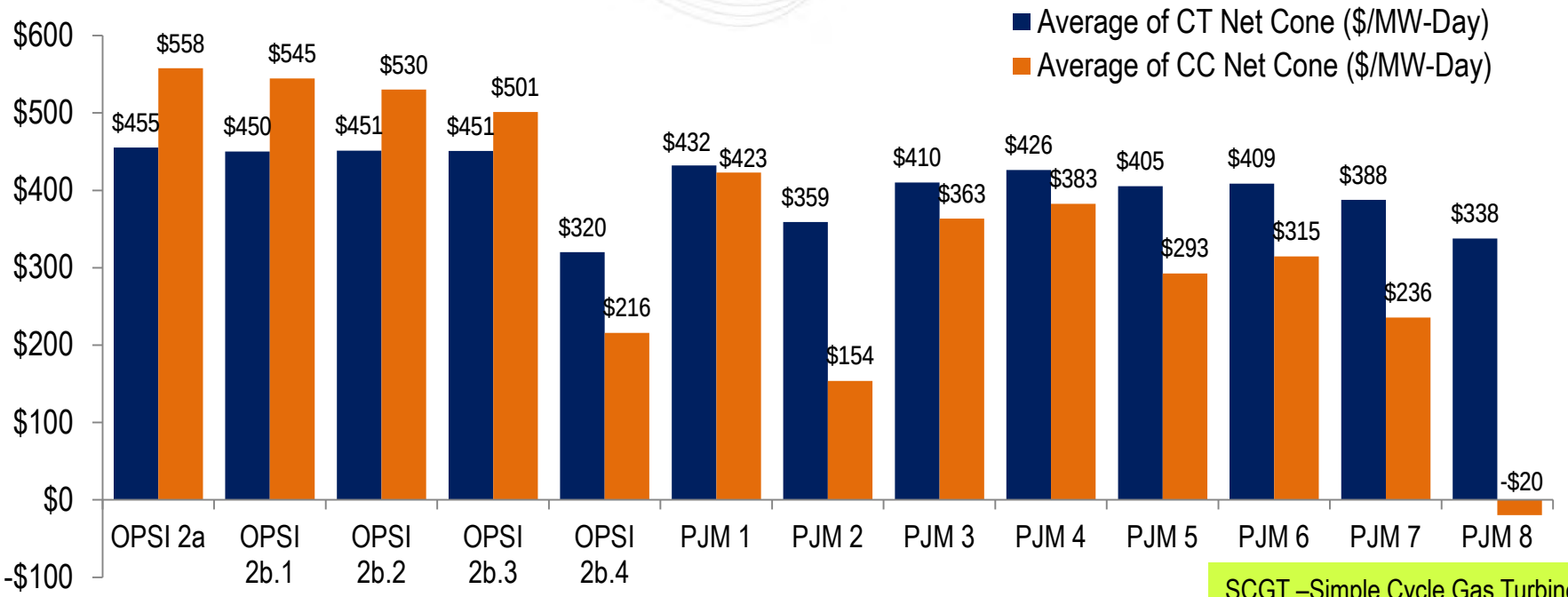
Criteria for Identifying At-Risk Units for Reliability Analysis

- The benchmark for retirement is based on the lesser of the Net Cone value of a reference CT or NGCC from the simulation[1]
- A generator is considered at-risk for retirement when its annual revenue requirement exceeds the Net-Cone benchmark (0.6 or 0.5)
  - Generator's capacity factor must decline significantly between the base and policy case
  - Congestion "cost" for capacity resources should not be significantly higher than the average for the Cone Area
- Generator must be at-risk in at-least 50% of the scenarios evaluated to be considered at-risk for reliability analysis

[1] Previous analysis used a CT as the reference resource. However, with the policy and stricter emissions targets NGCC resources are the cheapest supply source for meeting reliability targets on a Net-Cone basis in many of the scenarios.

NGCC and CT Net CONE under Different Scenarios: Using Scenario Simulated Net Energy Market Revenues

Comparison of NGCC and SCGT[1] Net Cost of New Entry with EPA Clean Power Plan Section 111(d)



SCGT –Simple Cycle Gas Turbine

At-Risk Analysis Scenario Groupings

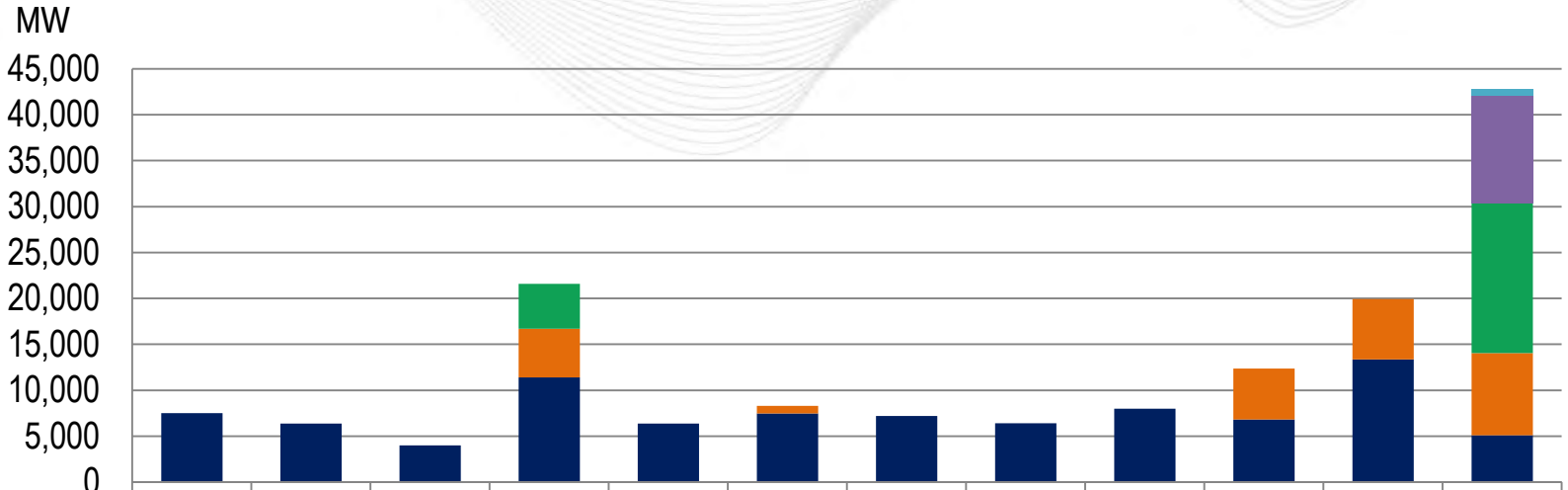
Scenario Group	Criteria
All Scenarios in all years	Generator fails to meet the % Net Cone Criteria in all scenarios for all years
50% of Scenarios	Generator fails to meet the % Net Cone Criteria in greater than 50% of the scenarios
Worse Case Scenarios	Generator fails to meet the % Net Cone criteria for each of the worse case scenarios (OPSI 2b.4, PJM 2, PJM 8)
High Renewable/EE	Generator fails to meet the %Net Cone criteria for each of the high renewable scenarios (OPSI 2a,OPSI 2b.1, OPSI 2b.2, PJM 1)
Low Renewable/EE	Generator fails to meet the % Net Cone criteria for each of the low renewable scenarios (PJM 4, PJM 5, PJM 6 & PJM 7)

At-Risk Unit Results using the Least-Cost New Entrant as the Reference Resource by Scenario to meet PJM Reliability Target (LOLE criteria) under Mass-Based Compliance

Economic Dynamics that Cannot be Modeled Easily… But Should be Considered in the Context of the "At Risk" Results

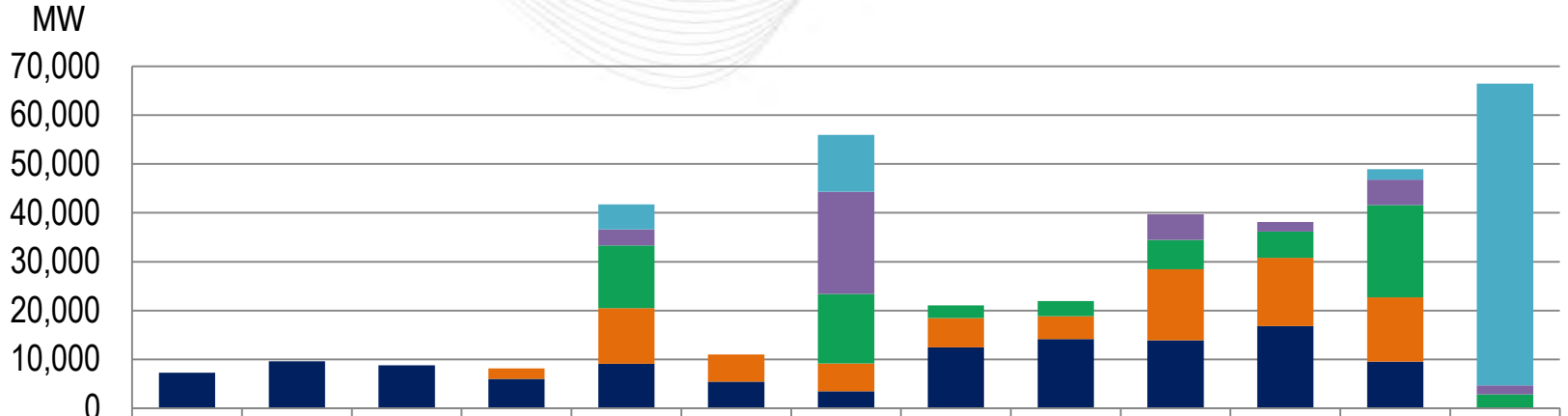
1. Retirement of less-efficient/high-emitting sources provides an immediate reduction in CO_2 emissions and mitigates the need for re-dispatch of more-efficient / lower-emitting sources
   a) To represent glide-path orderly (market-based) retirement of resources will reduce the policy's impact on revenues for generators that remain in service
   b) The implication is adverse impacts to reliability over the interim compliance period would be muted
2. More efficient sources tend to face additional pressure to retire as the mass or rate based limits decline over-time
   a) Retirement of less efficient resources earlier in the glide-path reduces CO_2 prices and demand for CO_2 allowances and mitigates cost impacts to more efficient resources
   b) Under the policy, load increases or increases in the gas/coal price spread do not help units that struggle to earn adequate revenues to cover their fixed costs

At-Risk Generating Unit MW using the Least-Cost New Entrant Net CONE for the 2020 Compliance Year



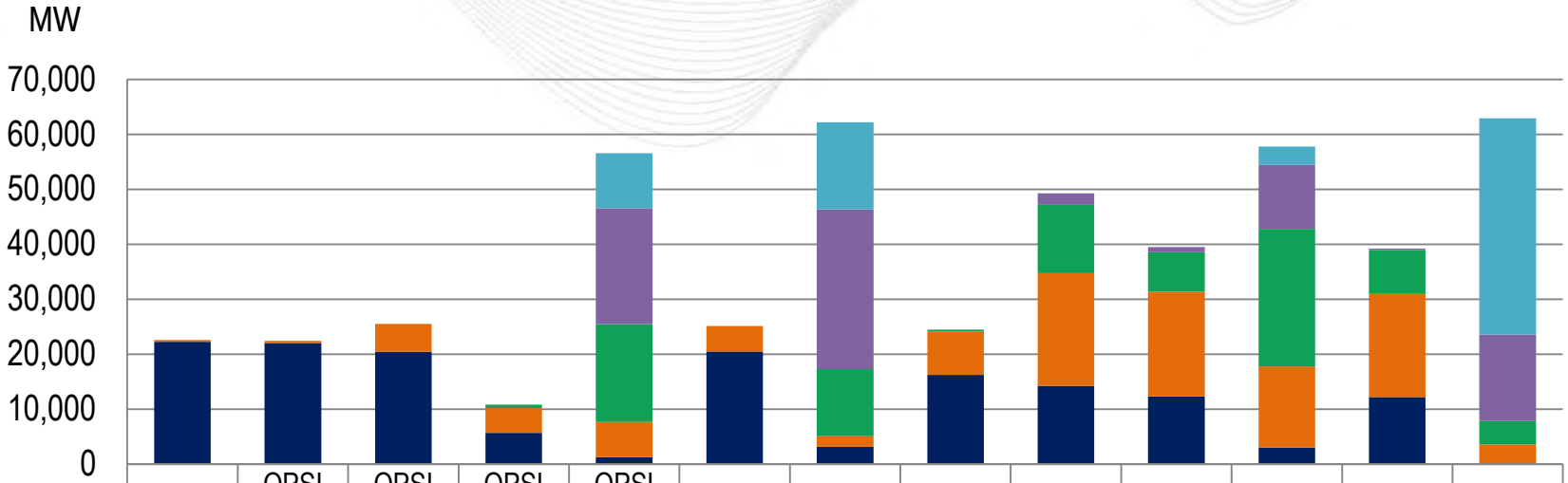
	OPSI 2a	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
>1.5 Net Cone												690
1.0 - 1.5 Net Cone												11,723
0.75 - 1.0 Net Cone				4,887								16,309
0.6 - 0.75 Net Cone				5,310		836				5,533	6,584	8,960
0.5 - 0.6 Net Cone	7,521	6,374	4,004	11,382	6,374	7,473	7,199	6,407	8,001	6,833	13,362	5,086

At-Risk Generating Unit MW using the Least-Cost New Entrant Net CONE for the 2025 Compliance Year



	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
>1.5 Net Cone					5,074		11,602					2,114	61,715
1.0 - 1.5 Net Cone					3,335		20,954			5,239	1,979	5,212	1,868
0.75 - 1.0 Net Cone					12,839		14,178	2,632	3,095	6,027	5,347	18,872	2,845
0.6 - 0.75 Net Cone				2,185	11,323	5,533	5,686	5,976	4,641	14,561	13,954	13,173	
0.5 - 0.6 Net Cone	7,275	9,599	8,770	5,984	9,136	5,474	3,514	12,460	14,181	13,899	16,837	9,534	

At-Risk Generating Unit MW using the Least-Cost New Entrant Net CONE for the 2029 Compliance Year

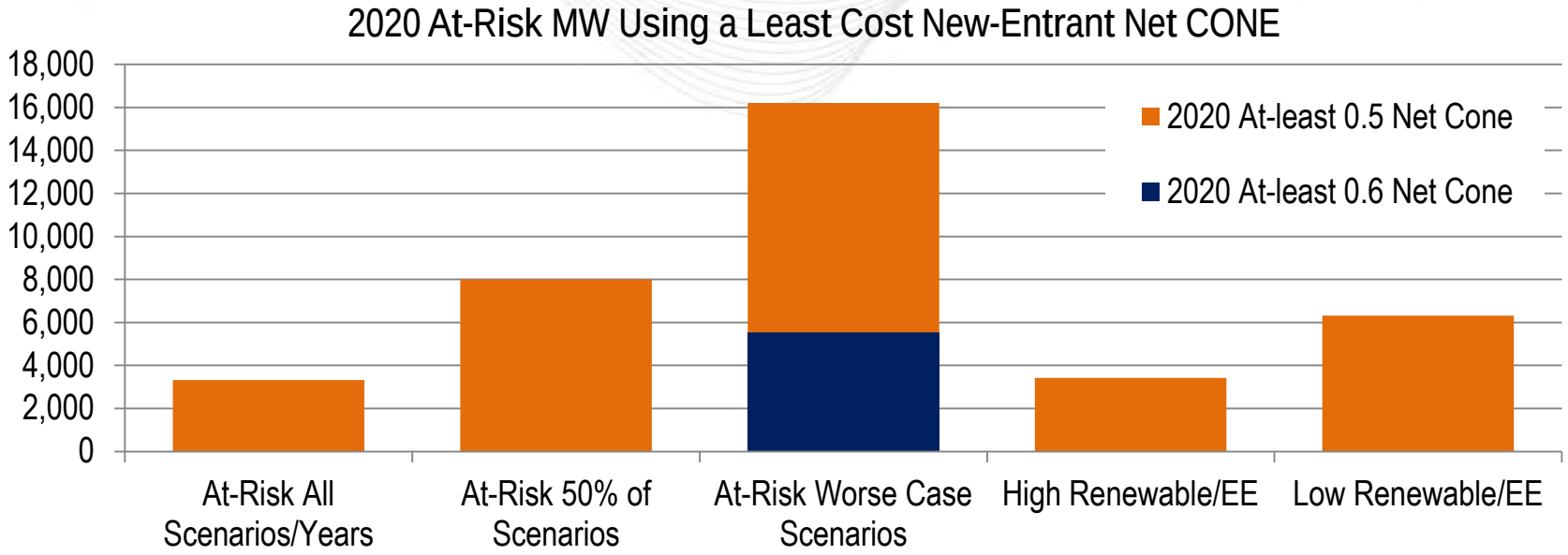


	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
>1.5 Net Cone					9,986		15,900				3,347		39,344
1.0 - 1.5 Net Cone					21,102		29,059		2,114	948	11,631	308	15,732
0.75 - 1.0 Net Cone				641	17,790		12,211	308	12,409	7,206	25,025	7,846	4,293
0.6 - 0.75 Net Cone	318	368	5,072	4,505	6,405	4,623	1,934	7,912	20,536	19,070	14,752	18,865	3,554
0.5 - 0.6 Net Cone	22,269	22,045	20,408	5,683	1,261	20,499	3,116	16,232	14,209	12,284	3,028	12,194	

Units “at Risk” for Retirement Increase over Time and are Dependent on Scenario Assumptions

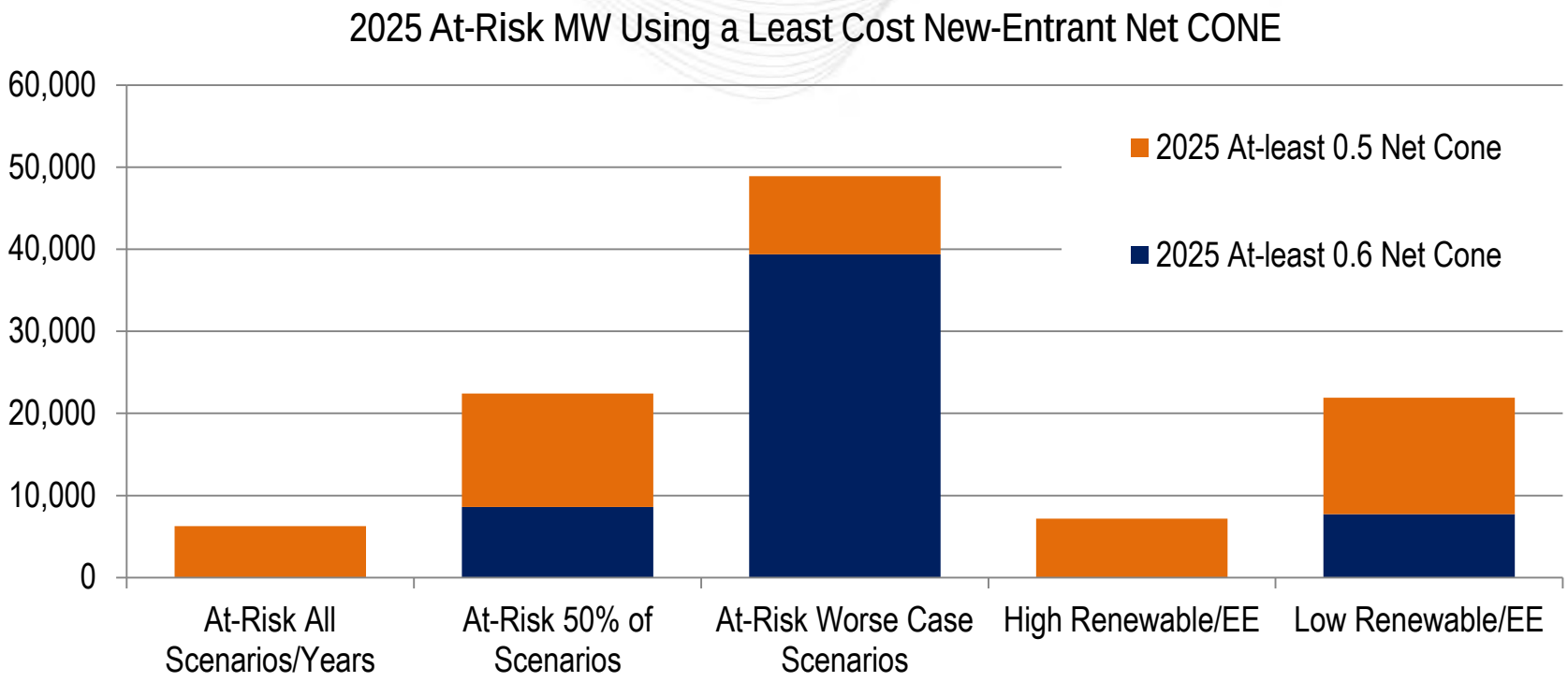
- Unlike the results in the EPA IPM runs, all possible unit retirements are not “front loaded” in 2020
  - Units “at risk” for retirement increase as the mass-based targets become more stringent and by extension CO_2 prices increase
- Units “at risk” for retirement are highly dependent upon scenario assumptions
  - Ironically, greater energy efficiency and renewable penetration and continued operation of existing nuclear results in fewer MW “at risk” for retirement
  - While greater energy efficiency, renewables, and nuclear have the effect of reducing energy market prices, however under the CPP, they also reduce CO_2 prices
    - A reduction in the CO_2 prices is indicative of less coal-to-natural gas re-dispatch
    - Being able to operate economically for more hours is more beneficial to coal unit revenues than the reduction in energy market prices.

Steam Turbine Generating Resource – MW at Risk for Retirement Benchmark Based on Units Requiring At-least 0.6 or 0.5 Net CONE

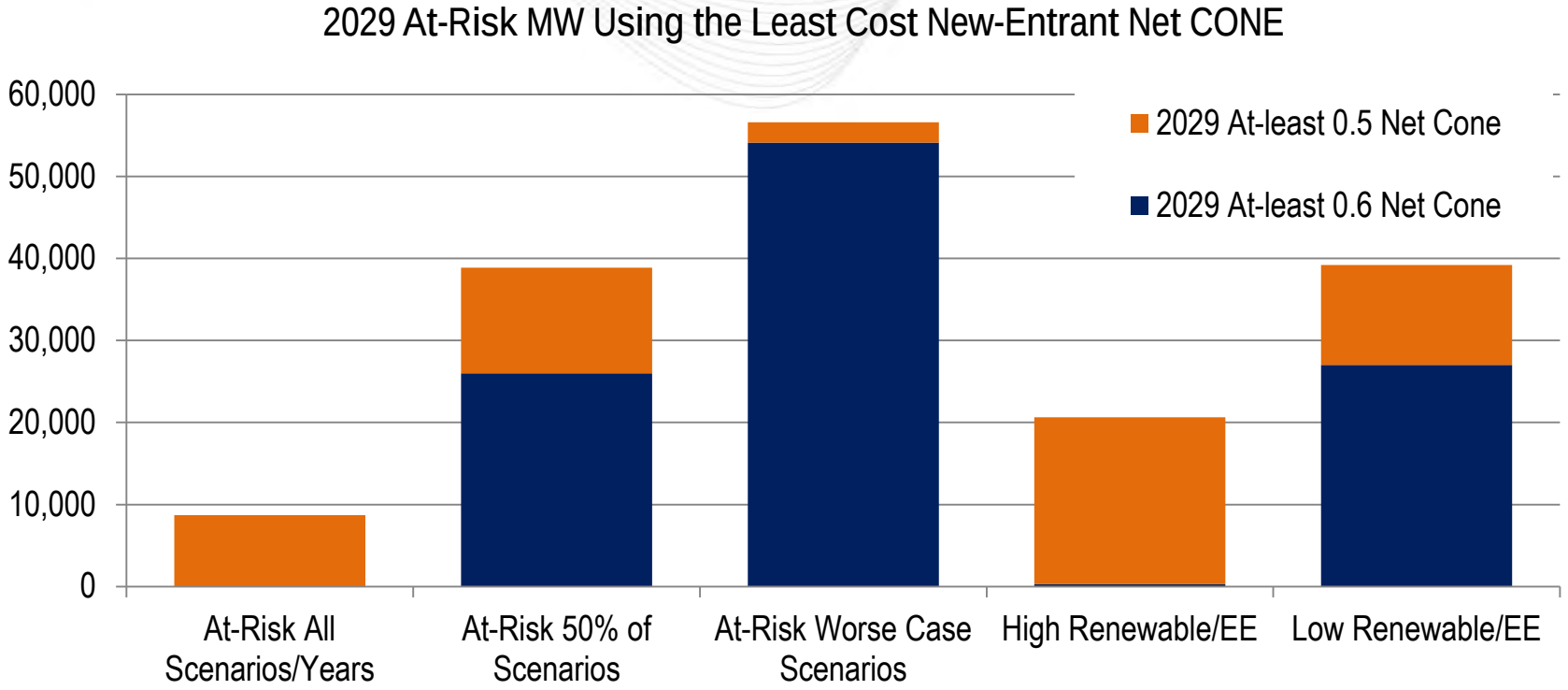


Some of the units designated as at-risk in 2020 would be in the absence of the policy based on continuation of existing market trends - low load growth, low gas prices and already planned new entrants in the PJM Interconnection Queue (highly efficient NGCC units and low-cost renewable)

Steam Turbine Generating Resource – MW at Risk for Retirement Benchmark Based on Units Requiring At-least 0.6 or 0.5 Net CONE

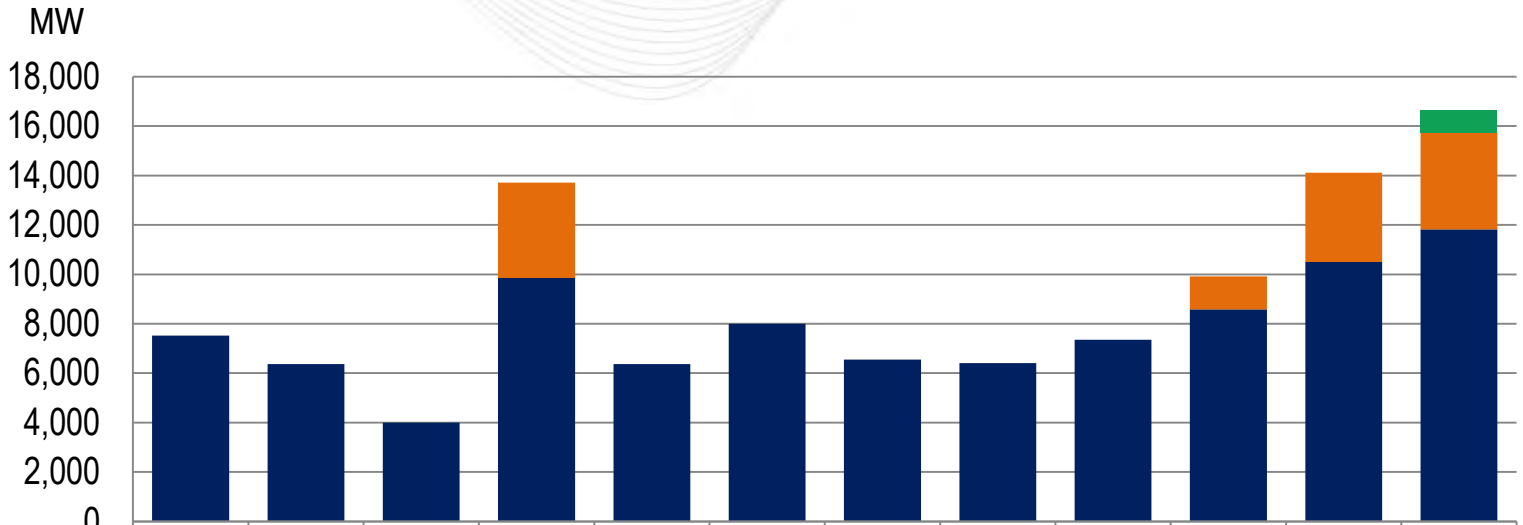


Steam Turbine Generating Resource – MW at Risks for Retirement Benchmark Based on Units Requiring At-least 0.6 or 0.5 Net CONE



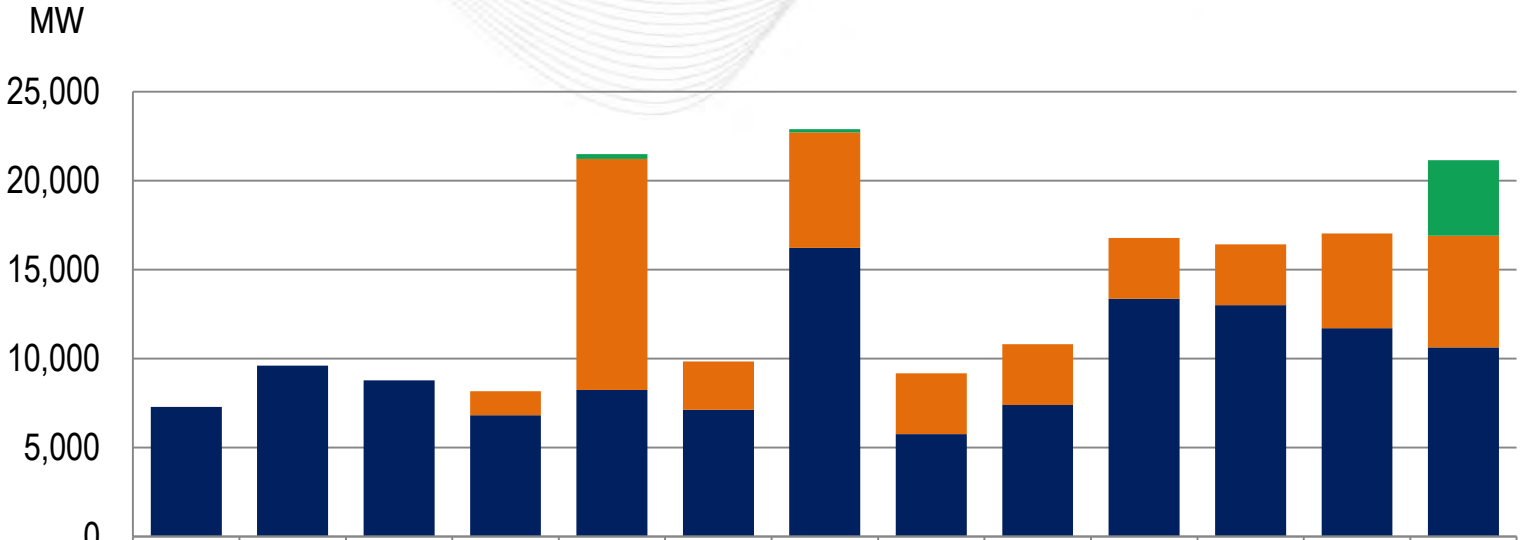
At-Risk Unit Results using a Combustion Turbine as the Reference Resource by Scenario to meet PJM Reliability Target (LOLE Criteria) under Mass-Based Compliance

At-Risk Generating Unit MW using a CT Reference Resource
2020 Compliance Year



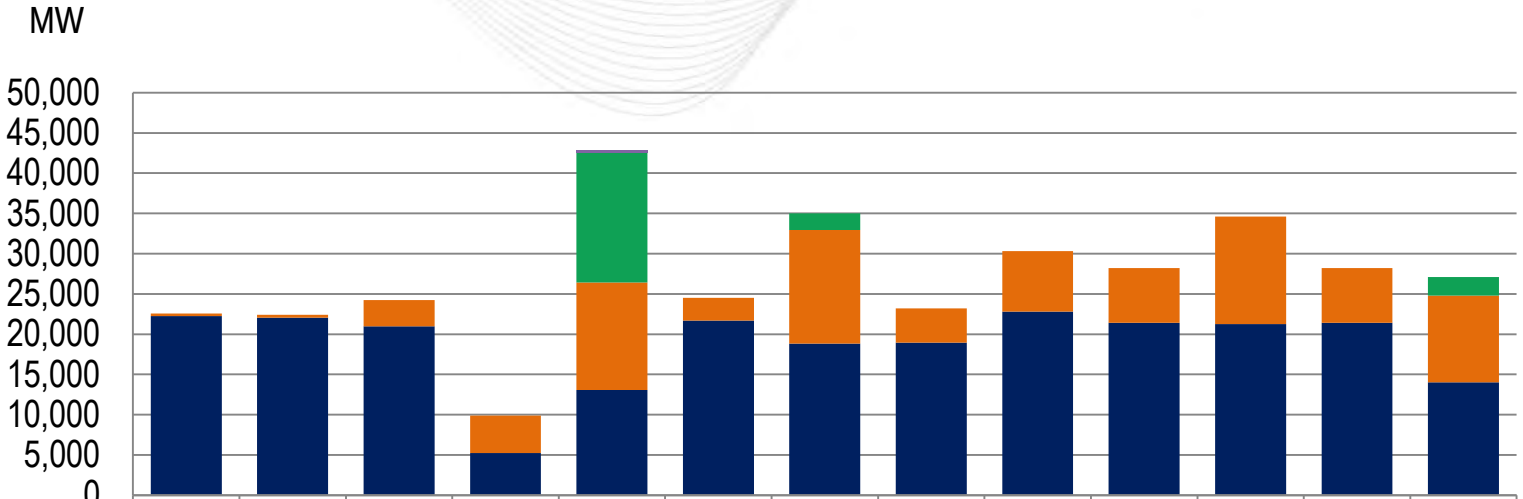
	OPSI 2a	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
0.75 - 1.0 Net Cone												896
0.6 - 0.75 Net Cone				3,852						1,337	3,614	3,930
0.5 - 0.6 Net Cone	7,521	6,374	4,004	9,856	6,374	8,001	6,554	6,407	7,356	8,580	10,500	11,824

At-Risk Generating Unit MW using a CT Reference Resource
2025 Compliance Year



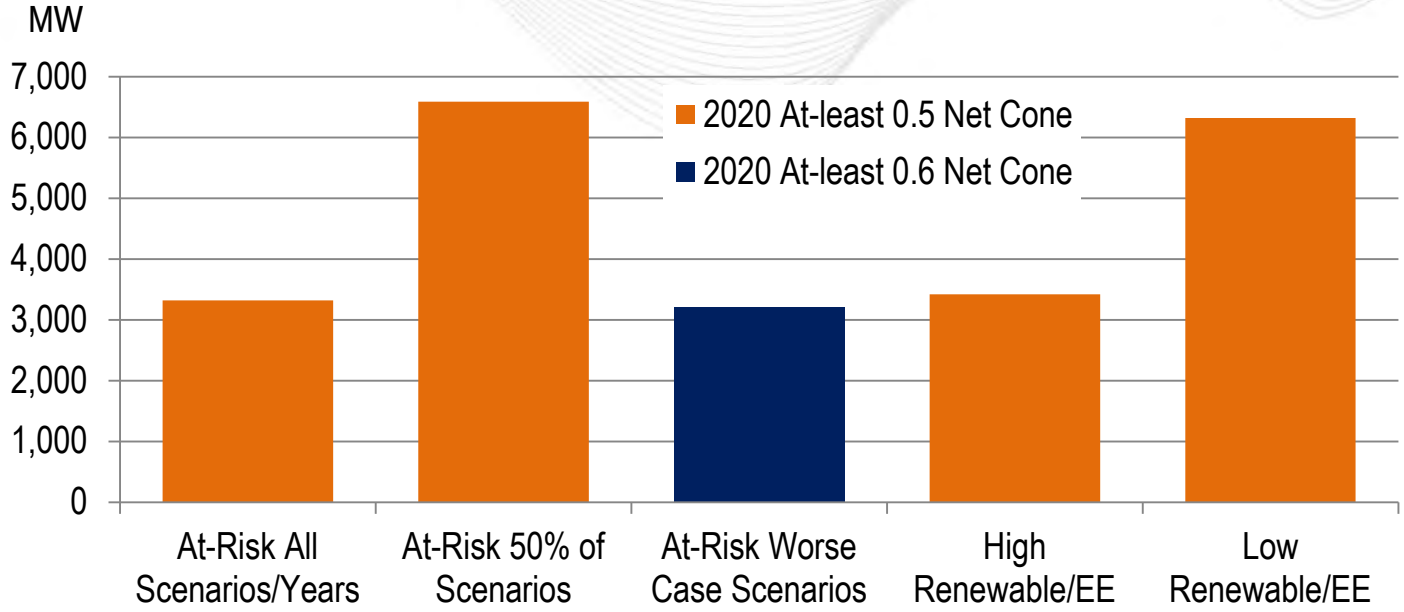
	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
0.75 - 1.0 Net Cone					268		185						4,250
0.6 - 0.75 Net Cone				1,355	12,972	2,703	6,484	3,419	3,419	3,419	3,419	5,331	6,269
0.5 - 0.6 Net Cone	7,275	9,599	8,770	6,814	8,243	7,124	16,227	5,755	7,390	13,360	12,992	11,700	10,628

At-Risk Generating Unit MW using a CT Reference Resource
2029 Compliance Year



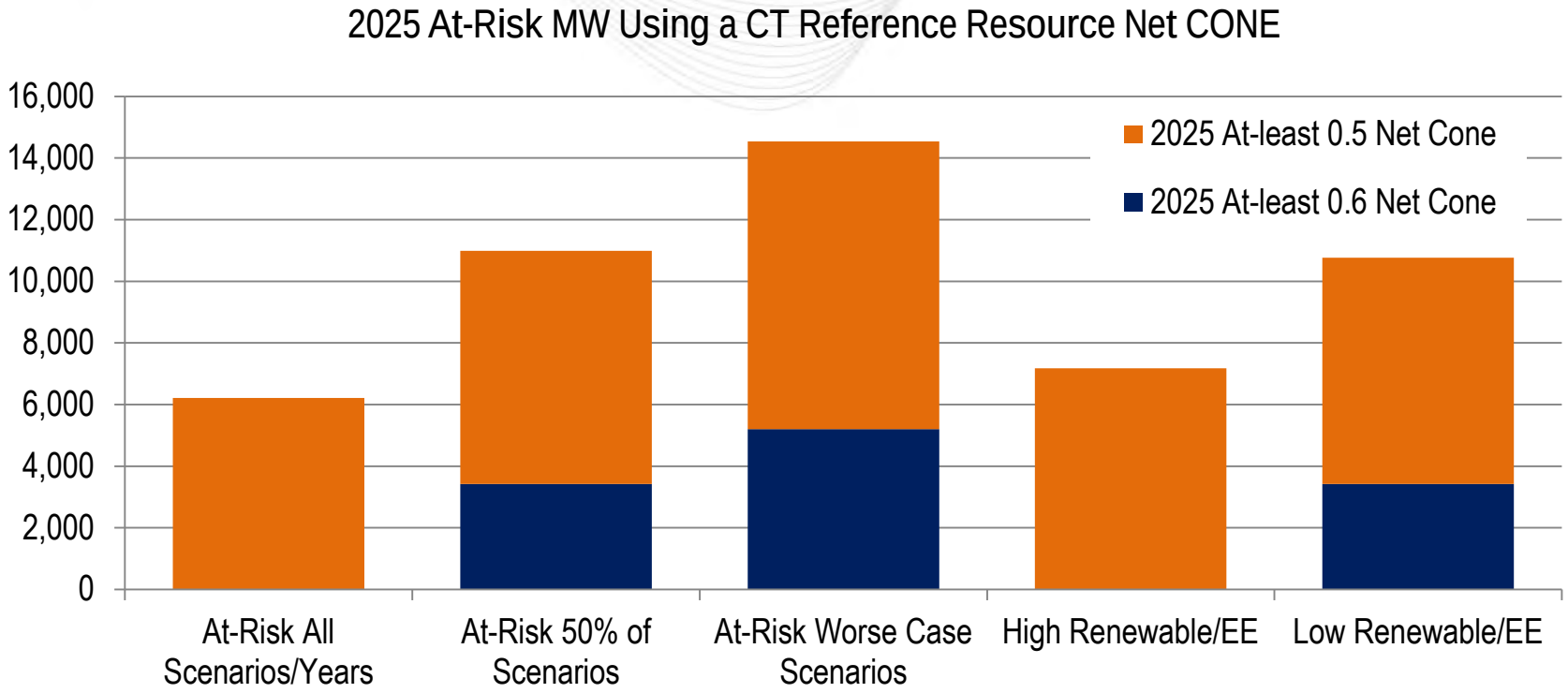
	OPSI 2a	OPSI 2b.1	OPSI 2b.2	OPSI 2b.3	OPSI 2b.4	PJM 1	PJM 2	PJM 3	PJM 4	PJM 5	PJM 6	PJM 7	PJM 8
1.0 - 1.5 Net Cone					268								
0.75 - 1.0 Net Cone					16,178		2,064						2,309
0.6 - 0.75 Net Cone	318	368	3,267	4,625	13,375	2,817	14,097	4,255	7,511	6,785	13,367	6,785	10,784
0.5 - 0.6 Net Cone	22,269	22,045	20,981	5,250	13,062	21,685	18,831	18,965	22,789	21,417	21,252	21,417	14,017

Steam Turbine Generating Resource – MW at Risks for Retirement Benchmark Based on Units Requiring At-least 0.6 or 0.5 Net CONE

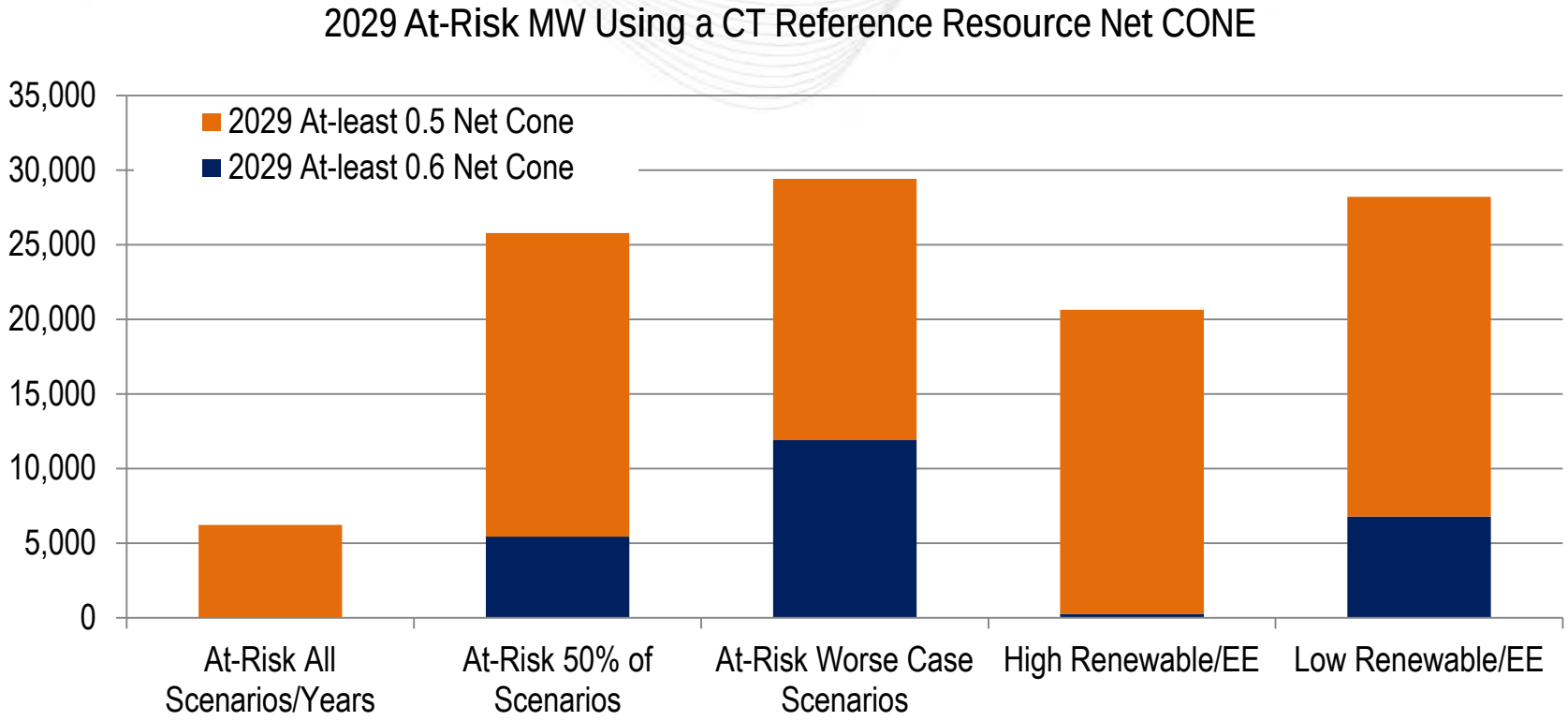


Some of the units designated as at-risk in 2020 would be in the absence of the policy based on continuation of existing market trends - low load growth, low gas prices and already planned new entrants in the PJM Interconnection Queue (highly efficient NGCC units and low-cost renewable)

Steam Turbine Generating Resource – MW at Risks for Retirement Benchmark Based on Units Requiring At-least 0.6 or 0.5 Net CONE



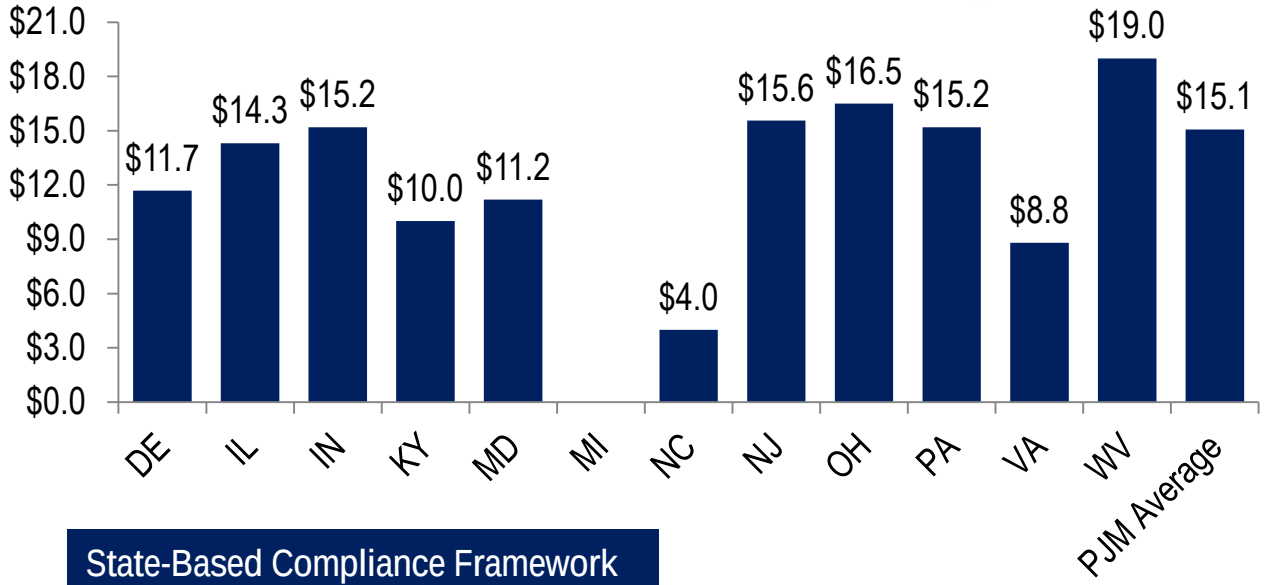
Steam Turbine Generating Resource – MW at Risks for Retirement Benchmark Based on Units Requiring At-least 0.6 or 0.5 Net CONE



At-Risk Unit Results State-by-State vs. Regional under Mass-Based Compliance

State-Based Compliance Versus Regional Compliance
Implied CO_2 Prices By State

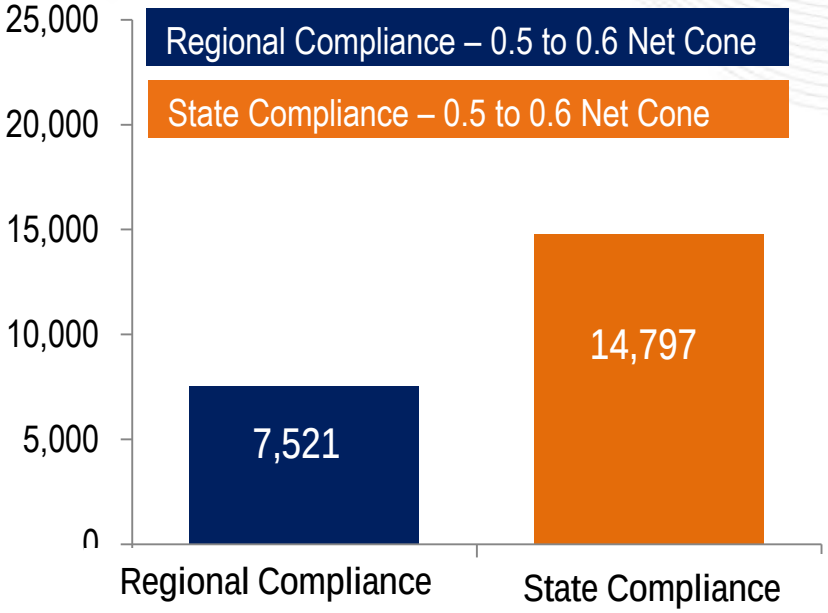
Renewable EE Targets in 2020
CO_2 Price ($/Ton)



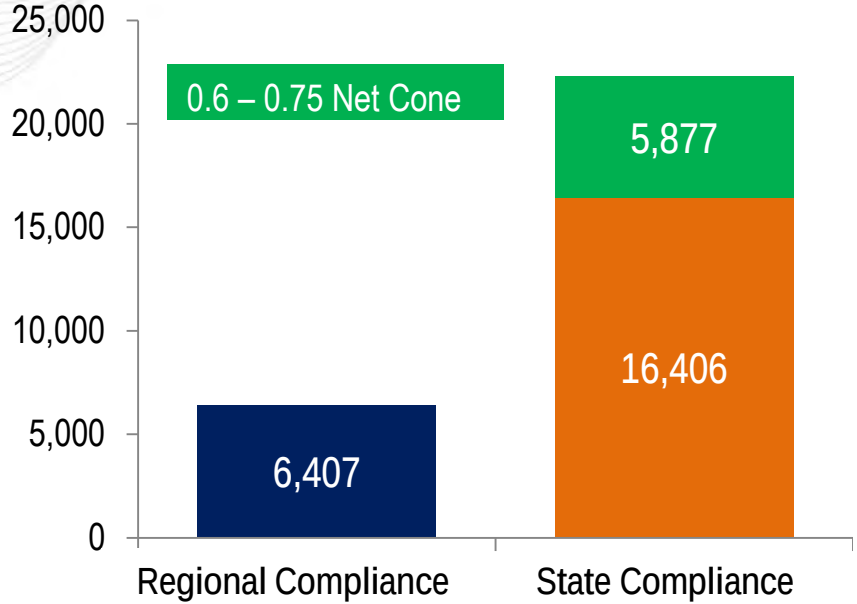
State-Based Compliance Framework

When studied within a Regional Compliance framework the scenario binds at $3.50 per CO_2 Short Ton . Compared to an average regional price of $15.10 per CO_2 Short Ton, there will be much less re-dispatch from coal resources to gas resources under regional compliance

State Compliance Versus Regional Compliance
Comparative Assessment of Resources At-Risk in 2020
Least-Cost New Entrant

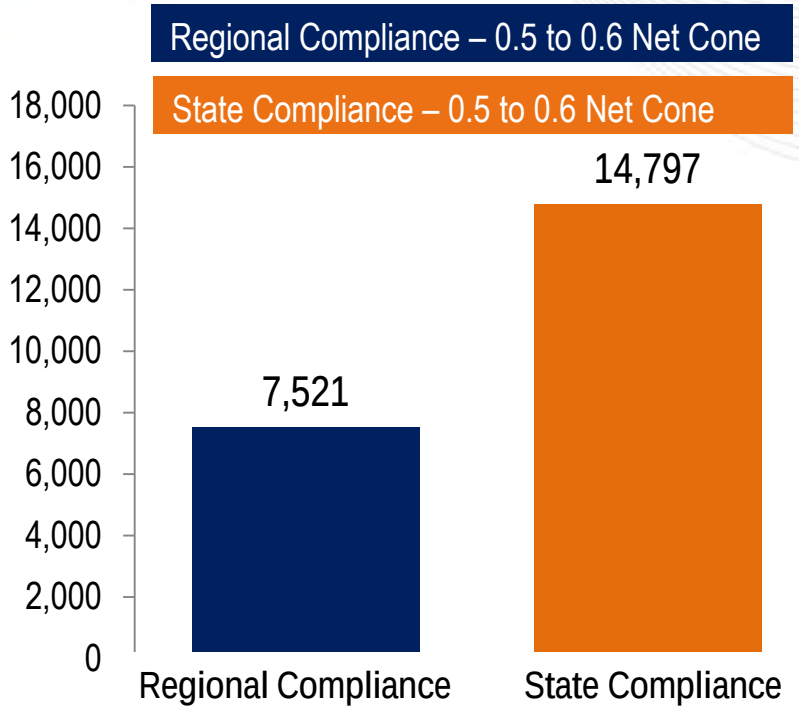


High Renewable Scenario

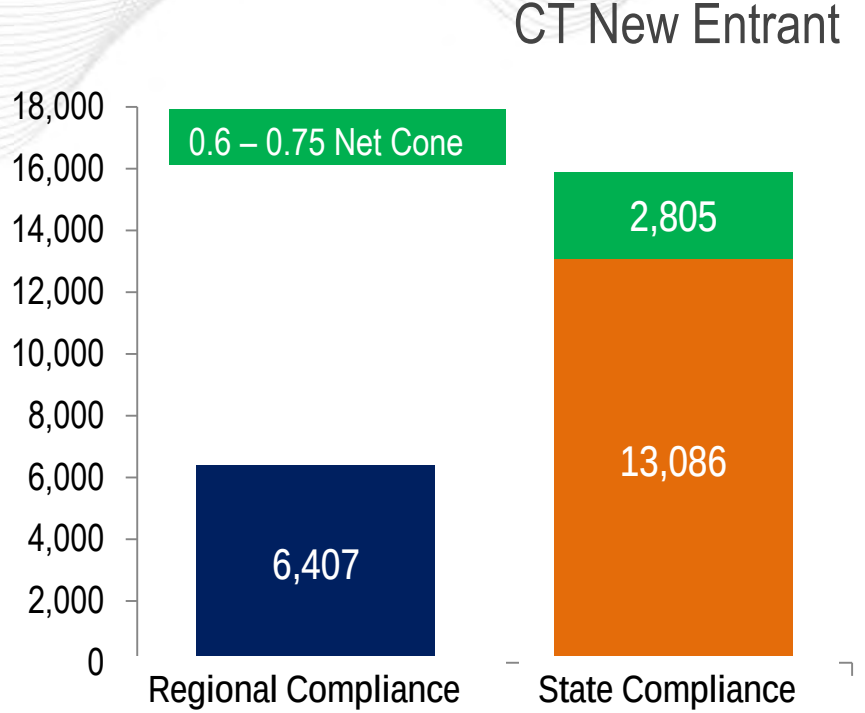


Lower Renewable/EE Scenario

State Compliance Versus Regional Compliance
Comparative Assessment of Resources At-Risk in 2020
CT New Entrant



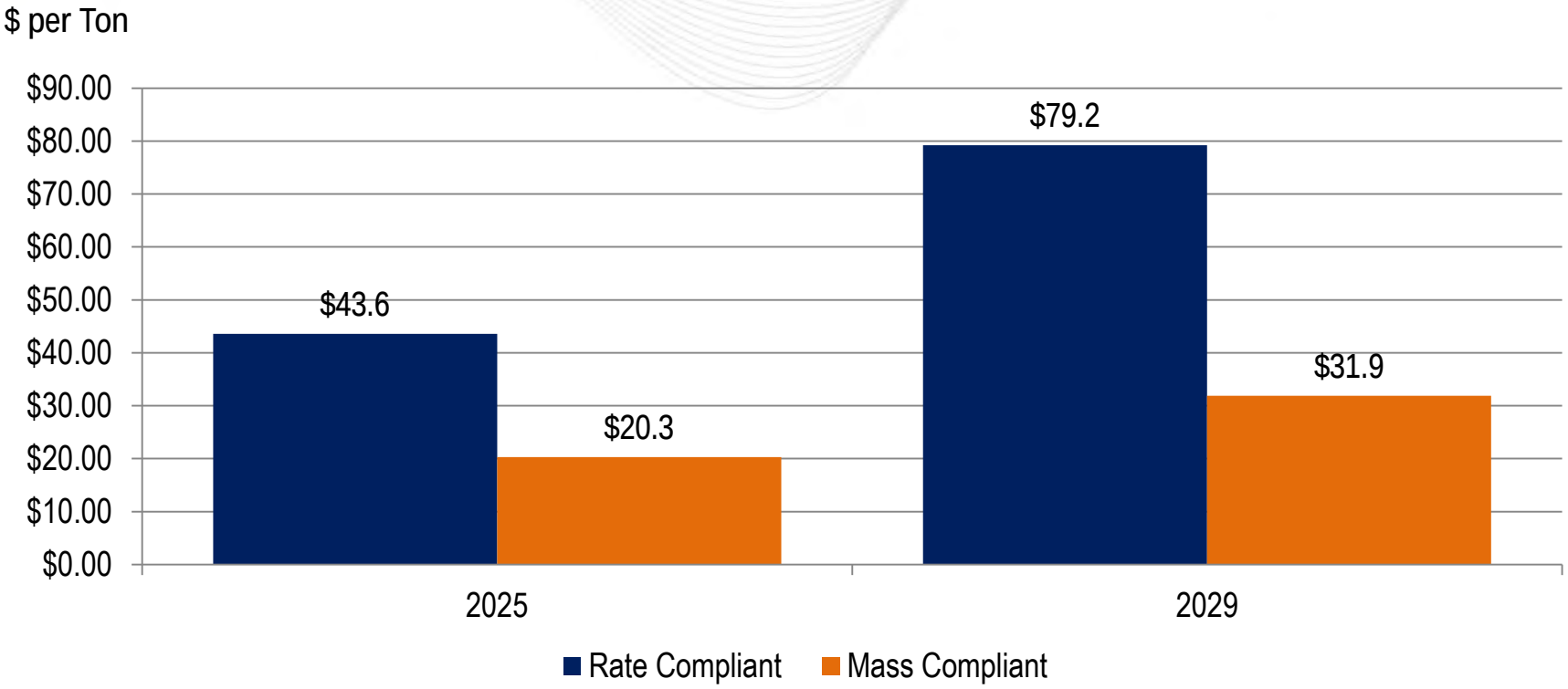
High Renewable Scenario



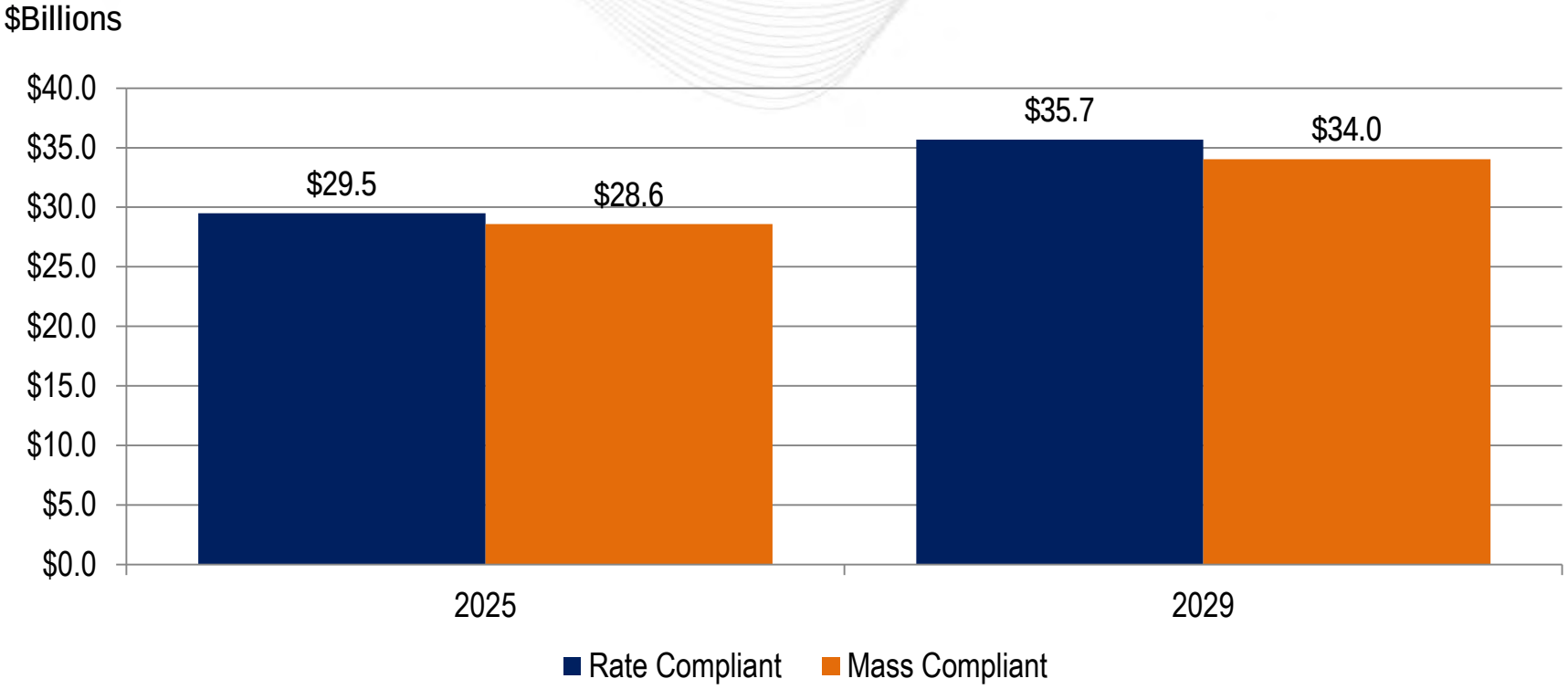
Lower Renewable/EE Scenario

At-Risk Unit Results Regional Compliance: Emissions Rate Based (PJM 10) vs. Mass-Based (PJM 4)

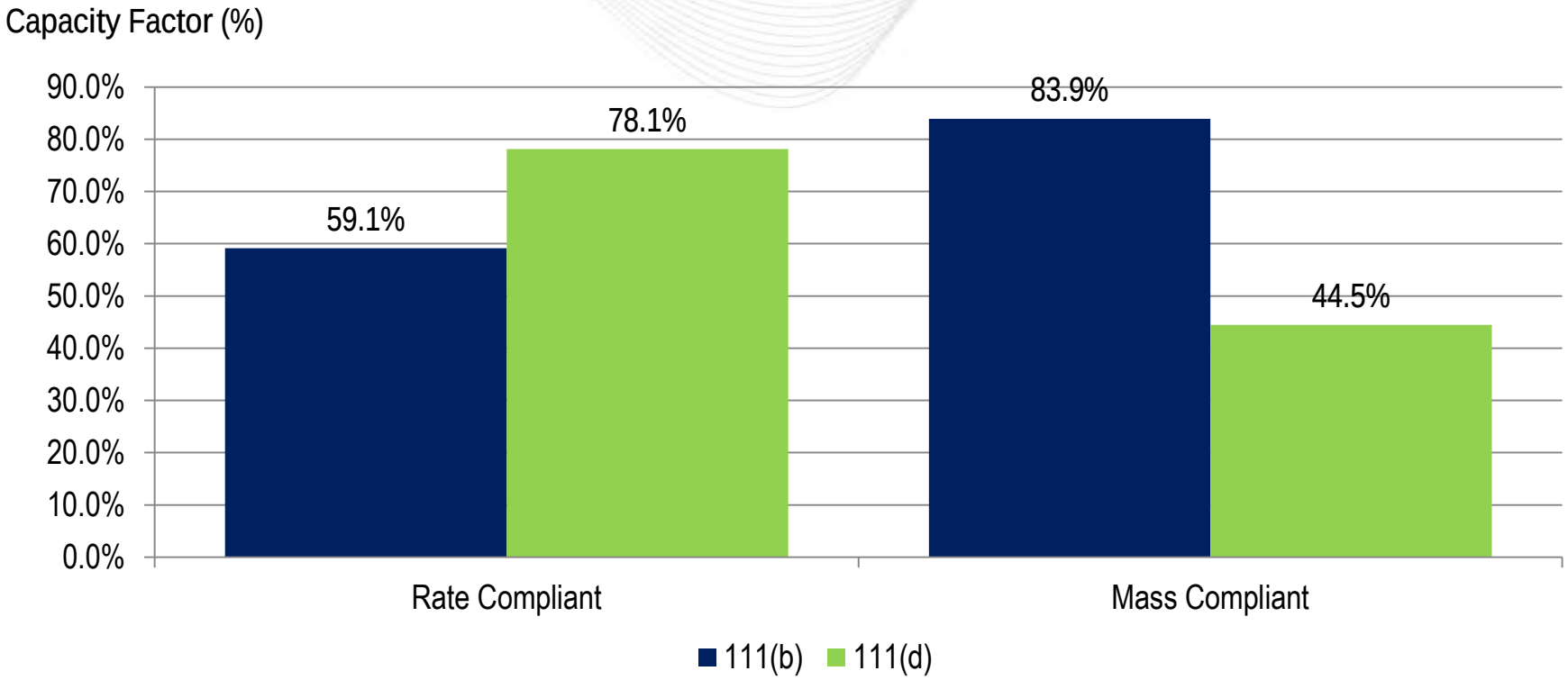
Rate Based Versus Mass Based Compliance Implied CO_2 Prices



Rate Based Versus Mass Based Compliance Impact to Fuel and O&M Expense

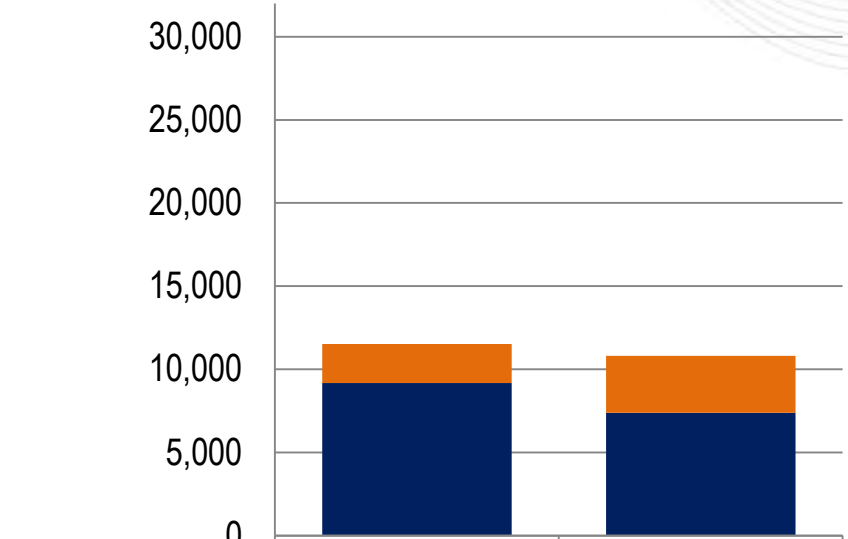


Rate Based Versus Mass Based Compliance
Impact on NGCC Unit Operation (Covered Versus Non-Covered Resources)



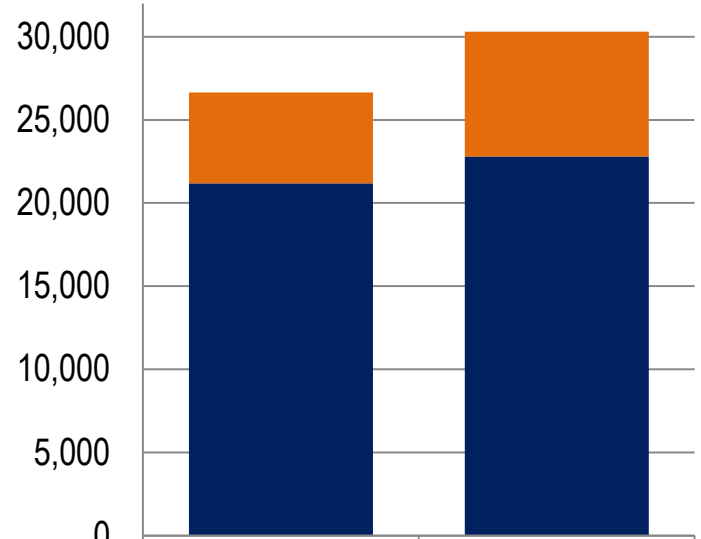
Emissions Rate based vs. Mass-Based Compliance

2025 At-Risk MW



	Rate Compliant	Mass Compliant
0.6 - 0.75 Net Cone	2,352	3,419
0.5 - 0.6 Net Cone	9,169	7,390

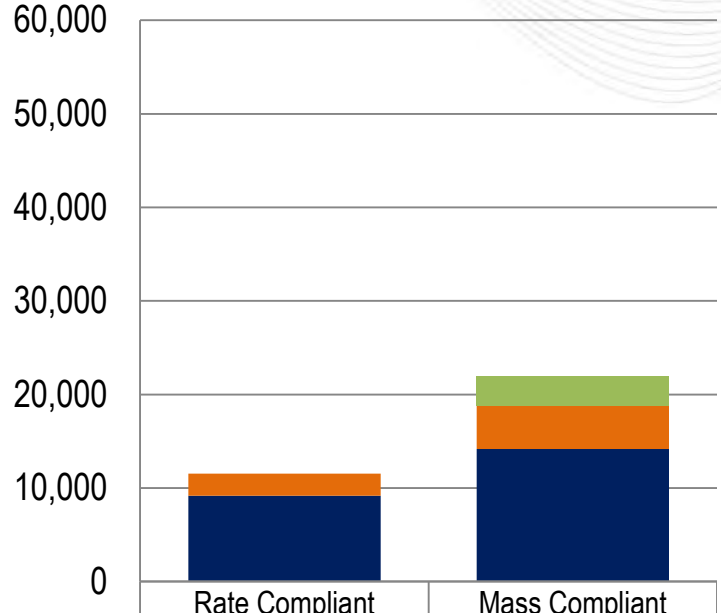
2029 At-Risk MW



	Rate Compliant	Mass Compliant
0.6 - 0.75 Net Cone	5,473	7,511
0.5 - 0.6 Net Cone	21,173	22,789

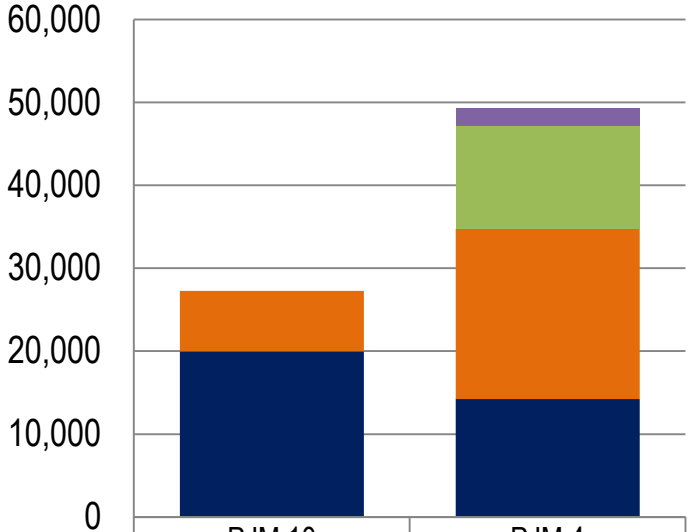
Comparative Retirement Risks Assessment
Using Least Cost Resource (CT or NGCC) as the Benchmark

2025 At-Risk MW



	Rate Compliant	Mass Compliant
0.75 - 1.0 Net Cone		3,095
0.6 - 0.75 Net Cone	2,352	4,641
0.5 - 0.6 Net Cone	9,169	14,181

2029 At-Risk MW



	PJM 10	PJM 4
1.0 - 1.5 Net Cone		2,114
0.75 - 1.0 Net Cone		12,409
0.6 - 0.75 Net Cone	7,279	20,536
0.5 - 0.6 Net Cone	19,980	14,209

111(d) Reliability Planning Assessment

111(d) Modelling Assumptions

- Reliability analyses will use a 2022 summer peak load RTEP case
- Generation Modeling Assumptions
  - All existing capacity units online (unless the owner has notified us of their intent to deactivate)
  - ISA and FSA generation will be modelled consistent with RTEP procedures
- Transmission Topology – include all upgrades approved by the PJM Board through the 2014 RTEP
- Reliability Tests
  - Generation and Load Deliverability
  - N-1-1

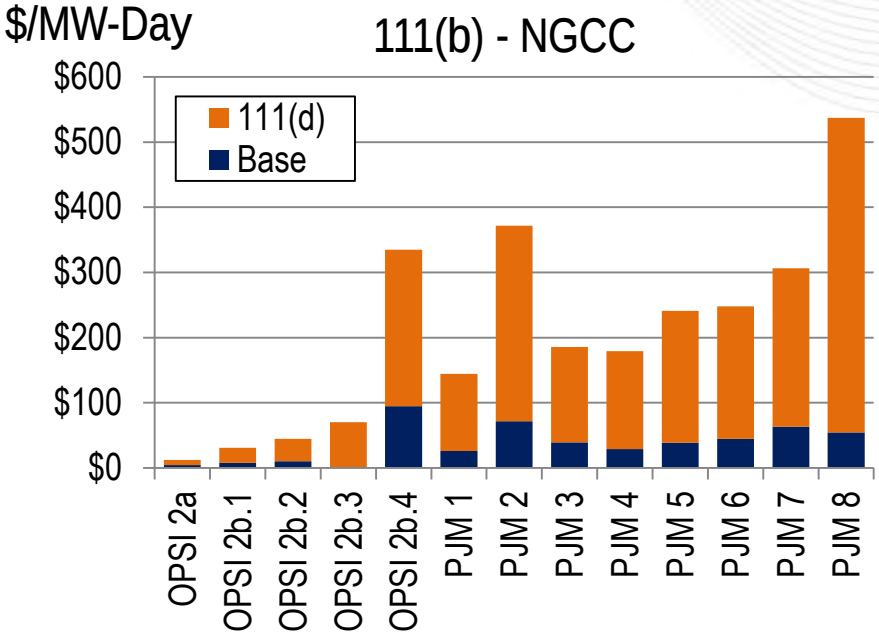
111(d) Analytical Approach

- Studies will assess the reliability impact of “at-risk” generation based on degree of risk
  - Look at at-risk generation from 2025 simulations and take average between CT Net CONE and Least-cost Net CONE benchmark (slides 41 and 48)
  - “At risk” in all simulations (6,200 MW)
  - “At risk” in at least 50% of simulations (16,500 MW)
  - “At risk” in “worst case” simulations (32,000 MW)
  - Caveat: As units retire, the financial prospects for remaining units improves
- Conductor limits will be used where available to identify potentially more significant upgrades

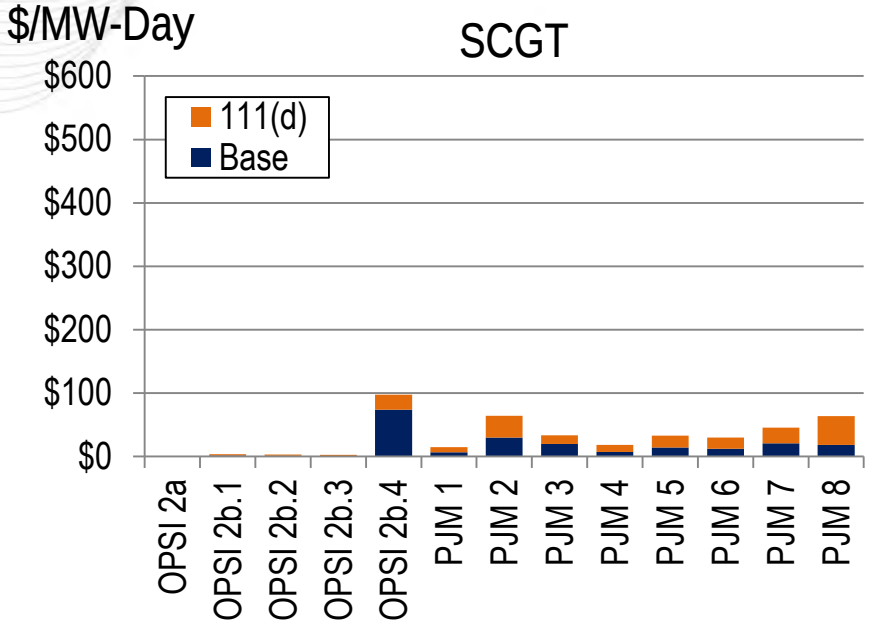
Appendix:

Why are There so Many Potential Steam Turbine Unit Retirements, and How Does the Selection of the Reference Resource Impact the Retirement Outlook

2025 Net Energy Market Revenue for NGCC and SCGT Units: NGCC Easily Cover ACR Once in Operation

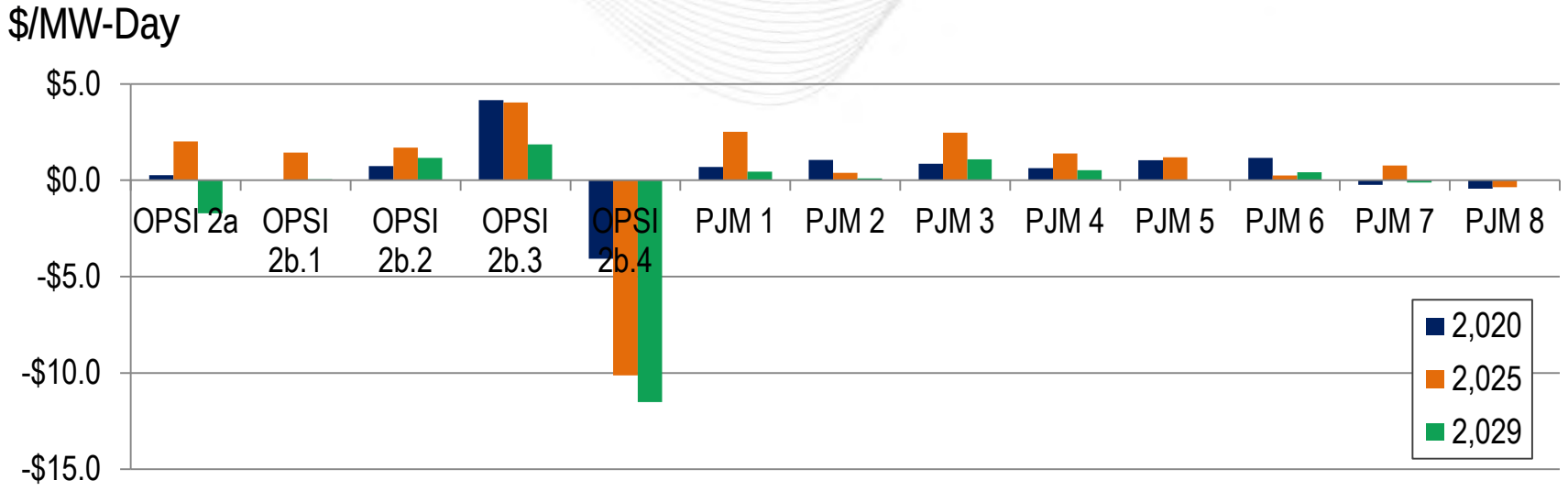


NGCC Avoidable Cost Rate = $58.3/MW-Day



SCGT Avoidable Cost Rate = $47.4/MW-Day

Average Congestion Revenue for At-Risk Steam Turbine Resources



- Congestion is not a significant driver of reduced revenues for steam-turbine driven units in compliance cases, and if anything increases revenues…seeing east to west flows!
- All else equal, with new gas in the east, and most "at risk" resources outside of the "gas rich areas", steam does not need to manage congestion costs … except in the 50% nuclear retirement case.