PJM Perspective of the EPA Clean Power Plan: Analysis

Consortium for Energy Policy Research
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PJM Interconnection

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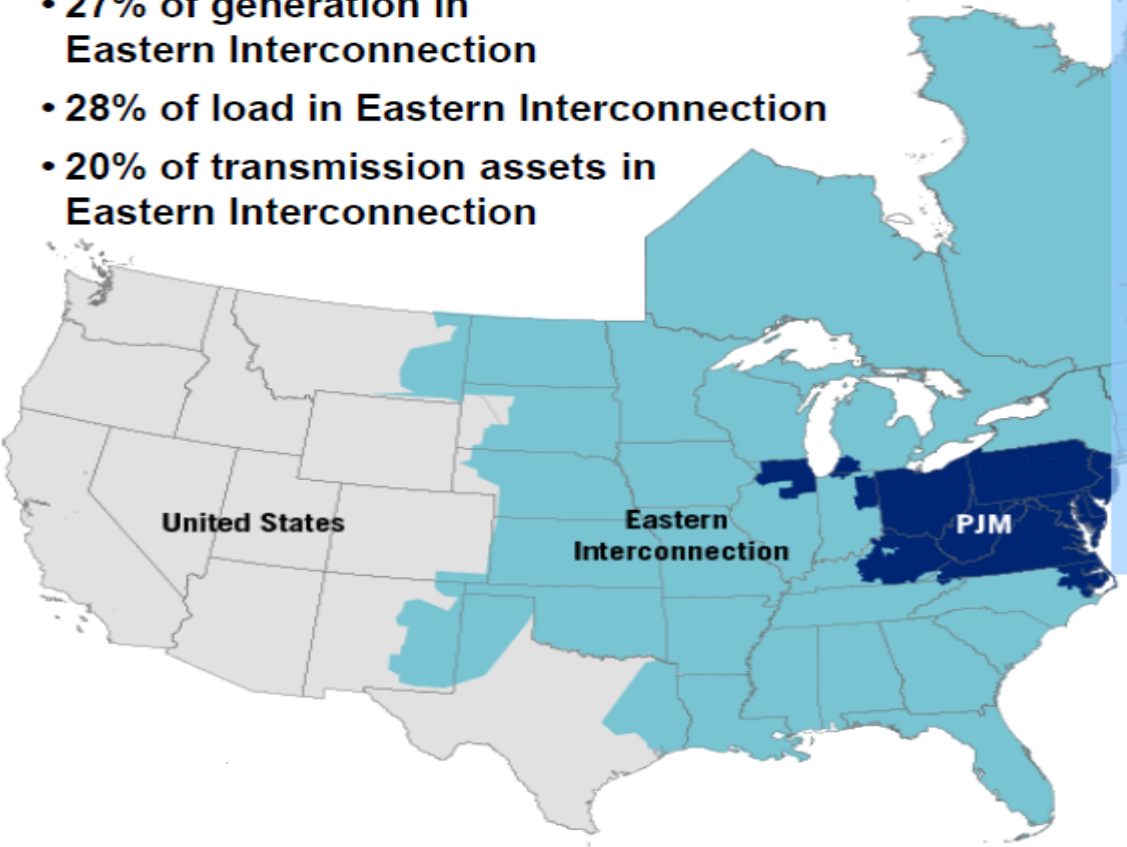
PJM as Part of the Eastern Interconnection

- **27% of generation in Eastern Interconnection**
- **28% of load in Eastern Interconnection**
- **20% of transmission assets in Eastern Interconnection**



KEY STATISTICS	
PJM member companies	850+
millions of people served	61
peak load in megawatts	165,492
MWs of generating capacity	185,600
miles of transmission lines	62,556
2013 GWh of annual energy	832,331
generation sources	1,365
square miles of territory	243,417
area served	13 states+DC
externally facing tie lines	191

21% of U.S. GDP produced in PJM

As of 1/1/2014

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PJM's Role in Evaluating the Effects of Proposed 111(d) GHG Regulation

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

- Responding state requests (OPSI)
- 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

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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

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Presentation Organization

- Overview of rule and scenario assumptions
- Sensitivity results changing different assumptions
  - Focus on the effect of “zero-emitting resources”
  - Drivers of CO_2 prices, redispatch, and capacity at risk for retirement
- Regional vs. State-by-state compliance
- Rate vs. Mass based compliance
- Reliability Safety Valve
- Concluding Observations

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- Similar to the Reliability Safety Valve for MATS
  - Keeps generation resources on-line to maintain reliability until a transmission solution can be implemented to ensure retirements do not jeopardize reliability
- Proposed Reliability Safety Valve for 111(d) has additional features
  - Up front analysis of SIPs to check for possible reliability issues intra-state and inter-state
  - On going analysis after implementation as generation resources may retire well after compliance obligations begin depending on flexibility of SIPs…in contrast MATS has a hard deadline for emissions rate compliance
  - Ongoing analysis of retirements same as MATS retirement analysis…standard deactivation analysis
  - More than just retirements…reliability in real-time operations

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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

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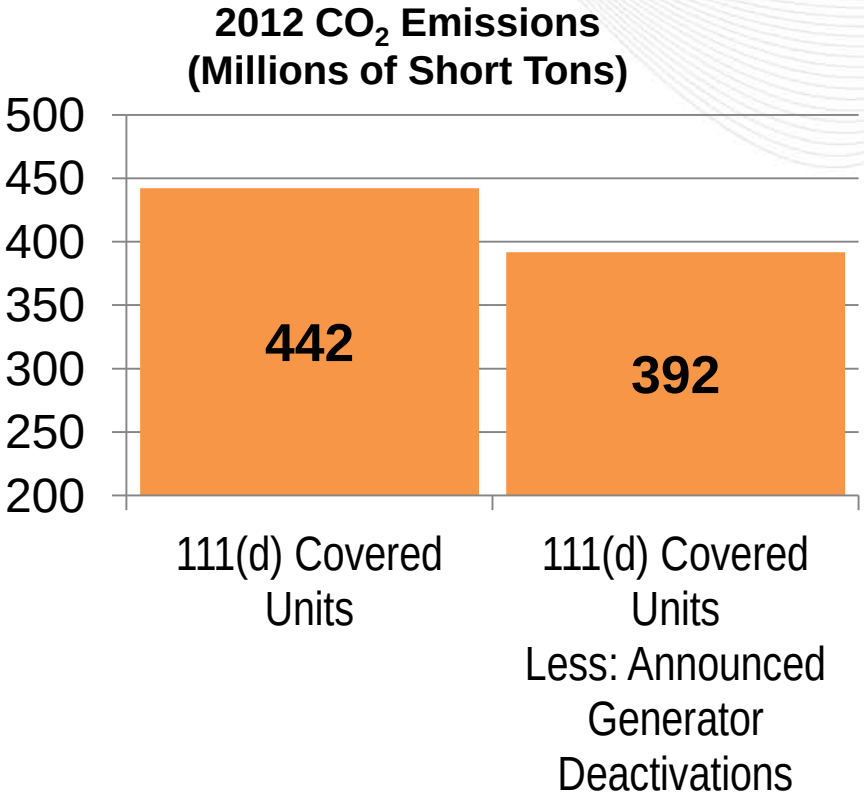
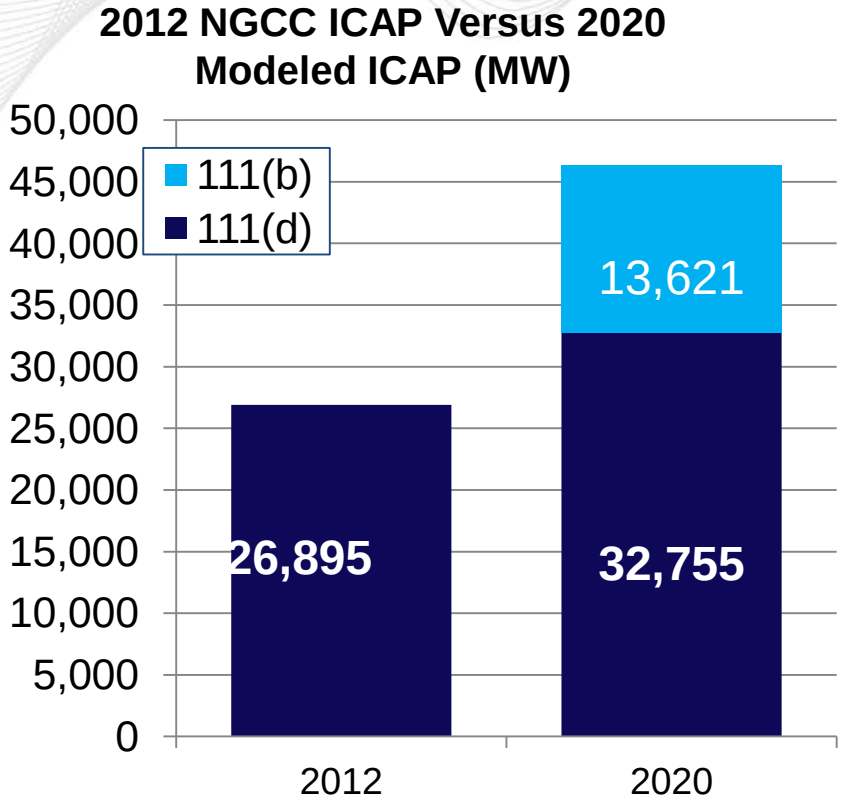
Impact of Retirements and New Resources Relative to 2012 Baseline: Mass Basis





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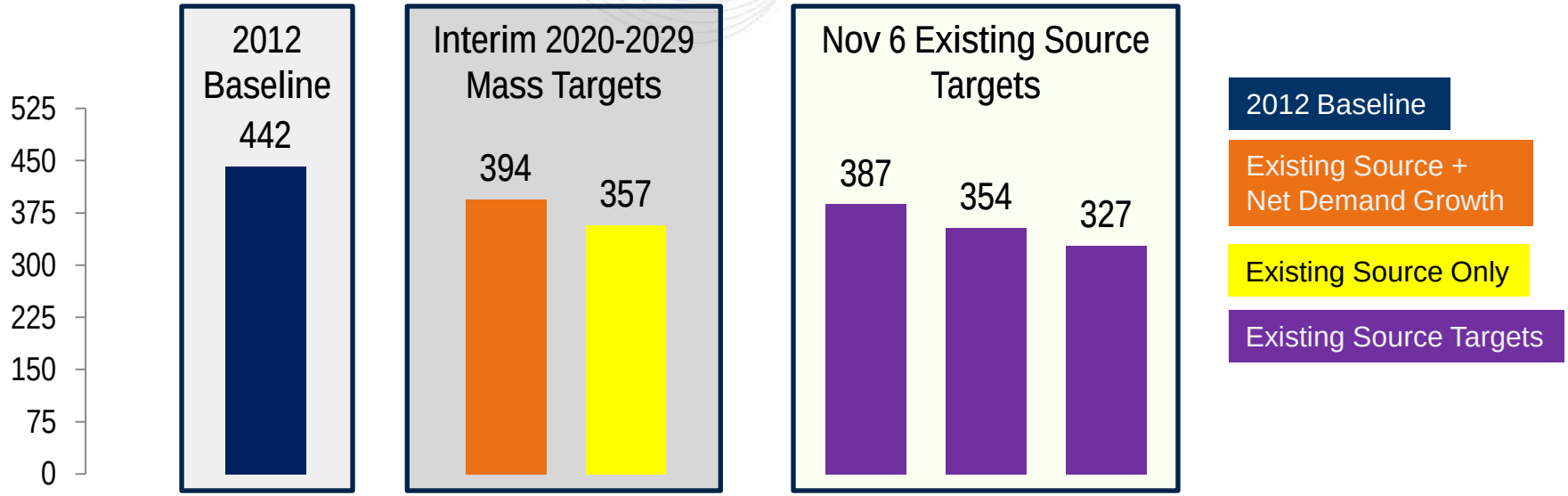
EPA Rate-to-Mass Conversion for Stricter (Existing Source) November 6 Guidance

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.

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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

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Figure 1. PJM Planning Model Average Delivered Natural Gas and Coal Prices

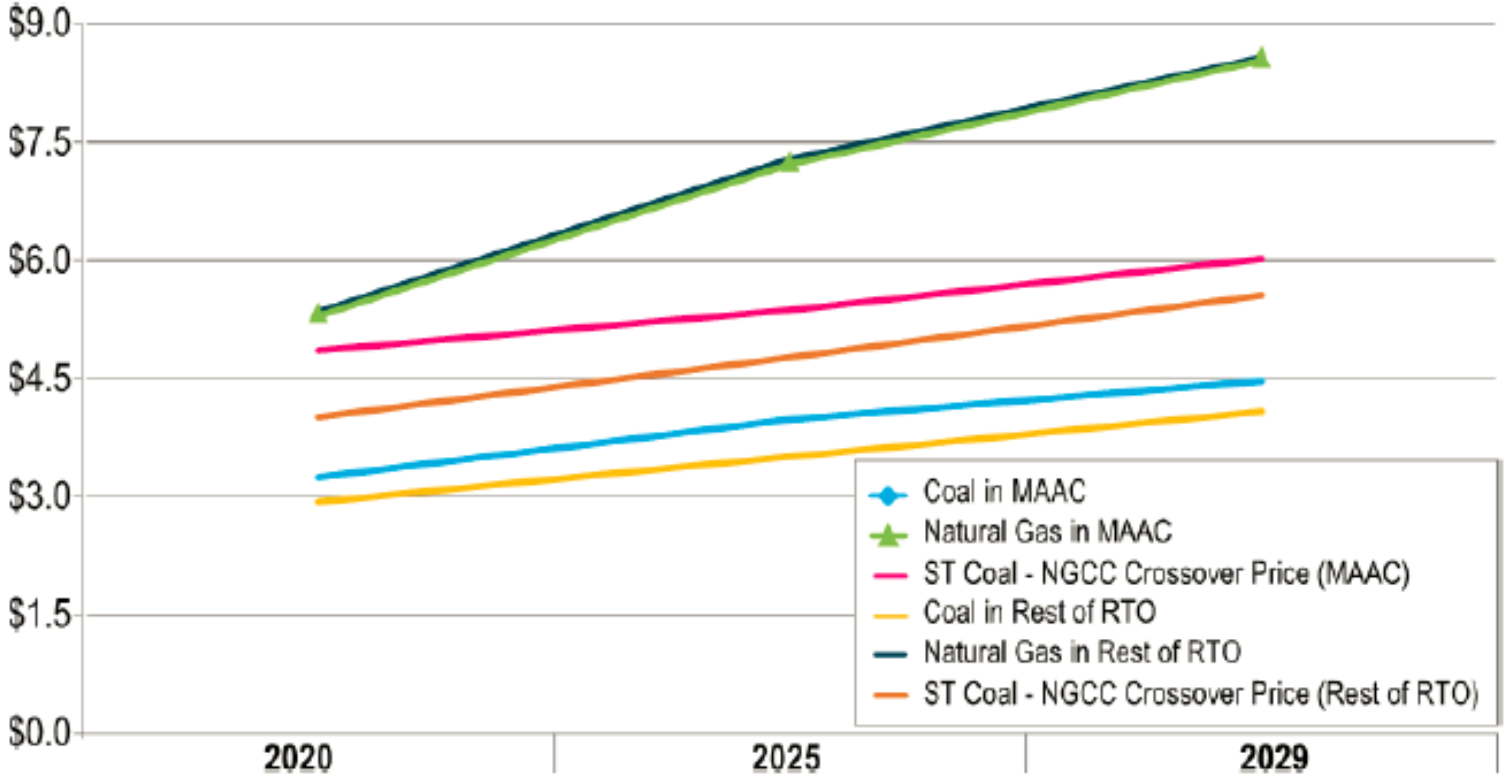

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Table 3. Definition and Assumptions of the OPSI Requested Scenarios

OPSI Scenarios	Fossil & Nuclear Resources	Renewables	Energy Efficiency
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		

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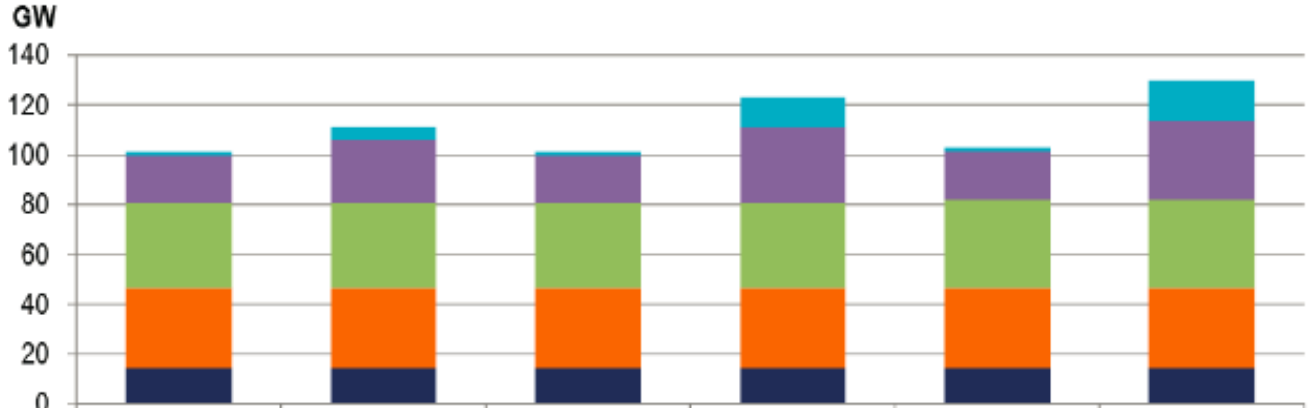
Figure 2. Comparison of the Resource Mix in the PJM Planning Case and the OPSI Scenario Satisfying RPS Requirement in PJM States and EPA Target Levels of Energy Efficiency



	2020		2025		2029	
	RTEP	OPSI 2a	RTEP	OPSI 2a	RTEP	OPSI 2a
Energy Efficiency	1.3	4.9	1.3	12.2	1.3	16.2
Wind & Solar	19.4	25.7	19.4	30.4	19.4	31.6
All Nuclear	34.1	34.1	34.1	34.1	35.7	35.7
111(d) NGCC	31.9	31.9	31.9	31.9	31.9	31.9
111(b) NGCC	14.5	14.5	14.5	14.5	14.5	14.5

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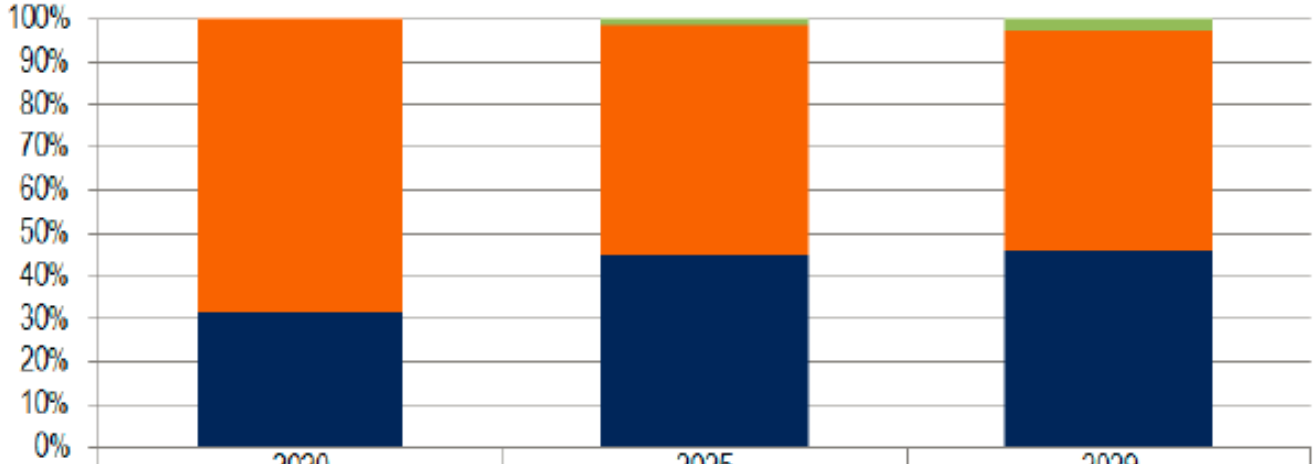
Renewables Displace Gas More than Coal

Figure 21. Percentage Displacement of Fossil Resources by Renewable Energy Resource Generation in OPSI Scenario 2a with PJM States Achieving RPS Standards



	2020	2025	2029
Other	0.0%	1.3%	2.5%
Natural Gas	68.7%	53.8%	51.6%
Coal	31.3%	44.9%	45.9%

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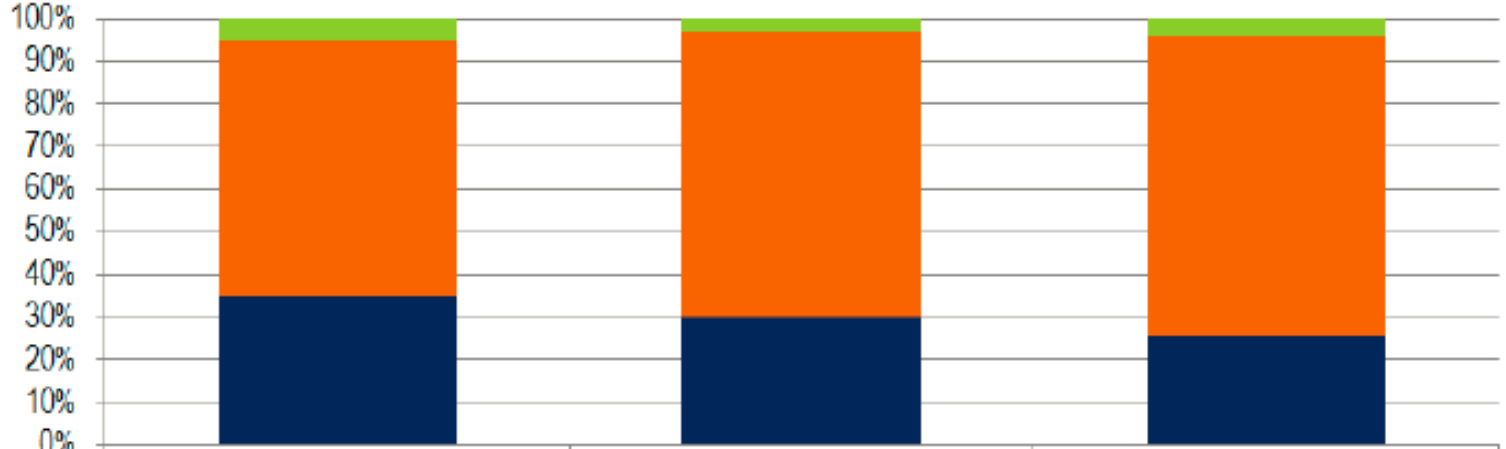
Energy Efficiency Displaces Gas More than Coal

Figure 32. Percentage Displacement of Fossil Resources by Energy Efficiency in OPSI Scenario 2a in the Absence of the Clean Power Plan



	2020	2025	2029
Other	5.2%	3.1%	4.0%
NGCC	60.0%	66.9%	70.2%
Coal	34.8%	30.1%	25.8%

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Table 4. Definition and Assumptions of the PJM Developed Scenarios

	Fossil Resources	Nuclear	Renewables	Energy Efficiency
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 – In Service, Under Construction 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 combined-cycle natural gas resource 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			
PJM11	Same as PJM 7 Scenario but simulated for state-by-state compliance			

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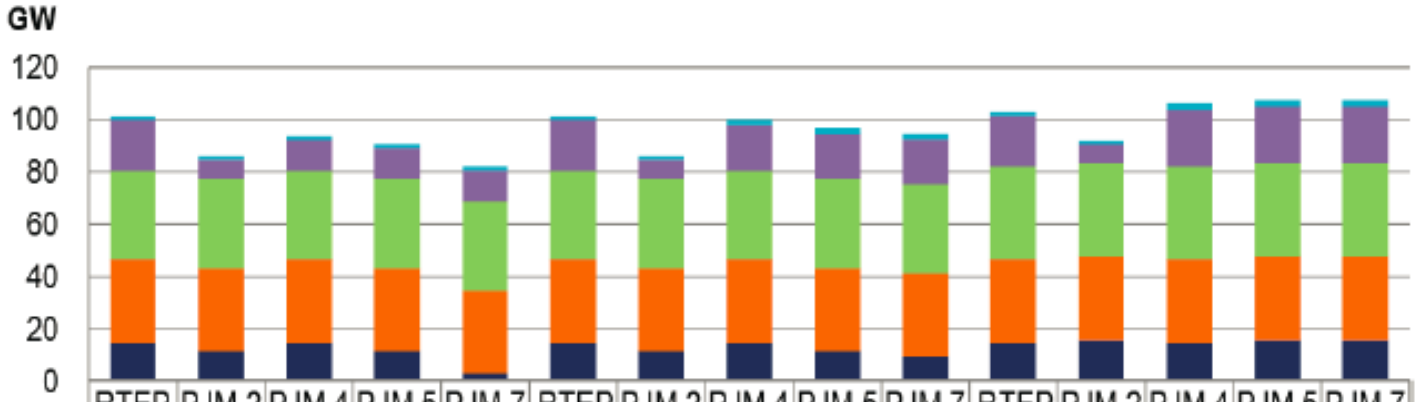
Figure 3. Comparison of the Resource Mix in the PJM Planning Case and Various PJM Scenarios



	RTEP	PJM 2	PJM 4	PJM 5	PJM 7	RTEP	PJM 2	PJM 4	PJM 5	PJM 7	RTEP	PJM 2	PJM 4	PJM 5	PJM 7
	2020					2025					2029				
Energy Efficiency	1.3	1.3	1.5	1.5	1.5	1.3	1.3	2.1	2.1	2.1	1.3	1.3	2.5	2.5	2.5
Wind & Solar	19.4	7.3	11.8	11.8	11.8	19.4	7.3	17.3	17.3	17.3	19.4	7.3	21.7	21.7	21.7
All Nuclear	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1	35.7	35.7	35.7	35.7	35.7
111(d) NGCC	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9
111(b) NGCC	14.5	11.4	14.5	11.4	2.8	14.5	11.4	14.5	11.4	9.3	14.5	15.7	14.5	15.7	15.7

[1] In 2029 two additional NGCC resources are added to PJM 2, 5, and 7

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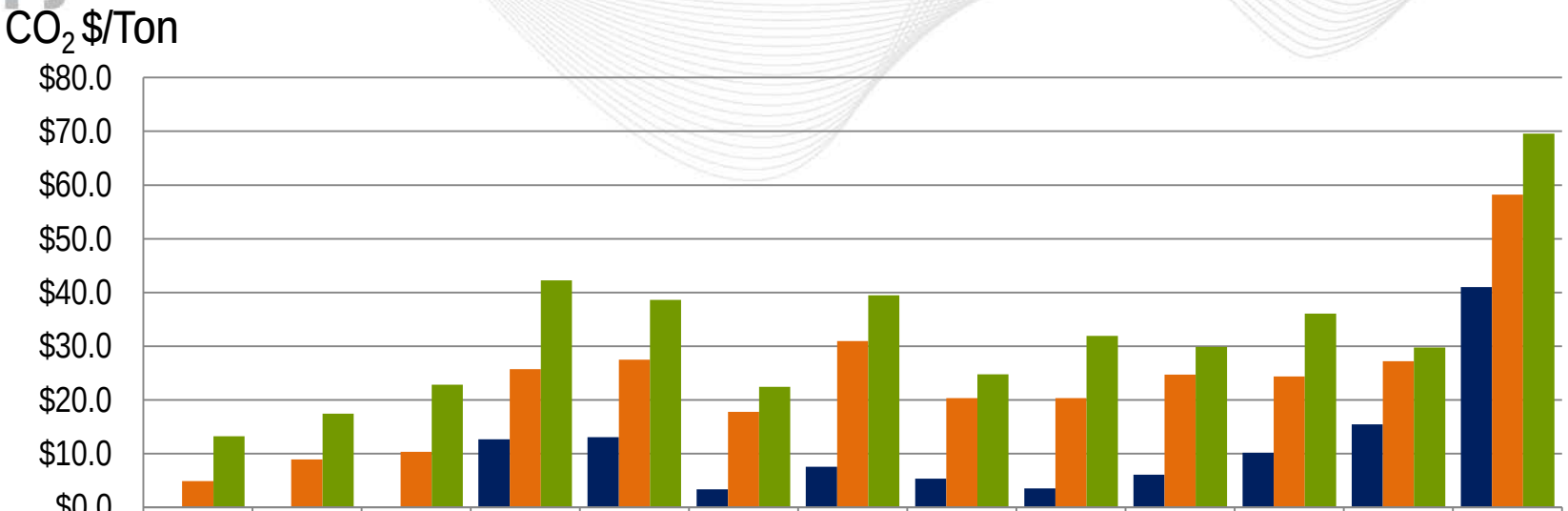
111(d) Implied CO_2 Price Impacts



	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	$22.8	$42.3	$38.6	$22.4	$39.5	$24.8	$31.9	$29.9	$36.0	$29.8	$69.6

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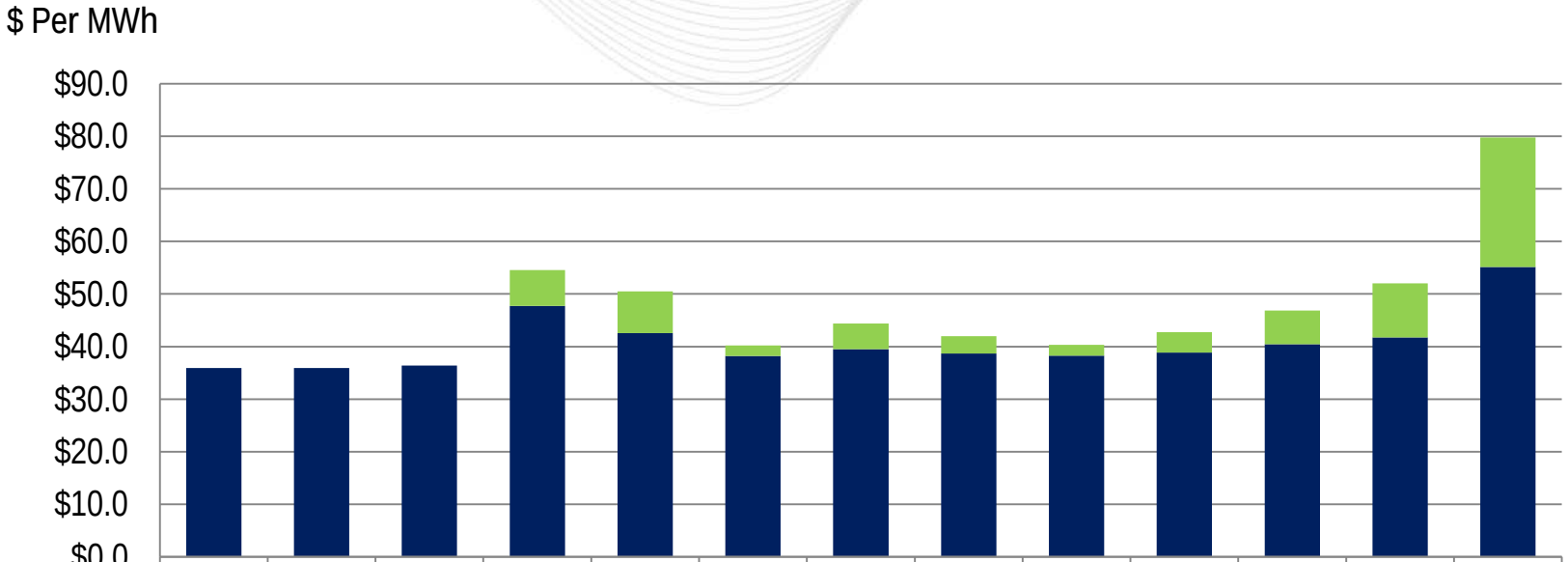
111(d) Impact to PJM Average Locational Marginal Price in 2020: Mass-Based Regional Compliance



	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

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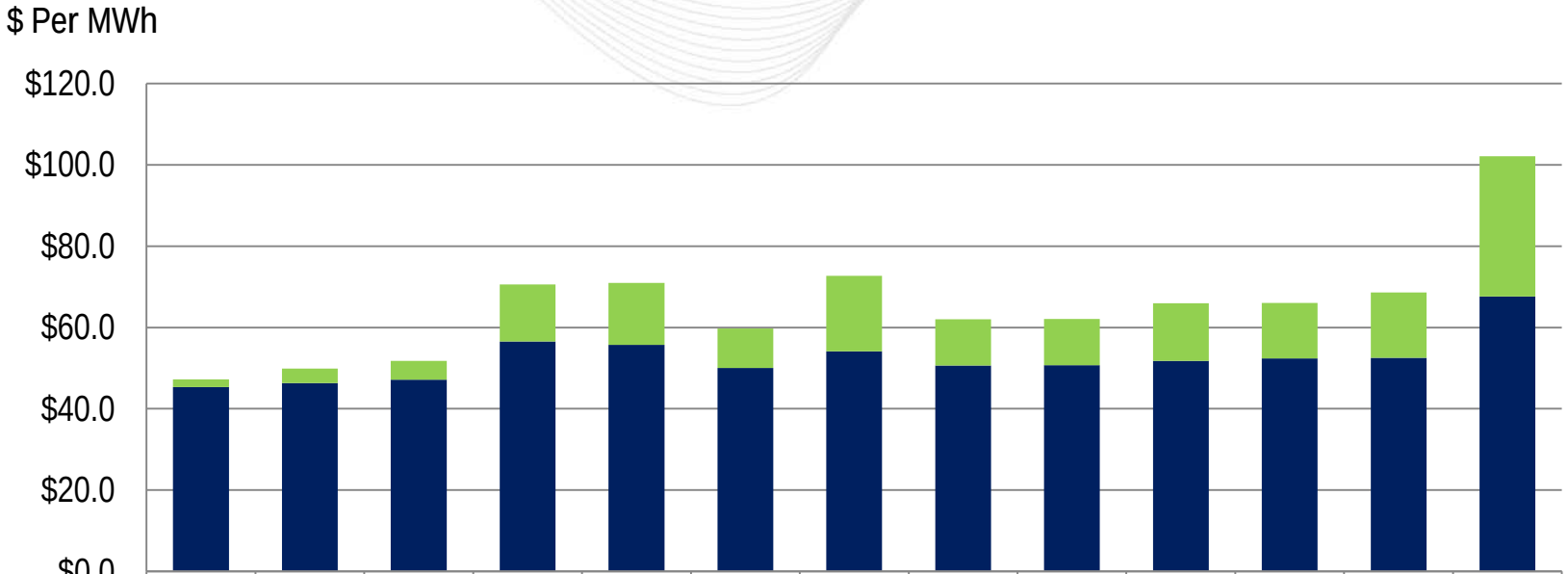
111(d) Impact to PJM Average Locational Marginal Price in 2025: Mass-Based Regional Compliance



	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

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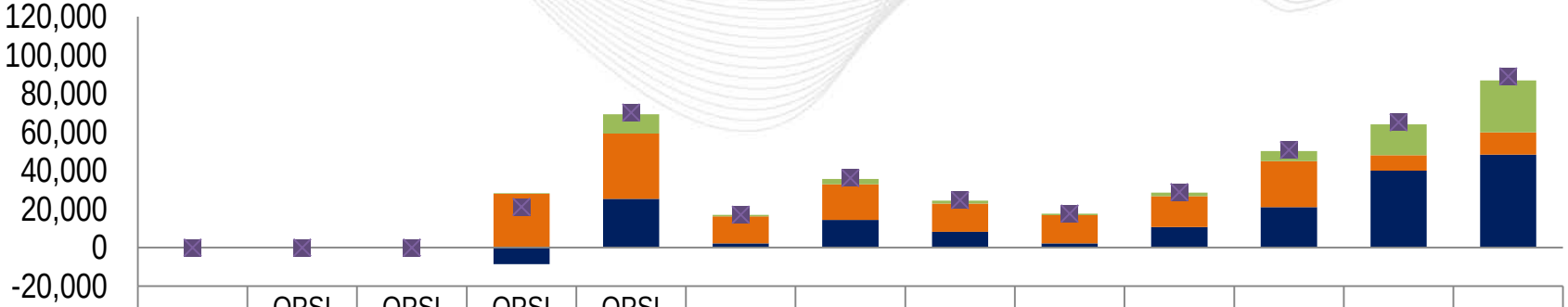
EPA Building Block #2 (Re-Dispatch) Participation in 2020

Displaced Energy (GWH)



	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
SCT Gas	0	0	0	338	10,057	765	2,865	1,520	795	1,810	5,148	16,054	26,933
111(b) NGCC	0	0	0	27,915	33,874	14,116	18,524	14,718	14,568	16,065	23,921	8,014	11,524
111(d) NGCC	0	0	0	-8,554	25,352	2,146	14,345	8,186	2,220	10,710	21,032	39,947	48,344
ST Coal	0	0	0	21,189	70,154	17,092	36,163	24,650	17,667	28,823	50,721	65,099	88,937

Positive value for 111(b) NGCC, 111(d) NGCC or SCT gas >> Resource dispatch up
Positive value for ST Coal >> Resource dispatched down
Negative value for 111(d) NGCC >> cheapest re-dispatch from 111(d) NGCC to 111(b) NGCC
CT re-dispatch >> CT cheaper than coal resource means significantly higher retirement risk

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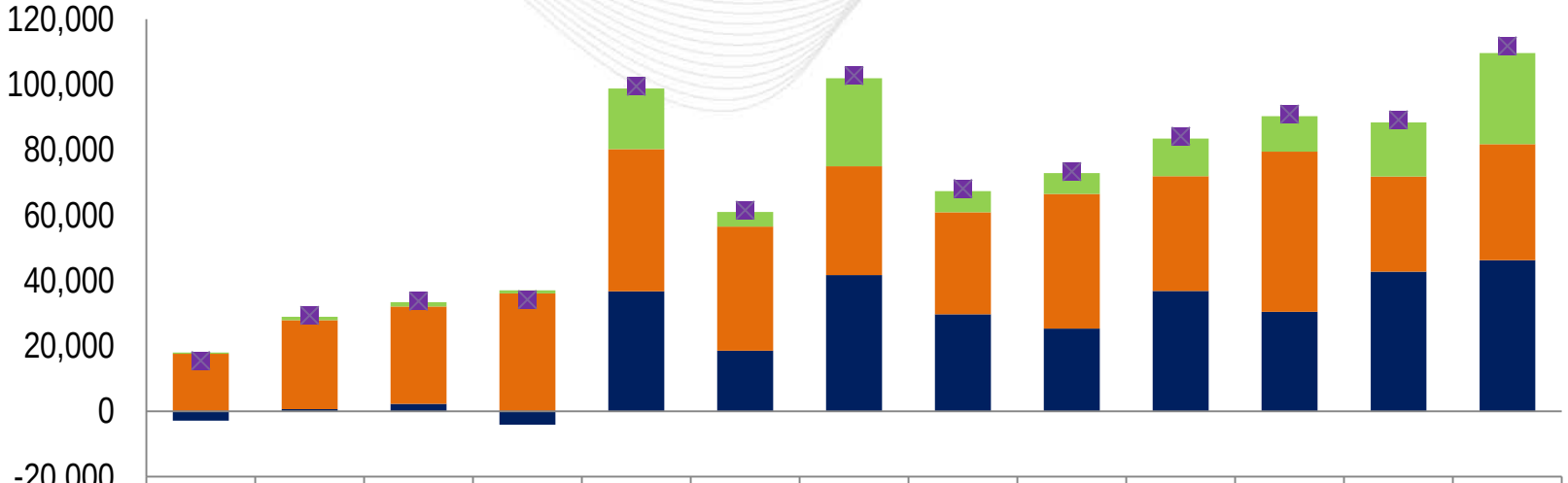
EPA Building Block #2 (Re-Dispatch) Participation in 2025



	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
SCT Gas	372	968	1,405	992	18,569	4,518	26,963	6,540	6,356	11,518	10,933	16,621	27,877
111(b) NGCC	17,605	27,274	29,796	36,016	43,503	37,962	33,362	31,144	41,170	35,106	48,995	29,074	35,520
111(d) NGCC	-2,890	611	2,204	-4,154	36,703	18,528	41,609	29,702	25,327	36,816	30,415	42,734	46,252
ST Coal	15,468	29,317	33,667	34,147	99,434	61,524	102,739	68,131	73,329	84,159	90,917	89,179	111,807

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Figure 6. Changes in Coal and Natural Gas Resource Dispatch due to Increasing Natural Gas Prices on in OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources

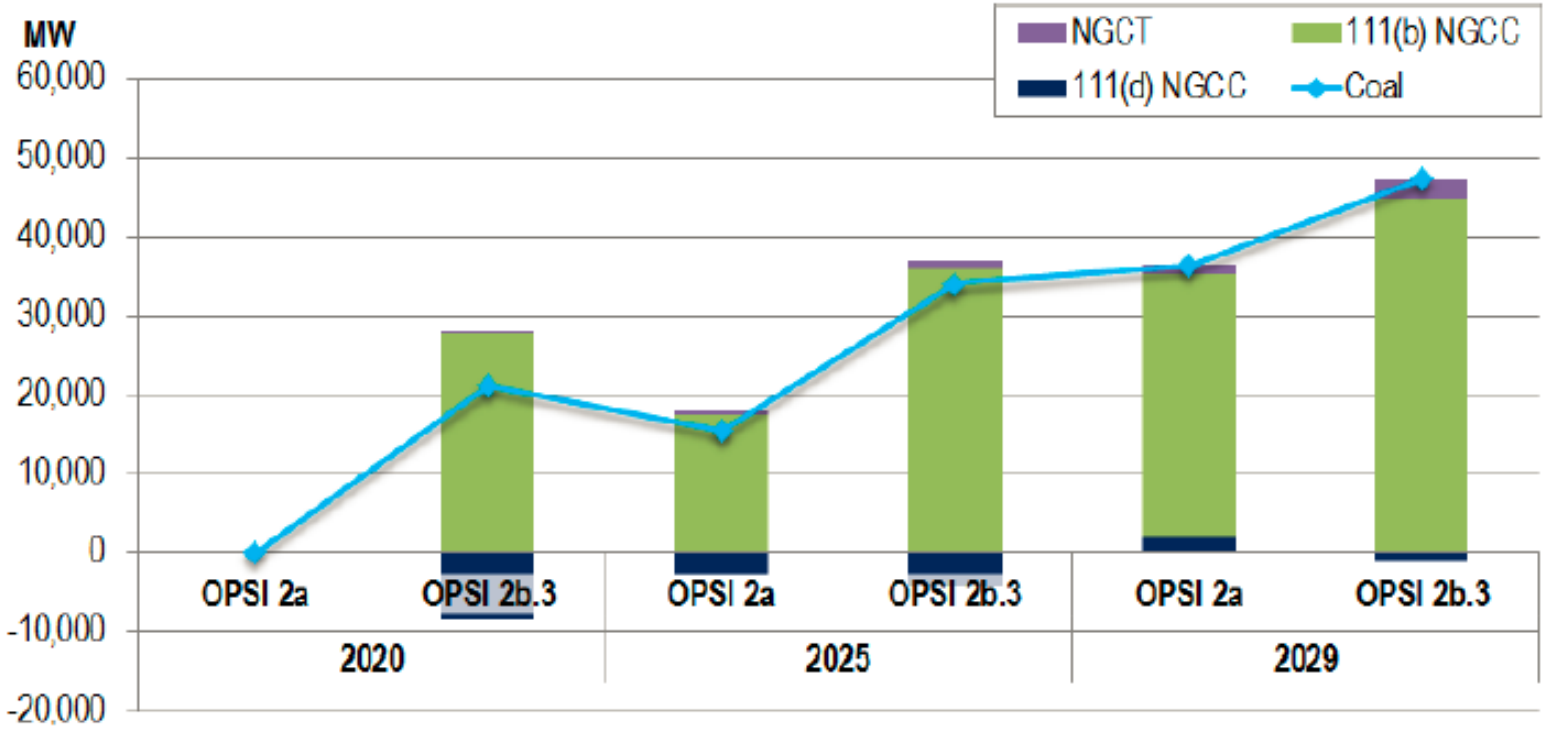

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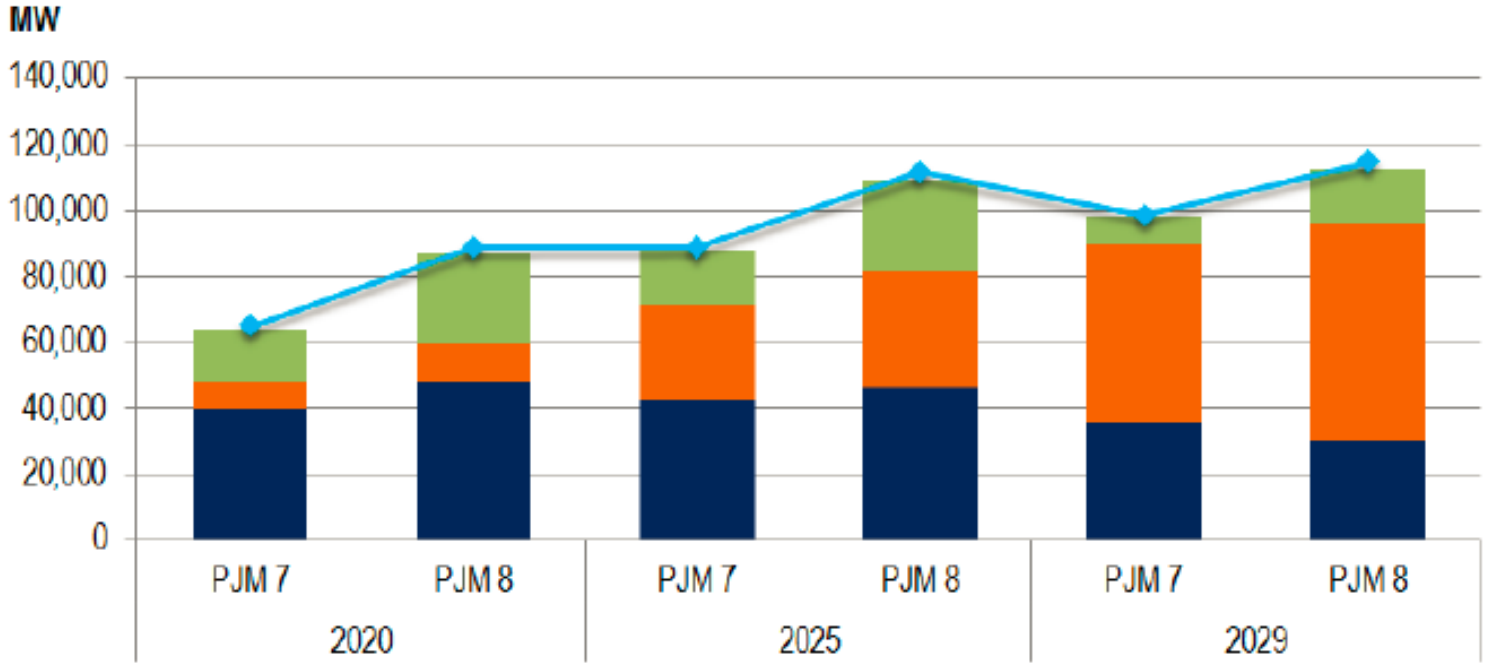
Figure 7. Changes in Coal and Natural Gas Resource Dispatch due to Increasing Natural Gas Prices in PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources



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Coal and Other Fossil Steam at Risk for Retirement: The Moving Parts

- Evaluate against a benchmark new entrant (natural gas combustion turbine) NGCT
- Clean Power Plan effects on coal net energy revenues
  - Reduced output (fewer MWh)
  - Each MWh is produced at higher cost
  - Each MWh sold is sold at a higher price
  - Effect on Net Revenues (price – cost) ambiguous, but probably lower
- Clean Power Plan effects on NGCT
  - With low EE and RE, and higher gas prices, higher net revenues since operating more, lower net cost of new entry making it more attractive

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Table 5. Combustion Turbine CONE Values for OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	OPSI 2a	$414.5	$4.3	$410.2
	OPSI 2b.3	$415.7	$5.6	$410.1
2025	OPSI 2a	$464.6	$9.3	$455.3
	OPSI 2b.3	$464.6	$13.6	$451.0
2029	OPSI 2a	$506.8	$19.1	$487.6
	OPSI 2b.3	$507.9	$32.8	$475.1

Table 6. Combustion Turbine CONE Values for PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency, and New Combined-Cycle Resources

Year	Scenario	CT Gross CONE ($/MW-Day)	CT Net EAS ($/MW-Day)	CT Net CONE ($/MW-Day)
2020	PJM 7	$415.7	$65.6	$350.1
	PJM 8	$415.7	$96.9	$318.8
2025	PJM 7	$464.1	$76.4	$387.7
	PJM 8	$463.9	$126.3	$337.7
2029	PJM 7	$507.6	$55.0	$452.5
	PJM 8	$507.0	$97.1	$409.9

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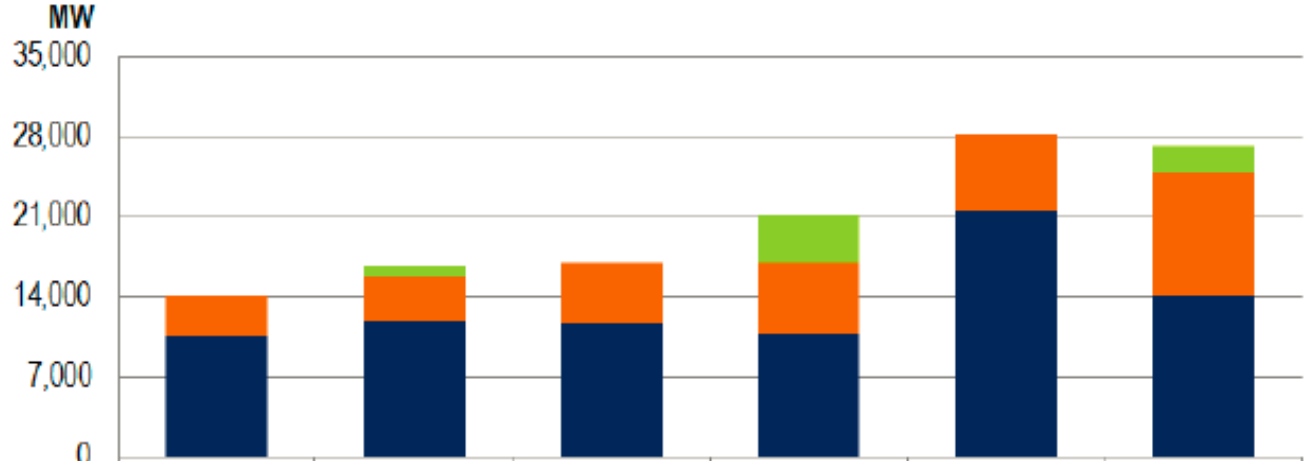
Figure 19. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for PJM Scenarios with Reduced Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	PJM 7 2020	PJM 8 2020	PJM 7 2025	PJM 8 2025	PJM 7 2029	PJM 8 2029
0.75 - 1.0 Net Cone		896		4,250		2,309
0.6 - 0.75 Net Cone	3,614	3,930	5,331	6,269	6,785	10,784
0.5 - 0.6 Net Cone	10,500	11,824	11,700	10,628	21,417	14,017

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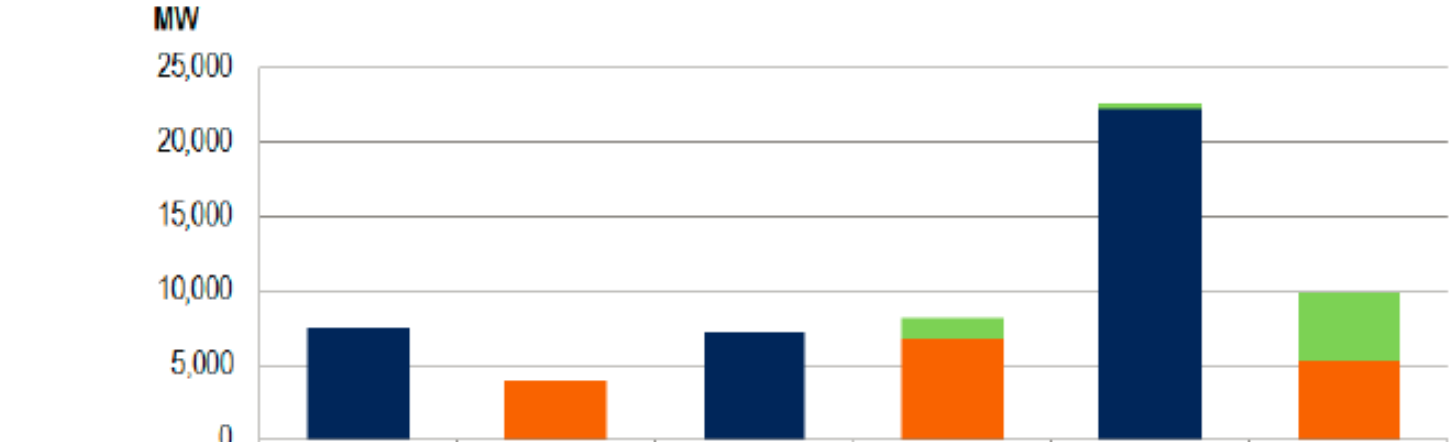
Figure 18. Fossil Steam Capacity Requiring More than 0.5 Net CONE to Cover Going Forward Costs for OPSI Scenarios with High Levels of Renewable Resources, Energy Efficiency and New Combined-Cycle Resources



	2020 OPSI 2a	2020 OPSI 2b.3	2025 OPSI 2a	2025 OPSI 2b.3	2029 OPSI 2a	2029 OPSI 2b.3
0.6 - 0.75 Net Cone				1,355	318	4,625
0.5 - 0.6 Net Cone	7,521	4,004	7,275	6,814	22,269	5,250

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

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Description of Scenarios Evaluated For State Analysis

Driver	OPSI 2a/2c	PJM 4/9	PJM 7/11
Renewables Modeled	88.8 GWh (Thousands)	46.5 GWh (Thousands)	46.5 GWh (Thousands)
111(b) NGCC	14.5 GW	14.5 GW	2.8 GW
Nuclear	33.4 GW	33.4 GW	33.4 GW
Natural Gas Price	Economic Forecast	Economic Forecast	Economic Forecast
Energy Efficiency Modeled	26.3 GWh (Thousands)	7.9 GWh (Thousands)	7.9 GWh (Thousands)
Description	Achieve State RPS and EPA EE Targets	Low Growth in Renewables and EE	Lower New NGCC Resources

State compliance was only evaluated for compliance with 2020 interim target

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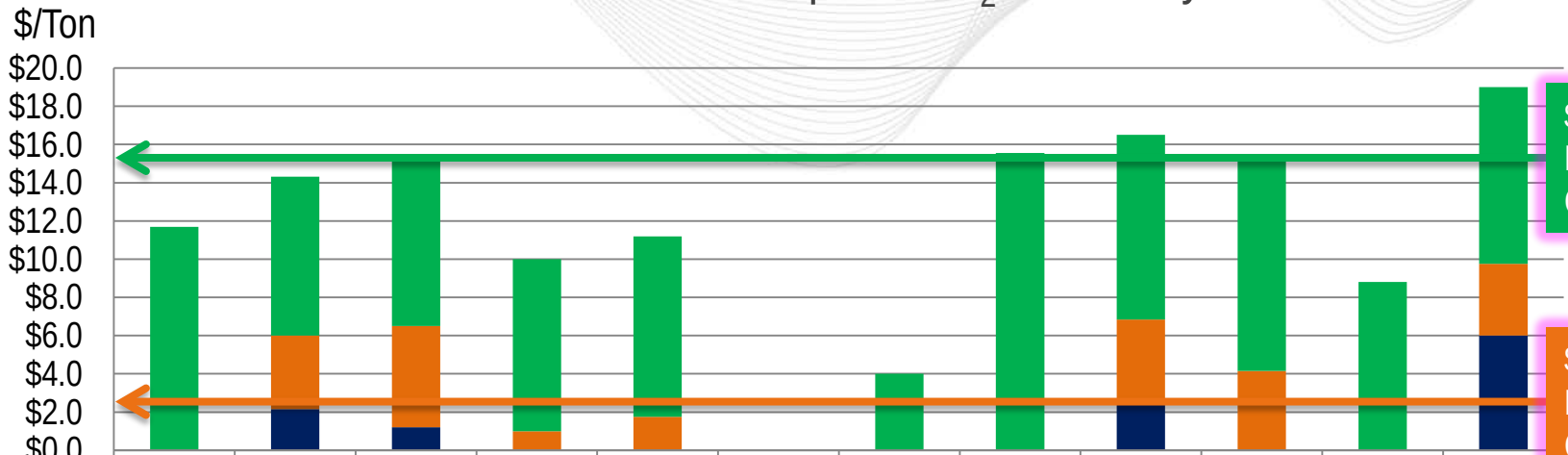
State-Based Compliance
Implied CO_2 Prices By State due to Sensitivity



	DE	IL	IN	KY	MD	MI	NC	NJ	OH	PA	VA	WV
C	$11.7	$8.3	$8.7	$9.0	$9.4	$0.0	$4.0	$15.6	$9.6	$11.0	$8.8	$9.2
B	$0.0	$3.9	$5.3	$1.0	$1.8	$0.0	$0.0	$0.0	$4.2	$4.1	$0.0	$3.7
A	$0.0	$2.2	$1.2	$0.0	$0.0	$0.0	$0.0	$0.0	$2.7	$0.0	$0.0	$6.0

A – Achieve State RPS and EPA EE Targets

B – Lower Renewable and EE Growth (60,500 GWh's)

C – Less NGCC Entry (11.7 GW)

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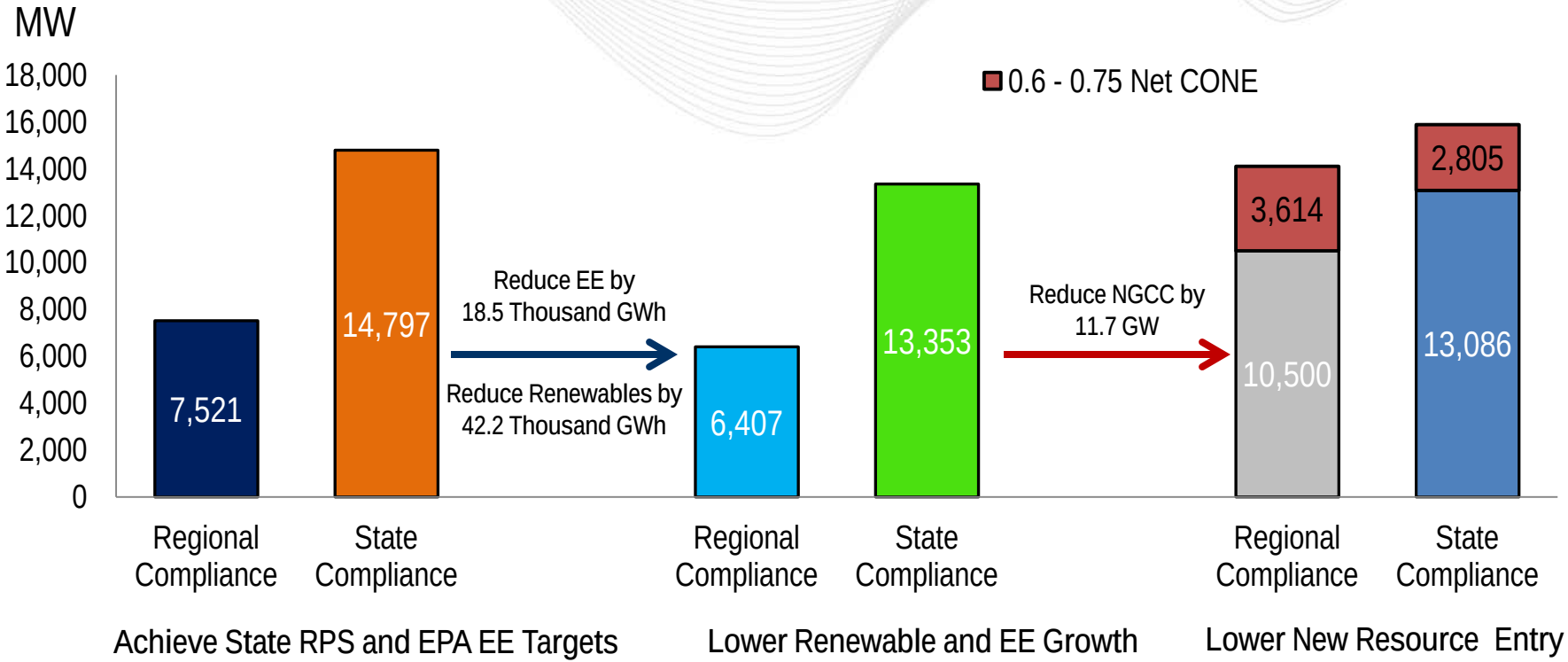
State Compliance Versus Regional Compliance

Comparative Assessment of Resources At Risk with CT Reference[1] in 2020



[1] At-Risk classification based on Revenue Requirement > 0.5 Net CONE unless otherwise noted

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Rate Based Versus Mass Based Compliance Implied CO_2 Prices

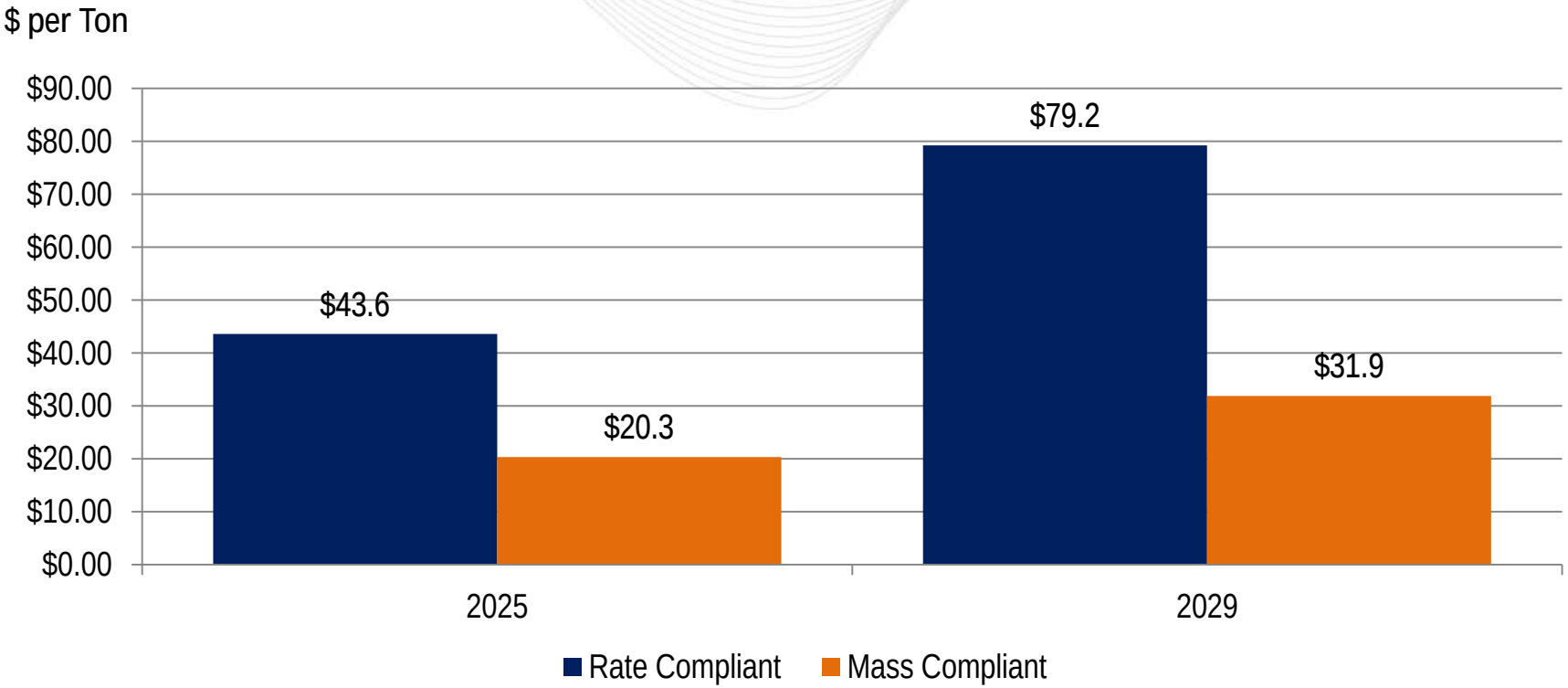

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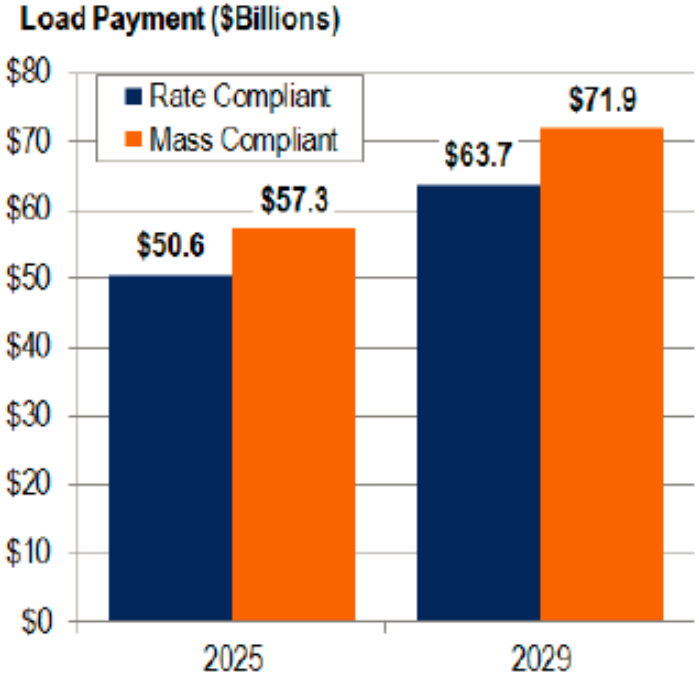
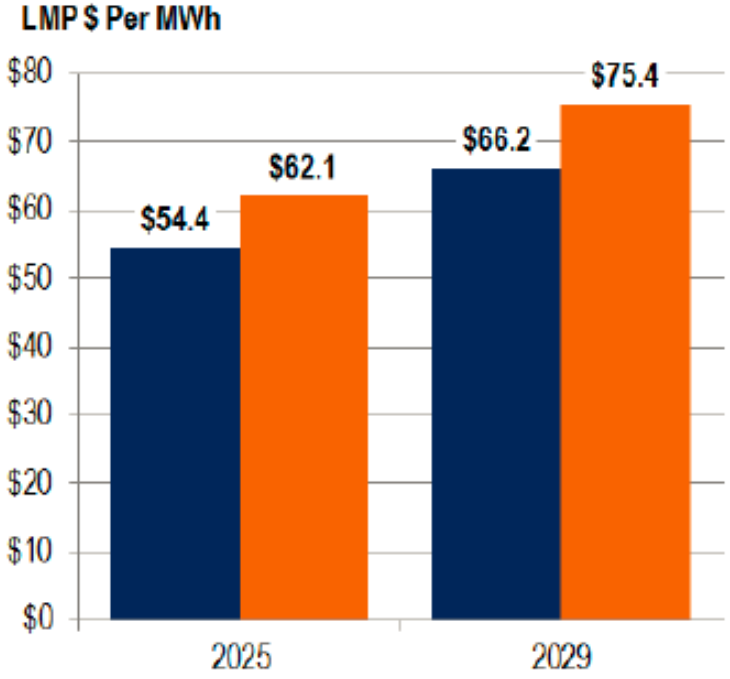
Figure 80. Rate- versus Mass-Based Compliance Effects of CO_2 Prices on Load-Weighted Average Wholesale Energy Market Prices and Load Energy Payments





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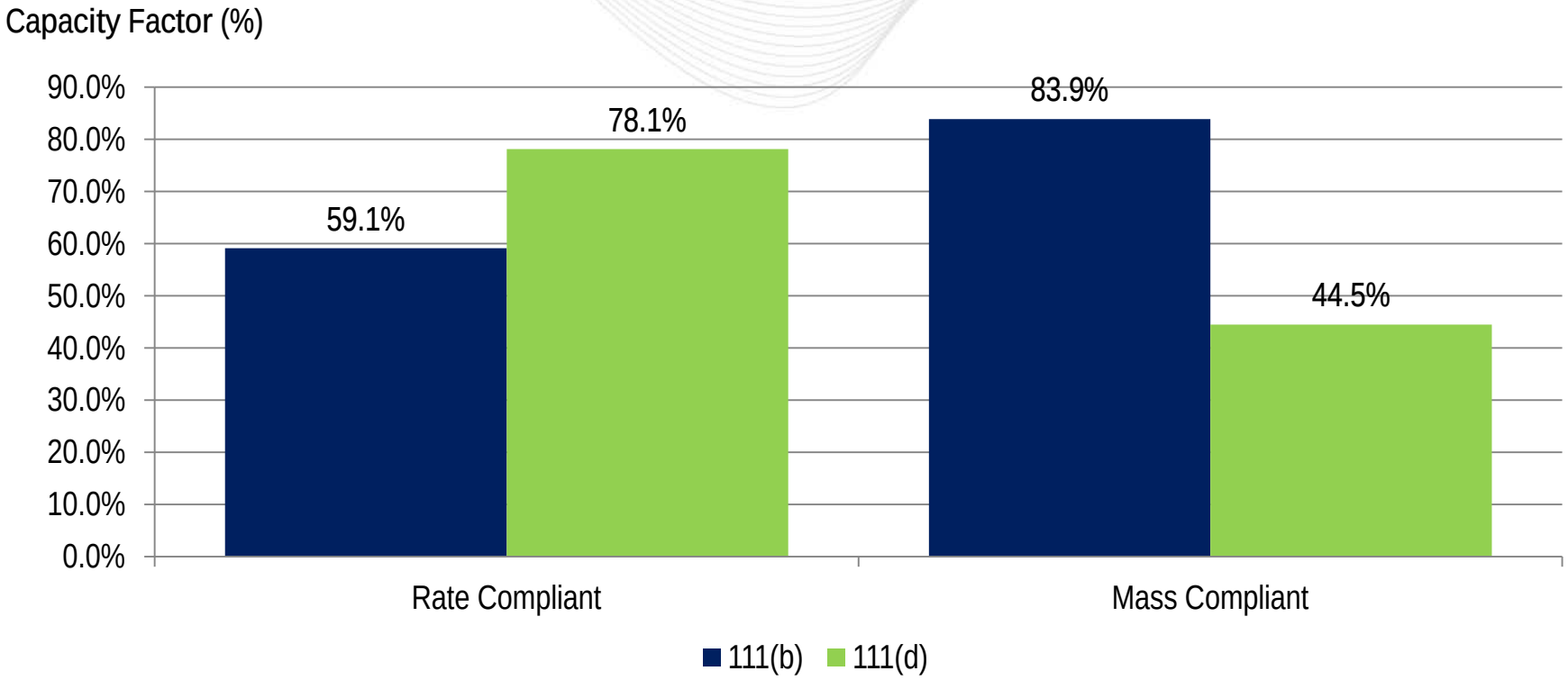
Rate Based Versus Mass Based Compliance
Impact on NGCC Unit Operation (Covered Versus Non-Covered Resources)



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Concluding Observations

- Simulated outcomes are highly dependent upon assumptions
  - Fuel costs, available resources
  - Inclusion or exclusion of resources not automatically subject to the Clean Power Plan
- Capacity at risk is not definitive
  - Only using a Net CONE benchmark
  - Perhaps we can refine by running capacity market simulations in conjunction with energy market simulations?
- New vs. Existing Resources
  - How would results change if all new resources were subject to the clean power plan?
  - Would results of rate- vs. mass-based converge if all resources were included?
- What are trade-offs between zero emitting capital intensive options vs. redispatch options?

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