



PJM's Final Long-term and Short-term Market Analysis of the Clean Power Plan and Reference Model

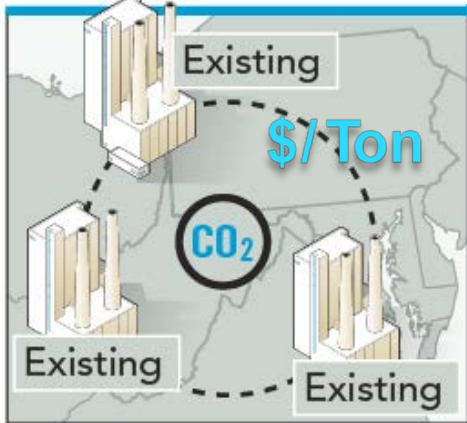
PJM Interconnection
September 15, 2016

Evaluate potential impacts of states complying with the Clean Power Plan on:

- Resource adequacy
- Operational impacts on the transmission system
- PJM energy and capacity market prices
- Compliance costs associated with achieving the U.S. EPA's CO₂ emission targets

- Resources and states in the PJM region achieve compliance with the Clean Power Plan under all studied scenarios and compliance pathways.
- Resource adequacy is maintained under all studied scenarios and compliance pathways
- Clean Power Plan compliance reduces and shifts transmission congestion
- Regional, mass-based compliance applied to existing sources leads to the lowest compliance cost over the 20 years studied

Trade-Ready



Single CO₂ limit applied to the PJM region for 111(d) existing resources

State Mass



Each state applies a CO₂ limit covering all 111(d) existing resources

New Source Complement



Single CO₂ limit applied to the PJM region for 111(d) existing and 111(b) new sources

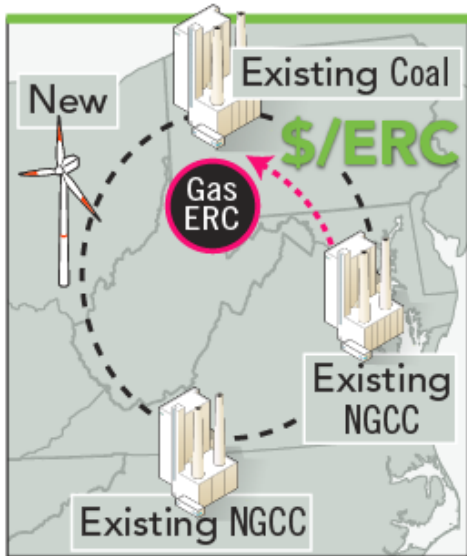
State Mass New Source Complement



Each state applies a CO₂ limit covering all 111(d) existing resources and 111(b) new sources

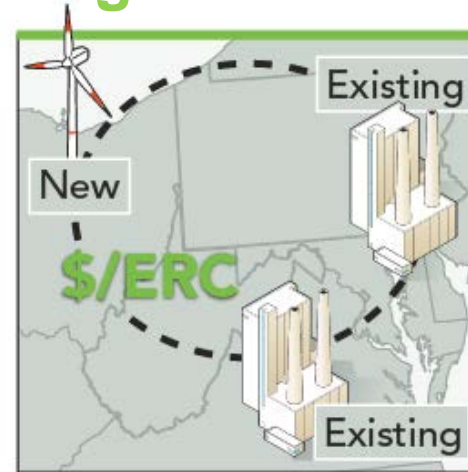
[1] [Proposed Federal Plan for the Clean Power Plan \(PDF\)](http://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22848.pdf) - <http://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22848.pdf>

Trade-Ready Rate



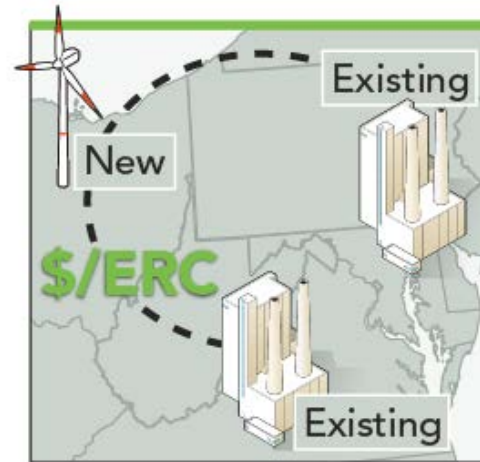
Emissions performance measured against the sub-category CO₂ emission rate targets for combined cycle and steam turbine resources

Regional Blended Rate



Emissions performance measured against a weighted average of PJM states' CO₂ emissions rate targets

State Blended Rate



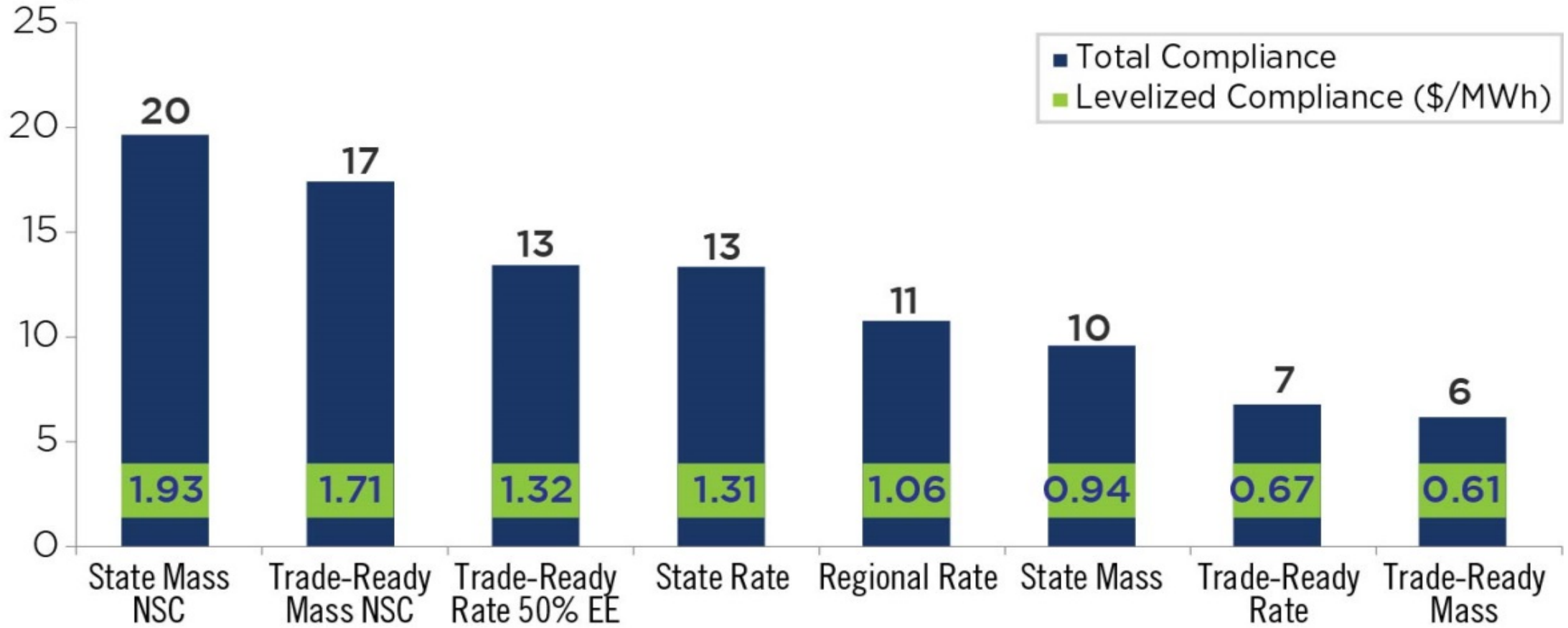
Emissions performance measured against the state CO₂ emissions rate target

[1] [Proposed Federal Plan for the Clean Power Plan \(PDF\)](http://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22848.pdf) - <http://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22848.pdf>



Going-Forward, Production and Investment Cost Increase CPP Compliance Cost (2018-2037)

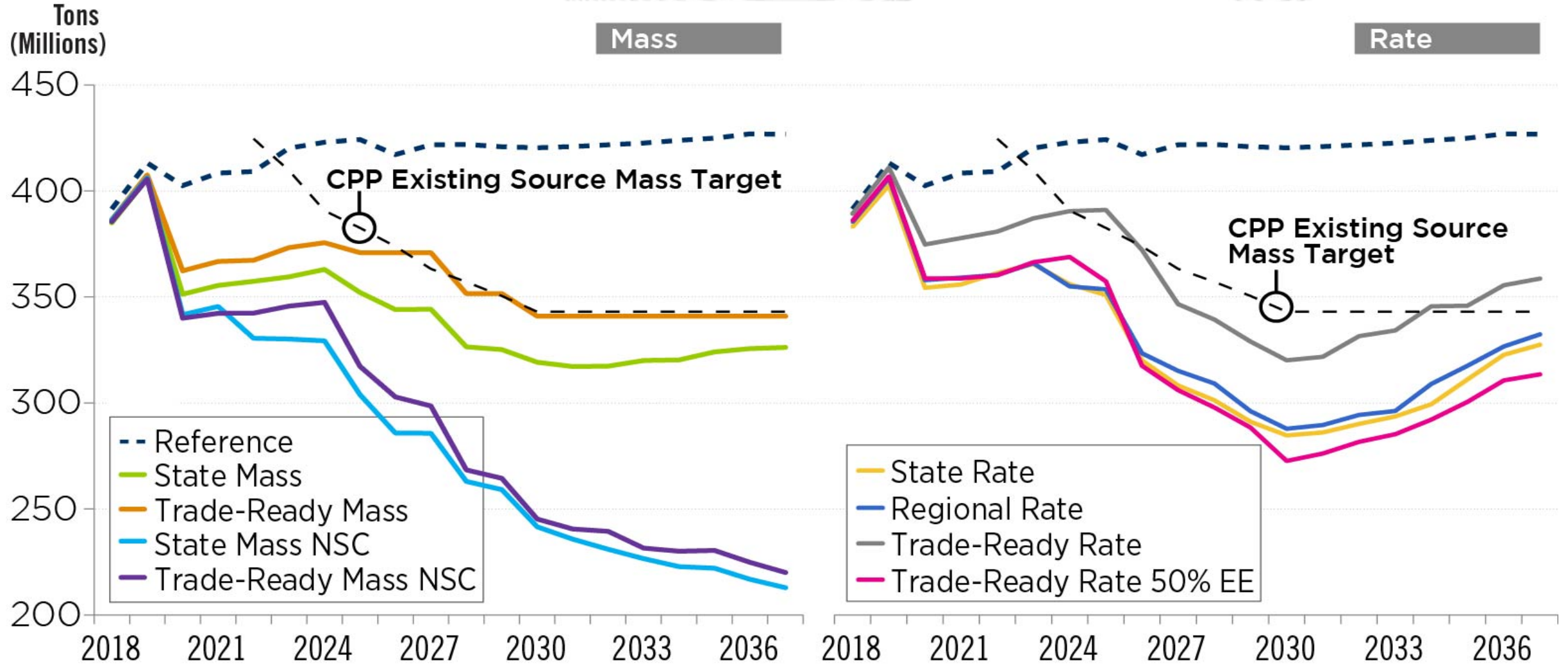
Net Preset
Value Compliance
(\$Billions)



Clean Power Plan Compliance: Emissions and Energy Prices

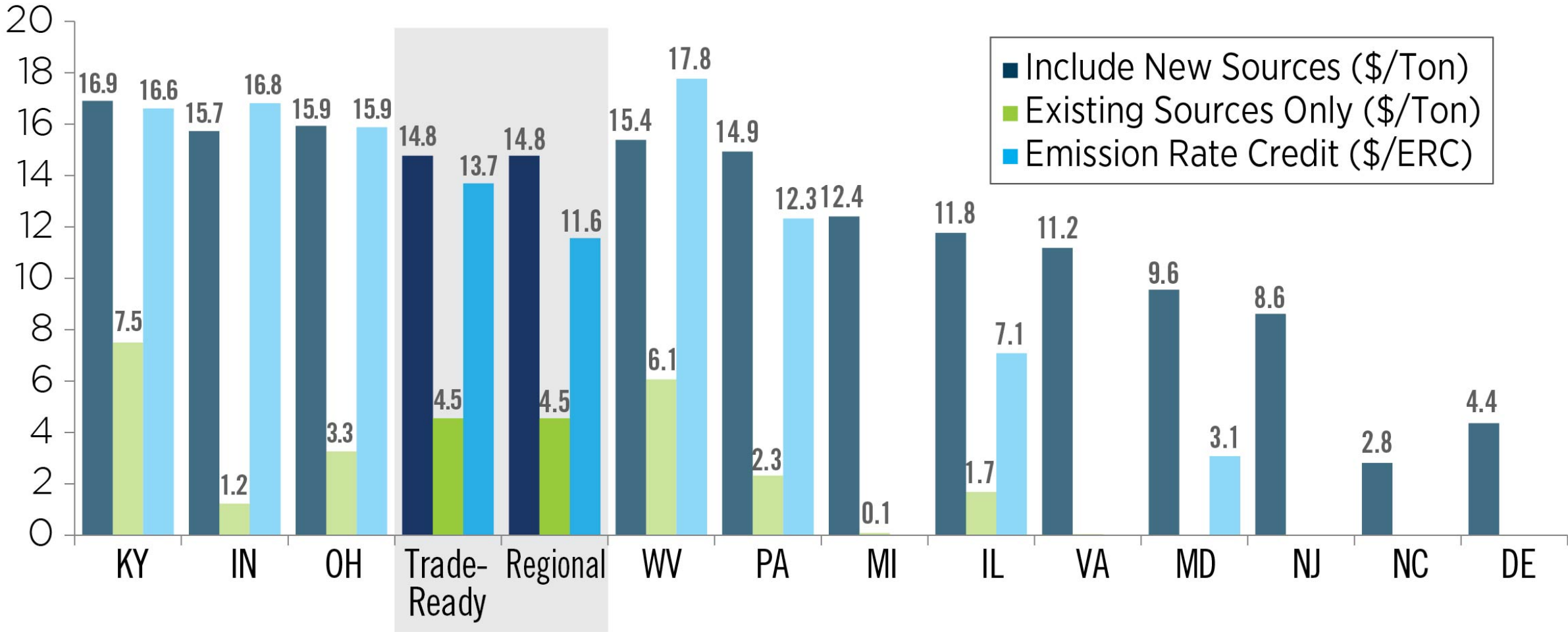


PJM States Achieve CO₂ Emissions Targets in all Scenarios



CO2 Prices (2022-2037) in Mass-based and Rate-based Markets

Levelized \$



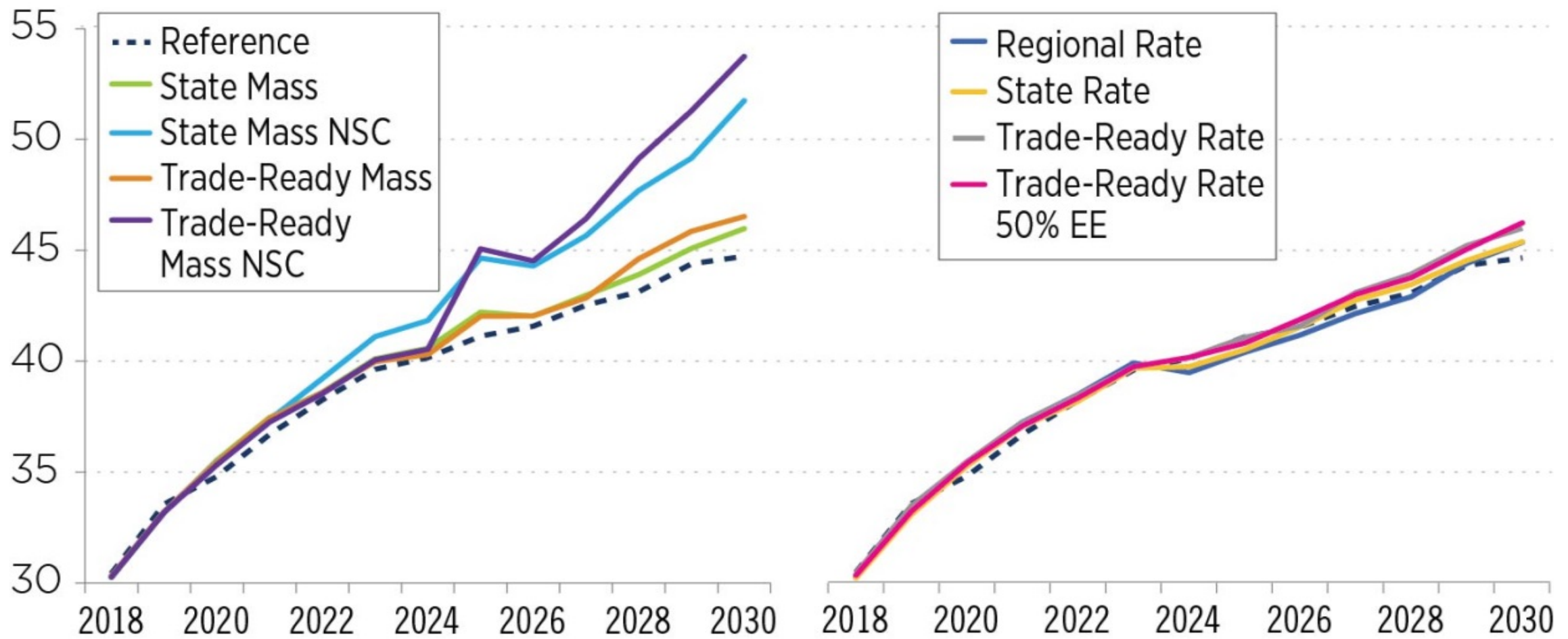


Energy Market Prices for the PJM Region under Mass- and Rate-based Compliance Pathways

Energy Price
\$2018/MWh

Mass

Rate

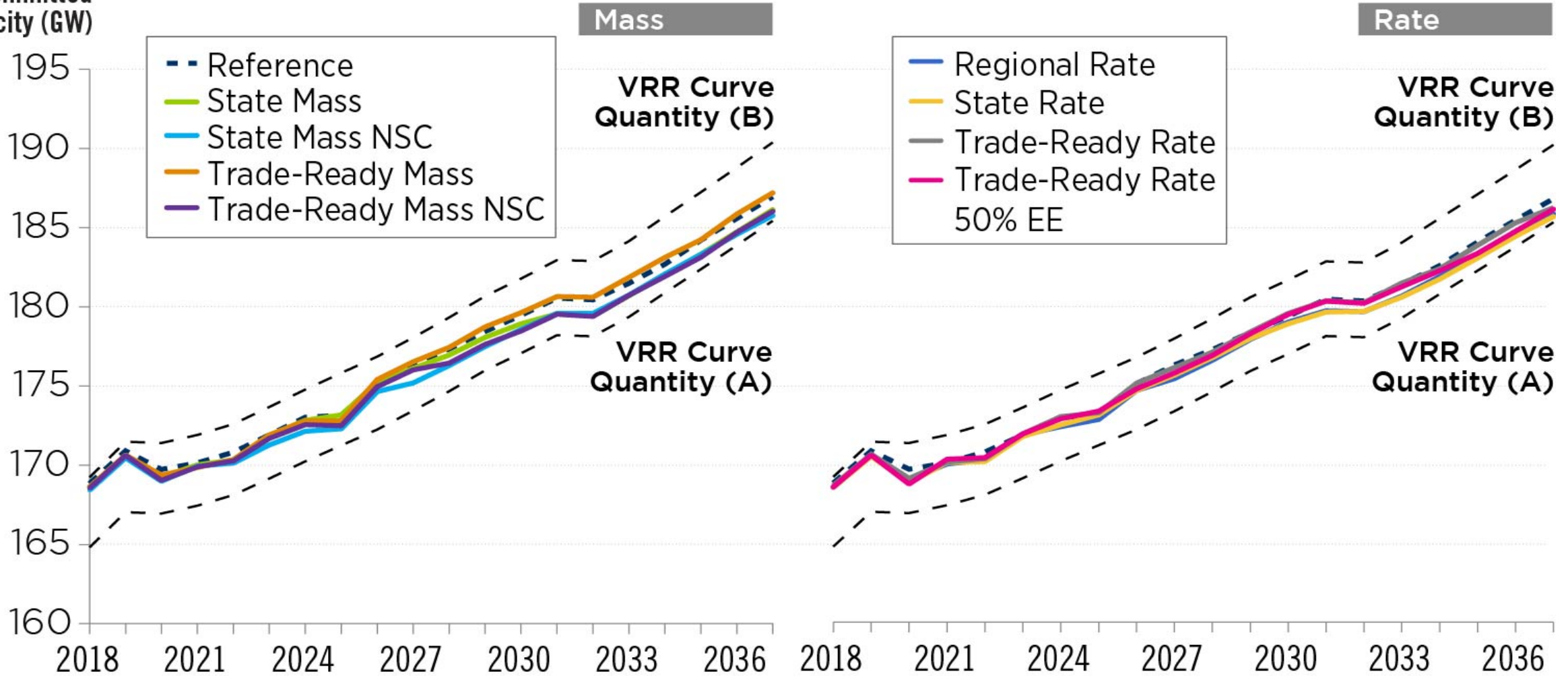


Clean Power Plan Compliance: Resource Adequacy, Generation Mix and Capacity Prices



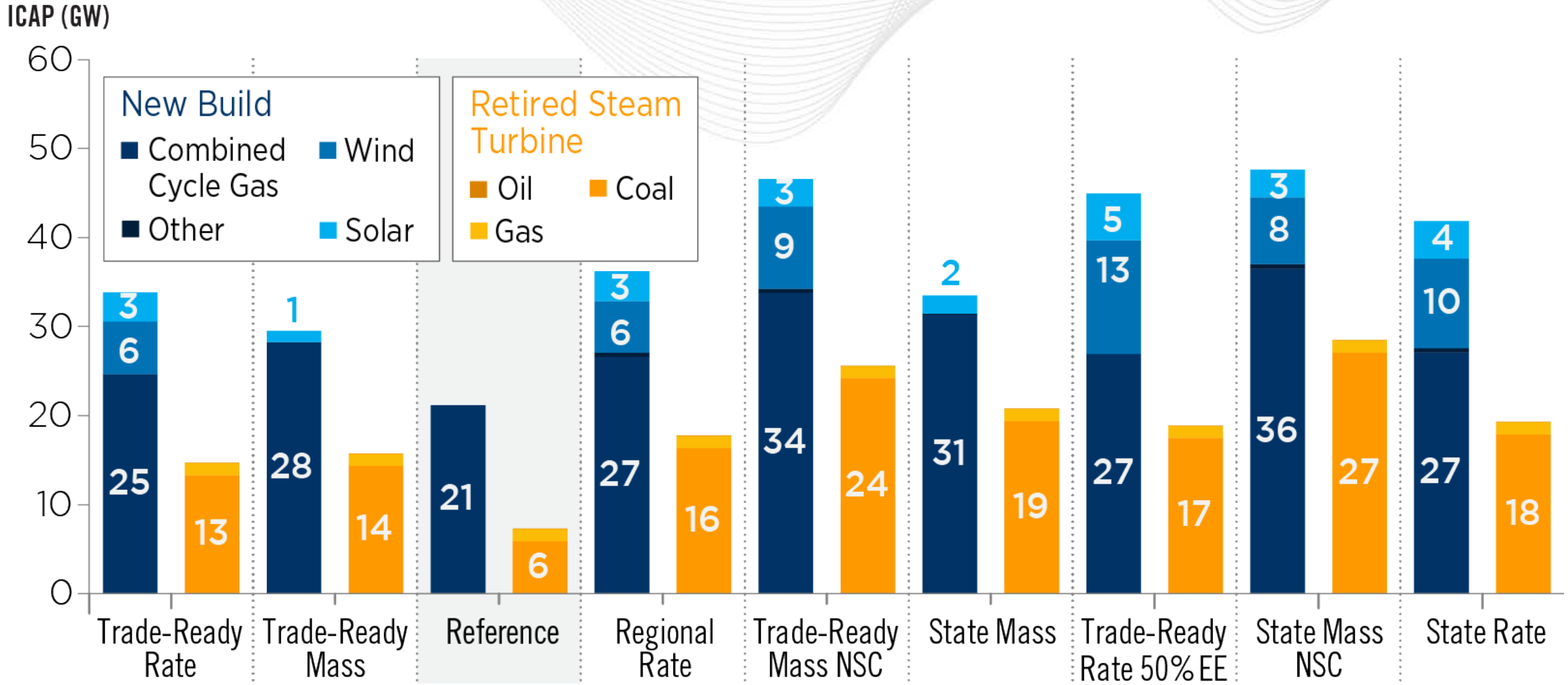
Resource Adequacy is Maintained Under all Compliance Pathways

Committed Capacity (GW)





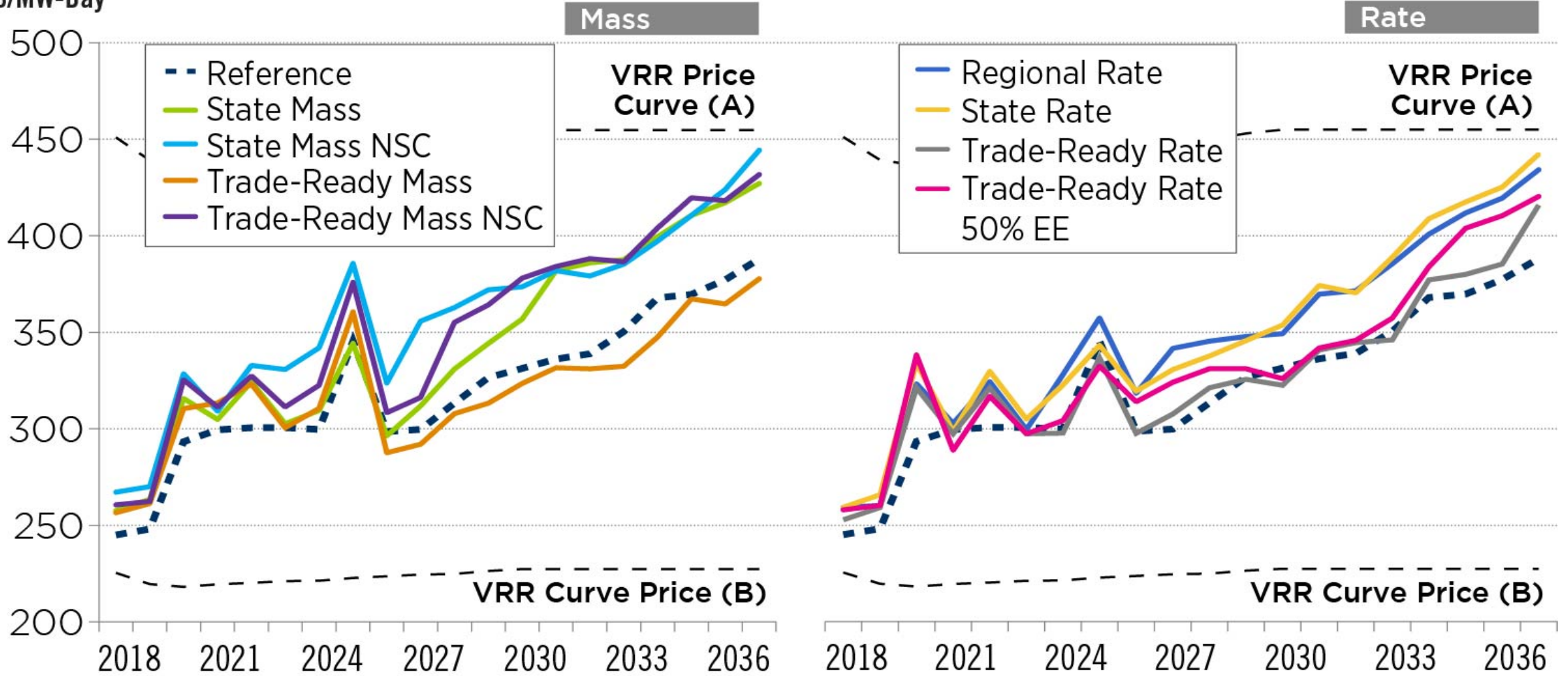
Turnover in Generating Resource Nameplate Capacity due to the Clean Power Plan (2018 -2037)





Capacity Market Prices for the PJM Region Under Mass- and Rate-Based Compliance Pathways

\$2018/MW-Day

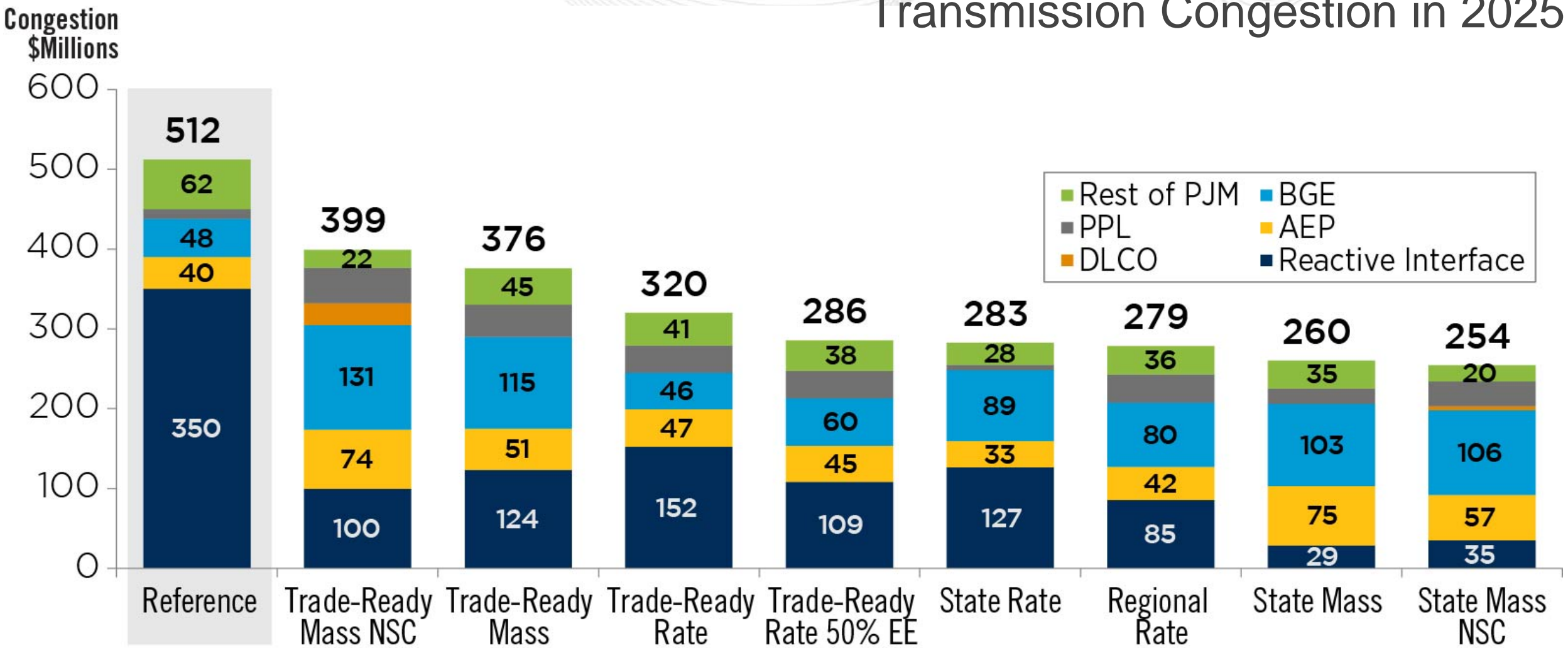




Clean Power Plan Compliance: Transmission System Effects

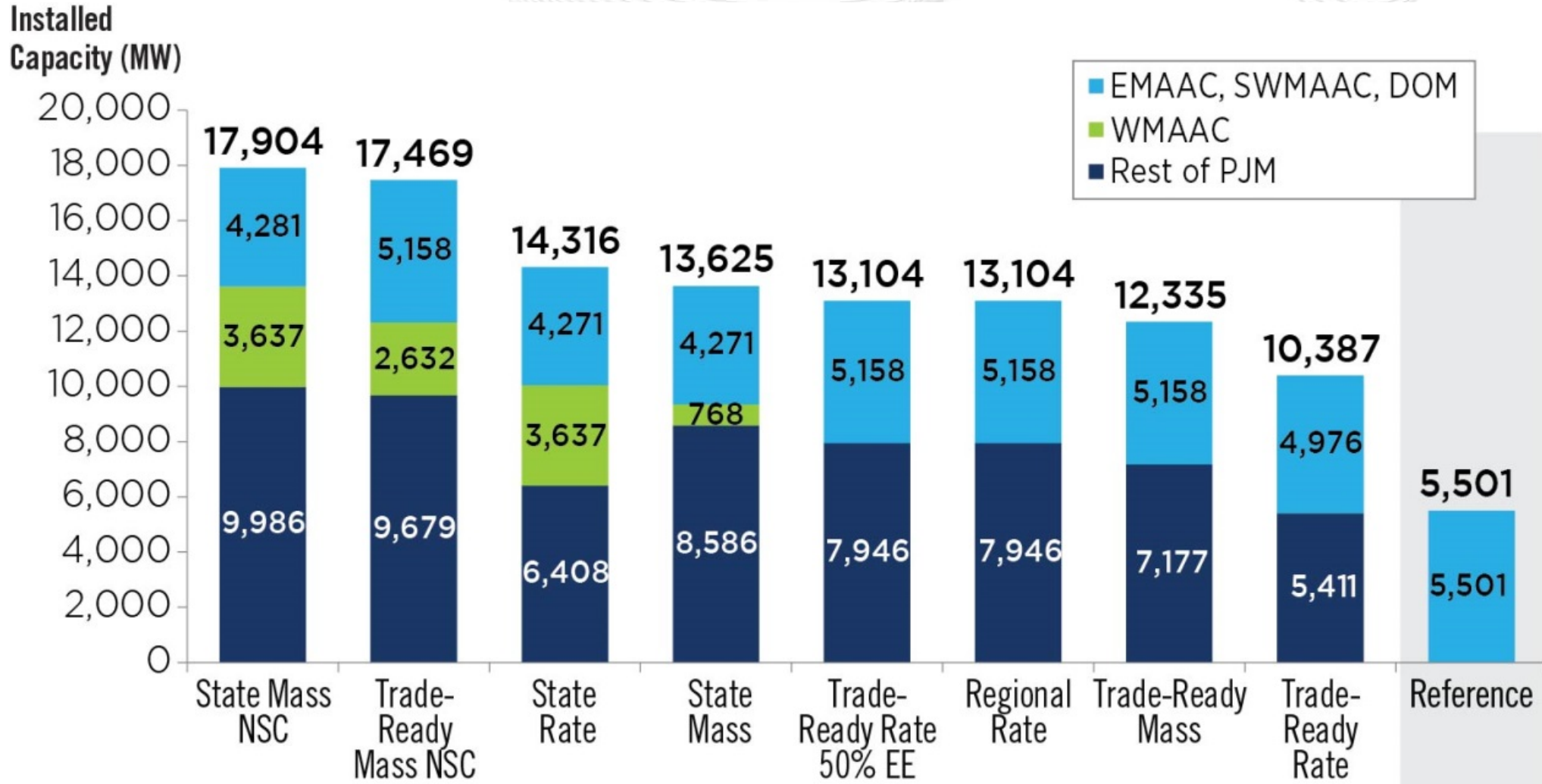


High Voltage Transmission System is Utilized Less Security Constrained Economic Dispatch Analysis Transmission Congestion in 2025



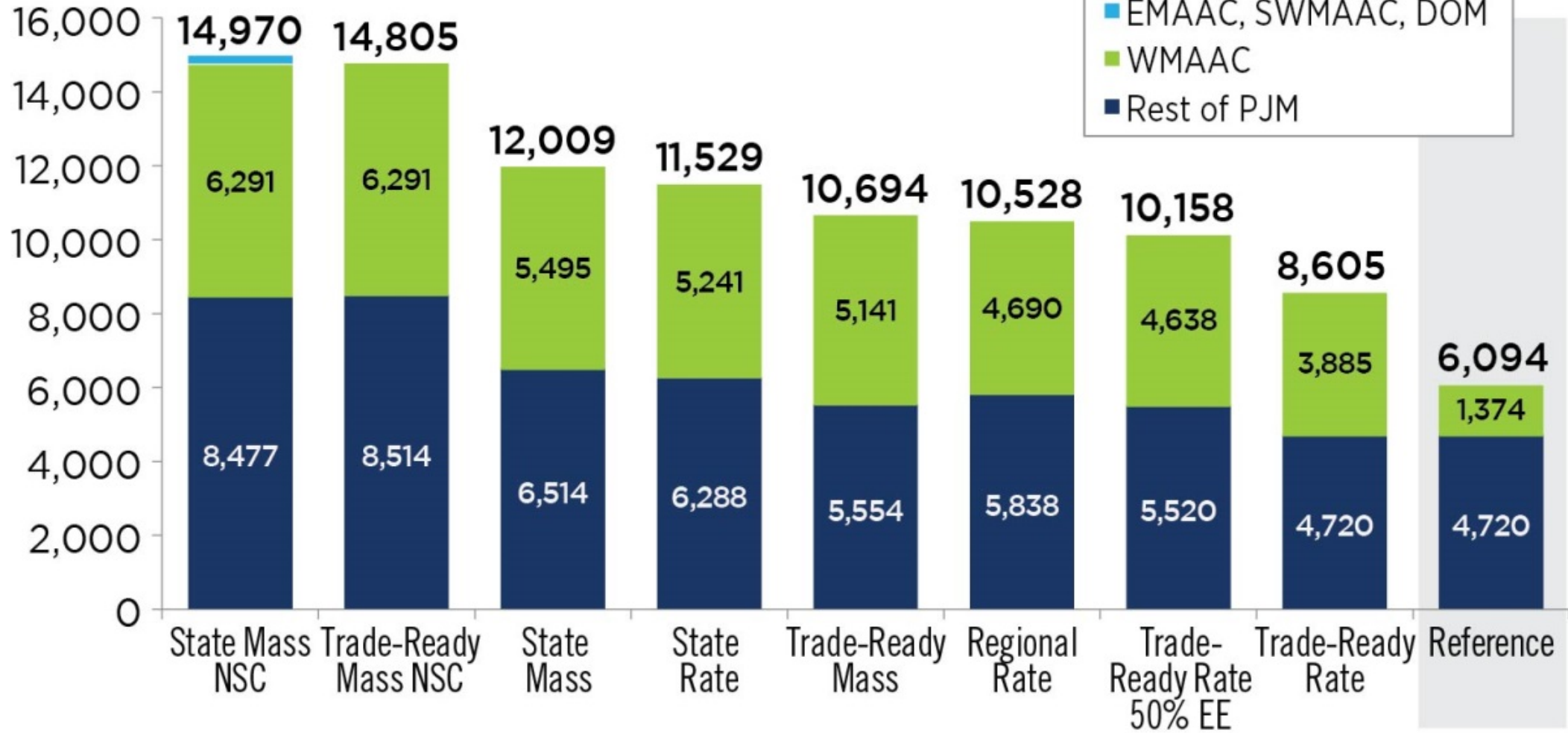
*Analysis focused on transmission limitations at the 230 kV system and up. Limited set of 138 kV or below constraints evaluated.

Distribution of Coal Retirements by Location by 2025



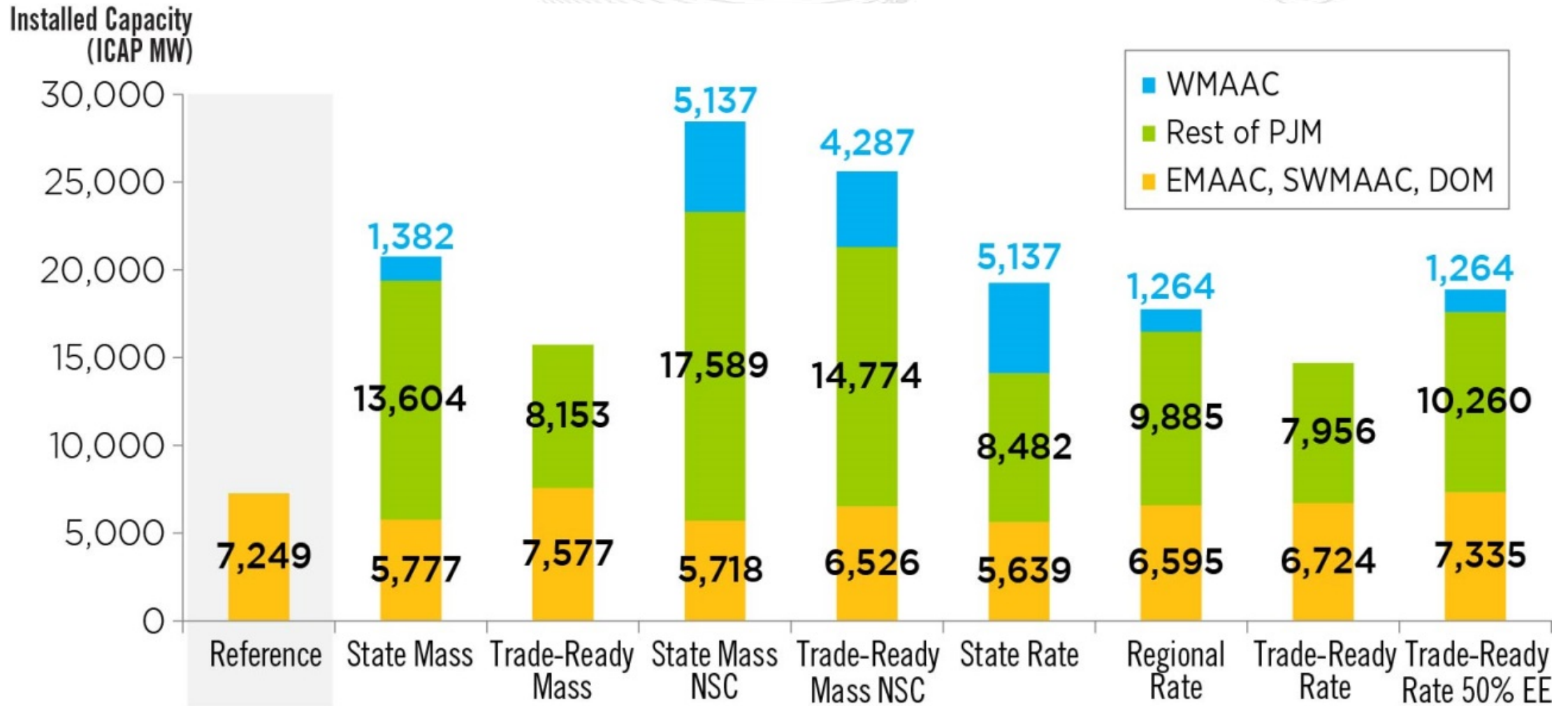
Distribution of New Generation by Location by 2025

Installed Capacity (MW)

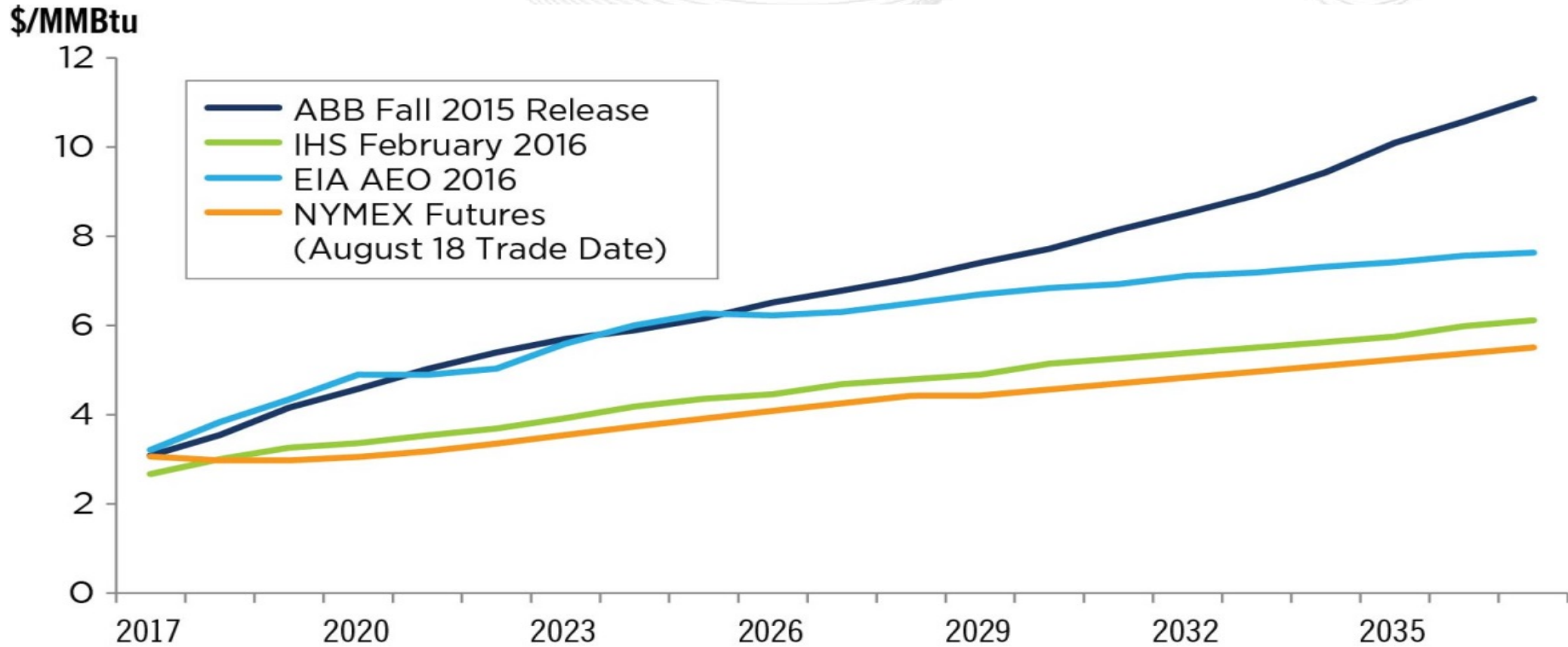




Distributional Effects on Generator Retirements (2018–2037)



Low Gas Price Sensitivity



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Low Gas Price Sensitivity: Transition to more Combined Cycle Natural Gas

Installed Capacity (MW)

100,000

80,000

60,000

40,000

20,000

0

2018

2020

2022

2024

2026

2028

2030

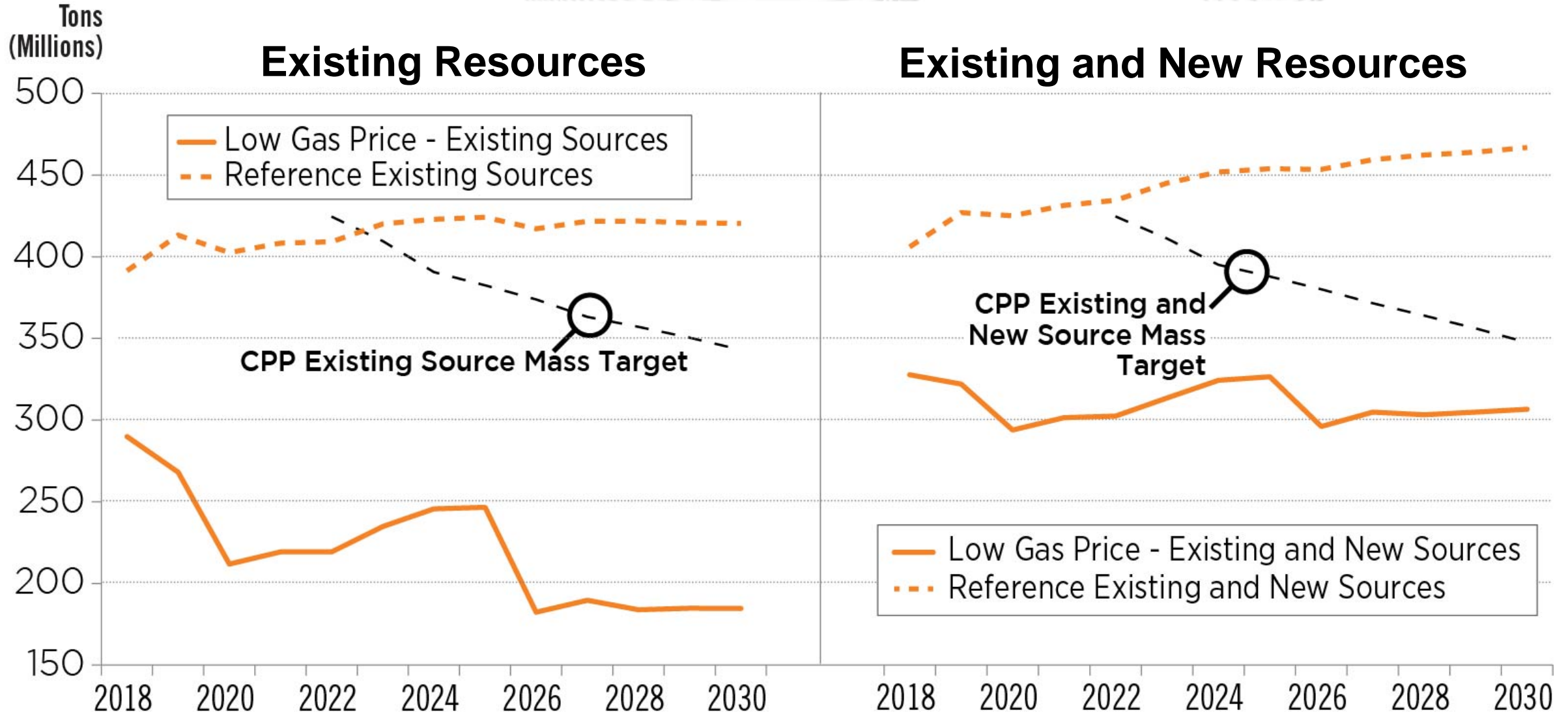


Low Gas Price
(Combined
Cycle Gas)



Low Gas Price
(Steam Turbine
Coal)

Reference

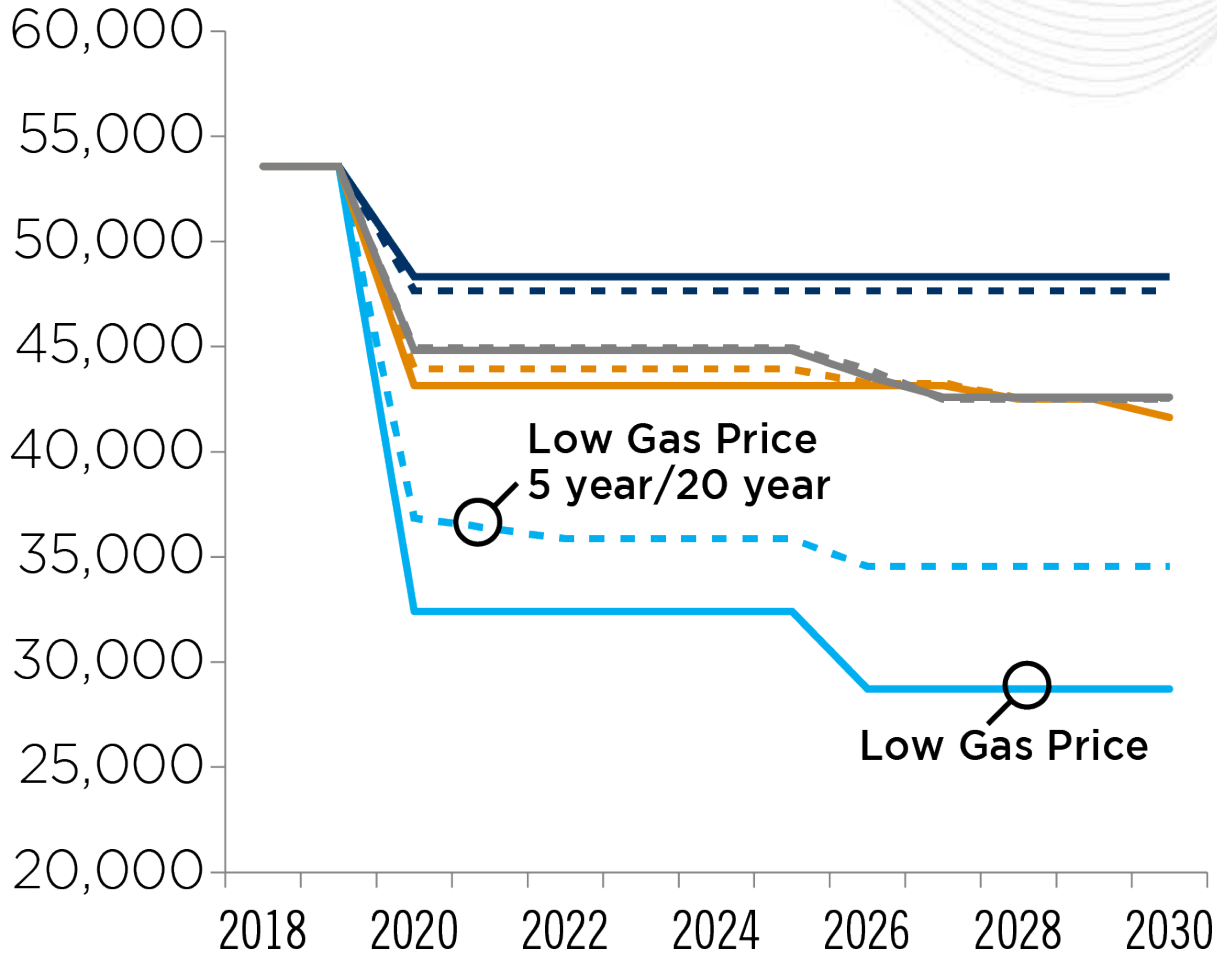


Initial 5 Year Horizon on Retirement and Go Forward Decisions

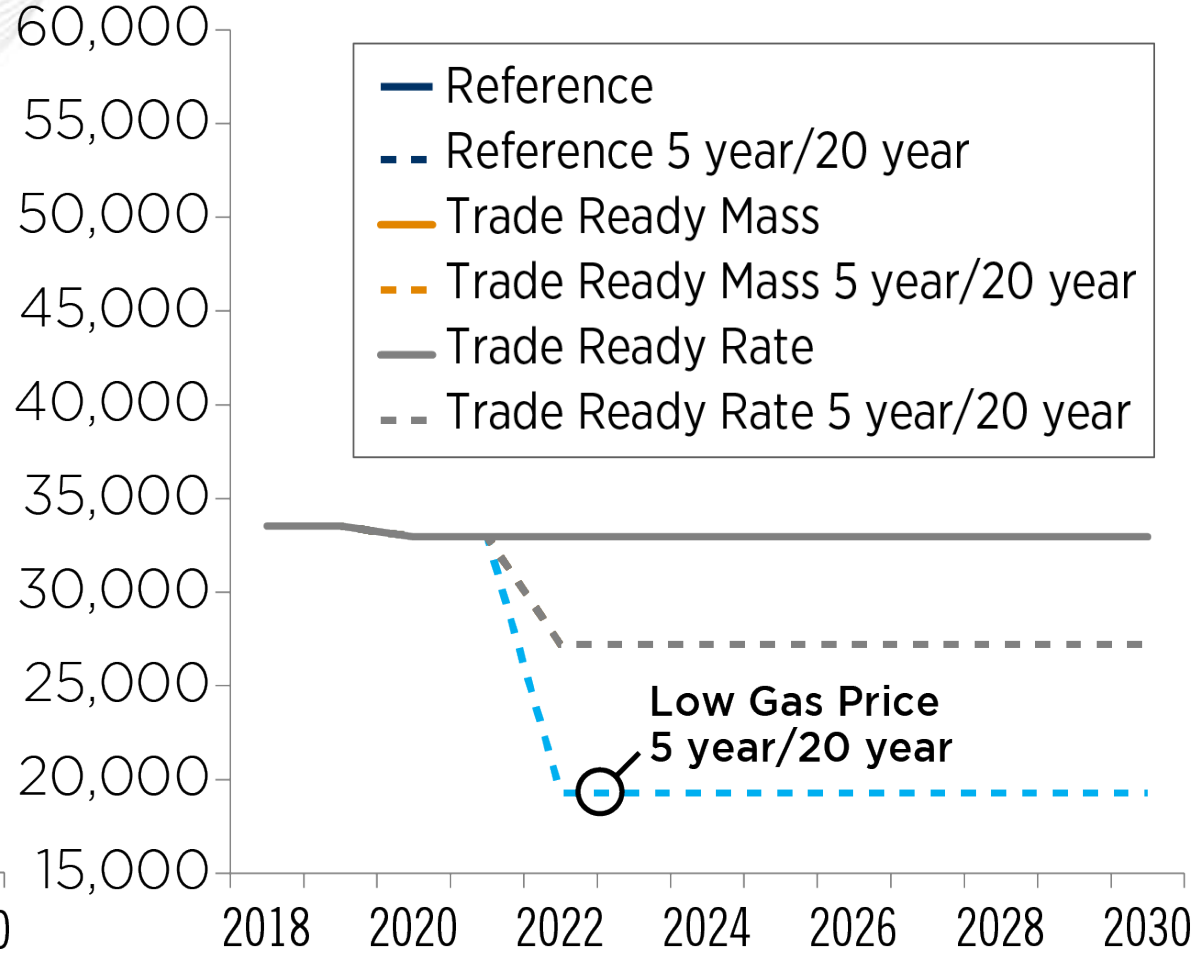


5 Year Horizon on Retire/Go Forward Decisions for Existing Resources

Steam Turbine Coal Unforced Capacity (MW)



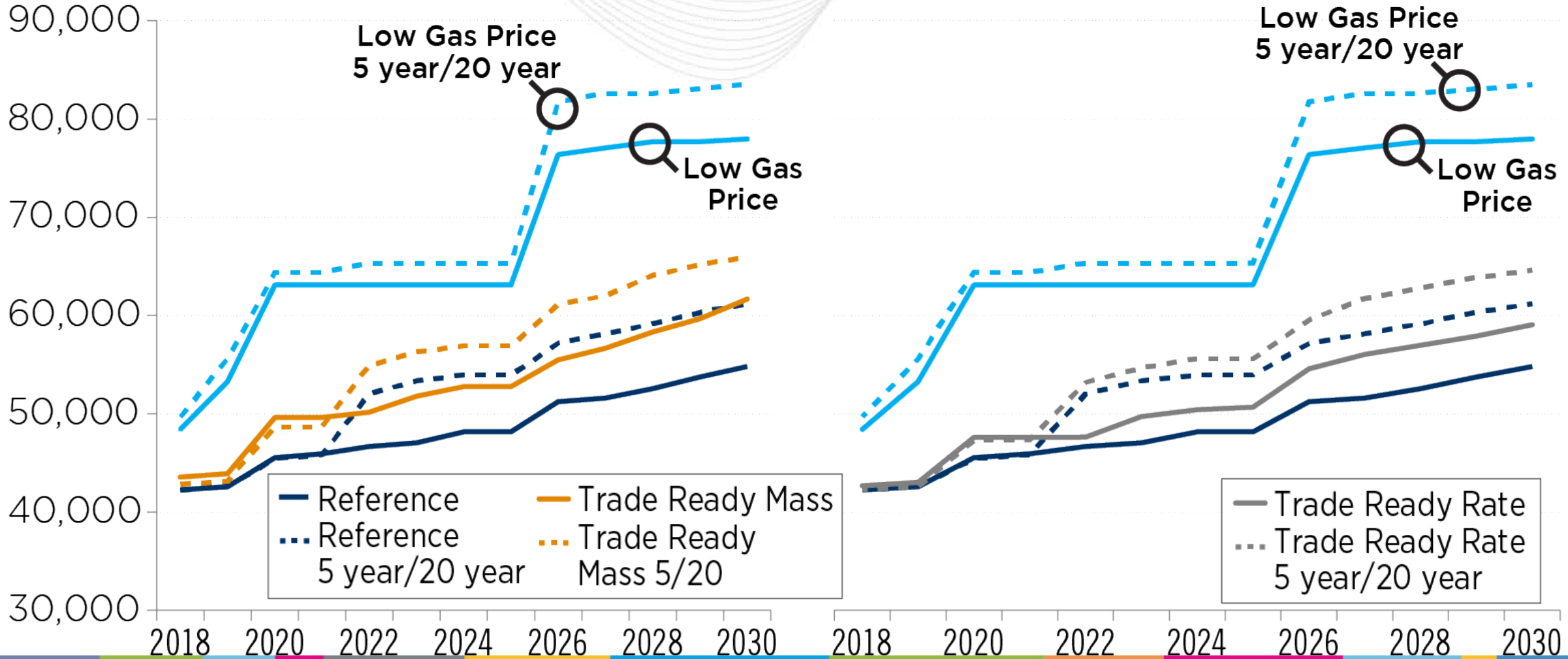
Nuclear Unforced Capacity (MW)





Resulting Gas Combined Cycle Entry with 5 Year Retirement/Go Forward Horizon

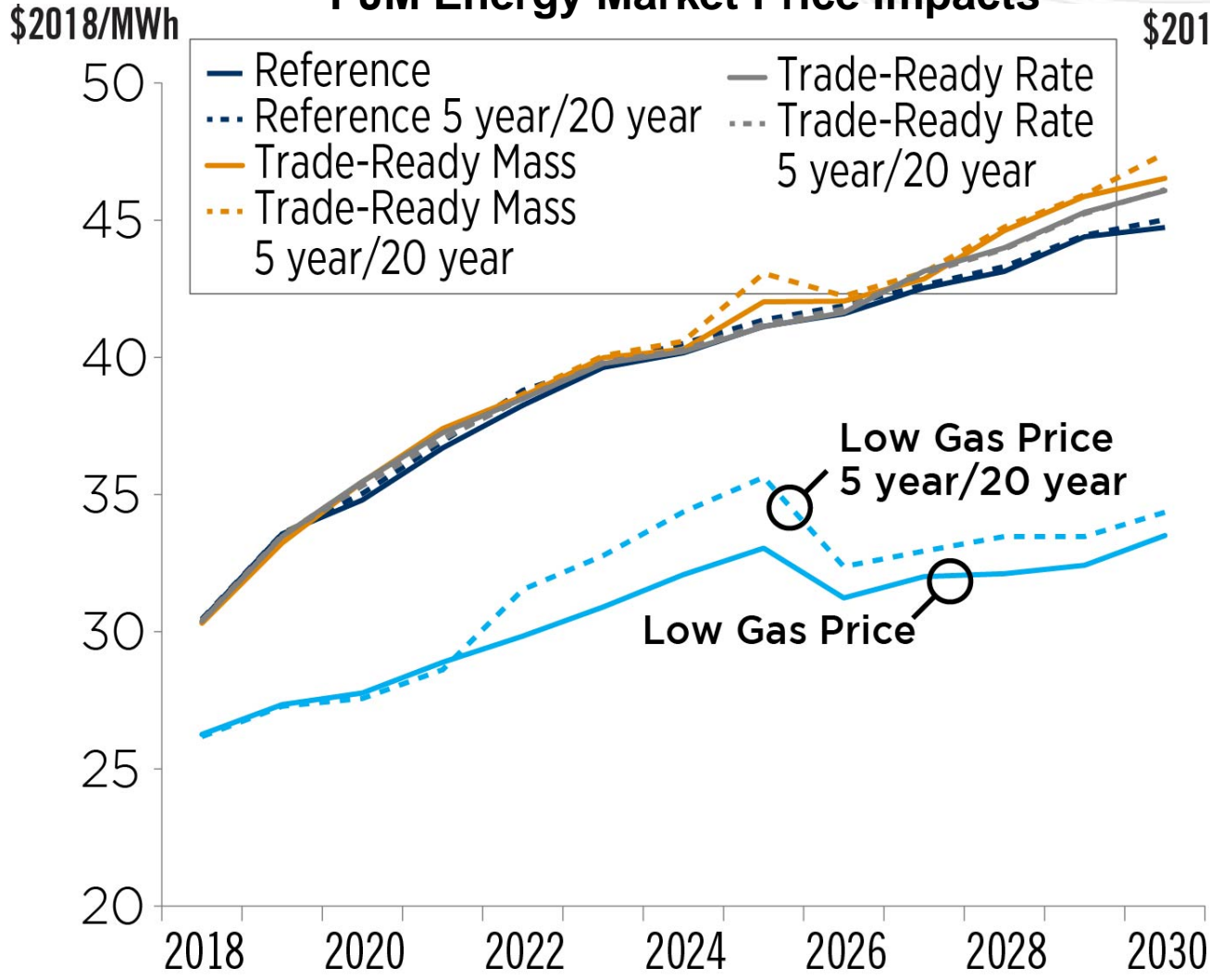
Combined Cycle Gas ICAP (MW)



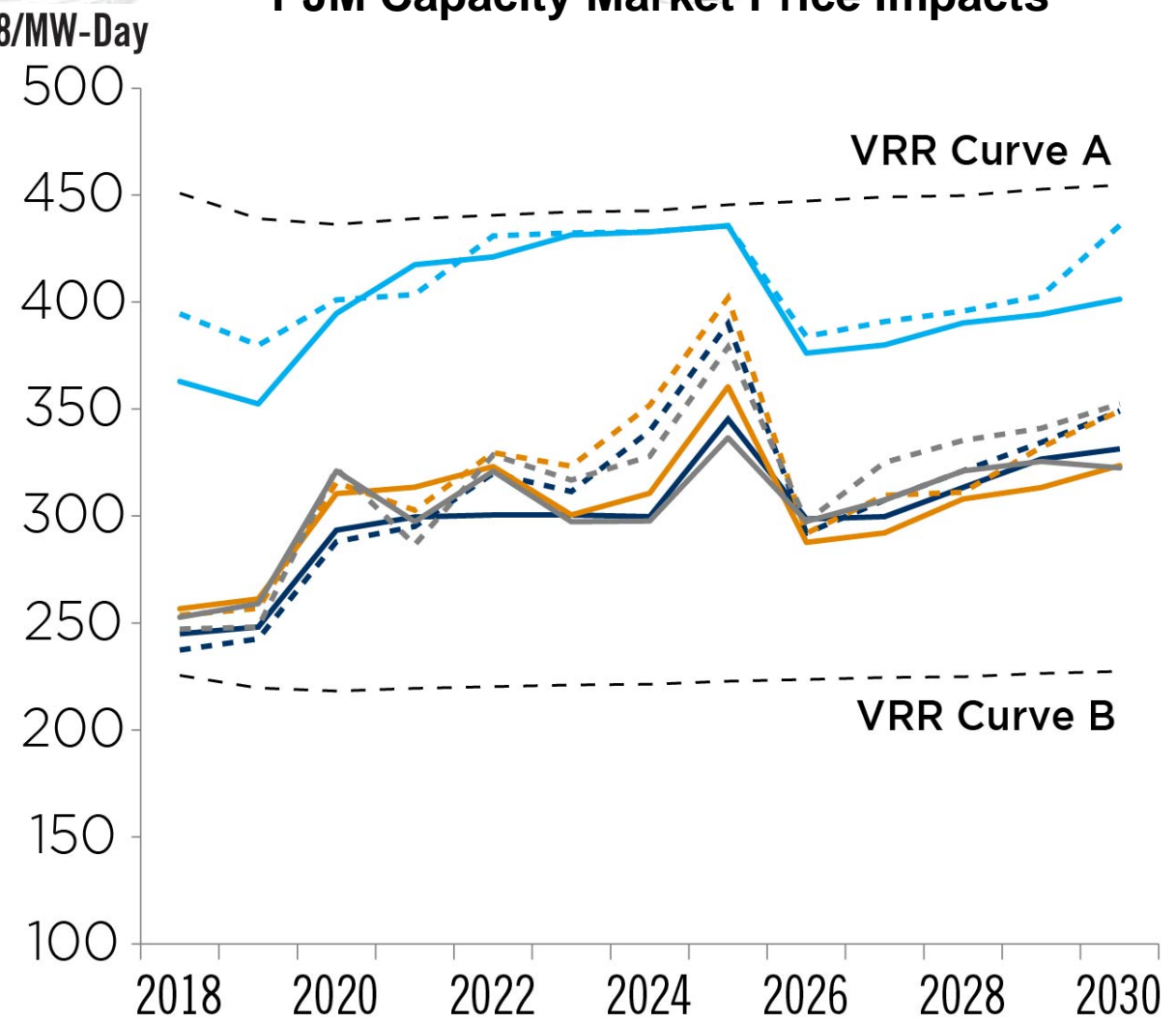


Market Effects of the 5 Year Retirement/Go Forward Horizon

PJM Energy Market Price Impacts



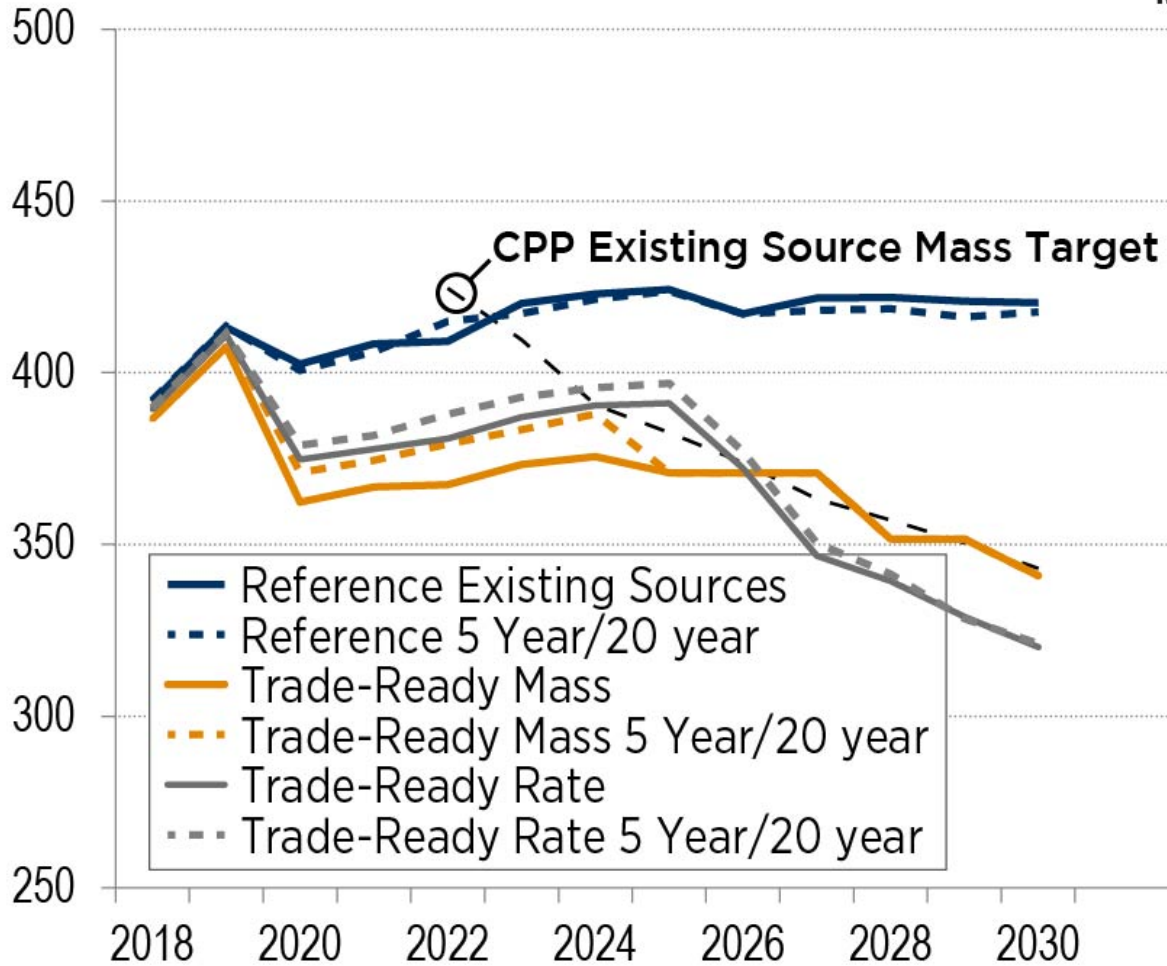
PJM Capacity Market Price Impacts



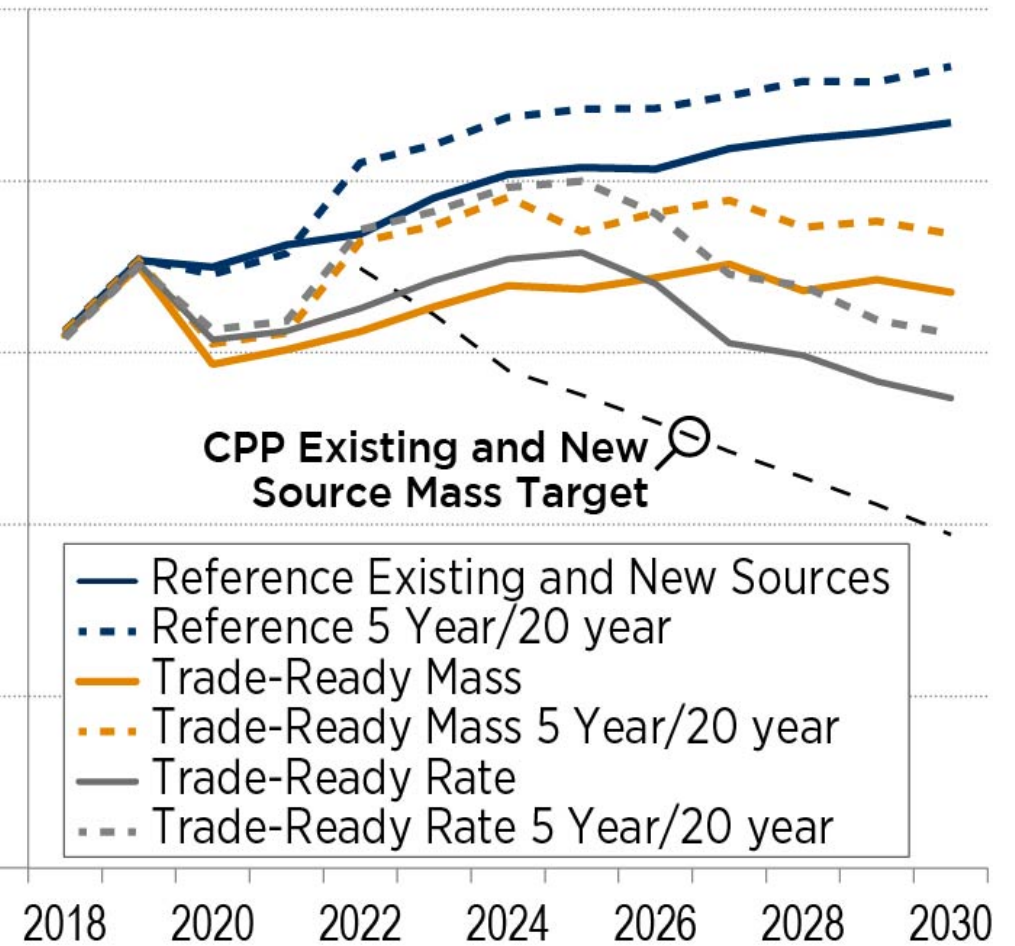


5 year Retirement/Go Forward Horizon: States Still Comply with the CPP Emission Targets

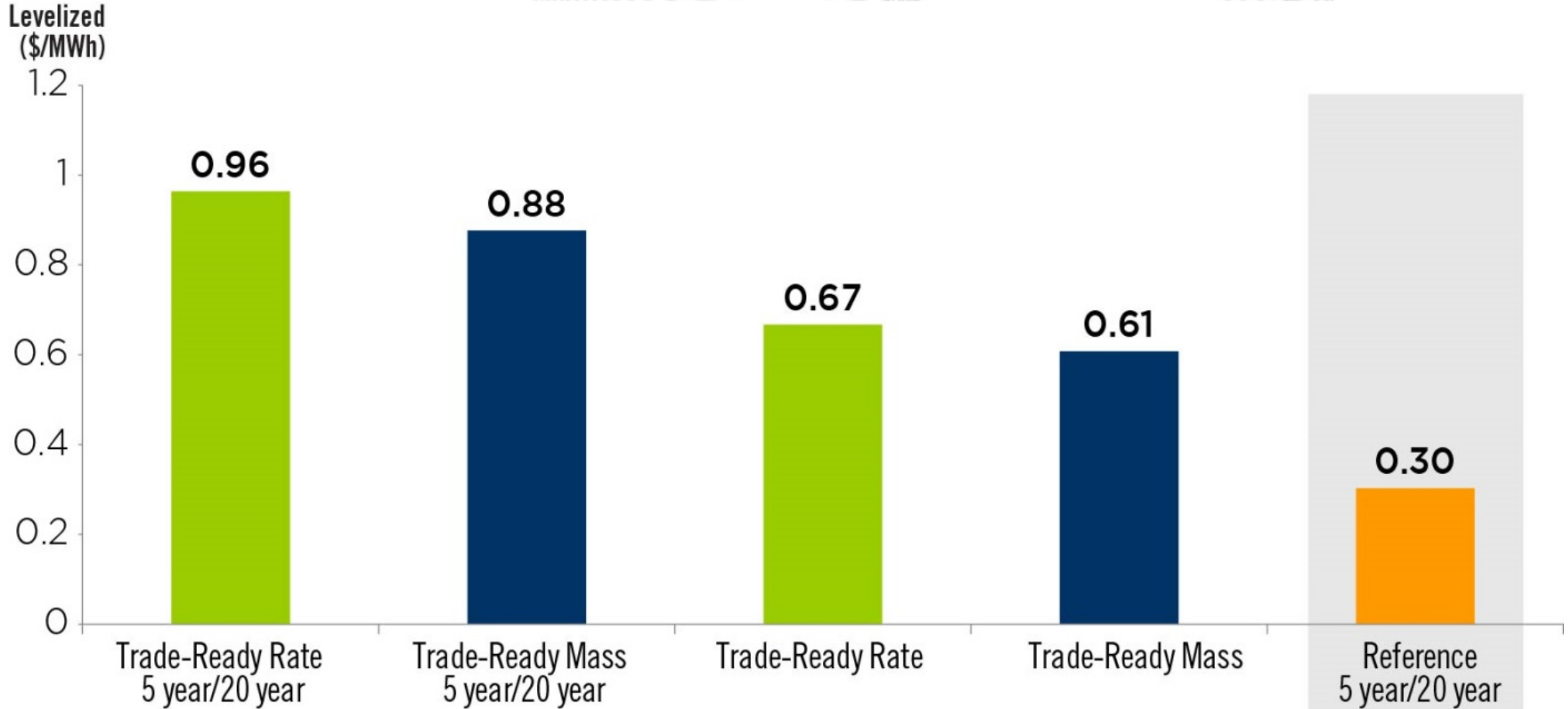
Existing Source CO2
Millions of Tons



Existing and New Source CO2
Millions of Tons



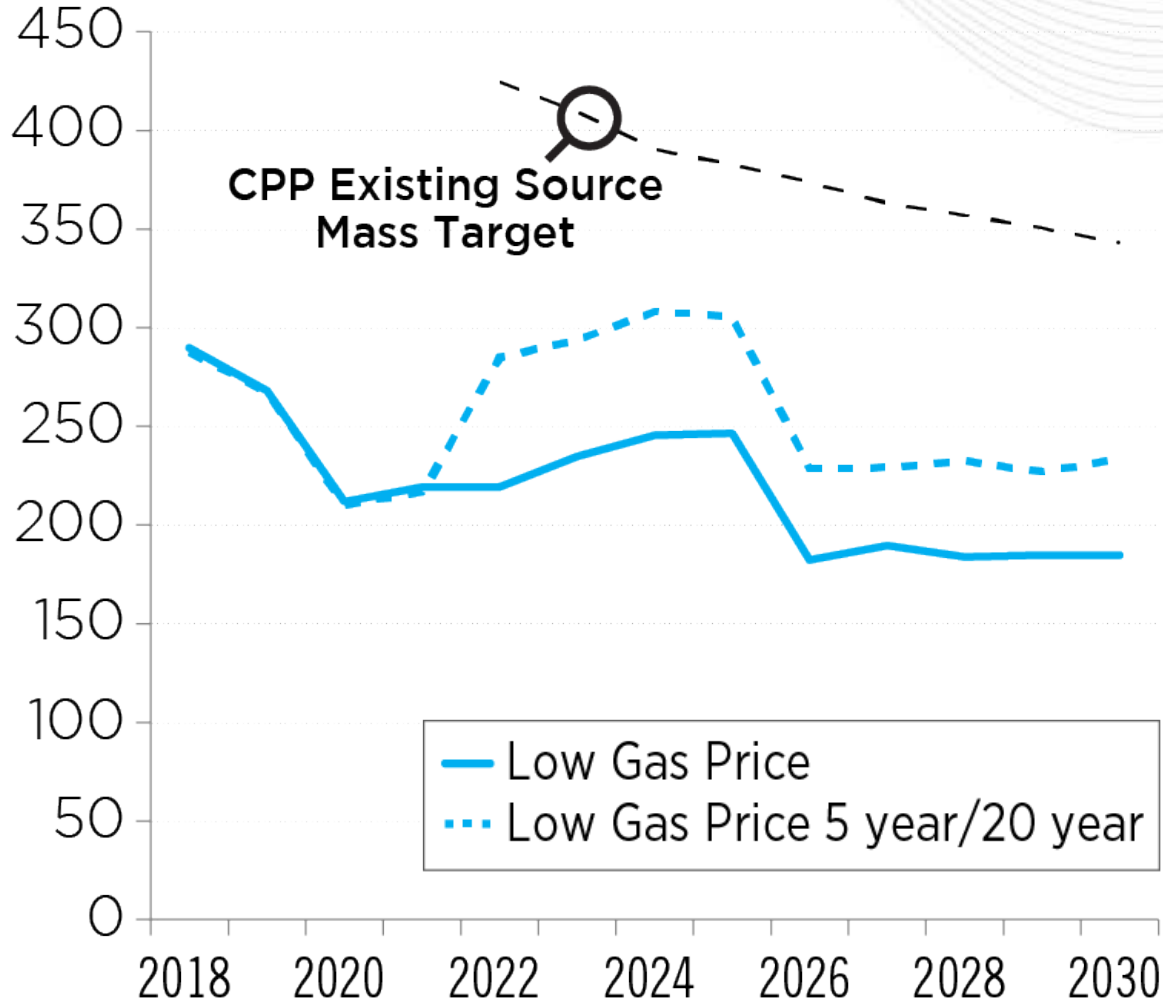
5 Year Retirement/Go Forward Horizon: Compliance Cost Goes Up in Reference Gas Scenario



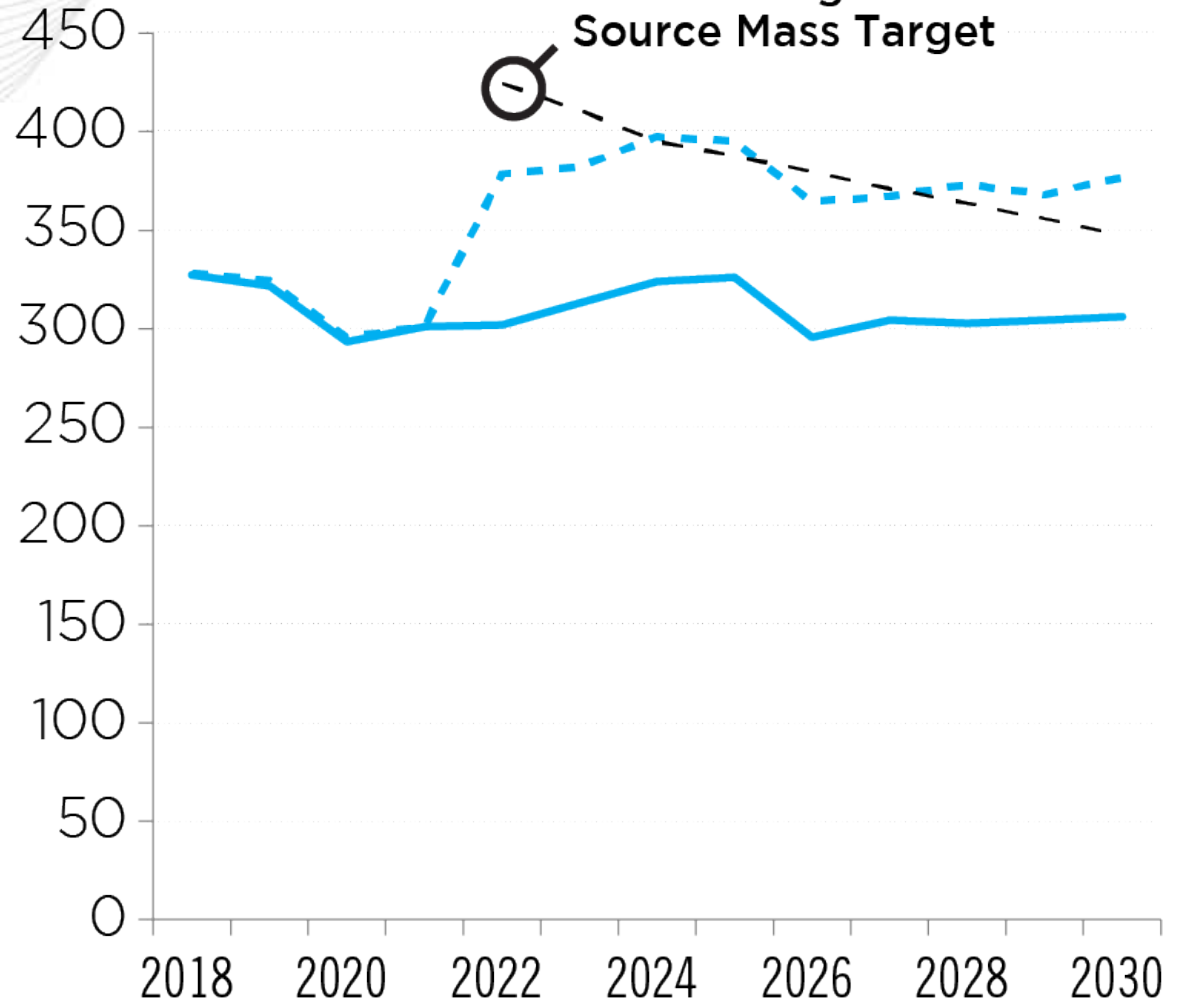


5 Year Retirement/Go Forward Horizon: Emissions in Low Gas Price Cases

Existing Source CO₂
Millions of Tons



Existing and New Source CO₂
Millions of Tons



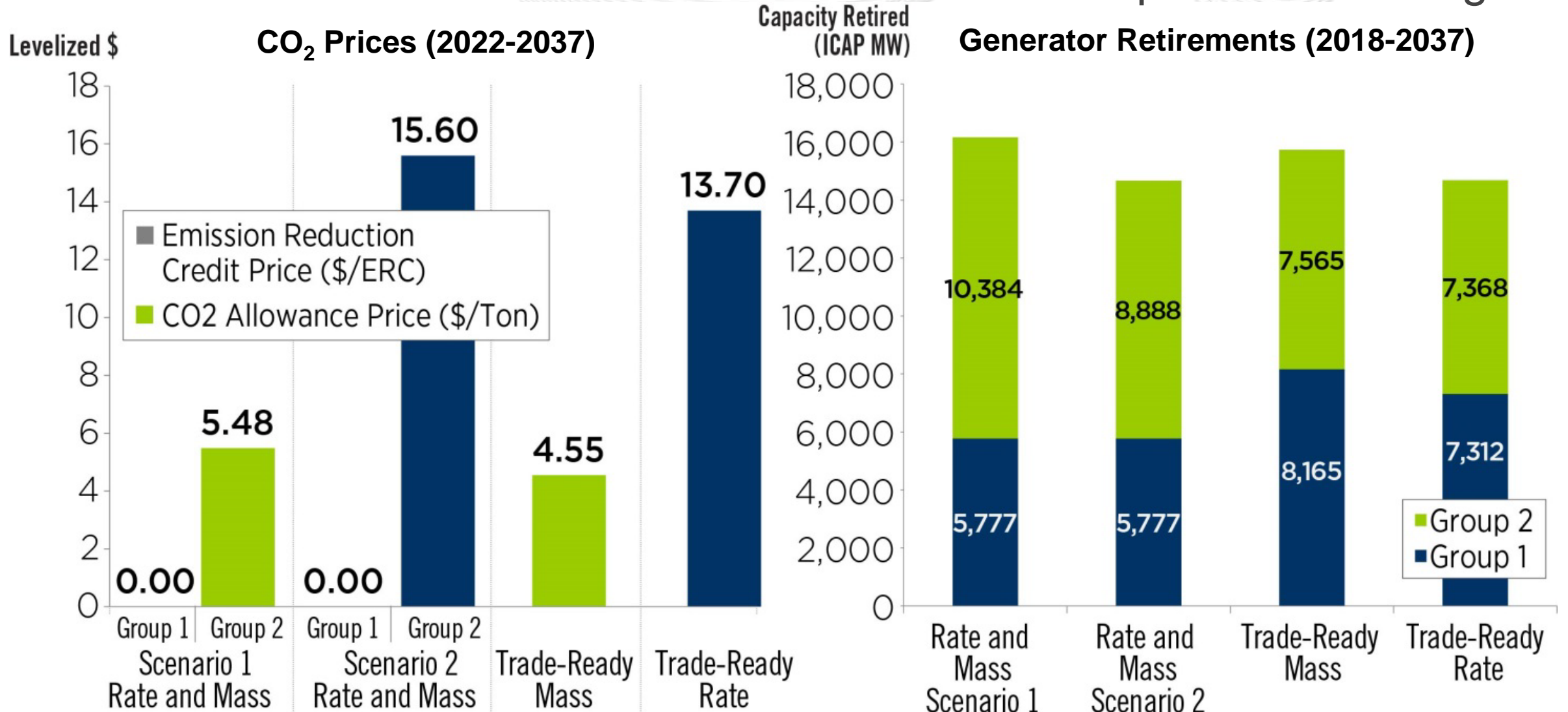
Rate and Mass Sensitivity



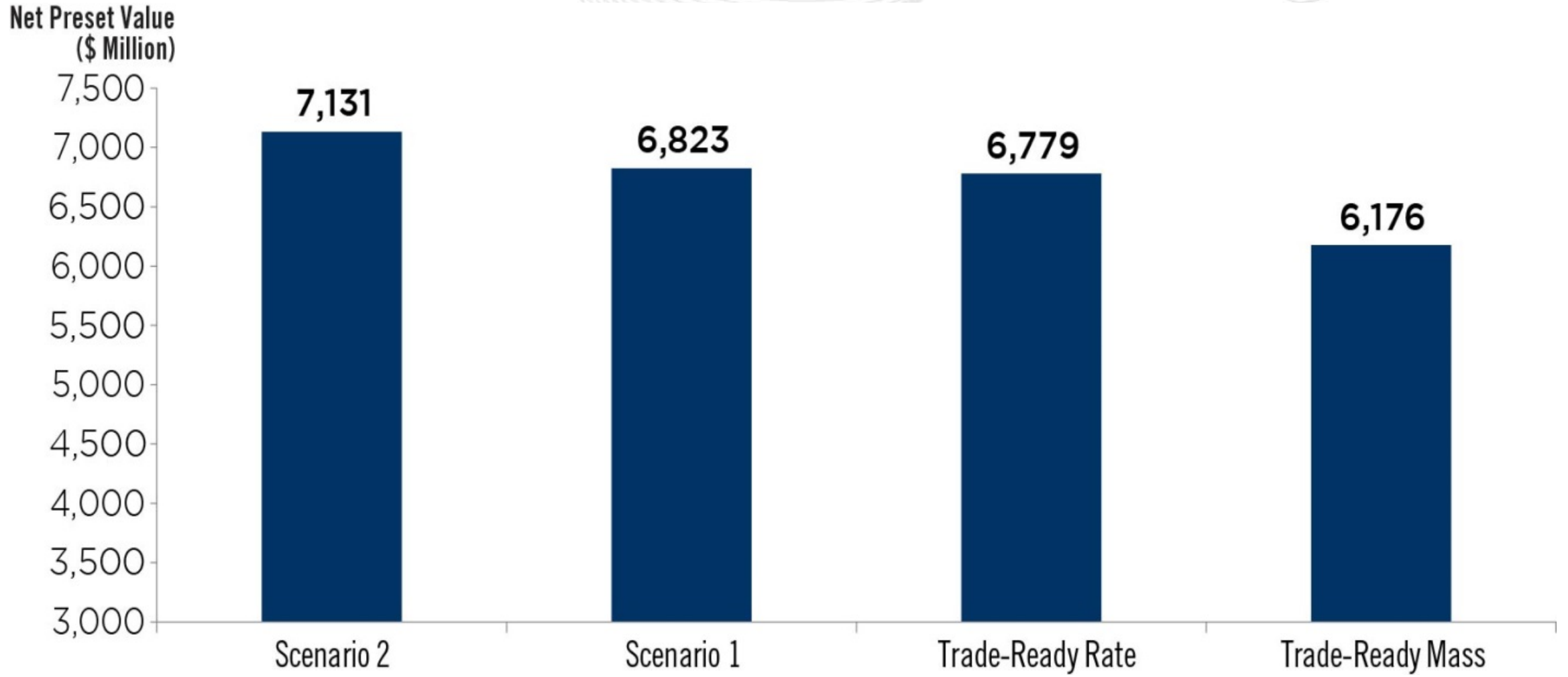
Sensitivity: States Form Multi-State Mass and Rate-based Compliance sub-Regions

	Group ID	States	Compliance
Scenario 1	Group 1 States	MD DE VA NJ PA	Multi-State Rate with Sub-Category Rate Targets
	Group 2 states	IL IN KY MI NC OH WV	Multi-State Mass
Scenario 2	Group 1 States	MD DE VA NJ PA	Multi-State Mass
	Group 2 states	IL IN KY MI NC OH WV	Multi-State Rate with Sub-Category Rate Targets

States Form Multi-State Mass and Rate-based Compliance sub-Regions



If States Form Multi-State Mass and Rate-based Compliance sub-Regions, Compliance Cost (2018-2037) Goes Up



- Continue PJM state and stakeholder outreach
- PJM Reliability Analysis of resource retirements – End of year
- PJM/MISO Coordinated Analysis underway – End of year

Appendix: Key Model Inputs



Modeling Procedure for Evaluation of the Clean Power Plan

Inputs

- Generator Capital and Maintenance Costs
- Unit Operation Characteristics
- Fuel Prices
- Environmental Emissions Prices (NO_x, SO₂, RGGI-CO₂)
- Wind and Solar Shapes

External

- CO₂ Emissions Constraints
- Renewable Portfolio Standards
- Federal Investment Tax Credit/Production Tax Credit

Policy & Regulation

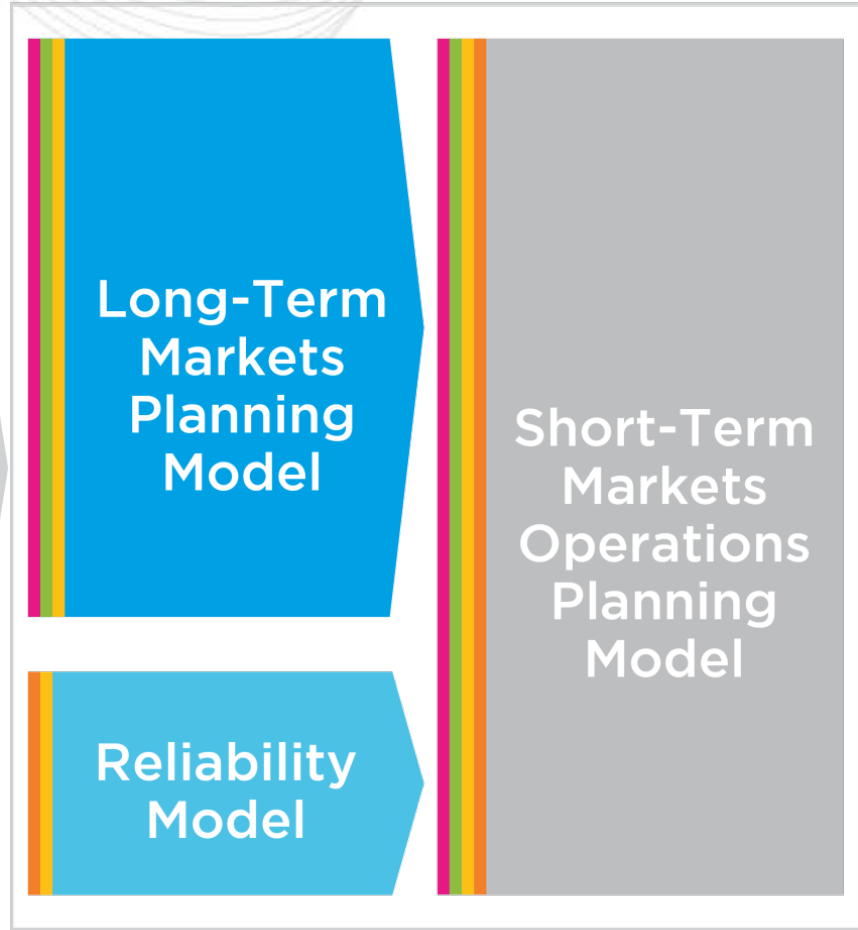
- Load Forecast
- BTM Solar
- Demand Response
- Energy Efficiency

Resource Adequacy

- Power Flow Cases
- Transmission Contingencies
- Voltage Limits

Transmission Planning

Processes



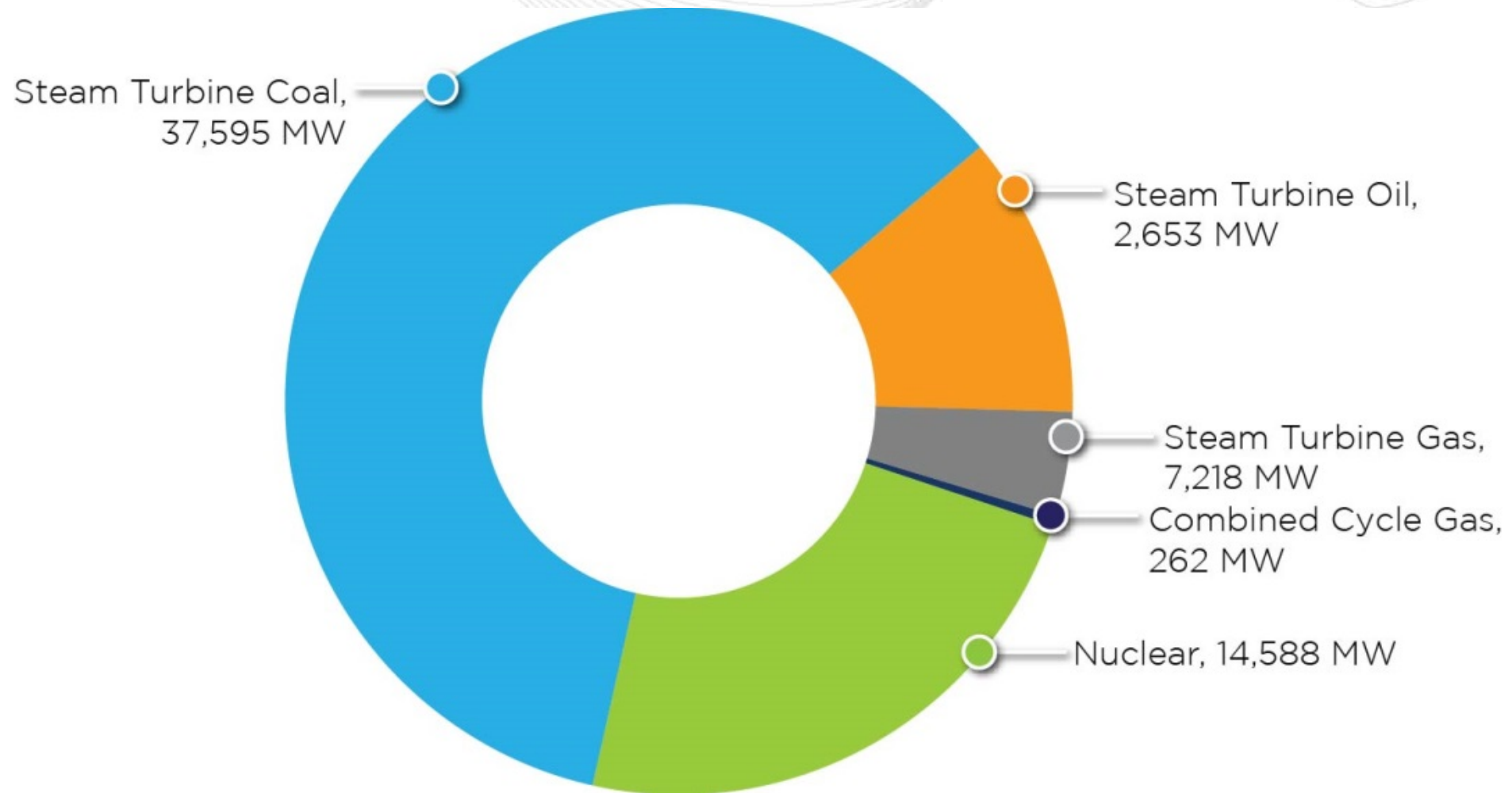
Outputs

- Resource Mix
- Emission Market Price
- Renewable Energy Credit
- Long-Term Energy Market Price

- Transmission Congestion
- Nodal Market Prices
- Emissions Quantity and Market Price

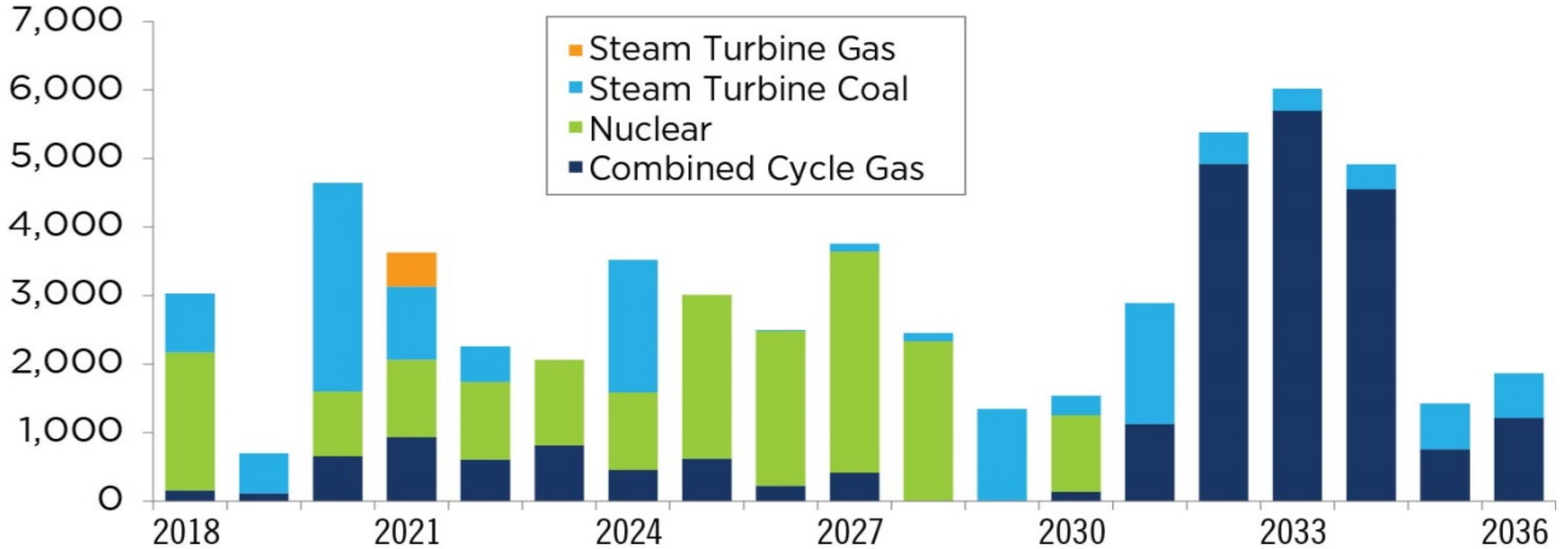
- Interface Limits
- Deliverability Study Limits
- Deliverability Study Thermal/Voltage Constraints
- Loss of Load Expectation

Steam Turbine and Nuclear units older than 40-years, Combined Cycles older than 30-years by 2018



Distribution of Existing Thermal Generating Units in PJM Reaching the end of their 40-year or 30-year Technical Life

Unforced Capacity (MW)



Potential Economic Generating Capacity Additions in the PJM footprint

