MISO/PJM Joint Modeling and Analysis of State Regulatory and Policy Drivers

Case Study: Clean Power Plan Analysis

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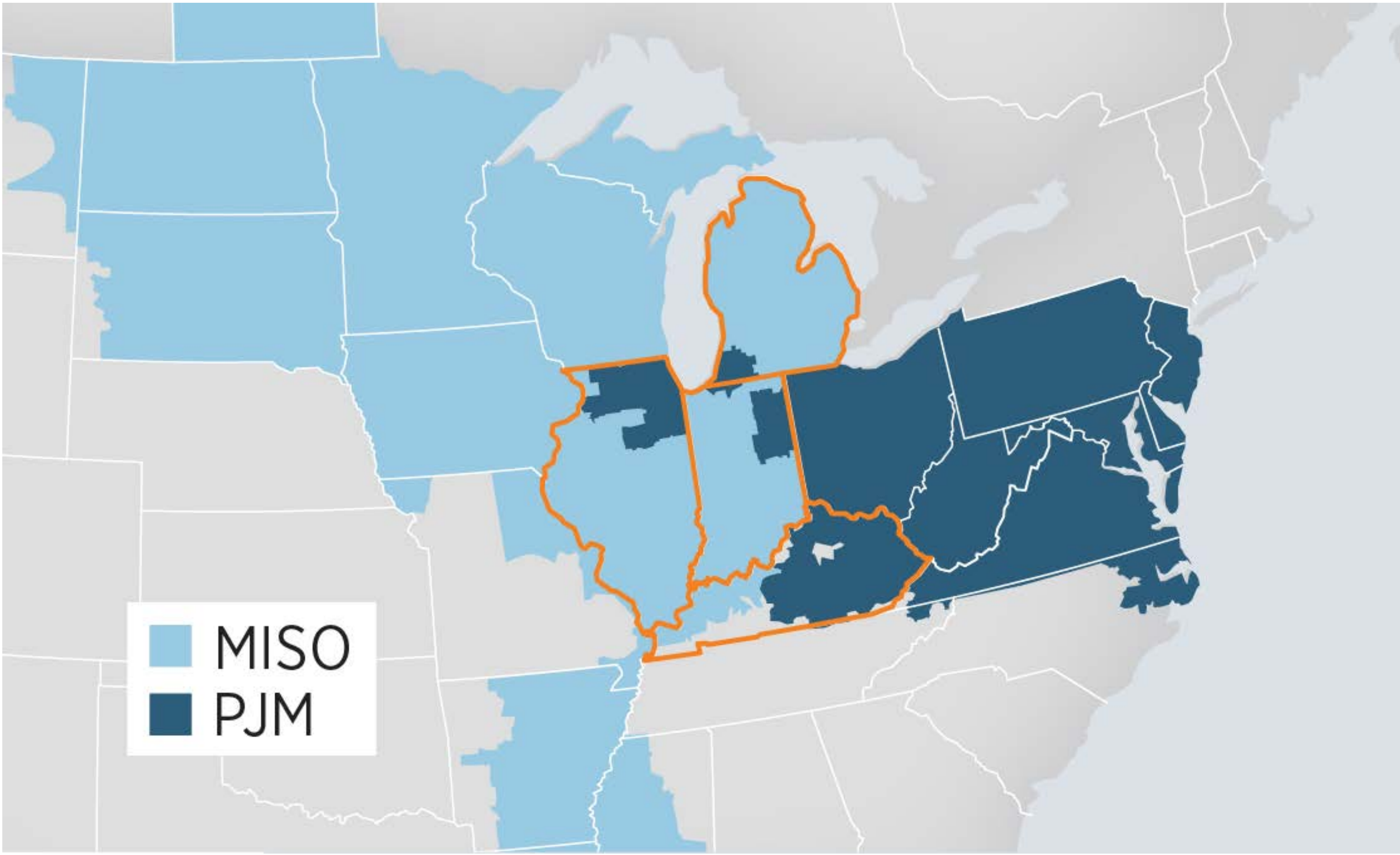
Intersection of Policy / Regulation with Markets



Demonstrate the potential impacts of regulation/policy along the PJM/MISO seam

Examples of regulation/policy that may impact seams states

- **U.S. EPA Clean Power Plan (case study)**
- U.S. EPA National Ambient Air Quality Standards
- State Renewable Portfolio Standards
- FERC Order 1000
- State Clean Energy Standards

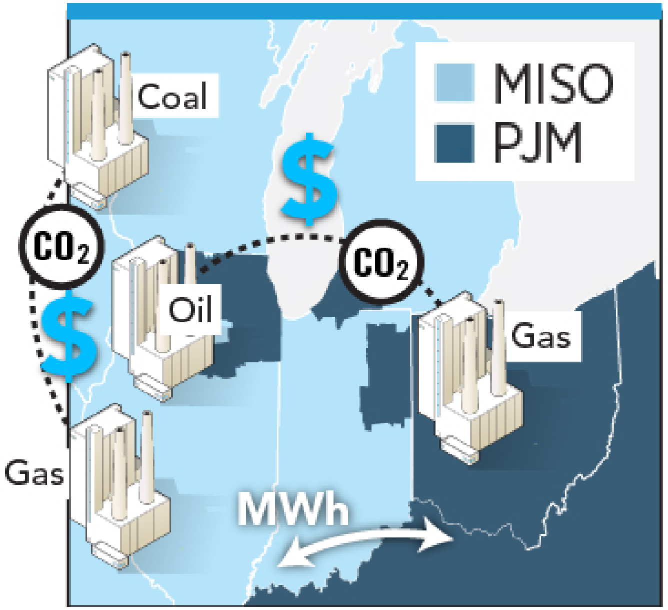
Both PJM's and MISO's earlier studies showed that the ability to trade to achieve compliance with the CPP regulation resulted in lower costs, fewer generation retirements, and more efficient generation investment.

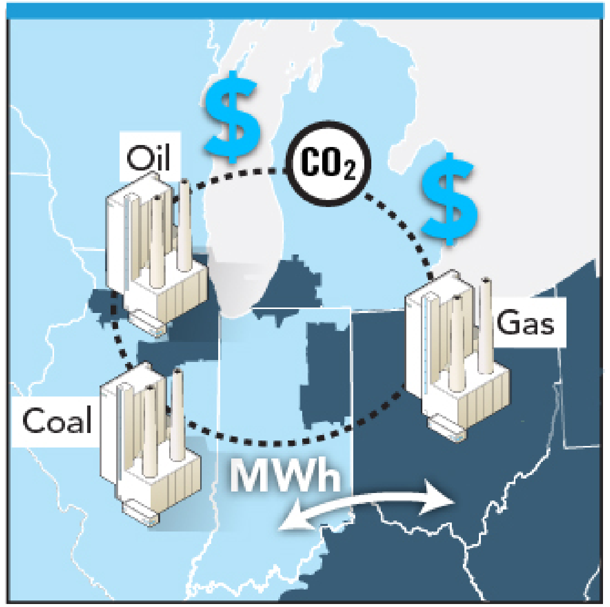
- **Determine and compare the potential impacts of state policy on:**
  - Economic interchange
  - Transmission system operations (congestion)
  - Utilization of various generation resource types
  - Generation production costs
  - MISO and PJM energy market costs

- **The study will not drive transmission upgrades to be included in future transmission expansion plans of PJM or MISO.**

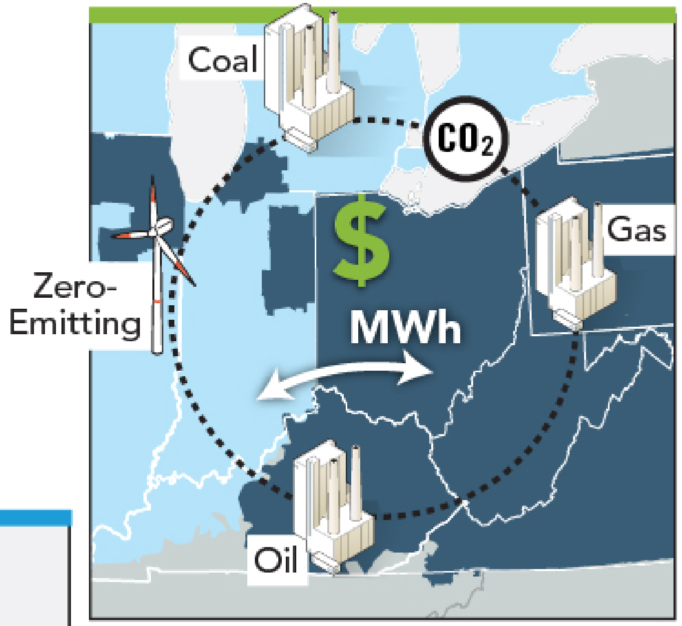
Analysis is not a forecast of future PJM and MISO market or planning outcomes.

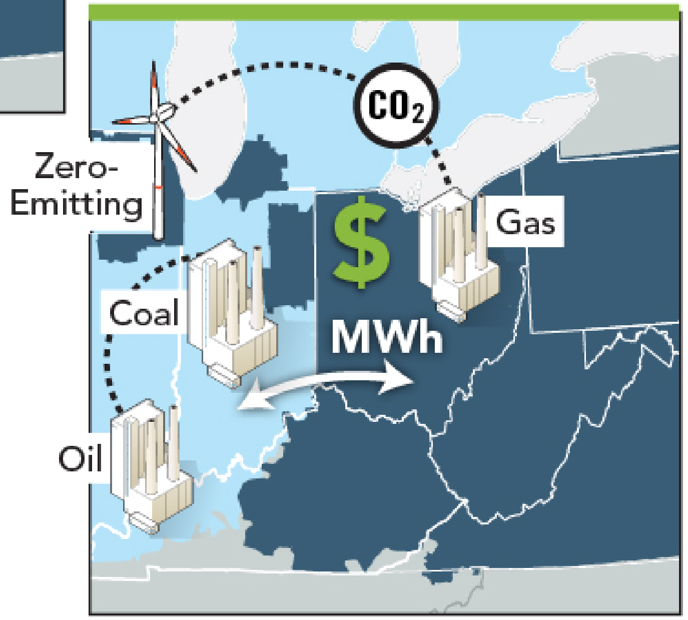
MISO and PJM Continue to Transact Energy Across the Seam Despite CO_2 Policy





Mass-Based





Rate-Based

MISO & PJM Developed Scenarios to Examine the Impacts of Emissions Policy on Seams States

Base Case	Description
Lower Renewable	• PJM’s resource expansion developed under trade-ready mass-based compliance • MISO’s resource expansion developed in MTEP17 Policy Regulation future • Blend of EIA 2016 Annual Energy Outlook & IHS CERA Monthly Natural Gas Briefing
Higher Renewable	• PJM’s resource expansion developed under trade-ready rate-based compliance • MISO’s resource expansion developed in MTEP17 Policy Regulation future • Blend of EIA 2016 Annual Energy Outlook & IHS CERA Monthly Natural Gas Briefing

Scenario	Base Case	MISO Trading Instrument	PJM Trading Instrument
MISO Mass, PJM Rate	Higher Renewable	Allowance	Emission Rate Credit
MISO Rate, PJM Mass	Lower Renewable	Emission Rate Credit	Allowance
Trade-Ready Rate	Higher Renewable	Emission Rate Credit	Emission Rate Credit
Trade-Ready Mass	Lower Renewable	Allowance	Allowance

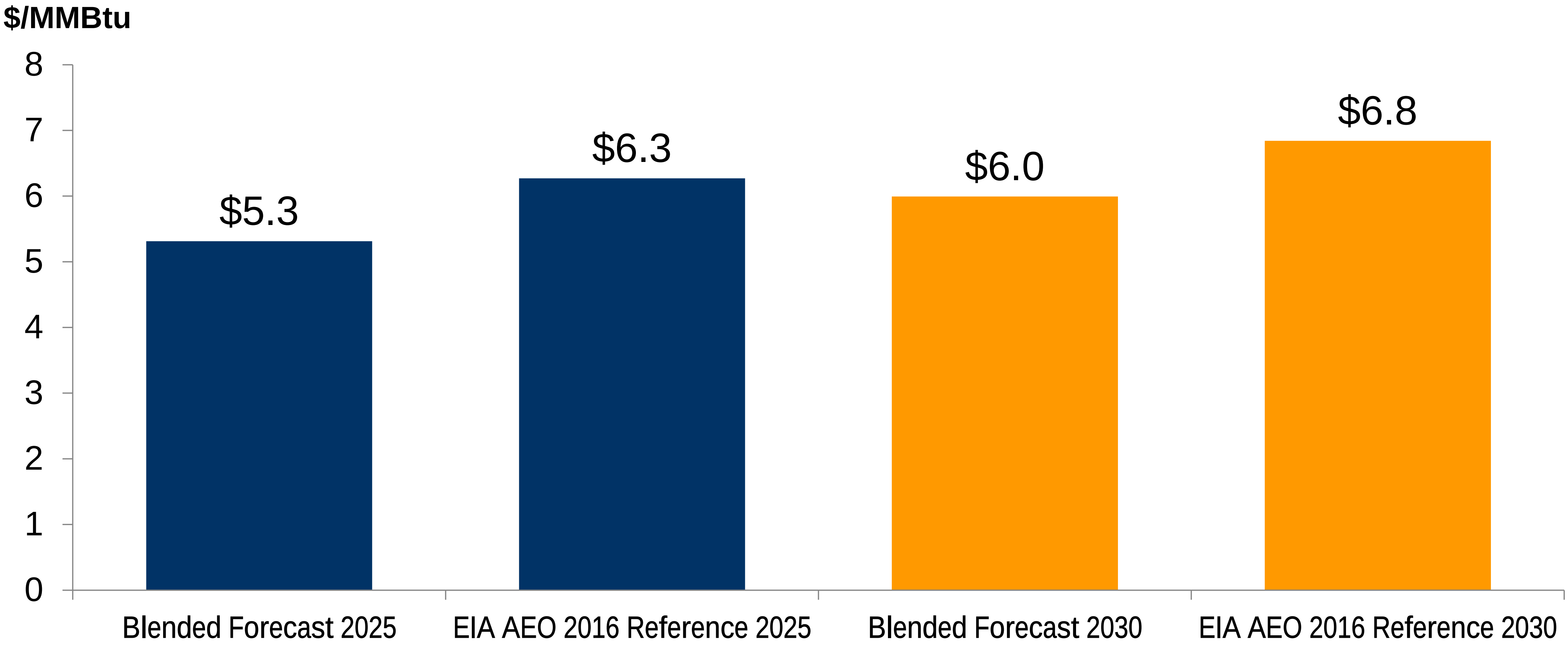
Section II: Background Information

Key Terms and Definitions

- **Production Costs** – Cost of generation including fuel, and variable operations and maintenance costs
- **Compliance Cost** – Change in production costs to comply with emission constraints
- **Locational Marginal Price (LMP)** – Value of energy at a specific location and time of delivery
- **Demand Costs** – Cost paid by load for purchase of energy at the LMP
- **Nameplate Capacity (MW)** – Maximum sustained output from a generating facility

Study Examines the Impact of Changes in the Natural Gas Price on Energy Market Cost and Dispatch

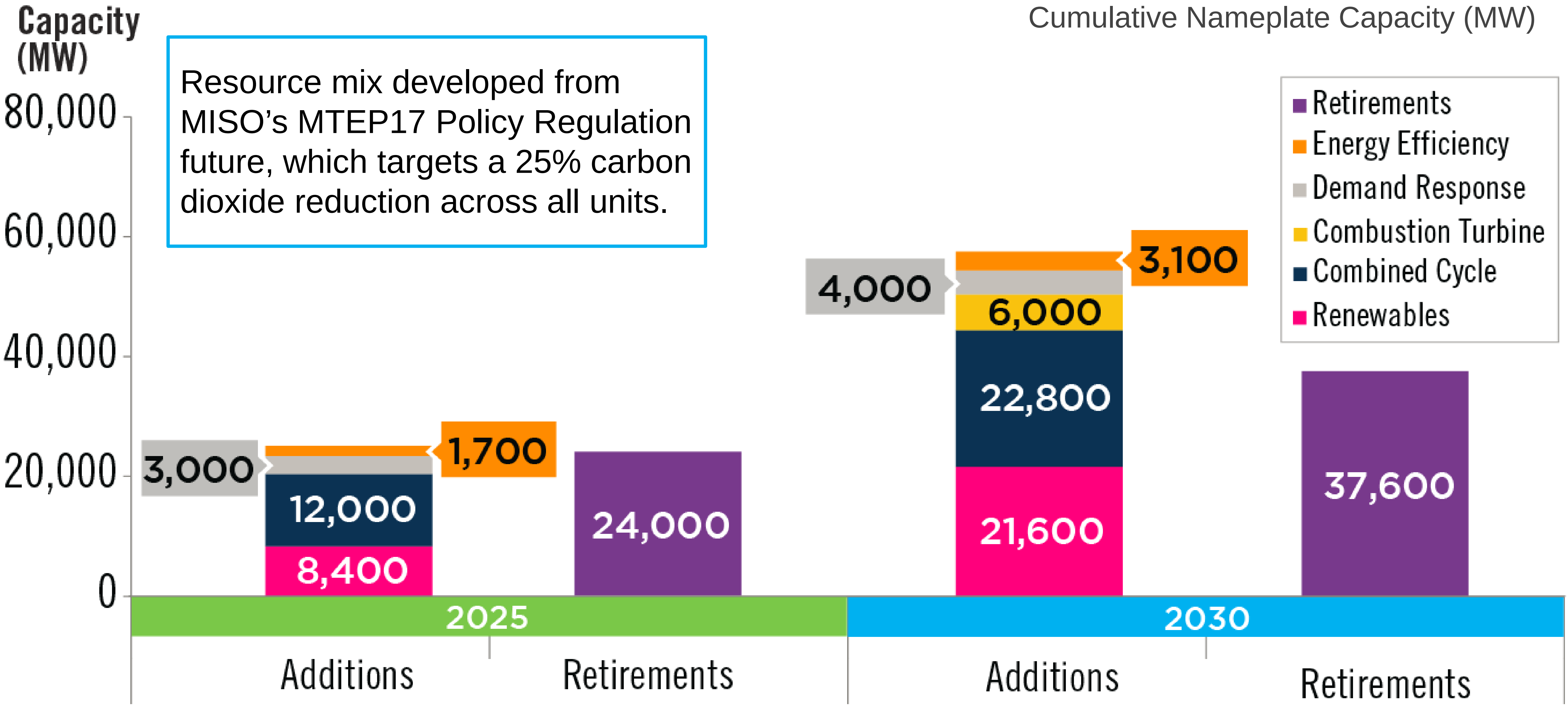
Annual Average Henry Hub Price (Nominal Dollars)



MISO Retirements Replaced by a Combination of Combined Cycle Gas and Renewable Resources

Cumulative Nameplate Capacity (MW)

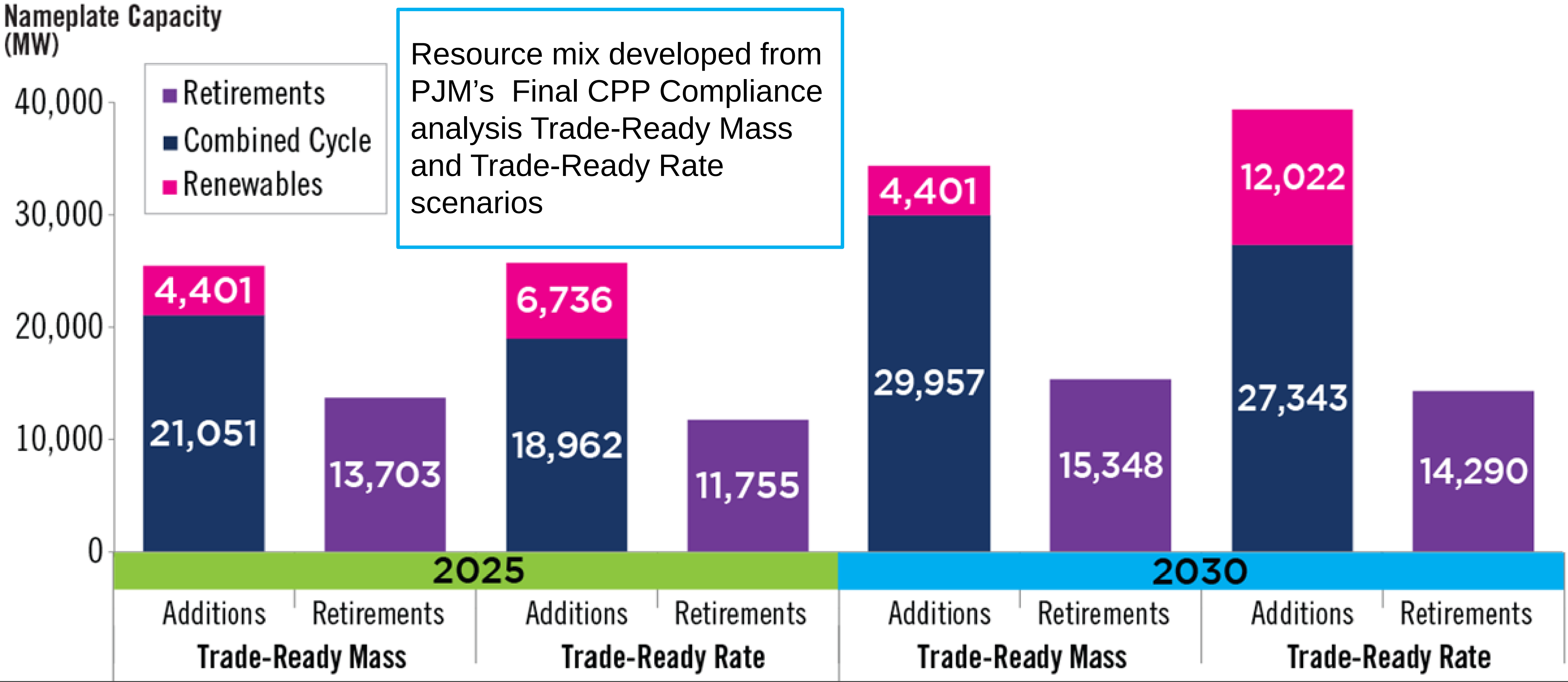
Resource mix developed from MISO's MTEP17 Policy Regulation future, which targets a 25% carbon dioxide reduction across all units.



PJM Retirements Replaced by a Combination of Combined Cycle Gas and Renewable Resources

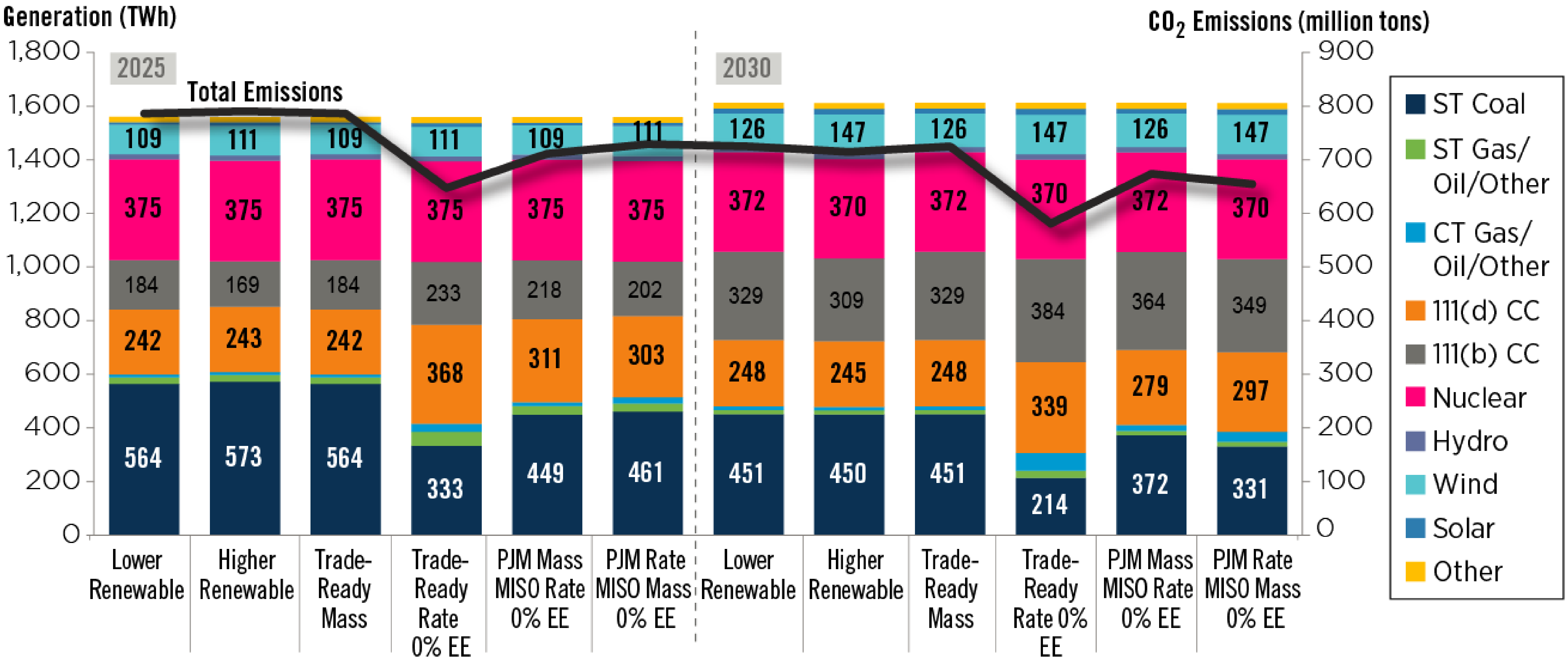
Cumulative Nameplate Capacity (MW)

Resource mix developed from PJM's Final CPP Compliance analysis Trade-Ready Mass and Trade-Ready Rate scenarios



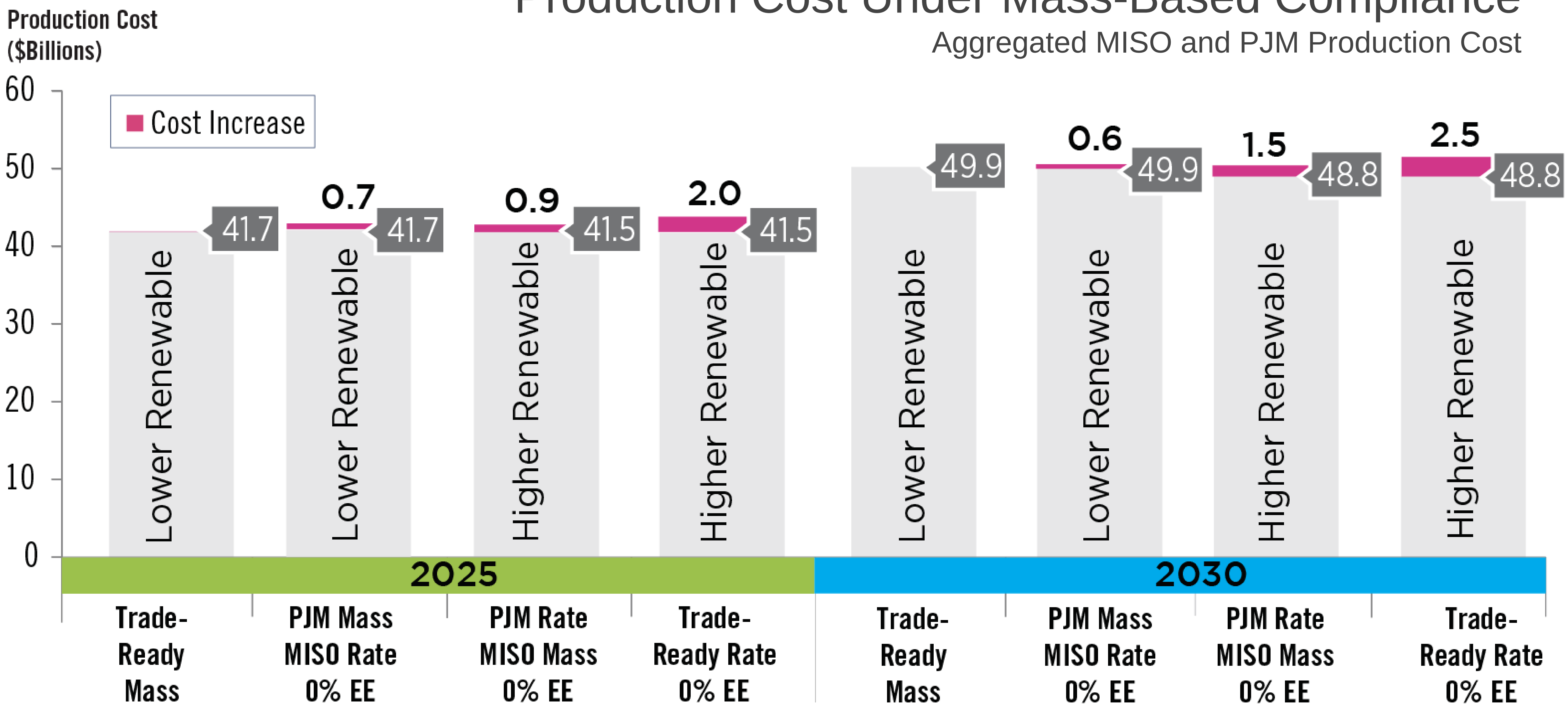
Section III: Emissions and Generation Results

Mass-Based Compared to Rate-Based Trading Leads to Less Change in System Operations

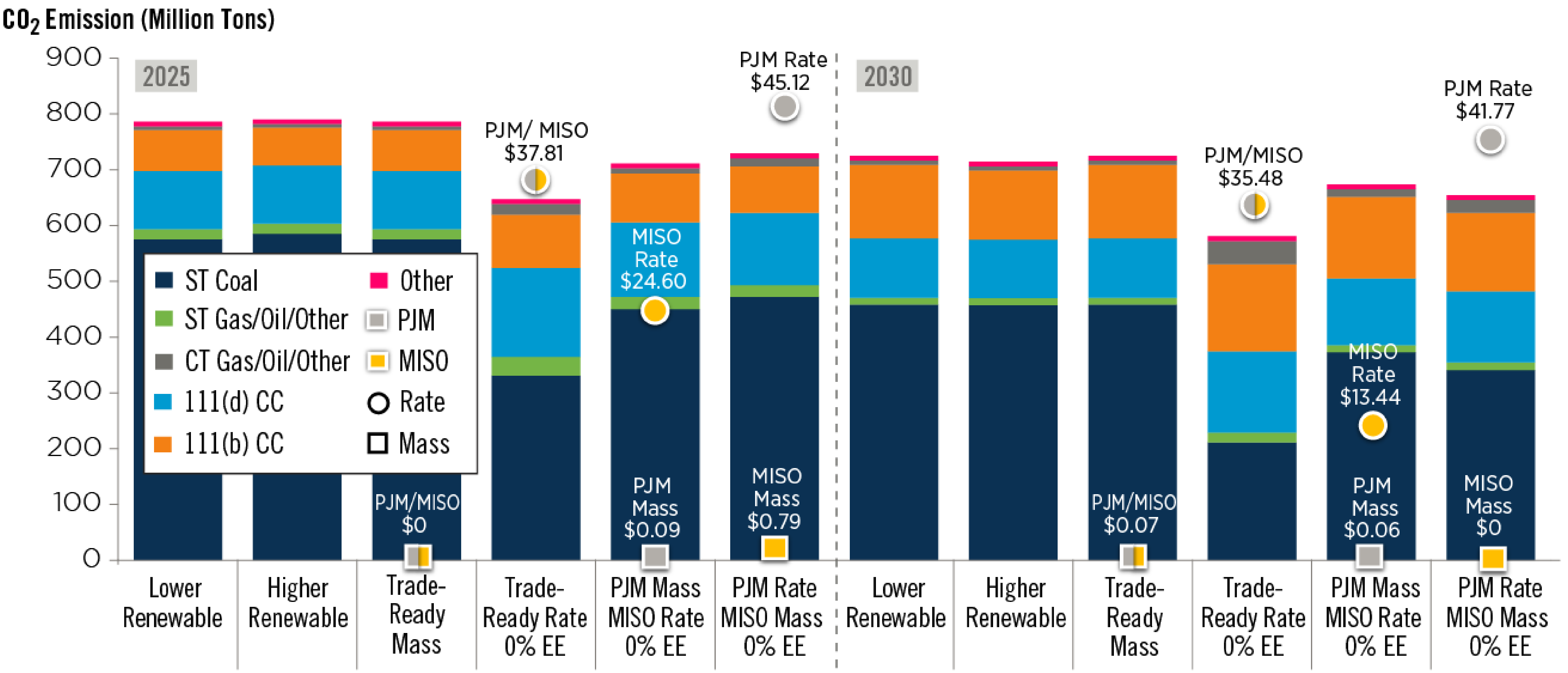


Low Natural Gas Prices Drive Smaller Changes in Production Cost Under Mass-Based Compliance

Aggregated MISO and PJM Production Cost

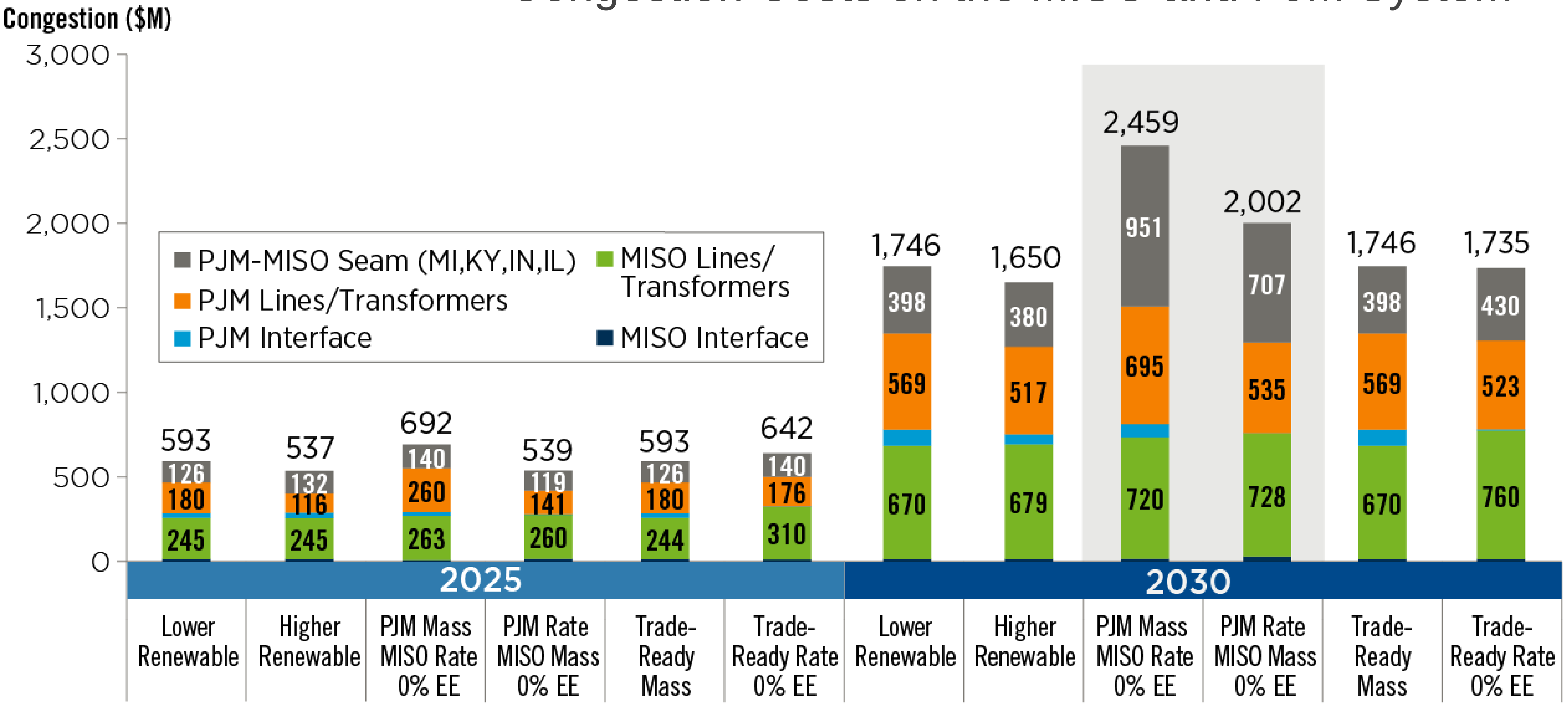


Low Natural Gas Prices Drive Mass-Based Trading CO_2 Prices Lower than Rate-Based Trading



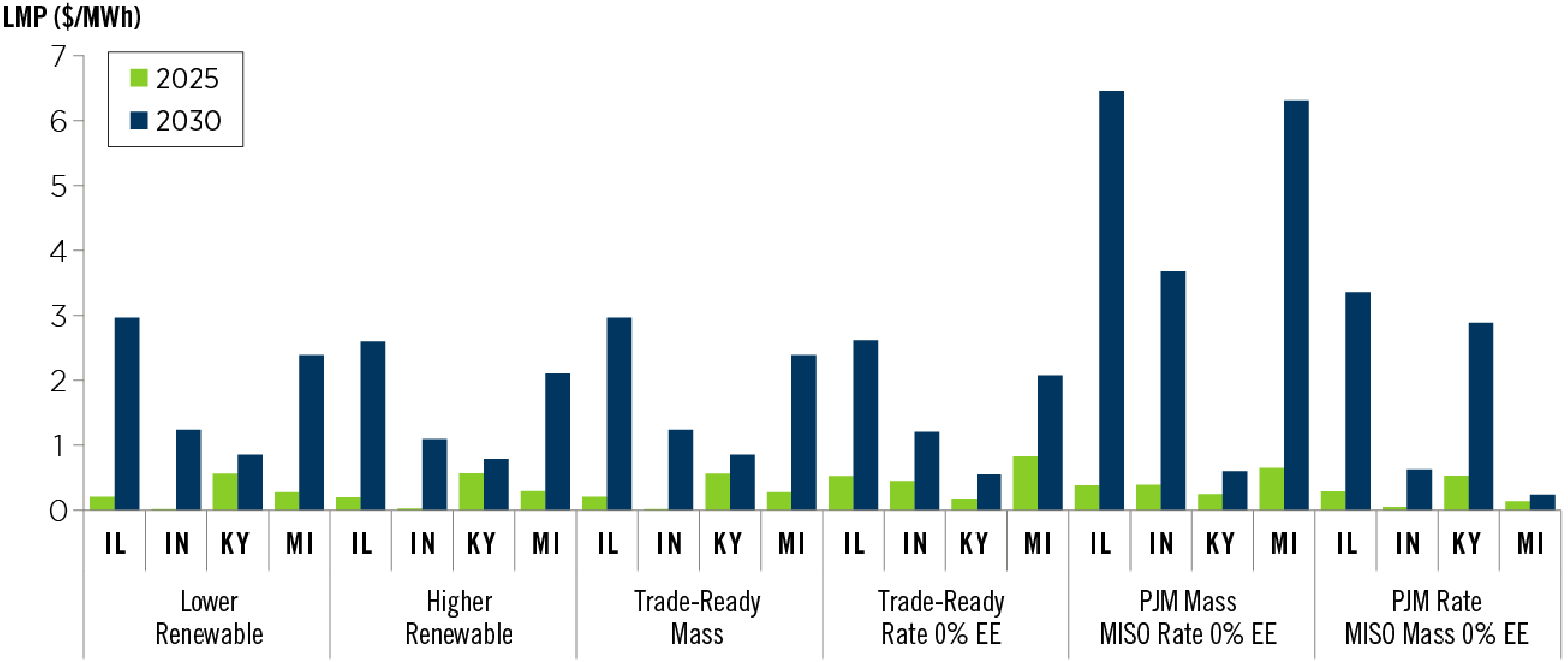
Section IV: Market Results

Consistent Policy Implementation Results in Less Congestion Costs on the MISO and PJM System



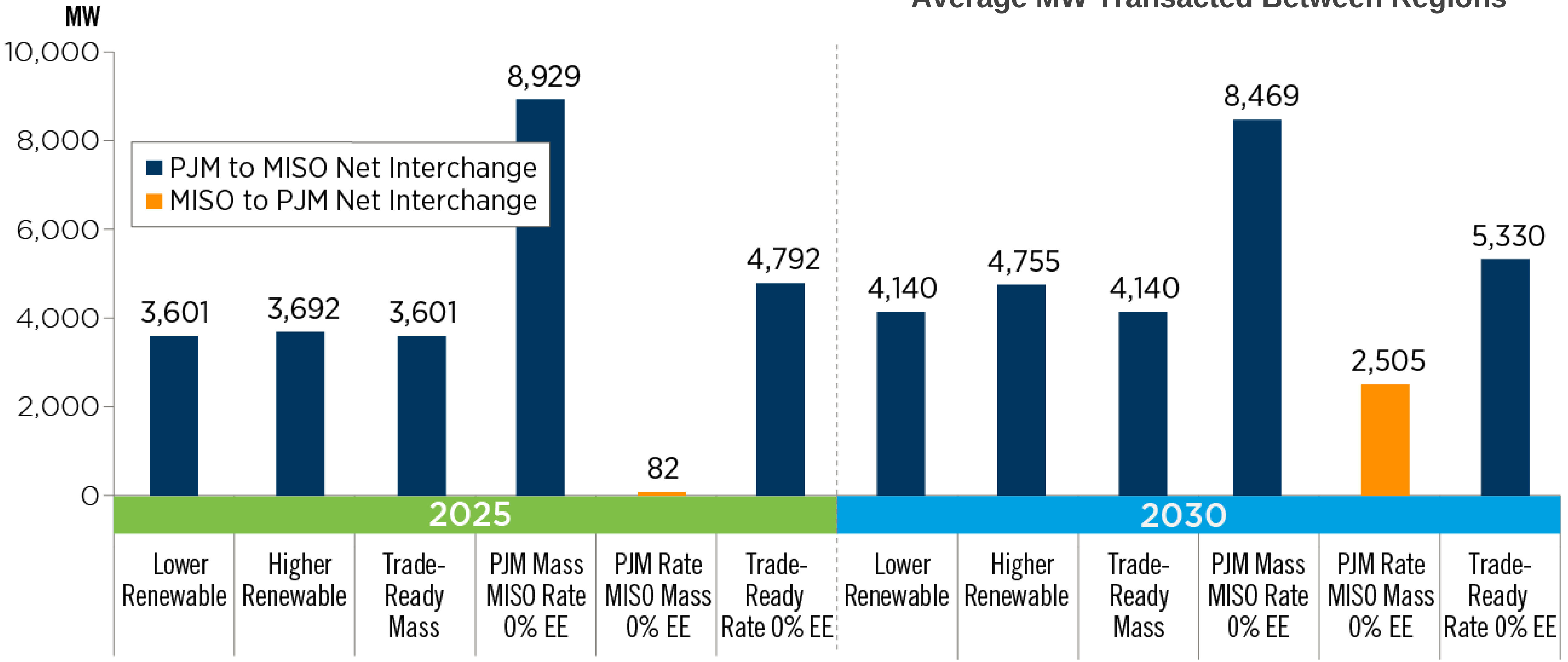
Consistent Policy Implementation Reduces Potential for PJM and MISO LMPs to Diverge

Absolute Difference Between MISO and PJM LMPs



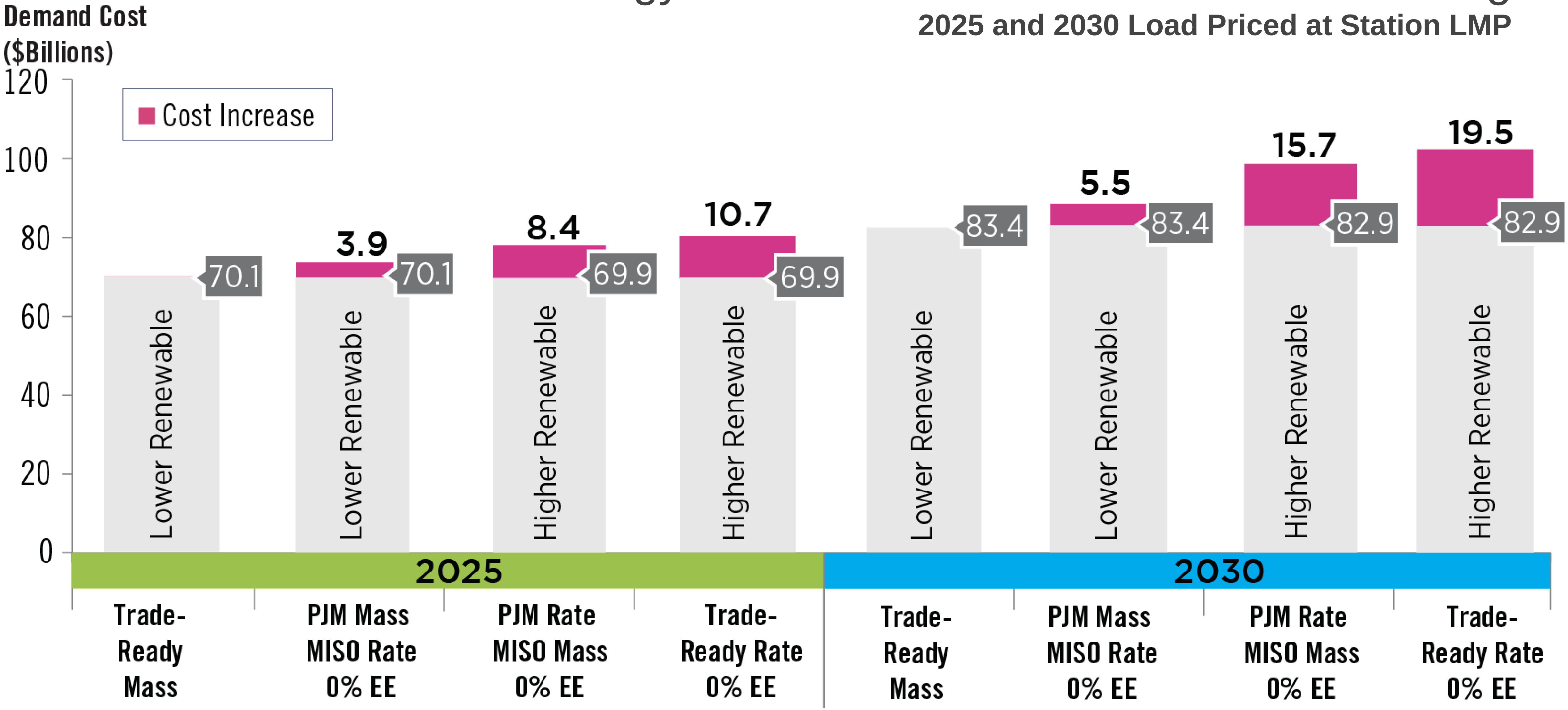
Consistent Policy Implementation Results in Less Volatility on the PJM and MISO Interface

Average MW Transacted Between Regions



Low Natural Gas Prices Drive Smaller Changes in Energy Demand Cost with Mass-Based Trading

2025 and 2030 Load Priced at Station LMP



Section V: Broader Trading Region

Performed using EIA's 2016 Annual Energy Outlook Reference Henry Hub forecast

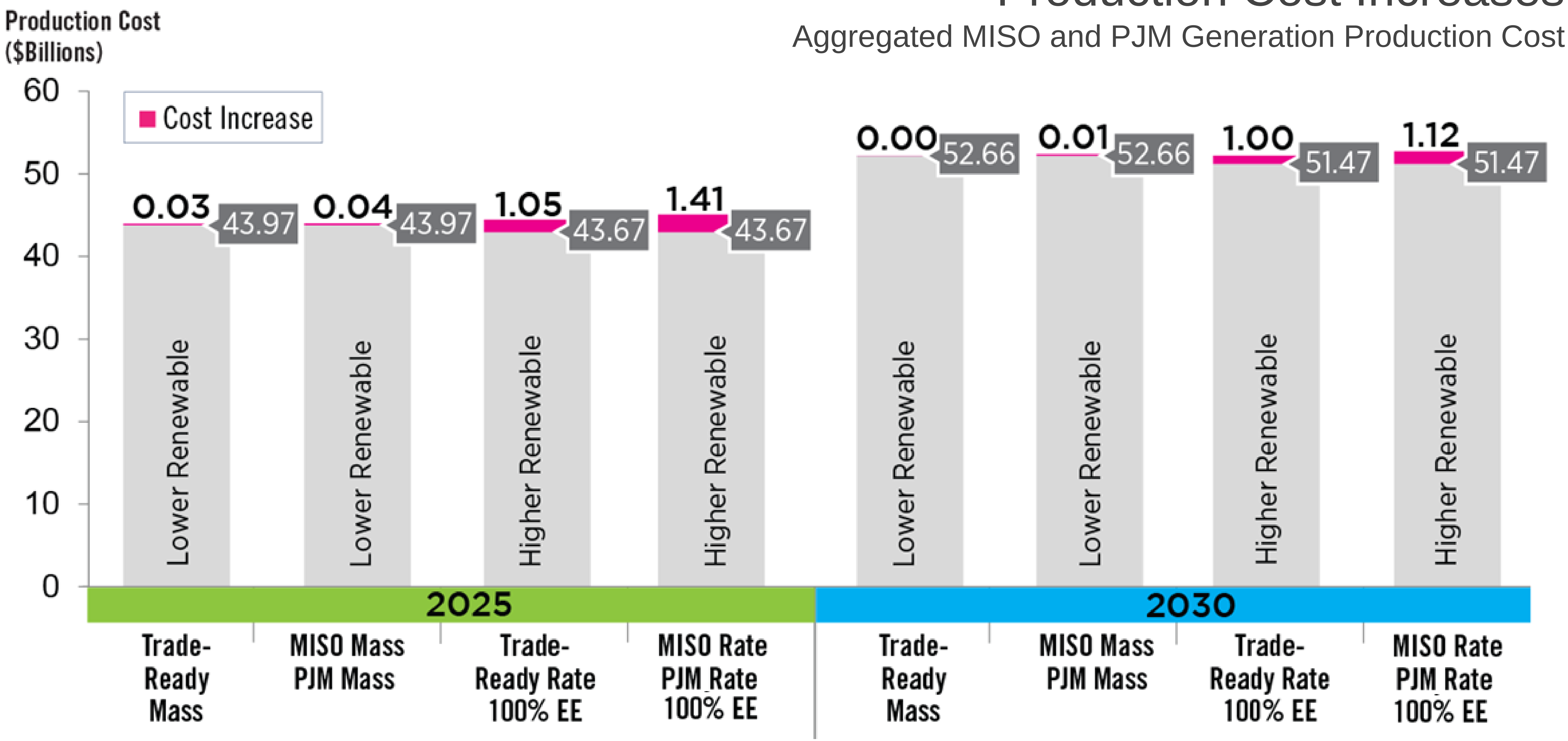
MISO and PJM Studied Impact of Broader Trading Region on the PJM and MISO Market

Base Case	Description
Lower Renewable	• PJM's resource expansion developed under trade-ready mass-based compliance • MISO's resource expansion developed in MTEP17 Policy Regulation future • EIA 2016 Annual Energy Outlook reference gas price forecast
Higher Renewable	• PJM's resource expansion developed under trade-ready rate-based compliance • MISO's resource expansion developed in MTEP17 Policy Regulation future • EIA 2016 Annual Energy Outlook reference gas price forecast

Scenario	Base Case	PJM <-> MISO Trading	MISO Trading Instrument	PJM Trading Instrument
MISO Mass, PJM Mass	Lower Renewable	No	Allowance	Allowance
MISO Rate, PJM Rate	Higher Renewable	No	Emission Rate Credit	Emission Rate Credit
Trade-Ready Rate	Higher Renewable	Yes	Emission Rate Credit	Emission Rate Credit
Trade-Ready Mass	Lower Renewable	Yes	Allowance	Allowance

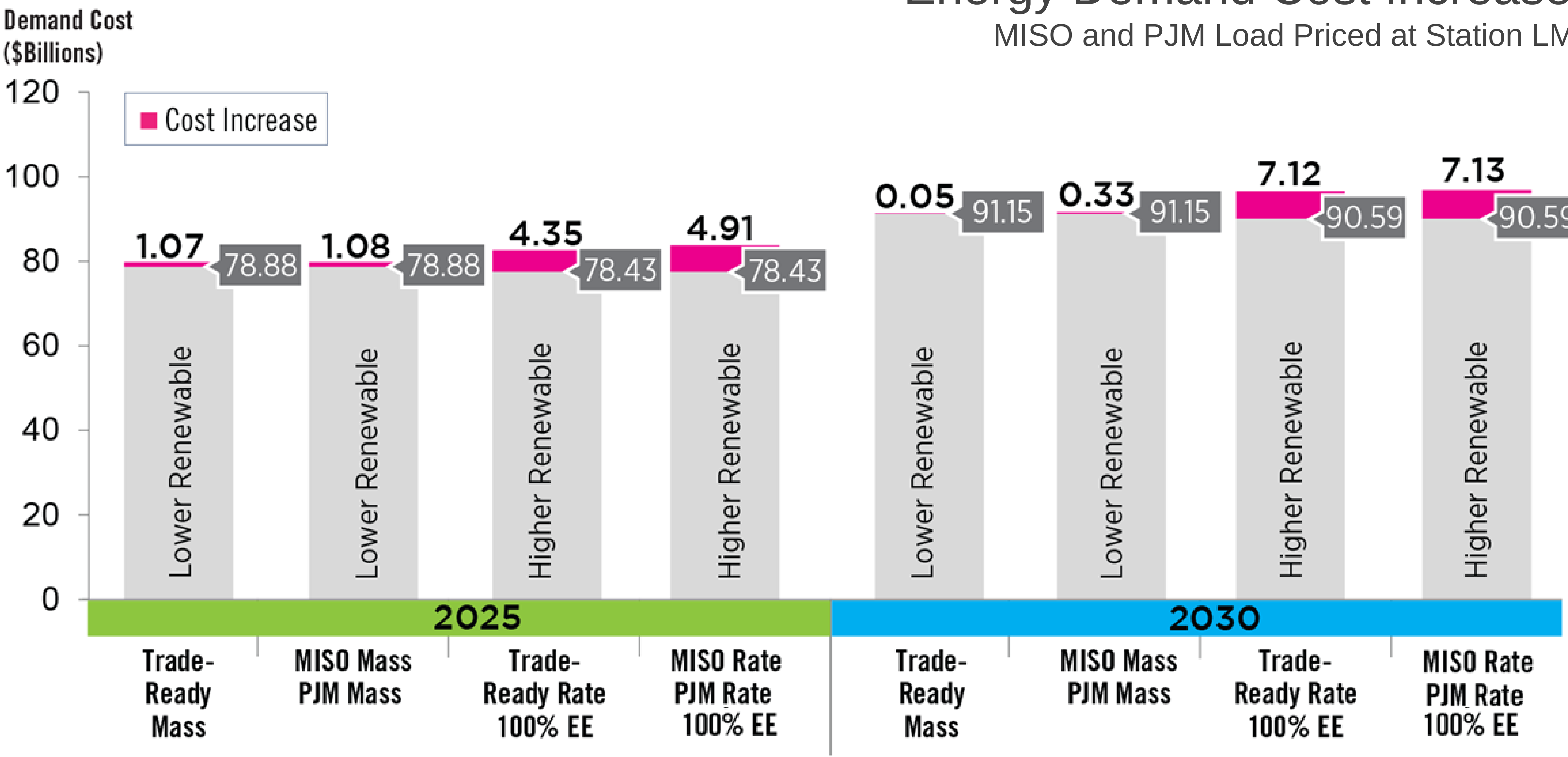
Broader Trading Region Reduces Policy Driven Production Cost Increases

Aggregated MISO and PJM Generation Production Cost

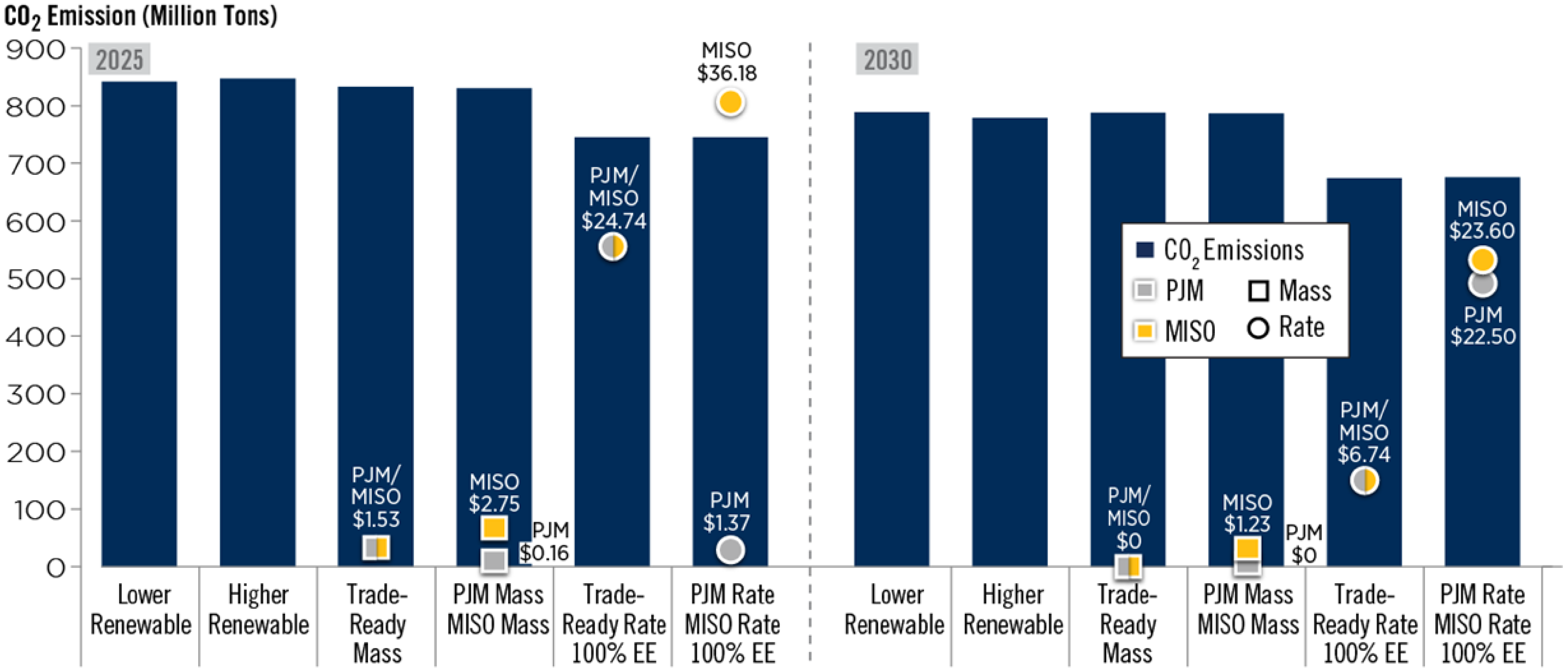


Broader Trading Region Reduces Policy Driven Energy Demand Cost Increases

MISO and PJM Load Priced at Station LMP



Broader Trading Areas Result in Lower CO_2 Prices



Section VI: Energy Efficiency Sensitivities

Performed using EIA's 2016 Annual Energy Outlook Reference Henry Hub forecast

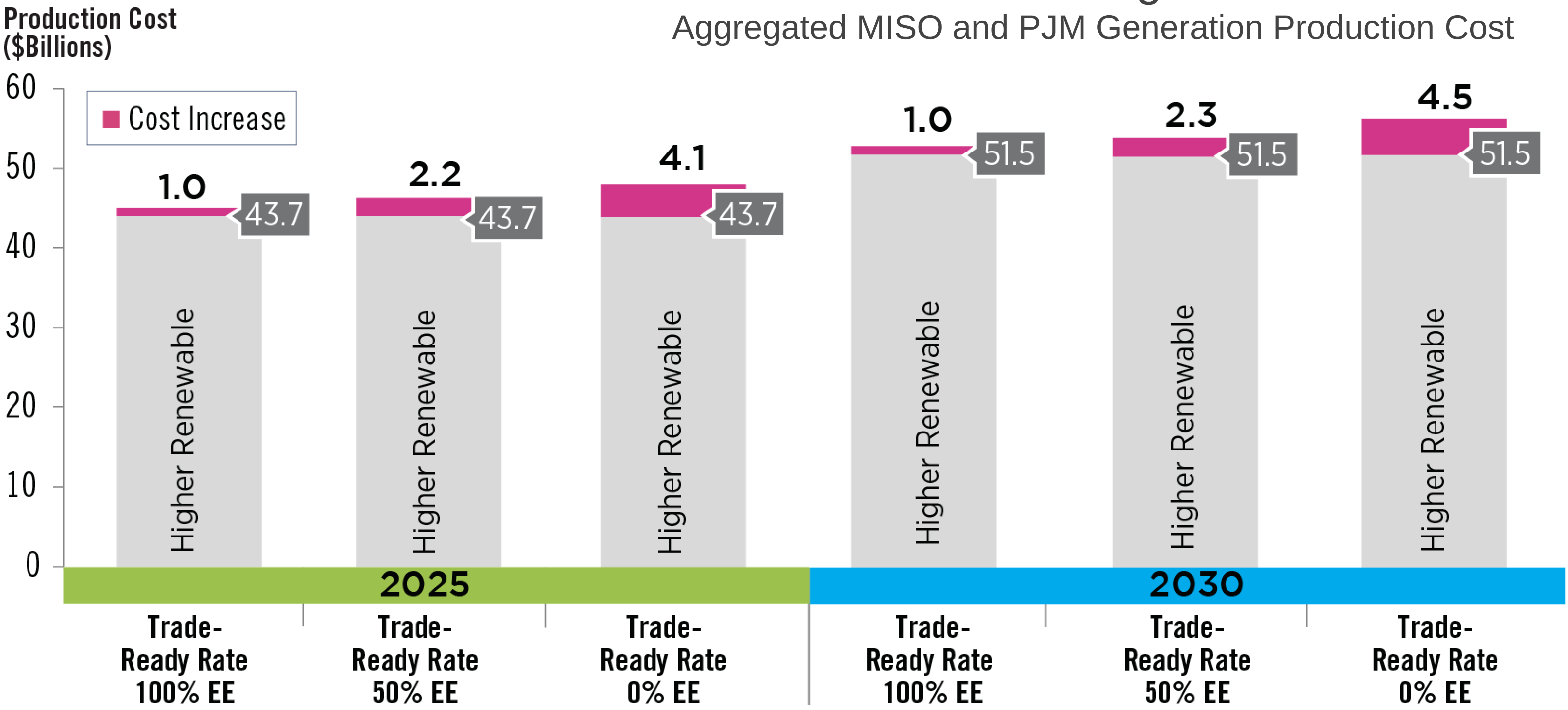
MISO and PJM Studied the Impact of State Energy Efficiency Measurement and Verification on Rate-Based Trading Cost

		Description
Base Case	Higher Renewable	• PJM's resource expansion developed under trade-ready rate-based compliance • MISO's resource expansion developed in MTEP17 Policy Regulation future
Sensitivity	Natural Gas Price	EIA 2016 Annual Energy Outlook reference gas price forecast
	Energy Efficiency	Amount of energy efficiency that is successfully measured and verified for crediting within a rate-based trading program adjusted from 0% to 50% to 100%

Scenario	PJM <-> MISO Trading	MISO Trading Instrument	PJM Trading Instrument
Trade-Ready Rate	Yes	Emission Rate Credit	Emission Rate Credit

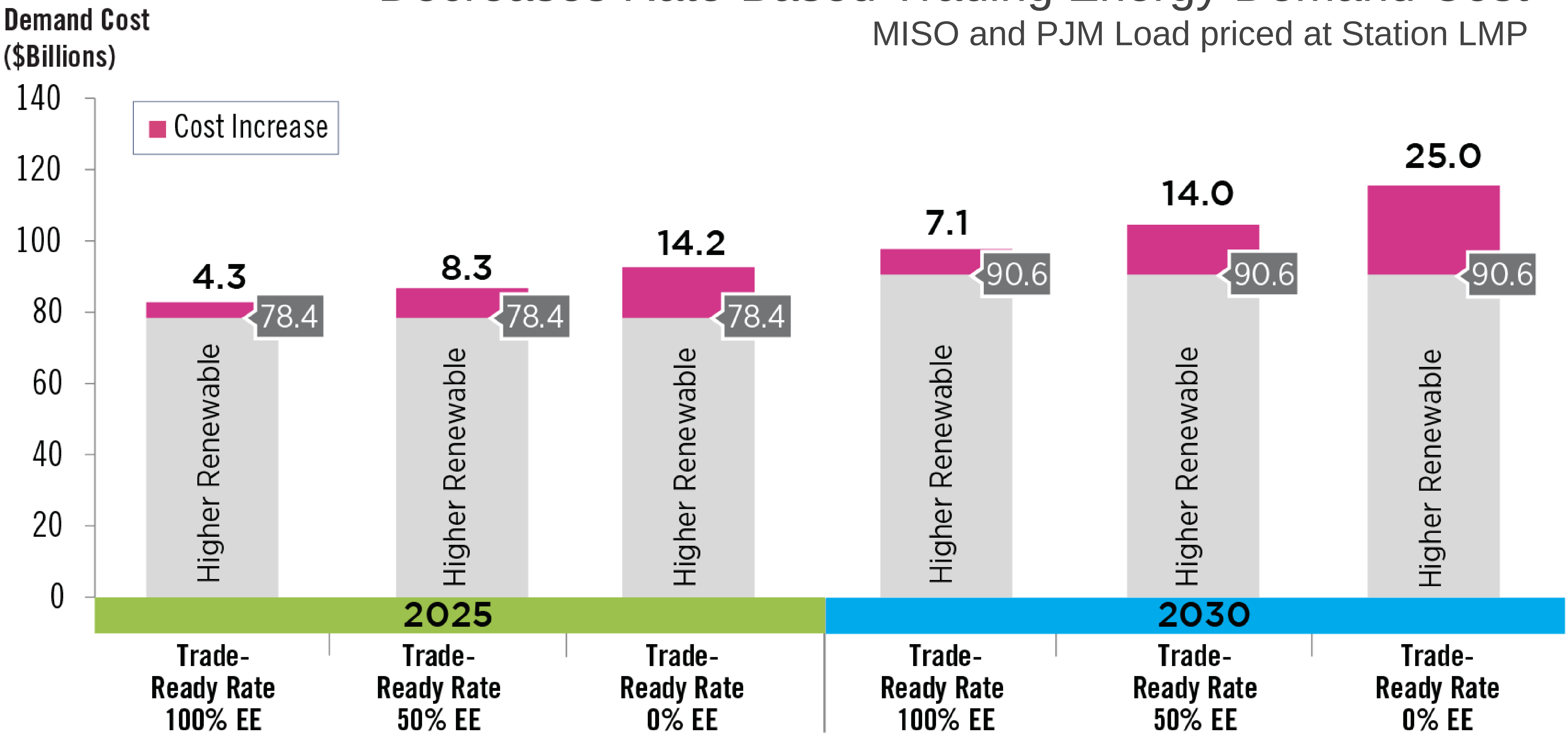
Wider Availability of Energy Efficiency Credits Decreases Rate-Based Trading Production Cost

Aggregated MISO and PJM Generation Production Cost

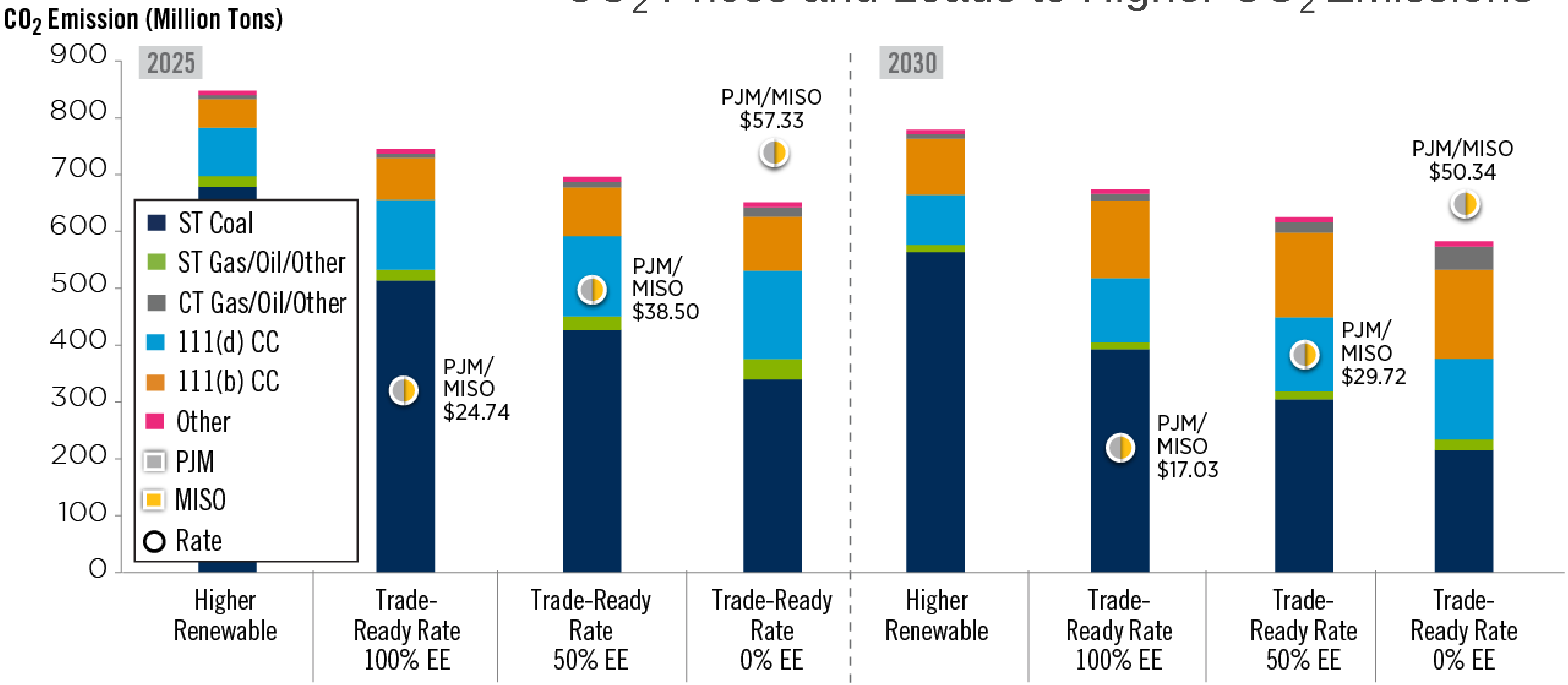


Wider Availability of Energy Efficiency Credits Decreases Rate-Based Trading Energy Demand Cost

MISO and PJM Load priced at Station LMP



Wider Availability of Energy Efficiency Credits Decreases CO_2 Prices and Leads to Higher CO_2 Emissions



Key Observations from Analysis

External economic drivers may overshadow state policy choices

Natural gas prices heavily influence the cost and impact of state policy objectives by influencing resource economics (zero-emitting project viability)

Standardization of state policy decisions may reduce associated program costs

The use of standardized energy efficiency measurement and verification among states leads to lower cost outcomes

Disconnected or siloed state policies can drive significant economic distortions along the seam and exacerbate transmission cost impacts

The ability to transact fungible products amongst states results in greater market efficiency

MISO and PJM welcome suggestions from states on additional sensitivities for study using the joint model

Potential 2017 Sensitivities
Hurdle rate levels Assume different transaction costs for economic sales and purchases between the MISO and PJM region
Gas combustion turbine utilization Impose a limit on the capacity factor of natural gas combustion turbine generators

Contact Information

For questions and comments, please contact the team listed below.

MISO:

- Jesse Phillips: jphillips@misoenergy.org
- Maire Waight: mwaight@misoenergy.org

PJM:

- Muhsin Abdurrahman: Muhsin.Abdurrahman@pjm.com

Appendix: Model Inputs and Assumptions

More information on individual studies:
PJM's CPP analysis report: CPP Compliance Assessment (PDF)
MISO's CPP analysis report: CPP Study Report (PDF)

Key Inputs for Analysis

Input	Primary Source for Data
Load Forecast	• 2016 PJM Load Forecast (0.7% Peak and 0.8% Energy Growth) • 2017 MTEP Load Forecast (0.7% Peak and Energy Growth)
DG/DR/EE (2030)	• PJM: DG - 2.2 GW, DR – 3.6 GW, EE- 15.7 GW • MISO: DG - 0 GW*, DR – 4 GW, EE- 2.8 GW *Included in solar PV economic additions in Slide 9
Transmission Model	Jointly developed power flow case

Forecast Fuel Prices	• Gas – Blend of the following:
	    • EIA 2016 Annual Energy Outlook
	    • IHS CERA September 2016 Natural Gas Briefing
	• Other - ABB NERC Spring 2016 database

[1] http://www.pjm.com/~/media/documents/reports/2016-load-report.ashx
[2] PJM and MISO to independently validate resource operating characteristics within respective ISO/RTO regions using publicly available data.
[3] NREL updated hourly shapes wind shapes based on the PJM Renewable Integration Study completed in 2013

Key Inputs for Analysis

Input	Primary Source for Data
Unit-Level Operating Characteristics	• ABB Simulation Ready database
Generation Model	• MISO MTEP17 Policy Regulations Model • PJM Trade-Ready Rate and Trade-Ready Mass Scenarios
Solar and Wind 8760 Shapes	• National Renewable Energy Laboratory
Transmission Constraints	• 2016 PJM Market Efficiency Basecase • MISO MTEP17 Policy Regulations Model • Additional flow-gates Identified during model development
PJM Reactive Interface Constraints	PJM Market Efficiency Assumptions
Economic Hurdle Rates	• MISO-PJM: $8/MWh • PJM-MISO: $1/MWh

[1] http://www.pjm.com/~/media/documents/reports/2016-load-report.ashx
[2] PJM and MISO to independently validate resource operating characteristics within respective ISO/RTO regions using publicly available data.
[3] NREL updated hourly shapes wind shapes based on the PJM Renewable Integration Study completed in 2013