Energy Storage Market Design Roadmap

WHOLESALE MARKET REFORMS TO UNLOCK THE POTENTIAL OF ENERGY STORAGE IN PJM, MISO, AND NYISO

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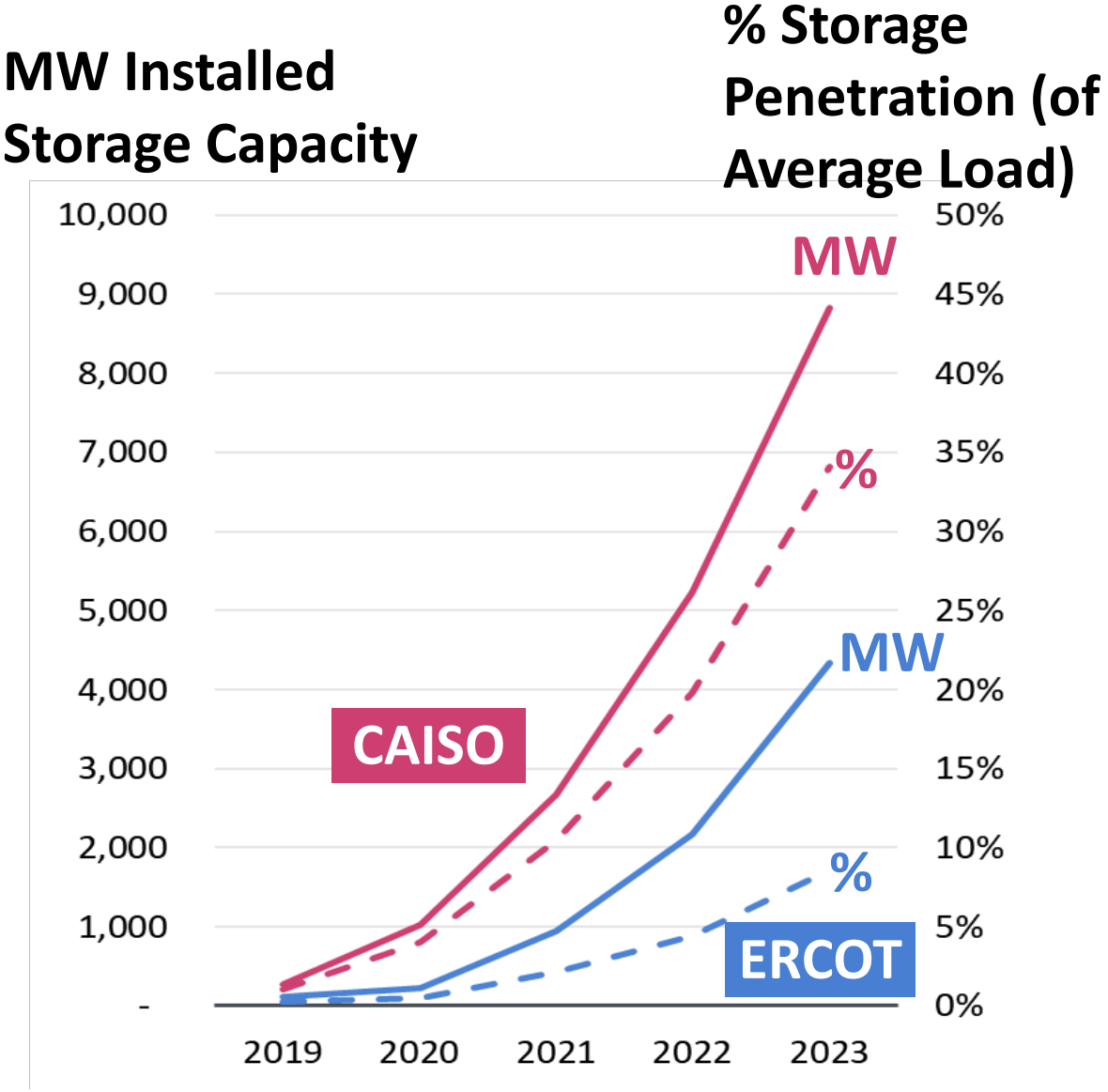
AMERICAN CLEAN POWER

Markets Shape Storage Deployment

Historical Battery Deployment in ERCOT & CAISO

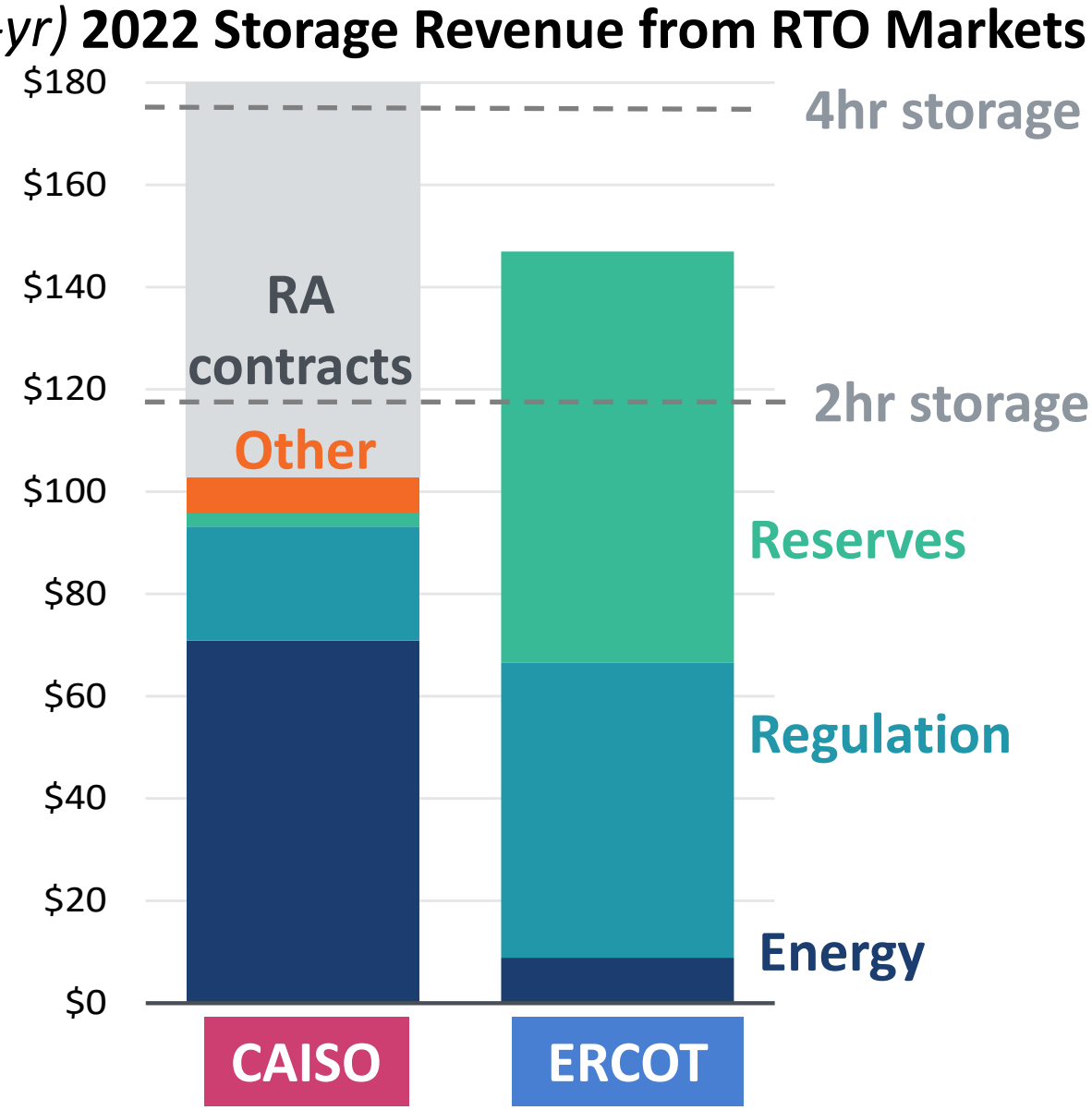
Battery deployment in **ERCOT** and **CAISO** is due to high amounts of variable generation, along with enhanced market designs



Sources and Notes: Figure reformatted from results in CAISO 2022 Special Report on Battery Storage Resources and from Modo Energy.

Markets Distinctly Enable Storage Revenues

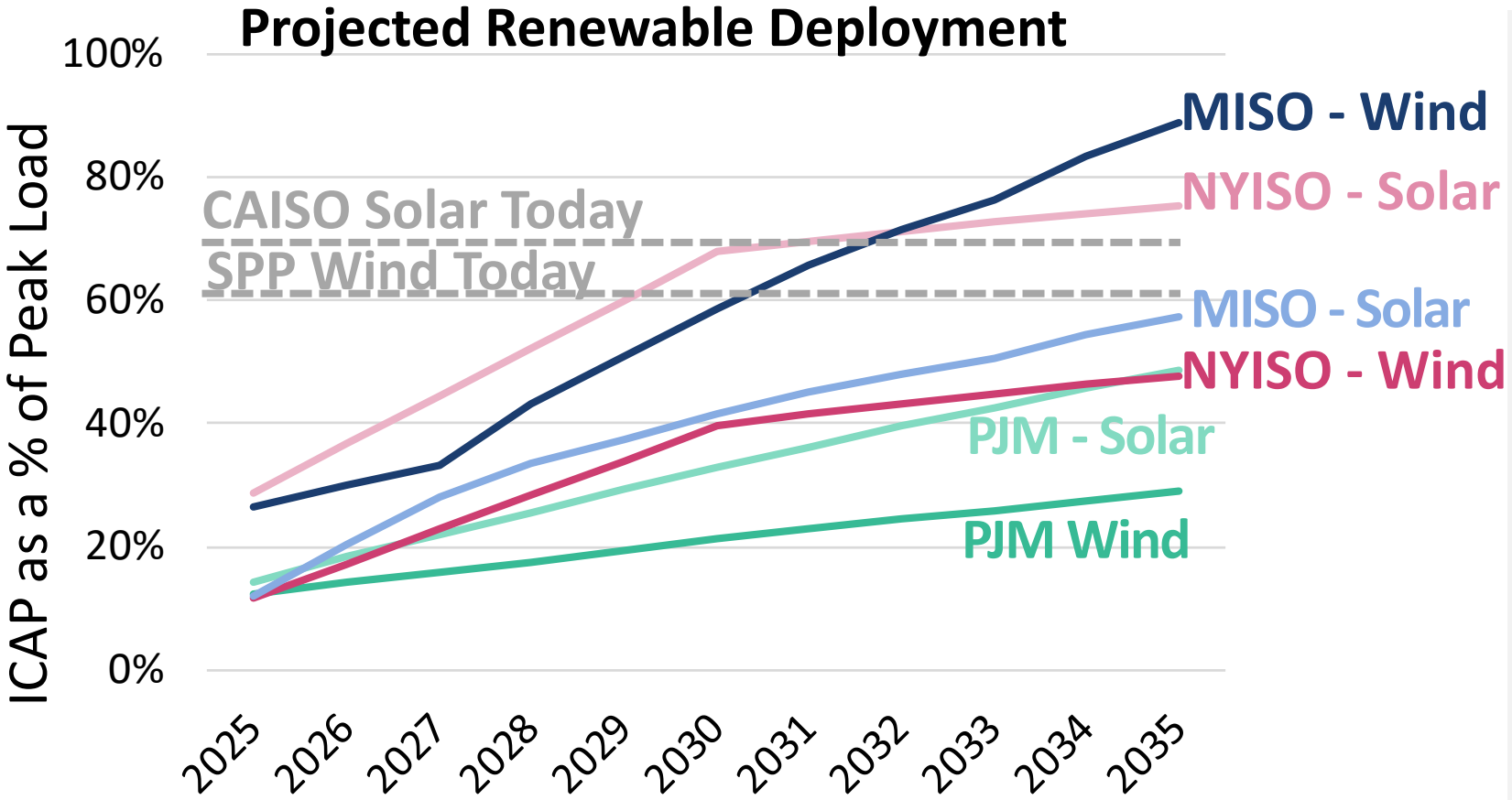
Unlocking Storage Value Across Energy, Ancillary Service, and Capacity Markets



Sources and Notes: Figure reformatted from results in CAISO 2022 Special Report on Battery Storage Resources and from Modo Energy. In 2022, batteries in CAISO received nearly $30.5 million of bid cost recovery (BCR) mostly from RT market (~10% of all BCR settled despite being 5% of ICAP). Energy category includes revenues from Imbalance schedules. CA RA contract revenue ranging from $60 - $96 /kW-year is from Figure 16 ("RA only") CPUC 2023 Energy Storage Procurement Study.

Limits of Conventional Market Design

Growing Reliance on Variable Resources Across the Country Will Increase Flexibility Needs Beyond the Limits of Current Market Design



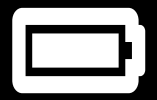
Sources: MISO, MISO Futures Report: Series 2A, Nov. 1, 2023; NYISO, 2023-2042 System & Resource Outlook, Appendix H, Jul. 23, 2024; PJM, LTRTP Workshop Policy Study, Oct. 1, 2024; : SPP, 2024 Wind Solar and ESR Study Report, Aug. 2024; CAISO, 2023 Annual Report on Market Issues & Performance, Jul. 2024; CAISO, Installed renewable resources as of 11/7/2024; CAISO, Solar Eclipse Technical Bulletin, pp. 5, April 2024

The Challenge:

- Load growth + retirements raise resource adequacy needs
- Increased reliance on variable resources (with fewer dispatchable fossil units) create flexibility needs

Storage can meet these challenges, but storage value is constrained by market designs that do not currently address all system needs, nor fully accommodate the special capabilities (and limitations) of storage resources

Key Market Design Elements to Leverage Storage Capabilities

	Conventional Grid	Emerging Clean Grid Enabled by Storage
Dominant Capabilities 	• Slow ramping conventional generators • High startup cost/time • Difficult installation in limited sites	• Fast ramping inverter-based resources • Always available • Storage installs quickly and in many places
Market Interaction 	Economics dominated by fuel costs/fuel availability of traditional resources	Volatile high and low prices, storage economics dominated by limited energy and opportunity costs of electricity
Grid Needs 	• Modest uncertainty and ramp • Simpler peak-load capacity needs • Legacy units integrated into transmission planning	• Increase in renewables increases the value of flexibility and RA needs change • Retirement of legacy generators creates new Tx challenges and opportunities

Missing Market Functions

New flexibility products

Energy market bidding rules allowing opportunity cost and faster bid updates

Capacity market based on hourly reliability

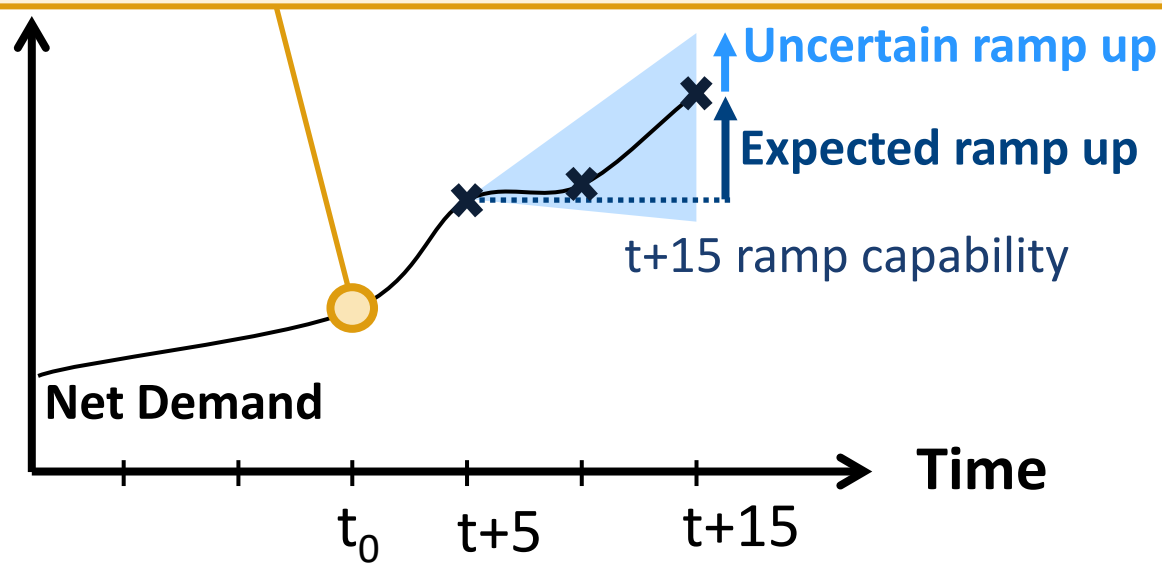
Better retirement planning

1 Ancillary Service Market Reform: Intrahour Ramp/Uncertainty Product with Operating Reserve Demand Curves

Impact Potential

- Transparent price to meet growing reliability need for flexibility
- Reduce uneconomic thermal cycling
- Reduce unnecessary renewable curtailment

Concept: Dispatch at t_0 meets net demand at t+5 and procures flexibility to ensure system can ramp to net demand at t+15

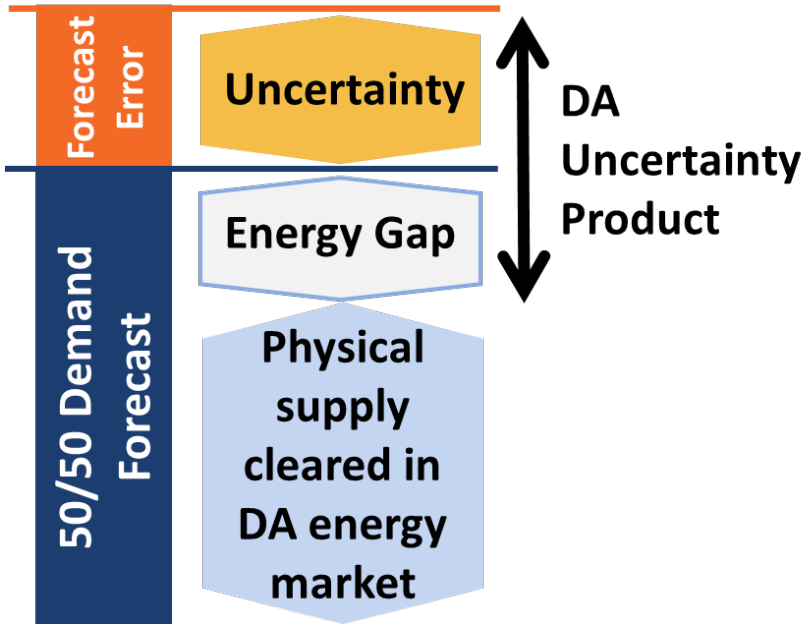


	SPP	CAISO	NYISO	MISO	PJM
Implemented?	✓	✓	**Proposed** (Uncertainty only)	✓	**Stakeholder process**

Kathleen Spees and Samuel Newell, Testimony prepared for NYSERDA, Docket No. AD21-10-000, Efficiently Managing Net Load Variability in High-Renewable Systems: Designing Ramping Products to Attract and Leverage Flexible Resources, February 2022; AEMO, Operating Reserve Design, November 2022; SPP, Ramp Product Whitepaper, March 18, 2019; SPP, Ramp Product Summary, May 21, 2019 MISO, "Ramp Capability Product Design for MISO Markets", December 22, 2013

2 Ancillary Service Market Reform: Day-Ahead Uncertainty Product with Operating Reserve Demand Curve

Value of flexibility increasing rapidly, but markets lack a product that captures this system need



Impact Potential

- Replaces out-of-market actions with transparent price signals for availability of dispatchable resources
- Can improve efficiency and reliability via more systematic procurement of availability beyond day-ahead energy commitments

	ISO-NE	CAISO	NYISO	MISO	PJM
Implemented DA Uncertainty Product?	✓ (DA Energy Gap only)	pending	✓ (DA Uncertainty only)	✗	Stakeholder Process

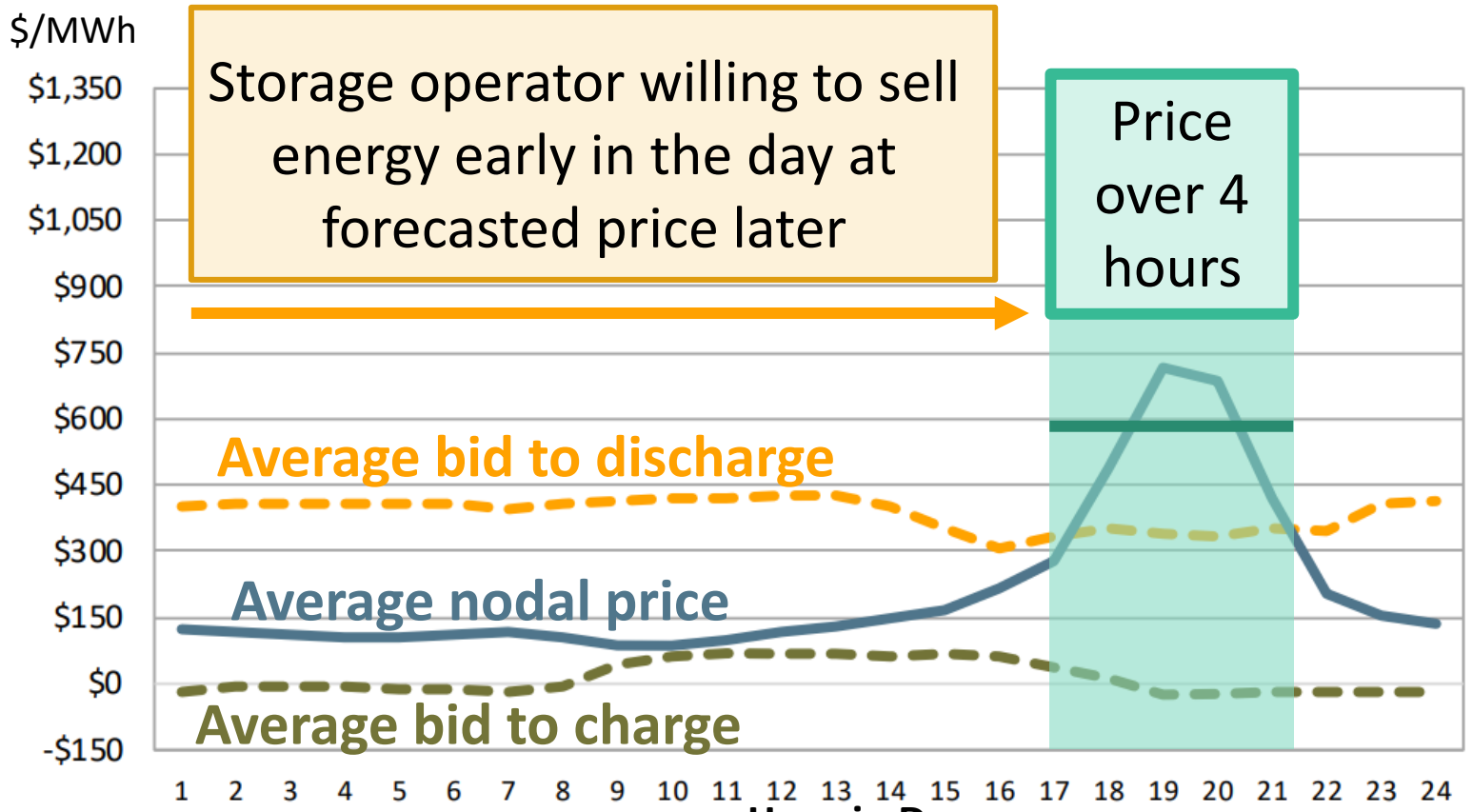
CAISO, Day-Ahead Market Enhancements, May 2023; IMM of ISO New England, Comments in Support of the Day-Ahead Ancillary Services Initiative, November 2023; SPP, Uncertainty Product Prototype Design Whitepaper, 2020; FERC Acceptance for ISO-NE Docket No. ER24-275-000, March 2025

3 Energy Market Reform: Enable Competitive, Efficient Energy Offers

Opportunity cost bidding is optimal, but not allowed everywhere

Impact Potential

- **Increased Reliability** – storage incented to be available during peak demand or scarcity
- **Enhanced Market Efficiency** – true offer costs reflected
- **Greater Flexibility** – storage can more effectively provide energy, reserves, frequency regulation
- **Revenue Clarity** for storage operators, encourages efficient investment



	CAISO	NYISO	MISO	PJM
Can storage bid their opportunity cost?	✓	✓	✓	✗

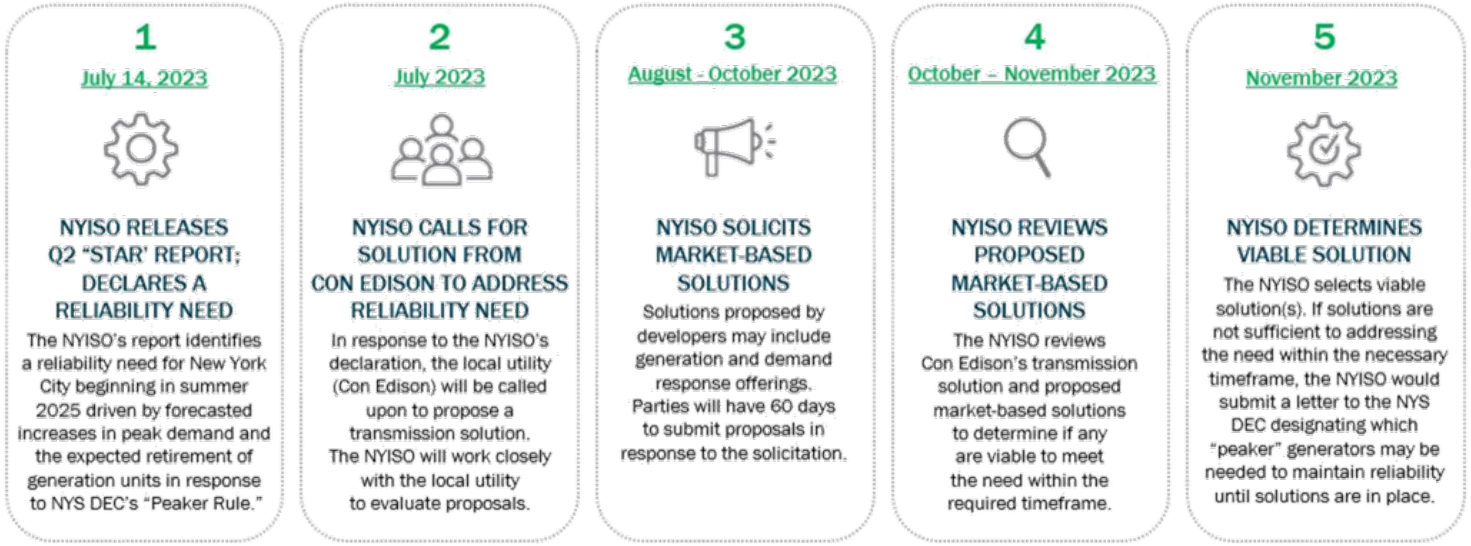
Figure: Average CAISO Day-Ahead Battery Bids and Nodal Prices August 31- Sept.9, 2022. Source: CAISO, Special Report on Battery Storage, July 7, 2023; NYISO Market Issues Working Group, Opportunity Costs for Energy Storage Resources, June 11, 2019

4 Alternative Reliability Solutions after Retirement: Meeting Needs the Market has Failed to Address

Impact Potential

Post-retirement reliability needs can be addressed with transmission, supply resources, or other non-wires solutions; selecting the most cost-effective solution from a broad array of options lowers bills and facilitates quicker adaption to transition

NYISO REVIEWS SUPPLY AND TRANSMISSION OPTIONS FOR MEETING RELIABILITY NEEDS



Source: NYISO, Reliability Planning Process and Declaring a Reliability Need: Next Steps, July 14, 2023.

	CAISO	NYISO	MISO	PJM
Appropriate Process to Procure Alternative Reliability Solutions After Retirement?	✓	✓	✗	✗

5 Capacity Market Reform: Accurate Storage Dispatch in Reliability Modeling

Scope: assess two previously identified topics that underestimate storage capacity value
without otherwise addressing core risk modeling

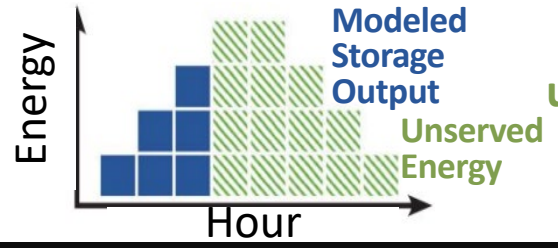
Topic 1: Change Simulated Storage Dispatch

- Marginal ELCC/MRI methods evaluate the impact of incremental additions of a resource with 3 simulation scenarios (baseline, with test resource, and with benchmark resource)
- Unlike PJM and NYISO, MISO uses a less accurate one-step heuristic method that does not evaluate incremental additions; it instead looks only at the base scenario, leading to underestimation of storage capacity value

Topic 2: Change Dispatch Order in Reliability Models

- Reliability models simulate stressed system conditions in which storage is exhausted after discharging for many hours
- If storage is dispatched before emergency procedures in the simulation (counter to actual operations in some cases), it experiences more resource exhaustion before risk hours, reducing the reliability value that storage otherwise could provide
- Furthermore, the dispatch order of similar energy-limited resources, (e.g. Demand Response) has substantial impact on capacity value

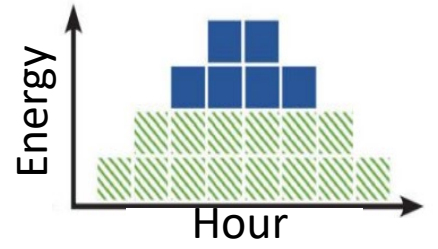
"EARLY METHOD" (Not Recommended)



No output in **unserved energy** hours means 0 UCAP

2025-26 ELCC Result: ***36%***

"EVEN LOSS"



Output in **unserved energy** hours counts towards UCAP

2025-26 ELCC Result: ***62%***

"BLENDED"

Small loss of load added to hours before full loss of load

2025-26 ELCC Result: ***50%***

Source: MISO RASC, LOLE Modeling Enhancements Storage Modeling, Nov 2024; Invenergy and Nextera Energy with Astrape Consulting, DLOL Enhancements Proposal, Aug 2023

Market Design for Energy Storage: Summary of Key Reforms

Proposed Market Reform	How Reform Improves Reliability
Ramp and uncertainty product: managing fast, short-term changes in net load	Manages fast, short-term fluctuations in net demand. By smoothing fluctuations, storage avoids unnecessary renewable curtailment and supports base generation by preventing inefficient ramping
Day-Ahead Uncertainty Product: ensuring resources are positioned for expected hourly changes in load	Ensures sufficient resources are available on the next day to meet net demand forecasts, including a margin for uncertainty. Storage meets these needs at low cost, and reduces the burden on traditional steam generators that incur substantial start-up costs. Procures greater flexibility to the grid to accommodate low-cost renewable generation
Opportunity Cost Bidding: ensuring storage can provide optimal reliability and efficiency benefits through pricing and real-time market participation	Enables storage to strategically charge when electricity is cheapest and discharge during highest-value periods of peak demand, maximizing reliability benefits and market efficiency. Improves price signals, reduces inefficient cycling of traditional generation, promotes stable pricing, overall lowers system costs
Contracting for local reliability needs after retirements: an alternative to costly Resource-Must-Run contracts and transmission upgrades	Competitive alternative to costly Reliability-Must-Run contracts (which keep uneconomic plants online) and transmission upgrades (which may take years). Can lower costs for ratepayers and enhance system reliability.
Accurate capacity accreditation: for energy storage and all resources ensures capacity ratings match real capability	Accurately valuing storage peak capacity contributions ensures the grid can quickly deploy all resources to meet growing reliability challenges of load growth, maintain most cost-effective mix of resources, reduce the risk of outages, enhance system resilience

Further Resources: Fact Sheets and Full Analysis

SCAN ME

Download **Full Analysis**

The American Clean Power Association and consultants from the Brattle Group have developed a roadmap to guide regional grid operators toward maximizing energy storage integration to provide more affordable, reliable, and cleaner electricity grids for American families and businesses.

Download ACP's Market Reform Roadmap and the full analysis from Brattle at the buttons above.

Additionally, find ISO-specific roadmaps based on the findings of the analysis:

- Download PJM Reform Roadmap
- Download MISO Reform Roadmap
- Download NYISO Reform Roadmap

[Energy Storage Market Reform Roadmap | ACP]

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