Energy Storage Market Design Reforms:

A Roadmap to Unlock the Potential of Energy Storage

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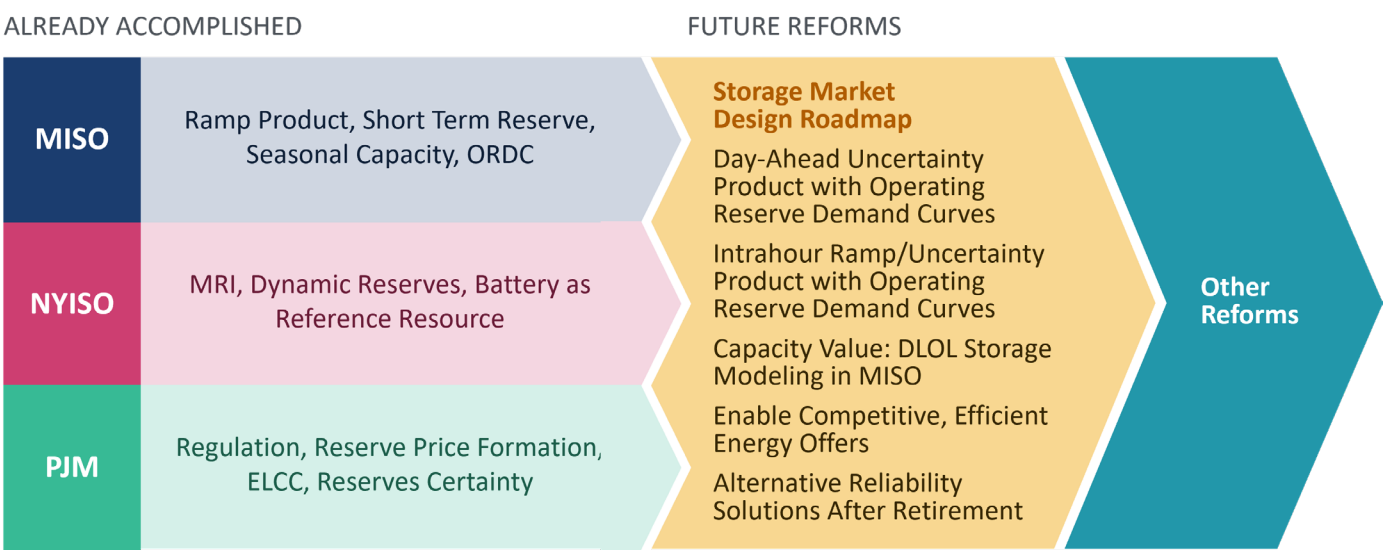
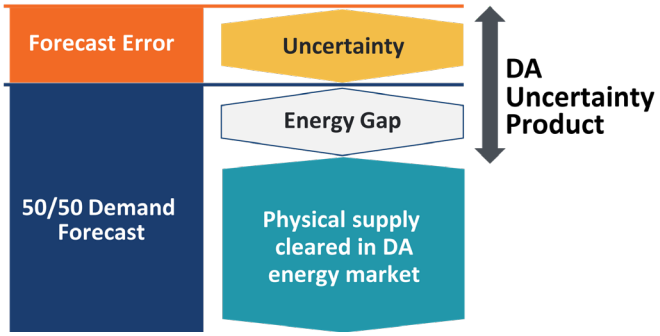


This research was prepared for The American Clean Power Association and member organizations. We identified 5 priority reforms in the following target markets: **MISO**, **NYISO**, and **PJM**. Among an array of reforms considered, these unlock the largest value at scale while exhibiting a feasible policy and implementation path forward.

Prioritized reforms address the limits of conventional market design in the face of growing reliance on variable resources, retiring fossil units, and load growth which all increase the need for market solutions to cost-effectively provide flexibility and reliability attributes to the electricity system.

1 Day-Ahead Uncertainty Product with Operating Reserve Demand Curve

A new reserve to cover forecasted demand that exceeds physical supply scheduled through the day-ahead energy market



PROBLEM STATEMENT

RTOs often commit inflexible generators out-of-market to cover forecasted day-ahead energy shortfalls (increasingly with a margin for uncertainty). Since prices do not fully reflect these costs (covered through uplift), the investment signal for availability and flexibility— especially during scarcity—is weakened. Efforts to limit out-of-market actions can risk under-availability, raising reliability concerns, particularly in extreme weather.

IMPACT POTENTIAL OF UNCERTAINTY PRODUCT

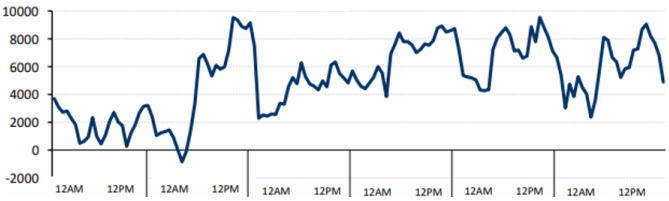
- Replaces out-of-market actions with transparent price signals for availability of dispatchable resources
- Potential to improve efficiency and reliability via more systematic procurement of availability beyond day-ahead energy commitments

IMPLEMENTATION PROGRESS

- PJM has started formal discussion of a DA uncertainty product; NYISO recently integrated DA uncertainty into its 30-minute reserve; MISO recognizes the need for a DA uncertainty product on its roadmap
- Key design features include an adequate quantity to capture uncertainty and the "energy gap," and an operating reserve demand curve that correctly reflects the system value

DAY-AHEAD ENERGY GAP SHORTFALL IN PJM

In the Day-Ahead Market, committed physical generation falls short of the load forecast



Note: examples from days in 2025; Source: PJM, RCSTF Work to Support Operations, March 12, 2025

PENDING DA UNCERTAINTY PRODUCTS

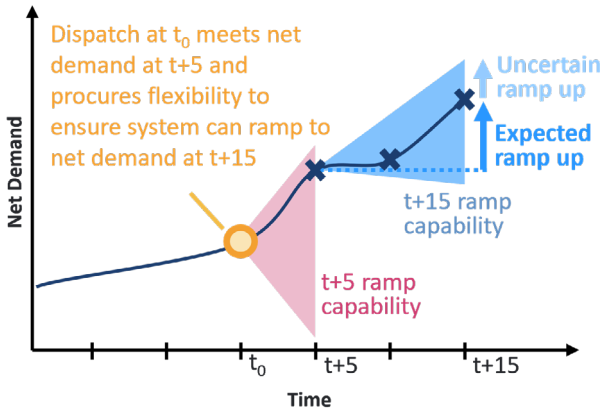
	CAISO	ISO New England
Name	Imbalance Reserve and Reliability Capacity	Energy Imbalance Reserve
Ramp-up Quantity	1,000-3,000 MW	TBD
Minimum Duration Req't	1 hour	1 hour
Day-Ahead Needs Procured	Uncertainty and energy gap	Energy gap only
Flexibility Requirement?	Yes, 30-min. ramp	Yes, 60-min. ramp
Highest Value	$55/MWh	$2,575/MWh

STUDIES

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

2 Intrahour Ramp/Uncertainty Product with Operating Reserve Demand Curves

New reserve product to provide real-time flexibility for net load ramps in the upcoming 10 – 60 minutes



PROBLEM STATEMENT

Systems can run short of intrahour flexibility to handle fluctuations and ramps, causing power balance issues and price spikes.

IMPACT POTENTIAL OF RAMP PRODUCT

Transparent price to meet growing reliability need for flexibility, reduce uneconomic thermal cycling, and ultimately reduce unnecessary renewable curtailment.

IMPLEMENTATION PROGRESS

- Nearly all RTOs have or are developing ramp/uncertainty products
- MISO was among the first to launch a ramp product; NYISO has filed with FERC an uncertainty product integrated with contingency reserves; PJM is considering solutions in the stakeholder process
- Most ramp designs address both expected and uncertain ramp needs; many feature both up and down ramp products

EXISTING INTRAHOUR RAMP/UNCERTAINTY PRODUCTS

	SPP	MISO	CAISO
Name	Ramp Capability Up and Down	Ramp Capability Product	Flexible Ramp Up and Down
Ramp Capability Timeframe	10-min ramp	10-min ramp	5-min ramp
Ramp-up Quantity	~500 MW	~800 MW	~1,000 MW
Maximum Value	$23/MWh	$31/MWh	$247/MWh
Ramp Capability Timeframe	10-min ramp	10-min ramp	5-min ramp
Typical Prices	~$1.50/ MWh	~$0.75/ MWh	~$0.15/ MWh
Procurement Timeframe	RT (and DA forward)	RT (and DA forward)	RT (5 and 15 min)

STUDIES

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

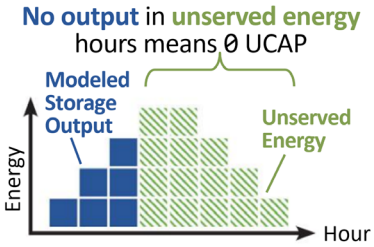
MISO, "Ramp Capability Product Design for MISO Markets", December 22, 2013

3 DLOL Storage Modeling Method in MISO that Aligns Capacity Value of Storage with Incremental Reliability Impact

MISO's capacity market is most effective when its accreditation method (called Direct Loss Of Load or DLOL) accurately reflects the marginal reliability value of resources—that is, when it reflects the increase in reliability (decrease in load shed) of an incremental addition of a resource type

DLOL STORAGE MODELING ALTERNATIVES

"EARLY" METHOD (NOT RECOMMENDED)

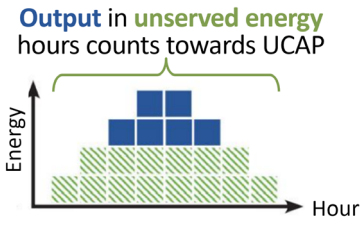


MISO's status quo "Early" DLOL method simulates storage discharge (blue in figure at left) at the start of events, leaving unserved energy (green hashes) for hours after storage is exhausted. The example shows no storage output during unserved energy hours. **Because DLOL evaluates the marginal value of storage based mainly on simulated output during modeled load shed hours, this would yield an inaccurate accreditation of zero in the example**—not reflecting the reduction in unserved energy when storage is added.

2025-26 ACCREDITATION RESULT:

36%

"EVEN LOSS"

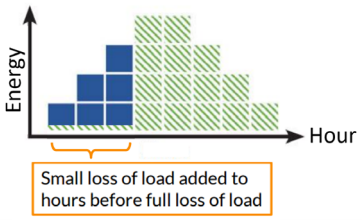


The "Even Loss" method simulates the dispatch of storage to minimize the depth of load shed. MISO states this is less realistic for load shed operations (although it is likely realistic for non-load-shed scarcity). Nonetheless, **this DLOL evaluation better reflects the fact that an incremental addition of storage would directly reduce unserved energy.**

2025-26 ACCREDITATION RESULT:

62%

"BLENDED"



MISO's intermediate "Blended" method is based on the Early method, with storage output slightly withheld in early hours (inducing some load shed), such that storage output in those hours counts in the final accreditation evaluation.

2025-26 ACCREDITATION RESULT:

50%

IMPACT POTENTIAL

Alternative methods more accurately recognize storage capability to meet reliability challenges under rapid load growth

IMPLEMENTATION PROGRESS

- As of Q1 2025, MISO is actively assessing all methods above
- Other ISO/RTOs use a direct multi-step reliability test for accrediting resources (e.g., ELCC or MRI), rather than DLOL's approximation of reliability impact

STUDIES

Invenergy and Nextera Energy with Astrapé Consulting, DLOL Enhancements Proposal, August, 2023

MISO RASC, LOLE Modeling Enhancements Storage Modeling, November 2024

4 Enable Competitive, Efficient Energy Offers

Storage participants are willing to sell only at prices above those forecasted for later in the day, because storage resources selling energy now give up their chance to sell energy or ancillary services later; rules limiting such "inter-hour opportunity costs" in offers restrict competition and can harm reliability

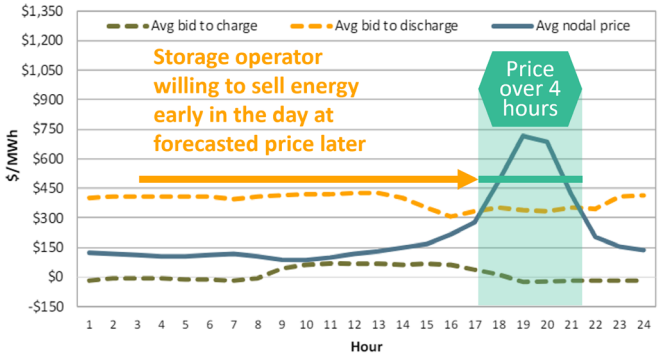
PROBLEM STATEMENT

Some markets disallow opportunity costs during key times by capping energy and reserve offers and unnecessarily limiting changes in energy offers intraday. This leads to suboptimal reliability outcomes as storage resources are discharged before they are most needed (or withhold dispatchable capability from the energy market to avoid that outcome) and ultimately leads to distorted prices that do not reflect underlying fundamentals.

IMPACT OF ENABLING COMPETITIVE OFFERS

- **Increased Reliability:** Accurate price signals ensure storage is available during peak demand or scarcity conditions (without depleting too soon), strengthening system reliability
- **Enhanced Market Efficiency:** Offers better reflect the competitive level, improving price formation and resource utilization by reflecting storage's true opportunity costs
- **Greater Flexibility:** Storage can more effectively provide energy, reserves, and frequency regulation by prioritizing the highest-value services
- **Revenue Clarity:** Storage operators gain better visibility into potential revenues, encouraging efficient investment in flexible resources

STORAGE OFFERS REFLECT VALUE OVER HOURS LATER IN DAY



Average CAISO Day-Ahead Battery Bids and Nodal Prices August 31- Sept.9, 2022. Source: CAISO, Special Report on Battery Storage, July 7, 2023

IMPLEMENTATION PROGRESS

	CAISO	NYISO	MISO	PJM
Enables inter-hour opportunity costs?	✓	✓	✓	✗

STUDIES

CAISO, Special Report on Battery Storage, July 7, 2023

NYISO Market Issues Working Group, Opportunity Costs for Energy Storage Resources, June 11, 2019

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

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 adaptation to transition

PROBLEM STATEMENT

- Many legacy generators were built to support local transmission needs, especially in load pockets; retirements of these generators will continue to trigger major transmission reliability violations, often too localized for capacity markets to solve
- Some RTOs only consider wires-based long-term solutions, even when supply options or other non-wires solutions are lower cost to customers (and more quickly deployed)
- Other RTOs do consider non-wires solutions, but they are rarely selected due to (1) lack of comprehensive cost-benefit analysis, and (2) short deactivation notice period

POTENTIAL IMPACT OF ALTERNATIVE RELIABILITY SOLUTIONS

- Potential to provide a more cost-effective resolution of reliability problems
- When storage is selected, it can be more quickly deployed, thus shortening the term of (or avoiding altogether) Reliability Must Run contracts

EXAMPLE OF NYISO PROCESS TO REVIEW SUPPLY AND TRANSMISSION OPTIONS FOR MEETING RELIABILITY NEEDS

1
July 14, 2023

NYISO RELEASES Q2 "STAR" REPORT; DECLARES A RELIABILITY NEED

The NYISO's report identifies a reliability need for New York City beginning in summer 2025 driven by forecasted increases in peak demand and the expected retirement of generation units in response to NYS DEC's "Peaker Rule."

2
July 2023

NYISO CALLS FOR SOLUTION FROM CON EDISON TO ADDRESS RELIABILITY NEED

In response to the NYISO's declaration, the local utility (Con Edison) will be called upon to propose a transmission solution. The NYISO will work closely with the local utility to evaluate proposals.

3
August - October 2023

NYISO SOLICITS MARKET-BASED SOLUTIONS

Solutions proposed by developers may include generation and demand response offerings. Parties will have 60 days to submit proposals in response to the solicitation.

4
October - November 2023

NYISO REVIEWS PROPOSED MARKET-BASED SOLUTIONS

The NYISO reviews Con Edison's transmission solution and proposed market-based solutions to determine if any are viable to meet the need within the required timeframe.

5
November 2023

NYISO DETERMINES VIABLE SOLUTION

The NYISO selects viable solution(s). If solutions are not sufficient to addressing the need within the necessary timeframe, the NYISO would submit a letter to the NYS DEC designating which "peaker" generators may be needed to maintain reliability until solutions are in place.

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

CASES

- In 2017, **CAISO** selected competitive storage solution following retirement of the 165 MW Oakland Station Natural Gas Plant
- **NYISO** recently solicited but did not select RMR Alternatives for the 565 MW Narrows and Gowanus Peaker Plant retirement

STUDIES

CAISO, Reply Brief for Application 20-04-013, December 4, 2020

NYISO, Short-Term Reliability Process Reports: 2025 Near-Term Reliability Need Solutions Selection, November 20, 2023