PJM's Perspective on Challenges and Potential Solutions for the RCSTF's Long-Term Scope

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Disclaimer

PJM has compiled the information provided here on practices in other ISO/RTOs from publicly available data and documents (i.e. business manuals, governing documents, FERC filing materials, etc.) and discussions with individuals within each organization as of Q4 2024. PJM cannot guarantee the perfect accuracy of this information.

Objectives

- Provide an overview of PJM's perspective on the challenges that need to be addressed by the RCSTF under the remaining scope of work
- Review PJM's initial thinking on a set of design and solutions areas for the RCSTF to undertake to address these challenges
- Solicit stakeholder feedback

Recent Education from Other ISOs

October

CAISO provided an overview of their Flexible Ramping and Imbalance Reserve products, including the uncertainty and variability drivers they face, implications for price formation and the move to locational procurement. (Presentation)

SPP provided an overview of their Operating Reserve products, including their Ramping Capability and Uncertainty Reserve products, and how they set their requirements. (Presentation)

Recent Education from Other ISOs

November
NYISO provided an overview of their Balancing Intermittency project, including how they are extending their existing 10- and 30-Minute reserve products to include their net-load forecast uncertainty. (Presentation)
ISO-NE provided an overview of their Day-Ahead Ancillary Services Initiative, including the development of a Day-Ahead Energy Imbalance Reserve product and how they will settle their day-ahead reserves as energy call-options. (Presentation)
MISO provided an overview of their recent Shortage Pricing efforts, including proposed changes to their Operating Reserve Demand Curve (ORDC) and Value of Lost Load (VOLL). (Presentation) *MISO also provided an overview of how they set their 30-minute reserve requirement to reflect their risk level and uncertainty to the RCSTF in February, 2024. (Presentation)*

PJM Guiding Principles

Price Formation Principles

• Reserve and energy prices reflect system conditions and appropriately value scarcity.	• Resources assigned reserves will provide them when deployed.
• ORDCs reflect the reliability value of reserves.	• Market power is mitigated.
• The actual reserve capability on the system is accurately measured.	• Social welfare is maximized.*

Additional Principles included in AD21-10

• Proper locational market signals that guide optimal investments.	• Rules that encourage robust participation and create efficient market results.
• Solutions that are nimble with evolution.	• Simplicity in market design where possible.
• Market rules that are non-discriminatory.	• Transparency.

NOTE: Maximizing social welfare is the objective function of the market clearing algorithms. The goal of this objective function is to optimally allocate resources for energy and reserves such that the final allocation simultaneously maximizes the benefit to consumers and the revenues to suppliers. This is done by maximizing the difference between the consumer's willingness to pay for a product and the bid production cost of cleared supply.

FERC Goals of Proper Price Formation

In FERC Docket No. AD14-14-000 the Commission stated that the goals of proper price formation are to:

1|	Maximize market surplus for consumers and suppliers.
2|	Provide correct incentives for market participants to follow commitment and dispatch instructions, make efficient investments in facilities and equipment and maintain reliability.
3|	Provide transparency so that market participants understand how prices reflect the actual marginal cost of serving load and the operational constraints of reliably operating the system.
4|	Ensure that all suppliers have an opportunity to recover their costs.

Energy Price Formation | Federal Energy Regulatory Commission (ferc.gov)

FERC has highlighted concerns when markets do not appropriately align with reliability and operational needs.

Use of uplift payments

"Use of uplift payments can undermine the market's ability to send actionable price signals."

Offer price mitigation and offer price caps

"These protocols require that the RTO/ISO's measure of marginal cost be accurate and allow a resource to fully reflect its marginal cost in its bid. To the extent existing rules on marginal cost bidding do not provide for this, bids and resulting energy and ancillary service prices may be artificially low."

Scarcity and shortage pricing

"To the extent that actions taken to avoid reserve deficiencies are not priced appropriately or not priced in a manner consistent with the prices set during a reserve deficiency, the price signals sent when the system is tight will not incent appropriate short- and long-term actions by resources and load."

Operator actions that affect prices

"To the extent RTOs/ISOs regularly commit excess resources [out-of-market], such actions may artificially suppress energy and ancillary service prices or otherwise interfere with price formation."

Energy Price Formation | Federal Energy Regulatory Commission (ferc.gov)

PJM's Reserve Needs Are Changing

PJM's existing reserve markets were designed primarily to manage risk associated with large unit loss.

PJM's existing reserve markets do not align with operational needs and reliability actions today, and this is discrepancy will grow moving forward.

Flexibility needs will be increasingly driven by forecast uncertainty, and reserve markets will need to be more dynamic and probabilistic.

Enhancements are needed to PJM's reserve markets to ensure reliability through the energy transition.

The Other ISOs Are Responding to These Developing Needs

	Uncertainty Reserves	Forecasted Ramping Reserves	Multi-Interval Dispatch*	Day-Ahead Specific Products	Reserve Offers > $0
PJM					✓
MISO	✓	✓			✓
CAISO	✓	✓	✓	✓	✓
ISO-NE				✓	✓
NYISO	✓	✓	✓		✓
SPP	✓	✓			✓
ERCOT	✓	✓			✓

ISOs currently using multi-interval dispatch do not settle all intervals in the look-ahead window.

Areas of Focus

1. PJM's market design must align with operational and reliability needs.
2. Accurately quantifying and valuing essential reliability services is critical.
3. Avoidable costs for providing reserve services should be recoverable through reserve markets.

Day-Ahead Reserves

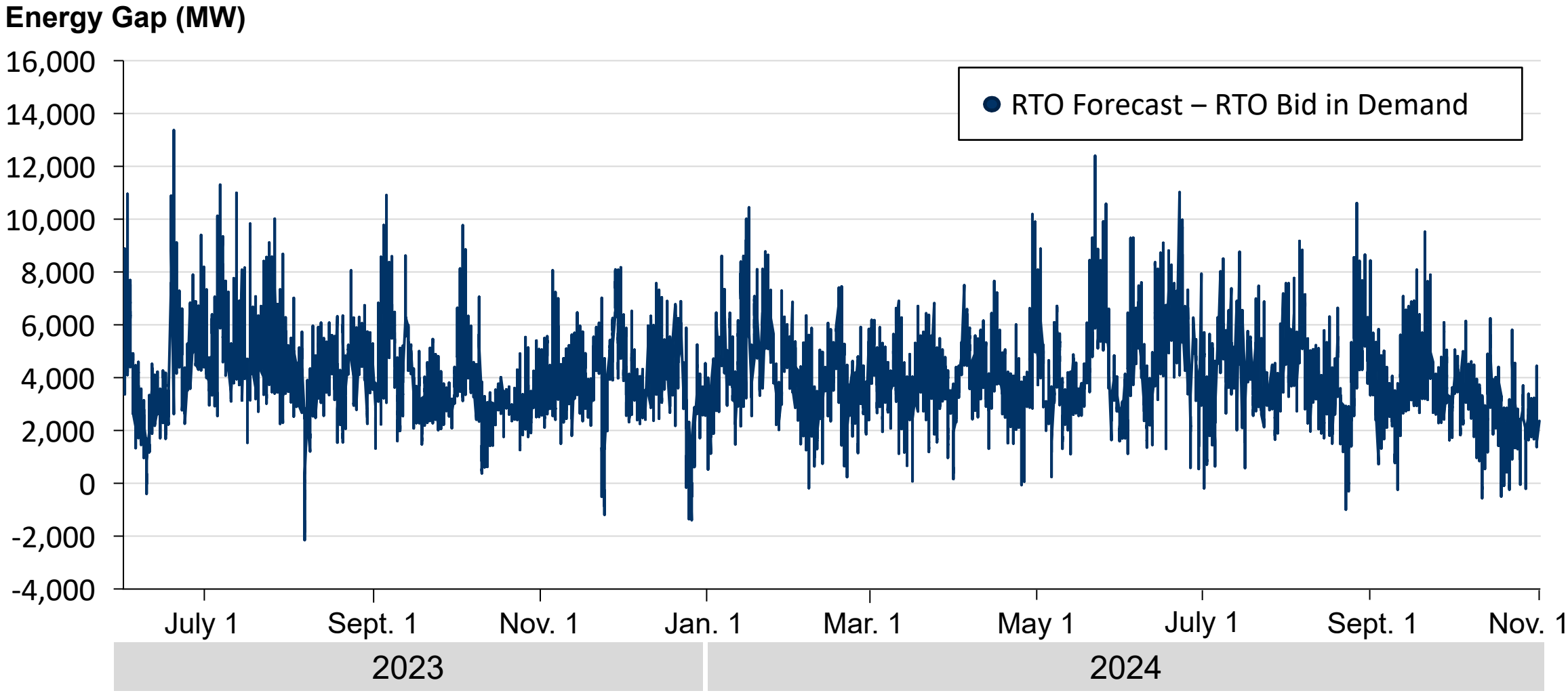
In PJM's existing market constructs, the Day-Ahead Energy Market does not procure sufficient reserves to manage operational risk.

- The Day-Ahead Energy Market clears enough supply to meet bid-in demand, which may be lower than the PJM load forecast for the next day.
- PJM's operations 30-Minute reserve requirement is routinely higher than the 30-Minute reserve requirement reflected in PJM's markets.
- Any shortfall in supply procured through the markets is handled through out-of-market commitments.

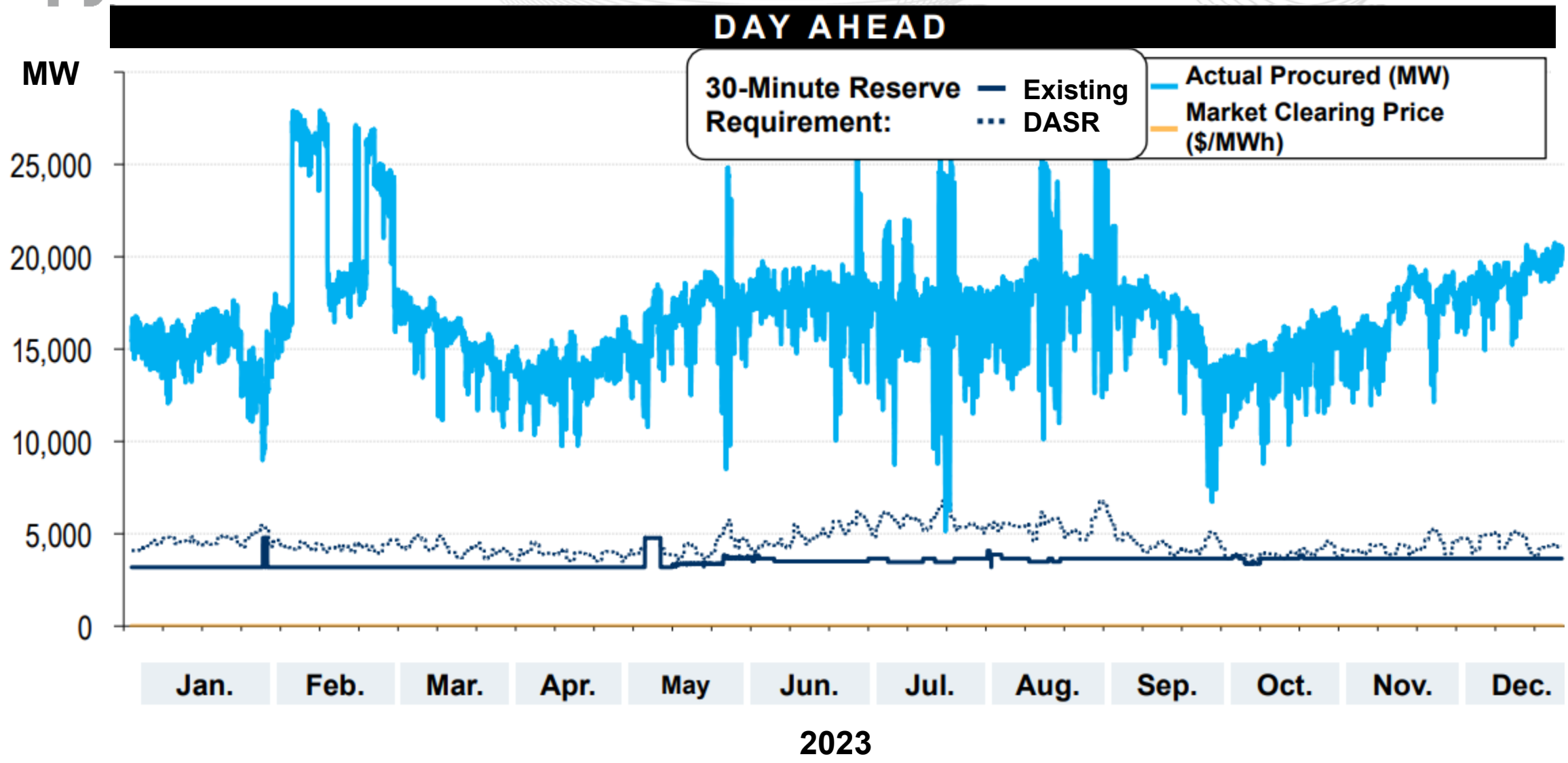
PJM currently uses the Reliability Adequacy Commitment tool to bridge the gaps between Day-Ahead Energy Market procurement, forecasted load and the Day-Ahead Scheduling Reserve (DASR).

Operator actions that affect prices

Day-Ahead Energy Gap



DASR vs. Existing 30-Min Reserve Market Requirement



Availability Costs for Providing Reserve Services

The cost of advanced fuel arrangements and other availability measures to provide reserves may be unrecoverable through PJM's existing market constructs.

- A failure to recognize these costs can lead to a misalignment in incentives between the profit maximizing behavior for resources and what is required for system reliability.
- This misalignment can compromise reliability and result in inefficient market outcomes.

"Balancing Authorities should consider… including a means of ensuring units are compensated for their commitment costs (including the costs of obtaining fuel) even if no dispatch occurs."

-- Winter Storm Elliott Report, issued by the Federal Energy Regulatory Commission (FERC) and the North American Energy Reliability Corporation (NERC)

Offer price mitigation and offer price caps

Resources providing reserves may lack avenues for cost recovery.

1. Current make-whole provisions in the Energy Market only make resources whole that are pool scheduled by PJM for energy.[1] If the resource is only providing reserves, it is not eligible.
2. Reserve market offer rules do not permit the inclusion of the cost of arranging fuel.[2] Indirectly this also means that reserve clearing prices do not reflect the cost of fuel arrangements that may be necessary to provide the service.
3. Generation Capacity Resources are required to offer reserves subject to their ability to provide the service.[3] Such resources are required to offer even if their cost to provide the service exceeds the allowable offer cap, currently $0.04/MWh (dropping to $0.00/MW in 2025) for Synchronized Reserves and $0/MWh for all other reserve services.

[1] OATT Attachment K, sections 3.2.3 (b) and (e)
[2] OATT Attachment K, section 1.2(j)(i)(3)
[3] OATT Attachment K, section 1.2(j)(i)(1)

Address the Day-Ahead Energy Gap Through the Market

- Operational actions that are consistently and predictably required to maintain system reliability Reflected in PJM markets to promote transparency and to attract and maintain critical reliability services.

- New reserve product(s), such as a Day-Ahead Energy Imbalance Reserve product, are needed to capture the shortfall of supply that is committed day ahead out-of-market.

- Evaluate reliability needs to determine appropriate procured quantities and performance obligations, as well as resource avoidable costs (e.g., fuel arrangement or charging costs) for providing day-ahead reserve services.

Day Ahead Reserve Product

- A day-ahead reserve product would provide a construct for PJM to carry reserves day-ahead without settling the service against a real-time requirement.
- ISO-NE's Day-Ahead Energy Imbalance Reserve product (as differentiated from CAISO's similar product) is co-optimized with energy in the day-ahead market clearing engine, which PJM views as beneficial.
- PJM will need to evaluate congestion and constraint control in the RTO, which may draw into question whether an RTO-level product (like the one developed by ISO-NE) would work in this footprint or if a more granular definition is appropriate.
- A new day-ahead product could allow the trade-off between energy and reserve commitments (like happens in ISO-NE for the energy gap) or treated more as a reserve service. The former may be more optimal, while the latter is simpler and might provide more flexibility depending on the reserve needs addressed.

	Day-Ahead Specific Products
PJM	
MISO	
CAISO	✓
ISO-NE	✓
NYISO	
SPP	
ERCOT	

- Like in the ISO-NE construct, resources should be able to reflect their avoidable costs into this market to encourage resources to take any needed actions day ahead to maintain availability.

Resource Availability Costs in Reserve Markets

- Avoidable costs associated with providing reserve services should be recoverable through PJM's Energy & Ancillary Service markets.
- Evaluate the costs to resources for providing reserve services and whether they vary based on system conditions, the nature of the reserve obligation, the amount of time in advance of delivery, a resource's operating posture, etc.
- Develop mechanisms for these costs to be reflected and recovered through PJM's markets.

Reserve Offer Reforms to Allow Resources to Reflect Costs

- PJM's reserve markets should provide competitive mechanisms for resources to recover avoidable costs for maintaining availability to provide these services.
- All other ISO/ RTO's allow some reflection of these avoidable costs in their reserve markets. Today, PJM only recognizes an average penalty risk in its synchronized reserve offers, which will drop to $0/MW starting in 2025.
- Reserve market offer rules should be re-examined in this light.
- Changes to reserve offers rules would entail broader market design discussions including:
  - Settlement implications and impacts
  - Reserve performance obligations and evaluation as well as consequences for non-performance
  - Market power mitigation

	Reserve Offers > $0
PJM	✓
MISO	✓
CAISO	✓
ISO-NE	✓
NYISO	✓
SPP	✓
ERCOT	✓

Uncertainty in PJM Markets

PJM's markets do not procure flexibility to manage forecast uncertainty (i.e., load, wind, solar, interchange and forced outage rates).

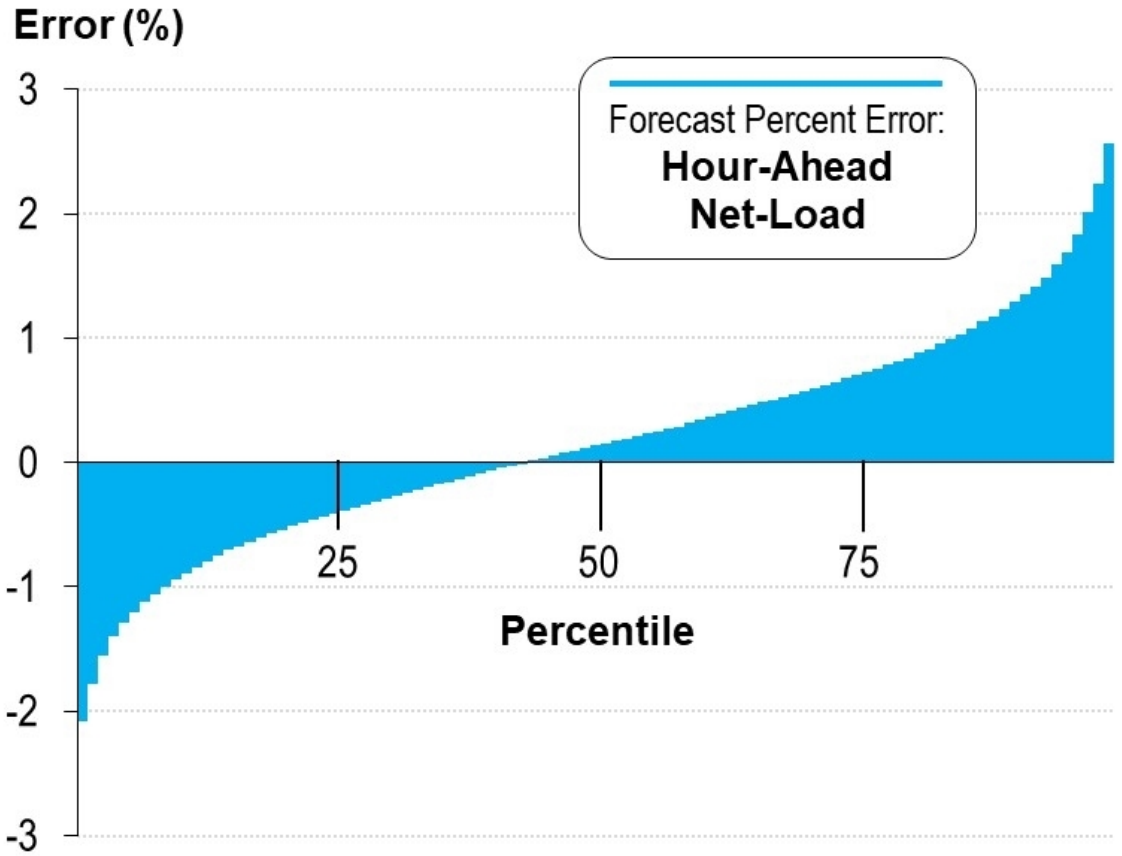
- Day-ahead, operations ensures that sufficient reserves are available to manage average load forecast error and generator forced outage rates through the DASR requirement. These reserve needs are not reflected in PJM's markets.
- As more wind, solar and behind-the-meter generation enter the system, forecast uncertainty will grow, introducing new reliability risks.

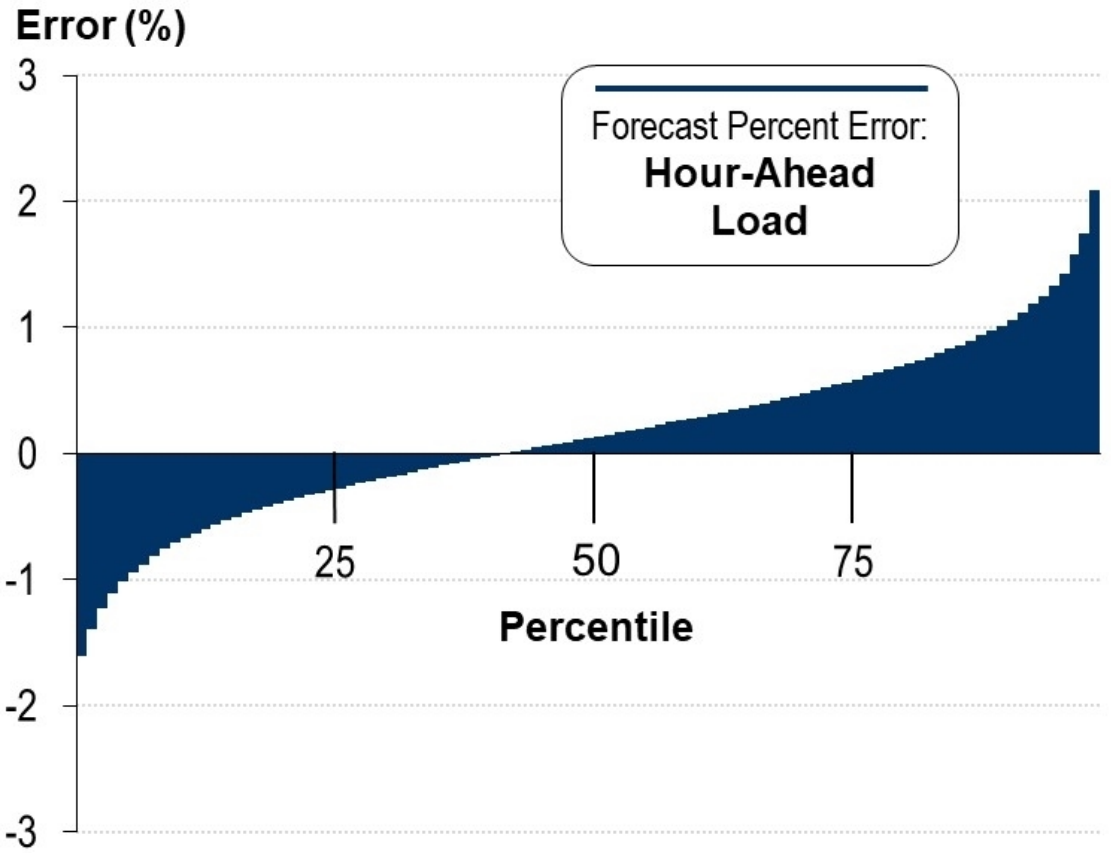
CAISO, NYISO, MISO and SPP have all designed their reserve markets to manage net-load forecast uncertainty.

Operator actions that affect prices

Net-Load vs. Load Forecast Uncertainty

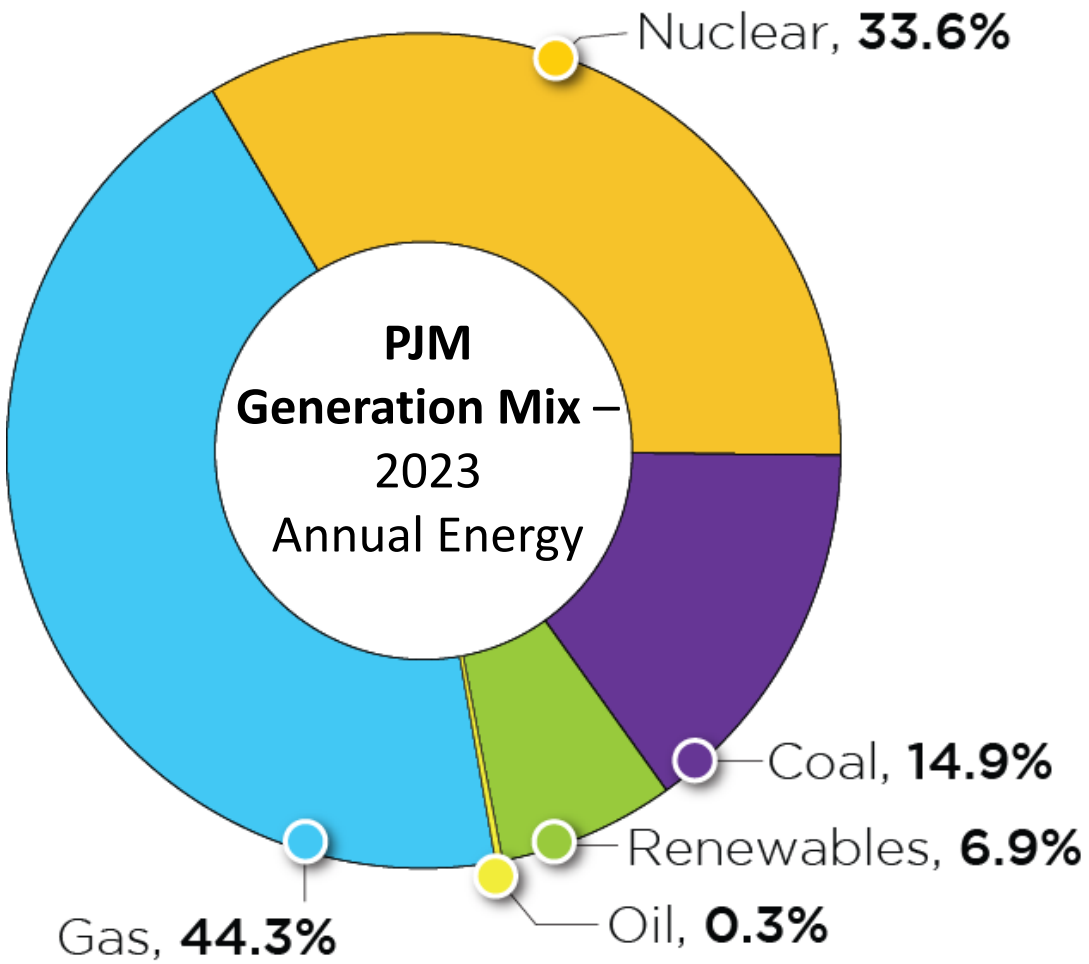
Hour-Ahead Net-Load and Load Forecast Uncertainty in the 2023/24 Delivery Year



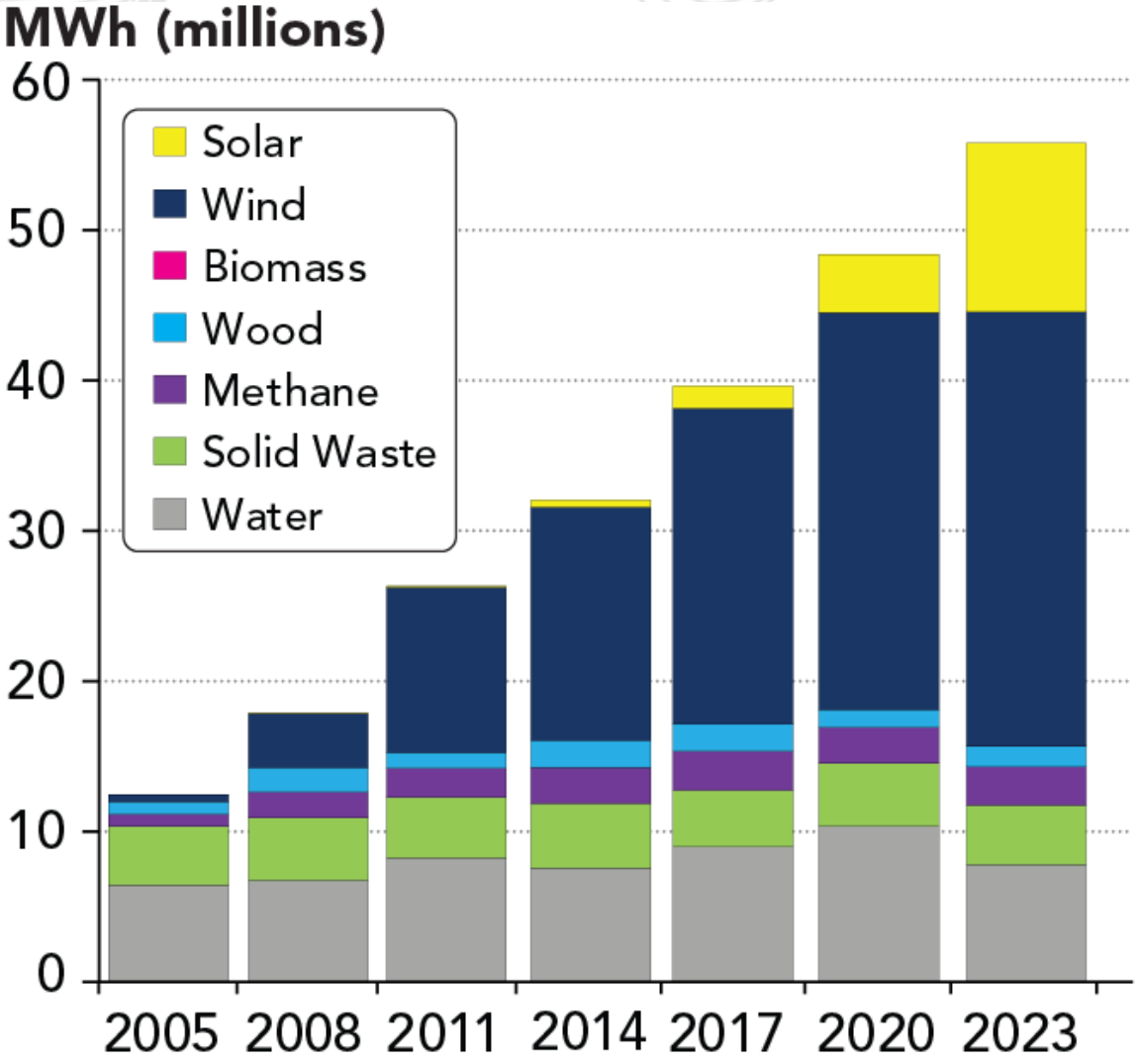


For more information on renewable forecasting, see the recent educational presentation given at the OC. (Presentation)

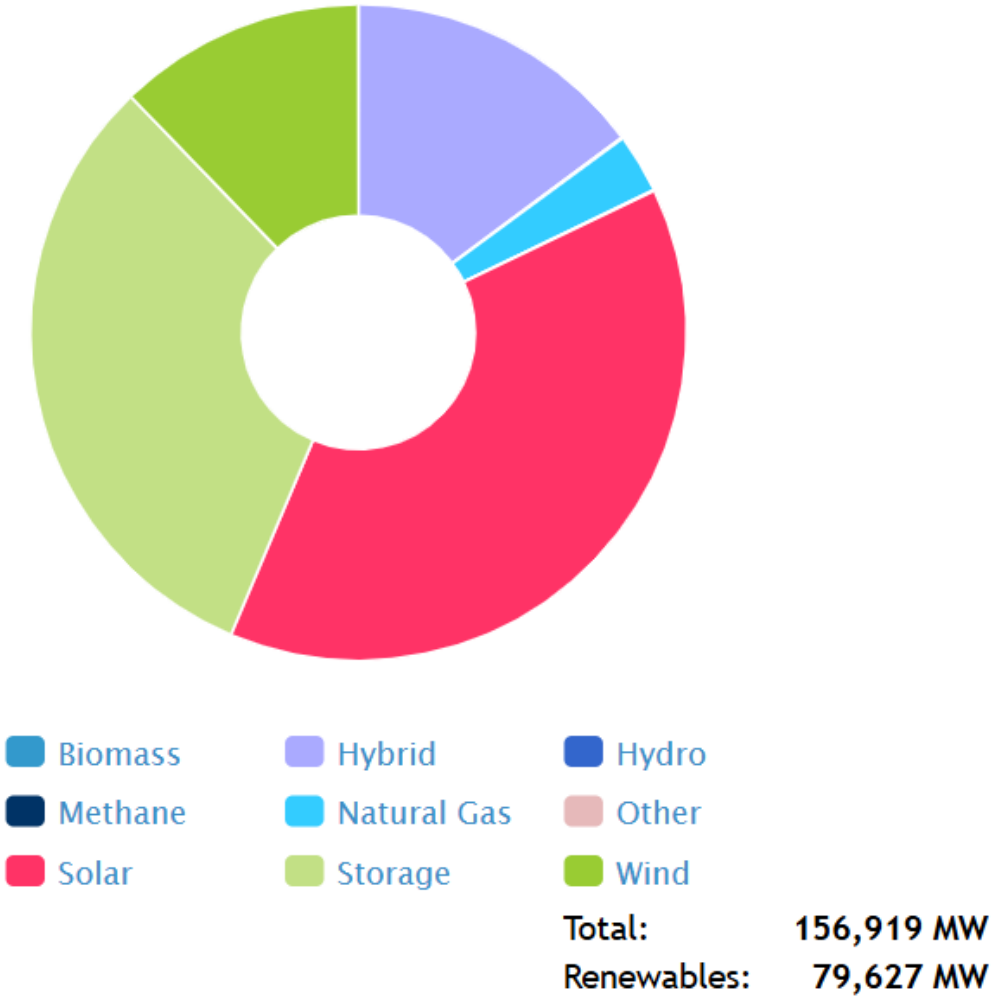
Percentage of Renewable Energy Is Small but Growing



As of 12/2023



Queued Generation Fuel Mix



Source: https://www.pjm.com/planning as of 2:49 pm EPT 12/4/2024

Forecasted Net-Load Ramp

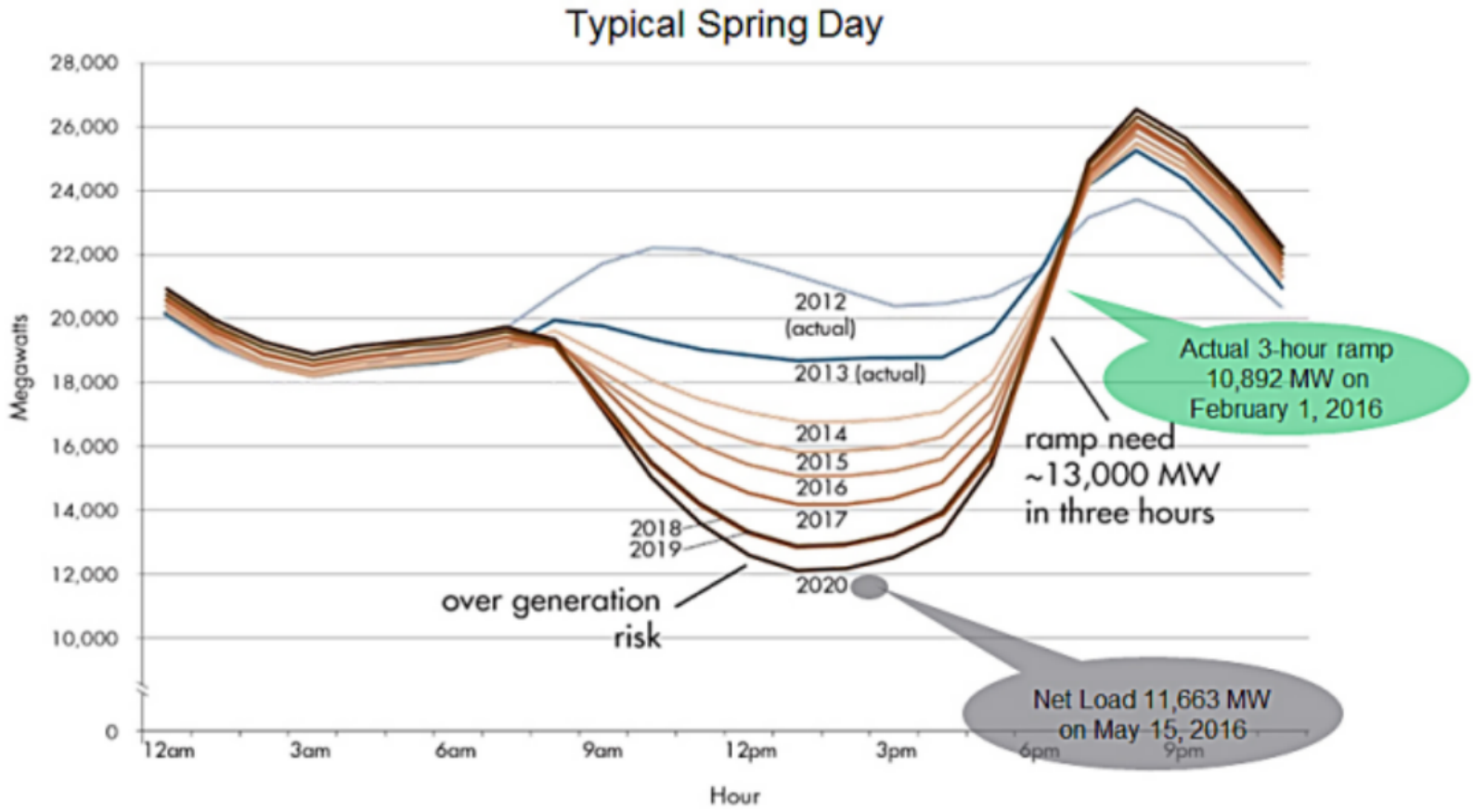
PJM's real-time dispatch engine does not account for flexibility and ramping needs forecasted in future intervals.

- With higher penetration of renewables, both up and down, net-load ramp will increase significantly.
- PJM's market clearing and dispatch engines must have tools to ensure that resources are positioned now to serve forecasted load later or PJM risks having insufficient flexibility to keep the system reliable.

In the recent accelerated renewable integration scenario studied, PJM's three-hour net-load ramp was projected to be greater than the peak load of the ERCOT system.*

* *Energy Transition in PJM: Flexibility for the Future*

Net-Load Ramp in CAISO



Source: https://www.pjm.com/-/media/DotCom/committees-groups/task-forces/rcstf/2024/20241016/20241016-item-05---caiso-reserve-and-ramping-products.pdf

Reflect Uncertainty and Flexibility Needs in PJM Markets

- PJM Markets should be structured to procure needed flexibility to manage operational risk and to attract and maintain these essential reliability services. New ramping and uncertainty reserve products are required to provide these mechanisms and successfully navigate the energy transition.
- Reserve requirements (i.e., procured quantities) and product definitions should reflect dynamic and evolving levels of operational risk, reliability needs and the operational characteristics of the fleet.
- The market should recognize any avoidable costs incurred to resources providing these services.
- Appropriate and clear performance obligations, settlement impacts and cost allocation structures will need to be defined for any new products developed.

Ramping/Uncertainty Reserves

- Without more probabilistic or stochastic market clearing engines (which are still an area of research) uncertainty reserve products will be needed to maintain reliability as more renewables enter the system.
- Reserve markets should be designed to procure sufficient reserves to reflect how uncertainty and ramping needs change over time as well as the flexibility required to operate reliably.
  - Longer lead reserve products may be more appropriate to capture further ahead risk and allow a larger pool of resources to provide reserve services
  - Shorter lead reserves capture immediate flexibility needs that longer lead reserves may not be able to meet
- Reserve needs depend on system conditions and quantified risks (such as load forecast error, renewable forecast error, forced outage rates, etc.), and reserve quantities must similarly be dynamic enough to accurately reflect the level of operational risk.

	Uncertainty Reserves
PJM	
MISO	✓
CAISO	✓
ISO-NE	
NYISO	✓
SPP	✓
ERCOT	✓

IT SCED Enhancements

In parallel with the RCSTF's efforts, PJM intends to consider enhancements to its Intermediate Term Security Constrained Economic Dispatch (IT SCED) engine that are complimentary with reserve market reforms advanced and anticipates exploring several things, which may include but are not limited to:

- ☑ Increasing the IT SCED look ahead window and evaluating how intervals are spaced within that window
- ☑ The forecast information that is used
- ☑ How the network is represented in future time intervals

Operating Reserve Demand Curves

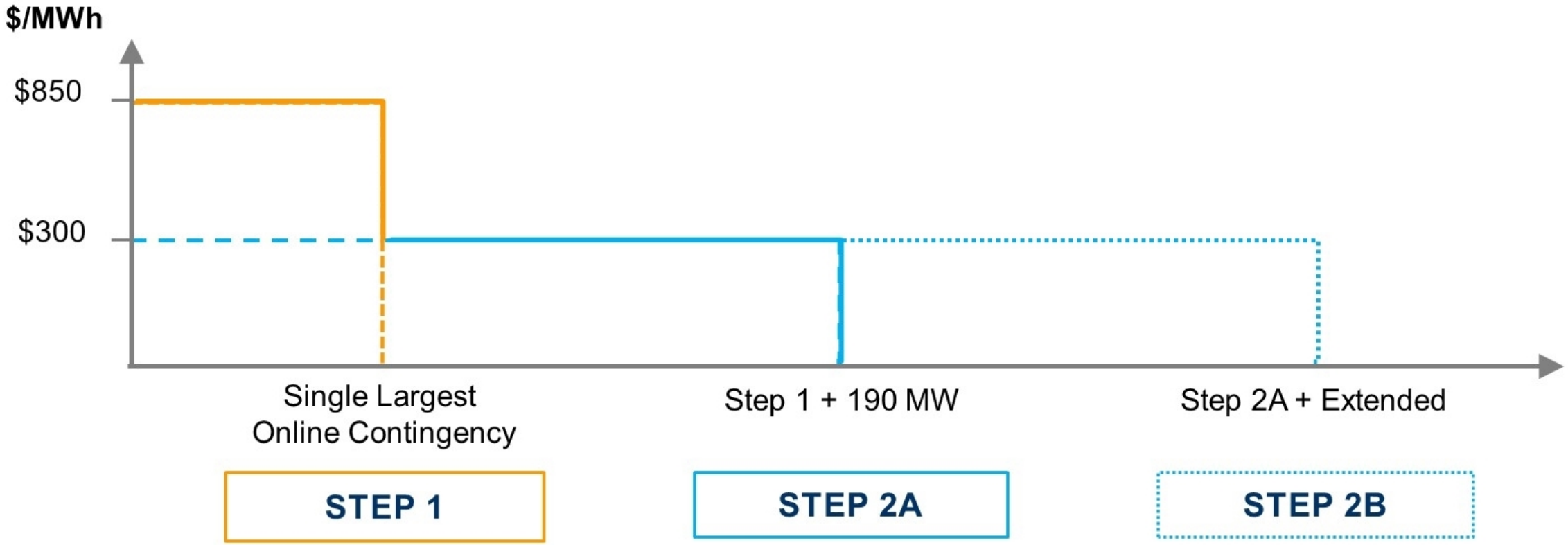
PJM's ORDCs are based on an old market design.

- Under Reserve Price Formation, PJM proposed a holistic re-design of PJM's reserve markets, including updates to our ORDCs.
- These reforms were initially approved by FERC and then later remanded, leaving PJM to implement an incomplete market design.

PJM's current ORDC penalty factors are based on lost opportunity cost information from an event in August 2007 and do not accurately reflect current operational reality.

Scarcity and shortage pricing

PJM's Existing Operating Reserve Demand Curves



Operating Reserve Demand Curves

- PJM's current demand curves do not properly reflect the marginal cost of serving load or align with the operational actions required to maintain reliability on the system to avoid shedding load. To be effective ORDCs should:
  - Be consistent with operational needs and willingness to pay to mitigate reserve shortage and ultimately to avoid loss of load
  - Ensure that all more-cost effective measures are exhausted before triggering shortage pricing or shedding firm load
  - Appropriately value reserve services in the context of system conditions
  - ***"Incent appropriate short- and long-term actions by resources and load"***
    - *FERC position on scarcity and shortage pricing*

Updates to PJM's ORDCs

- Evaluate the lost opportunity costs that resources can reasonably be expected to incur based on current operational data and energy offer caps.
- Evaluate the operational costs and actions that would be taken to mitigate shortage of reserve services.
- Explore how the ORDCs for reserve services work together, across existing reserve products and any new products developed.
- The ORDCs should be designed to support reliability, internal consistency and market efficiency with the goal of ensuring that all more cost-effective measures are exhausted before hitting shortage pricing and that reserve services are appropriately valued.

Additional Discussions

In addition to the challenges described above, there are some enhancements that may be needed to support the broader market design, some of which were discussed previously in the RCSTF.

- Performance evaluation and incentives
- Incentives to follow PJM dispatch
- Locational procurement of reserves

PJM's Ask for Stakeholders

- Starting in 2025, we hope to dive into some of these design discussions, and we'd like to hear from you in preparing for those discussions
  - Do these challenges and priorities resonate?
  - Are there things that are missing?
  - Is there additional education that you need to allow you to participate in these discussions?

Summary

Challenges to be Addressed

- The Day-Ahead Energy Market does not procure sufficient reserves to manage operational risk, leading to out-of-market reliability actions.
- PJM's markets do not procure flexibility to manage forecast uncertainty (i.e., load, wind, solar, interchange and forced outage rates).
- PJM's real-time dispatch engine does not account for flexibility and ramping needs forecasted in future intervals.
- PJM's ORDCs are based on an old market design.
- The cost of advanced fuel arrangements and other availability measures to provide reserves may at times be unrecoverable through PJM's existing market constructs.

Proposed Solutions to Explore

Enhancements to Existing Reserve Markets

- Updates to PJM's ORDCs
- Changes to resource offer rules into reserve markets to enable cost recovery
- IT SCED enhancements to better manage upcoming flexibility needs
- Performance evaluation and incentives to ensure alignment with operational needs
- Incentives to follow PJM dispatch
- Locational procurement of reserves for reliability

New Reserve Products

- Day-ahead reserve product(s) to better align with day-ahead operational needs
- Ramping/uncertainty reserve products to manage growing operational uncertainty

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PJM's Preliminary Reserve Certainty Priorities

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Appendix: Practices in Other ISO/RTOs to Address the Identified Challenges

Addressing the Day-Ahead Energy Gap between Committed Generation and Forecasted Load

1. CAISO and ISO-NE both have market-based solutions to mitigate the energy gap and allow resources to submit bids to provide this service.

2. CAISO procures both Reliability Capacity Up and Reliability Capacity Down, seeing a need to address a gap in either direction.

3. ISO-NE's design co-optimizes with energy, allowing the economic trade-off between procuring more reserves and committing more physical supply in the day-ahead market.

Capturing Availability Costs

1. ISO-NE, MISO, NYISO, SPP, CAISO and ERCOT all currently (or soon will) allow resources to submit offer prices for providing reserve services.

2. Some ISOs differentiate between online and offline reserves, recognizing additional costs for providing offline reserve services. NYISO recognizes costs day ahead but not in real-time.

3. ISO-NE's recently approved reforms include explicit recognition of avoidable fuel and charging costs for providing reserve services.

Procuring Flexibility for Uncertainty

1. MISO, NYISO, SPP, ERCOT and CAISO all currently or plan to procure reserves to manage uncertainty associated with net-load forecast error, including load, wind, solar and interchange uncertainties.

2. MISO, NYISO, SPP, ERCOT and CAISO all identified reliability needs as a driver for developing these reserve products as well as reducing price volatility by mitigating shortage events.

3. CAISO initially designed its ramping product to be procured at a system level but has moved to procuring the product nodally. SPP is evaluating similar reforms.

Positioning the System for Forecasted Net-Load Ramping

1. MISO and SPP procure reserves to ensure sufficient flexibility is available to meet forecasted net-load ramp in future intervals.

2. NYISO and CAISO or use multi-interval dispatch to ensure sufficient flexibility is available to meet forecasted net-load ramp in future intervals. Neither ISO currently settles intervals beyond the first.

Operating Reserve Demand Curves

1. MISO recently advanced a set of reforms that decreases its ORDC penalty factor near 100% of its reserve requirement and increases it as shortage conditions approach 50% of the requirement.

2. Decreasing the requirement for relatively small shortages is intended to support better constraint control and allowing the penalty to rise for larger shortages is intended to better reflect the value of lost load.

3. NYISO recently advanced reforms to extend its ORDC below their current requirement level to reflect additional reserves procured to manage net-load uncertainty. Other ISOs accomplish similar goals using separate products.

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Acronyms

Acronym	Term & Definition
RTO	A **Regional Transmission Organization is** an entity, such as PJM Interconnection, that manages and coordinates the flow of electricity across a large geographical region.
ISO	An **Independent System Operator** is an organization that manages and coordinates the electric grid in a geographical region.
FERC	The **Federal Energy Regulatory Commission** is
NERC	The **North American Electric Reliability Corporation** is
MW	A **Megawatt** is a unit of power equaling one million watts (1 MW = 1,000,000 watts) or one thousand kilowatts (1 MW = 1,000 KW).
ORDC	An **Operating Reserve Demand Curve** is a market mechanisms that dictates the maximum willingness to pay for reserves at different levels.

Acronyms

Acronym	Term & Definition
VOLL	**Value of Lost Load** the willingness to pay to avoid electrical service interruption, often considered in dollars per megawatt-hour.
DASR	**Day-Ahead Scheduling Reserve** is the quantity of reserves PJM carries to ensure that sufficient reserves are available going into the operating day to manage risks associated with load forecast error and generator forced outage rates.
LOLP	**Loss of Load Probability** is the probability that firm load will need to be shed based on operational risk factors.
OR	**Operating Reserves** are available generating capacity that can be used to balance supply and demand.
IT SCED	The **Intermediate Term Security Constrained Economic Dispatch** is the intra-day commitment engine that PJM uses to evaluate future intervals and ensure that sufficient generation capacity is online to meet forecasted demand for its look ahead window.

PROTECT THE POWER GRID

THINK BEFORE YOU CLICK!

pjm

Be alert to malicious phishing emails.

Report suspicious email activity to PJM.

(610) 666-2244 / it_ops_ctr_shift@pjm.com