PJM’s Perspective on Solutions to Address the Day-Ahead Energy Gap

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Focus of today's discussion

Overview of Identified Reforms

Challenges to be Addressed	Proposed Solutions to Explore

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

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 Day-Ahead Market is handled through subsequent commitments outside of this market.

Today, both 1) the **energy gap** between cleared physical supply and forecasted demand and 2) the need for **Day-Ahead Scheduling Reserves (DASR)** are handled through operational practice outside of the Day-Ahead Energy Market.

There are two primary drivers for day-ahead reserve needs that change as we enter real-time.

Day-Ahead Energy Gap	**Day-Ahead Uncertainties**
Reserves required to ensure that enough physical generation is available to meet the PJM load forecast.	Reserves required to manage uncertainty associated with day-ahead forecast error (load, wind and solar) and generator forced outages.
Day-Ahead Energy Gap = PJM Load Forecast + Net Firm Export – Physical Supply Cleared in the DAM	**Day-Ahead Uncertainty Reserves = (PJM Load Forecast) x DASR %** **DASR %* = Avg. Load Forecast Error + Avg. Generator Forced Outage Rate**

** Today, the DASR % does not include load and wind forecast error, but moving forward, it will need to for reliability.*

Differences Between Reserve Drivers

Day-Ahead Energy Gap	Day-Ahead Uncertainties
Reserve need does not exist in real-time. Therefore, a corollary product will not be cleared in the real-time market.	Reserve need exists in real-time, but at a lower level. Therefore, a corollary product might be cleared in the real-time market.
Reserve need is based on the 50th percentile forecast.	Reserve need is based on an uncertainty distribution around the 50th percentile forecast.
A trade-off could exist in market clearing between clearing more physical supply and procuring more reserves to address the Day-Ahead Energy Gap.	Uncertainty needs should be addressed by the clearing of reserves, and not by clearing additional physical supply.

PJM Perspective on Day-Ahead Reserve Solutions

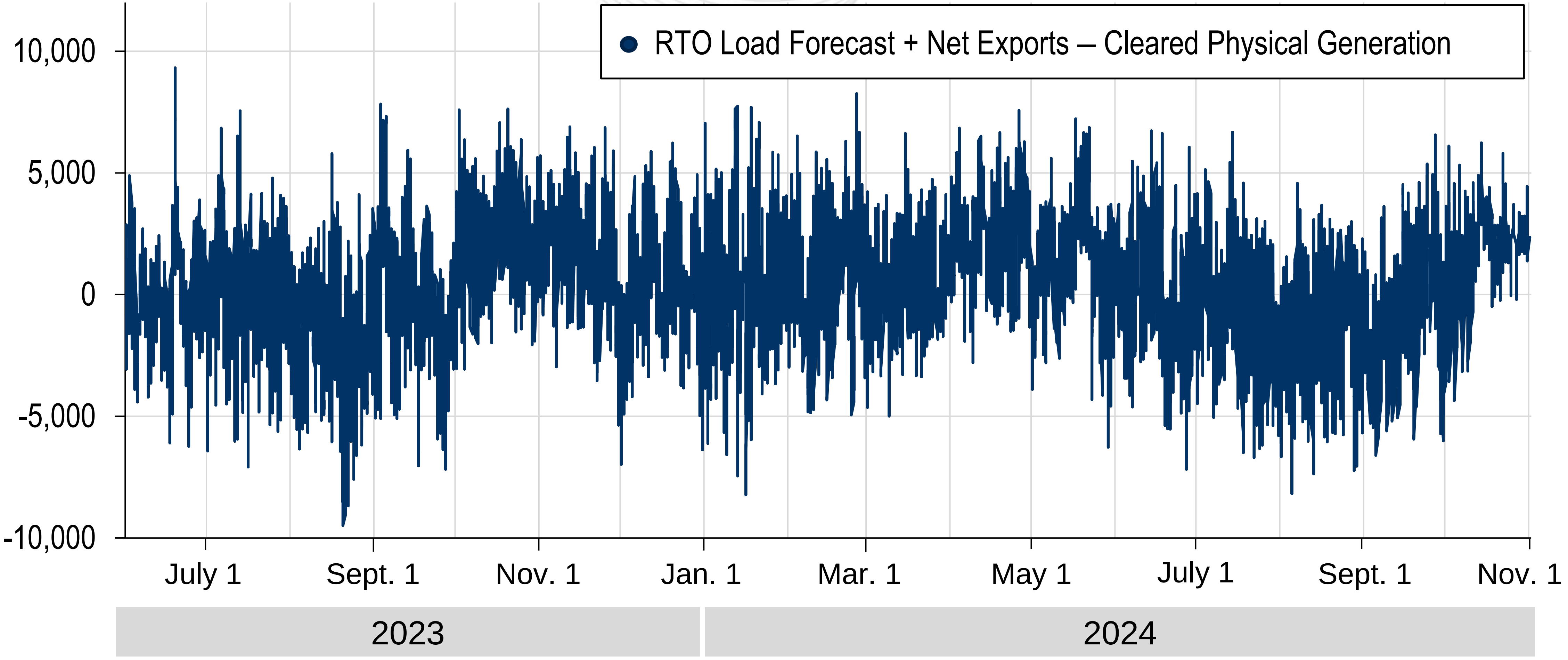
The differences in these reserve drivers lead PJM to believe that we require different market solutions to address these challenges.

Today, we will discuss addressing the **day-ahead energy gap** through a new **Day-Ahead Energy Imbalance Reserve (DA-EIR) product**.

In a future session, we will discuss addressing **day-ahead uncertainty** through new **uncertainty products** in the context of the broader set of uncertainty reserve needs.

Day-Ahead Energy Gap

Energy Gap (MW)



In-Market Solutions for Addressing the Energy Gap in Other ISOs

CAISO

- Implemented Reliability Capacity Up and Down products in its Residual Unit Commitment (RUC)
- Clears these products in RUC based on resource offers and thereby sets market clearing prices

ISO-NE

- Implementing a Day-Ahead Energy Imbalance Reserve (DA-EIR) product
- Clears DA-EIR Day-Ahead Market, co-optimizing it with energy and other ancillary services
- Allows the trade-off between clearing additional physical supply and procuring more DA-EIR
- Settles all day-ahead reserve products as energy call options

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

How does PJM Envision Utilizing DA-EIR?

Day-Ahead Energy Imbalance Reserves would be “deployed” through normal energy dispatch, and the performance obligation would entail being ***available for dispatch*** and ***following dispatch instructions***.

Availability: Resources would be expected to be available to provide energy in each hour in which they were assigned, at a minimum, at a level consistent with their day-ahead energy commitments + their Day-Ahead Energy Imbalance reserve commitments.

Dispatchability: Resources would be expected to follow energy dispatch instructions in real-time.

Product Definition and Resource Eligibility: Design Decisions

Product Definition	Resource Eligibility Requirements
How quickly do resources need to respond if called upon to provide energy to meet the operational need?	Can the service be provided by either online or offline resources?
How long does the response need to be sustained?	

Product Definition and Resource Eligibility: PJM Perspective

Product Definition

How quickly do resources need to respond if called upon to provide energy to meet the operational need?

Because the requirement will be based on the average hourly forecasted demand, the reserve MWs should be deliverable within 60 minutes. Therefore, the quantity of reserves that could be cleared on a resource would depend on its available 60-minute ramp capability.

How long does the response need to be sustained?

To meet operational needs, resources must be able to sustain their response for a minimum of 60 minutes.

Resource Eligibility Requirements

Can the service be provided by either online or offline resources?

Both online and offline resources should be able to provide this service under normal operating conditions.

For offline resources:

- Resource time to start must be less than or equal to 30 minutes.
- Resource minimum run times should be less than or equal to the window in which the response needs to be sustained (i.e., 60 minutes).
- Resource maximum run times should be greater than or equal to the window in which the response needs to be sustained (i.e., 60 minutes).

Locational Procurement

- Procurement of Day-Ahead Energy Imbalance Reserves needs to align with how the system must be positioned day-ahead for reliable operations
- To the extent possible, the reliability and deliverability constraints that would require different/additional resources to be committed should be modeled in the market
- This will reduce out-of-market commitments, promote market efficiency and transparency, and align incentive signals with operational needs

Requirement and Optimization Formulation: Two Options

The objective of this product is to ensure that sufficient physical generation capacity is available entering the operating day to meet the load forecast plus net firm export:

Day-Ahead Energy Imbalance Reserves + Cleared Physical Supply >= Load Forecast + Net Firm Export

Option 1: Sequential Approach	**Option 2: Full Co-optimization**
Clear Day-Ahead Energy Imbalance Reserves sequentially, after clearing resources for energy, and take the cleared physical supply as a given fixed quantity.	Clear Day-Ahead Energy Imbalance Reserves in a co-optimization with energy, allowing for the quantity of cleared physical supply to be increased if that results in a lower over all production cost.

Requirement and Optimization Formulation: Options

Option 1: Sequential Approach	Option 2: Full Co-optimization
Would not allow for additional physical generation to be cleared (e.g., in lieu of virtual supply) to help meet the energy gap	Would allow the optimization to trade-off between clearing additional physical supply (thereby decreasing the energy gap) or procuring more Day-Ahead Energy Imbalance Reserves (to address the gap)
Would frame Day-Ahead Energy Imbalance Reserves more like a traditional reserve product with a fixed requirement, which could allow for more flexibility in how the requirement is set/what reserve needs are included in the product definition.	Would frame Day-Ahead Energy Imbalance Reserves as a trade-off with energy, which could lead to more optimal solutions/market efficiency.

Requirement and Optimization Formulation: Example

Demand:

Bid-in Demand	250 MW
Load Forecast	275 MW

For simplicity, this example assumes there are no Decrement Bids, no Price Responsive Demand, and no interchange and that the Day-Ahead Energy Imbalance Reserve product is an hourly product based on hourly ramping capability.

Resource offers:

Market Participant	Price	MW	Ramp
R1 (physical resource)	$10	200 MW	1 MW/min.
R2 (physical resource)	$50	200 MW	.5 MW/min.
I1 (virtual Increment Bid)	$20	20 MW	

Market Clearing without a Day-Ahead Energy Imbalance Product:

R1	R2	I1	Cleared Physical Generation (i.e., R1 + R2)	System Energy Price
200 MW	30 MW	20 MW	230 MW	$50

Requirement and Optimization Formulation: Example

Sequential Approach: Option 1	Full Co-optimization: Option 2
DA-EIR ≥ load forecast – physical supply DA-EIR ≥ 275 MW – 230 MW **DA-EIR ≥ 45 MW** At the same time, because of ramp limitations on R2, R1 needs to be backed down to provide additional headroom for providing the reserve service, changing the energy dispatch and causing R1 to incur lost opportunity cost.	In the fully co-optimized formulation that allows the trade-off, additional physical supply would be committed (reducing the net virtual supply) and less DA-EIR would be cleared because this is the cost-minimizing solution.

	Energy Assignments			DA-EIR Assignments				
Scenario	**R1**	**R2**	**I1**	**R1**	**R2**	**System Energy Price**	**DA-EIR Cost***	**Total Production Cost**
Sequential Approach	185 MW	45 MW	20 MW	15 MW	30 MW	$50	$40	$4,500
Full Co-optimization	200 MW	45 MW	5 MW	0 MW	30 MW	$20	$30	$4,350

**For the purposes of this example, DA-EIR Cost is based on lost opportunity cost.*

Requirement and Constraint Formulation: PJM Perspective

Option 2, the “Full Optimization” approach would provide more optimal solutions from the perspective of production cost minimization.

The existence of this trade-off between DA-EIR procurement and committing more physical supply means that physical supply is substitutable with DA-EIR, which would differentiate DA-EIR from other reserve products.

Ultimately, the constraint formulation will need to be coherent and feasible within the full market design to ensure that the optimization remains tractable and that price formation makes sense.

DA-EIR Procurement and Clearing

In general, PJM's existing reserve market constructs are designed to ensure that reserves are available to provide the needed reliability benefit, but do not consider or attempt to minimize the cost of deploying those reserves.

Unlike Synchronized Reserves, which are deployed explicitly and only during an event, DA-EIR will be "deployed" economically through normal energy dispatch, and PJM is making that procurement with the expectation that that quantity of supply will be needed in real-time to serve forecasted demand.

This limitation might therefore be more significant in the context of DA-EIR than it is in other reserve constructs.

Example: Resource Availability vs. Deployment Costs

Assume there are two resources, R1 and R2, which have different operating postures. R1 has no avoidable costs day-ahead to provide reserve services. R2 could be available to run in real-time, but must make arrangements at some cost today to be available to provide reserves tomorrow. Based on the day-ahead energy prices, neither resource will get an energy commitment, but both are eligible to provide DA-EIR. For simplicity, both resources have sufficient capability to meet all of a 100 MW DA-EIR requirement.

Day-Ahead Offer	R1	R2
Energy	$150	$50
DA-EIR (i.e., availability costs)	$0	$25

Take two different scenarios: one where the market clears DA-EIR solely based on availability costs, and a second where the market considers deployment costs when clearing DA-EIR.

Example: Resource Availability vs. Deployment Costs

DA-EIR is cleared to minimize availability costs.

Scenario 1

Resource	DA-EIR			Real-Time Energy			Total
	Offer	Commitment	Cost	Offer	Commitment	Cost	
R1	$0	100 MW	$0	$150	100 MW	$15,000	$15,000
R2	$25	0 MW	$0	N/A	0 MW	$0	$0
Total			$0			$15,000	**$15,000**

DA-EIR is cleared to minimize both availability *and* expected deployment costs.

Scenario 2

Resource	DA-EIR			Real-Time Energy			Total
	Offer	Commitment	Cost	Offer	Commitment	Cost	
R1	$0	0 MW	$0	$150	0 MW	$0	$0
R2	$25	100 MW	$2,500	$50	100 MW	$5,000	$7,500
Total			$2,500			$5,000	**$7,500**

Availability vs. Deployment Costs: Considerations

At a minimum, procurement of DA-EIR is intended to provide a reliability service not currently represented in PJM's DAM: the need to ensure that sufficient physical generation is available to reliably serve forecasted demand.

However, if we expect to need the quantity of energy procured as DA-EIR in real-time to meet forecasted demand, the most efficient solution may sometimes be to incur additional but lesser costs day-ahead to avoid incurring greater costs in real-time.

Concept One:
Clearing Energy Imbalance Reserves to Minimize Resource Availability Costs

Resource Offers for DA-EIR

- Resources would submit a $/MWh availability offer for Day-Ahead Energy Imbalance Reserves.
- The quantity of reserves that could be cleared would be based on energy offer parameters.
- Availability costs should be reflected in offers, which could include the cost of fuel arrangements or charging costs, performance risk, and expected settlement costs (as appropriate to the settlement design).

Settlement Considerations

In PJM's existing reserve constructs, such as 30-Minute Reserves, a day-ahead reserve assignment is settled against a corollary real-time reserve assignment.

The energy gap in day-ahead that DA-EIR is intended to address does not exist in real-time. Therefore, there is not a natural real-time product to settle the assignment against.

New settlement rules would therefore be needed to evaluate resources' performance and to settle that performance appropriately.

Performance and Settlement: New Performance and Settlement Rules

Performance Evaluation	Settlement Consequences for Non-Performance
1. Evaluate whether the resource is available 2. Evaluate whether the resource follows dispatch instructions	Possible options: • Claw back of DA-EIR revenue • Payment for replacement energy based on real-time LMP • Others?

Economic Obligations in Real-Time

For any Day-Ahead Energy Imbalance Reserve megawatts cleared, the market could be structured such that resources would have to make those megawatts available to the market based on their day-ahead energy offers.

These rules would have to be complementary with the settlement consequences for non-performance and rules for resource offers.

Limitations and Potential Challenges

When reserve services are cleared based solely on the cost of maintaining ***availability*** to provide energy (i.e., lost opportunity cost, avoidable costs for providing reserve services, etc.) the markets may not make procurement decisions that would results in the lowest ***dispatch*** costs when those reserve services are converted to energy in real-time.

New performance evaluation and settlement rules will need to be developed, which may be complicated given the nature of this product.

Concept Two:
Clearing Energy Imbalance Reserves to Minimize Availability and Expected Dispatch Costs

Considerations

- When developing its EIR product, ISO-NE developed an energy call-option, which incentivizes resources to bid both their availability costs and their expected settlement costs given their dispatch costs and the probability that real-time prices exceed the set strike price.
- The energy call option design is an elegant way to allow the market to trade-off between availability and deployment costs when clearing DA-EIR. However, ISO-NE procures its EIR product at an RTO level, which simplifies the market design.
- PJM believes that DA-EIR in its footprint may need to be procured locationally, which would complicate an energy call-option implementation enough that it may be impractical to implement.
- PJM intends to explore other avenues to considering deployment costs in the procurement of DA-EIR to evaluate their potential benefit in comparison to clearing DA-EIR based solely on availability costs, more akin to PJM's other reserve products.

DA-EIR Procurement and Clearing: Central Questions

1. Is DA-EIR purely intended to manage the identified reliability need or should real-time market outcomes be considered in its procurement to the extent possible?

2. Can real-time deployment costs be practically represented in clearing DA-EIR in a way that consistently improves market efficiency?

Summary of the Options to Explore Moving Forward

1. Clearing DA-EIR based only on resource availability costs to minimize costs day-ahead to ensure the reliability need is met.

2. Clearing DA-EIR with a view to minimizing both availability and deployment costs to minimize expected production costs in both day-ahead and real-time.

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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
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.
DA-EIR	**Day-Ahead Energy Imbalance Reserve** is a reserve product cleared day-ahead to ensure that any gap between the day-ahead load forecast and physical generation cleared through the market can be met by physical resources.
RAC	The **Reliability Assessment and Commitment** tool is a commitment tool that PJM runs after the Day-Ahead Market to ensure that sufficient generation is committed to the system to meet reliability needs.
LMP	**Locational Marginal Price** is the marginal price for energy at the location where the energy is delivered or received. LMP is a pricing approach that addresses transmission system congestion and loss costs, as well as energy costs.


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