Updates and Clarifications to PJM's Proposed Solution Options

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December 10, 2025

DASR Requirement Calculation: Hourly Values

Energy Gap Reserve Quantities

Settlement Examples

DASR Requirement Calculation: Hourly Values

Reminder: DASR Percentages as a Function of Risk

Proposed Risk Values	Percentile	Load	Generator Performance	Solar	Wind
Low	80th Load / 50th Others	2.19%	2.03%	11.28%	9.68%
	80th All	2.19%	3.12%	19.71%	21.48%
Medium	85th All	2.42%	3.49%	22.50%	24.19%
High	90th All	2.79%	3.88%	25.51%	26.54%
	95th All	3.55%	4.68%	31.33%	32.43%

Reminder: DASR Requirement Calculations

The DASR Quantities for a given day are calculated by multiplying the appropriate percentages (as a function of risk) by the relevant forecasts.

$$DASR = Load\ Forecast \times\ Load\ Uncertainty\ \% +$$

$$Load\ Foreacst \times\ Gen\ Uncertainty\ \% +$$

$$Solar\ Forecast \times Solar\ Uncertainty\ +$$

$$Wind\ Foreacst \times Wind\ Forecast\ \%$$

What's Changed?

Previously, PJM had presented that DASR would be a single requirement for all hours in the day, calculated based on the peak load forecast hourly.

- This raised questions about whether the market would clear more reserves than necessary during off-peak hours.

PJM now proposes to calculate the DASR Requirement for every hour of the day, based on the load, wind and solar forecast for each hour.

- The hourly DASR quantities would be capped by the DASR quantity at the peak load forecast hour, meaning that the DASR Requirement in any other hour would never exceed the DASR Requirement at the peak load forecast hour.

Updated DASR Requirement Calculation

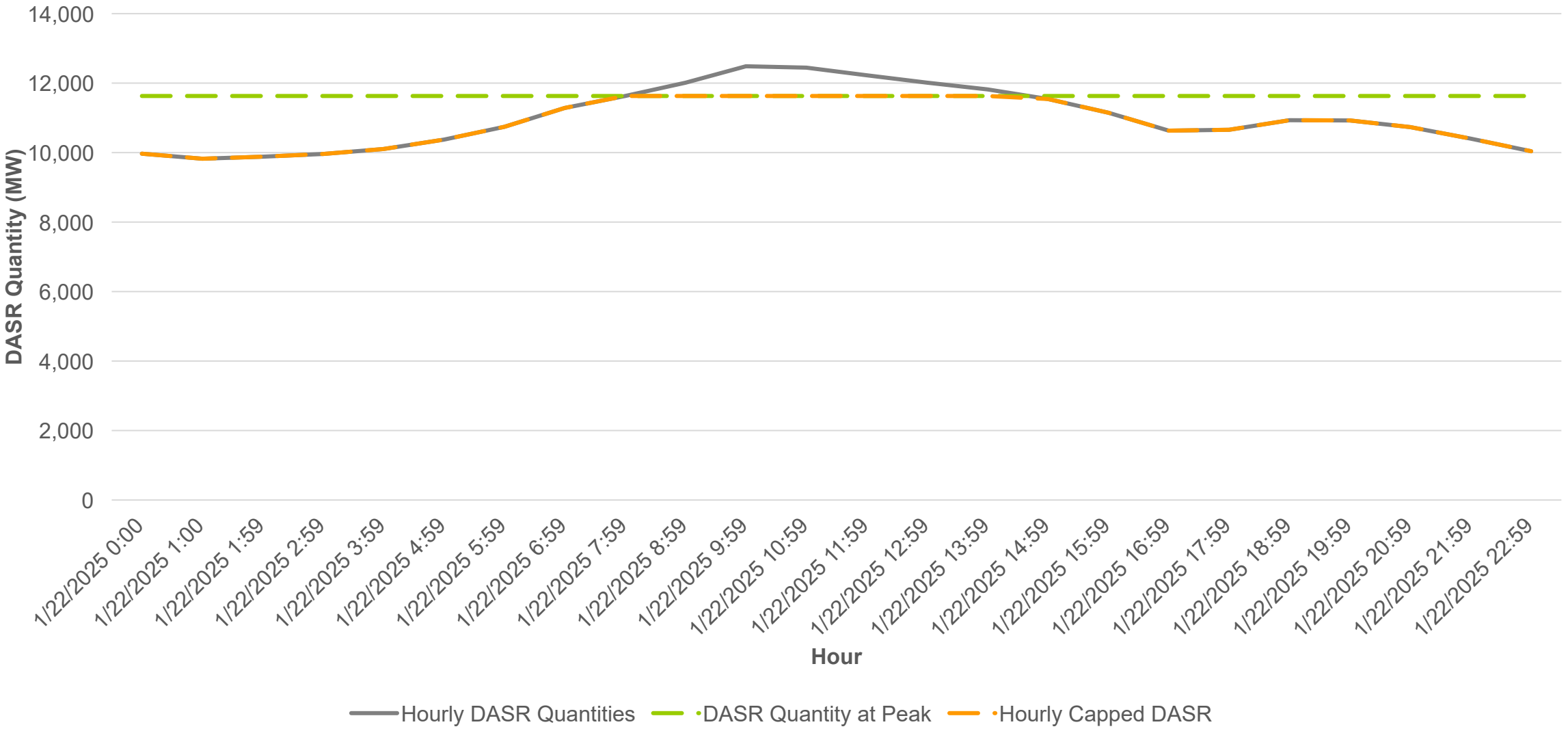
For every hour t, the DASR quantity would be:

$$DASR_t = Load\ Forecast_t \times Load\ Uncertainty\ \% +$$
$$Load\ Forecast_t \times Gen\ Uncertainty\ \% +$$
$$Solar\ Forecast_t \times Solar\ Uncertainty +$$
$$Wind\ Forecast_t \times Wind\ Forecast\ \%$$

For every hour t, the capped DASR Requirement would be:

$$DASR_t' = MIN(DASR_t, DASR_{peak})$$

January 22nd, 2025, DASR Quantities



Energy Gap Reserve Quantities

Reminder: Energy Gap Background and Motivation

- If we ignore interchange, which is not included in PJM's load forecast, the Day-Ahead Market clears supply based on the following power balance equation.

Physical Supply + Increment Bids – Decrement Bids – Price Sensitive Demand = Fixed Demand + Expected Losses

- If the Day-Ahead Market does not clear sufficient physical supply to meet its load forecast PJM will mitigate this risk by committing additional resources using its RAC commitment process.
- This is something that PJM is particularly concerned about during days of elevated risk, when reliability requires that some of the resources PJM depends on make advanced arrangements to be ready to operate (e.g., fuel procurement).
- Going forward, PJM proposes to address this reliability need in its Day-Ahead Market rather than through a separate RAC process later in the day. This will more transparently reflect these reliability needs in the market, provide earlier notice to resources that they may be required to operate, and provide resources that are needed for reliability with a Day-Ahead Market position that includes clear performance expectations.

Reminder: Previously Presented Approach for Quantifying the Energy Gap

- On Medium- and High-Risk days, PJM would increase its reserve requirements in the Day-Ahead Market to procure reserves to manage the Energy Gap, which reflects the difference between the physical supply cleared in the market and PJM's load forecast.
- Previously, PJM presented an approaching for calculating the amount to increase the DASR requirement level based on the difference between PJM's load forecast and the Adjusted Fixed Demand for that day plus Expected Losses.
- This approach was based on the Seasonal Conditional Demand Factor that was used to quantify the DASR Adder before Reserve Price Formation was implemented.
- The Seasonal Conditional Demand Factor was calculated using historical operational data.

What's Changed?

As previously noted, an analysis of the total cleared demand (including cleared virtual bids), which the Adjusted Demand is attempting to model shows that this quantity varies significantly day-to-day.

This raises questions about the accuracy of the Adjusted Demand calculation and whether the previously discussed approach is falsely precise.

PJM is now considering approaches that use a seasonal demand curve to represent the market's willingness to pay for energy gap reserves based on historical market clearing outcomes. ***PJM is also proposing to do this only on elevated risk days in winter, when the energy gap presents the greatest reliability risk.***

This would simplify the market design, establish a consistent approach for handling the energy gap on elevated risk days in winter, and represent historical probabilities directly in the procurement through the demand curve.

Energy Gap Reserve Demand Curve: Methodology

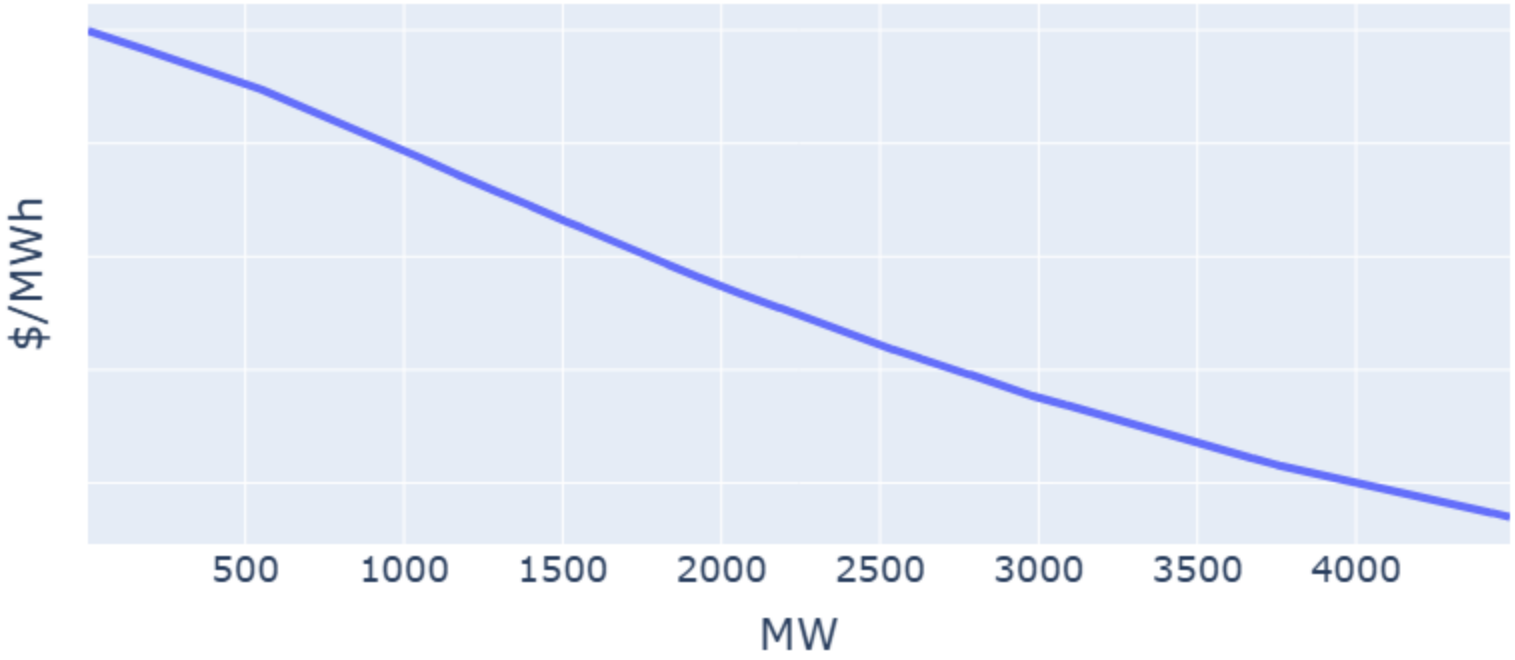
- The downward sloping demand curve associates a marginal value ($/MWh) at a specific Energy Gap reserve level (in MW) as detailed below
- Uncertainty distribution fit to historical realizations of energy gap from Dec 2022 through Nov 2025 for the winter season. Cumulative Distribution Function for season S denoted F^S
- For a given energy gap level $r \geq 0$, the following function represents probability of clearing less physical supply in the Day-Ahead Market as compared to the load forecast in season S

$$P^S(r) = 1 - F^S(r)$$

- $P^S(r)$ is scaled by a constant scaling factor to obtain the inverse demand function
- We restrict $F^S(r)$ at the 90-th percentile, so that the terminal point of the demand curve is the 90-th percentile of the historical observations of the Energy Gap (in MW)

Energy Gap Reserve Demand Curve: Winter

- An Energy Gap Demand Curve shape for winter is illustrated in the plot in the lower right.
- This curve is based on historical observations from November – March from December 1, 2022 through December 1, 2025.
- The terminal point of the demand curve is at roughly 4,500 MW (90-th percentile of the historical observed Energy Gap in winter).
- The price at this point is approximately 15% of the price at 0 MW of the Energy Gap Reserve level.



Summary of PJM's Updated Proposal for Managing the "Energy Gap"

- On Medium- and High-Risk winter days, PJM would clear "Energy Gap Reserves" in the Day-Ahead Market to represent the need to ensure that reserves are available to mitigate the risk that less physical supply is cleared in the Day-Ahead Market than is needed to meet PJM's load forecast.
- "Winter" for the purpose of informing when Energy Gap Reserves would be procured would be defined as November – March.
- Only online resources would be eligible to clear to meet the Energy Gap reserve requirement, and these reserves would need be deliverable in 60 minutes (i.e., based on the amount that a resource could increase its output or reduce its load within 60 minutes).
- Energy Gap reserves would be cleared based on an ORDC with a downward sloping shape that reflects the historical observations of instances where PJM's Day-Ahead Market cleared less physical supply than PJM's load forecast in winter months over the preceding three years.

Settlement Examples

Day-Ahead Market Example Set-Up

Product	Requirement	Clearing Price
DASR	50 MW	$1/MW
Energy Gap	34 MW	$3/MW
10-Min RUR	9 MW	$3/MW
30-Min RUR	15 MW	$3/MW
30-Min SECR	15 MW	$1/MW
SR	10 MW	$3/MW

	Online?	DASR	Energy Gap	10-Min RUR	30-Min RUR	30-Min SECR	SR
R1	Yes	0 MW	14 MW	9 MW	5 MW	0 MW	0 MW
R2	Yes	0 MW	20 MW	0 MW	10 MW	0 MW	10 MW
R3	No	50 MW	0 MW	0 MW	0 MW	15 MW	0 MW

Real-Time Market Example Set-Up, Scenario 1

Product	Requirement	Clearing Price
DASR	N/A	N/A
Energy Gap	N/A	N/A
10-Min RUR	9 MW	$3/MW
30-Min RUR	15 MW	$3/MW
30-Min SECR	15 MW	$1/MW
SR	10 MW	$3/MW

	Online?	10-Min RUR	30-Min RUR	30-Min SECR	SR
R1	Yes	9 MW	5 MW	0 MW	0 MW
R2	Yes	0 MW	10 MW	0 MW	10 MW
R3	No	0 MW	0 MW	15 MW	0 MW

For this first set of solutions, assume that except for DASR and the Energy Gap Reserves (which don't exist in real-time) all other reserve quantities and clearing prices remain the same.

Scenario 1 R1 Reserve Settlement

	Day-Ahead Market			Real-Time Market		
	Reserve Assignment	**Clearing Price**	**Revenue**	**Reserve Assignment**	**Clearing Price**	**Revenue**
DASR	0 MW	$1/MW	$0	N/A	N/A	$0
Energy Gap	14 MW	$3/MW	$42	N/A	N/A	$0
10-Min RUR	9 MW	$3/MW	$27	9 MW	$3/MW	$0
30-Min RUR	5 MW	$3/MW	$15	5 MW	$3/MW	$0
30-Min SECR	0 MW	$1/MW	$0	0 MW	$1/MW	$0
SR	0 MW	$3/MW	$0	0 MW	$3/MW	$0
		Total	**$84**		**Total**	**$0**

- R1 is available to provide energy or reserves at the level cleared day ahead, and therefore meets its Energy Gap Reserve obligations
- R1's reserve assignments are the same in real-time as in day-ahead, and so it has no resettlement of those assignments

Scenario 1 R2 Reserve Settlement

	Day-Ahead Market			Real-Time Market		
	Reserve Assignment	Clearing Price	Revenue	Reserve Assignment	Clearing Price	Revenue
DASR	0 MW	$1/MW	$0	N/A	N/A	$0
Energy Gap	20 MW	$3/MW	$60	N/A	N/A	$0
10-Min RUR	0 MW	$3/MW	$0	0 MW	$3/MW	$0
30-Min RUR	10 MW	$3/MW	$30	10 MW	$3/MW	$0
30-Min SECR	0 MW	$1/MW	$0	0 MW	$1/MW	$0
SR	10 MW	$3/MW	$30	10 MW	$3/MW	$0
		Total	**$120**		**Total**	**$0**

- R2 is available to provide energy or reserves at the level cleared day ahead, and therefore meets its Energy Gap Reserve obligations
- R2's reserve assignments are the same in real-time as in day-ahead, and so it has no resettlement of those assignments

Scenario 1 R3 Reserve Settlement

	Day-Ahead Market			Real-Time Market		
	Reserve Assignment	Clearing Price	Revenue	Reserve Assignment	Clearing Price	Revenue
DASR	50 MW	$1/MW	$50	N/A	N/A	$0
Energy Gap	0 MW	$3/MW	$0	N/A	N/A	$0
10-Min RUR	0 MW	$3/MW	$0	0 MW	$3/MW	$0
30-Min RUR	0 MW	$3/MW	$0	0 MW	$3/MW	$0
30-Min SECR	15 MW	$1/MW	$15	15 MW	$1/MW	$0
SR	0 MW	$3/MW	$0	0 MW	$3/MW	$0
		Total	**$65**		**Total**	**$0**

- R3 is available to provide energy or reserves at the level cleared day ahead, and therefore meets its DASR obligations.
- R3's reserve assignments are the same in real-time as in day-ahead, and so it has no resettlement of those assignments

Real-Time Market Example Set-Up, Scenario 2

Product	Requirement	Clearing Price
DASR	N/A	N/A
Energy Gap	N/A	N/A
10-Min RUR	9 MW	$4/MW
30-Min RUR	15 MW	$4/MW
30-Min SECR	15 MW	$4/MW
SR	10 MW	$4/MW

	Online?	10-Min RUR	30-Min RUR	30-Min SECR	SR
R1	Yes	9 MW	6 MW	0 MW	1 MW
R2	No	0 MW	0 MW	0 MW	0 MW
R3	Yes	0 MW	9 MW	15 MW	9 MW

In this second scenario, assume that R2 becomes unavailable in real-time due to an unplanned outage, and so R3 is called online to provide online reserves. As a result, the reserve clearing prices increase.

Scenario 2 R1 Reserve Settlement

	Day-Ahead Market			Real-Time Market		
	Reserve Assignment	Clearing Price	Revenue	Reserve Assignment	Clearing Price	Revenue
DASR	0 MW	$1/MW	$0	N/A	N/A	$0
Energy Gap	14 MW	$3/MW	$42	N/A	N/A	$0
10-Min RUR	9 MW	$3/MW	$27	9 MW	$4/MW	$0
30-Min RUR	5 MW	$3/MW	$15	6 MW	$4/MW	$4
30-Min SECR	0 MW	$1/MW	$0	0 MW	$4/MW	$0
SR	0 MW	$3/MW	$0	1 MW	$4/MW	$4
		Total	**$84**		**Total**	**$8**

- R1 is available to provide energy or reserves at the level cleared day ahead, and therefore meets its Energy Gap reserve obligations
- R1's reserve assignments increase in real-time given the loss of R2, yielding it an additional $8 in reserve revenue in the real-time market and resulting in a total revenue of **$92**.

Scenario 2 R2 Reserve Settlement

	Day-Ahead Market			Real-Time Market		
	Reserve Assignment	Clearing Price	Revenue	Reserve Assignment	Clearing Price	Revenue
DASR	0 MW	$1/MW	$0	N/A	N/A	$0
Energy Gap	20 MW	$3/MW	$60	N/A	N/A	($80)
10-Min RUR	0 MW	$3/MW	$0	0 MW	$4/MW	$0
30-Min RUR	10 MW	$3/MW	$30	0 MW	$4/MW	($40)
30-Min SECR	0 MW	$1/MW	$0	0 MW	$4/MW	$0
SR	10 MW	$3/MW	$30	0 MW	$4/MW	($40)
		Total	**$120**		**Total**	**($160)**

- R2 is unavailable to provide energy or reserves at the level cleared day ahead and therefore does not meet its Energy Gap reserve obligations. It is assessed a penalty of the greater of 1.25 times the day-ahead reserve market clearing price ($3.75/MW) or the real-time 30-Min RUR market clearing price ($4/MW).

- R2 has to buy out of its day-ahead 30-Min RUR and SR assignments at the real-time market clearing prices, resulting in a charge of $160, which nets with its day-ahead review to a total of **($40)**.

Scenario 2 R3 Reserve Settlement

	Day-Ahead Market			Real-Time Market		
	Reserve Assignment	**Clearing Price**	**Revenue**	**Reserve Assignment**	**Clearing Price**	**Revenue**
DASR	50 MW	$1/MW	$50	N/A	N/A	$0
Energy Gap	0 MW	$3/MW	$0	N/A	N/A	$0
10-Min RUR	0 MW	$3/MW	$0	0 MW	$4/MW	$0
30-Min RUR	0 MW	$3/MW	$0	9 MW	$4/MW	$36
30-Min SECR	15 MW	$1/MW	$15	15 MW	$4/MW	$0
SR	0 MW	$3/MW	$0	9 MW	$4/MW	$36
		Total	**$65**		**Total**	**$72**

- R3 is available to provide energy or reserves at the level cleared day ahead and therefore meets its DASR obligations.
- R3's reserve assignments increase in real-time given the loss of R2, yielding it an additional $72 in reserve revenue in the real-time market and resulting in a total revenue of **$137**.

Notes on Settlement Outcomes

- PJM recognizes that under this paradigm, resources would not always be indifferent to clearing for a day-ahead-only reserve product vs. a product that carries in real-time, namely because a resource with a day-ahead-only reserve assignment could clear for reserves in the real-time market and earn that additional revenue.
- This difference could be reflected in how resources offer into the reserve markets. However, PJM also recognizes that creates some additional complexity in how resources offer day-ahead.
- Another option could be to nest the 30-Min RUR, 30-Min SECR, Energy Gap and DASR products, which would be possible because the duration requirement currently contemplated for all four products would be the same (i.e., four hours).
- This nesting could result in more 30-Min RUR and 30-Min SECR being cleared day-ahead than in real-time, which would need to be considered in the design. The ORDCs for the products might also need to be updated to reflect the nesting. However, PJM is considering this as an alternative and will come back with some more discussion and examples in a future meeting.

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Updates and Clarifications to PJM's Proposed Solution Options

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Acronyms

Acronym	Term & Definition
DASR	**Day-Ahead Scheduling Reserves** are reserves procured day ahead to manage day-ahead uncertainties.
SR	**Synchronized Reserves** are reserves provided by resources that are synchronized to the grid and can respond within 10 minutes.
PR	**Primary Reserves** are reserves provided by resources that are either synchronized or not synchronized to the grid and can respond within 10 minutes.
RUR	**Ramping/Uncertainty Reserves** are reserves that would be procured to manage forecasted ramp and uncertainty operational flexibility needs.
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).

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