



Reserve Price Formation: Implementation

May 27, 2022

Special Session of the Market
Implementation Committee

Overview

- Offer and Capability Business Rules
- DA/RT Product Alignment
- Tier 1/Tier 2 Consolidation
- Flexible Reserve Subzones
- Price Capping
- Q/A

PJM has made all efforts possible to accurately document all information in this presentation. The information seen here does not supersede the PJM Operating Agreement or the PJM Tariff or any pending FERC Filings or Orders.

Effective October 1, 2022 several aspects to the PJM Reserves market will change

Result of Reserve Price Formation efforts, 2018 to-date

The intent of this special session is to:

Refresh understanding of new terminology and concepts

Ensure awareness of business rule changes and impacts

Create opportunity for clarifying questions

Informing Manual language is not part of this session – will be presented through normal process beginning in July

Markets Gateway changes are not part of this session

- Changes presented at a Tech Change Forum Special Session – New Reserve Market Changes on 5/13/2022
- Link to the education materials provided below

<https://pjm.com/-/media/committees-groups/forums/tech-change/2022/20220513-special/20220513-reserve-price-formation-markets-gateway-education.ashx>

Reserve Capability and Offer Rules

Generation Resources and Economic Load Response resources are eligible to provide Reserves except if:

The resource is not within the metered boundaries of PJM
The entire output is offered as Emergency Only
The resource type includes: Nuclear, Wind, or Solar

Nuclear, Wind and Solar resources may seek to be deemed eligible by PJM and IMM

Must submit written request to PJM and IMM containing documentation to support the resource's ability to follow dispatch

Ex/ Historical operating data showing voluntary response to reserve events and/or technical information about the physical operation of the resource

Resource will be notified within 30 business days

All generation resources that have submitted energy offers and are eligible to provide reserves will be considered as offered into the reserve market

This excludes Hydro and Energy Storage Resources who must submit specific reserve offers to be considered.

Generation resources with a Capacity commitment (RPM or FRR) that are capable of providing Reserves must offer their 10-minute and 30-min capability

Reserve offers for Generation resources consist of:

Availability	Set through Energy Offer (except for ESR/Hydro and Load Response Resources who must specify separately)
MW	Calculated using Energy offer parameters (as detailed on “Calculated Capability” slide)
Price	SR offer price must be cost-based, capped at the Expected Value of Synchronized Reserve Penalty
	NSR and Secondary Reserve offer price is \$0/MWh

Offer parameters can vary hourly, as today, and include: ramp rate, eco min, lesser of Synch/Secondary max and Eco max, condense to generate time (if applicable)

A resource's choice to self-schedule or provide fixed output does not alter its capability to provide reserves. Self-scheduled units must provide reserves like all other online generating resources

PJM will calculate a self-scheduled/fixed output unit's reserve capability using the lesser of synch max or eco max, and the unit's 10 minute ramping capability, consistent with the calculations for PJM-scheduled resources

If a resource that has a reserve must offer requirement chooses to not make its reserve capability available, for example through self-scheduling or offering a fixed output, **when the resource is otherwise able to operate with a dispatchable range**, the resource is defined to be violating the reserve must offer requirement

The maximum level of synchronized reserve offers will be modified:

The Variable Operations & Maintenance component was removed from SR offers as part of the Reserve Price Formation filing.

The existing \$7.50/MWh offer margin will be reduced to the expected value of the penalty

The expected value takes into account the actual penalty, as well as the probabilities that a resource will underperform and that a synchronized reserve event will occur:

$$\text{Expected Value of Synchronized Reserve Penalty} = \text{Average Penalty Rate (\$/MWh)} * \text{Probability of an event} * \text{Probability of underperformance}$$

At the time of implementation of this rule the expected value of the penalty shall be \$0.02/MWh, and for the period from the second month after implementation through the second January 1 following such date of implementation, the expected value of the penalty shall be recalculated on a monthly basis using data from the implementation date of this rule through the 15th day of the current month, and the revised value shall be effective the 1st day of the following month. Values will be communicated through the CDS and will be capped in Markets Gateway.

Reserve Market	Resource Type					
	Condensers	Other Gen*	Wind/Solar/ Nuclear	ESR/Hydro**	Load Response	
SR	Set Through Energy Offer			Yes, submit in Markets Gateway		
NSR				ESR is unavailable for NSR. Yes for Hydro		No - LR ineligible for NSR
SecR				Yes, submit in Markets Gateway		

*Non-Capacity Resources must be located internal to PJM

**ESR refers to resources utilizing the ESR participation model

Option	Reserve Market	Resource Type				
		Condensers	Other Gen	Wind/Solar/ Nuclear	ESR/Hydro	Load Response
Self-Schedule Eligibility	SR	Yes				
	NSR	No				
	SecR	No				
Entering Self-Schedule MWs	SR	No, use PJM calculated capability			Yes, use Offer MW	
	NSR	N/A				
	SecR	N/A				

Parameter	Reserve Market	Resource Type				
		Condensers	Other Gen	Wind/Solar/ Nuclear	ESR/Hydro	Load Response
SR/SecR Max*	SR	Yes, if qualified via existing process				N/A
	NSR	N/A				
	SecR	Yes, if qualified via existing process				N/A
Offer MW	SR	No	No	No	Yes	Yes
	NSR	N/A			Yes (N/A ESR)	N/A
	SecR**	No	No	No	Yes	Yes
Offer Price	SR	Yes, cannot exceed expected value of penalty				
	NSR	N/A				
	SecR	N/A				

*SR Max and SecR Max are both able to be updated intra-hour; requests must be sent and approved by PJM and IMM

**Offer MW can be updated up to 65 mins prior to start of operating hour

If a resource cannot, due to physical characteristics, reach its Eco Max within 10 (Synch) or 30 (Secondary) minutes, it may submit documentation to be reviewed with a lower max capability

- Hourly ramp rates must be updated regularly to account for latest ambient conditions, etc.

All resource-specific documentation must be sent to the IMM and PJM for review

If approved, Synch Max or Secondary Max below Eco Max may be submitted in Markets Gateway

Reserve Market	Resource Type				
	Condensers	Other Gen	Wind/Solar/ Nuclear	ESR/Hydro	Load Response
SR	Based on the following offer parameters submitted as part of the resource's energy offer: (A) ramp rate; (B) condense to generation time constraints; (C) Economic Minimum; and (D) the lesser of Economic Maximum and Synchronized Reserve Maximum	Based on the resource's initial energy output and the following offer parameters submitted as part of the resource's energy offer (A) ramp rate; (B) Economic Minimum; and (C) the lesser of Economic Maximum and Synchronized Reserve Maximum MW		Use SR Offer MW Constrained by Eco Limits	
NSR	Based on the following offer parameters submitted as part of the resource's energy offer: (A) startup time; (B) notification time; (C) ramp rate; (D) Economic Minimum; and (E) the lesser of Economic Maximum and Synchronized Reserve Maximum MW,			Use NSR Offer MW for Hydro Constrained by Eco Limits	No - LR ineligible for NSR



Calculated Capability – Secondary Reserves

Reserve Market	Resource Type				
	Condensers	Other Gen	Wind/Solar/ Nuclear	ESR/Hydro	Load Response
SecR	<p>Based on the following offer parameters submitted as part of the energy offer:</p> <ul style="list-style-type: none"> (A) ramp rate; (B) condense to generation time constraints; (C) Economic Minimum; and (D) the lesser of Economic Maximum and Secondary Reserve Maximum MW 	<p>Online Resources: Based on the resource’s initial energy output, the resource’s available Synchronized Reserve capability; and the following offer parameters submitted as part of the energy offer: (A) ramp rate; (B) Economic Minimum; and (C) the lesser of Economic Maximum and Secondary Reserve Maximum MW</p> <p>Offline Resources: Based on the resource’s available Secondary Reserve capability and the following offer parameters submitted as part of the resource’s energy offer: (A) startup time; (B) notification time; (C) ramp rate; (D) Economic Minimum; and (E) the lesser of Economic Maximum and Secondary Reserve Maximum MW</p>		<p>Use SecR Offer MW Constrained by Eco Limits</p>	

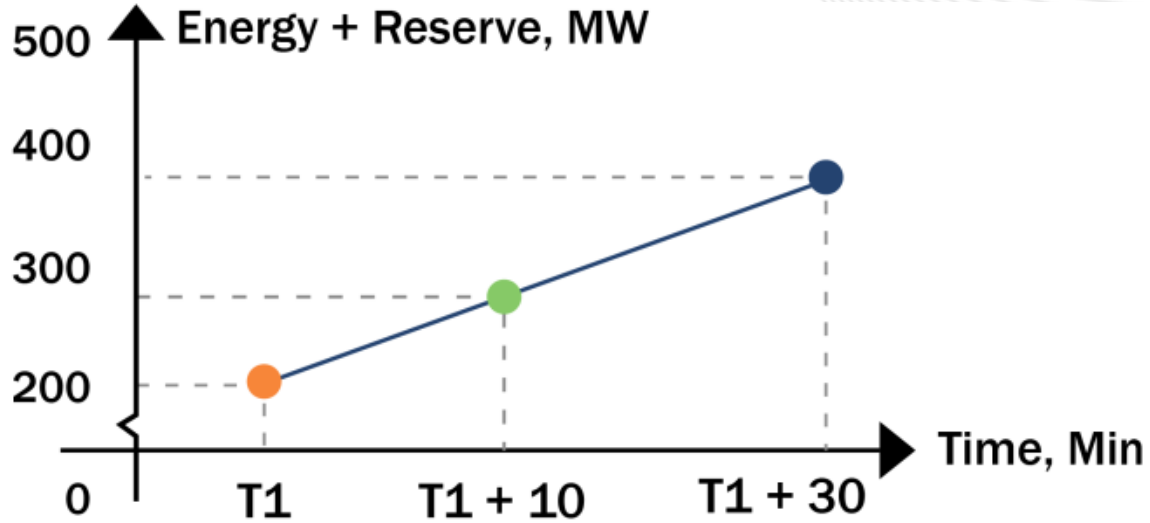
Resources available to provide 30-Min reserve

- Online and Offline resources within RTO that are available to provide energy;
- Nuclear, Wind and Solar are not eligible, unless approved with exception;

Reserve offer MW is not allowed for conventional units. PJM calculates SR, NSR and SecR capability using ramp rate, startup/notification time, Eco limits (Synch/Secondary max), and dispatch MW.
Examples to follow.

Hydro, Energy Storage, Load Response – allow to submit reserve MW offer as their reserve capability. These resources are self-committed for energy and PJM also may not capture all the parameters (e.g. battery state of charge) necessary to accurately calculate the reserve capability.

Reserve MW Calculation Example from an Online Unit



Unit A

STATUS: Online 200 MW		STARTUP TIME: 5 Min	NOTIFICATION TIME: 0 Min
ECOMIN: 100 MW	ECOMAX: 600 MW	RAMP RATE (RR): 5 MW/Min	

$$SR = \min[EcoMax - MW, RR * 10]$$

$$= \min[600 - 200, 5 * 10]$$

$$= \min[400, 50]$$

$$= \mathbf{50 MW}$$

$$SecR = \min[EcoMax - MW, RR * 30] - SR$$

$$= \min[600 - 200, 5 * 30] - 50$$

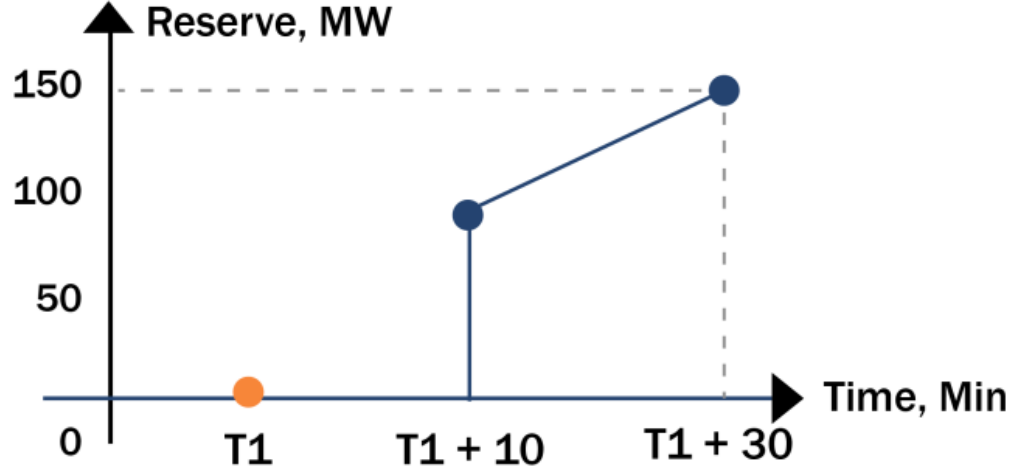
$$= \min[400, 150] - 50$$

$$= 150 - 50$$

$$= \mathbf{100 MW}$$



Reserve MW Calculation Example from an Offline Unit



Unit A

STATUS: Offline 0 MW		STARTUP TIME: 5 Min	NOTIFICATION TIME: 2 Min
ECOMIN: 50 MW	ECOMAX: 150 MW	RAMP RATE (RR): 10 MW/Min	

$$\text{NSR} = \min[\text{EcoMax}, \text{EcoMin} + (10 - \text{StartTime} - \text{NotifTime}) * \text{RR}]$$

$$= \min[150, 50 + (10 - 5 - 2) * 10]$$

$$= \min[150, 50 + 3 * 10]$$

$$= \min[150, 80]$$

$$= \mathbf{80 \text{ MW}}$$

$$\text{SecR} = \min[\text{EcoMax}, \text{EcoMin} + (30 - \text{StartTime} - \text{NotifTime}) * \text{RR}] - \text{NSR}$$

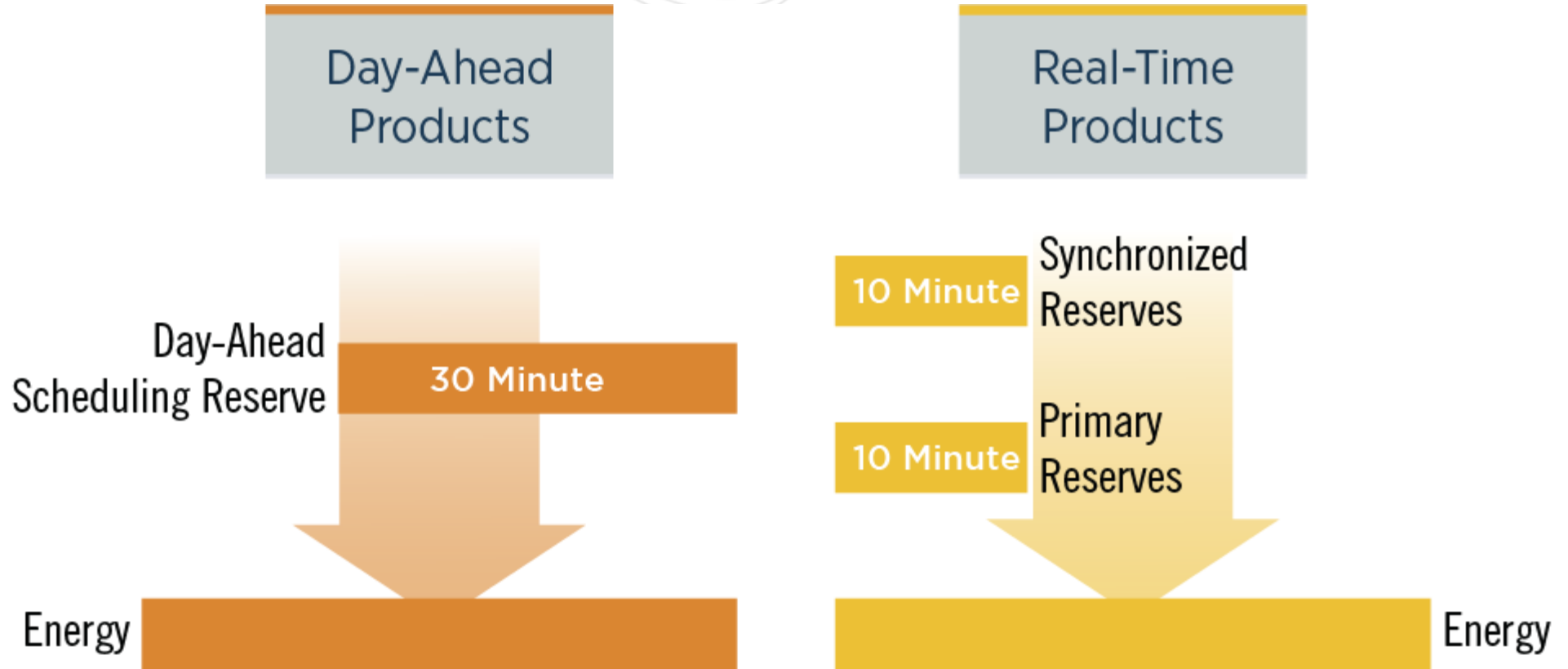
$$= \min[150, 50 + (30 - 5 - 2) * 10] - 80$$

$$= \min[150, 280] - 80$$

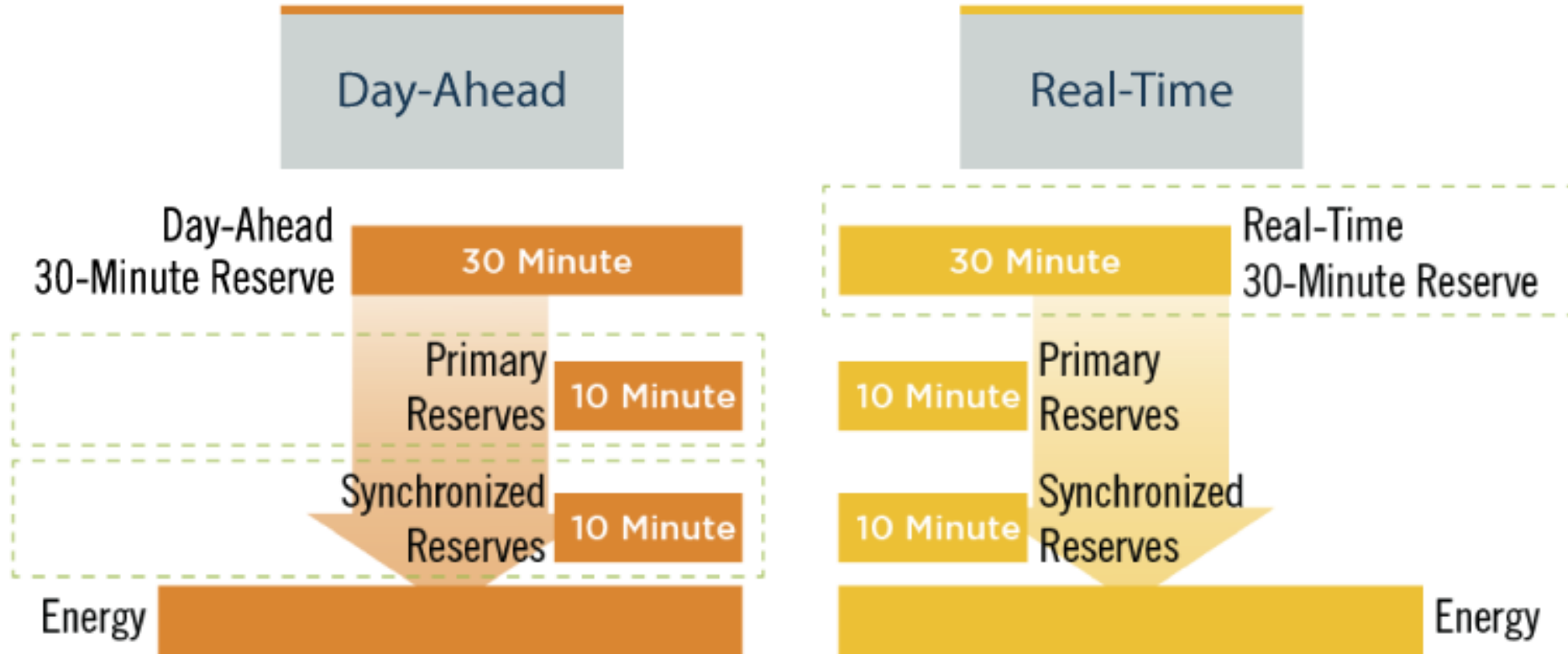
$$= 150 - 80$$

$$= \mathbf{70 \text{ MW}}$$

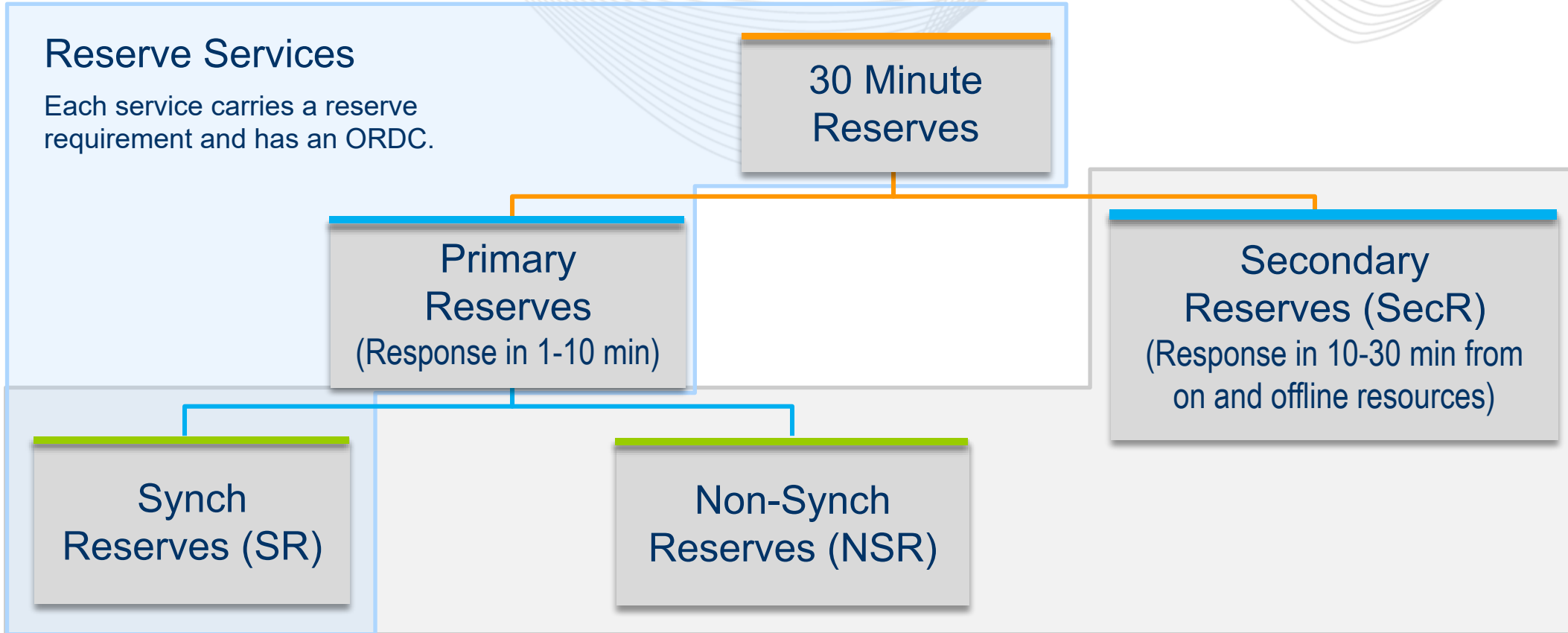
Reserve Market Alignment – RT/DA



Day-Ahead and Real-Time Reserve Alignment



Solidify financial incentives to provide reserves when assigned due to day-ahead financial commitment.
Remove modeling differences between Day-Ahead and Real-Time Energy Markets.



<p>Clearing Price represents procurement of the Synch Reserve requirement</p>	<p>Clearing price represents procurement of the balance of the Primary Reserve Requirement not met by Synch Reserves</p>	<p>Clearing price represents procurement of the balance of the 30 Min Requirement not met by Synch and Non-Synch Reserves</p>
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Reserves and energy will be co-optimized the same way in DA and RT

- The two-stepped ORDC will be implemented in DA and RT: generally, same reserve requirements; penalty factors will be identical for DA and RT
- Same reserve zone configuration in DA and RT unless there is an operational emergency requiring it to be changed in RT

There will be differences in cleared MW and prices between DA and RT markets

Condensers and Inflexible Economic Load Response resources that are cleared day-ahead will have their commitments carried to real-time

Need to have a min run time no greater than one hour and notification time between ten and thirty minutes

Commitment is carried over unless in real-time the resource is committed to provide energy or another reserve product

Consolidation of Tier 1 and Tier 2 Synchronized Reserve Products

Consolidation of Tier 1 and Tier 2 Synchronized Reserve products



Tier 1 Market Product

Remaining ramping capability on flexible dispatchable generation resources after economic dispatch



10-minute response time



Obligation to respond



Non-compliance penalty



Paid for response to an event

Vs.



Tier 2 Market Product

- Generation resources reduced from their economic set point
- Synchronous condensing resources and DR



10-minute response time



Obligation to respond



Non-compliance penalty



Paid market clearing price regardless of deployment

Tier 1 and Tier 2 reserve products will be consolidated into one, uniform, Synchronized Reserve product that is similar to Tier 2 today

This unified product will:

- Be obligated to respond to PJM instructions during a Synchronized Reserve Event
- Be compensated at the applicable clearing price for the assigned MW amount
- Face the existing penalty if the resource does not respond during an event

This proposed change is motivated by the need to enhance the accuracy of PJM's reserve measurements and the reliability of response in addition to creating comparable compensation for comparable service.

By applying these standards across all Synchronized Reserve resources, PJM expects the following benefits:

- More accurate reserve calculations that require less operator intervention
- More reliable reserve assignments that will improve Synchronized Reserve performance
- Consistent compensation and penalties for all resources providing the same service
- More accurate energy and reserve pricing due to improved Synchronized Reserve measurement

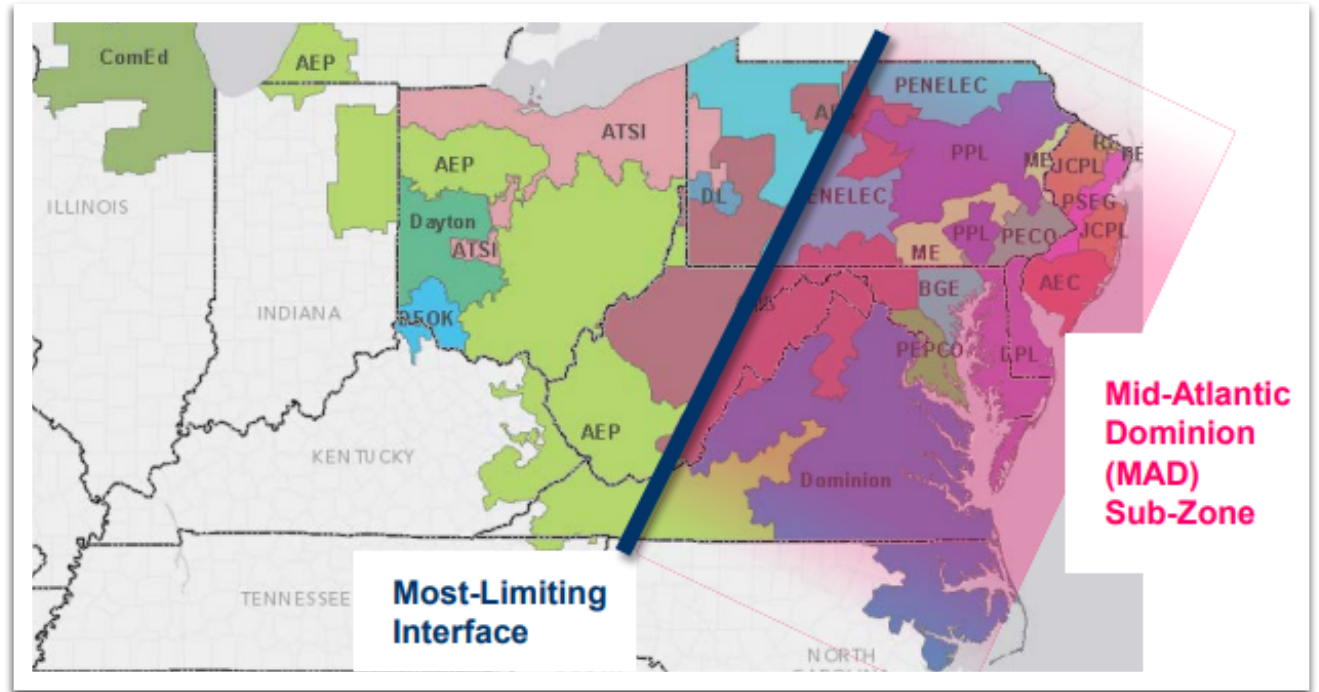


Reserves Flexible Subzone Modeling

Currently, PJM models two locations for the procurement of reserves:

- Each location has a Primary Reserve and Synchronous Reserve Requirement (MW)
- MAD reserve subzone and is defined by the most-limiting reactive transfer interface
 - Intent is to procure reserves that will not overload critical constraints when reserves are deployed during a synchronized reserve event

RTO
Mid-Atlantic Dominion (MAD)



The Reserve Price Formation implementation introduces the ability to have Flexible Reserve Subzones to:

More dynamically adjust the reserve subzone to better reflect system conditions

Better enable reliable operations and result in market results that are more consistent with system operations

Only one subzone will be active at any given time and will be communicated in the Markets Gateway application

New reserve subzones can be defined for constraints in these three categories:

Reactive transfer interfaces (AP South, BED-BLA, etc.)	230 KV or above actual overload constraint (i.e. Conastone-Peach Bottom 500kV actual overload)	Contingency overload exceeding the load dump limit on a 230kV or above facility
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New reserve subzones will be defined as far in advance as possible, and cannot be created on a same-day basis.

Reserve subzones will be defined as all buses that have a 3% or greater (raise-help) distribution factor on the associated transmission constraint

- Definitions will be posted on Ancillary Services page of pjm.com
- Reserve subzone definitions will be re-evaluated and published quarterly or coincides with the network model builds

A resource may belong to multiple Reserve Subzones

- Resources assigned Reserve subzone and active subzone will reflect in Markets Gateway

A new Reserve Subzone will be introduced with the Reserve Price Formation implementation: Baltimore, Pepco, Dominion (BPD)

BPD will only be used during the heavy North-South flow or during a specific transmission outage

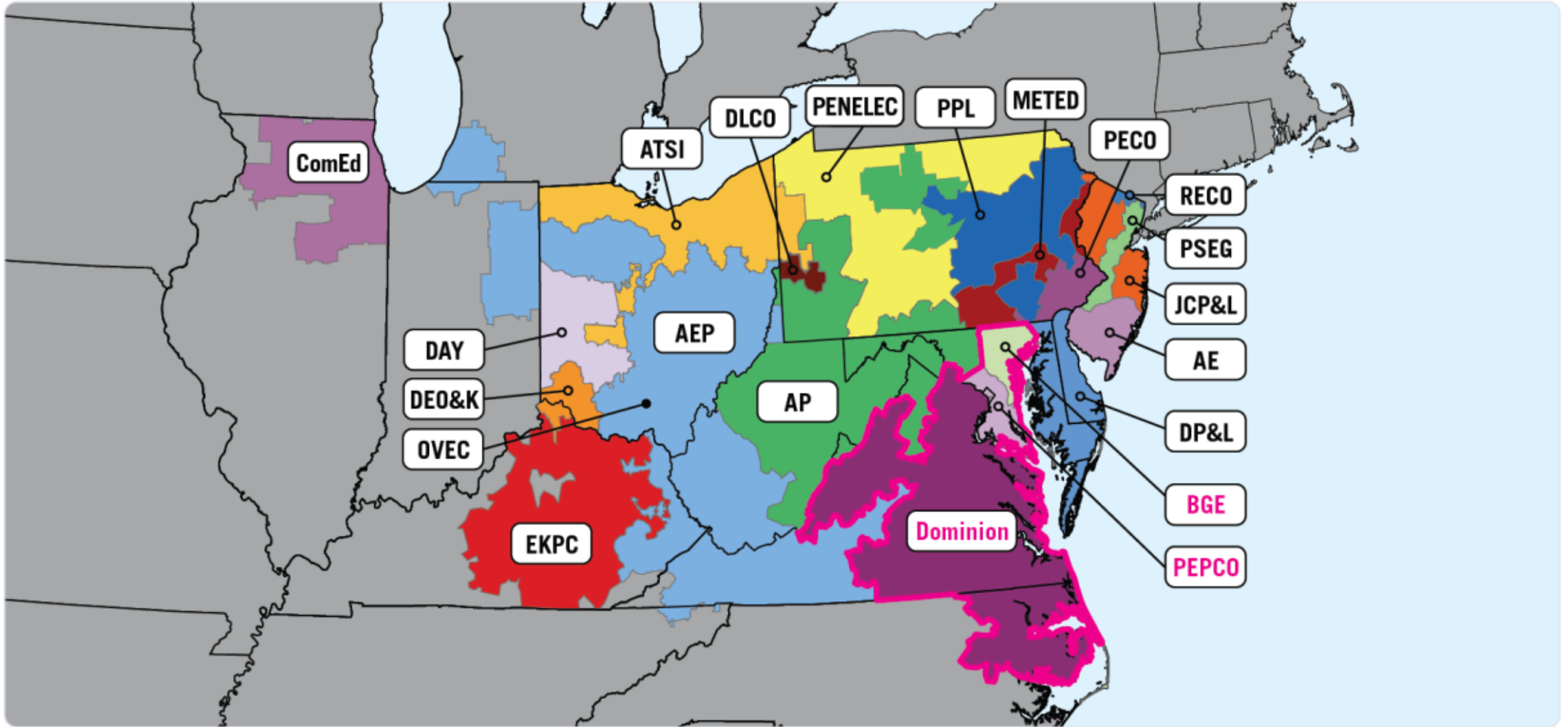
The resources included in the Reserve Subzone will be predefined

Predefined list available on the Ancillary Services page of pjm.com

The predefined list will be updated periodically, or at least every quarter to coincide with the network model update

MAD will remain the default subzone despite the new BPD subzone creation

Baltimore Pepco Dominion (BPD) Subzone



As system conditions dictate, PJM may need to update the active subzone in the Reserve Markets

Active subzone for an operating day will be communicated via Active Subzone screen in Markets Gateway

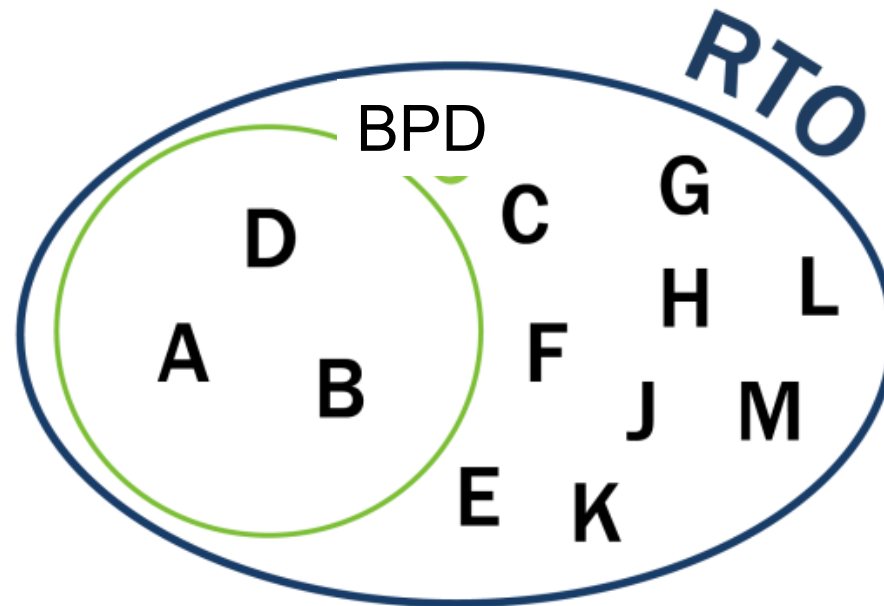
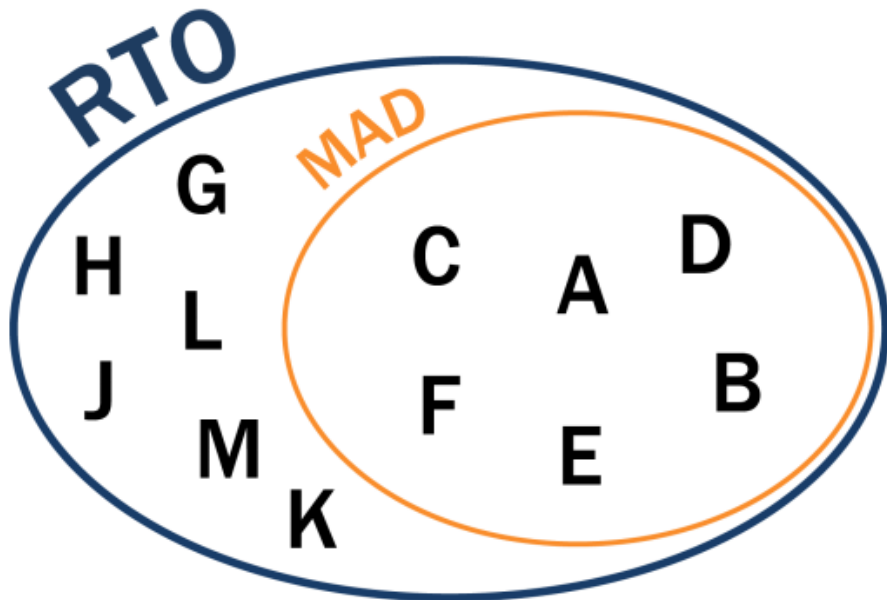
By default, the 30-Minute Reserve Market will not model an active Reserve subzone

On an as needed basis, due to gas contingencies or other operational conditions, PJM may model an active Reserve subzone requirement for 30 Minute Reserves

Activation of a Reserve subzone for 30-Minute Reserves will be done on a day ahead basis only

Subzones will be modeled on a day-ahead basis and will apply for the entire operating day

<ul style="list-style-type: none"> By default, the same subzone will be active in the Day-Ahead and Real-Time Markets 	<ul style="list-style-type: none"> Changes to the active reserve subzone can be made in real-time intraday on an exception basis 	<ul style="list-style-type: none"> Stakeholders will be notified of all intraday switches in the active reserve subzone via Markets Gateway 	<ul style="list-style-type: none"> Markets Gateway will reflect resource's assigned active subzone
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*A-M represent resource locations

Energy and Reserve Price Capping Rules

**Energy Component of LMP will be capped at the energy offer cap +
2 * Penalty Factor from first step of reserve ORDC**

Max Energy Component $\$2,000 + 2 * \$850 = \$3,700$

Total LMPs can still rise above this level when factoring in locational congestion and loss prices.

Administrative Energy Price cap will be applied in Pricing run only.

Administrative Reserve Price Capping will be implemented under Reserve Price Formation as below:

Synchronized Reserve Clearing price will be capped at 2*Penalty Factor	\$1,700
Primary Reserve Clearing price will be capped at 1.5*Penalty Factor	\$1,275
30 Min Reserve Clearing Price will be capped at 1*Penalty Factor	\$850

Administrative Reserve Price Capping will be implemented in pricing run only.

Next session scheduled for June 21st

- Focus will be on market settlement updates and follow up questions from today's session
- Manual first reads tentatively scheduled for July standing committee meetings (M-10, 11, 12, 13, 15, 18, 28, 29, 40)