

# Energy and Reserve Co-optimization and Pricing Impacts of Reserve Shortages

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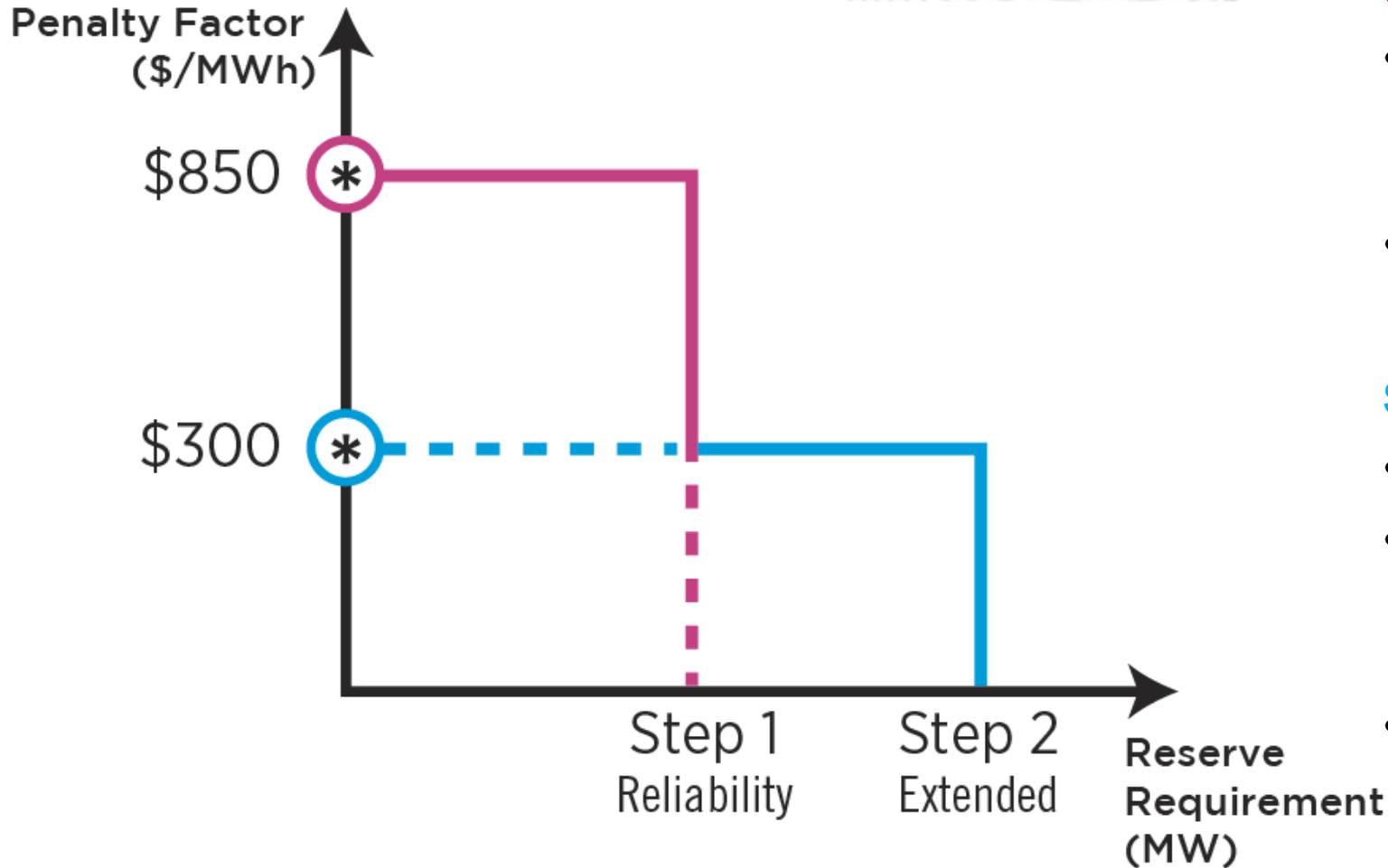
Market Design & Economics

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- The Real-Time Reserve markets are cleared using Operating Reserve Demand Curves (ORDCs).
- When the reserve requirement cannot be met, the reserve shortage is priced using the **penalty factor** from the ORDC.
- It sends a signal to market participants that as the reserve market clearing price reaches the penalty factor, reserve shortage may occur.

**Penalty Factor**  
Sets a price for being unable to meet the reserve requirement.



## Step 1 of the Demand Curve

- This represents the Reliability Requirement, which is generally the output of the largest online unit.
- The penalty factor for being short Step 1 is \$850/MWh.

## Step 2 of the Demand Curve

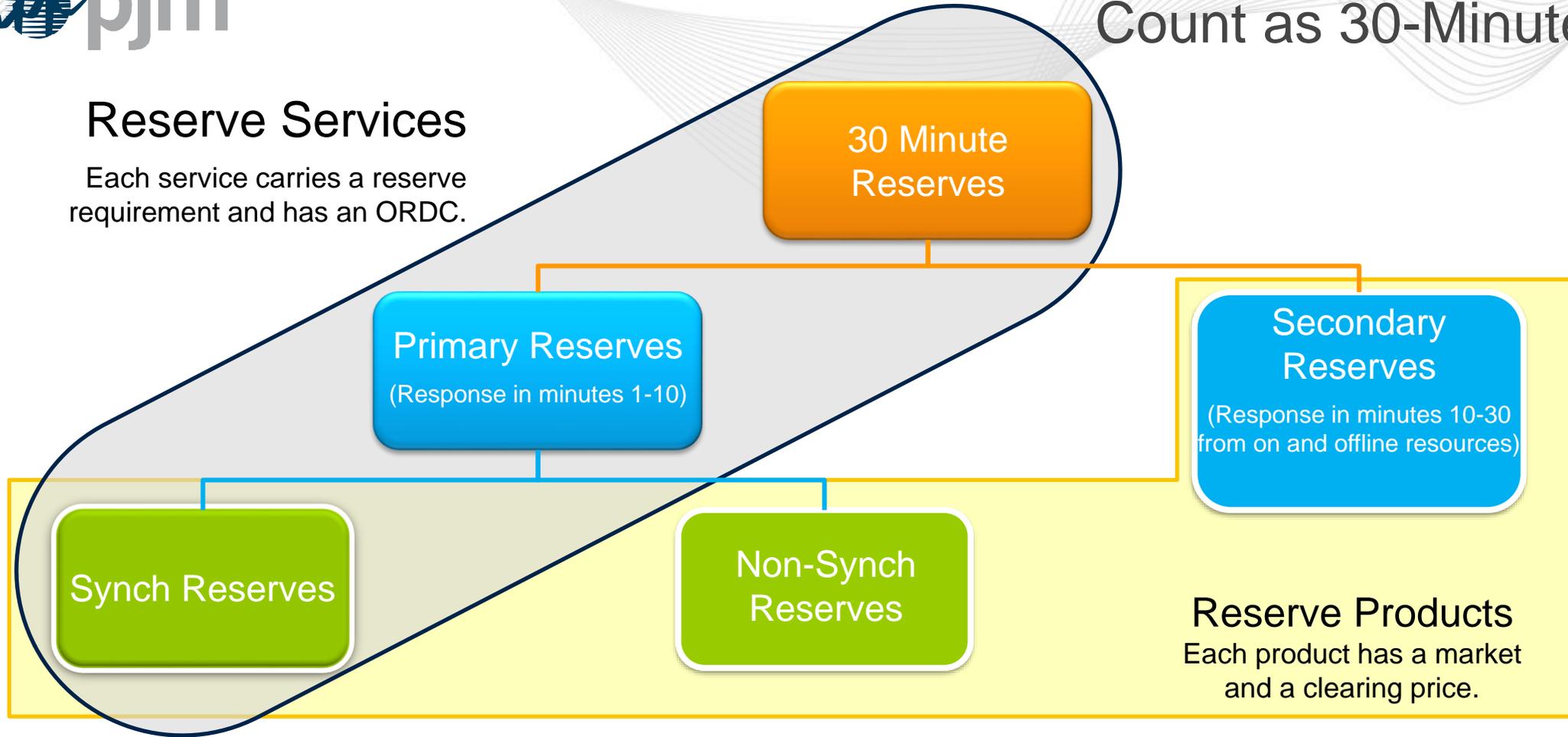
- Adds 190 MW to the Reliability Requirement
- Also includes an Optional Adder MW that can be used to capture additional reserves that are scheduled for reliability reasons
- The penalty factor for being short Step 2 is \$300/MWh.

# Reserve Product Interaction and Shadow Price Additivity

# Synchronized and Primary Reserves Count as 30-Minute Reserves

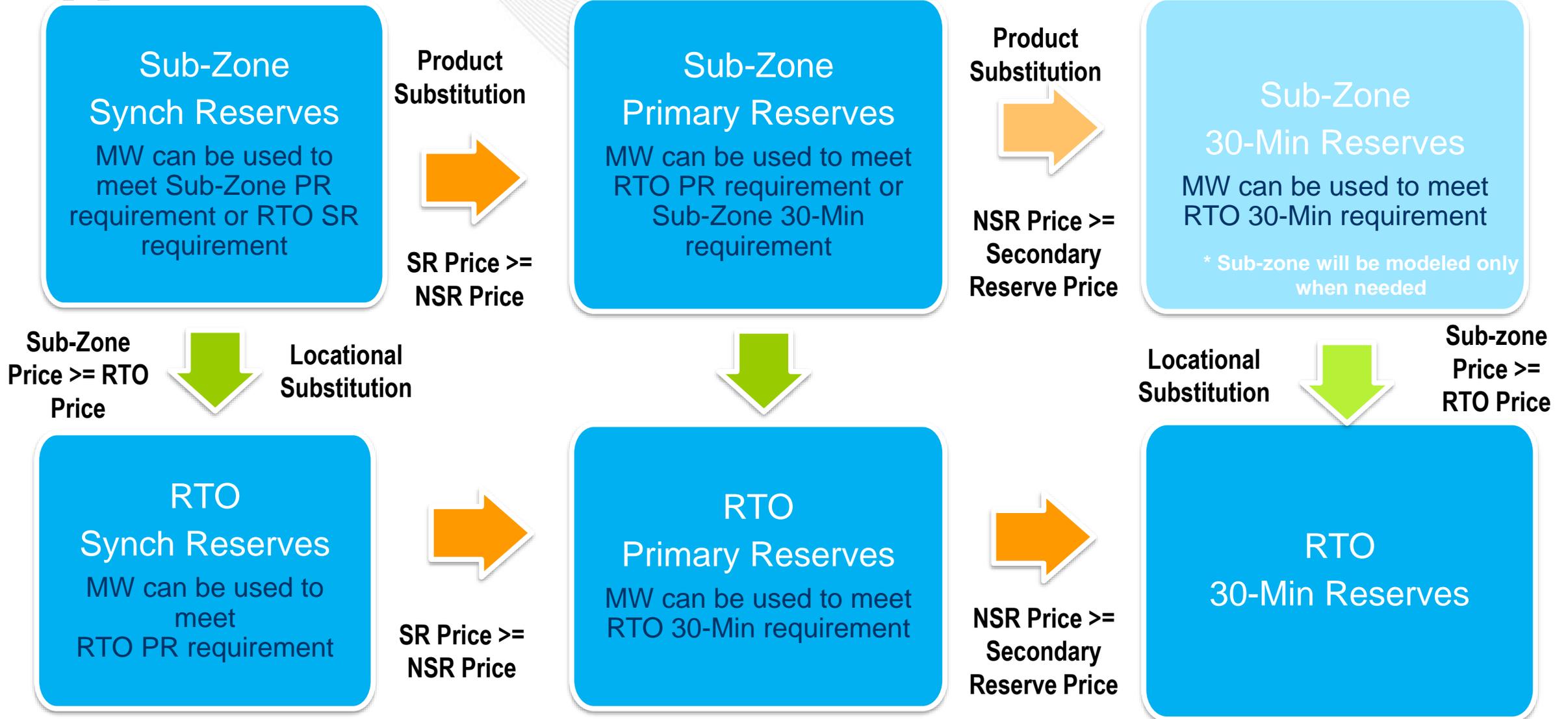
## Reserve Services

Each service carries a reserve requirement and has an ORDC.



- Clearing Price represents procurement of the Synch Reserve requirement
- Clearing price represents procurement of the balance of the Primary Reserve Requirement not met by Synch Reserves
- Clearing price represents procurement of the balance of the 30 Min Requirement not met by Synch and Non-Synch Reserves

# Reserve Substitution and Shadow Price Additivity



- The ORDC represents the reliability value of a single product in a single location
  - Five separate ORDCs will exist to model reserves for each product/location combination
    - A sixth ORDC will be created for Sub-Zone 30 Minute Reserves, but will only be modeled when operationally necessary due to gas contingencies or other conservative operations
- When there are multiple reserve products with substitution, the ability of one product to meet the requirement for another increases the reliability value of the “multi-purpose” reserve products
  - Prices are calculated by adding shadow prices from the co-optimization

# Examples – Co-Optimization of Energy and Reserve

- Sub-zone reserve requirements are not considered. Only RTO level reserve requirements are considered for simplicity.
- Energy dispatch time horizon is 5 minutes.
- All examples are for a snapshot of one RTSCED/LPC interval.
  - RTSCED/LPC only dispatches units and does not make any commitment decisions.
- Single step ORDCs with Penalty Cost of \$850.
- Ramp rates for all units are 1 MW/Min.
- Unit 3 has start-up plus notification time of 10 minutes

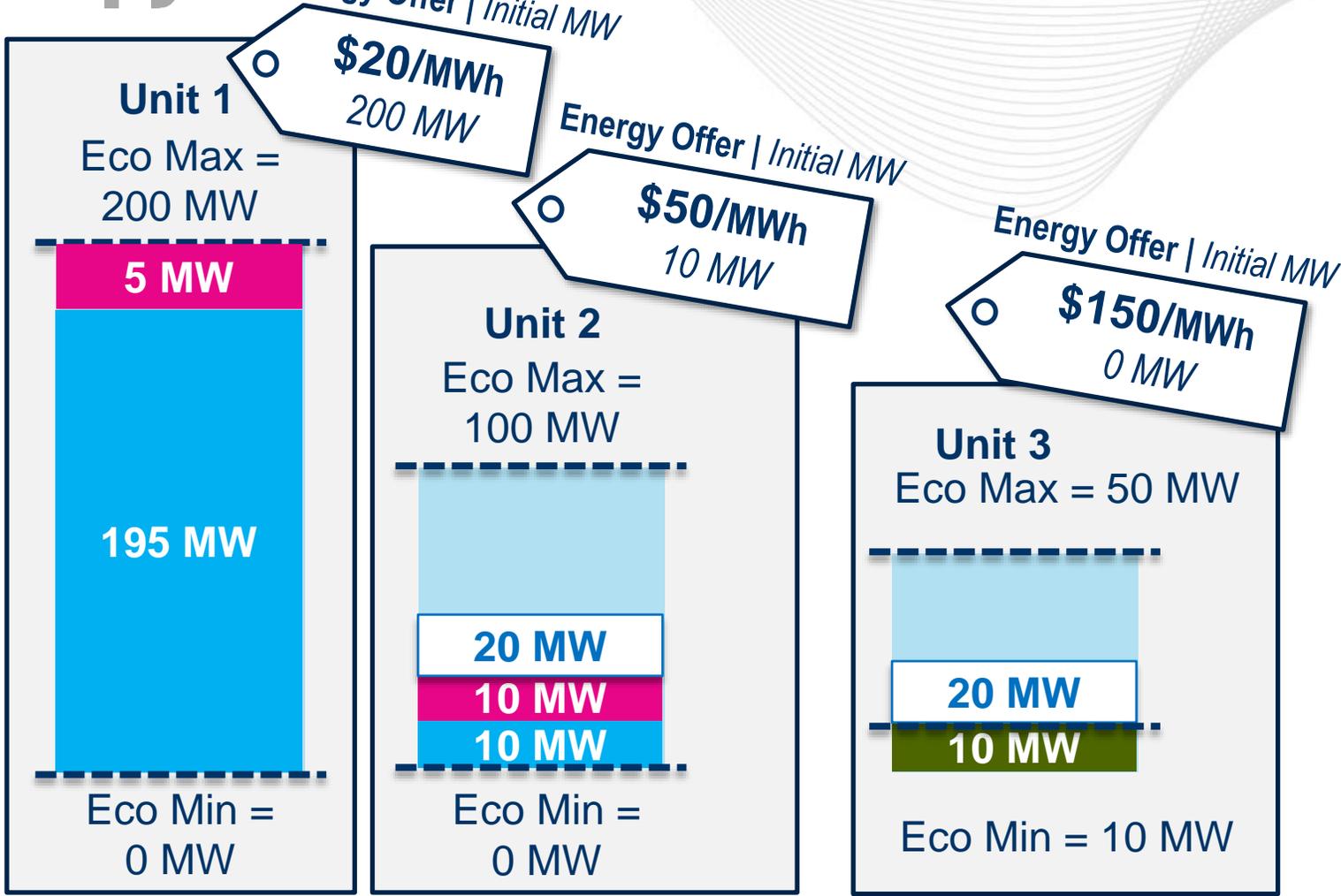


# Determination of Reserve Clearing Prices

Clearing Price		Calculation
<b>30-Minute Reserve</b>	=	Shadow Price of 30-Minute Reserve Requirement
<b>Non-Synchronized Reserve</b>	=	Shadow Price of Primary Reserve Requirement + Shadow Price of 30-Minute Reserve Requirement
<b>Synchronized Reserve</b>	=	Shadow Price of Synchronized Reserve Requirement + Shadow Price of Primary Reserve Requirement + Shadow Price of 30-Minute Reserve Requirement
<b>Energy Price</b>	=	Shadow Price of Power Balance Constraint (includes Synchronized Reserve clearing price if marginal Energy MW comes from converting Reserve into Energy)



# Example 1 - Shortage in SR with no effect on Energy Price



<b>Load</b>	205 MW
<b>SR Req.</b>	16 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	205	\$50	<b>\$50</b>
<b>Sync Res</b>	15	\$850	<b>\$850</b>
<b>Primary Res</b>	25	\$0	<b>\$0</b>
<b>30-Minute Reserve Req.</b>	65	\$0	<b>\$0</b>

**COLOR KEY:** ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared) ■ NSR (Cleared)



# Example 2 - Shortage in SR with Penalty cost reflected in Energy Price

Energy Offer | Initial MW

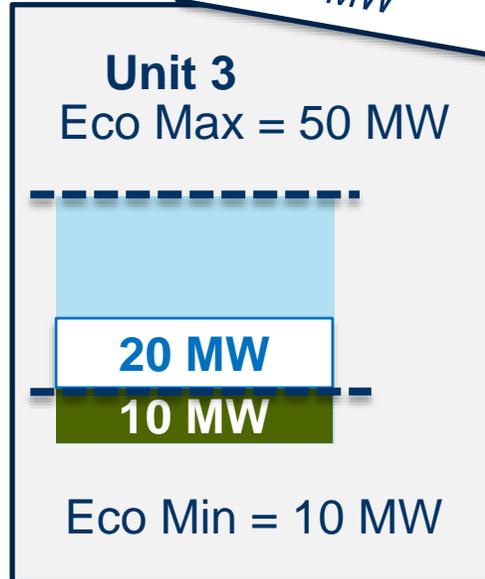
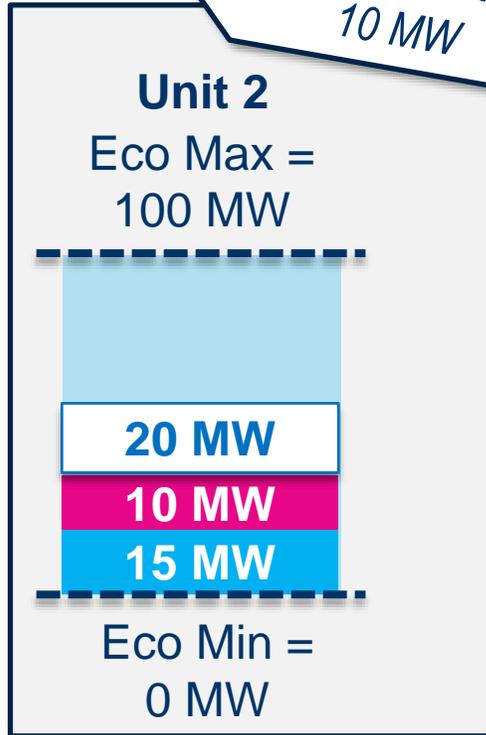
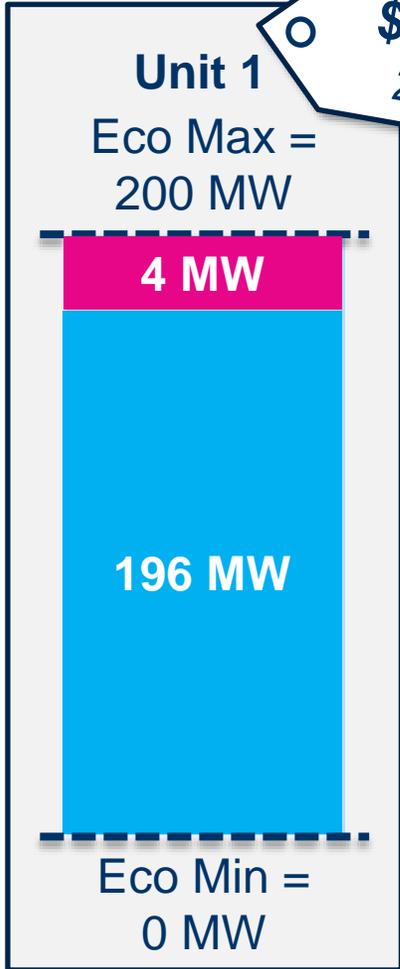
\$20/MWh  
200 MW

Energy Offer | Initial MW

\$50/MWh  
10 MW

Energy Offer | Initial MW

\$150/MWh  
0 MW

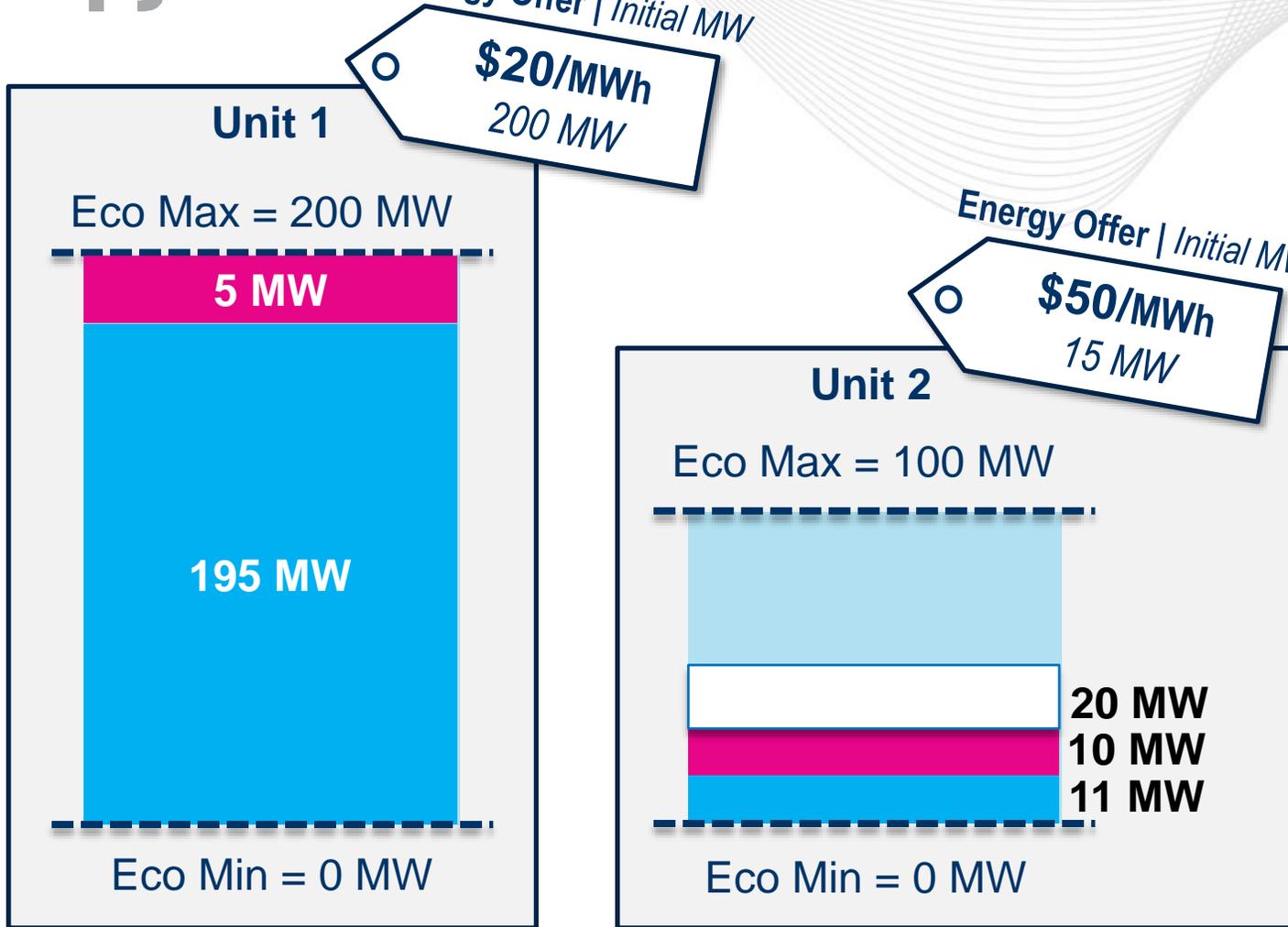


<b>Load</b>	211 MW
<b>SR Req.</b>	16 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$870	<b>\$870</b>
<b>Sync Res</b>	14	\$850	<b>\$850</b>
<b>Primary Res</b>	24	\$0	<b>\$0</b>
<b>30-Minute Reserve Req.</b>	64	\$0	<b>\$0</b>

COLOR KEY: ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)  NSR (Cleared)

# Example 3 - Shortage in PR with no effect on Energy Price



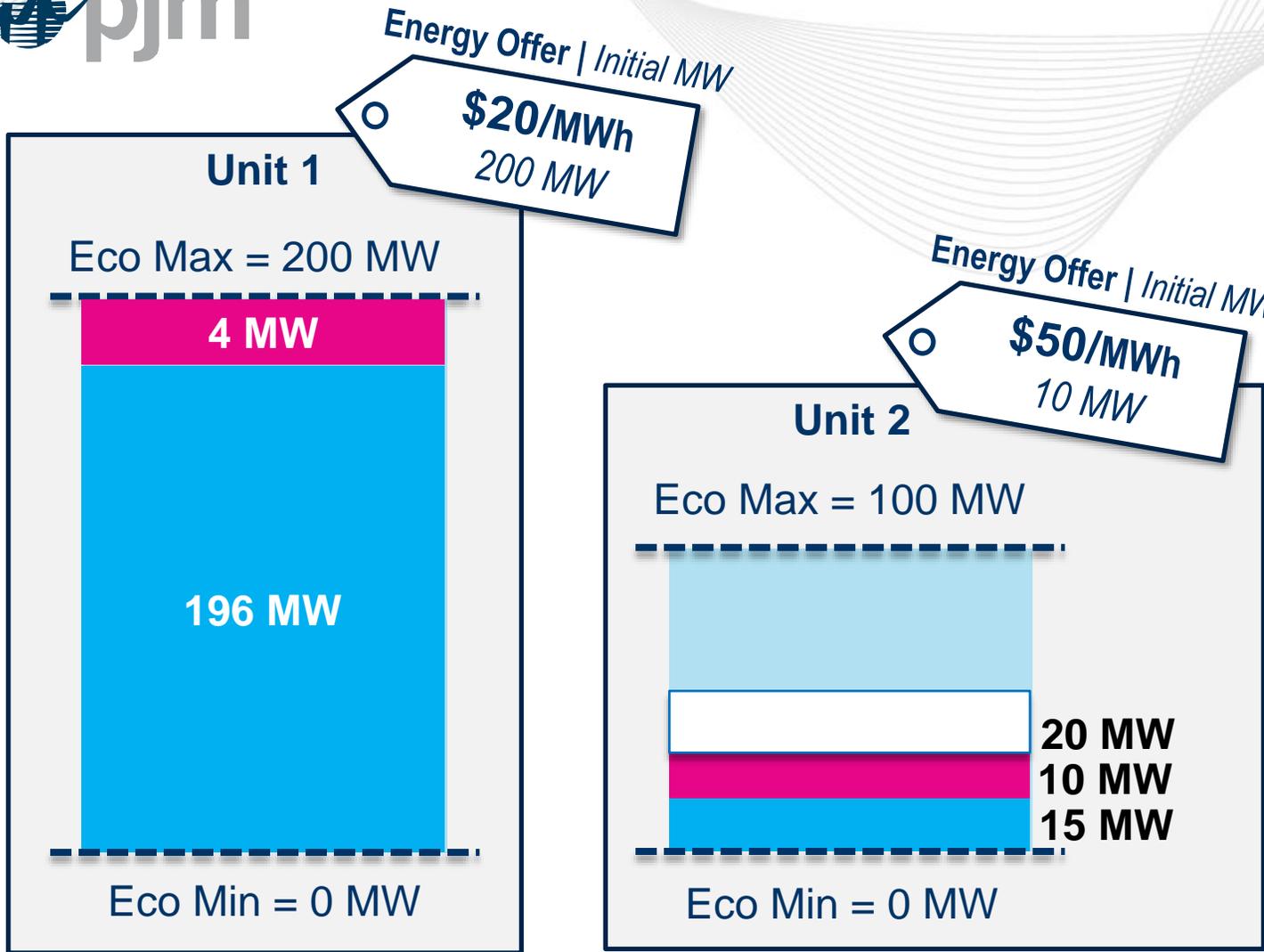
<b>Load</b>	206 MW
<b>SR Req.</b>	8 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	206	\$50	<b>\$50</b>
<b>Sync Res</b>	15	\$0	<b>\$850</b>
<b>Primary Res</b>	15	\$850	<b>\$850</b>
<b>30-Minute Reserve Req.</b>	35	\$0	<b>\$0</b>

**COLOR KEY:** ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)



# Example 4 - Shortage in PR with Penalty Cost reflected in Energy Price



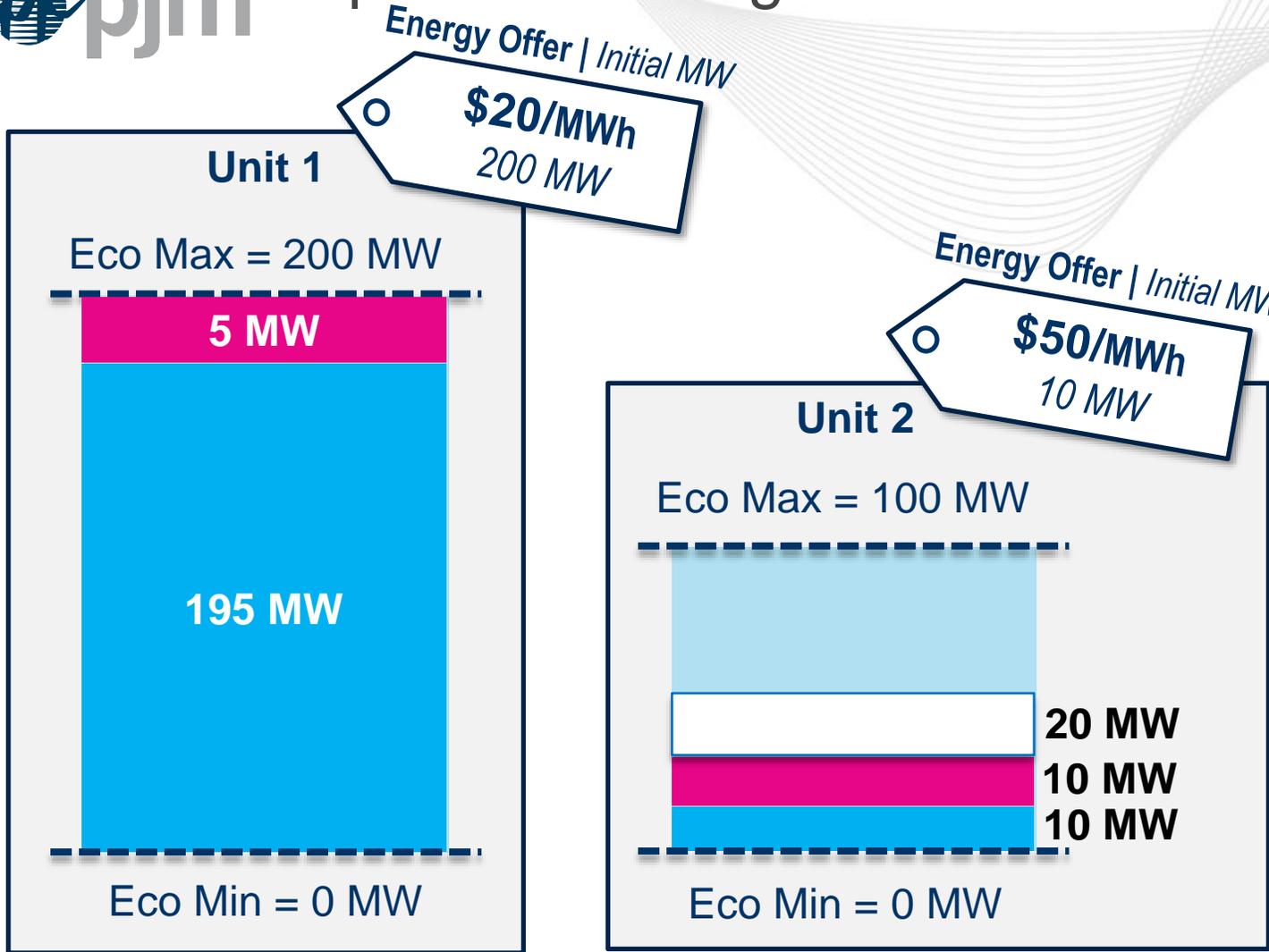
<b>Load</b>	211 MW
<b>SR Req.</b>	8 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$870	<b>\$870</b>
<b>Sync Res</b>	14	\$0	<b>\$850</b>
<b>Primary Res</b>	14	\$850	<b>\$850</b>
<b>30-Minute Reserve Req.</b>	34	\$0	<b>\$0</b>

**COLOR KEY:** ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)



# Example 5 - Shortage in SR & PR with no effect on Energy Price

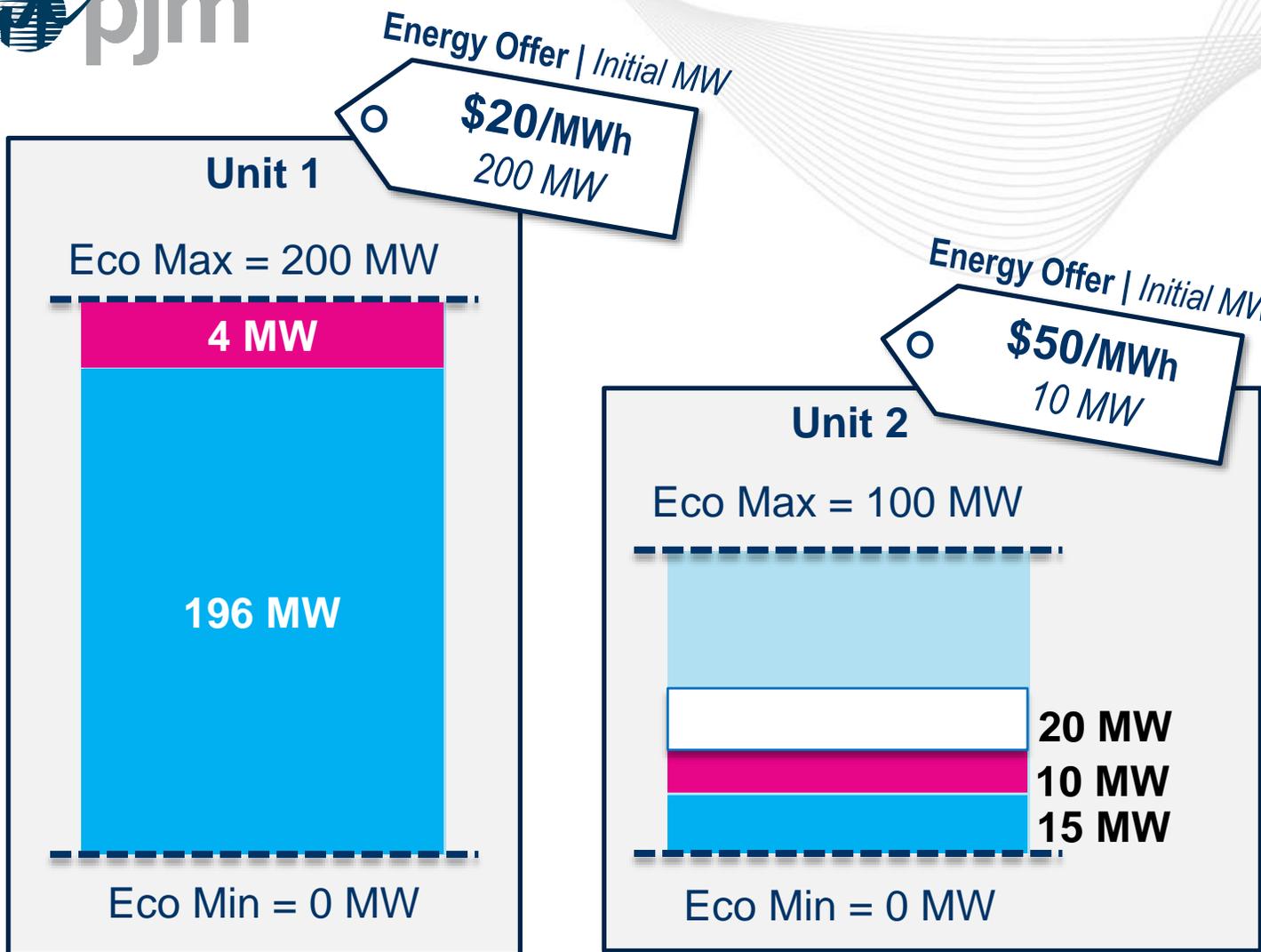


<b>Load</b>	205 MW
<b>SR Req.</b>	16 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	205	\$50	<b>\$50</b>
<b>Sync Res</b>	15	\$850	<b>\$1,700</b>
<b>Primary Res</b>	15	\$850	<b>\$850</b>
<b>30-Minute Reserve Req.</b>	35	\$0	<b>\$0</b>

COLOR KEY: ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)

# Example 6 - Shortage in SR & PR with Penalty cost reflected in Energy Price



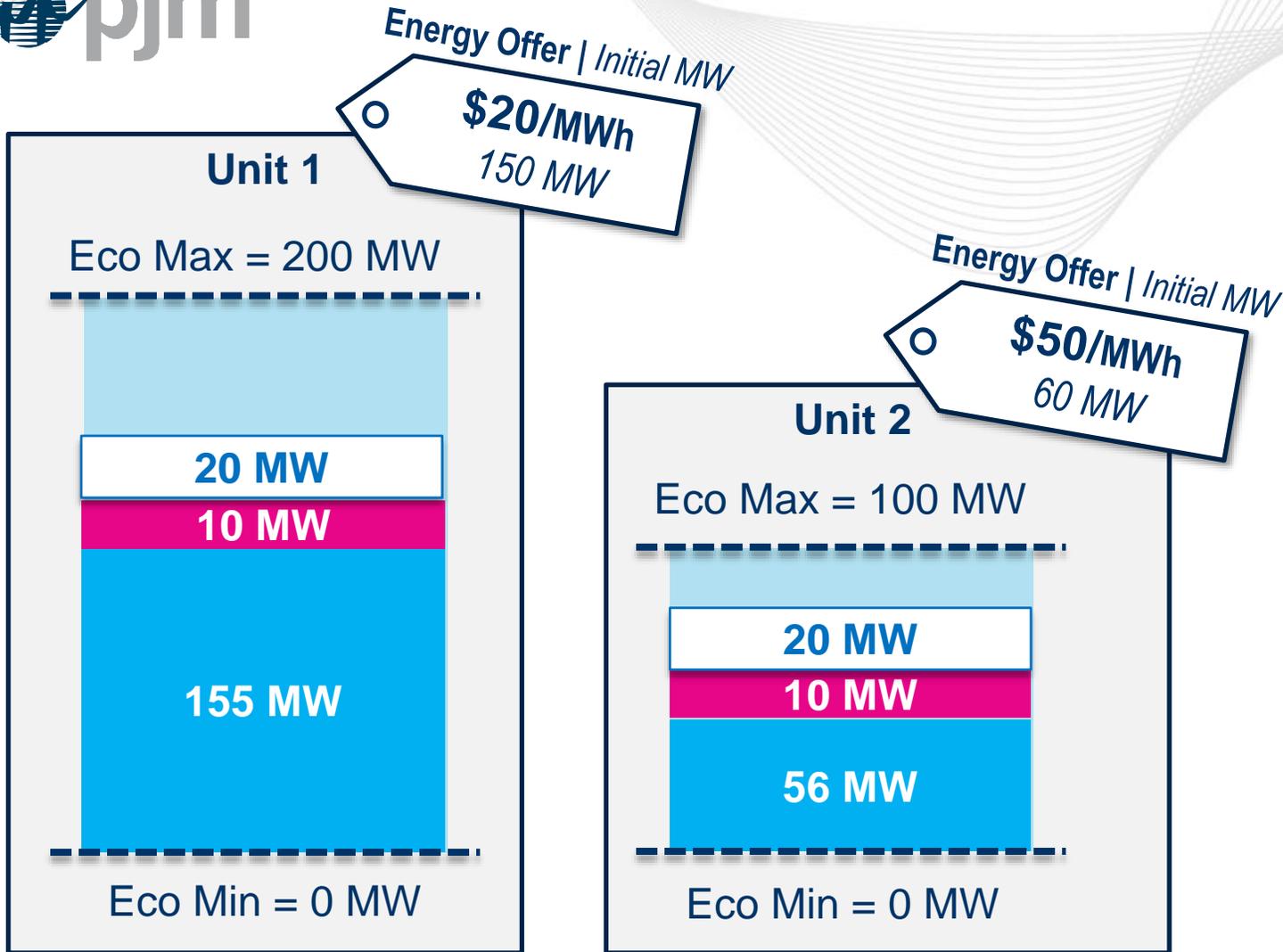
<b>Load</b>	211 MW
<b>SR Req.</b>	16 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$1,720	<b>\$1,720</b>
<b>Sync Res</b>	14	\$850	<b>\$1,700</b>
<b>Primary Res</b>	14	\$850	<b>\$850</b>
<b>30-Minute Reserve Req.</b>	34	\$0	<b>\$0</b>

**COLOR KEY:** ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)



# Example 7 - Shortage in 30 Min Reserve with no effect on Energy Price



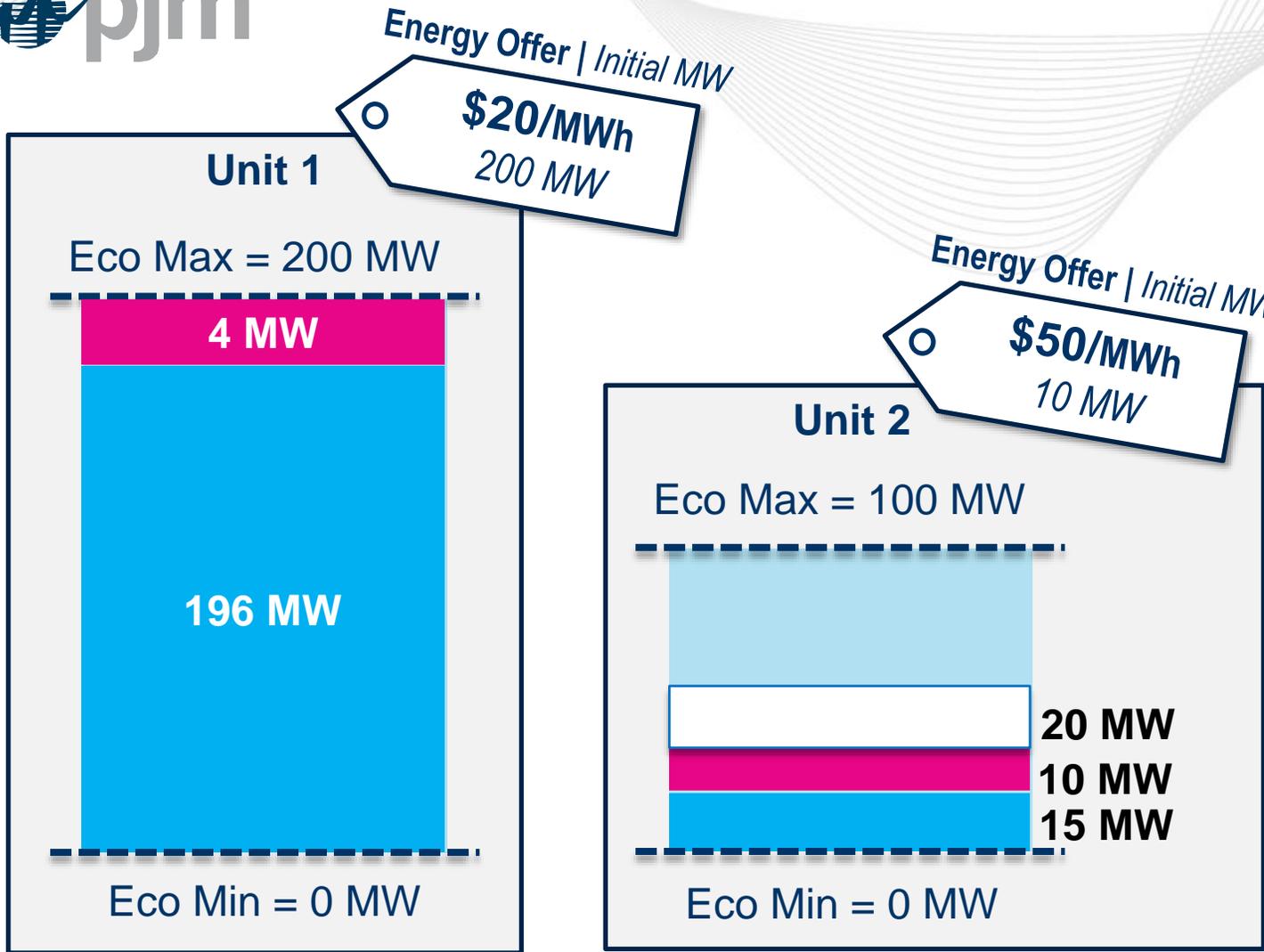
<b>Load</b>	211 MW
<b>SR Req.</b>	8 MW
<b>PR Req.</b>	12 MW
<b>30-Min Res Req.</b>	65 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$50	<b>\$50</b>
<b>Sync Res</b>	20	\$0	<b>\$850</b>
<b>Primary Res</b>	20	\$0	<b>\$850</b>
<b>30-Minute Reserve Req.</b>	60	\$850	<b>\$850</b>

COLOR KEY: ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)



# Example 8 - Shortage in 30 Min Reserve with Penalty cost reflected in Energy Price



<b>Load</b>	211 MW
<b>SR Req.</b>	8 MW
<b>PR Req.</b>	12 MW
<b>30-Min Res Req.</b>	35 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$870	<b>\$870</b>
<b>Sync Res</b>	14	\$0	<b>\$850</b>
<b>Primary Res</b>	14	\$0	<b>\$850</b>
<b>30-Minute Reserve Req.</b>	34	\$850	<b>\$850</b>

COLOR KEY: ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)

# Energy and Reserve Price Capping Rules



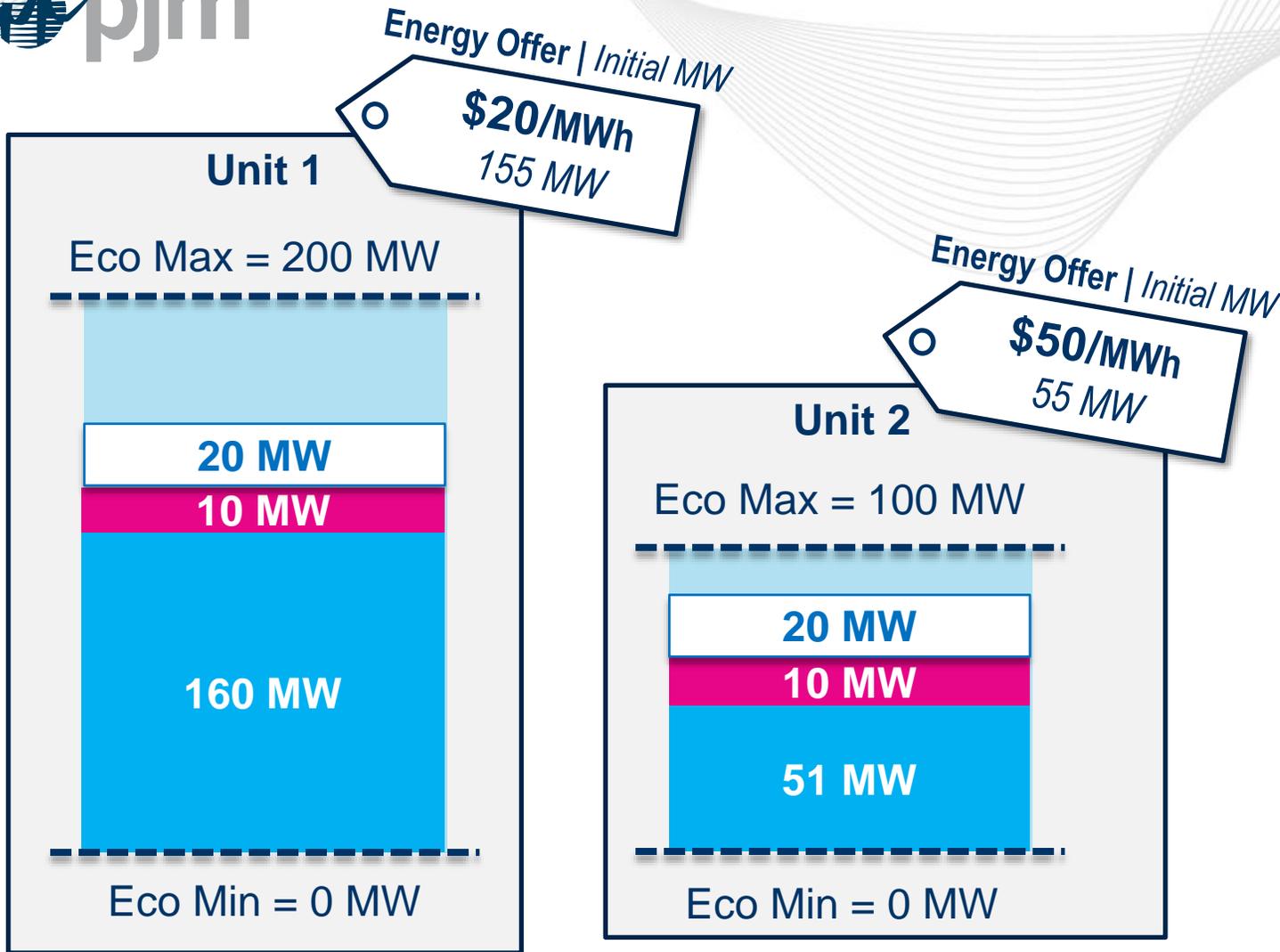
# Price Capping for Reserves in Reserve Price Formation

- Administrative Price Capping will be implemented under Reserve Price Formation as below:
  - Synchronized Reserve Clearing price will be capped at  $2 \times \text{Penalty Factor}$  (\$1,700).
  - Primary Reserve Clearing price will be capped at  $1.5 \times \text{Penalty Factor}$  (\$1,275).
  - 30 Min Reserve Clearing Price will be capped at  $1 \times \text{Penalty Factor}$  (\$850).
- Administrative Price Capping will be implemented in pricing run only.

- Energy Component of LMP is 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.



# Example 9 - Shortage in SR, PR, and 30 Min Reserve with no effect on Energy Price



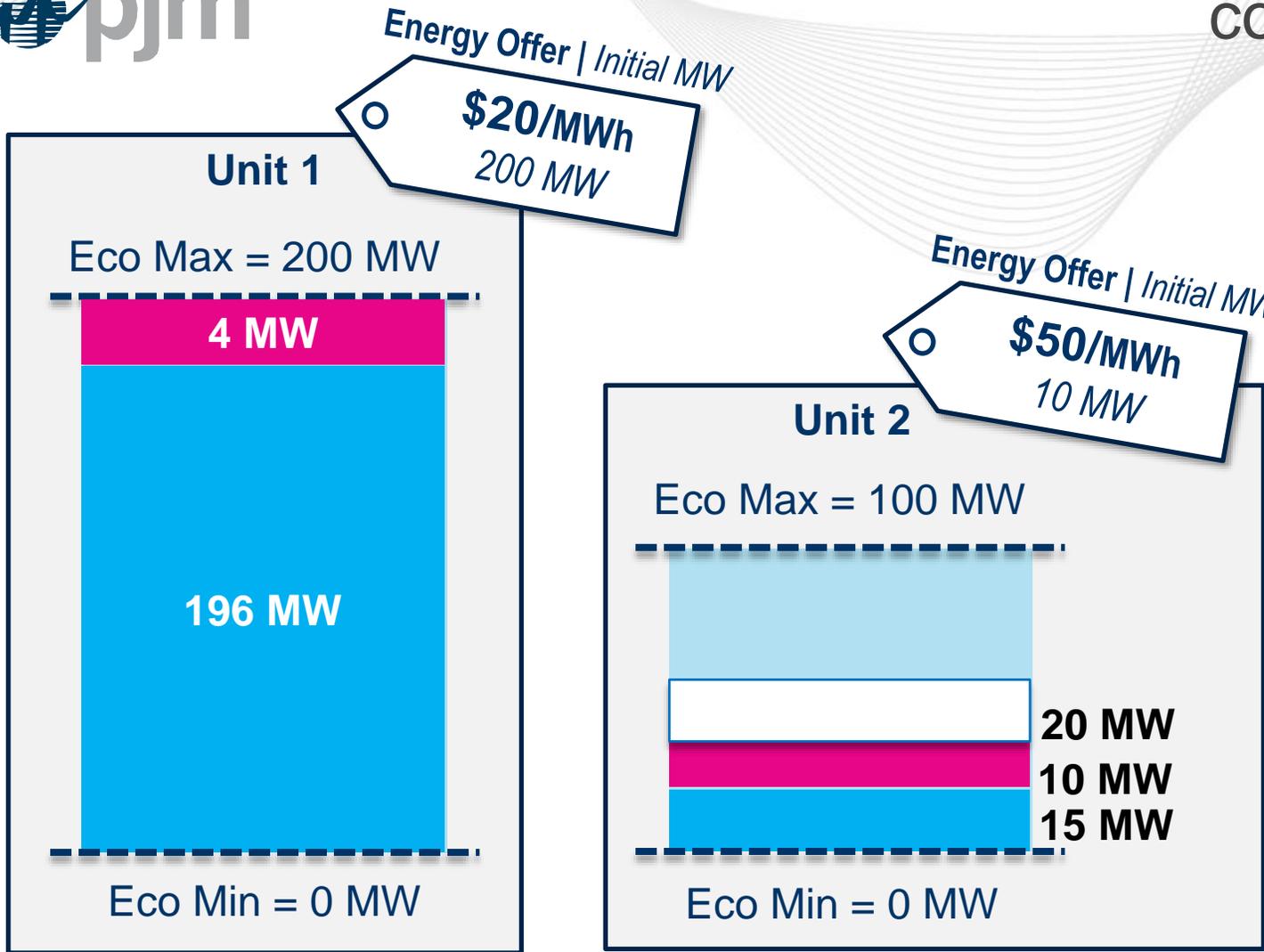
<b>Load</b>	211 MW
<b>SR Req.</b>	25 MW
<b>PR Req.</b>	30 MW
<b>30-Min Res Req.</b>	65 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$50	<b>\$50</b>
<b>Sync Res</b>	20	\$850	<b>\$2,550</b>
<b>Primary Res</b>	20	\$850	<b>\$1,700</b>
<b>30-Minute Reserve Req.</b>	60	\$850	<b>\$850</b>

**COLOR KEY:** ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)



# Example 10 - Shortage in SR, PR, and 30 Min Reserve with Penalty cost reflected in Energy Price

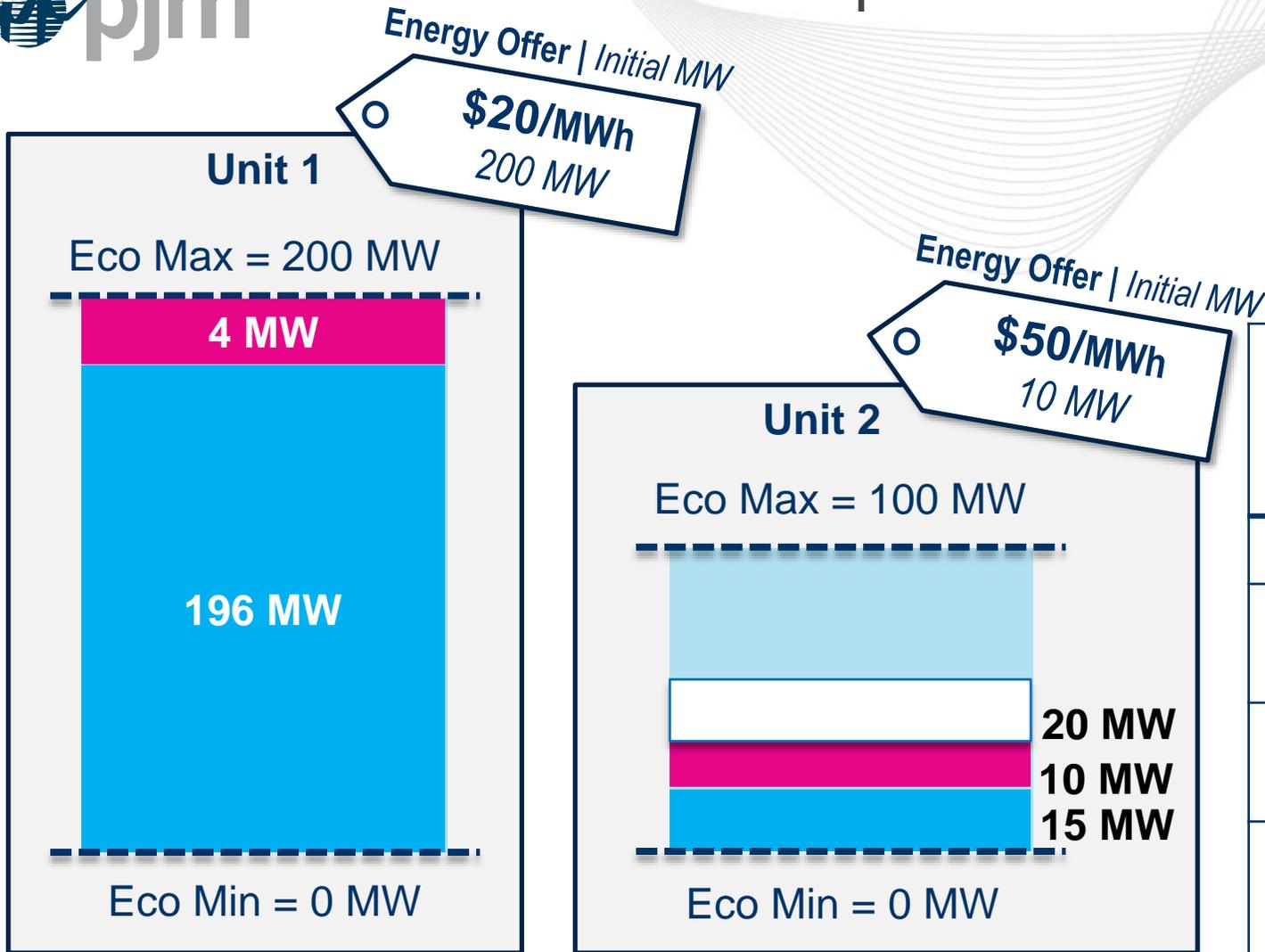


<b>Load</b>	211 MW
<b>SR Req.</b>	15 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	35 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$2,570	<b>\$2,570</b>
<b>Sync Res</b>	14	\$850	<b>\$2,550</b>
<b>Primary Res</b>	14	\$850	<b>\$1,700</b>
<b>30-Minute Reserve Req.</b>	34	\$850	<b>\$850</b>

**COLOR KEY:** ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)

# Example 11 – Reserve Price Capping Scenario

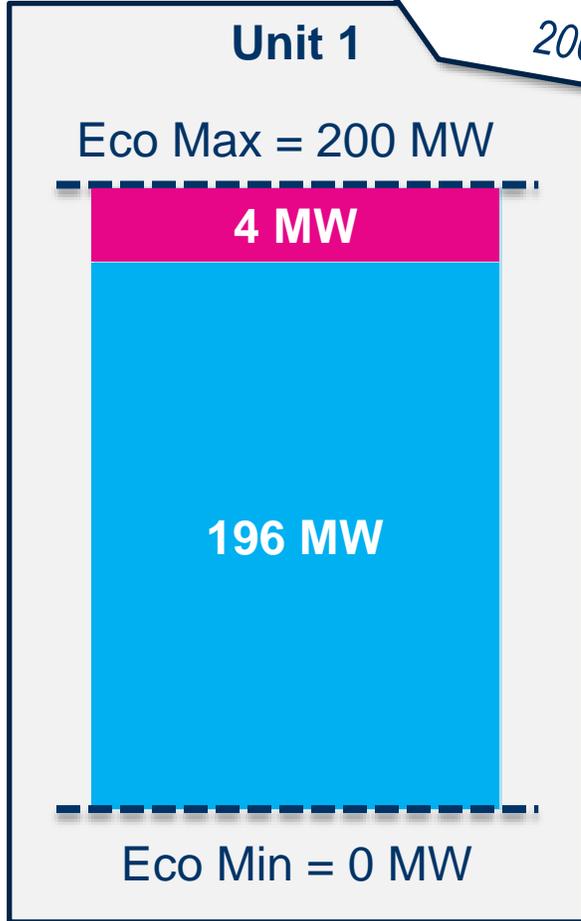


<b>Load</b>	211 MW
<b>SR Req.</b>	15 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	35 MW

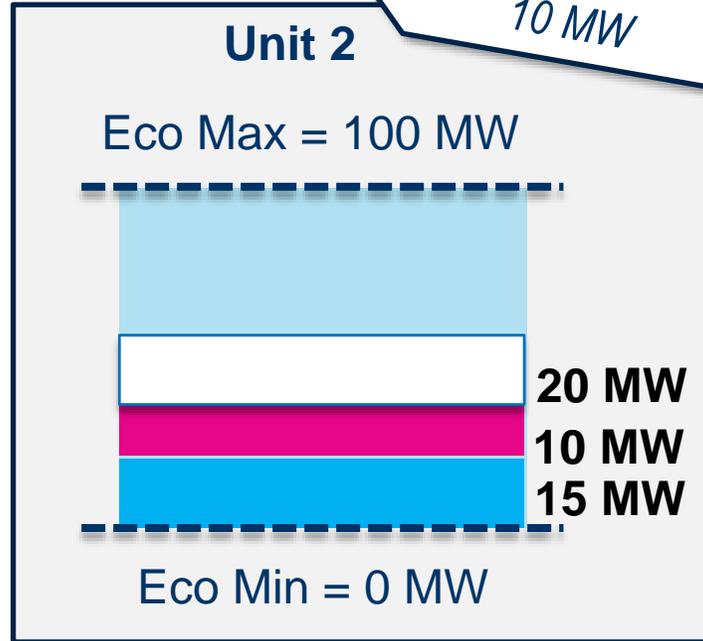
	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$2,570	<b>\$2,570</b>
<b>Sync Res</b>	14	\$850	\$2,550 <b>\$1700</b>
<b>Primary Res</b>	14	\$850	\$1,700 <b>\$1,275</b>
<b>30-Minute Reserve Req.</b>	34	\$850	<b>\$850</b>

**COLOR KEY:** ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)

# Example 12 – Energy and Reserve Price Capping Scenario



Energy Offer | Initial MW  
\$2000/MWh  
200 MW



Energy Offer | Initial MW  
\$50/MWh  
10 MW

<b>Load</b>	211 MW
<b>SR Req.</b>	15 MW
<b>PR Req.</b>	20 MW
<b>30-Min Res Req.</b>	35 MW

	Total Cleared MW	Shadow Price	Clearing Price
<b>Energy</b>	211	\$4,550	<b>\$3,700</b>
<b>Sync Res</b>	14	\$850	<b>\$2,550</b>
<b>Primary Res</b>	14	\$850	<b>\$1,700</b>
<b>30-Minute Res Req.</b>	34	\$850	<b>\$850</b>

COLOR KEY: ■ Energy MW (Cleared) ■ Synchronized Reserve (Cleared)  Secondary Reserve (Cleared)

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