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

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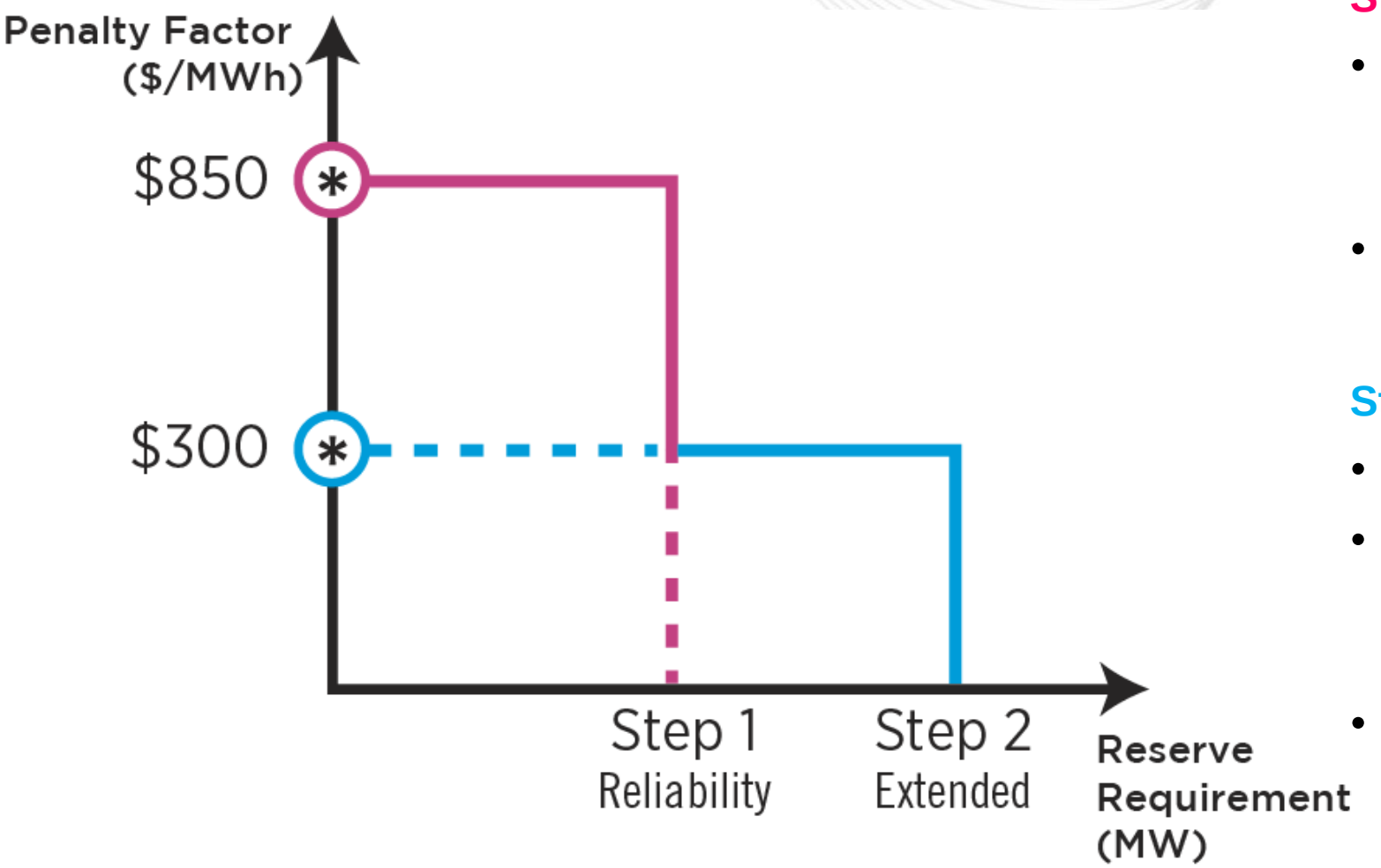
Pricing Reserve Shortages

- 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.

ORDC curve for Reserve Req.



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

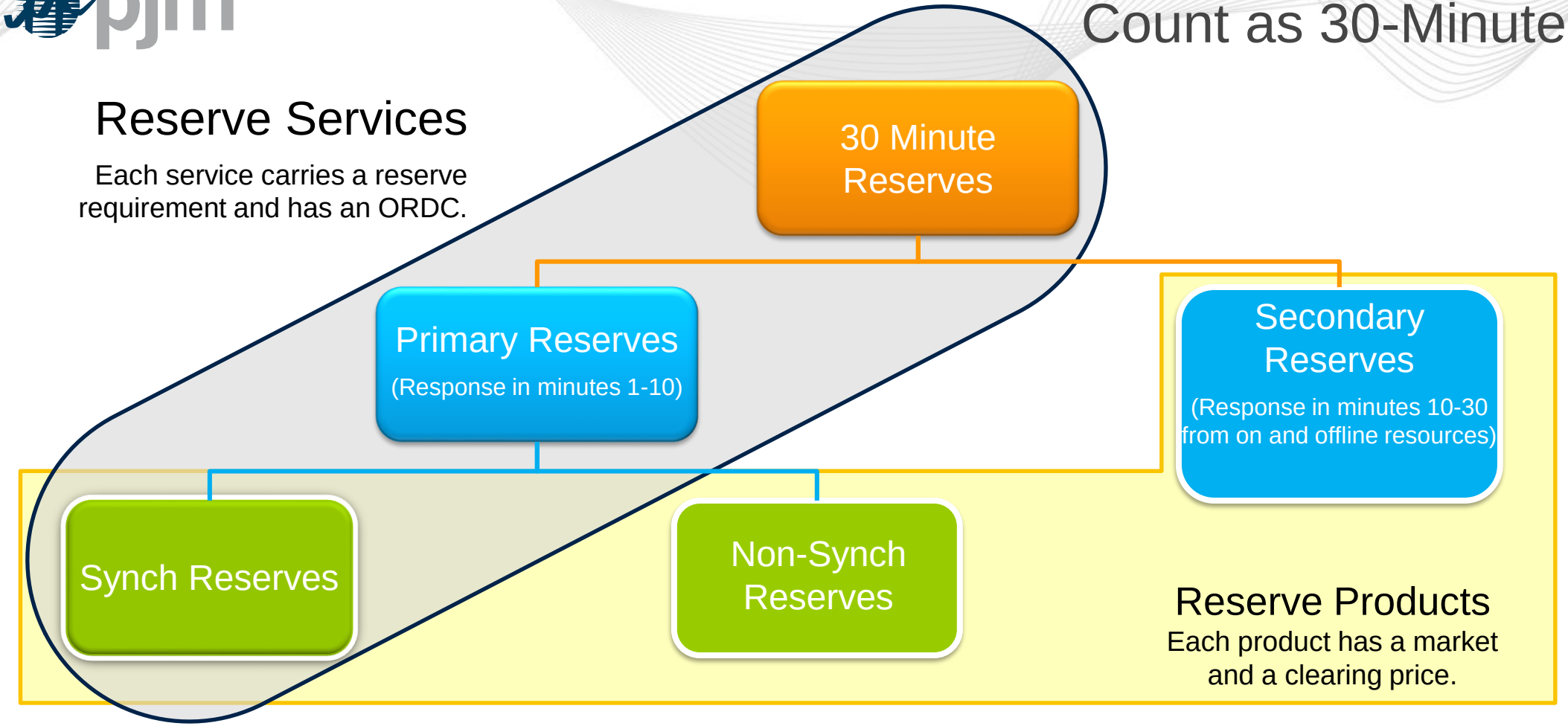
- Adds 190 MW to the Reliability Requirement
- Also includes an Optional Adder MW that can be used to capture additional reserves that are scheduled for reliability reasons
- The penalty factor for being short Step 2 is $300/MWh.

Reserve Product Interaction and Shadow Price Additivity

Synchronized and Primary Reserves Count as 30-Minute Reserves

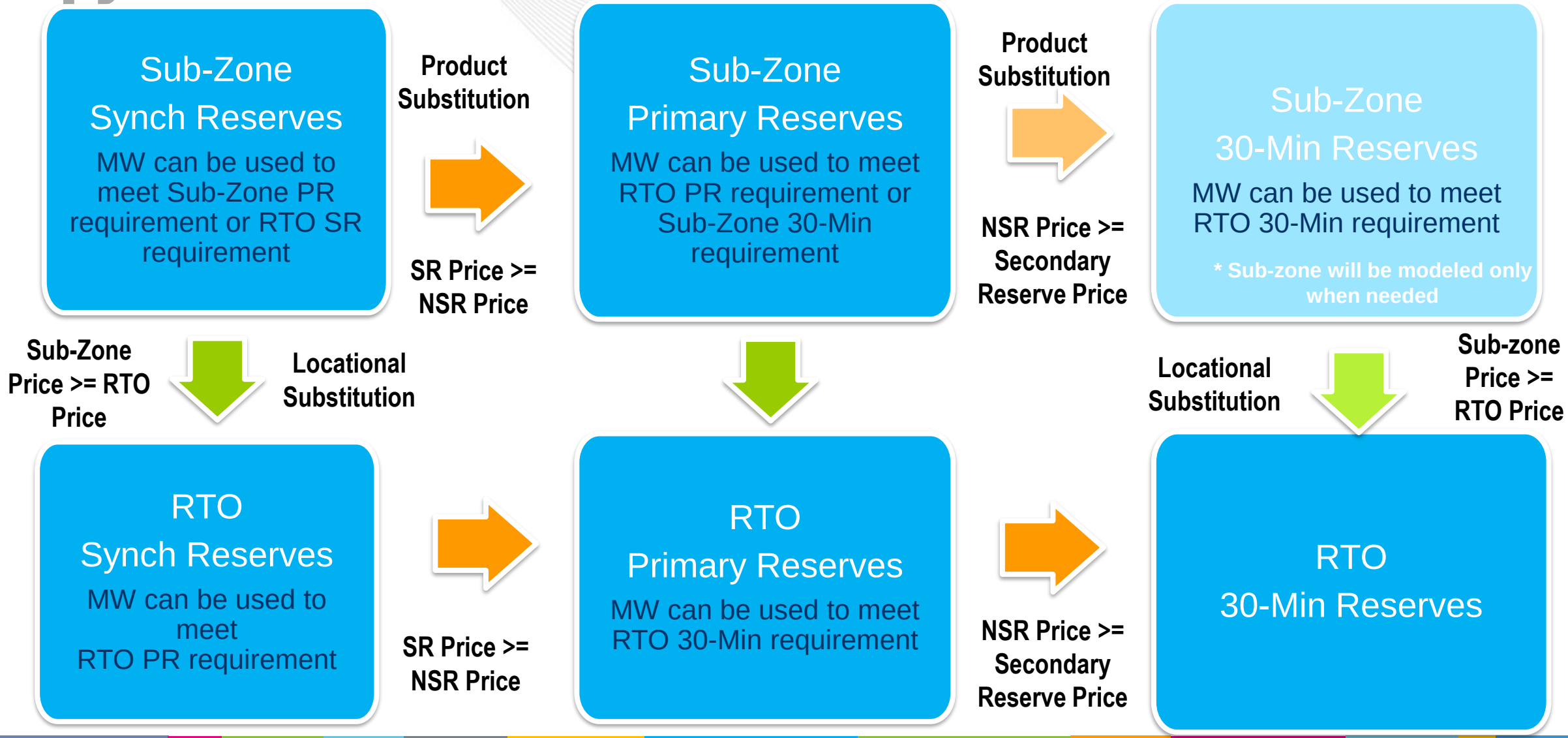
Reserve Services

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



Impact of Multiple Simultaneous Reserve Shortages

- 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

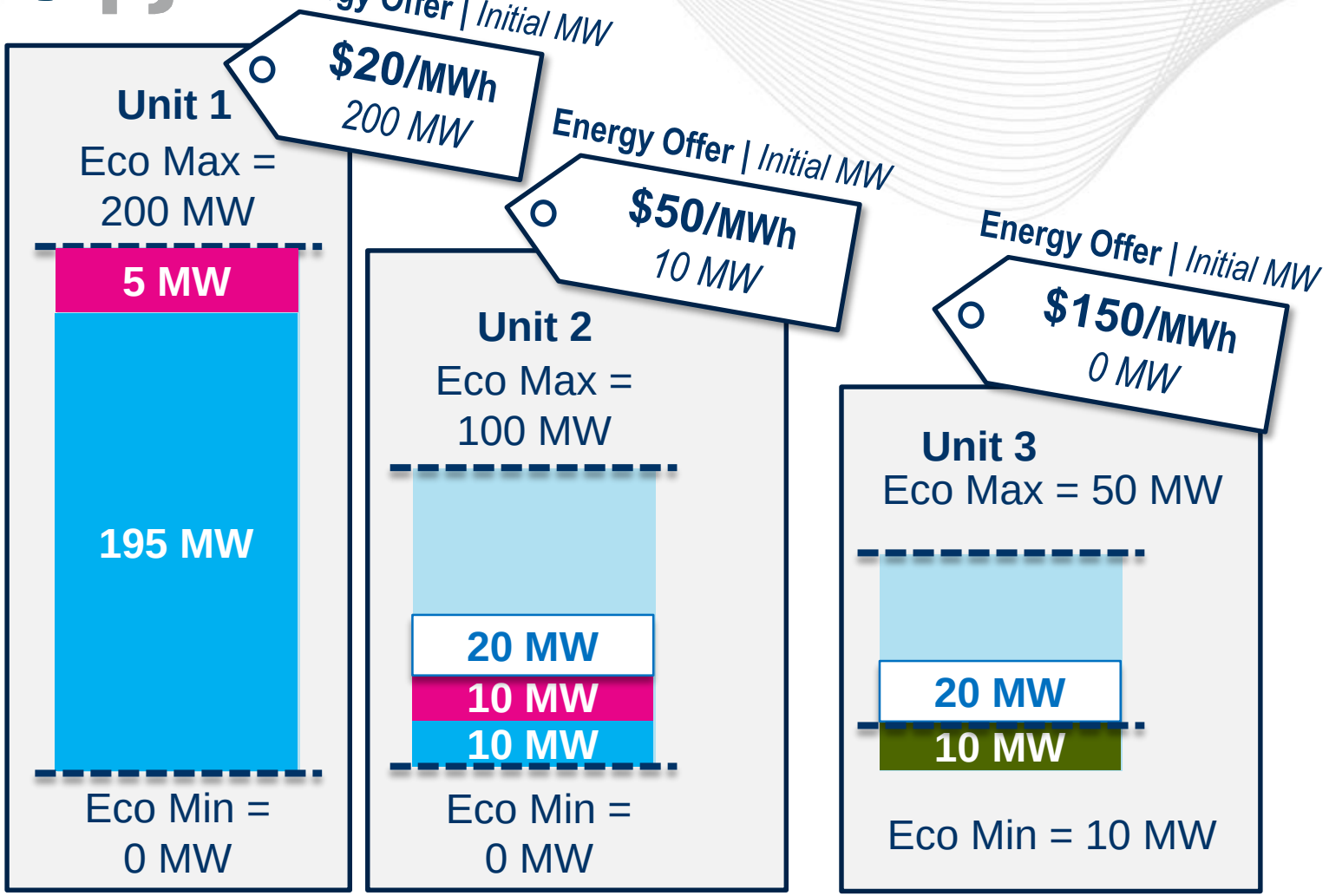
Assumptions for Examples

- 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
30-Minute Reserve	=	Shadow Price of 30-Minute Reserve Requirement
Non-Synchronized Reserve	=	Shadow Price of Primary Reserve Requirement + Shadow Price of 30-Minute Reserve Requirement
Synchronized Reserve	=	Shadow Price of Synchronized Reserve Requirement + Shadow Price of Primary Reserve Requirement + Shadow Price of 30-Minute Reserve Requirement
Energy Price	=	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

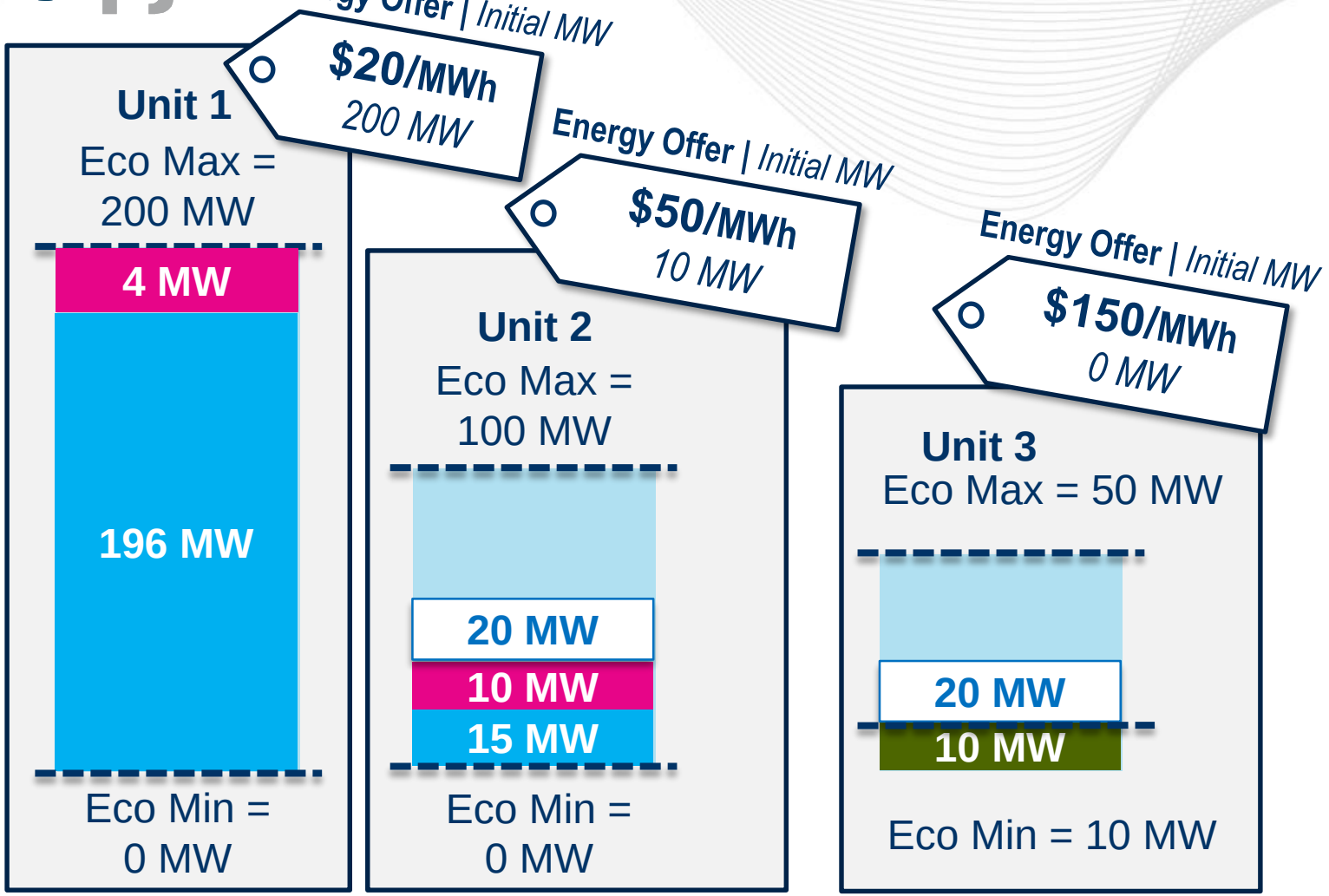


Load	205 MW
SR Req.	16 MW
PR Req.	20 MW
30-Min Res Req.	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	205	$50	**$50**
Sync Res	15	$850	**$850**
Primary Res	25	$0	**$0**
30-Minute Res	65	$0	**$0**

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

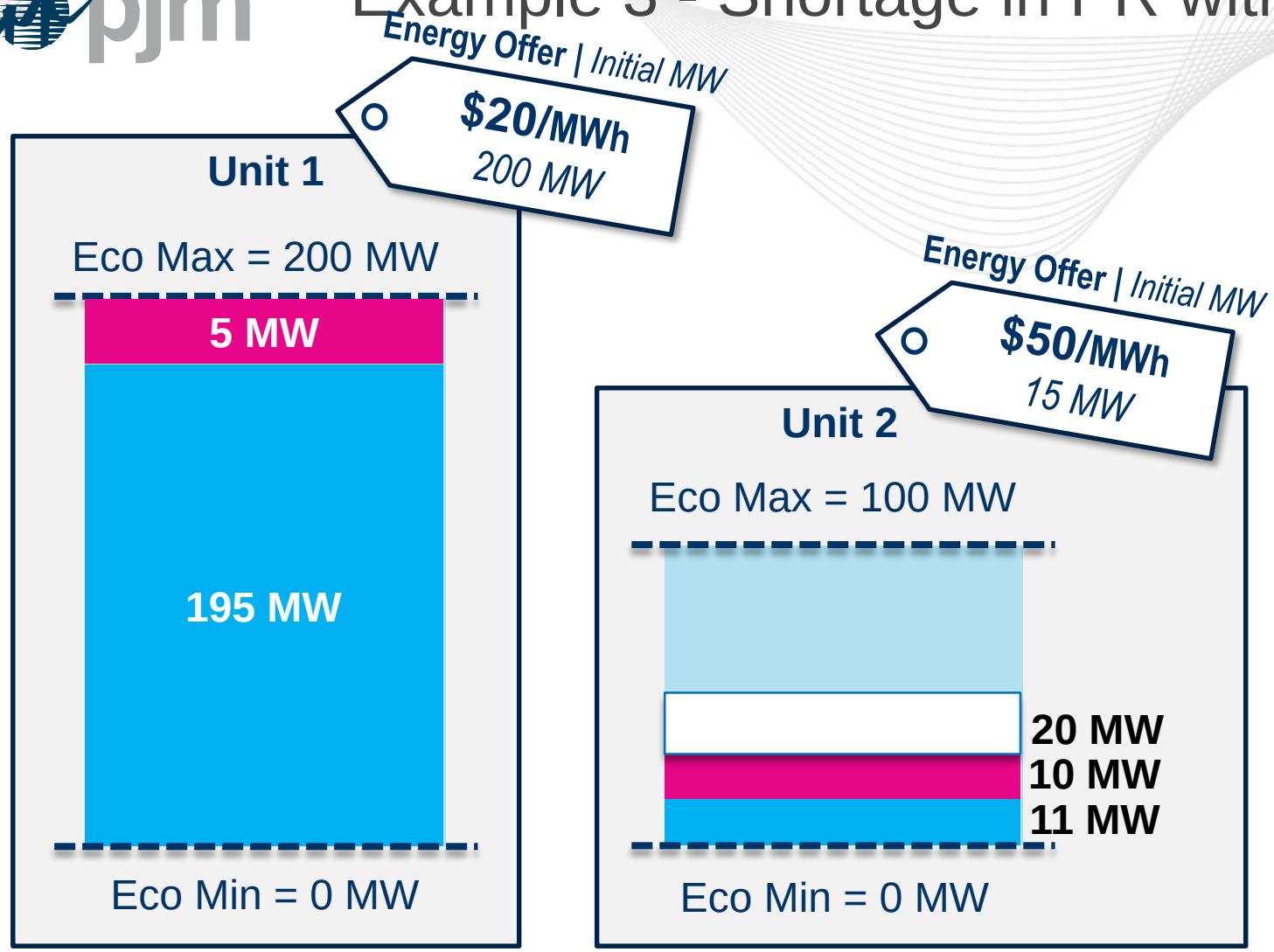


Load	211 MW
SR Req.	16 MW
PR Req.	20 MW
30-Min Res Req.	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$870	**$870**
Sync Res	14	$850	**$850**
Primary Res	24	$0	**$0**
30-Minute Res	64	$0	**$0**

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

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

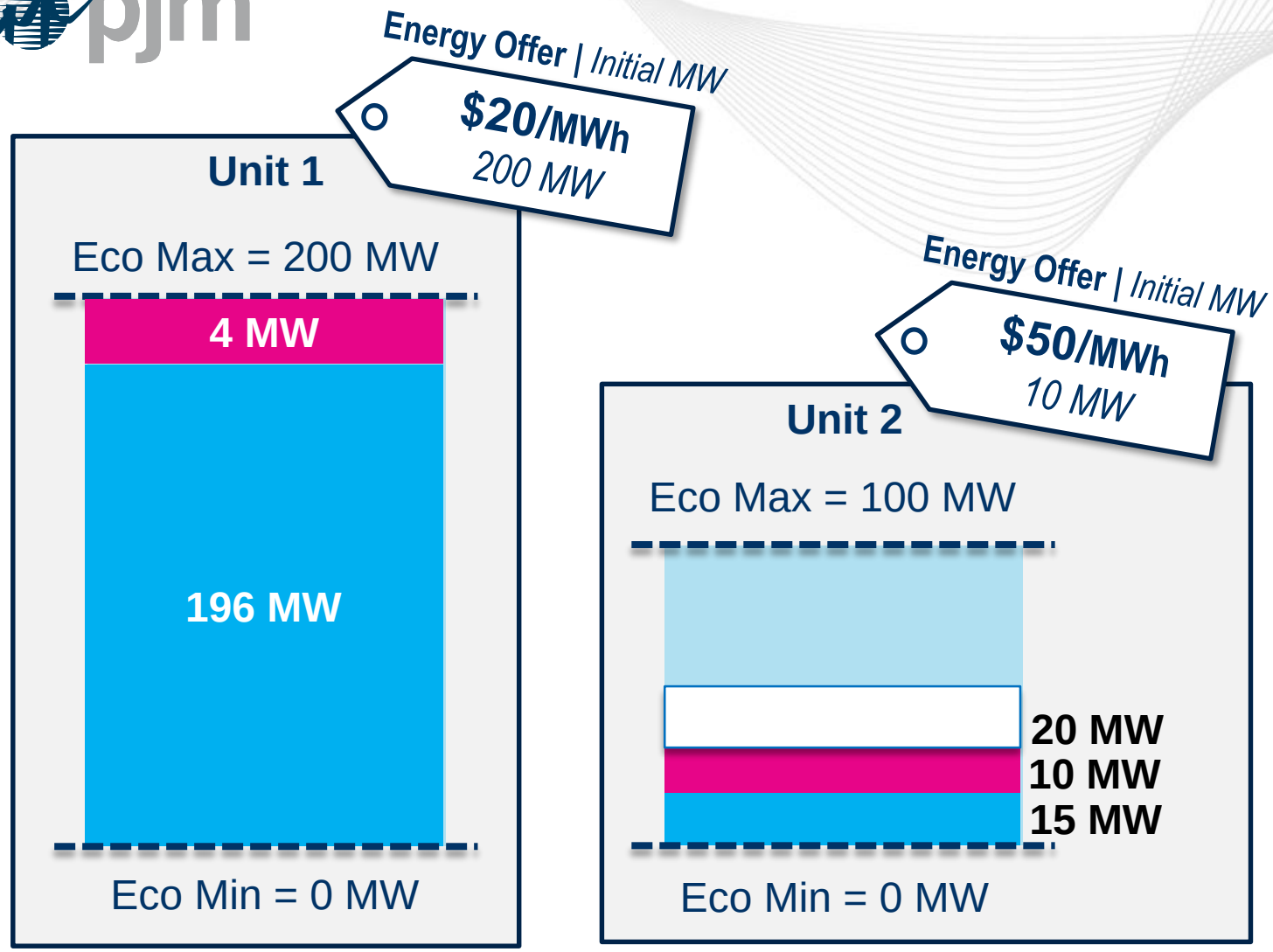


Load	206 MW
SR Req.	8 MW
PR Req.	20 MW
30-Min Res Req.	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	206	$50	**$50**
Sync Res	15	$0	**$850**
Primary Res	15	$850	**$850**
30-Minute Res	35	$0	**$0**

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

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

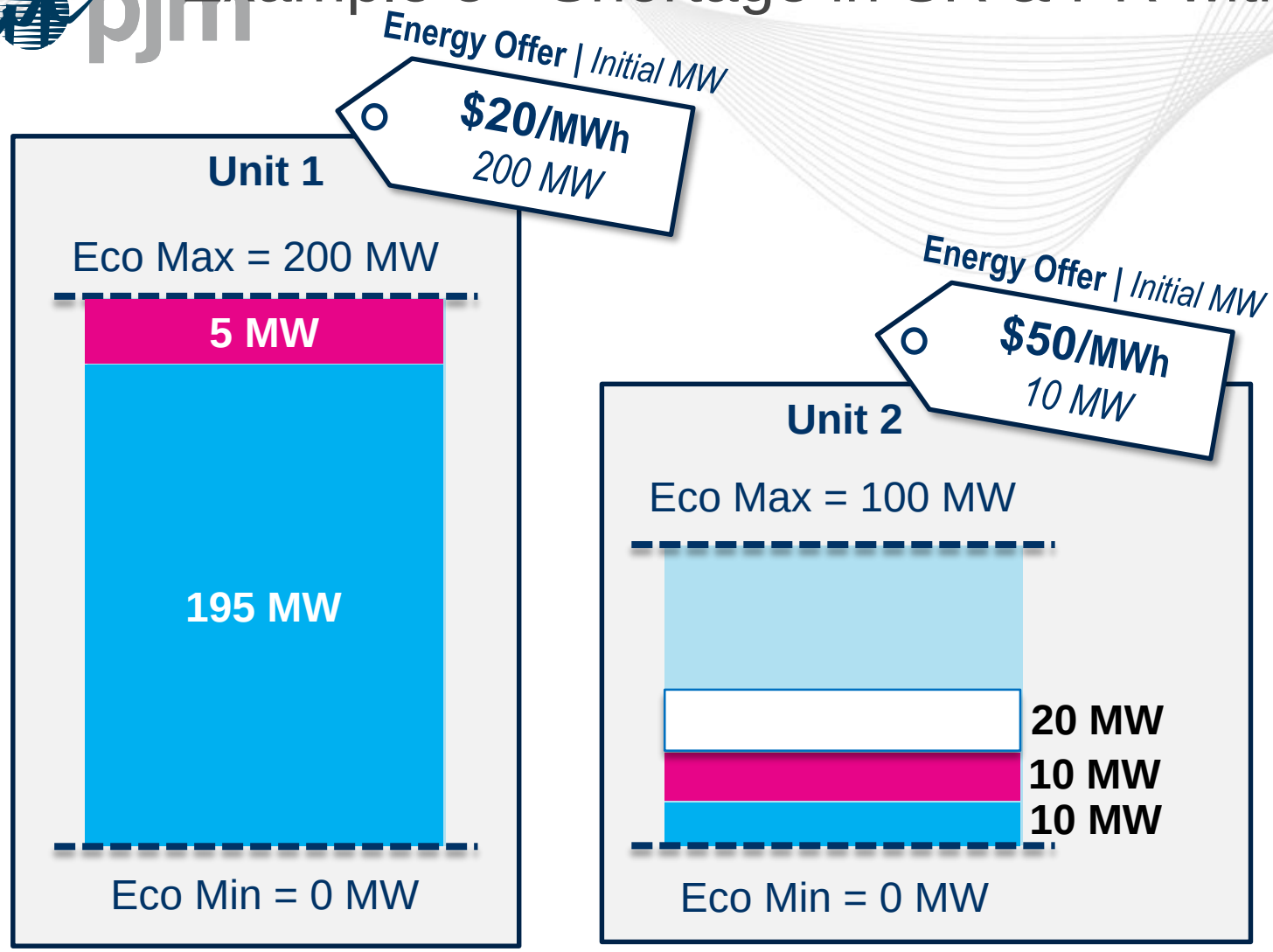


Load	211 MW
SR Req.	8 MW
PR Req.	20 MW
30-Min Res Req.	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$870	**$870**
Sync Res	14	$0	**$850**
Primary Res	14	$850	**$850**
30-Minute Res	34	$0	**$0**

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

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

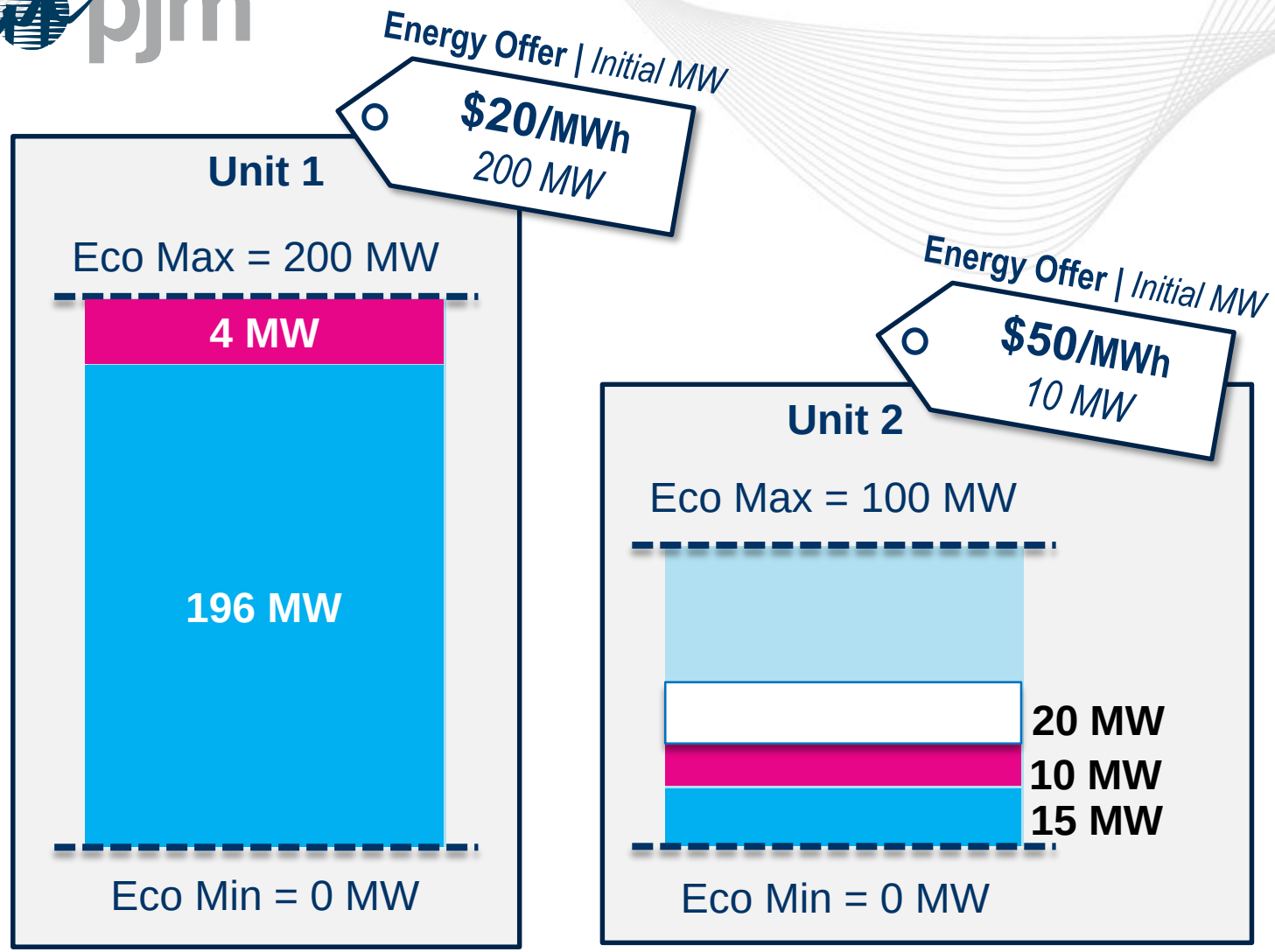


Load	205 MW
SR Req.	16 MW
PR Req.	20 MW
30-Min Res Req.	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	205	$50	**$50**
Sync Res	15	$850	**$1,700**
Primary Res	15	$850	**$850**
30-Minute Res	35	$0	**$0**

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

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

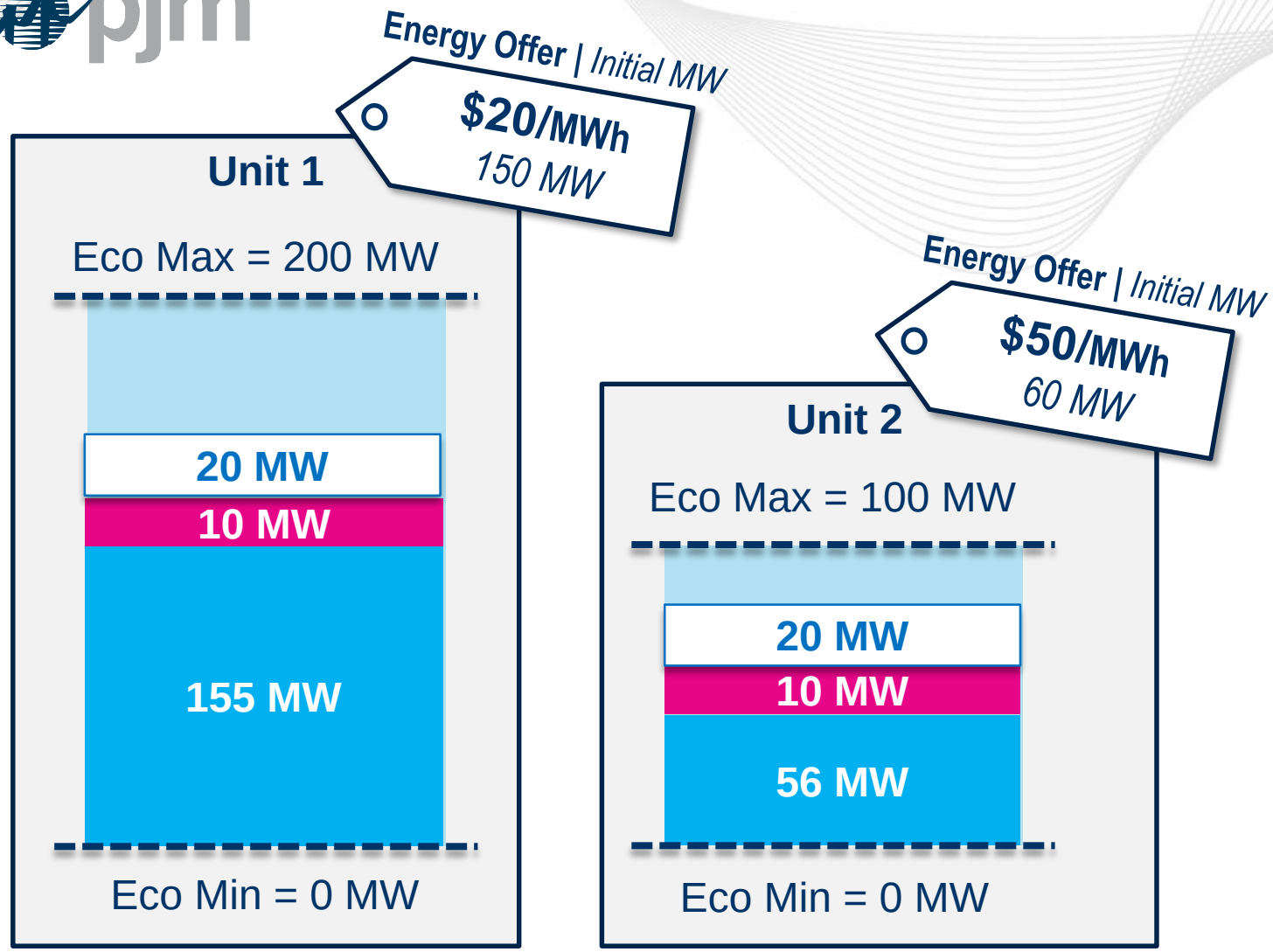


Load	211 MW
SR Req.	16 MW
PR Req.	20 MW
30-Min Res Req.	25 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$1,720	**$1,720**
Sync Res	14	$850	**$1,700**
Primary Res	14	$850	**$850**
30-Minute Res	34	$0	**$0**

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

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

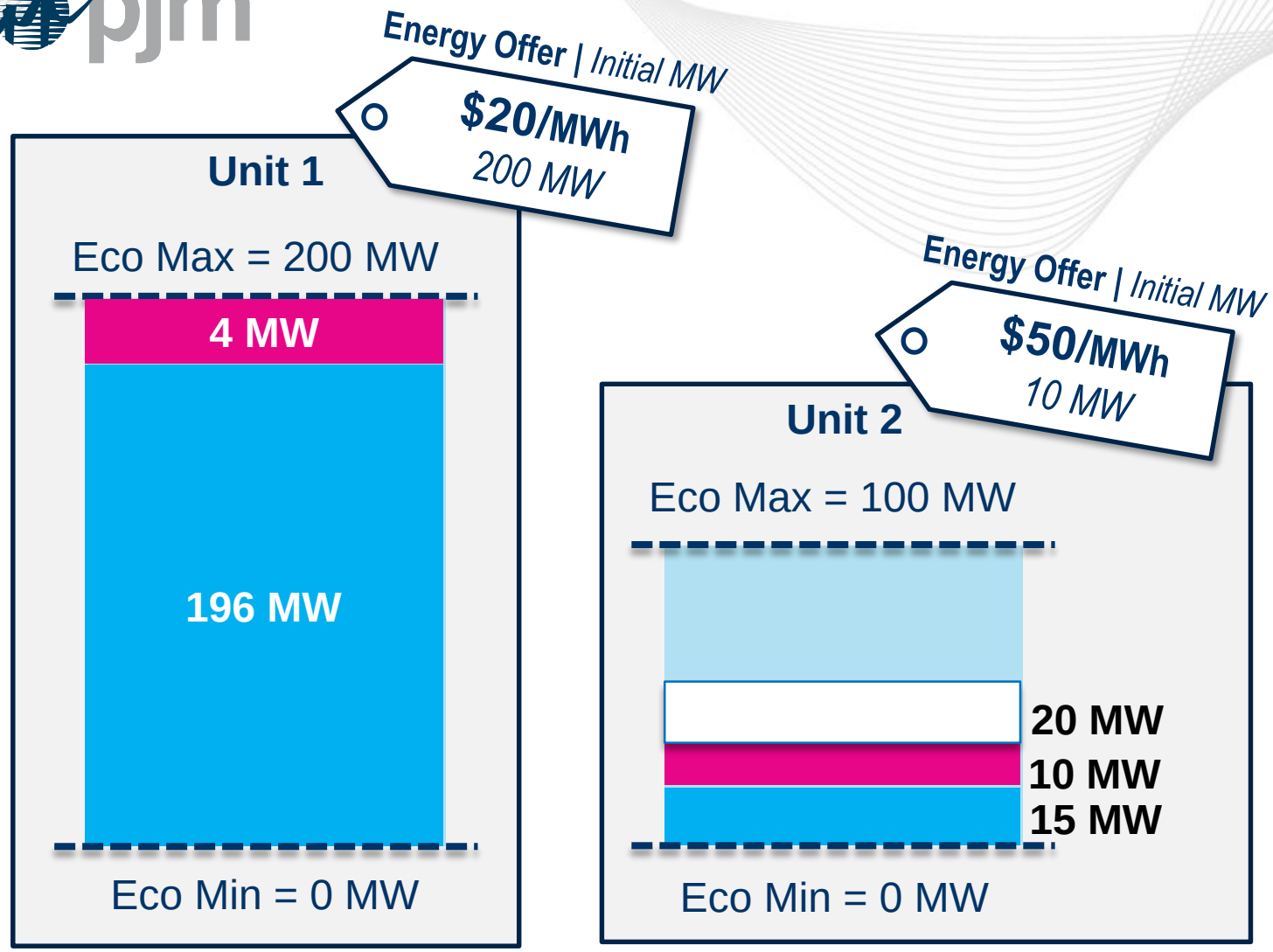


Load	211 MW
SR Req.	8 MW
PR Req.	12 MW
30-Min Res Req.	65 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$50	**$50**
Sync Res	20	$0	**$850**
Primary Res	20	$0	**$850**
30-Minute Res	60	$850	**$850**

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



Load	211 MW
SR Req.	8 MW
PR Req.	12 MW
30-Min Res Req.	35 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$870	**$870**
Sync Res	14	$0	**$850**
Primary Res	14	$0	**$850**
30-Minute Res	34	$850	**$850**

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

Energy and Reserve Price Capping Rules

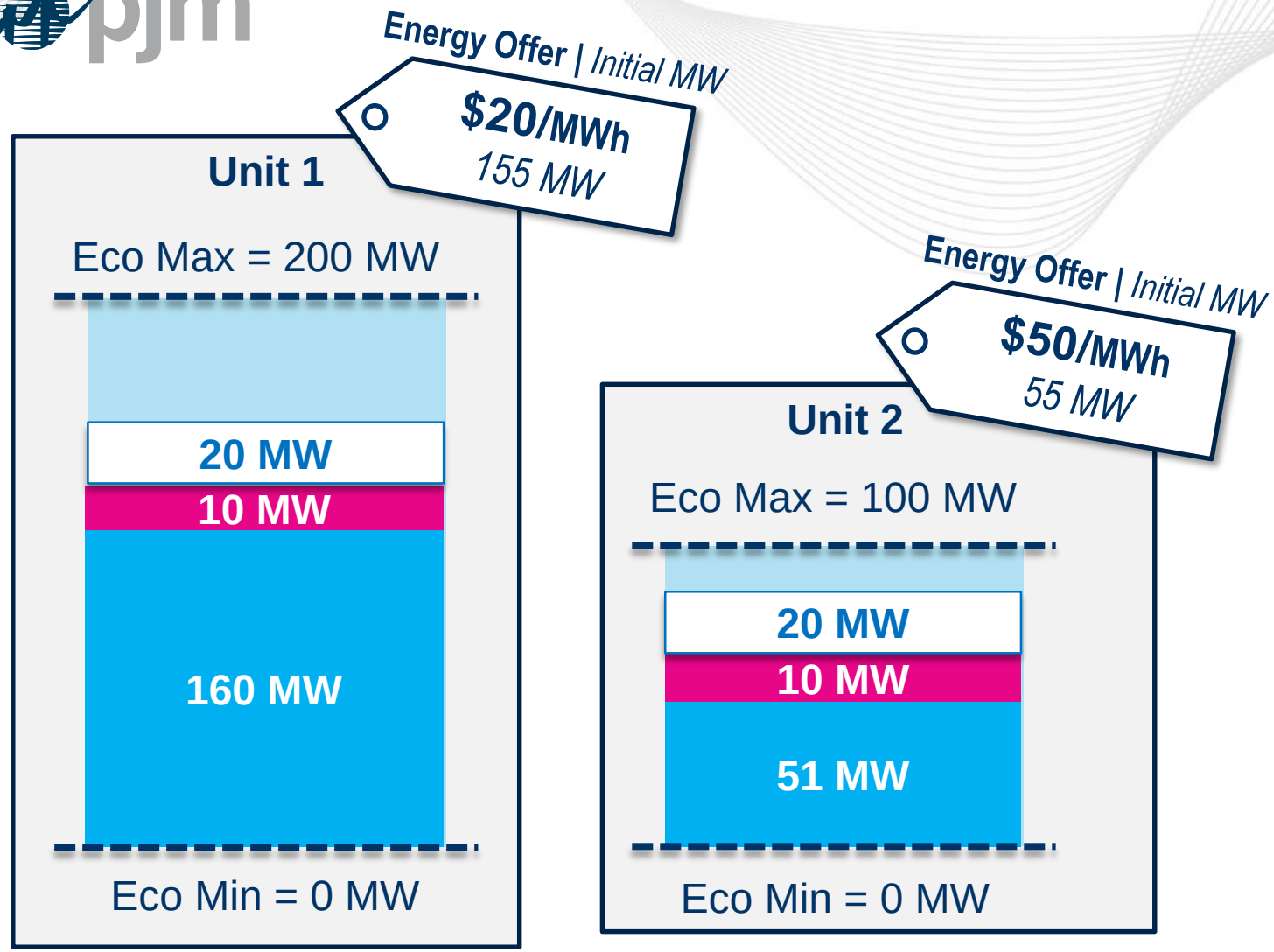
Price Capping for Reserves in Reserve Price Formation

- Administrative Price Capping will be implemented under Reserve Price Formation as below:
  - Synchronized Reserve Clearing price will be capped at 2*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 Price Capping will be implemented in pricing run only.

Energy Price Caps

- 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

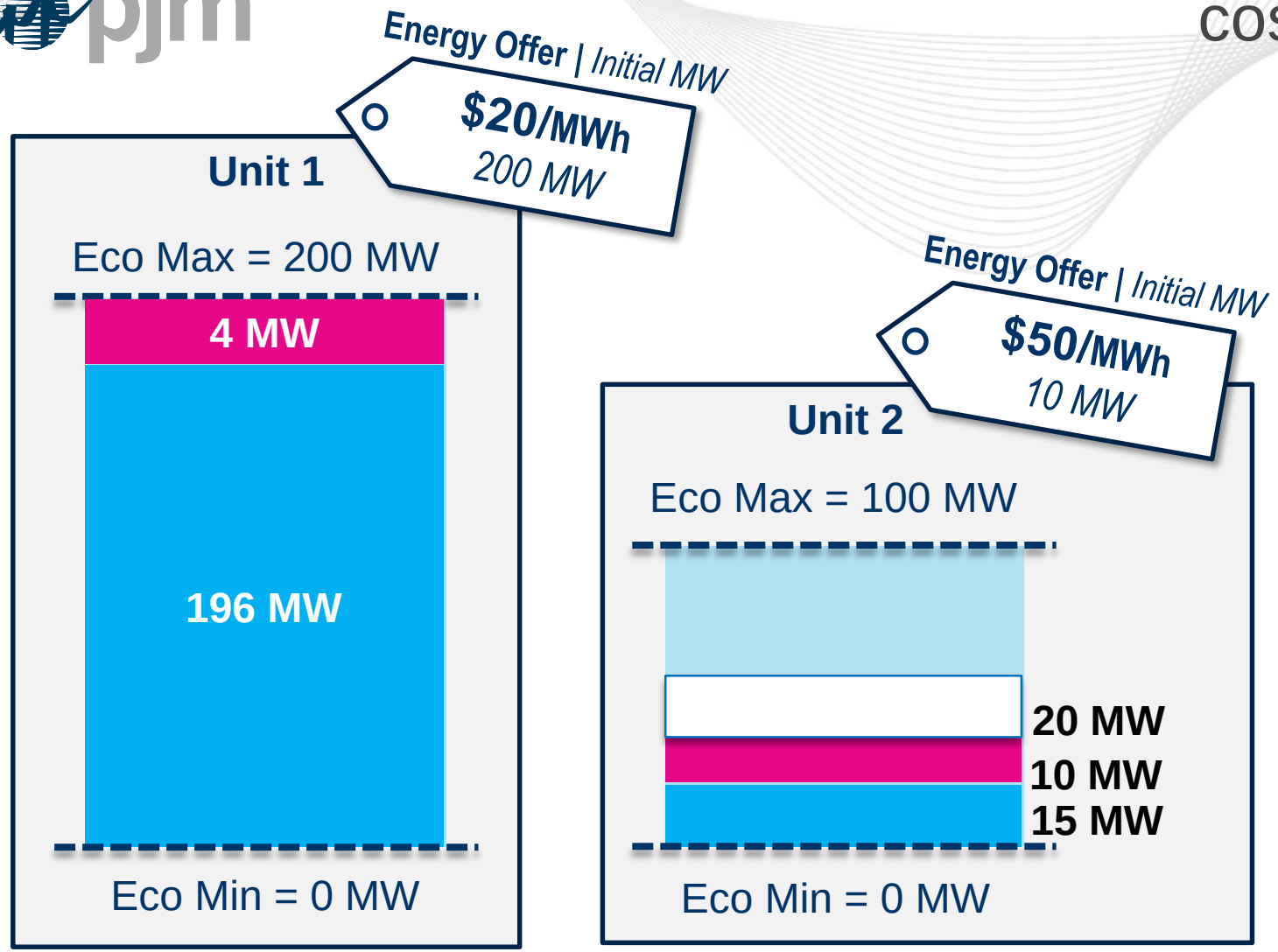


Load	211 MW
SR Req.	25 MW
PR Req.	30 MW
30-Min Res Req.	65 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$50	**$50**
Sync Res	20	$850	**$2,550**
Primary Res	20	$850	**$1,700**
30-Minute Res	60	$850	**$850**

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

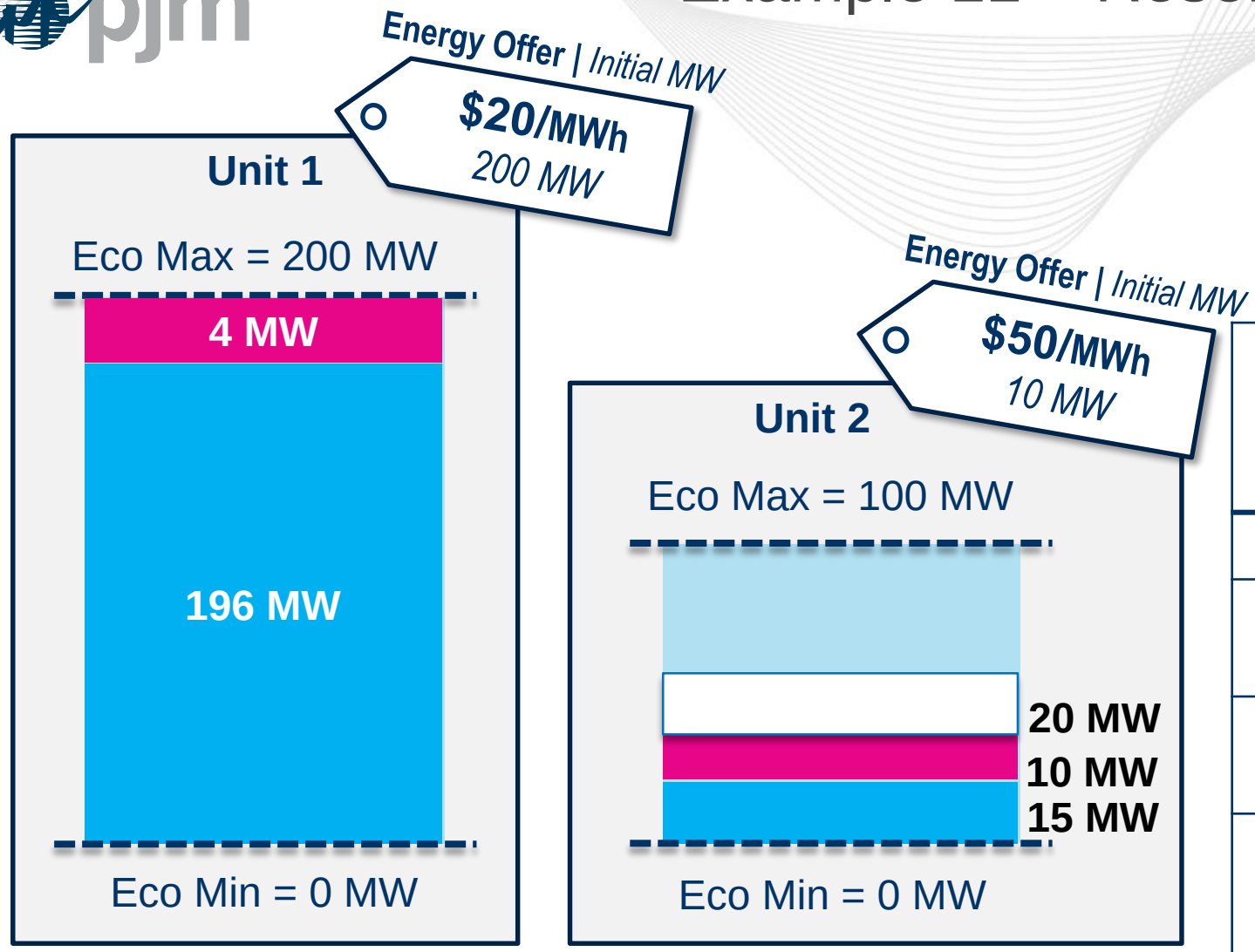


Load	211 MW
SR Req.	15 MW
PR Req.	20 MW
30-Min Res Req.	35 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$2,570	**$2,570**
Sync Res	14	$850	**$2,550**
Primary Res	14	$850	**$1,700**
30-Minute Res	34	$850	**$850**

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

Example 11 – Reserve Price Capping Scenario

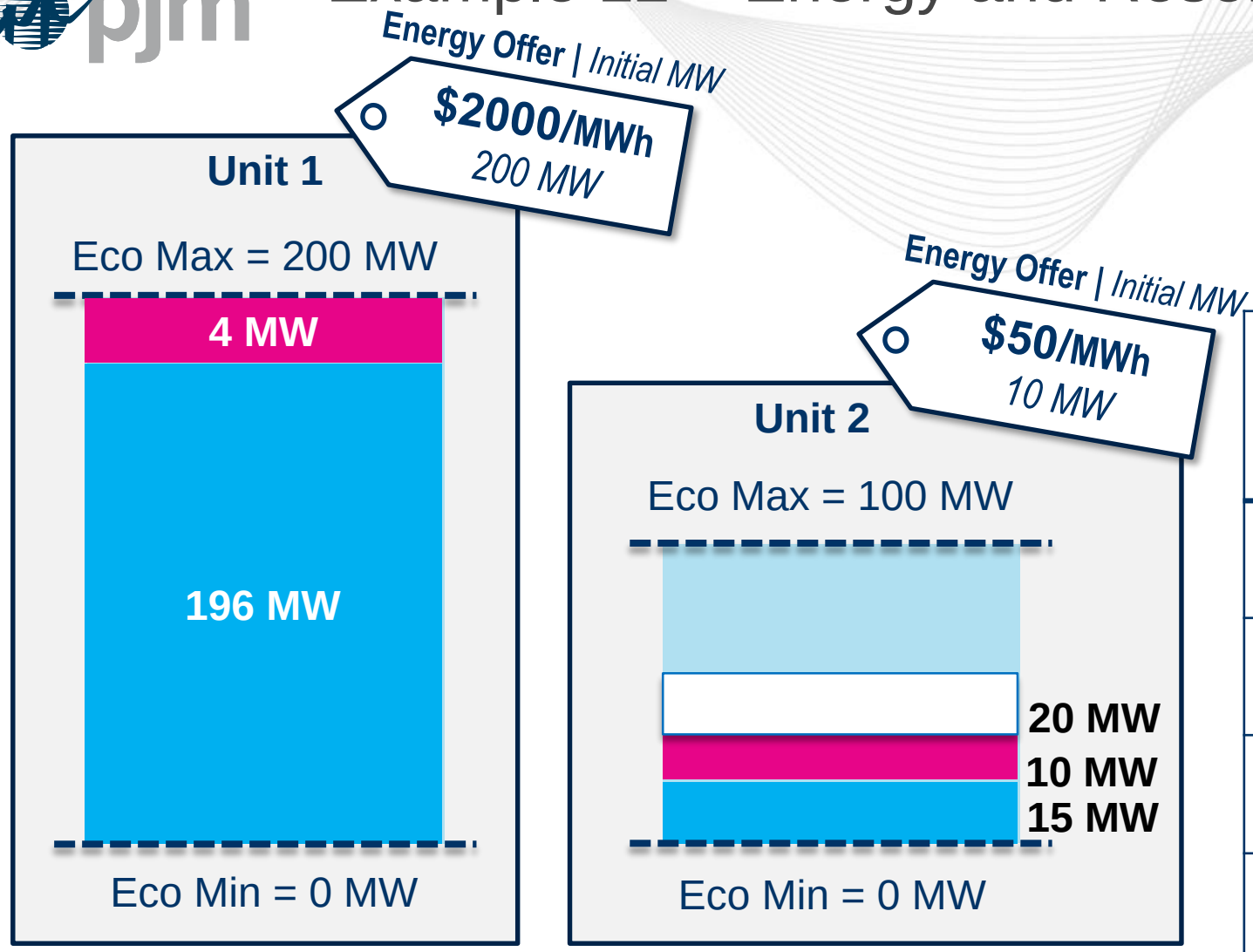


Load	211 MW
SR Req.	15 MW
PR Req.	20 MW
30-Min Res Req.	35 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$2,570	**$2,570**
Sync Res	14	$850	~~$2,550~~ **$1700**
Primary Res	14	$850	~~$1,700~~ **$1,275**
30-Minute Res	34	$850	**$850**

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

Example 12 – Energy and Reserve Price Capping Scenario

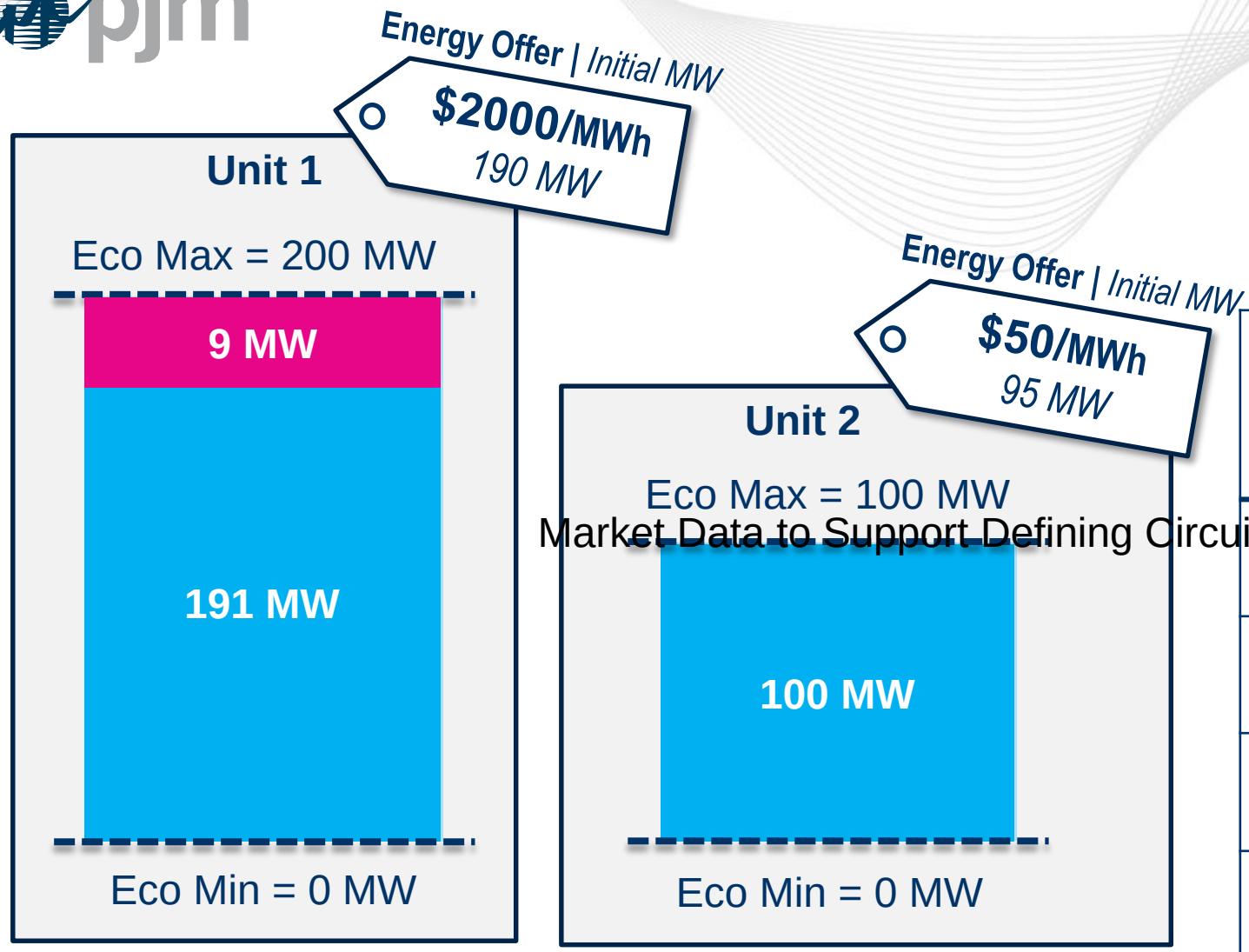


Load	211 MW
SR Req.	15 MW
PR Req.	20 MW
30-Min Res Req.	35 MW

	Total Cleared MW	Shadow Price	Clearing Price
Energy	211	$4,550	~~$4,550~~ **$3,700**
Sync Reserve	14	$850	~~$2,550~~ **$1700**
Primary Reserve	14	$850	~~$1,700~~ **$1,275**
30-Minute Res	34	$850	**$850**

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

Example 13 – Energy and Reserve Price Capping Scenario (emergency conditions)



Load	291 MW
SR Req.	15 MW
PR Req.	20 MW
30-Min Res Req.	35 MW

Market Data to Support Defining Circuit Breaker Trigger

	Total Cleared MW	Shadow Price	Clearing Price
Energy	291	$4,550	~~$4,550~~ **$3,700**
Sync Reserve	9	$850	~~$2,550~~ **$1700**
Primary Reserve	9	$850	~~$1,700~~ **$1,275**
30-Minute Res	9	$850	**$850**

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

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