Shortage Pricing and Pricing Impacts due to Reserve Shortages

EPFSTF

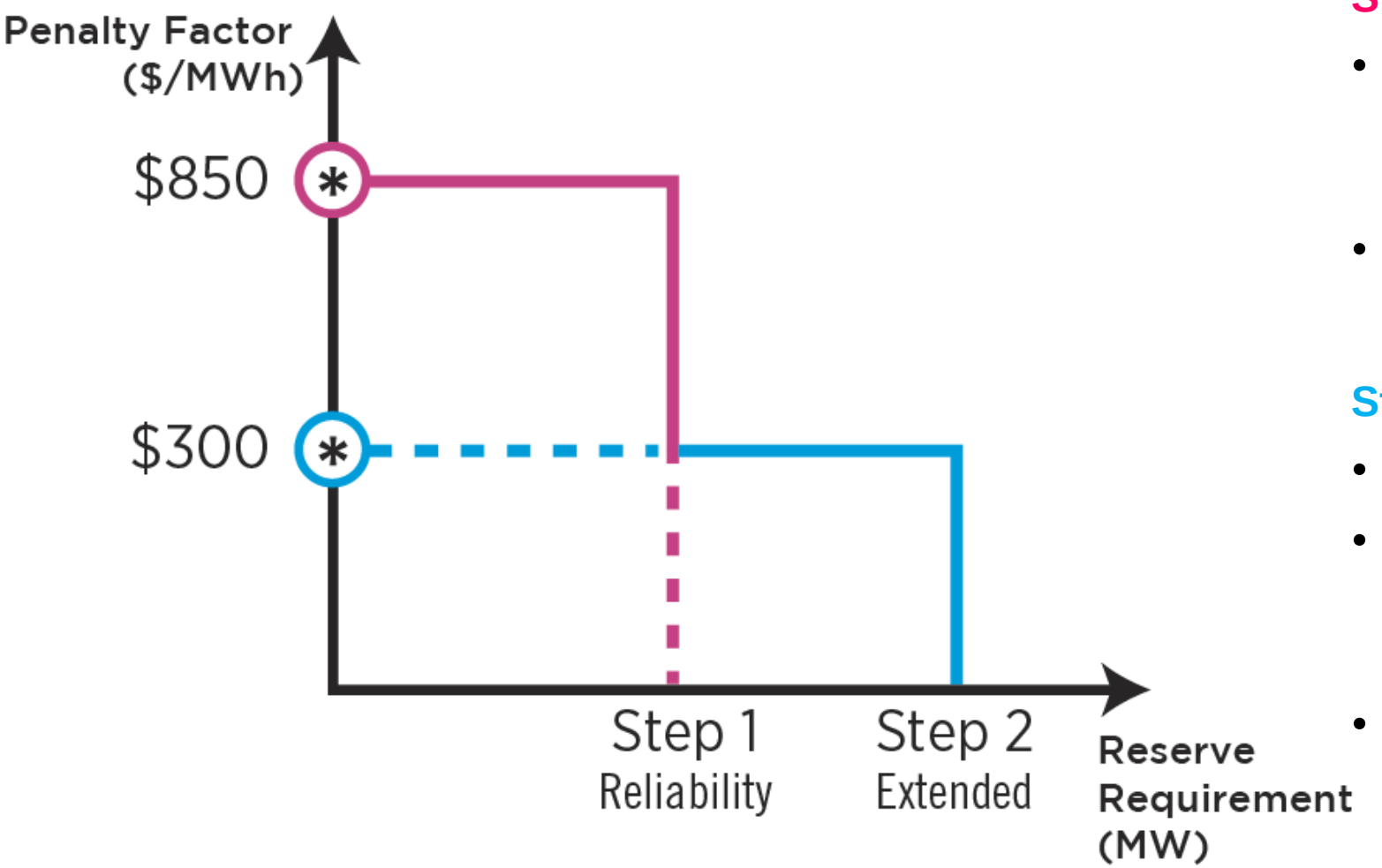
Aug. 9, 2021

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.

Current ORDC



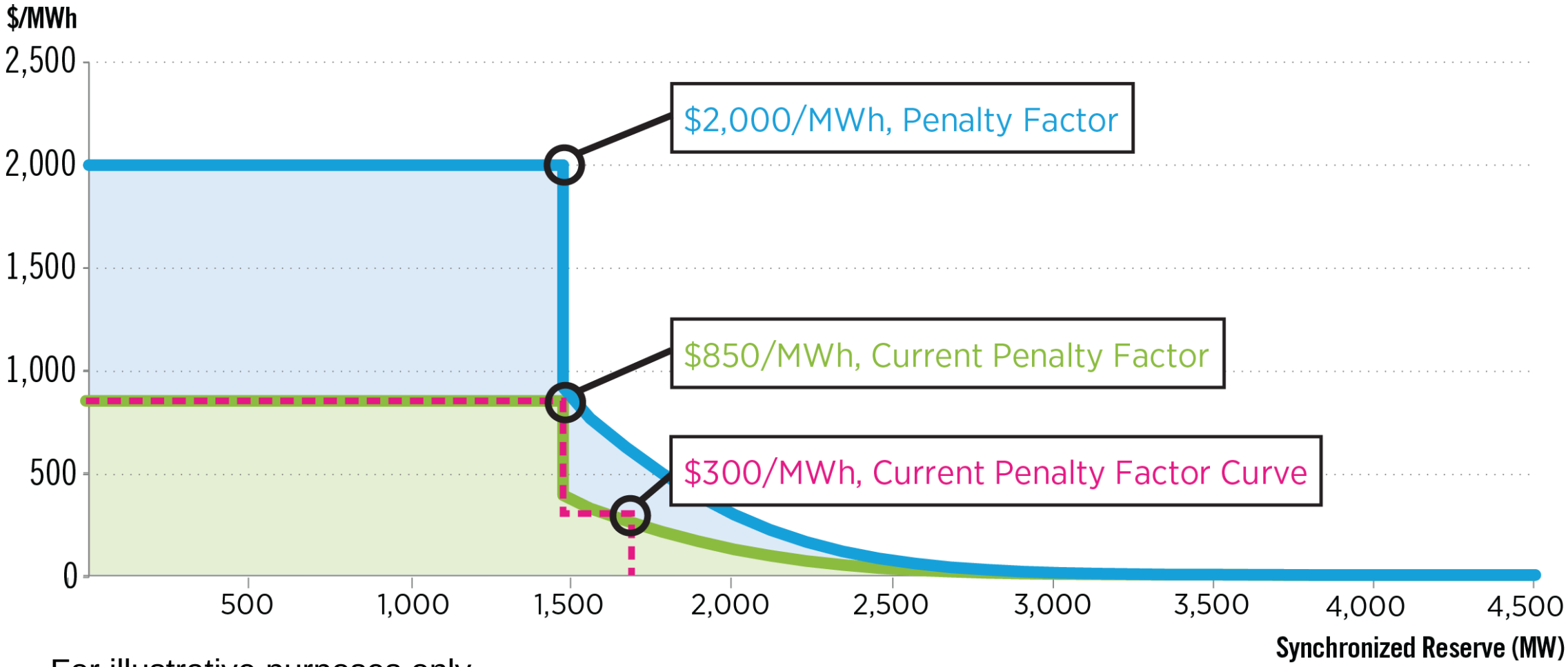
Step 1 of the Demand Curve

- 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.

Comparison of Current ORDC and Downward Sloping ORDC



For illustrative purposes only.

Elements for Downward Sloping ORDC Construction

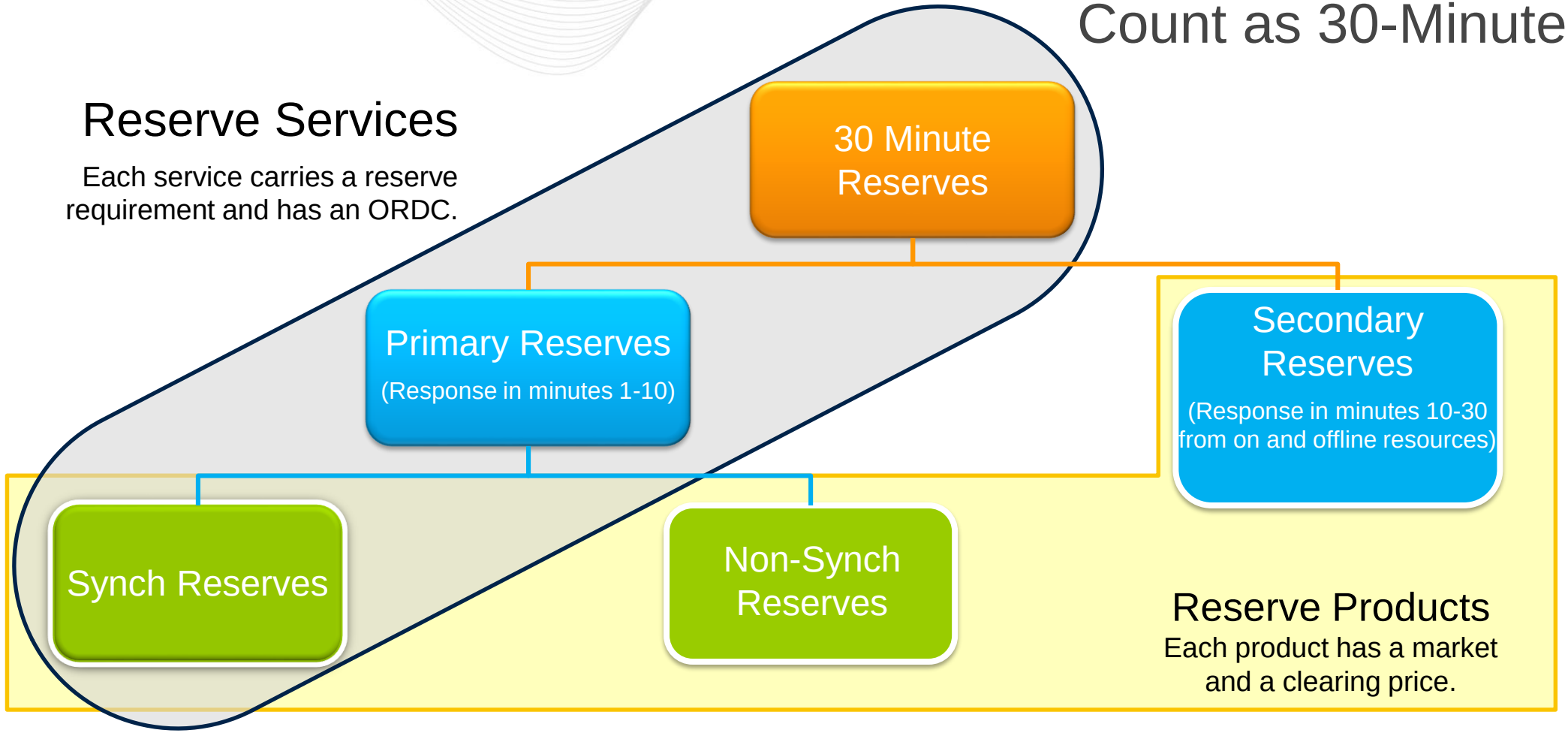
	10-Min (SR)	10-Min (PR)	30-Min
MRR	DA – Largest EcoMax of available resources.* RT – Max (Output of largest online resource or largest EcoMax of online resources)*	DA and RT - 150% of the SR requirement.	DA and RT – (Max of 3,000 MW or largest active gas contingency or PR requirement)**
Uncertainties	Load, Wind, Solar, Thermal Forced Outages	Load, Wind, Solar, Thermal Forced Outages	Load, Wind, Solar, Thermal Forced Outages, Net Interchange
Adjusted by Regulation?	Yes	Yes	Yes
Look-Ahead Uncertainty Interval	30 minutes	30 minutes	60 minutes
Penalty Factor	$2,000/MWh	$2,000/MWh	$2,000/MWh

* Under normal operating conditions. May be increased due to additional spin needed due to transmission outage condition (M11 section 4.2.2) or operator actions.

** May be increased due to operator actions.

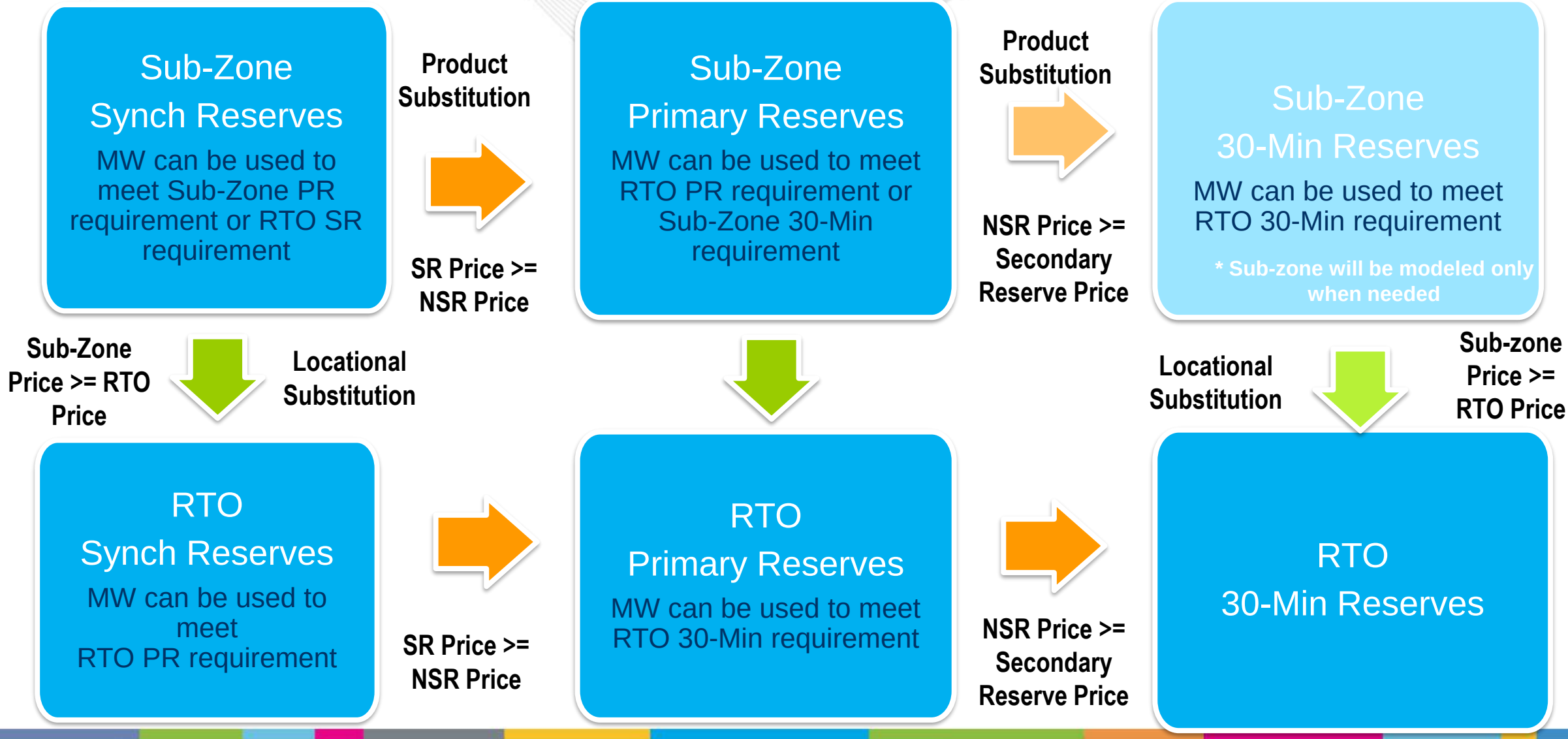
Reserve Product Interaction and Shadow Price Additivity

Synchronized and Primary Reserves Count as 30-Minute Reserves



- 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

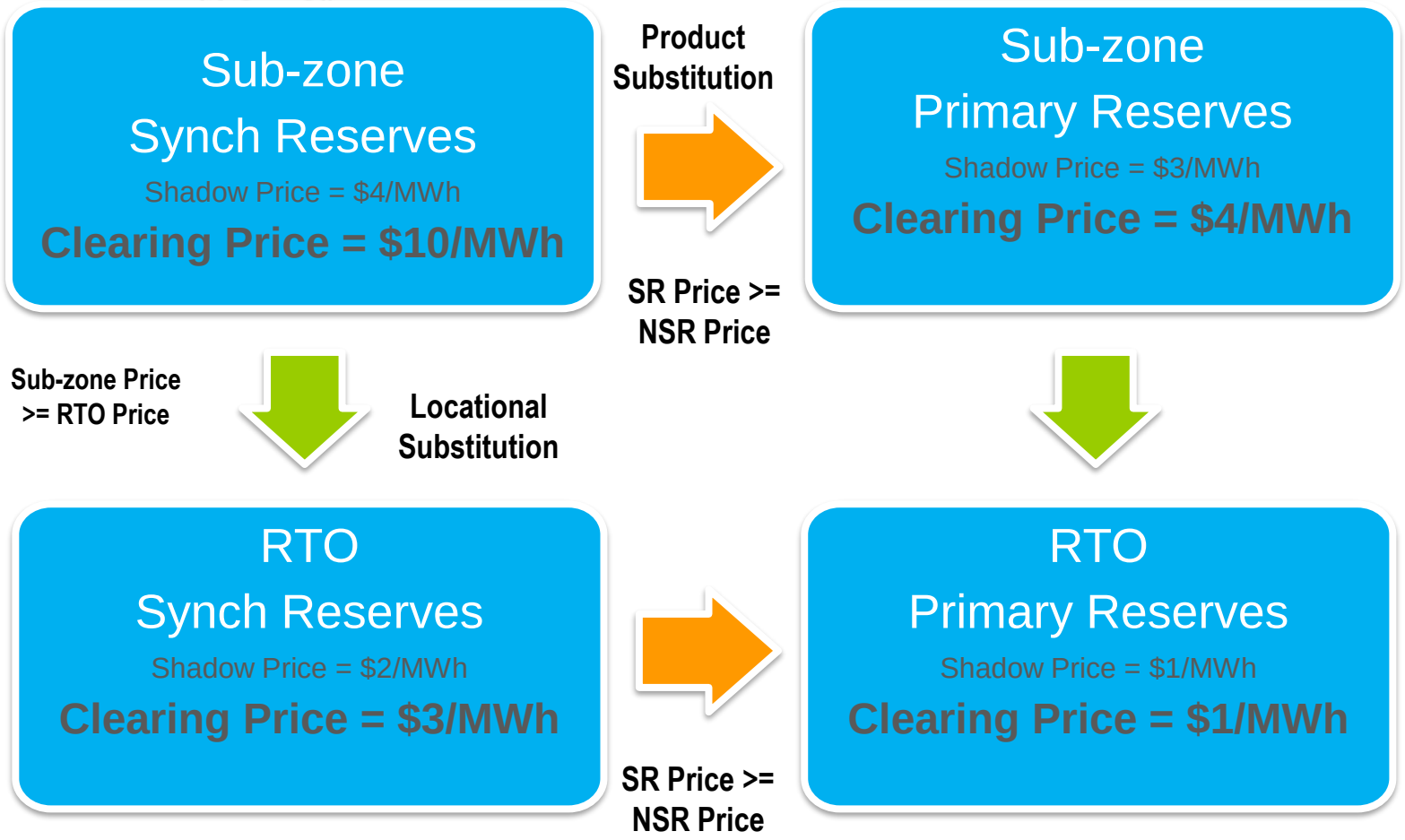
Reserve Substitution and Shadow Price Additivity



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

Example: Shadow Price Additivity



- Shadow prices are added to determine clearing prices due to product substitutability

Example: Shadow Price Additivity Continued

In the previous example (slide 10)

- Subzone SR Clearing Price = $10/MWh (4/MWh+$3/MWh+$2/MWh+$1/MWh)
  - 1 MW of SR in subzone can be used to meet all 4 reserve requirements.
- Subzone PR Clearing Price = $4/MWh ($3/MWh+$1/MWh)
  - Subzone PR shadow price + RTO PR Shadow Price
- RTO SR Clearing Price = $3/MWh ($2/MWh+$1/MWh)
  - RTO SR shadow price + RTO PR Shadow Price
- RTO PR Clearing Price = $1/MWh
  - In this example RTO PR MWs cannot be used for any additional product substitution.

Effect of Reserve Product Substitution on Reserve and Energy Prices

If short Primary Reserve, the Primary Reserve penalty factor is generally incorporated into the synchronized reserve price and the energy price.

Price		Calculation
30-Minute Reserve	=	Marginal cost of Secondary Reserve
Non-Synchronized Reserve	=	Primary Reserve penalty factor
Synchronized Reserve	=	Marginal cost of Synchronized Reserve + Primary Reserve penalty factor
Energy Price	=	Marginal cost of energy + the Primary Reserve penalty factor*

* Assumes next MW of energy comes from converting reserves to energy

Effect of Reserve Product Substitution on Reserve and Energy Prices

If short both Primary Reserve and Synchronized Reserve:

Price	Calculation
30-Minute Reserve	= Marginal cost of Secondary Reserve
Non-Synchronized Reserve	= Primary Reserve penalty factor
Synchronized Reserve	= Synchronous Reserve penalty factor + Primary Reserve penalty factor
Energy Price	= Marginal cost of energy + Synchronized Reserve penalty factor + Primary Reserve penalty factor*

* Assumes next MW of energy comes from converting reserves to energy

Effect of Reserve Product Substitution on Reserve and Energy Prices

If short 30-Minute Reserve, the 30-Minute Reserve penalty factor is generally incorporated into both reserve prices and the energy price.

Price		Calculation
30-Minute Reserve	=	30-Minute Reserve penalty factor
Non-Synchronized Reserve	=	Marginal cost of Primary Reserve + 30-Minute Reserve penalty factor
Synchronized Reserve	=	Marginal cost of Synchronized Reserve + 30-Minute Reserve penalty factor
Energy Price	=	Marginal cost of energy + the 30-Minute Reserve penalty factor*

* Assumes next MW of energy comes from converting reserves to energy

Impact of Multiple Simultaneous Reserve Shortages

When there is a nested region within another (a reserve sub-zone), like MAD within RTO, the prices may be additive by location depending on system conditions.

Additive pricing happens in the Reserve Sub-Zone when:

- Imports limit the ability to deliver reserves from the remainder of RTO to the Reserve Sub-zone.
- The reserve sub-zone and RTO requirements are simultaneously short.

Current Energy and Reserve Price Capping Rules

Limitations on Additivity of Shortages

- From a pricing perspective, the most extreme shortage condition that could occur would be a shortage of Synchronized Reserve and Primary Reserve in both RTO and MAD.
  - Violation of all four reserve requirements → 4 * Penalty Factor
- As part of the initial implementation of shortage pricing in 2012, an administrative rule was implemented to allow, at maximum, two simultaneous shortages to affect energy and reserve prices (2 * Penalty Factor).
  - The new rule assuages concerns about implementation of demand curves and co-optimization of energy and reserves.
  - Prior to the implementation of shortage pricing in 2012, historical experience was that there had never been more than two simultaneous reserve requirement violations at any one time.
  - During the Polar Vortex in 2014, PJM experienced a shortage of all four reserve requirements.

Reserve Price Caps

- The Synch Reserve Market Clearing Price is capped at 2 * Penalty Factor ($1,700).
- The Primary Reserve Market Clearing Price is capped at the Penalty Factor ($850).
- The above price caps are applicable regardless of:
  - The existence of a shortage condition
  - The existence of additive locational shortage
- This is an administrative constraint that may understate the reliability contribution of some reserve types.
  - Example: The MAD Synch Reserve Clearing Price is still capped at 2 * Penalty Factor even if reserve shortages exist for all four reserve requirements, despite MAD Synch Reserve being able to satisfy all four requirements.

Energy Price Caps

Prior to factoring in congestion and losses, the energy component of LMP is capped at the energy offer cap + 2 * Penalty Factor from the first step on the ORDC + a buffer to account for congestion and loss contribution.

- $2,000 + 2 * $850 +$50 = $3,750 maximum energy component
- **Total LMPs can still rise above this level when factoring in locational congestion and loss prices.**

Reserve Price Formation Changes May 2022

High Level Changes Under Reserve Price Formation

- A $2,000 penalty factor is used for all reserve product ORDCs.
  - SR, PR, and 30-minute reserves
- The changes discontinue the practice of administratively capping the reserve prices.
  - This allows the value of product and locational substitution to be fully recognized in the prices.
- The current Energy Price Cap is eliminated.
- Downward-sloping ORDC will affect the amount of MW cleared for Reserves.
  - And therefore, the amount available to be deployed during a reserve event
- Downward sloping ORDC will affect the clearing price for Reserves.
  - In general, not just during reserve events

Resulting Increases to Max Energy & Reserve Prices

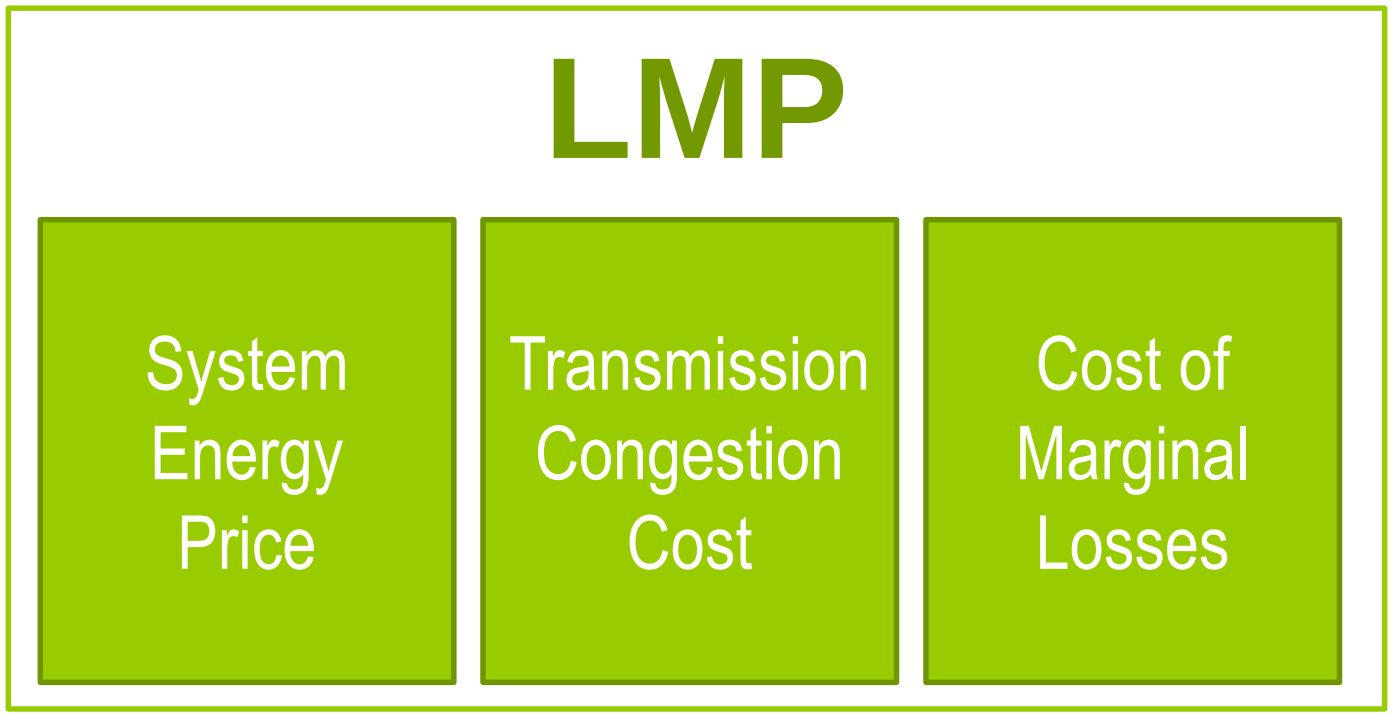
Using a penalty factor of $2,000/MWh on each of the ORDCs will result in the following changes to the maximum energy and reserve clearing prices in the unlikely scenario of simultaneous shortage of all three reserve products in all locations.

Product	Current Maximum Clearing Price($/MWh)	Future Maximum Clearing Price ($/MWh)
Secondary Reserves	N/A	$2,000*
Primary Reserves	$850	$6,000*
Synchronized Reserves	$1,700	$10,000*
Energy	$3,750	$12,000+* (assumes the marginal energy resource is $2,000)

* Assumes the sub-zone is not modeled for 30-Minute Reserve. In instances when the sub-zone is modeled, the $2000 penalty factor on the 30-Minute Reserve Sub-Zone ORDC would also cascade through the above prices.

Transmission Constraint Penalty Factors and Impact on Pricing

Locational Marginal Price



What is included in the LMP?

- System Energy Price
- Transmission Congestion Cost(s)
- Cost of Marginal Losses
- Effect of Reserve Shortages

System Energy LMP

System Energy LMP is the total cost increase resulting from increasing the output of the marginal resource while considering the impact of marginal losses to meet the next MW of load.

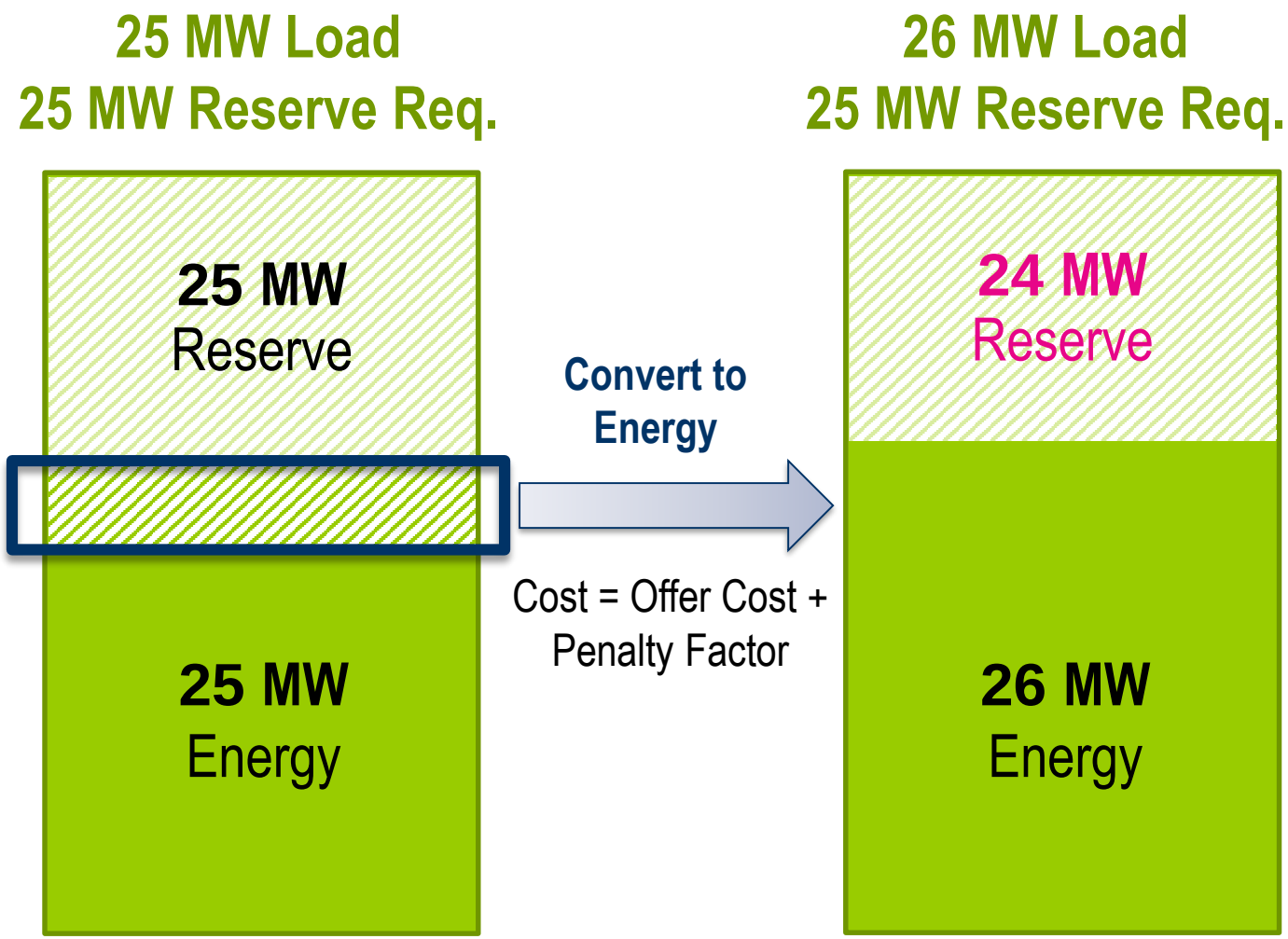
Three contributing factors are considered when calculating the total cost increase of the marginal resource to meet this additional MW of load:

- Marginal cost (including impact of marginal loss)
- Congestion cost
- Lost Opportunity Cost (LOC)

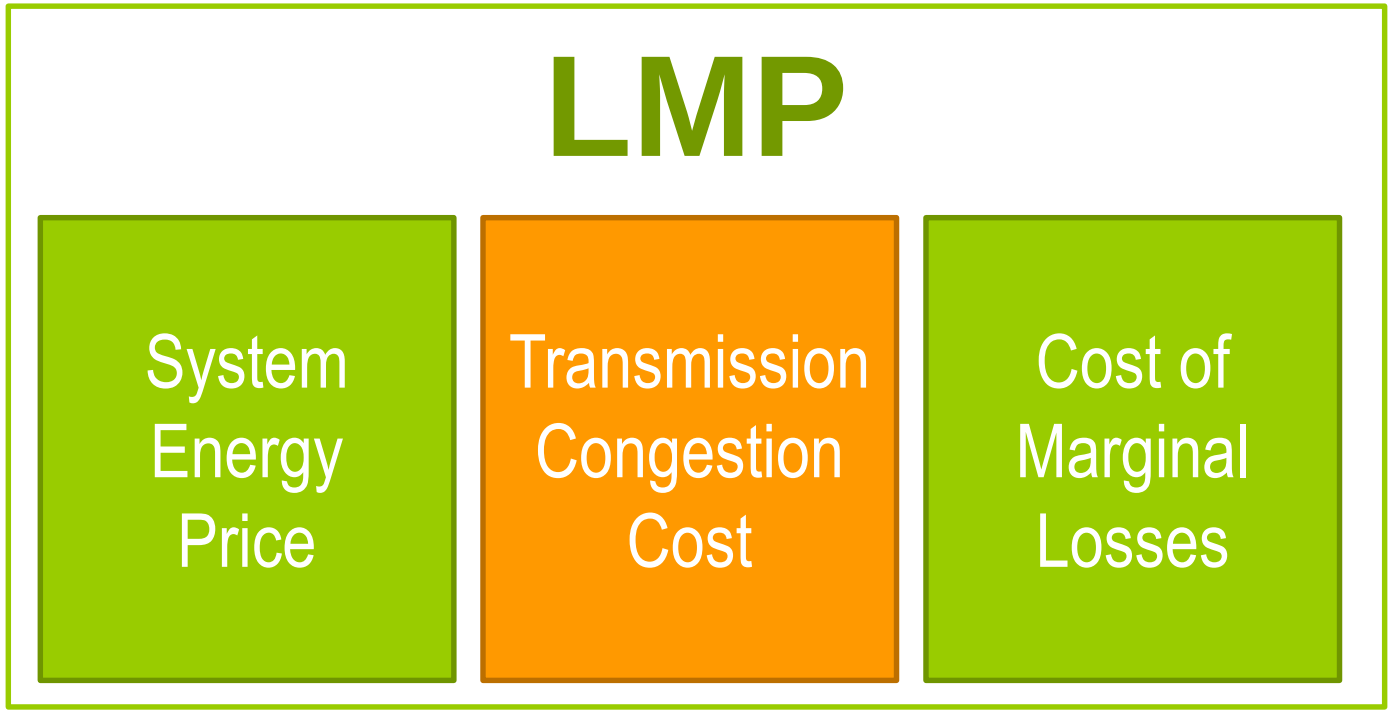
Pricing Energy During a Reserve Shortage

During a reserve shortage, the price of energy will continue to represent the cost of serving the next MW of load.

- When the system is short reserves, this cost includes the cost of converting a MW of reserve into energy.
- In other words, the energy price is the offer cost of energy, plus the penalty of going short one more MW of reserve.
  - The Locational Marginal Price (LMP), as well as the reserve market clearing price, will include the reserve penalty factor.



Locational Marginal Price



Congestion Price – Represents the price of congestion for binding constraints.

- Calculated using cost of marginal units controlling constraints and distribution factor on each bus
- No change in this calculation – will be zero if no constraints
- Will vary by location if system is constrained

Transmission Constraint Penalty Factors and Impact on Pricing

Transmission Constraint Penalty Factors
These are parameters used by the Security Constrained Economic Dispatch (SCED) applications to determine the maximum cost of the re-dispatch incurred to control a transmission constraint.

- The ultimate effect of the Transmission Constraint Penalty Factors is that they limit the controlling actions that can be taken to resolve a constraint by respecting the cost limits that the system is willing to incur to control it.
  - Similar in concept to the Operating Reserve Demand Curves used for pricing reserve shortages used in the reserve market.

Transmission Constraint Penalty Factors and Impact on Pricing

- PJM internal constraints, regardless of voltage level, are defaulted to a $2,000/MWh transmission constraint penalty factor.
  - This was selected as the default value because historically, most constraints can be effectively controlled at a cost below $2,000/MWh.
- The default value can be overridden on an individual constraint basis.
  - This is dependent on system conditions and the amount of generation able to be re-dispatched to control the constraint.

Transmission Constraint Penalty Factors and Impact on Pricing

As a result of a 2018 stakeholder process initiative, the **Transmission Constraint Penalty Factor** is allowed to set the shadow price of a transmission constraint in the market-clearing software when the constraint cannot be adequately controlled in the market-clearing software.

Example LMP Calculation

	System Energy Price	X	* 1.0	=	System Energy Component
System Energy Component	$33.11	X	1.0	=	$33.11

	System Energy Price	X	Marginal Loss Sensitivity Factor	=	Marginal Loss Component
Loss Component	$33.11	X	-0.0315	=	($1.04)

Congestion Components	Constraint Shadow Price	X	DFAX	=	Congestion Component
Constraint A	-$9.96	X	-0.3151	=	$3.14
Constraint B	-$13.88	X	0.1225	=	($1.70)
Constraint C	-$26.06	X	-0.2151	=	$5.61
Constraint D	-$2000	X	-0.0200	=	$40.00

LMP = $79.12

Performance Assessment Interval and Shortage Pricing

Performance Assessment Interval (PAI) shall mean each Real-Time Settlement Interval for which an Emergency Action has been declared by PJM.

PAI Triggers:

Steps 1–10 in Sections 2 and 5 of Emergency Procedures Manual 13
Pre-Emergency Load Management Reduction Action (30, 60 or 120 minutes)
Emergency Load Management Reduction Action (30, 60 or 120 minutes)
Primary Reserve Warning
Maximum Generation Emergency Action
Emergency Voluntary Energy-Only Demand Response Reduction Action
Voltage Reduction Warning & Reduction of Critical Plant Load
Curtailment of Non-Essential Building Load
Deploy All Resources Action
Manual Load Dump Warning
Voltage Reduction Action
Manual Load Dump Action

Warnings
Actions

Section 5.7 of Emergency Procedures Manual 13
Load Shed Directive

Hot Weather Alerts and Cold Weather Alerts **ARE NOT PAI** triggers

Voltage Reduction Action and Manual Load Dump Action **Automatically Trigger Shortage Pricing**

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