



U.S. ISO/RTO Wholesale Market Caps

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- Overview of PJM
- Energy Market Caps
- Reserve Market Products and Caps
- Other PJM Market Caps
- Questions

Overview of PJM

- **Regulated by** the Federal Energy Regulatory Commission (FERC)
- **Reliability coordinator** for the PJM region under the North American Electric Reliability Corporation (NERC)
- **Independent** of companies in the marketplace and neutral on technology



Reliability

- Grid Operations
- Supply/Demand Balance
- Transmission monitoring

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Regional Planning

- 15-Year Outlook

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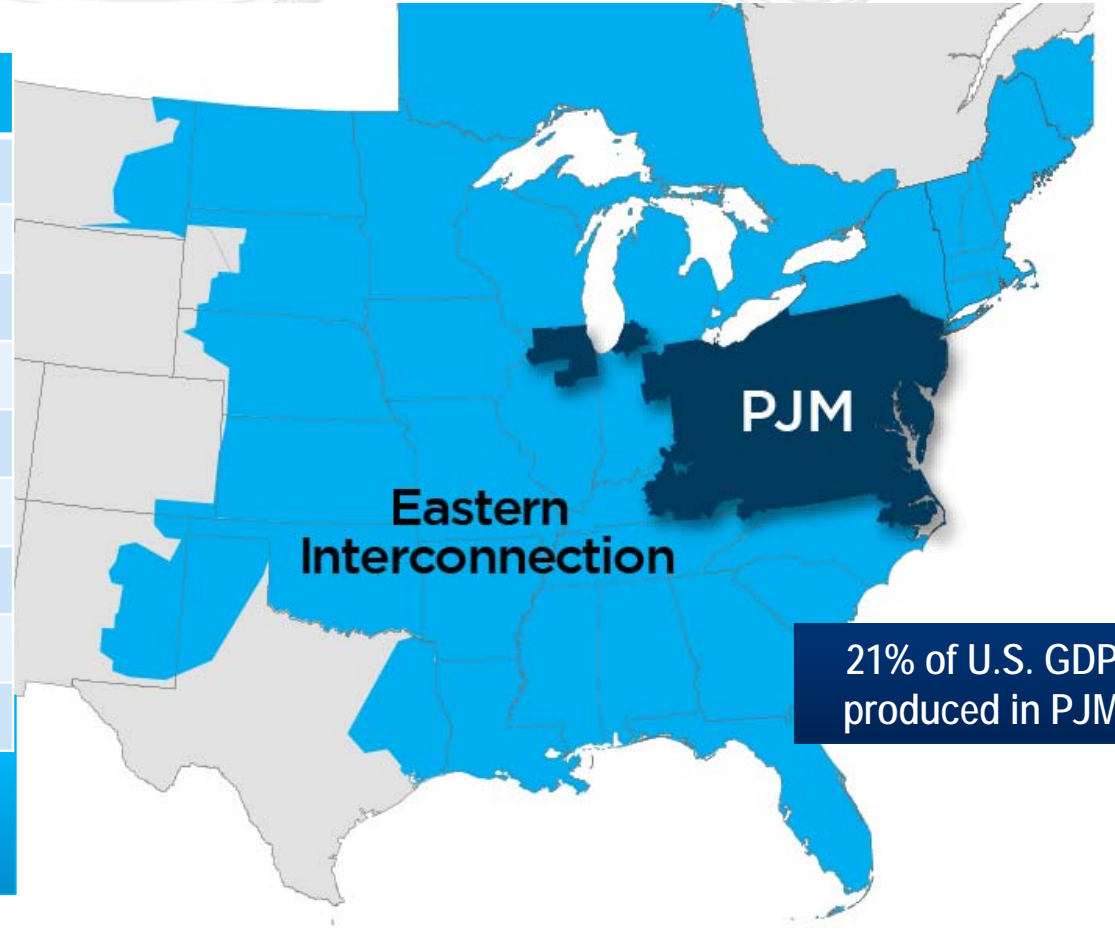
Market Operation

- Energy
- Capacity
- Ancillary Services

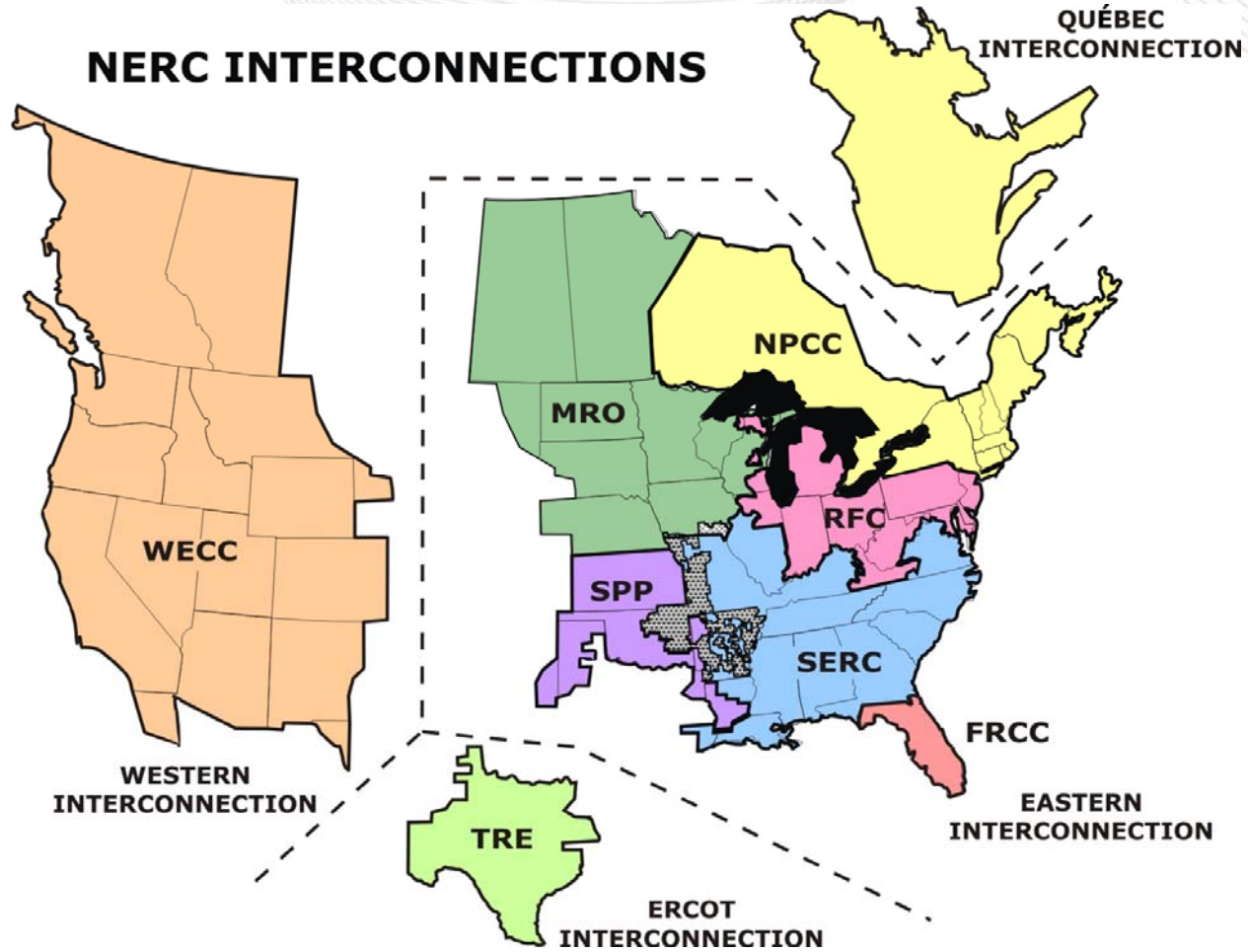
Key Statistics

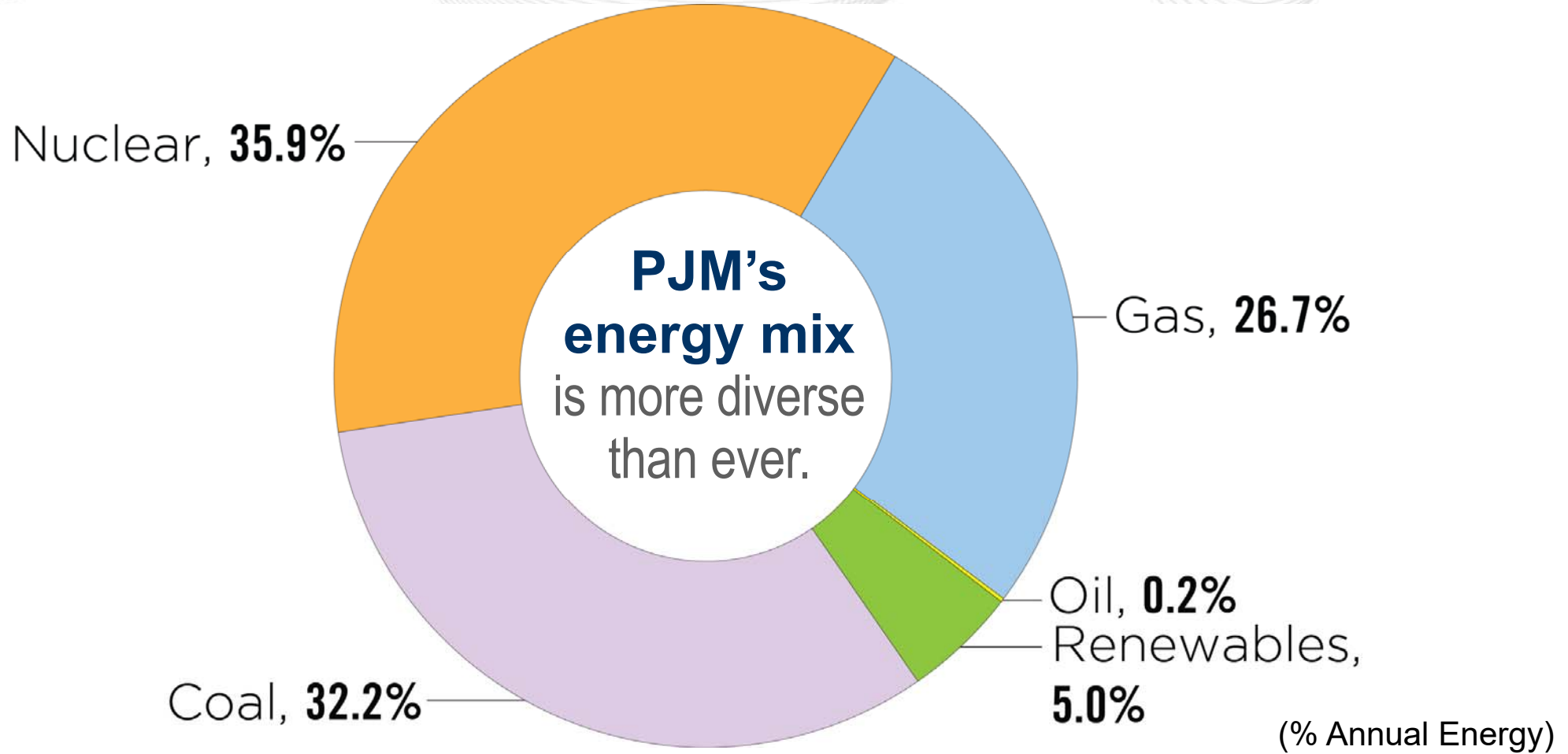
Member companies	1,040+
Millions of people served	65
Peak load in megawatts	165,492
MW of generating capacity	178,563
Miles of transmission lines	84,042
2017 GWh of annual energy	773,522
Generation sources	1,379
Square miles of territory	243,417
States served	13 + DC

- 28% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection



As of 2/2018





Energy Market Caps

- Electricity markets are more susceptible than other markets to the exercise of market power by suppliers.
 - Low price elasticity of demand (little change in electricity use as prices rise)
 - When supplies are tight, generators are typically needed at almost any price
- FERC has used two approaches to limit market power:
 - Offer caps
 - Market power mitigation

- Limit the extent to which generators can raise prices when markets are not competitive
- Much higher than the cost of generating electricity from almost all resources

- Offer rules established to ensure that outcomes below the offer caps are competitive
- Limits how much a resource can offer above its costs
- If a unit's offer exceeds these limits **and** impacts market outcomes, its offer is changed to one that reflects its costs

- Issued in November 2016 regarding offer caps for resource incremental energy offers in the day-ahead and real-time energy markets
- Applies to all U.S. markets under FERC jurisdiction:
 - California Independent System Operator (CAISO)
 - ISO New England (ISO-NE)
 - Midcontinent Independent System Operator (MISO)
 - New York Independent System Operator (NYISO)
 - PJM
 - Southwest Power Pool (SPP)
- Implemented in PJM on April 12, 2018

- Market participants can only submit incremental energy offers up to 1,000 US\$/MWh without review
- Offers above 1,000 US\$/MWh need to be verified on a cost basis before they are allowed to set price
- Offers above 2,000 US\$/MWh must also be verified on a cost basis, but they are exempt from setting price

- FERC specifies no offer floors
- Some ISOs/RTOs have offer floors:

ISO/RTO	Offer Floor (US\$/MWh)
CAISO	-150
ISO-NE	-150
MISO	-500
SPP	-500

- FERC specifies no price caps or price floors
- Markets under FERC jurisdiction do not have any specific energy market price caps or price floors with the exception of MISO
- MISO specifies a Value of Lost Load (VoLL) that caps energy market prices at 3,500 US\$/MWh

- Not under FERC jurisdiction
 - Regulated by the Public Utility Commission (PUC) of Texas
- Maximum offer cap: 9,000 US\$/MWh
- Offer floor: -250 US\$/MWh
- The offer cap is used to achieve adequate scarcity pricing since ERCOT has an energy-only market, and the caps are linked to the value of lost load (VoLL).
- The ERCOT VoLL was determined by the PUC of Texas during proceedings related to resource adequacy. However, VoLL is not defined in any ERCOT protocols or PUC substantive rules.

- PJM –
 - Only hit on two days in the past several years (2014).
 - Longest duration was for 5 hours
 - Average duration was for 2 hours
- ERCOT –
 - Not reached since 2011
 - Longest duration was for 3 hours
 - Average duration was for 75 minutes

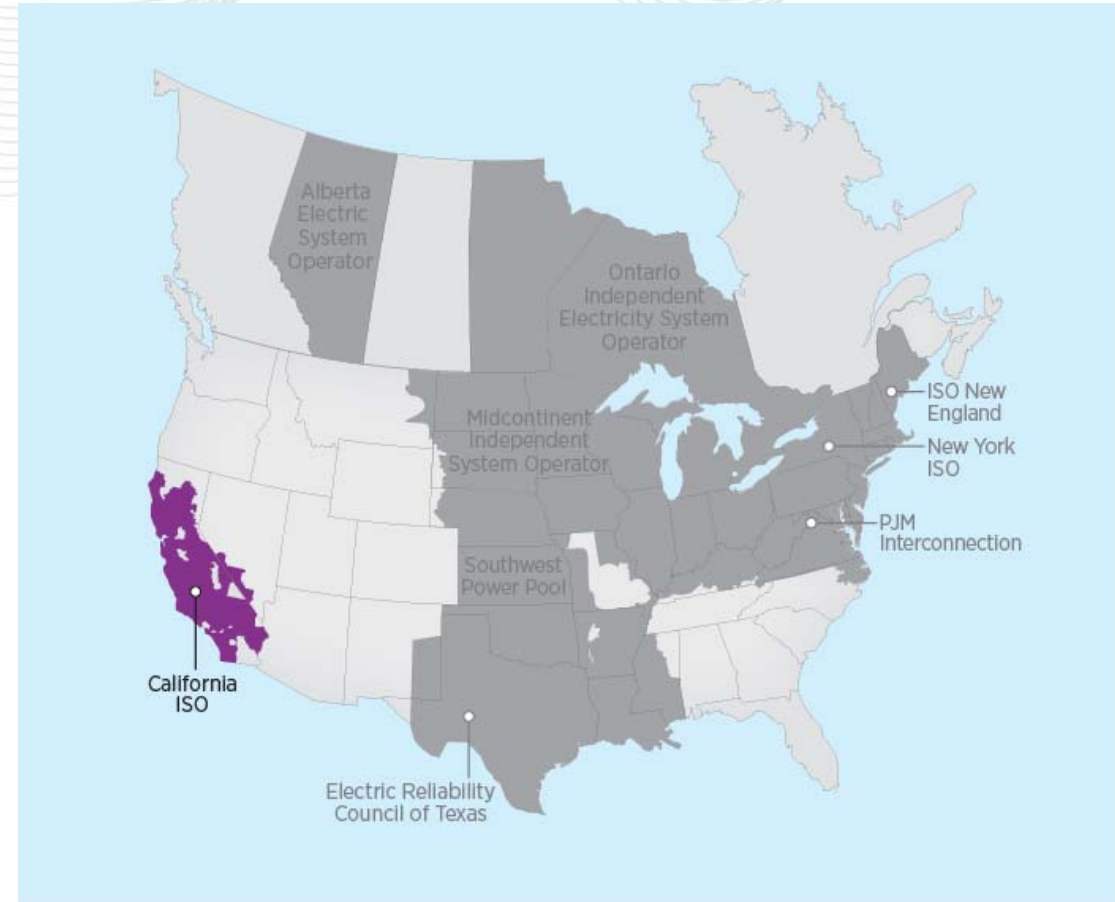


Reserve Market Products and Caps

Reserve Products

- Spinning Reserve (10-minute)
 - Non-spinning Reserve (10-minute)
 - Subregional Reserve Requirements
- Day-ahead and real-time reserve products
 - Simultaneously co-optimize energy, reserves, and regulation service
 - Cascading prices

Regulation-Up \geq Spinning \geq Non-Spinning



Requirement	Shortage Amount	Value (US\$/MWh)
Regulation-Up	Any	200
Spinning	Any	100
Non-Spinning	0 MW–70 MW	500
	70 MW–210 MW	600
	More than 210 MW	700

Reserve Products

- 10-Minute Spinning Reserve
 - 10-Minute Non-Spinning Reserve
 - 30-Minute Operating Reserve
 - Local 30-Minute Operating Reserve
- Real-time reserve products only
 - Simultaneously co-optimize energy and reserves
 - Cascading prices
 - 10-Minute Spinning \geq 10-Minute Non-Spinning \geq 30-Minute Operating



Requirement	Sub-Category	Value (US\$/MWh)
10-Minute Spinning		50
10-Minute Non-Spinning		1,500
30-Minute Operating	Minimum Requirement	1,000
	Replacement Reserves	250
Local 30-Minute Operating		250

Reserve Products

- Spinning Reserve (10-minute)
 - Supplemental (Non-Spinning) Reserve (10-minute)
 - Zonal Reserve Requirements
- Day-ahead and real-time reserve products
 - Simultaneously co-optimize energy, reserves, and regulation service
 - Cascading prices
Regulation \geq Spinning \geq Supplemental



Requirement	Region	Shortage Amount	Value (US\$/MWh)
Regulation	All	Any	Max(100, peaker commitment cost for 1 hour)
Spinning	MISO	0–10% of requirement	65
		More than 10% of requirement	98
	Reserve Zone	0–10% of requirement	65
		More than 10% of requirement	98
Total Operating Reserves	MISO	0–4% of requirement	200
		4%–96% of requirement	1,100–3,400
		More than 96% of requirement	3,400
	Reserve Zone	0–20% of requirement	200
		20%–90% of requirement	1,100
		More than 90% of requirement	3,400

Reserve Products

- Day-Ahead Scheduling Reserve (30-minute)
- Real-Time Synchronized Reserve (10-minute)
- Real-Time Non-Synchronized Reserve (10-minute)
- Zonal Reserve Requirements

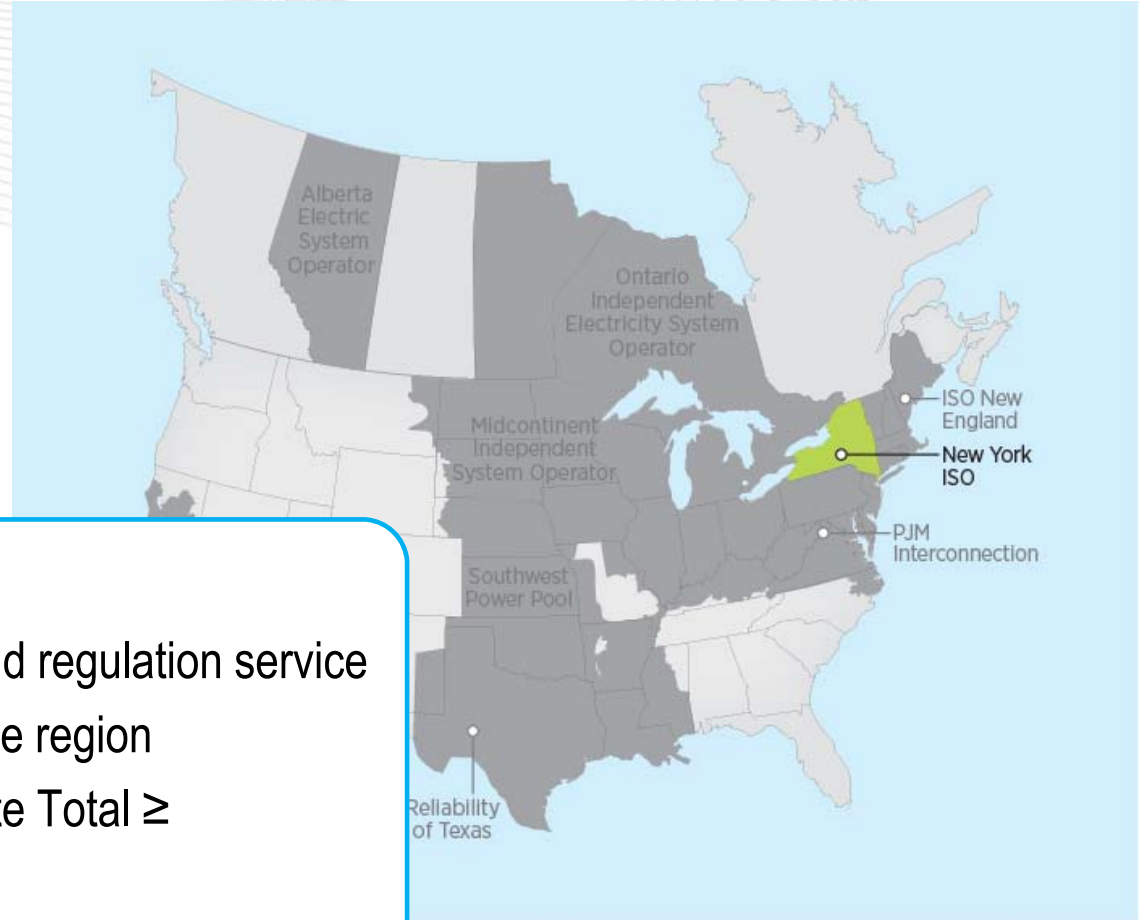
- Day-Ahead and Real-time reserve products
- Simultaneously co-optimize energy and reserves
- Cascading prices
Synchronized \geq Non-Synchronized



Requirement	Region	Shortage Amount	Value (US\$/MWh)
Synchronized Reserve	System	0 MW – 190 MW	300
		More than 190 MW	850
	MAD	0 MW – 190 MW	300
		More than 190 MW	850
Non-Synchronized Reserve	System	0 MW – 190 MW	300
		More than 190 MW	850
	MAD	0 MW – 190 MW	300
		More than 190 MW	850

Reserve Products

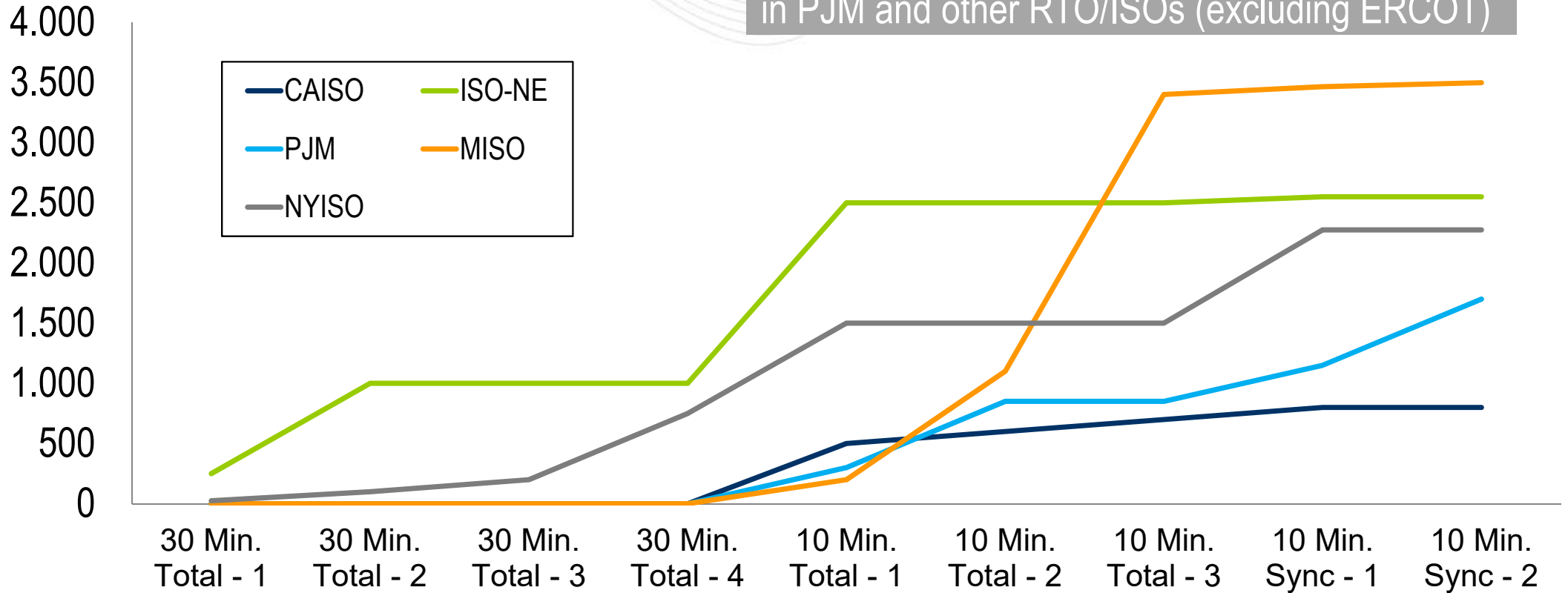
- 10-Minute Spinning Reserve
 - 10-Minute Total Reserve
 - 30-Minute Operating Reserve
 - Regional Reserve Requirements
- Day-ahead and real-time reserve products
 - Simultaneously co-optimize energy, reserves and regulation service
 - Cascading prices by reserve product and reserve region
 - Regulation \geq 10-Minute Spinning \geq 10-Minute Total \geq 30-Minute Operating
 - LI \geq SENY \geq EAST \geq NYCA



Requirement	Region	Shortage Amount	Value (US\$/MWh)
Regulation	NYCA	0 MW–25 MW	25
		25 MW–80 MW	400
		More than 80 MW	775
10-Minute Spinning	NYCA	Any	775
	All Other		25
10-Minute Total	NYCA	Any	750
	EAST	Any	775
	All Other	Any	25
30-Minute Operating	NYCA	0 MW–300 MW	25
		300 MW–655 MW	100
		655 MW–955 MW	200
		More than 955 MW	750
	SENY	Any	500
	All Other	Any	25

Cascaded Shortage Price (US\$/MWh)

Cascading Shortage Prices for Selected Products in PJM and other RTO/ISOs (excluding ERCOT)

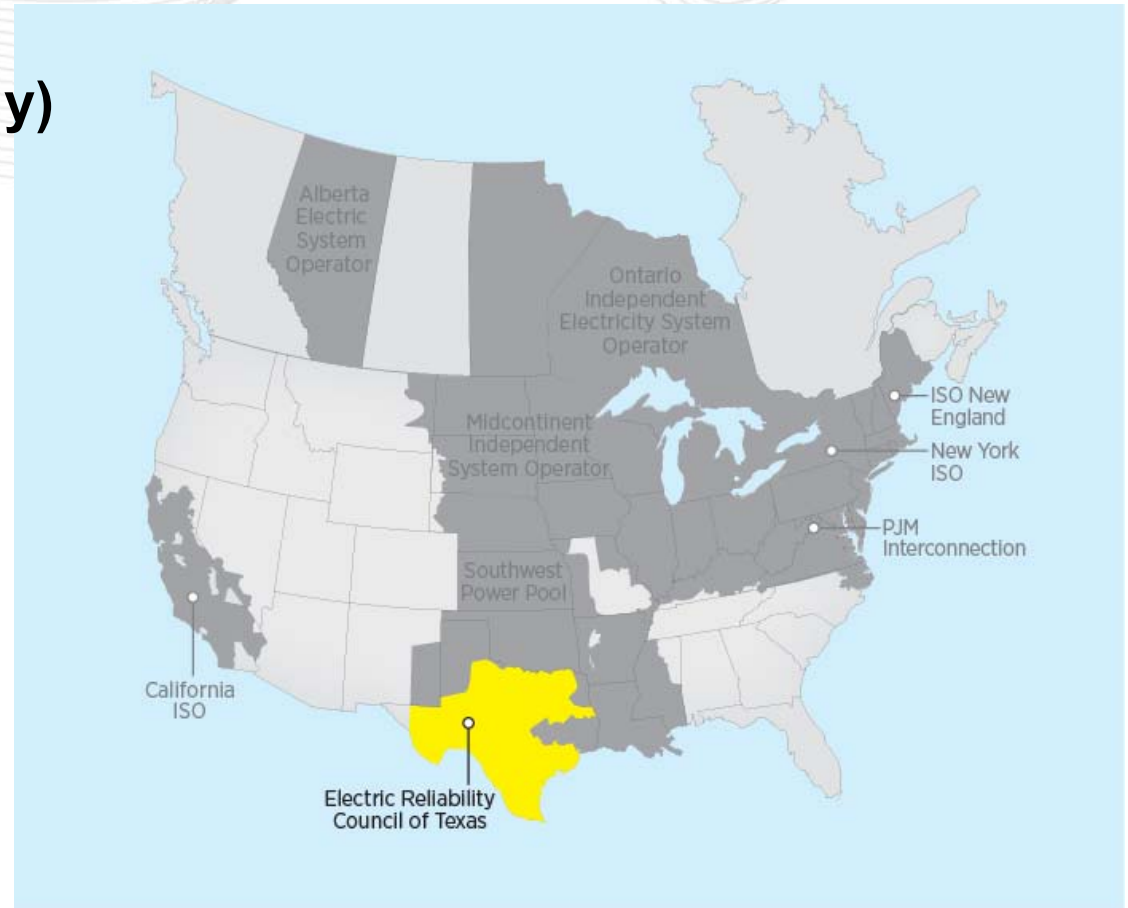


While there are differences in the types of products available in PJM and the other ISO/RTOs reviewed so far, all of them share some common features:

- Products have a certain MW requirement with associated penalty factors
- These requirements and penalty factors are combined to derive vertical (or stepwise) Operating Reserve Demand Curves (ORDCs) with prices capped at the penalty factors
- **ERCOT is different** because its ORDCs are downward-sloping and prices are capped at the Value of Lost Load (VoLL)

Reserve Products (system-wide only)

- Responsive Reserve (Spinning)
 - Non-spinning Reserve (30-minute)
- Day-ahead and real-time reserve products
 - No co-optimization of energy and reserves
 - Operating Reserve Demand Curves (ORDCs) used to price reserves in real-time
 - Cascading prices
Responsive \geq Non-Spinning

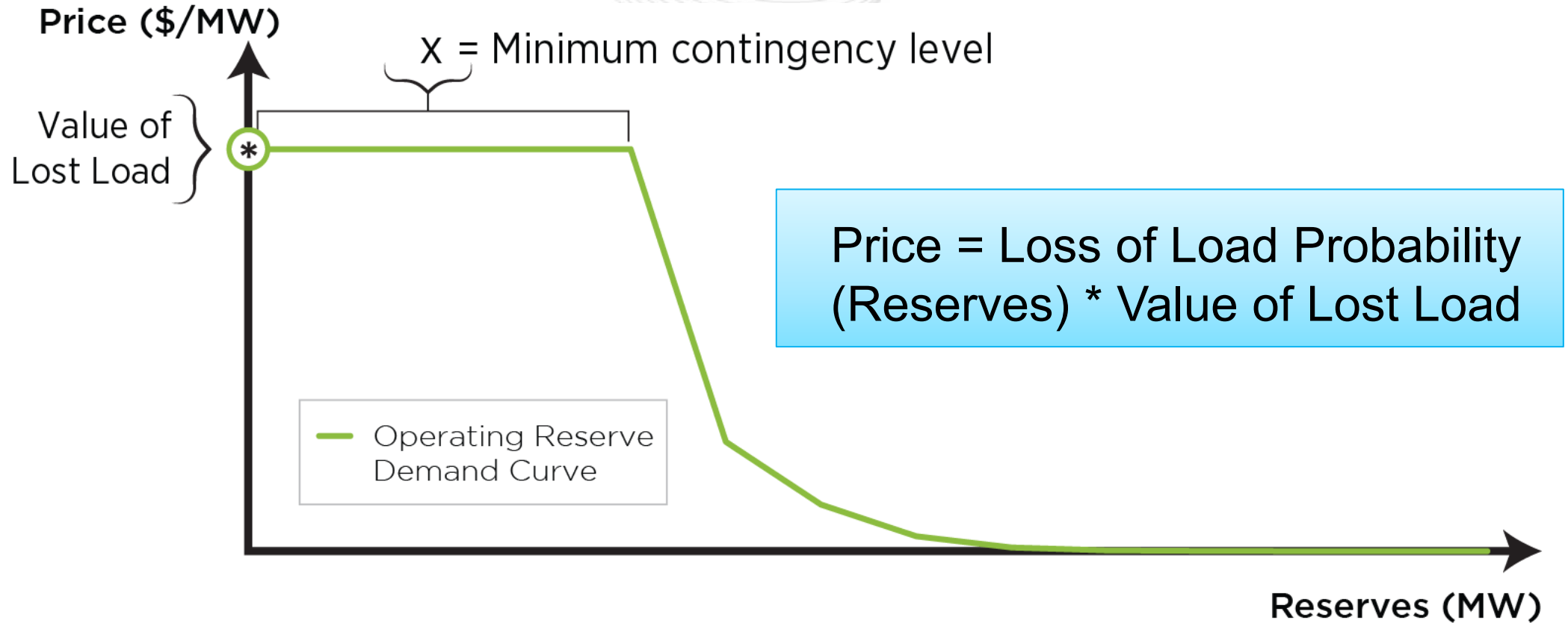


Key concepts

- **Value of Lost Load (VoLL):** value (in dollars) that a 1 MW reserve increment has in preventing a 1 MW shedding of load
- **Loss of Load Probability (LOLP):** in general, probability that, at a time t , available capacity minus load is less than 0 MW (or a minimum contingency MW value)

Implementation

- Not via co-optimization of energy and reserves; price adder based on a side calculation
- System-wide ORDC



- VoLL approved by ERCOT board
 - Currently set at US\$9,000 per MWh
- VoLL is shifted down by the System Lambda
 - System Lambda is the energy component of the LMP
- X, the minimum contingency level, currently at 2,000 MW
- LOLP is not calculated at the 0 MW threshold but at the minimum contingency level (X)

Other PJM Market Caps

- Offer Cap: Participants can submit offers up to the higher of avoidable cost or the cost of new entry
- Price Cap: Set by the demand curve

- Offer Cap: Participants can submit offers up to the higher of actual costs or 100 US\$/MWh
- There are no price caps.