

VALUE OF ANCILLARY SERVICES

Current Revenues and Future Scenarios

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Workshop

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Thanks to Erik Ela, Udi Helman, and Qingyu Xu

Outline

- Ancillary services by compensation
- Recent price trends
- Takeaways

Information from upcoming report

Report outline

- What is each ancillary service, including requirements and eligibility?
- Elements of ancillary service auction-based competitive markets
- Ancillary service price outcomes
- Insights and future research needs

Ancillary Services in the United States

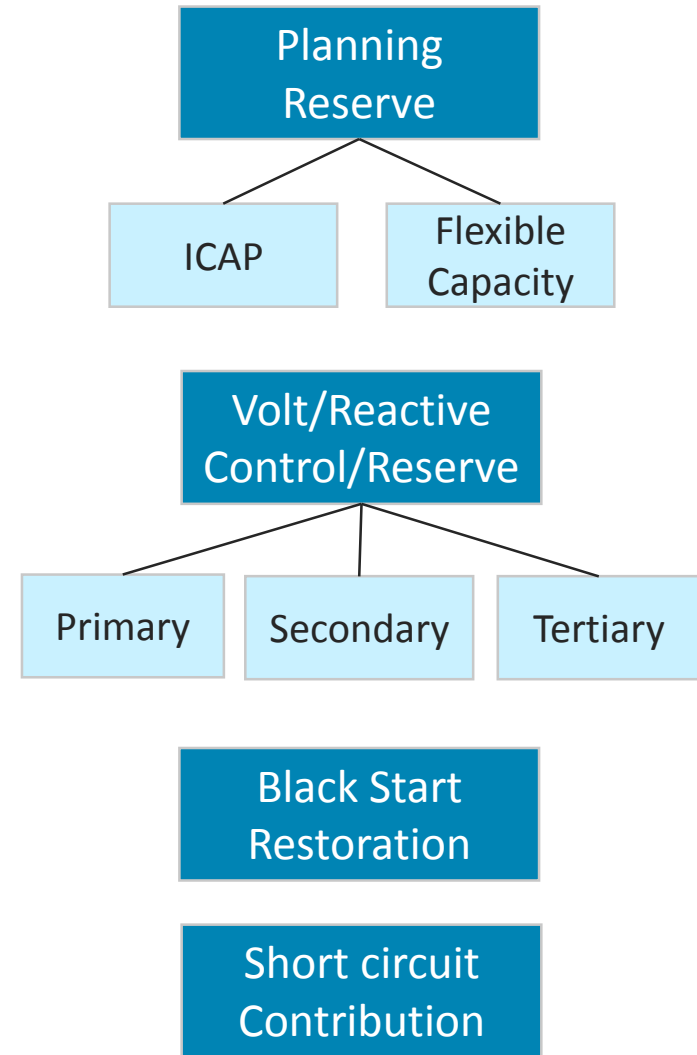
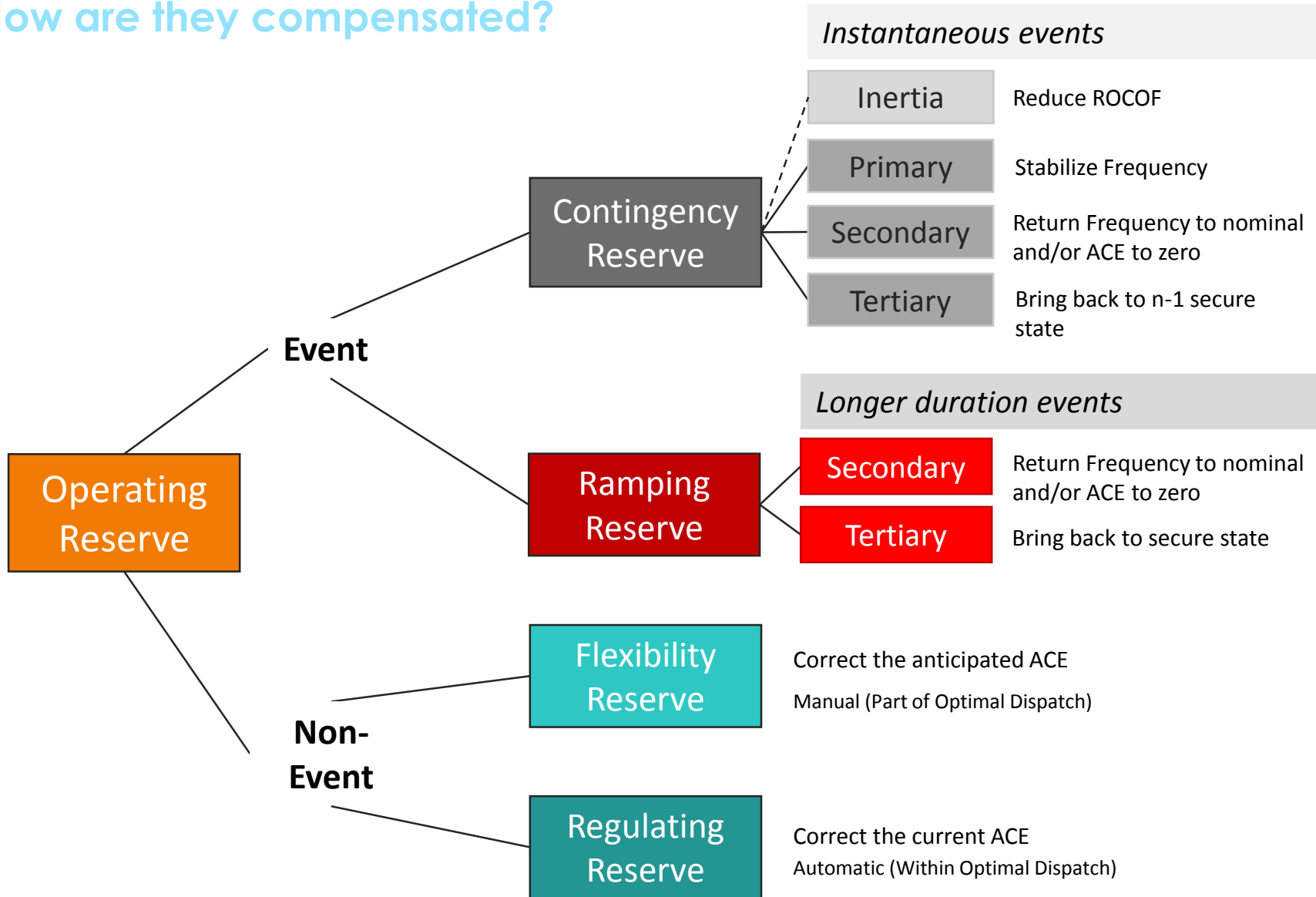
Technical Requirements, Market Designs and Price Trends

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Erik Ela, Robin Broder Hytowitz, Udi Helman





Reliability Services

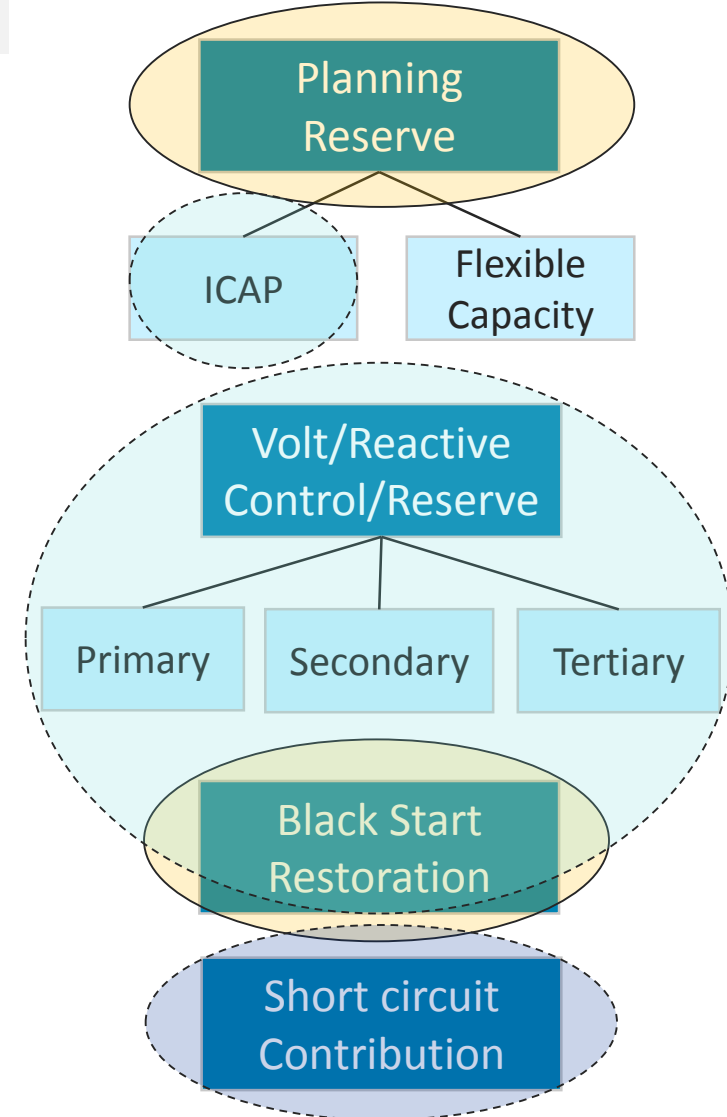
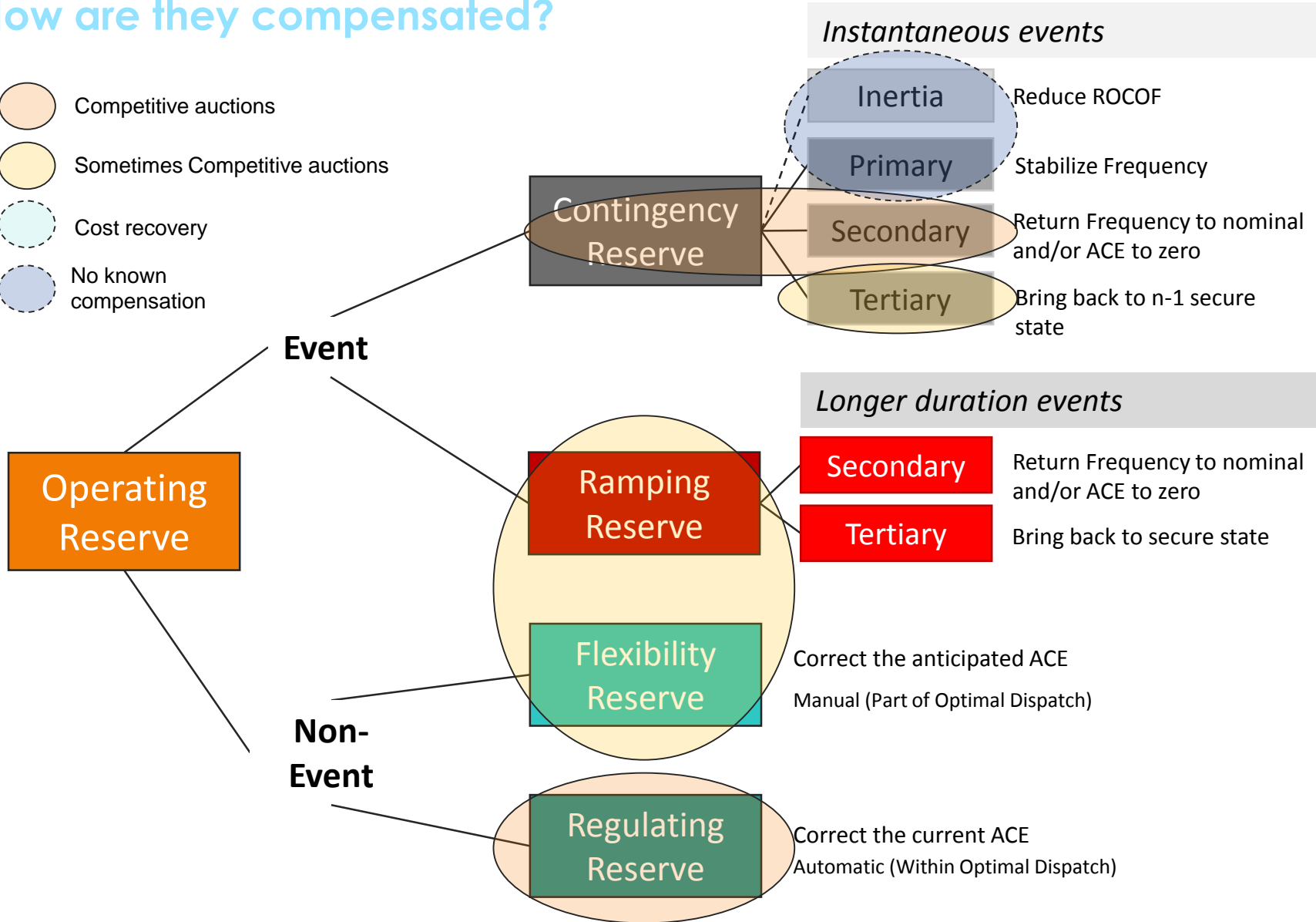
How are they compensated?



Reliability Services

How are they compensated?

-  Competitive auctions
-  Sometimes Competitive auctions
-  Cost recovery
-  No known compensation



Reliability Services

Should every service be priced through competitive markets?

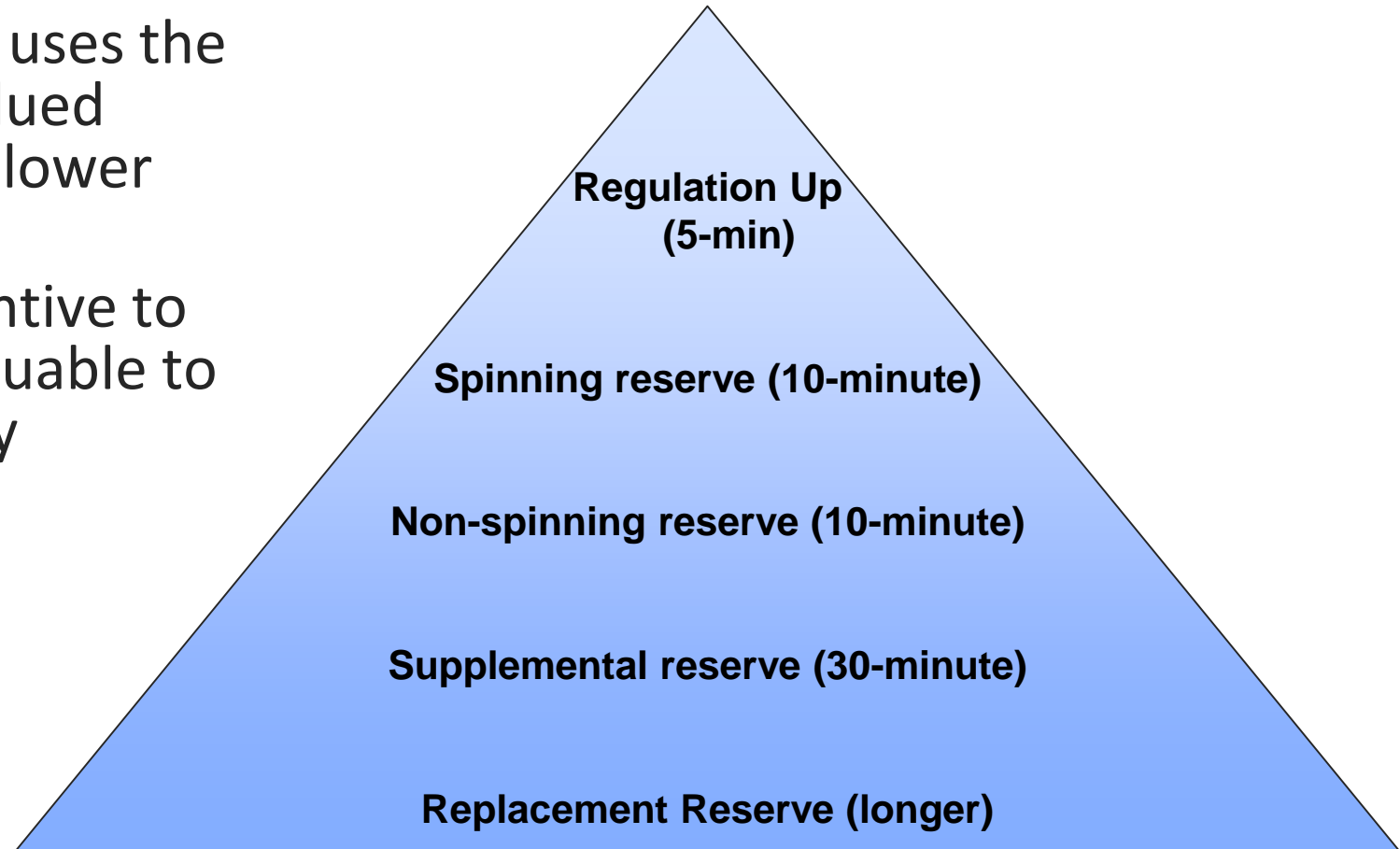
- Some reliability attributes are not currently incentivized
- Sometimes auctions and market-based pricing for certain services may be impractical

Reasons why a market product may not be implemented	Example
Too complex to design (e.g., software complexity)	Volt/VAR support
Too specific to certain local areas (little to no competition)	Volt/VAR support
System inherently has more than sufficient amounts of the service	Synchronous Inertia
Costs for the service may be small, so cost of administering market product may outweigh benefits	Black start (restoration) service
A specific resource requirement rather than a system-wide need	Low Voltage Ride Through

The examples are used for illustrative purposes only and the reason may not be necessarily true for each example in each region.

Pricing Hierarchy

- Pricing hierarchy in place in most U.S. markets
 - A higher valued service that uses the same capacity as a lower valued service should never have a lower price
 - Ensures a resource has incentive to provide the service most valuable to the market and for reliability
- Different markets may vary on hierarchy (e.g., not all include regulation in every market)

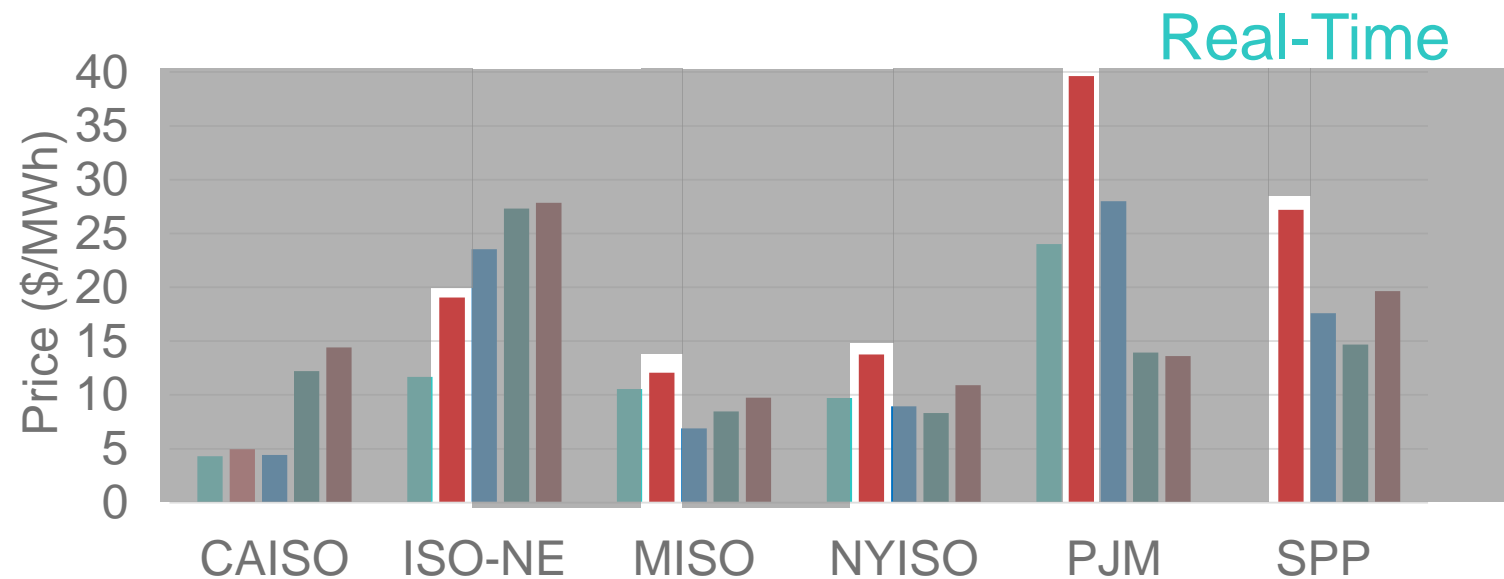
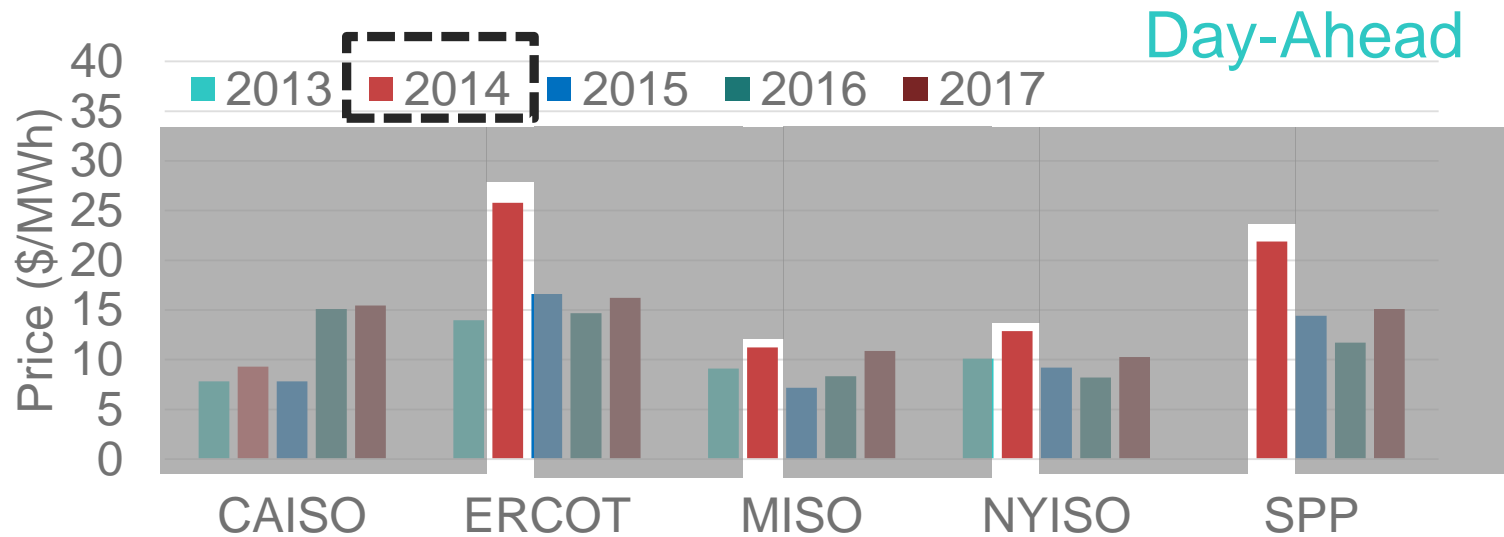


REGULATING RESERVE

Regulating Reserve Prices

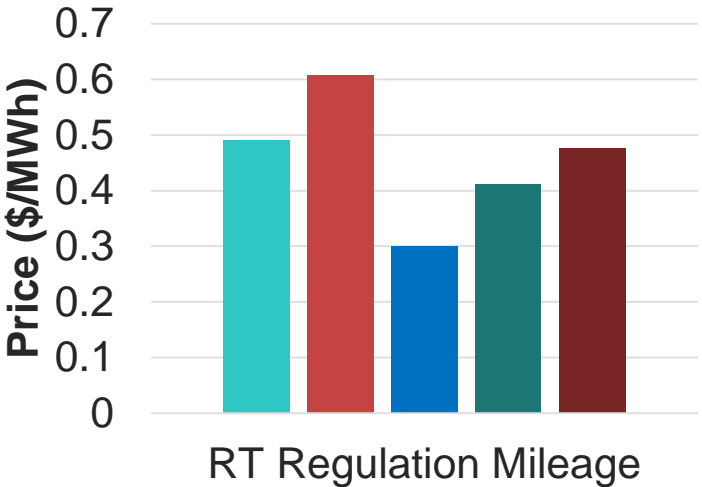
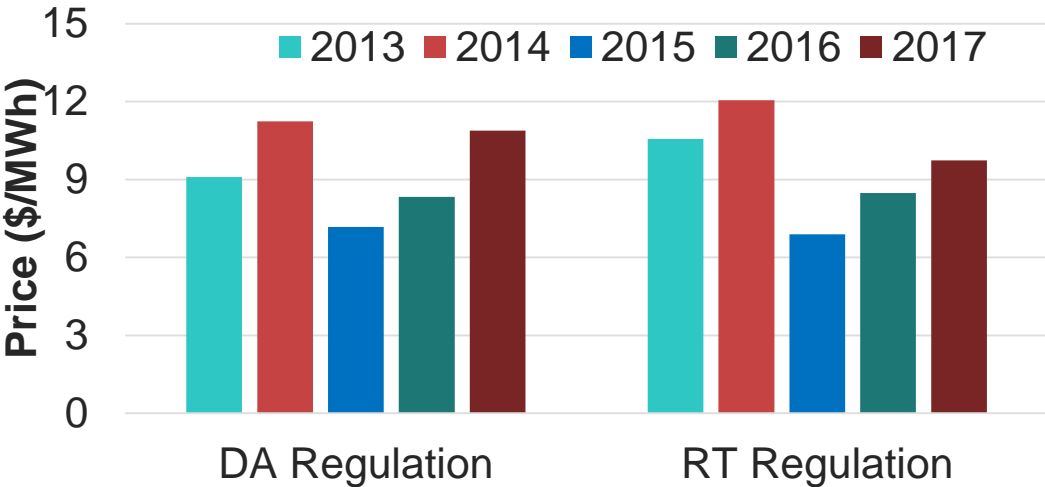
Other Common names: Regulation, AGC reserve, load frequency control, regulating up and regulating down

- Shows combined regulation product and regulation up + down (summed)
- Products in day-ahead and real-time range by ISO

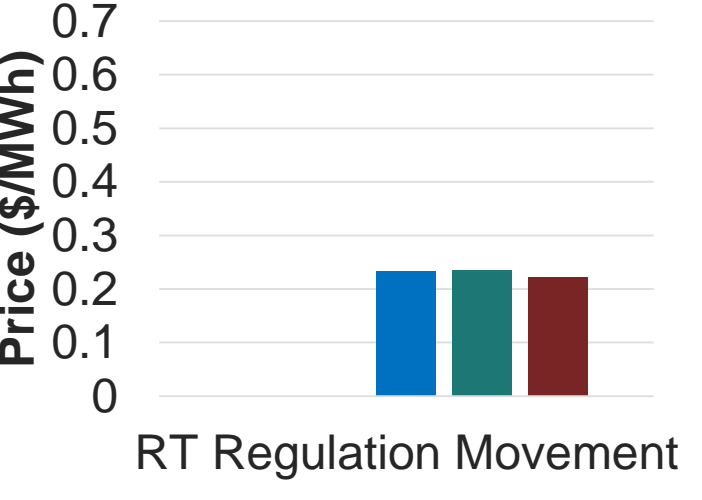
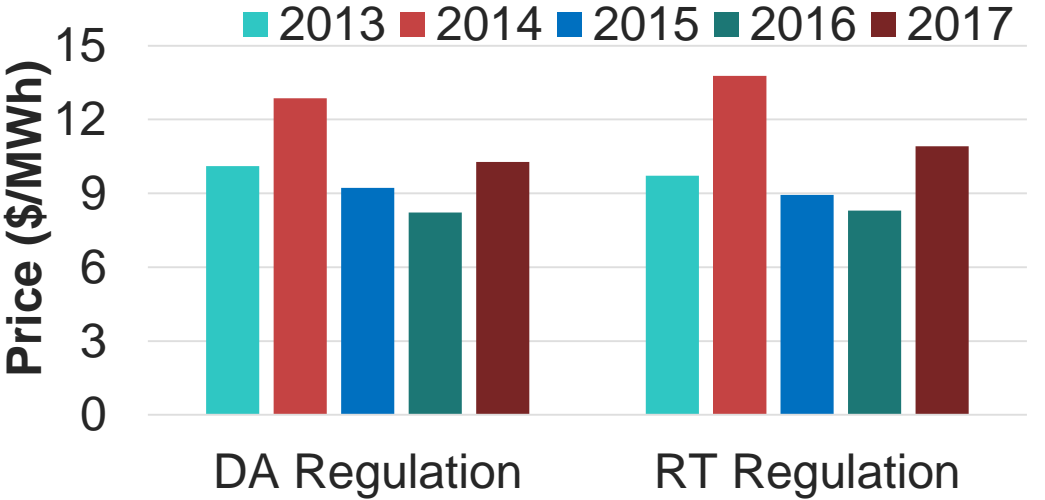


Regulating Reserve Products

MISO

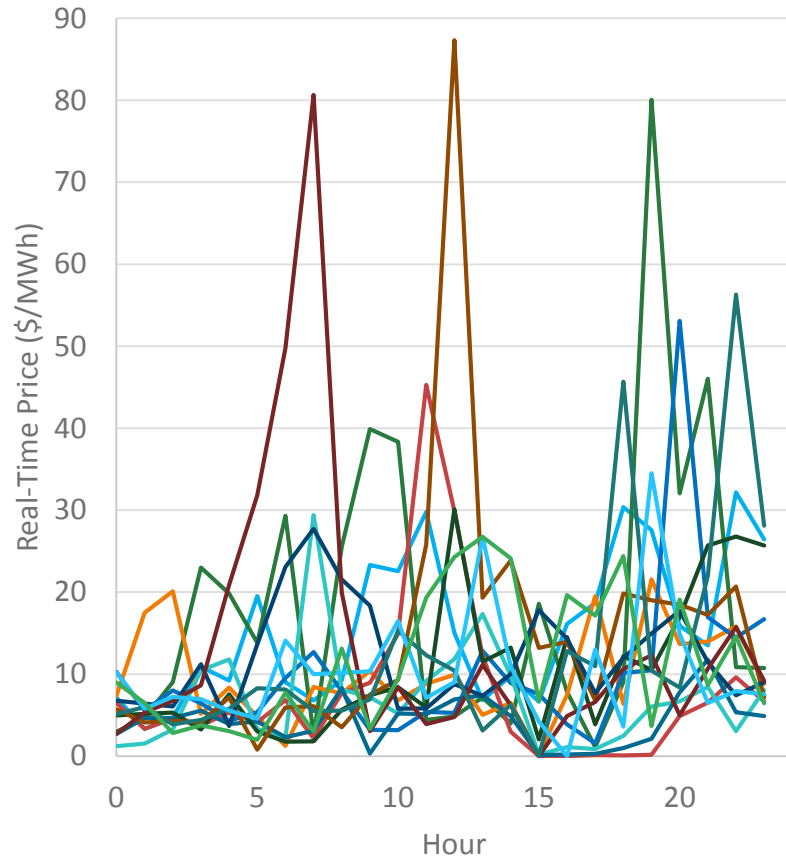


NYISO

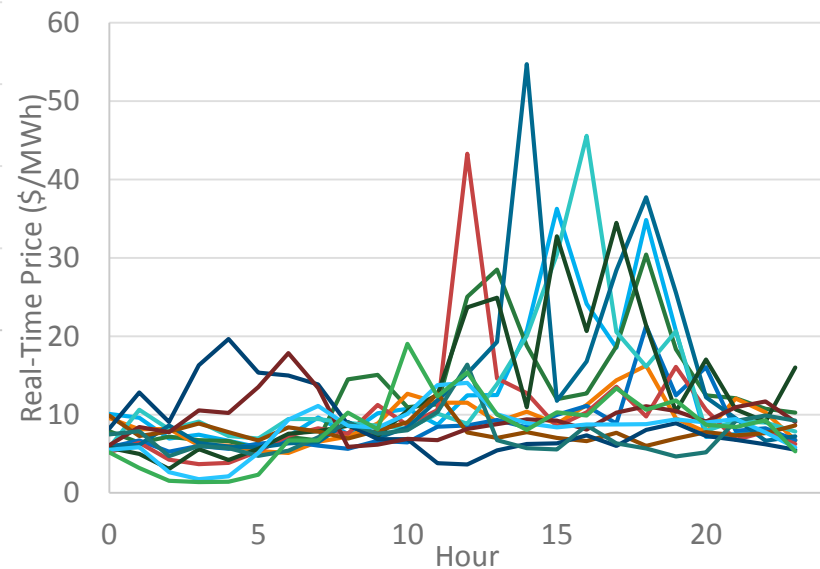
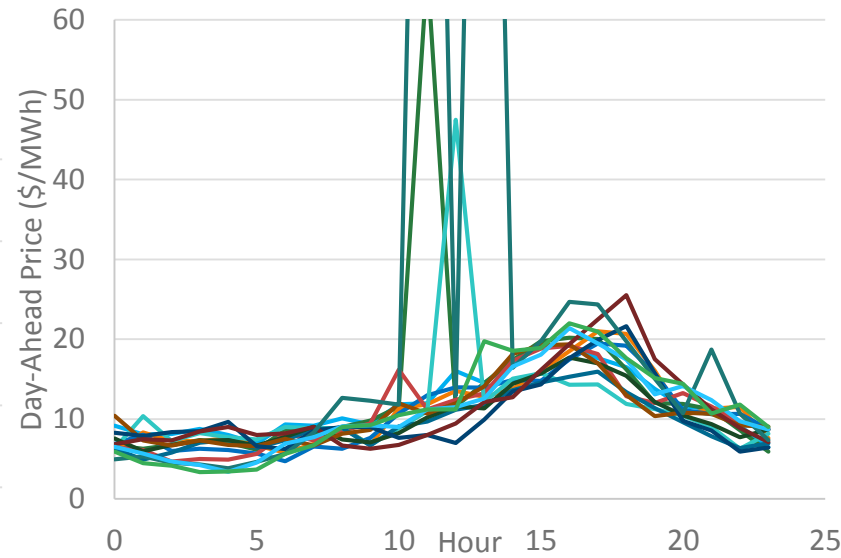


June 1-14, 2017 regulating reserve prices

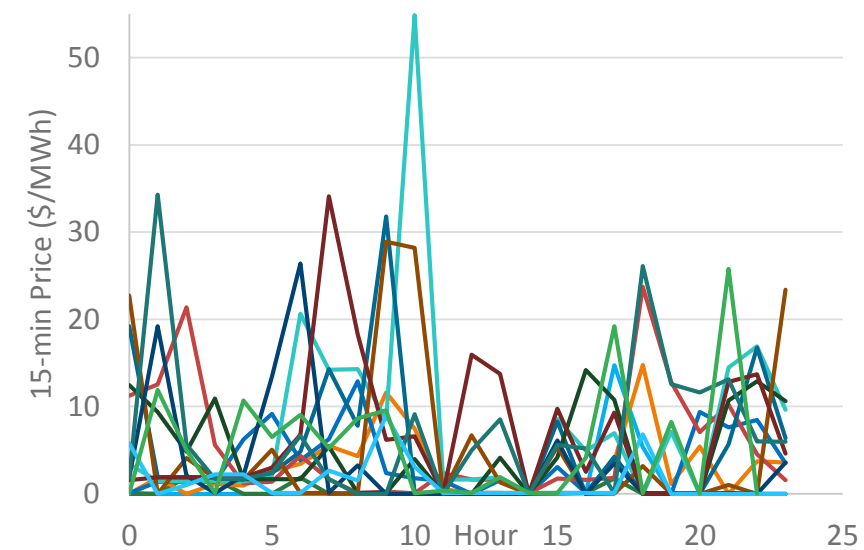
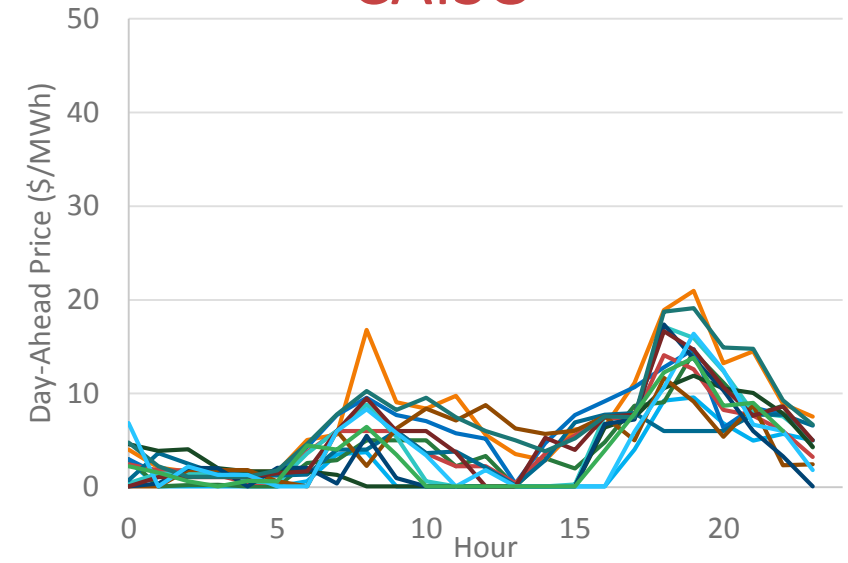
PJM



MISO



CAISO



Monthly and hourly averaged real-time regulation prices, 2017

NYISO and PJM show a combined product, CAISO shows regulation up

Hr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2	4	9	14	10	9	6	4	3	5	5	6	1	9	6	10	20	15	12	8	8	8	15	14	9	1	19	11	8	6	12	6	8	6	19	9	7	32
2	2	3	7	11	7	6	4	3	2	5	4	4	2	11	9	12	18	13	14	7	8	5	8	17	10	2	8	7	6	8	6	6	5	6	12	8	8	23
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CAISO

NYISO

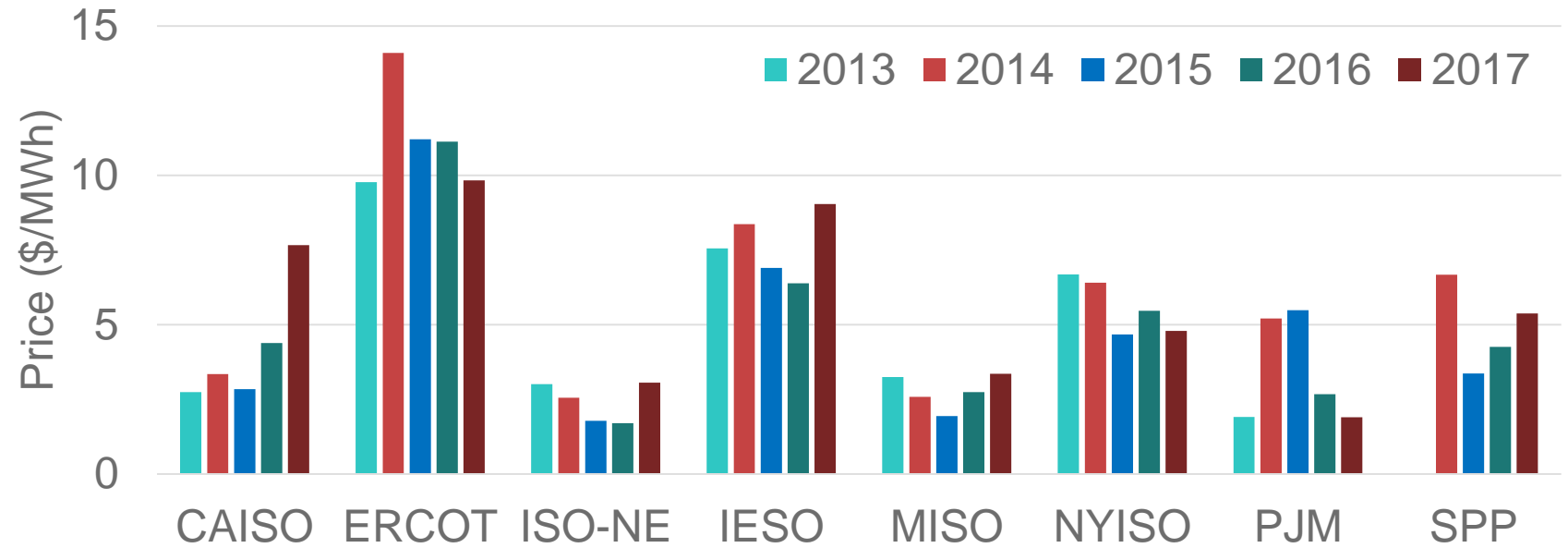
PJM

CONTINGENCY RESERVE

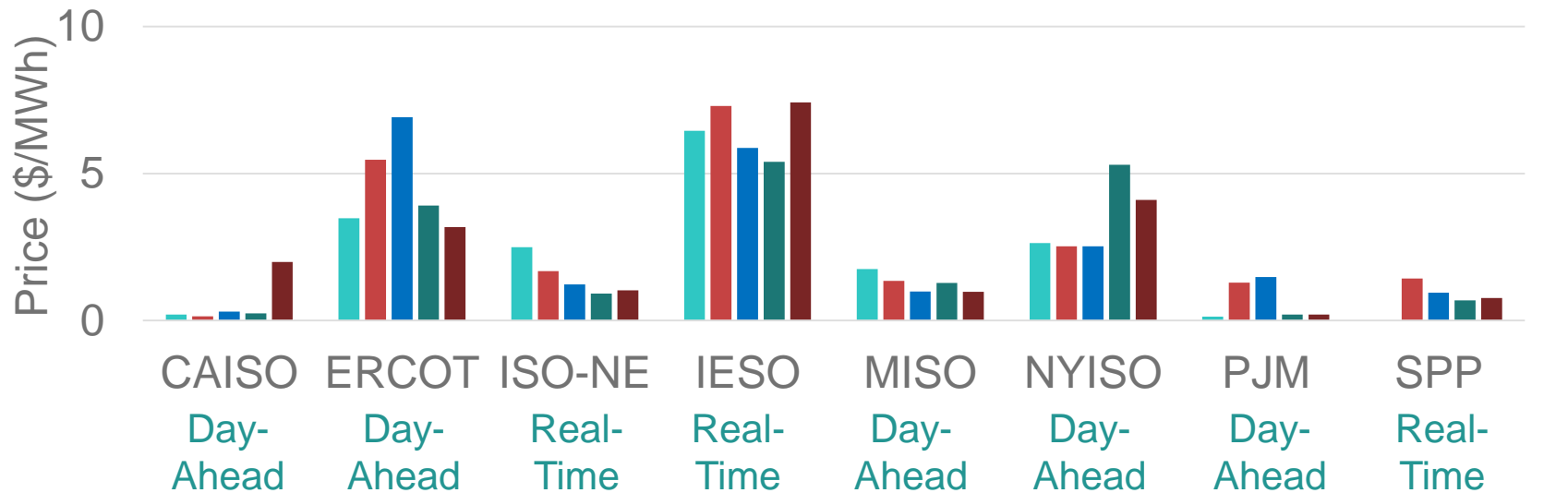
Contingency Reserve Prices

Other Common names: Spinning, non-spinning, synchronized, non-synchronized, ten-minute

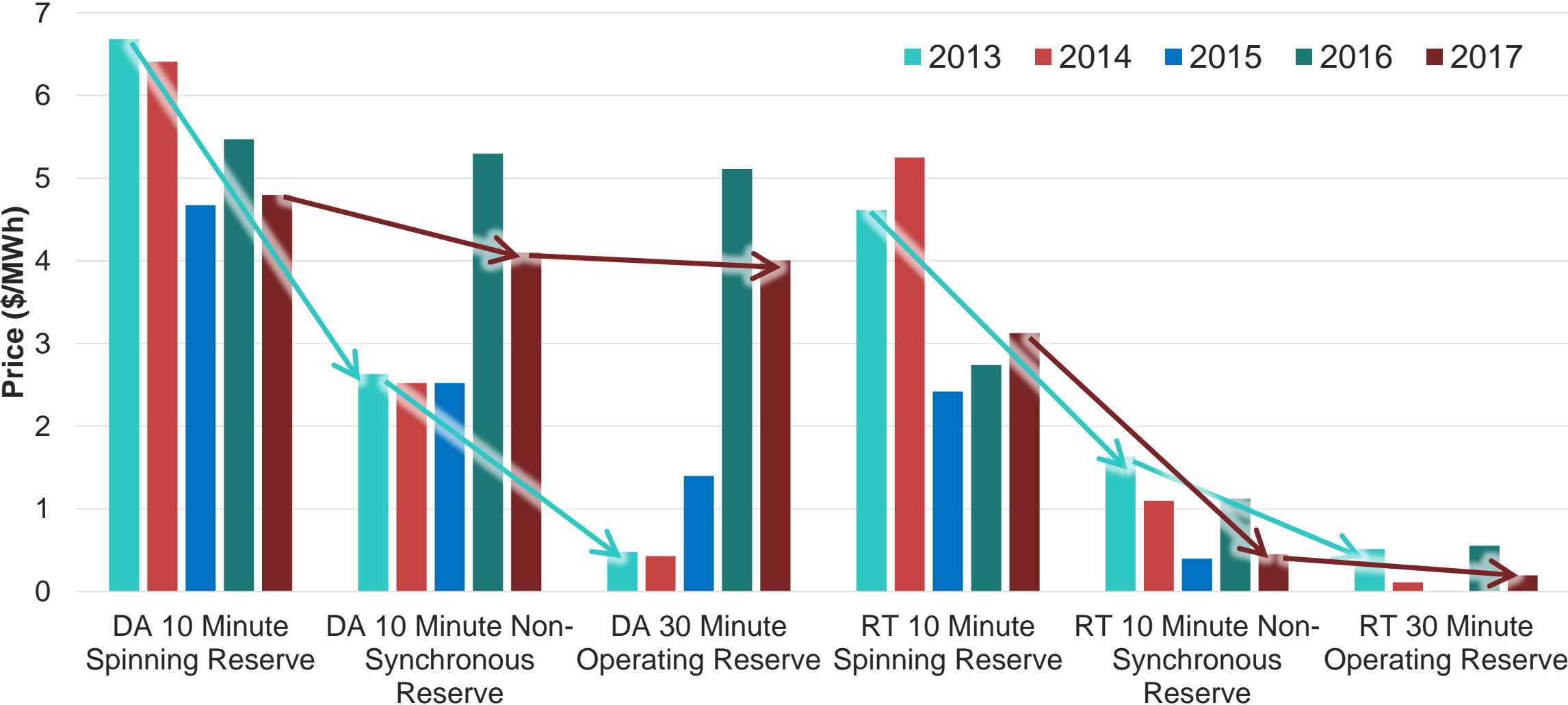
- Spinning reserve



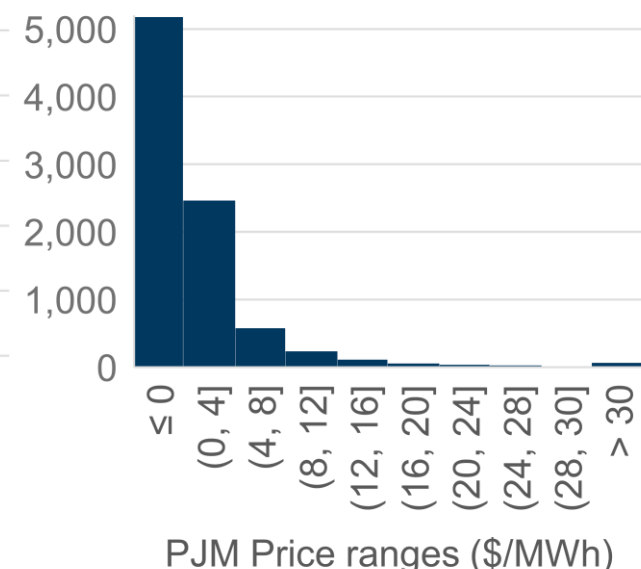
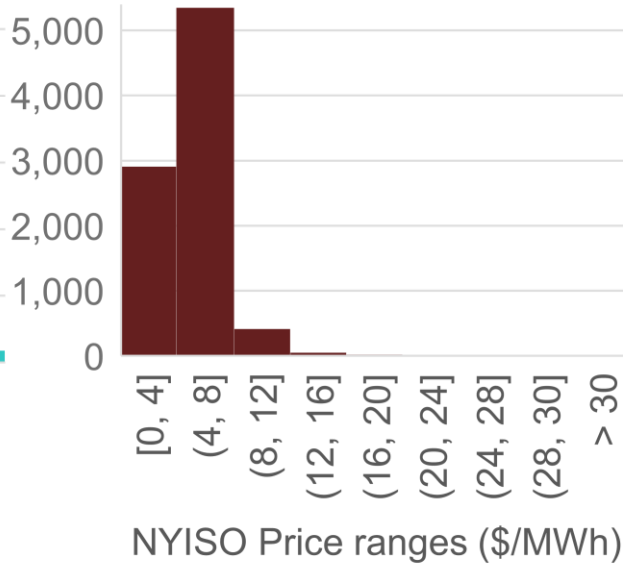
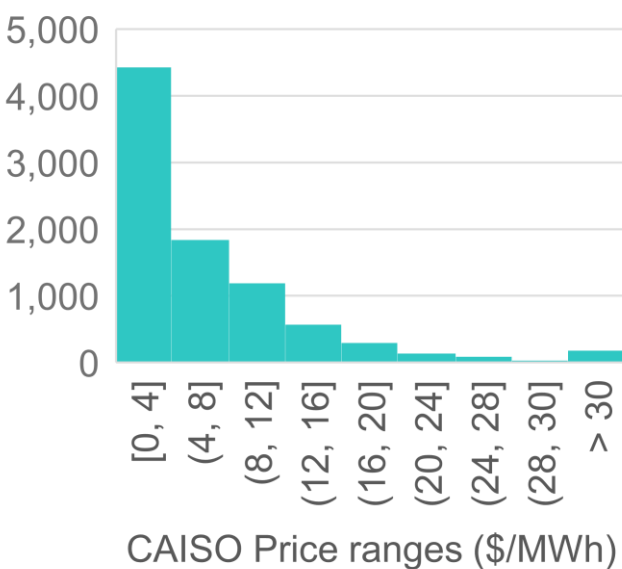
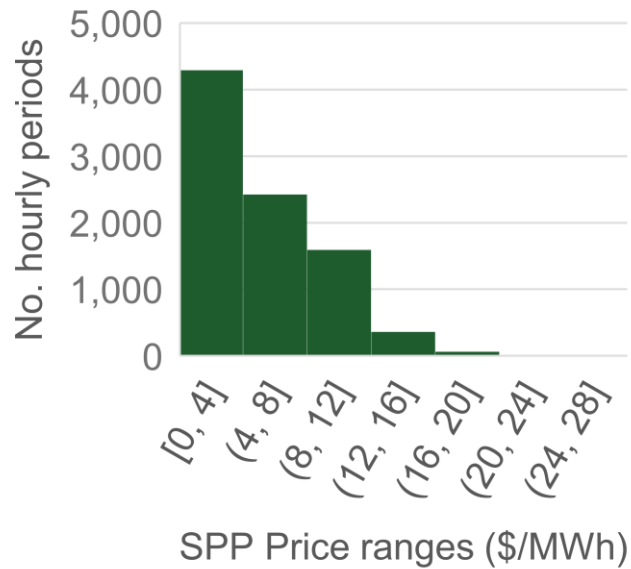
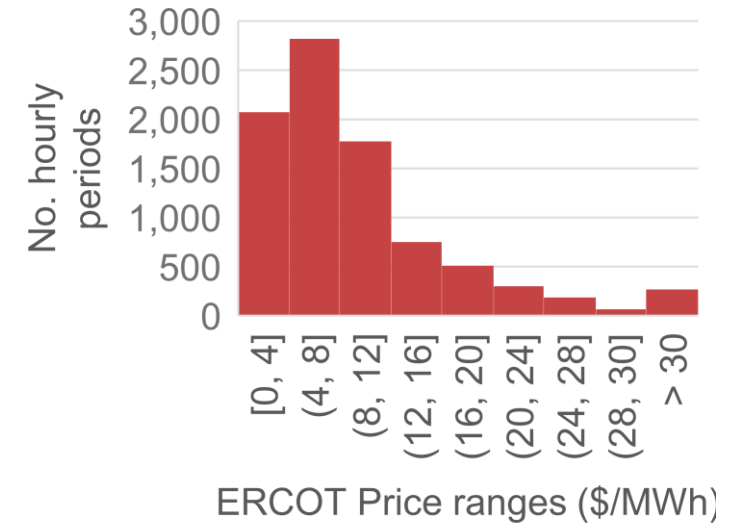
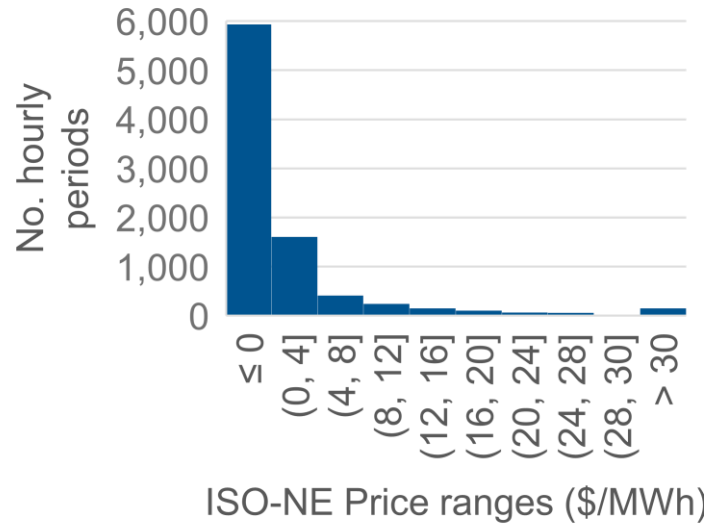
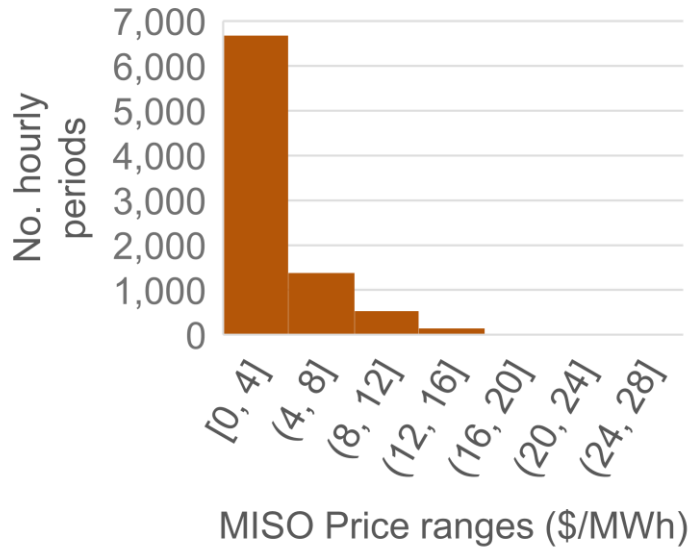
- Non-spinning



NYISO Contingency Reserve Products



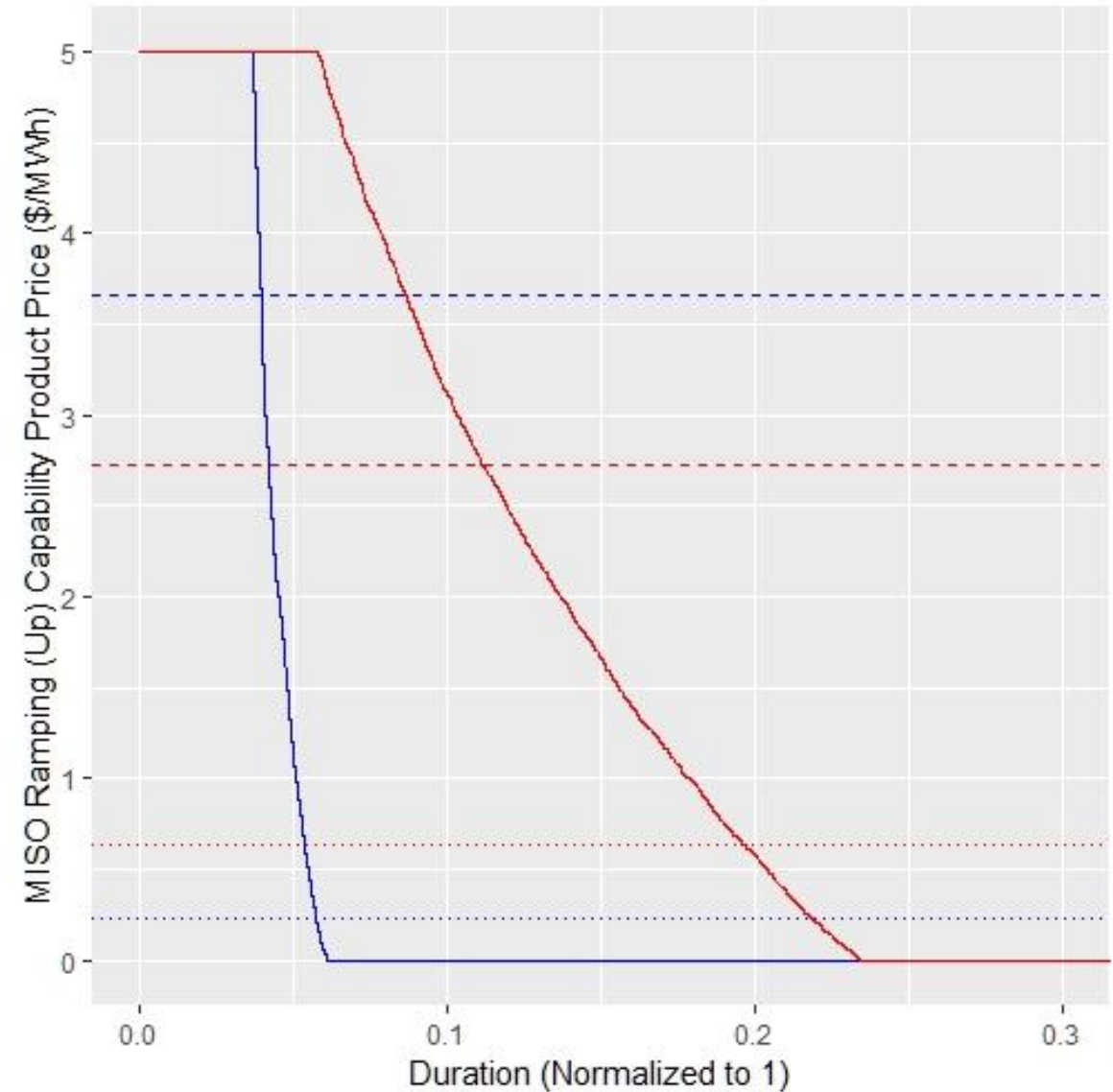
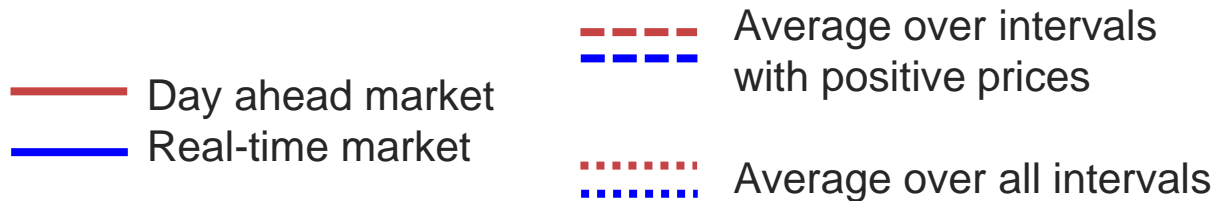
Real-time spinning reserve histograms for 2017



RAMP RESERVE

MISO Ramp Capability Product

- Few periods have non-zero prices
 - Down ramping had no positive prices during period
 - Up ramp had positive prices 23% of the time in day-ahead, 6% in real-time
- Price hit cap of \$5/MWh in day-ahead 5.8% of time and 3.7% in real-time
- Average prices
 - Day-ahead: \$0.64/MWh
 - Real-time: \$0.22/MWh



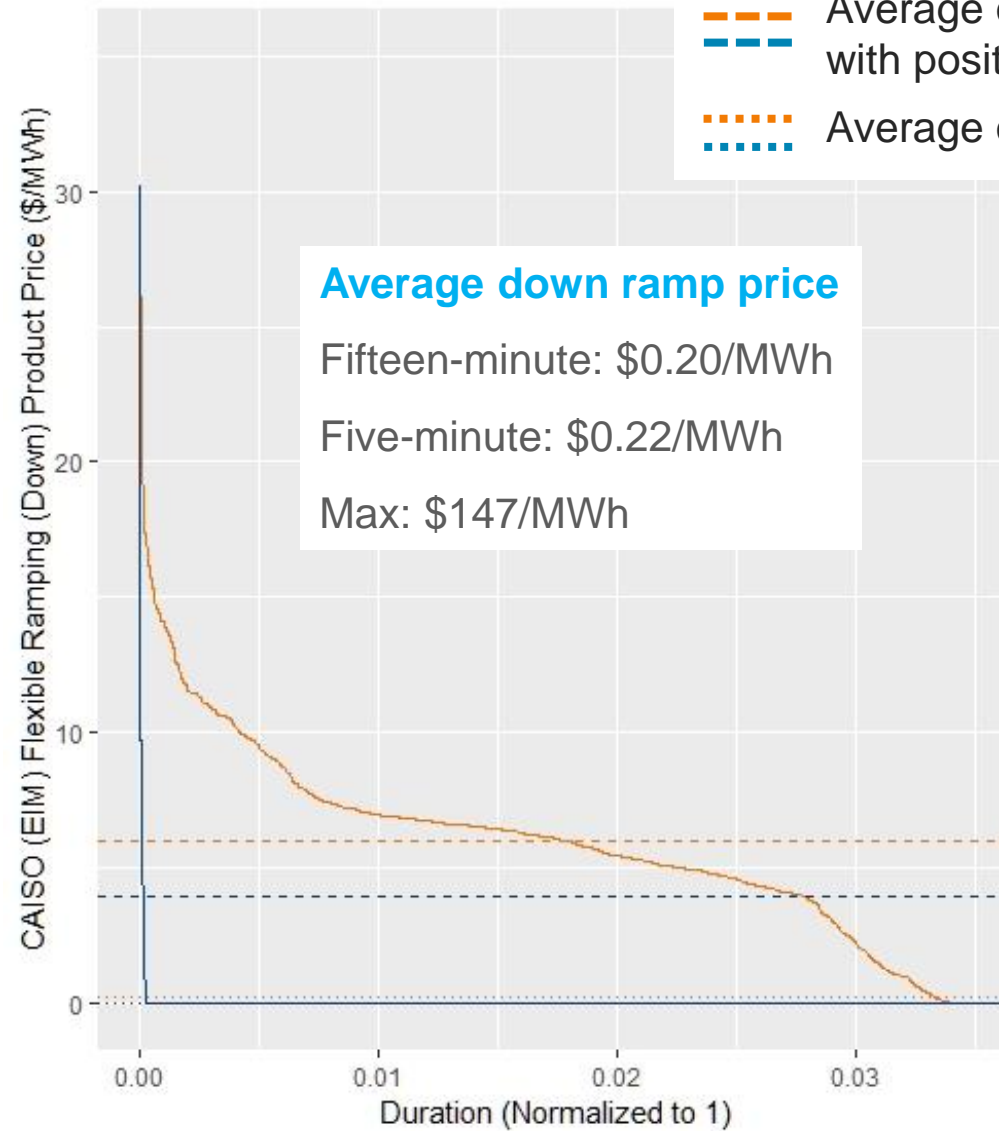
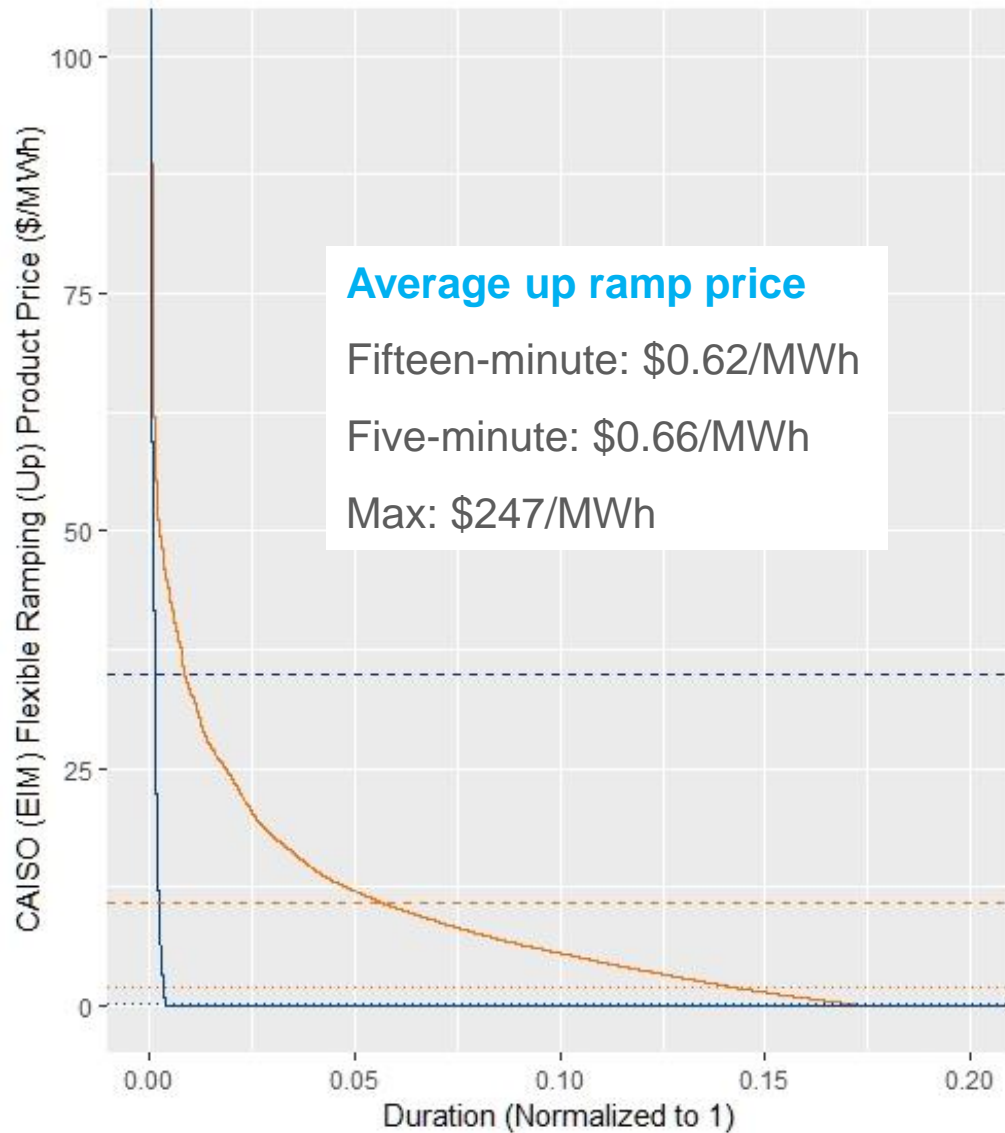
MISO Ramp Capability Product

Binding (positive) ramp up intervals since product start averaged monthly and hourly

Endhour	2016								2017								2018										
	2016 May	2016 Jun	2016 Jul	2016 Aug	2016 Sep	2016 Oct	2016 Nov	2016 Dec	2017 Jan	2017 Feb	2017 Mar	2017 Apr	2017 May	2017 Jun	2017 Jul	2017 Aug	2017 Sep	2017 Oct	2017 Nov	2017 Dec	2018 Jan	2018 Feb	2018 Mar	2018 Apr	2018 May	2018 Jun	2018 Jul
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.33%	0.00%	0.00%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.23%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.23%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.13%	0.00%	3.33%	16.67%	0.00%	0.00%
5	3.23%	0.00%	0.00%	0.00%	0.00%	38.71%	3.33%	6.45%	9.68%	0.00%	48.39%	46.67%	12.90%	0.00%	0.00%	0.00%	0.00%	25.81%	23.33%	0.00%	38.71%	3.57%	46.67%	50.00%	0.00%	0.00%	
6	3.23%	0.00%	0.00%	0.00%	0.00%	41.94%	50.00%	48.39%	45.16%	21.43%	67.74%	60.00%	32.26%	0.00%	0.00%	0.00%	0.00%	41.94%	53.33%	32.26%	70.97%	46.43%	70.00%	66.67%	3.23%	0.00%	
7	3.23%	0.00%	0.00%	0.00%	0.00%	32.26%	50.00%	61.29%	67.74%	46.43%	70.97%	60.00%	32.26%	3.33%	0.00%	0.00%	0.00%	38.71%	66.67%	48.39%	77.42%	46.43%	66.67%	70.00%	12.90%	0.00%	
8	0.00%	0.00%	16.13%	0.00%	3.33%	35.48%	13.33%	32.26%	38.71%	3.57%	61.29%	66.67%	32.26%	10.00%	3.23%	6.45%	10.00%	29.03%	30.00%	25.81%	41.94%	14.29%	53.33%	63.33%	22.58%	3.45%	8.33%
9	6.45%	16.67%	35.48%	29.03%	33.33%	48.39%	23.33%	25.81%	25.81%	3.57%	54.84%	73.33%	48.39%	26.67%	22.58%	22.58%	40.00%	38.71%	36.67%	19.35%	41.94%	10.71%	40.00%	70.00%	67.74%	17.24%	29.17%
10	16.13%	40.00%	61.29%	58.06%	46.67%	51.61%	20.00%	9.68%	22.58%	3.57%	38.71%	63.33%	58.06%	40.00%	54.84%	61.29%	60.00%	48.39%	36.67%	16.13%	29.03%	10.71%	26.67%	50.00%	77.42%	41.38%	70.83%
11	22.58%	56.67%	77.42%	64.52%	56.67%	54.84%	13.33%	3.23%	9.68%	0.00%	25.81%	66.67%	64.52%	50.00%	67.74%	77.42%	76.67%	45.16%	23.33%	3.23%	9.68%	0.00%	16.67%	33.33%	87.10%	72.41%	79.17%
12	25.81%	70.00%	77.42%	83.87%	66.67%	51.61%	16.67%	3.23%	0.00%	0.00%	25.81%	66.67%	67.74%	70.00%	77.42%	93.55%	90.00%	48.39%	20.00%	0.00%	0.00%	3.57%	13.33%	30.00%	90.32%	89.66%	83.33%
13	16.13%	76.67%	87.10%	87.10%	80.00%	51.61%	10.00%	0.00%	0.00%	0.00%	16.13%	66.67%	67.74%	80.00%	87.10%	93.55%	93.33%	45.16%	16.67%	0.00%	0.00%	3.57%	6.67%	23.33%	87.10%	96.55%	91.67%
14	16.13%	66.67%	96.77%	93.55%	80.00%	45.16%	10.00%	0.00%	0.00%	0.00%	6.45%	63.33%	74.19%	80.00%	100.00%	93.55%	93.33%	41.94%	13.33%	0.00%	0.00%	3.57%	0.00%	16.67%	87.10%	96.55%	100.00%
15	19.35%	73.33%	96.77%	93.55%	63.33%	54.84%	6.67%	0.00%	0.00%	0.00%	3.23%	66.67%	67.74%	70.00%	96.77%	93.55%	93.33%	45.16%	10.00%	0.00%	0.00%	0.00%	0.00%	20.00%	87.10%	96.55%	95.83%
16	19.35%	33.33%	74.19%	67.74%	23.33%	70.97%	13.33%	6.45%	16.13%	0.00%	6.45%	73.33%	74.19%	56.67%	87.10%	80.65%	66.67%	41.94%	36.67%	3.23%	3.23%	3.57%	0.00%	26.67%	80.65%	68.97%	83.33%
17	0.00%	0.00%	19.35%	19.35%	20.00%	83.87%	83.33%	87.10%	74.19%	14.29%	25.81%	70.00%	51.61%	26.67%	35.48%	35.48%	26.67%	80.65%	83.33%	61.29%	64.52%	17.86%	10.00%	43.33%	54.84%	27.59%	16.67%
18	3.23%	0.00%	0.00%	3.23%	30.00%	80.65%	66.67%	74.19%	87.10%	53.57%	74.19%	76.67%	29.03%	6.67%	0.00%	12.90%	53.33%	80.65%	80.00%	61.29%	83.87%	78.57%	83.33%	56.67%	29.03%	0.00%	0.00%
19	12.90%	0.00%	0.00%	0.00%	0.00%	0.00%	3.33%	22.58%	29.03%	21.43%	77.42%	100.00%	61.29%	0.00%	0.00%	3.23%	3.33%	6.45%	36.67%	12.90%	32.26%	28.57%	76.67%	93.33%	38.71%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.45%	12.90%	3.57%	6.45%	13.33%	3.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.13%	0.00%	3.33%	23.33%	9.68%	0.00%	0.00%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
24	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

CAISO Flexible Ramp Product

- Fifteen-minute market
- Five-minute market
- - - Average over the intervals with positive prices
- - - Average over all intervals



CAISO Flexible Ramp Product

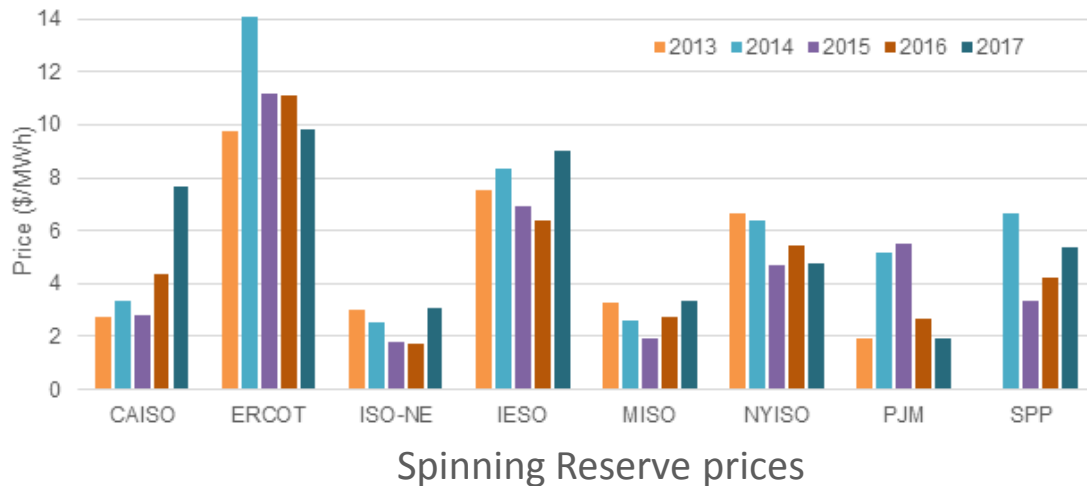
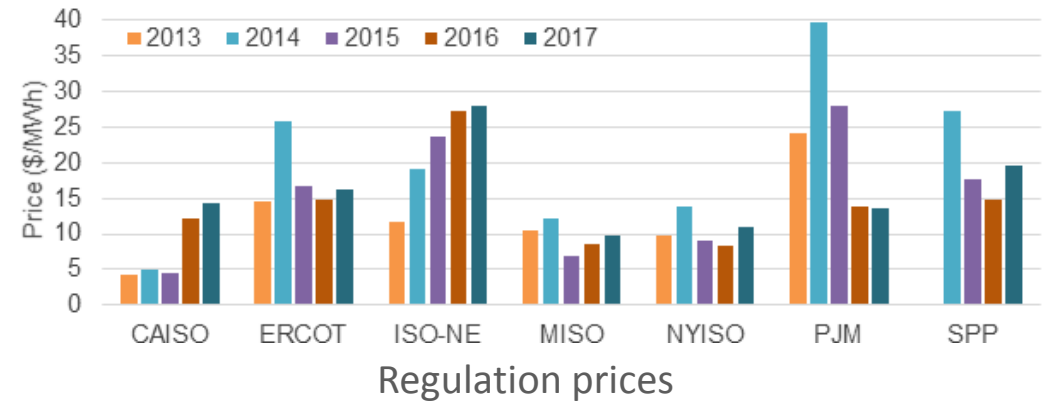
Binding (positive) ramp up intervals since product start averaged monthly and hourly

	2016		2017												2018					
	2016 Nov	2016 Dec	2017 Jan	2017 Feb	2017 Mar	2017 Apr	2017 May	2017 Jun	2017 Jul	2017 Aug	2017 Sep	2017 Oct	2017 Nov	2017 Dec	2018 Jan	2018 Feb	2018 Mar	2018 Apr	2018 May	2018 Jun
1	12.71%	4.03%	16.94%	14.41%	23.97%	22.88%	18.55%	20.83%	26.61%	17.74%	18.33%	0.00%	1.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	5.08%	0.00%	0.00%	0.00%	3.23%	8.40%	2.42%	1.67%	2.42%	0.00%	0.83%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	5.08%	3.23%	0.00%	6.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	1.61%	0.00%	5.65%	2.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6	0.00%	0.00%	0.81%	2.68%	1.61%	0.00%	2.42%	0.00%	1.61%	0.00%	0.83%	0.00%	0.00%	0.00%	0.00%	0.89%	2.42%	0.83%	0.00%	0.00%
7	4.17%	3.23%	8.06%	0.89%	8.06%	8.33%	26.61%	17.50%	16.94%	14.52%	15.83%	0.00%	0.00%	0.00%	0.00%	0.00%	20.97%	29.17%	4.03%	1.67%
8	77.50%	83.87%	89.52%	95.50%	87.90%	88.33%	67.74%	30.83%	38.71%	27.42%	55.00%	43.55%	22.50%	40.32%	57.26%	33.04%	19.35%	22.50%	6.45%	1.67%
9	59.17%	68.55%	74.19%	75.89%	81.45%	79.17%	67.74%	9.17%	2.42%	0.00%	5.00%	7.26%	10.00%	8.87%	9.68%	20.54%	42.74%	39.17%	4.03%	0.00%
10	23.33%	44.35%	41.94%	55.36%	31.45%	29.17%	12.90%	0.00%	0.00%	0.00%	0.83%	0.00%	1.67%	0.00%	0.81%	11.61%	33.06%	25.00%	7.26%	0.00%
11	4.20%	17.74%	25.00%	41.07%	12.90%	5.83%	6.45%	2.50%	1.61%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.45%	5.83%	4.84%	0.00%
12	1.69%	13.71%	16.13%	35.71%	1.61%	5.00%	3.23%	2.50%	0.81%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.81%	0.83%	0.00%	0.00%
13	2.52%	15.32%	5.65%	6.25%	12.10%	8.40%	4.03%	4.17%	3.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
14	5.93%	8.87%	4.03%	17.86%	29.03%	9.17%	12.10%	15.00%	12.10%	0.81%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.33%	0.81%	1.67%
15	14.17%	11.29%	11.38%	14.29%	22.58%	14.17%	16.13%	11.67%	8.06%	9.68%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.65%	3.33%	0.00%	1.67%
16	18.42%	9.84%	3.28%	9.91%	13.11%	21.05%	20.97%	19.17%	16.94%	23.39%	22.50%	0.00%	2.50%	0.00%	0.00%	0.00%	18.55%	12.50%	1.61%	0.83%
17	26.89%	16.26%	0.83%	5.41%	6.50%	10.00%	20.97%	25.83%	10.48%	24.19%	17.50%	2.42%	2.50%	0.00%	0.00%	8.04%	12.10%	16.67%	10.48%	2.50%
18	45.83%	50.81%	48.39%	44.55%	19.35%	13.45%	25.81%	13.33%	12.90%	40.32%	28.33%	21.77%	12.50%	1.61%	4.84%	2.68%	25.00%	24.17%	16.13%	6.67%
19	27.73%	57.26%	66.94%	75.68%	55.65%	9.17%	19.35%	15.00%	15.32%	38.71%	50.00%	45.97%	6.67%	2.42%	9.68%	8.04%	33.06%	30.83%	23.39%	13.33%
20	46.67%	55.65%	54.03%	51.79%	85.37%	48.33%	17.74%	28.33%	72.58%	91.13%	66.67%	20.16%	6.67%	2.42%	3.23%	2.68%	16.94%	48.33%	34.68%	9.17%
21	63.03%	66.94%	58.06%	62.50%	85.37%	81.67%	66.94%	50.00%	66.94%	69.35%	77.50%	44.35%	12.50%	12.90%	12.10%	7.14%	7.26%	26.67%	17.74%	3.33%
22	67.50%	61.29%	64.52%	73.21%	82.11%	74.17%	84.68%	85.83%	81.45%	89.52%	84.17%	50.00%	29.17%	19.35%	19.35%	9.82%	7.26%	3.33%	1.61%	0.00%
23	76.67%	66.94%	67.74%	56.25%	62.90%	84.17%	73.39%	85.83%	91.13%	83.87%	80.00%	47.58%	27.50%	16.13%	11.29%	3.57%	0.00%	0.83%	0.81%	0.00%
24	58.33%	33.06%	42.74%	36.61%	34.17%	50.00%	60.48%	70.00%	71.77%	60.48%	61.67%	14.52%	9.17%	0.00%	1.61%	2.68%	0.00%	0.00%	0.00%	0.00%

Ancillary Service Market Outcomes

Key findings

- No across the board (all region, all service) annual trends
- Regulation highest priced service
- Prices not correlated to system size or requirement level



- Ramp product price is zero for majority of intervals
- High energy price events likely lead to high ancillary price events
- AS Price forecasting is difficult due to many complex features

Takeaways

Area	Key Point
Reserve Requirements	<p>Characteristics and requirement methods are based on just a few NERC reliability standards.</p> <p>But, since ISOs and regional reliability organizations can create stricter standards, unique products and requirements can be found around the US.</p>
Eligibility	<p>Eligibility differs region by region, varying from tests and certification to restrictions on certain technologies.</p>
Compensation	<p>Not all ancillary services receive direct compensation. This evolves with ISO priorities and may be changing now.</p>
Market design	<p>Market designs for ancillary services differ more across ISOs than the product definitions themselves.</p>
New Products	<p>New products are being created in some markets, drivers can include the resource mix and system characteristics.</p>
New Services	<p>Many services have been provided for a long time but have not been explicitly recognized as a service, recently new standards have been introduced.</p>
Price Trends	<p>In recent years products have not been uniformly increasing or decreasing across markets. Prices follow the general hierarchy of products (regulation is highest) and are greatly influenced by regional events like storms or cold snaps.</p>
Renewables	<p>Certain characteristics of variable renewable resources may change ancillary service needs, and they have the potential to become greater suppliers of ancillary services.</p> <p>Understanding how the markets function for these services will be important for future providers of these services to ensure economic provision.</p>

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