PJM Reserve Certainty Senior Task Force

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California ISO Facts

As a federally regulated nonprofit organization, the ISO manages the high-voltage electric grid California and a portion of Nevada.

52,061 MW record peak demand Sept. 6, 2022)

239.1 million megawatt-hours of electricity delivered (2022)

76,184 MW power plant capacity

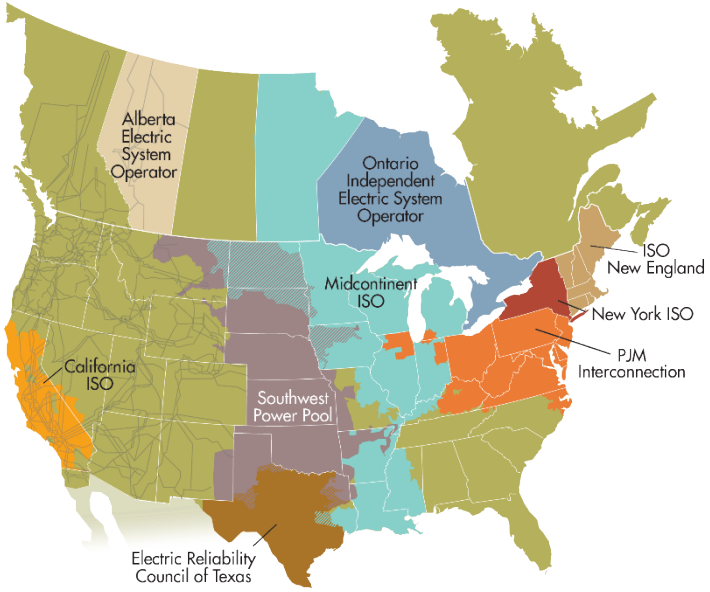
Source: ISO's Masterfile, August 2023

1,119 power plants

Source: California Energy Commission

32 million people served

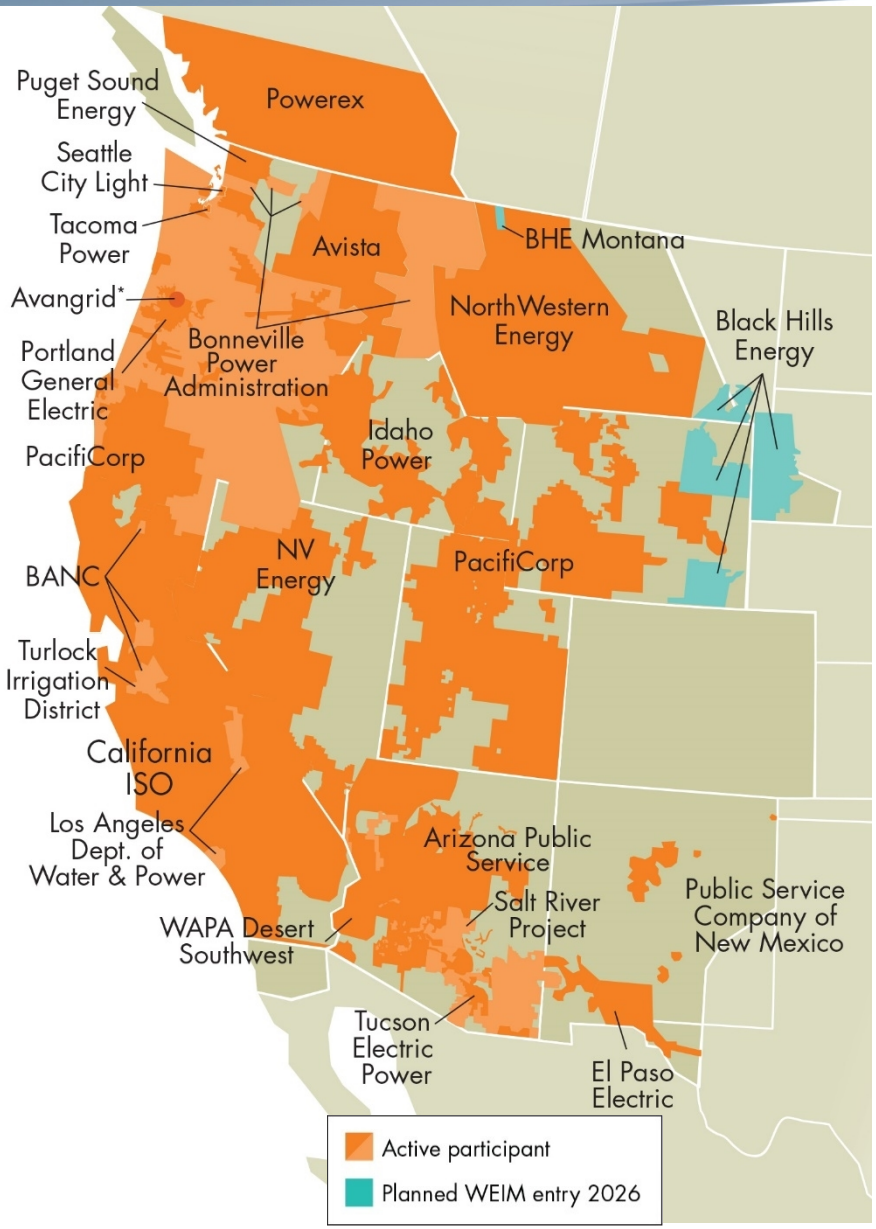
One of **9** ISO/RTOs in North America



Western Energy Imbalance Market (WEIM)

Since its launch in 2014, the WEIM has enhanced grid reliability, generated billions of dollars in benefits for participants, and improved the integration of renewable energy resources.

- 22 participating entities
- Gross benefits exceeds $5 billion
- Reduced 925,568 metric tons of CO_2



*Avangrid office, generation only BAA with distribution across multiple states.
Map boundaries are approximate and for illustrative purposes only.

A growing EDAM market footprint across the West

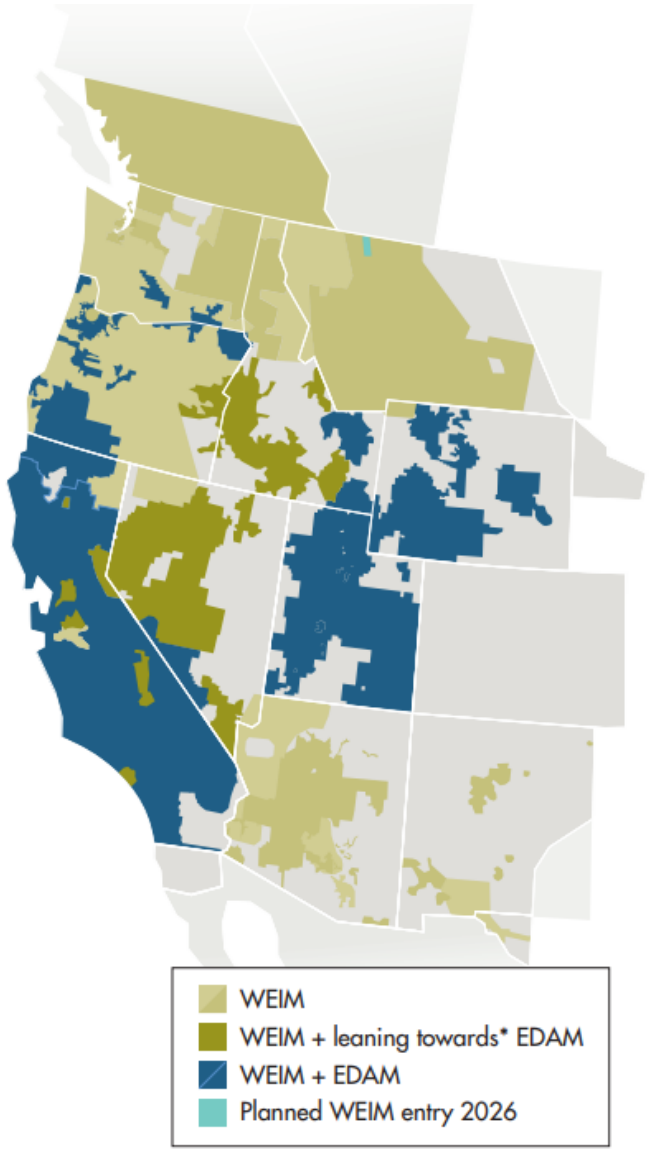
EDAM policy design has been fully approved by FERC

Executed EDAM Implementation Agreements:

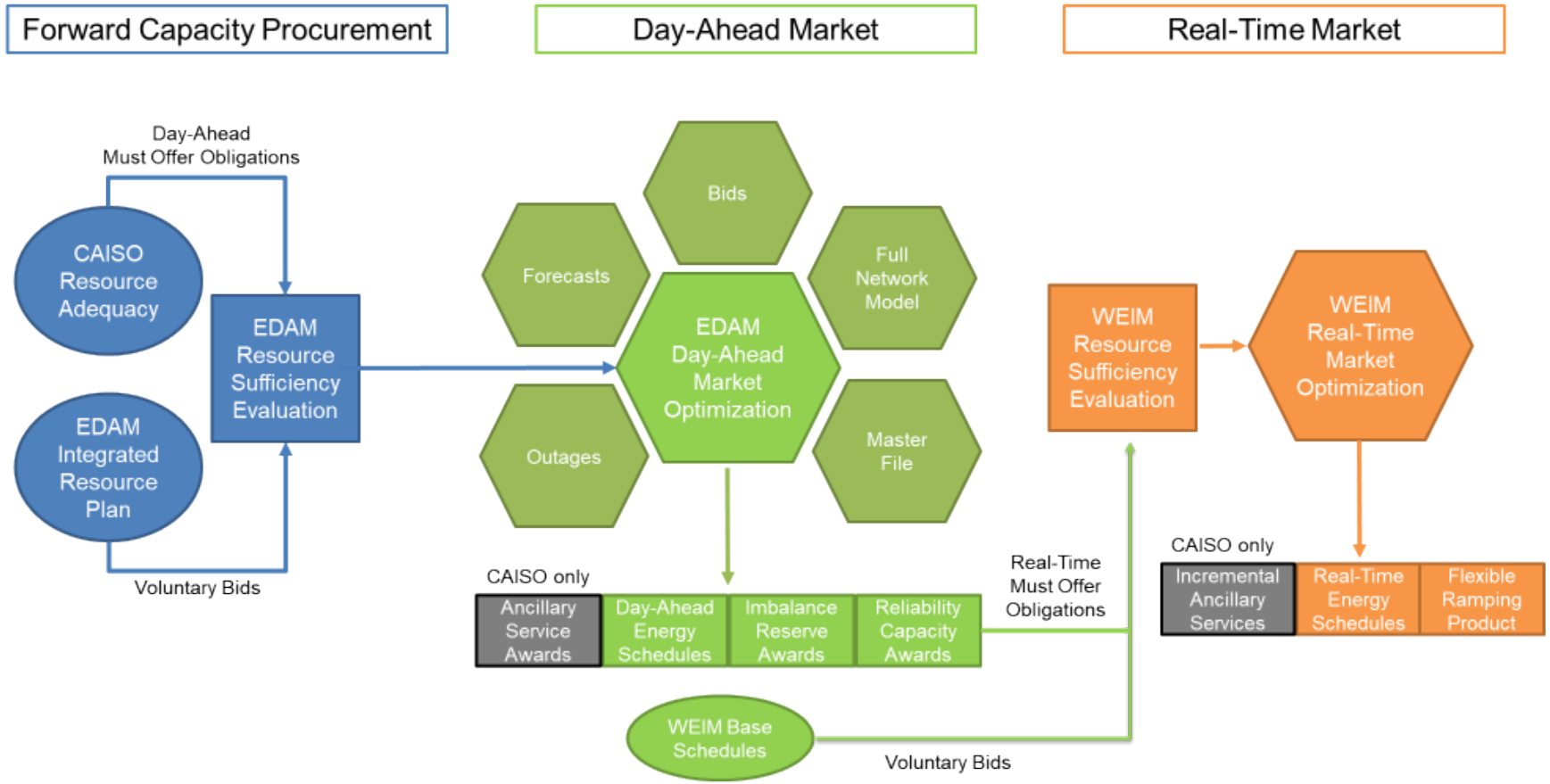
- PacifiCorp (2026)
- Portland General Electric (2026)

Publicly Indicated Leaning Towards EDAM:

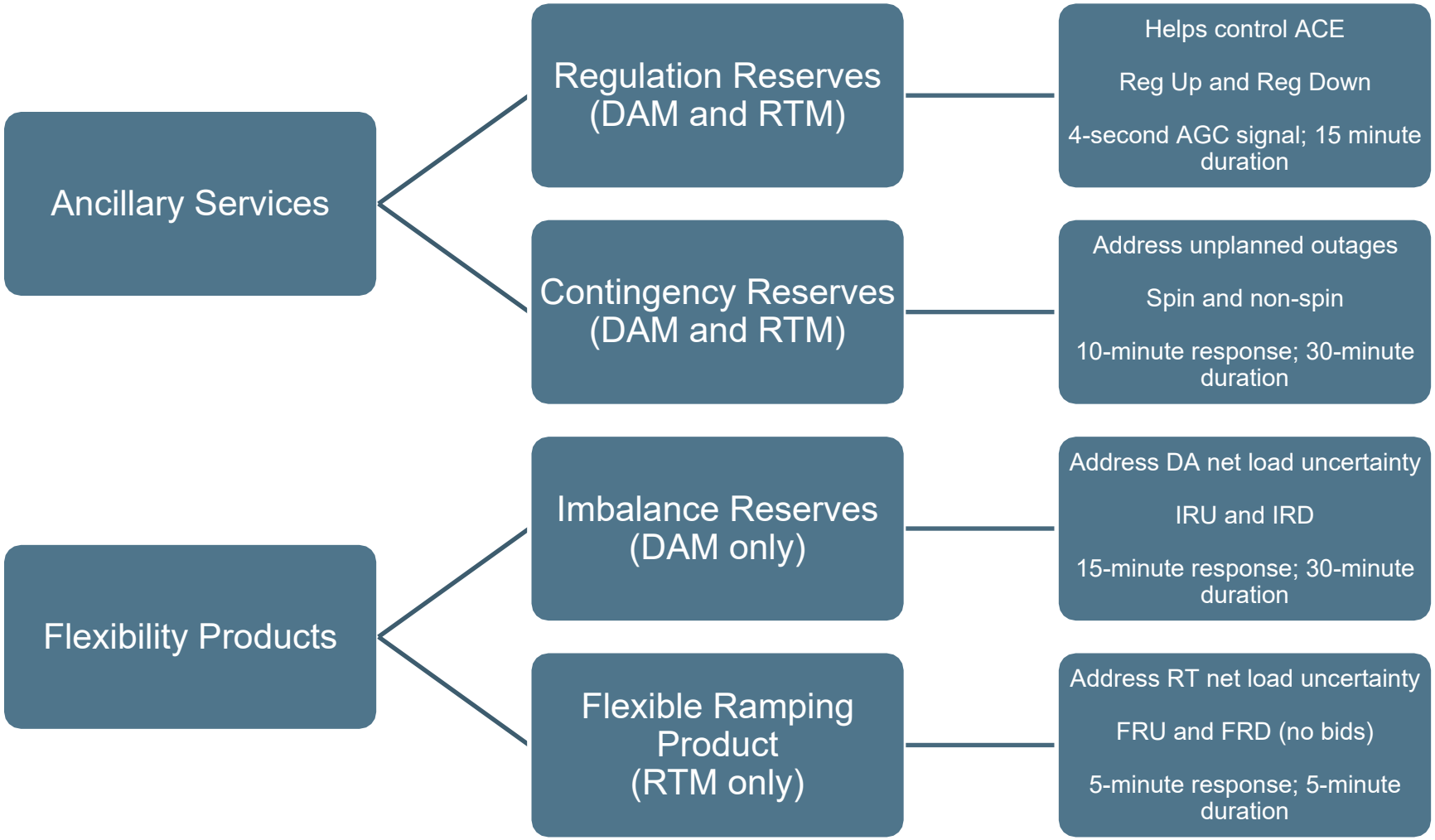
- Balancing Authority of Northern California
- Los Angeles Department of Water and Power
- Idaho Power Company
- Nevada Energy



CAISO Market Framework

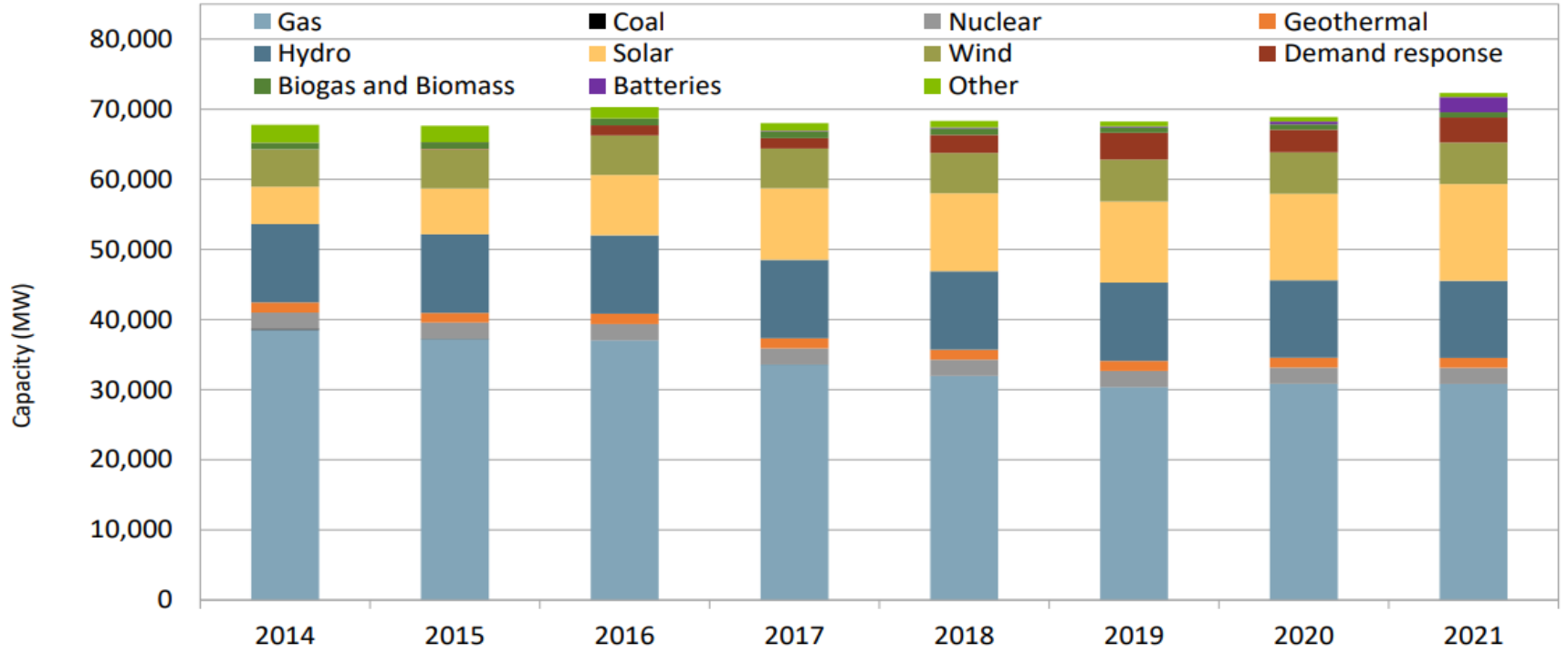


Overview of Reserve Products



Motivations for Reserve Market Design Changes

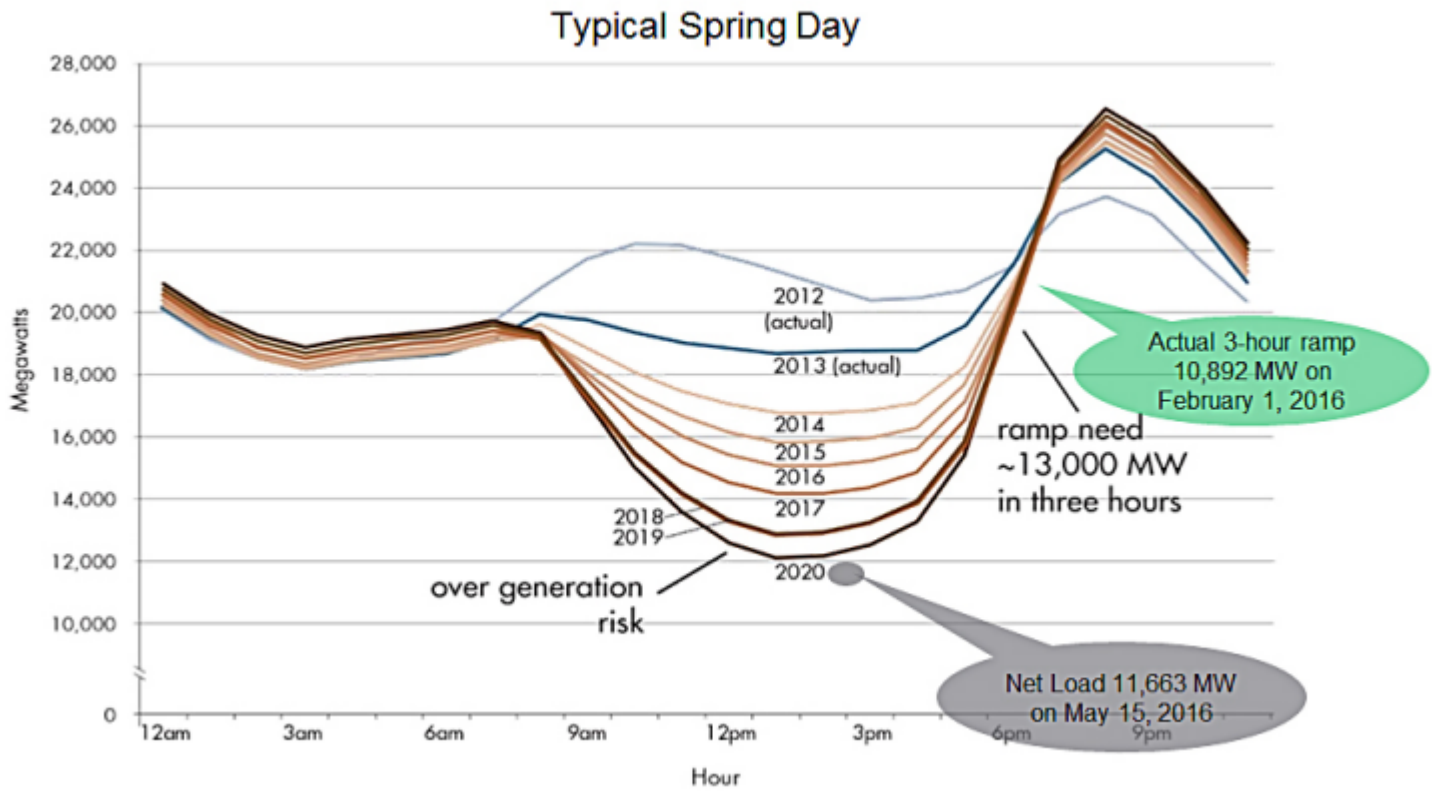
Increasing Penetration of Renewables



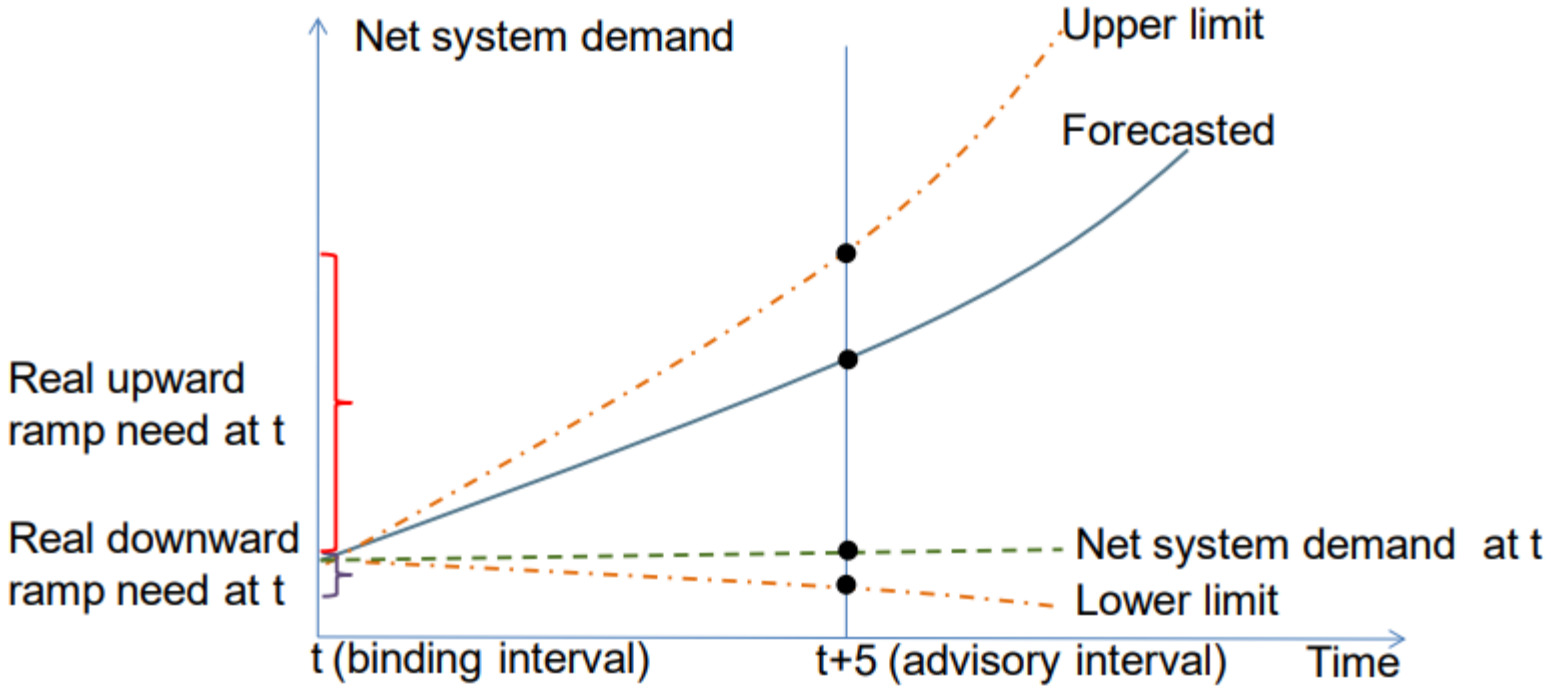
Fuel Type	2014 (MW)	2024 (MW)
Wind/Solar	~10,000	~28,000
Natural Gas	~38,000	~29,000
Batteries	0	~9,300

Motivations for Reserve Market Design Changes

Increased Variability in System Operations



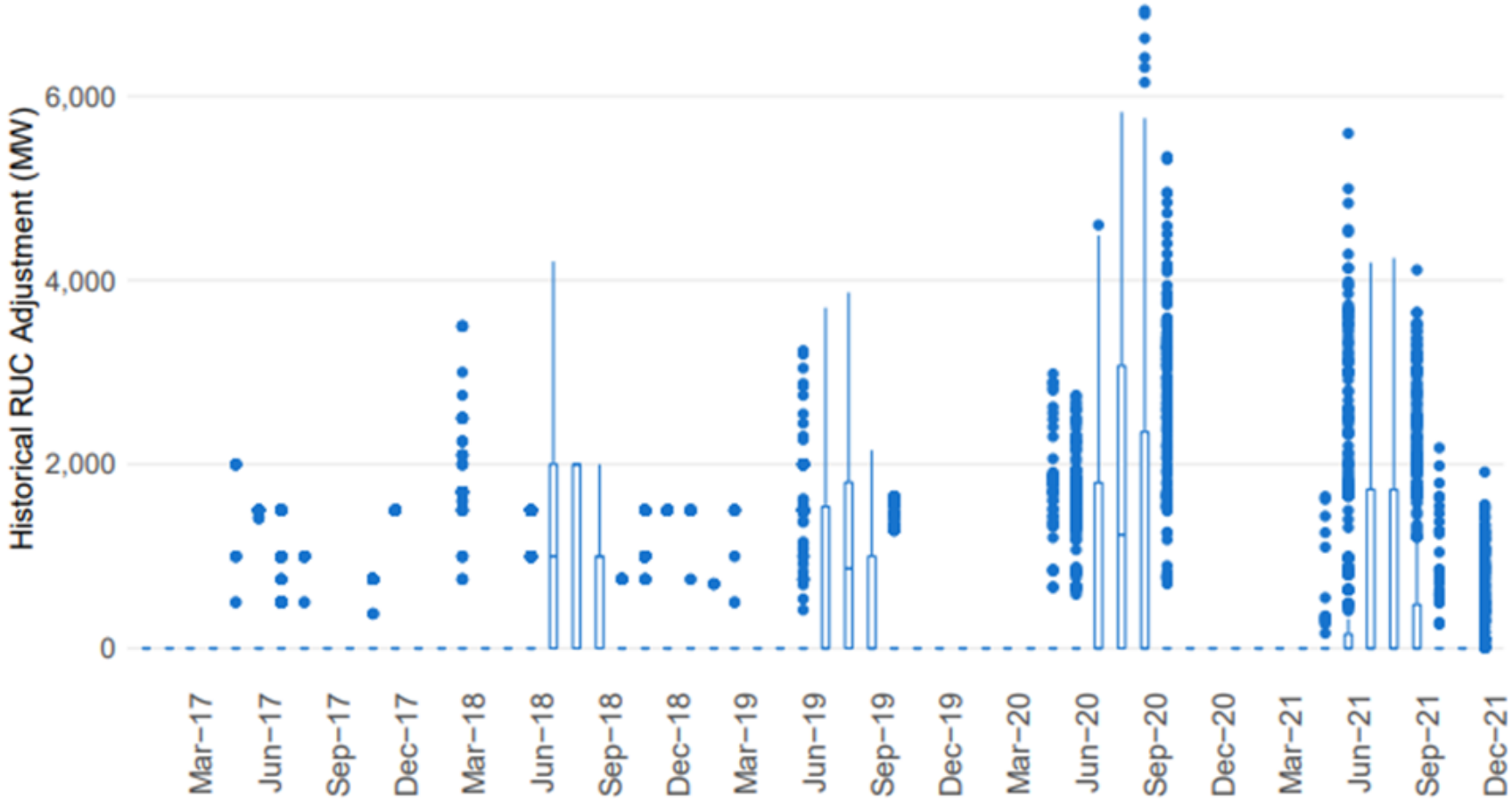
Motivations for Reserve Market Design Changes
Increased Uncertainty in System Operations



Real ramping need:
Potential net demand change from interval t to interval t+5
(net system demand t+5 – net system demand t)

Motivations for Reserve Market Design Changes

Increased Uncertainty in System Operations

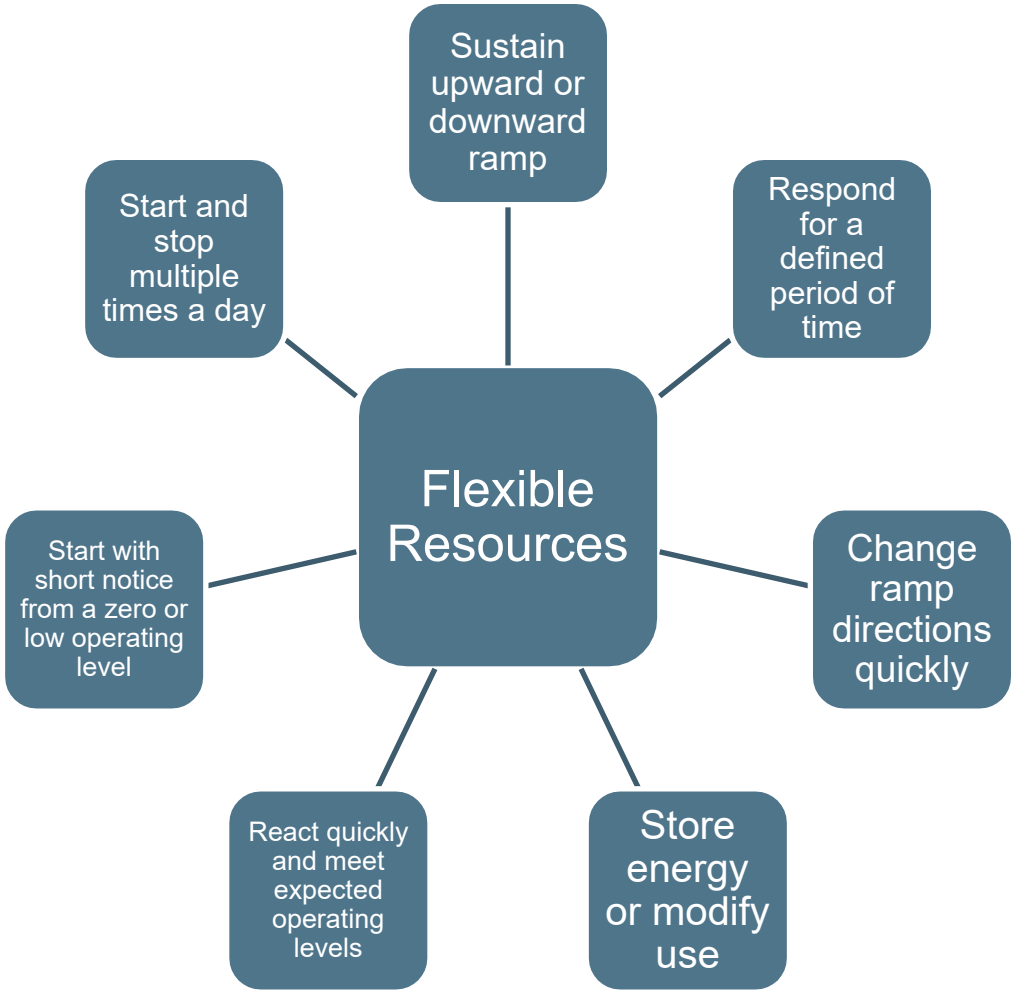


Motivations for Reserve Market Design Changes
Consequences of Insufficient Ramping Capability

- Insufficient ramping capability sometimes causes power balance violations, which means the market cannot maintain supply and demand power balance with feasible RTD schedules. This leads to at least three undesirable outcomes:
  1. The system must rely on regulation to resolve the issue in real-time, addressing the imbalance only after it has already caused a frequency deviation or area control error (ACE).
  2. Power balance violations result in energy prices being set by administrative penalty prices instead of economic bids, which eventually creates market inefficiency, as imbalance energy from resources providing regulation services gets priced by these penalties.
  3. Insufficient regulation service increases reliance on the interconnection, which can undermine the system's ability to meet required operational performance criteria.

Motivations for Reserve Market Design Changes

Reliable Green Grids Require Flexible Resources

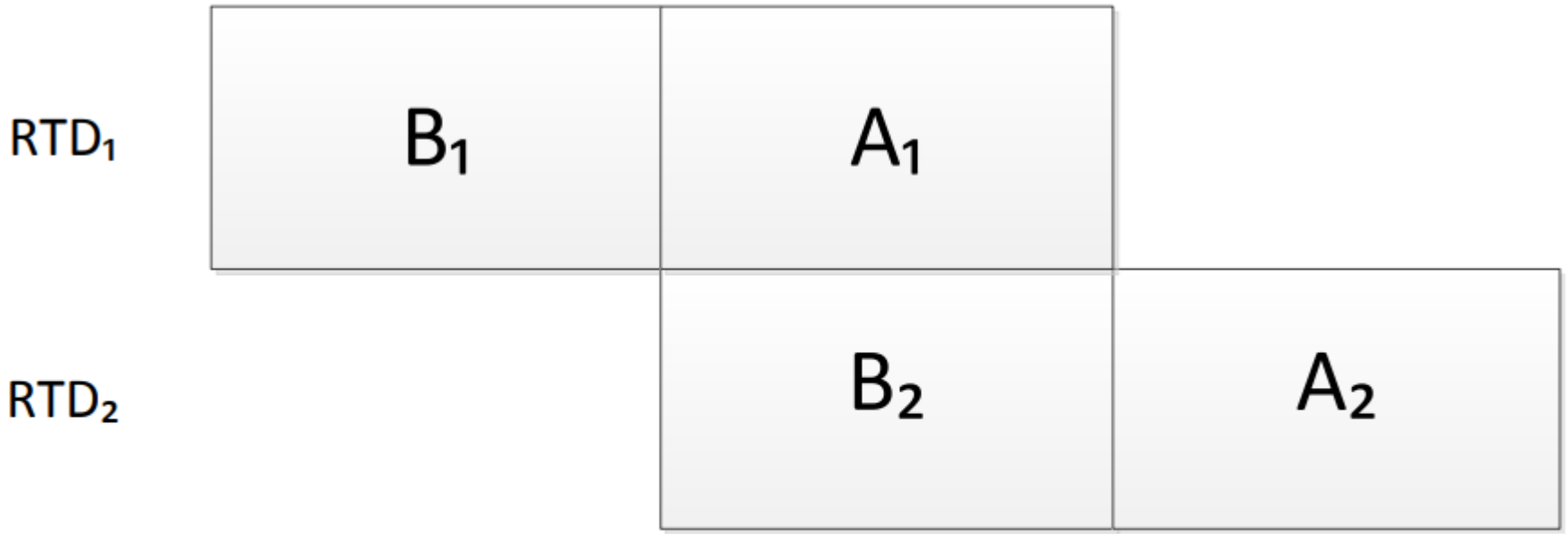


Flexible Ramping Product (2016)
Purpose and Characteristics

Purpose: to improve the market's ability to manage the ramping capability needed to handle changes in net load, whether forecasted or unexpected

Requirements	Characteristics
Direction	Upward and Downward
Time Requirement	5 minutes
Procurement	System-level
Markets	RTPD (15-minute market) and RTD (5-minute market)
Requirement Method	Histogram approach (97.5 and 2.5 percentiles)
Bids	No (opportunity cost based)
Co-Optimization	Yes
Demand Curve	Yes

Flexible Ramping Product (2016)
Requirement Histogram Construction



$$B_2 - A_1$$

Flexible Ramping Product (2019)

Non-Locational Procurement Leads to Under-Utilization

- The market **did not consider the location** of resources when procuring the flexible ramping product

- This approach led to situations where the procured ramping capacity could not be fully utilized due to transmission constraints (congestion)

Flexible Ramping Product (2019)

Non-Locational Procurement Leads to Under-Utilization

- The market may procure **upward flexible ramping capacity** from a resource that is being dispatched down to manage congestion
  - If there's an unexpected need to deploy this ramping capacity (e.g., a sudden increase in demand), the resource cannot ramp up as required because increasing its output would exacerbate congestion

- The opportunity cost of reserving these resource for upward FRP (the profit they forgo by not selling that energy) appears low to the market optimization
  - $0 prices in >99% of intervals

The market procured ramping capacity that could not be deployed when needed, defeating the purpose of FRP

Flexible Ramping Product (2022)
Purpose and Characteristics

Purpose: introduce nodal procurement and a regression-based requirement

Requirements	Characteristics
Direction	Upward and Downward
Time Requirement	5 minutes
Procurement	Nodal
Markets	RTPD (15-minute market) and RTD (5-minute market)
Requirement Method	Regression approach (97.5 and 2.5 percentiles)
Bids	No (opportunity cost based)
Co-Optimization	Yes
Demand Curve	Yes

Flexible Ramping Product (2022)

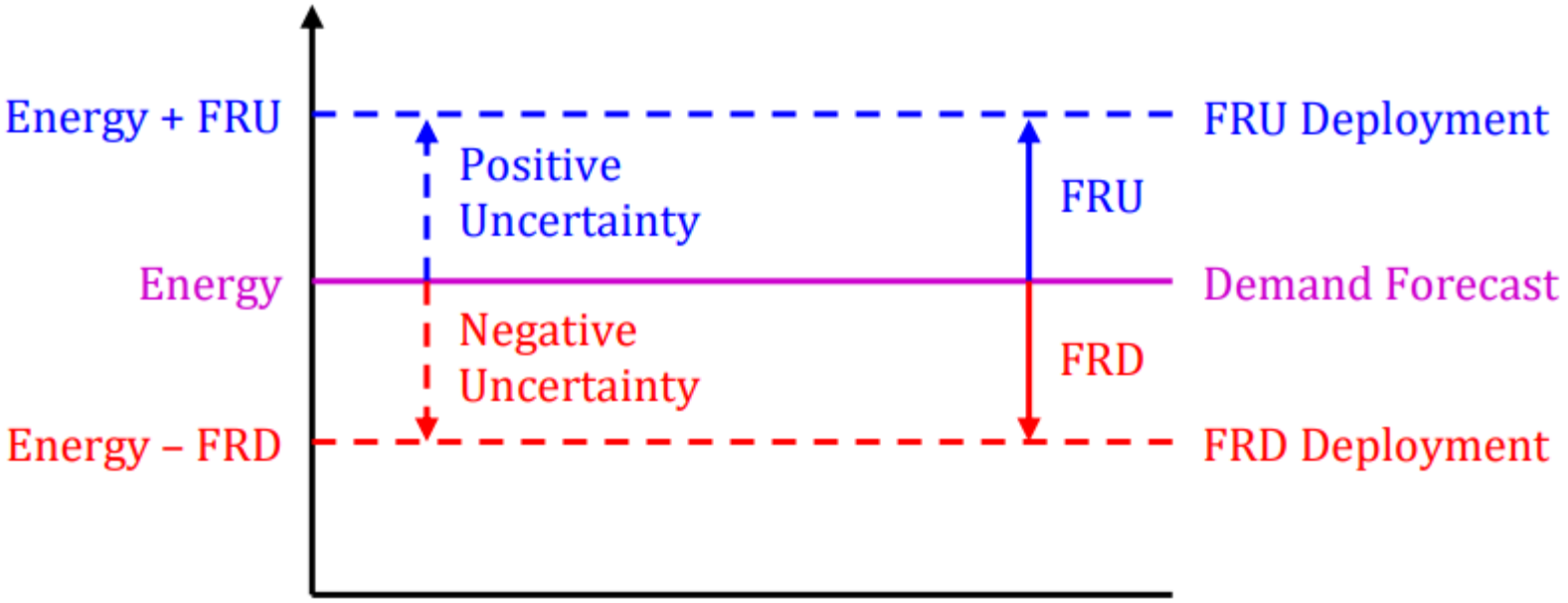
Deployment Scenarios

- **Deployment scenarios** procure locational FRP awards to ensure that their full deployment respects transmission constraints.

- To achieve this, the RTM optimization problem includes FRP deployment scenarios subject to the same transmission constraints that are enforced in serving the demand forecast.

Flexible Ramping Product (2022)

RTM Targets for Energy and FRU/FRD



$$\left.\begin{aligned} \sum_i EN_{i,t} &= D_t \\ \sum_i FRU_{i,t} &\geq FRUR_t \\ \sum_i FRD_{i,t} &\geq FRDR_t \end{aligned}\right\}, t = 1,2,\dots,N$$

Flexible Ramping Product (2022)

Deployment Scenarios

- In each BAA, demand for uncertainty is divided among three main resource categories: **Load**, **Solar**, and **Wind**

- CAISO uses historical data to assess each category's typical contribution to overall uncertainty.
  - **Allocation Factors:** These percentages represent each category's share of total uncertainty. For example, if wind generation historically accounts for 30% of uncertainty, it will receive 30% of the ramping requirements. This ensures ramping capacity is available where it's most needed.

Flexible Ramping Product (2022)

Introduction to Quantile Regression

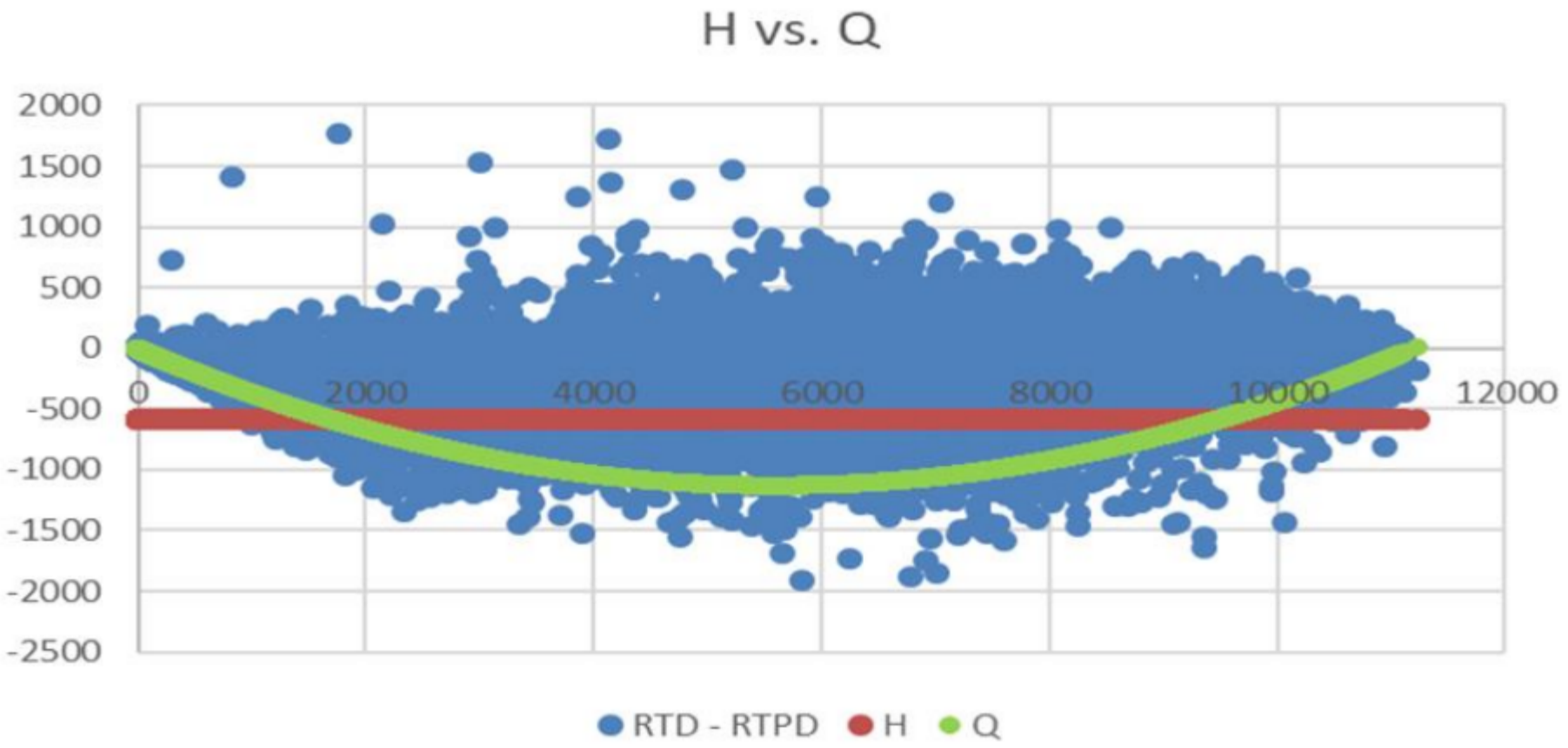
- CAISO shifted the FRP requirement calculation from a histogram approach to a **quantile regression** approach.

- Quantile regression estimates the quantiles of a dependent variable based on the values of independent variables.

- This approach is more suitable than standard linear regression here because it focuses on extreme high and low observations (the 2.5th and 97.5th percentiles) of net load imbalances, rather than the average net load imbalance.

Flexible Ramping Product (2022)

Introduction to Quantile Regression

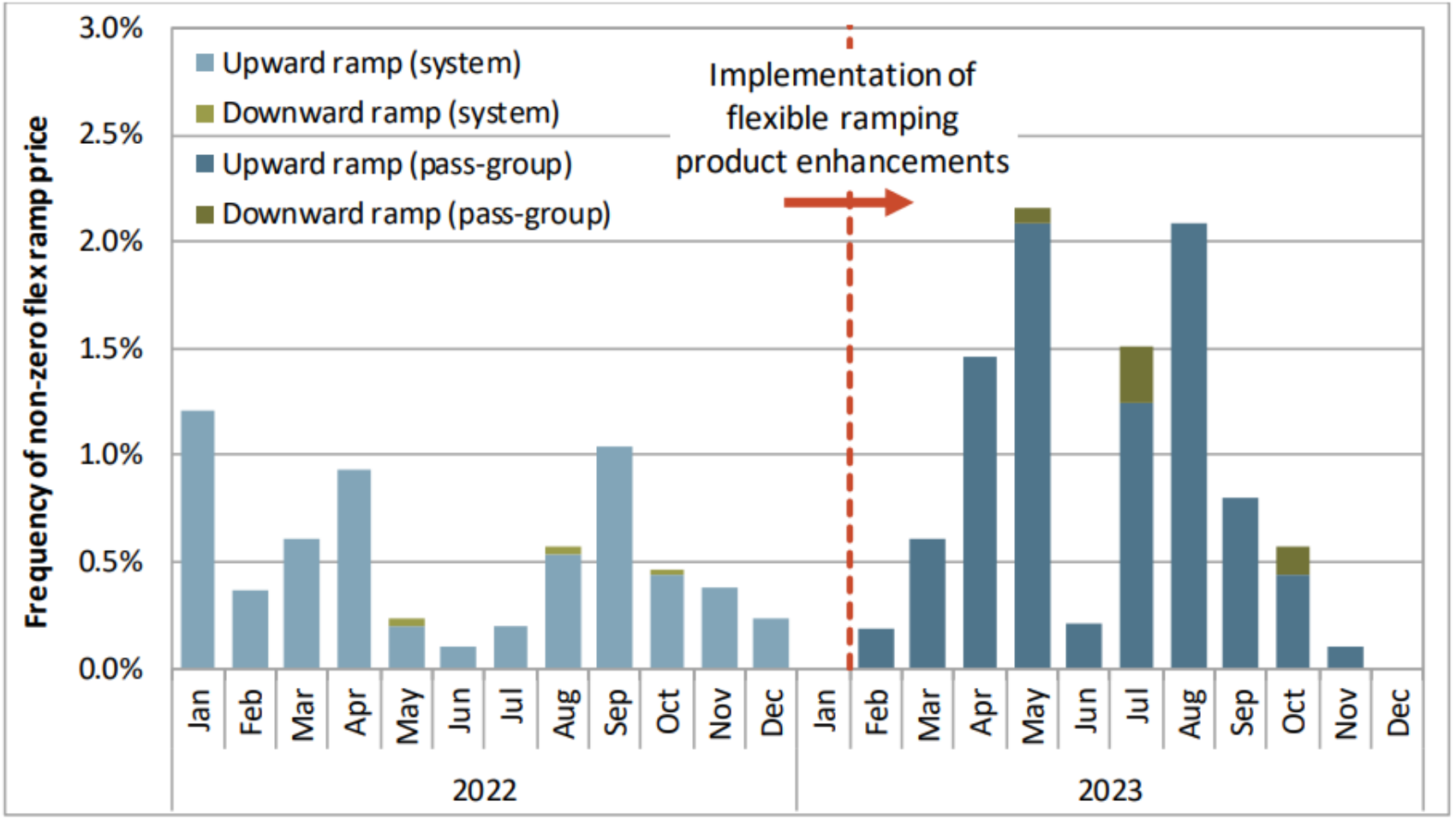


Flexible Ramping Product (2023)

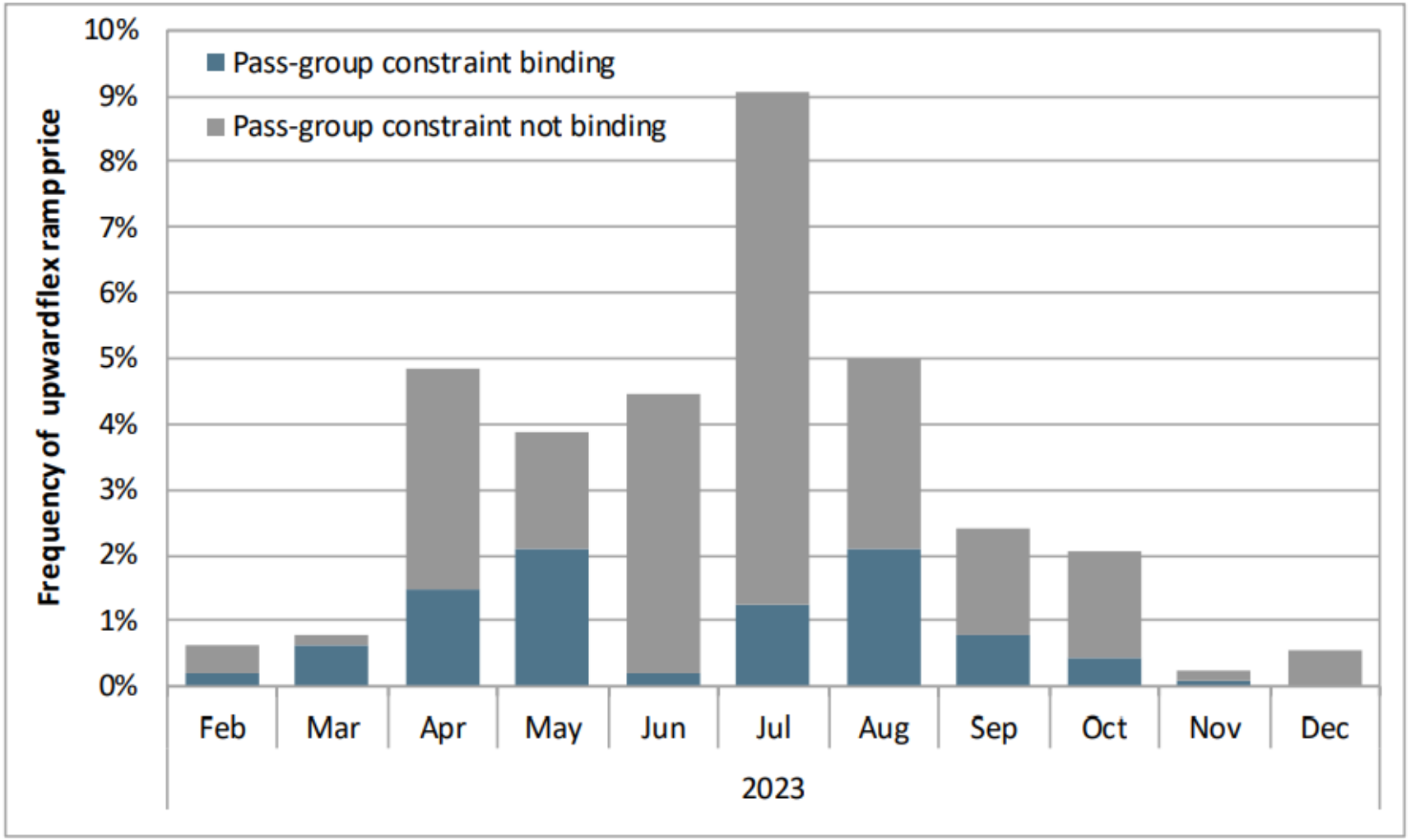
Implementation

- **February 1, 2023**
  - Implemented with only base flowgate constraints included
- **September 7, 2023**
  - Nomogram constraints included
- **June 4, 2024**
  - Contingency constraints activated but de-activated on June 12 due to issues with solution run-times

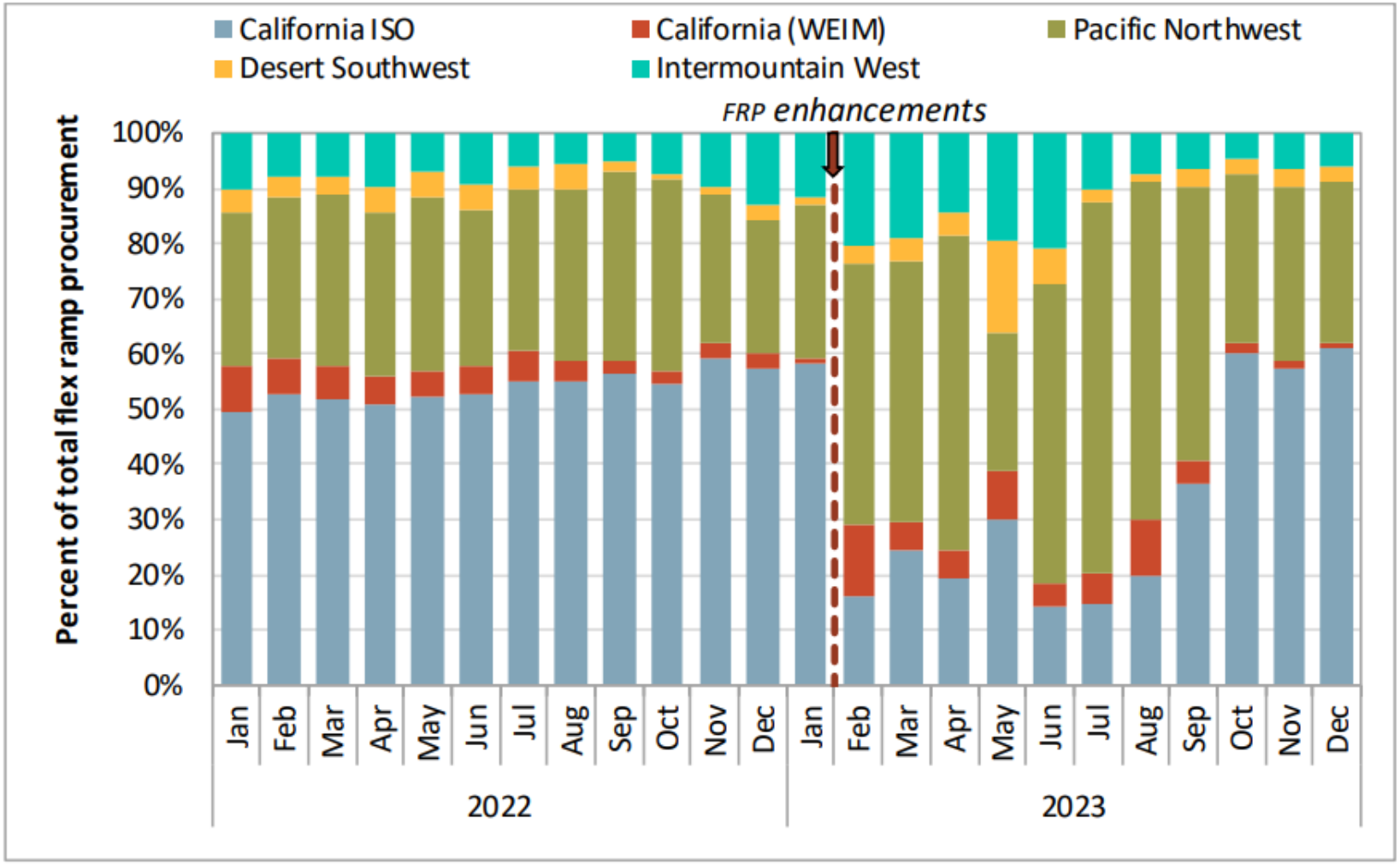
Flexible Ramping Product (2023)
Frequency of Non-Zero Prices



Flexible Ramping Product (2023)
Frequency of Non-Zero Prices



Flexible Ramping Product (2023)
Procurement by Region



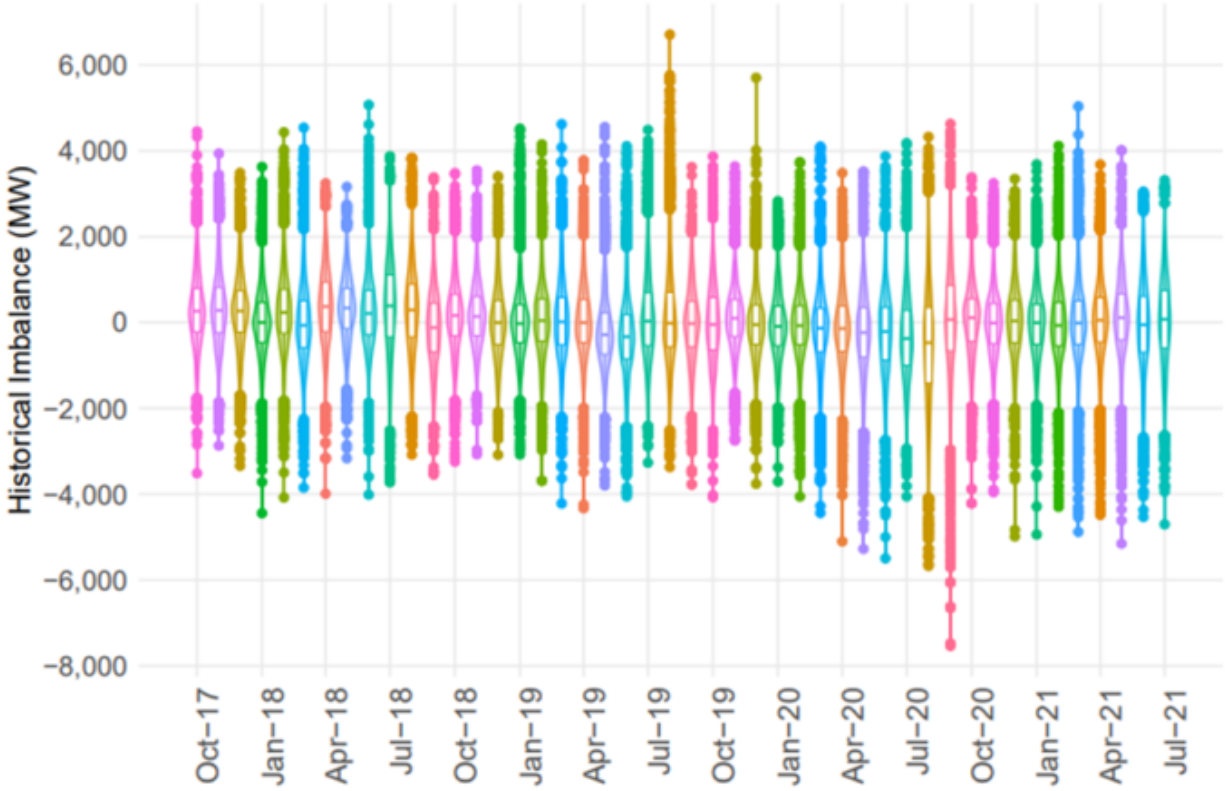
Imbalance Reserves (2024)
Purpose and Characteristics

Purpose: introduce a flexibility reserve in the day-ahead market

Requirements	Characteristics
Direction	Upward and Downward
Time Requirement	15 minute start; 30 minute duration
Procurement	Nodal
Markets	IFM (day-ahead market)
Requirement Method	Regression approach (97.5 and 2.5 percentiles)
Bids	Yes
Co-Optimization	Yes
Demand Curve	Yes

Imbalance Reserves (2024)

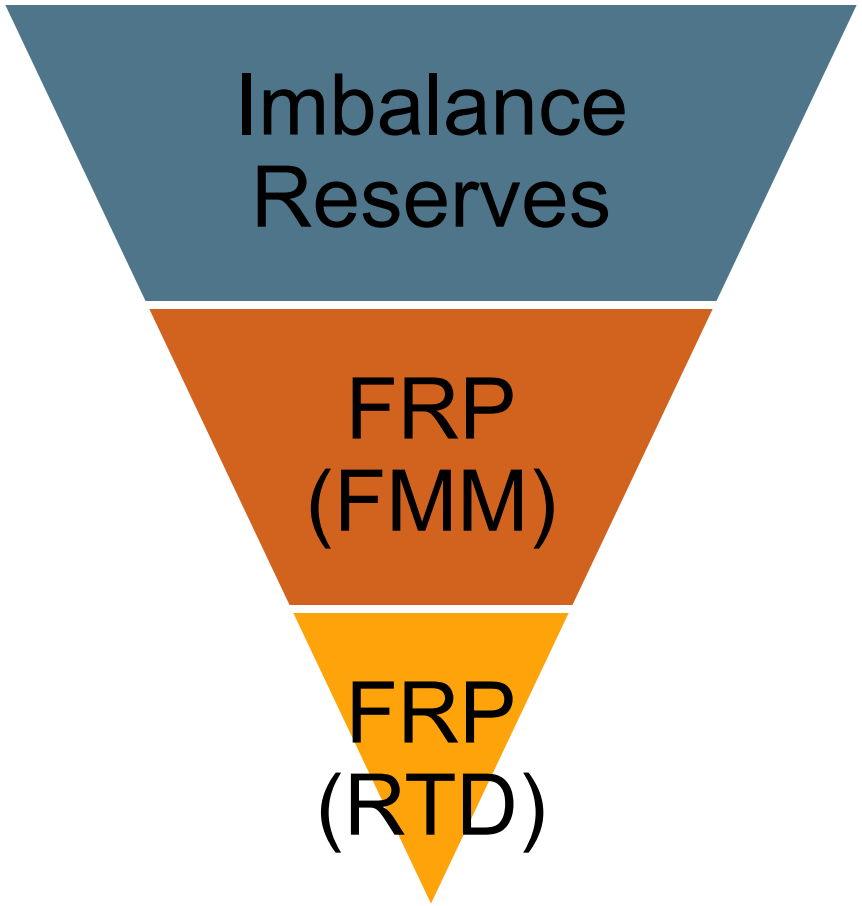
Imbalances Between Day-Ahead and Real-Time



Imbalance Reserves (2024)
Overall Picture

- Awards obligate suppliers to provide energy bids in the real-time market above/below their day-ahead energy schedule for the quantity of their up/down awards.

- These awards settle against each other



Questions?

Feel free to reach out to me at jfriedrich@caiso.com

Thank you for having me!