



Integrating Renewables at CAISO's Markets

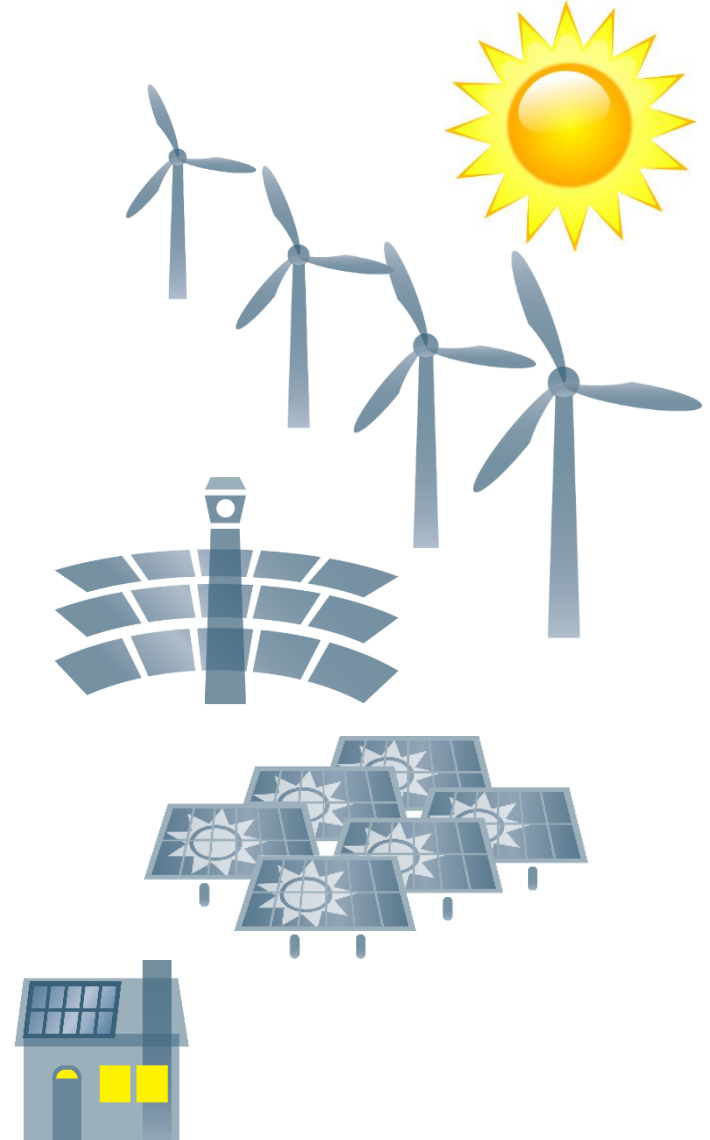
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PJM Operating Committee
March 10, 2021



Major progress on meeting CA's renewable goals

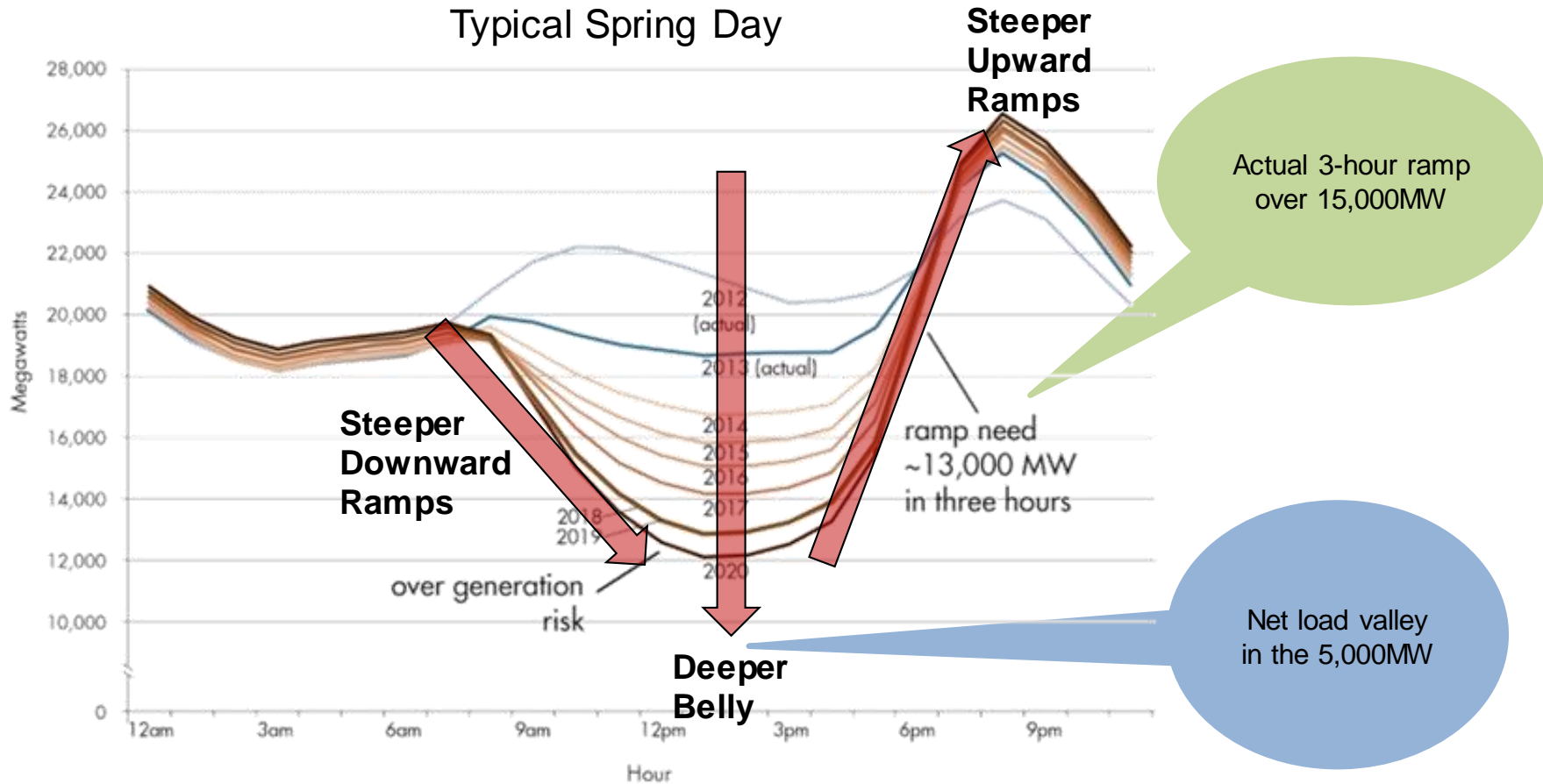
- Currently Installed:
 - 21,000 MW of utility-scale renewables
 - ~11,000 MW of consumer rooftop solar
- Additional renewables:
 - 4,000+ MW additional utility-scale renewables by 2026
 - ~19,000 MW of consumer rooftop solar by 2030
- Projected 5000+ MW of storage and hybrid resources



System and markets are evolving towards a non-deterministic environment

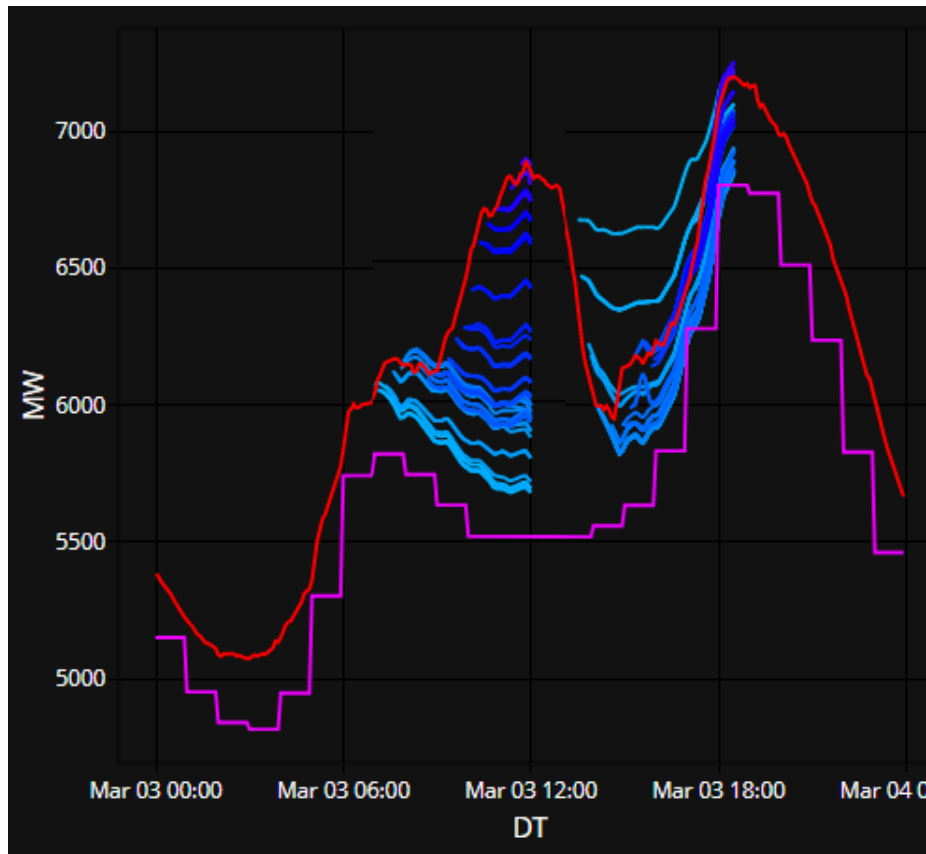
- Weather variables, such as temperatures, introduce uncertainty components to multiple variables in the power system, including
 - Load forecast
 - Behind the meter generation
 - Utility-based wind and solar generation
 - Regulation requirements
- CAISO still uses a deterministic market clearing process with deterministic inputs
- Different products and procedures are developed to “factor in” uncertainty

The duck turns 10 years old: Actual net-load and 3-hour ramps are approximately four years ahead of the CAISO's original estimate

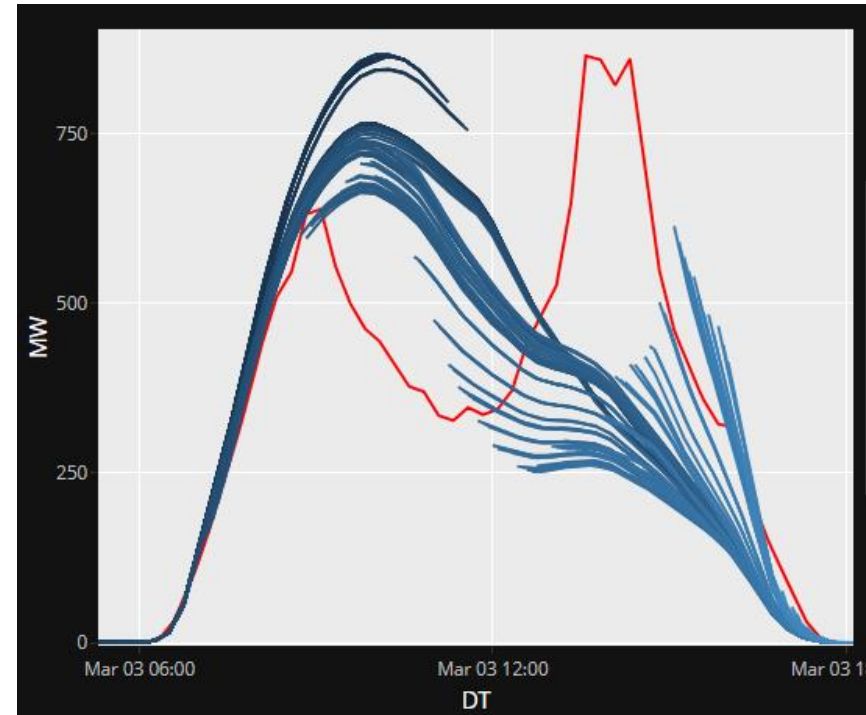


Demand Forecast Movement due to Behind the Meter Solar

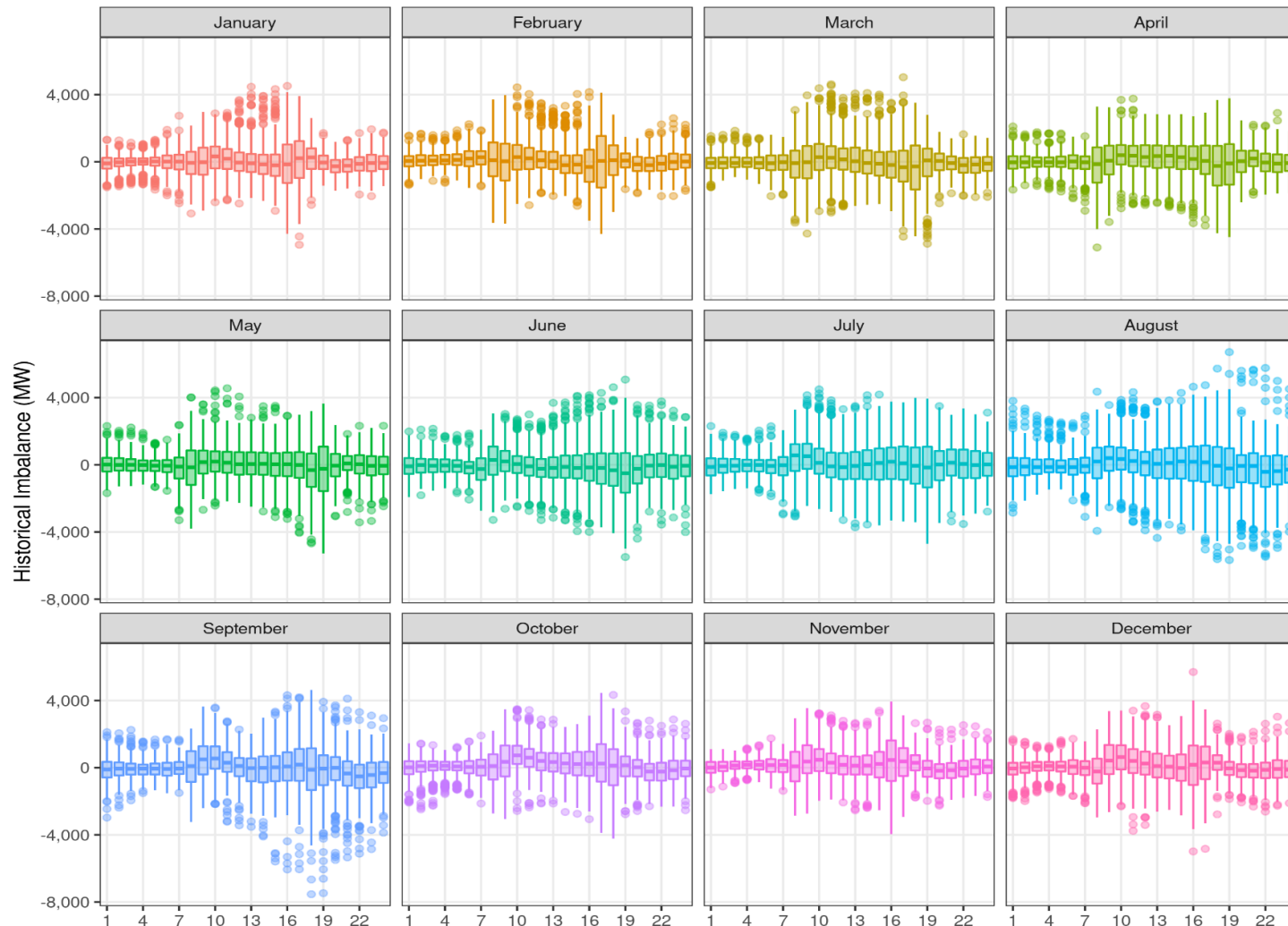
Load Forecast Movement due to BTM Solar



BTM Solar Forecast Updates vs. Actual



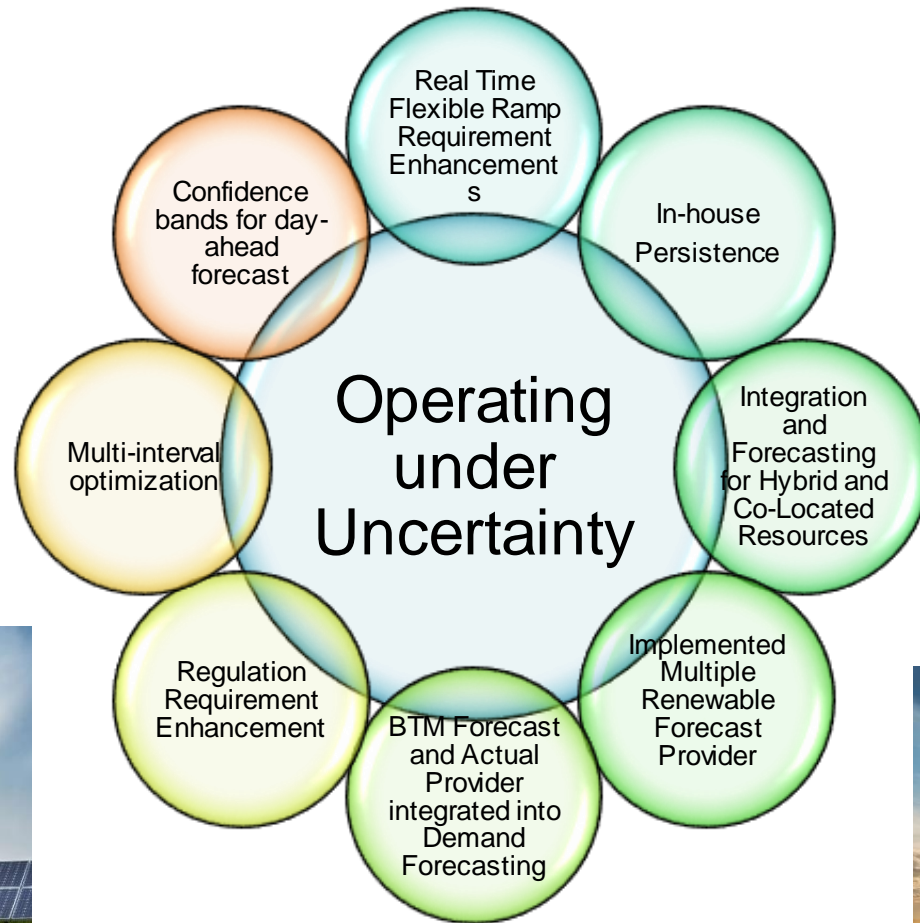
Variability poses a great forecasting challenge which results in uncertainty in market and systems operations



How does CAISO integrate renewables? CAISO's markets are technology agnostic

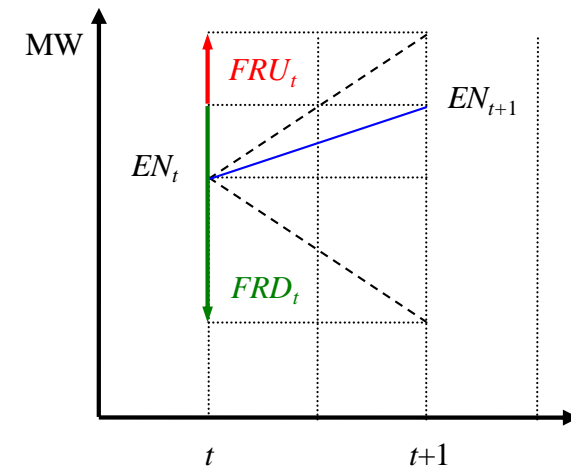
- Renewable forecast are generated and consumed every 5 minutes
- Renewable resources can economically bid
- Renewable resources are optimally dispatched in the market like any other type of generation resource
- Renewable resources receive and must follow operating instructions
- Ancillary services requirements consider the impact of renewable resources
- New flexible ramping product to handle uncertainty of renewable resources

Advancements to handle uncertainty in CAISO's market and system



Flexible ramping product implemented in 2016 makes important changes to the real-time market

- Secures ramping capability in the fifteen-minute market and real-time dispatch
- Accounts for upward and downward ramping needs
- Compensates resources that provide ramping and charges those that consume ramping capability
- Procures ramping capability for uncertainty when expected value greater than cost
- Aligns cost allocation with those who benefit from additional ramping capability to meet net load uncertainty



Wind & Solar Forecasting at CAISO

Eligible Intermittent Resources (EIR) Provide

- Asset Registration Information
- Outage/De-Rate Schedules
- Real-Time Generation Telemetry (MW)
- Real-Time Telemetry for Meteorological Information

Wind & Solar Forecast Service

Two Forecast Service Providers each provide:

- **Hourly Day-Ahead Forecasts for each EIR** out 4 Days; updated at 5:30 am and 8:45am Day Previous
- **Real-Time Forecasts** for rolling 9 hours at a 5 minute granularity. Updated every 5 minutes
- One Provider Provides Probabilistic Forecasts used for risk assessment

CAISO Systems

- Forecasting Team can select “active” Forecast Provider for DA, RT, and Blend Configurations
- **Hourly Forecast** used in all reliability studies (RUC, Outage Coordination, Next Day Study)
- **Real-Time Forecast** used in real time dispatch to set DOT for EIR Resources
- **Internal Persistence Forecast** used in RTD to improve accuracy 40% from FSP providers.



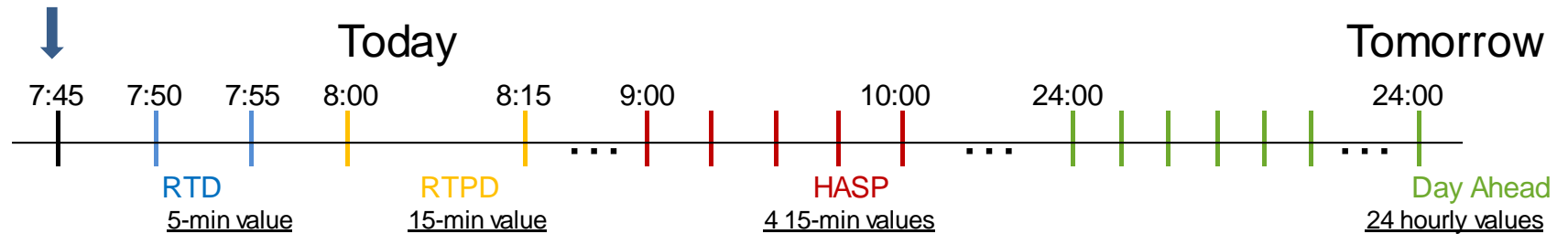
Tehachapi Pass



Topaz Solar Farm, San Luis Obispo County, California

Forecast Horizons

Forecast
Published



RTD

- Value produced **every 5 min** for interval 5-10 min ahead
- 288 binding intervals per day

RTPD

- Value produced **every 15 min** for interval 15-30 min ahead
- 96 binding intervals per day

HASP

- Values produced **every hour** for intervals
- 75-90 min ahead
- 90-105 min ahead
- 105-120 min ahead
- 120-135 min ahead

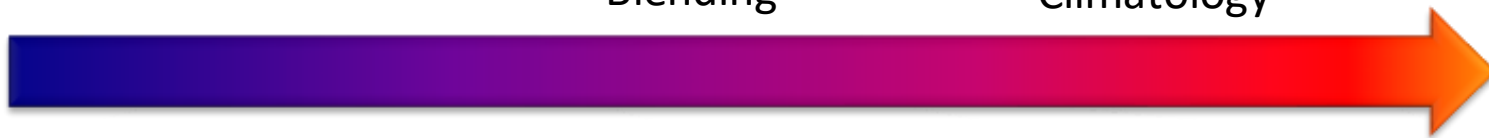
Day Ahead

- Values are **published once a day**

Persistence

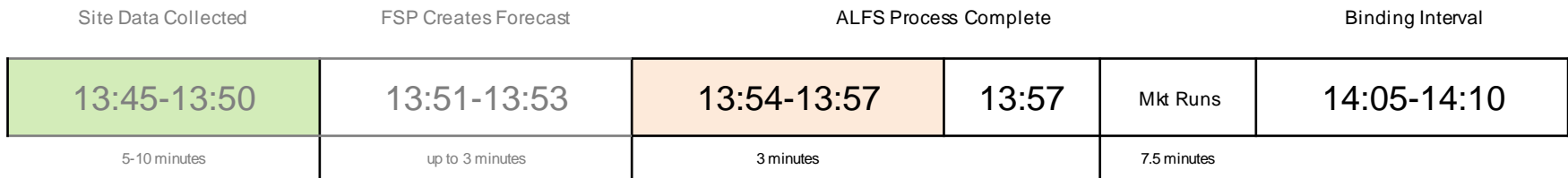
Blending

Climatology



Why Is the Persistence Method needed?

Current:



PI Data submitted to FSP

Forecast to ALFS

Site Data Collected

Data to Market

Binding Interval



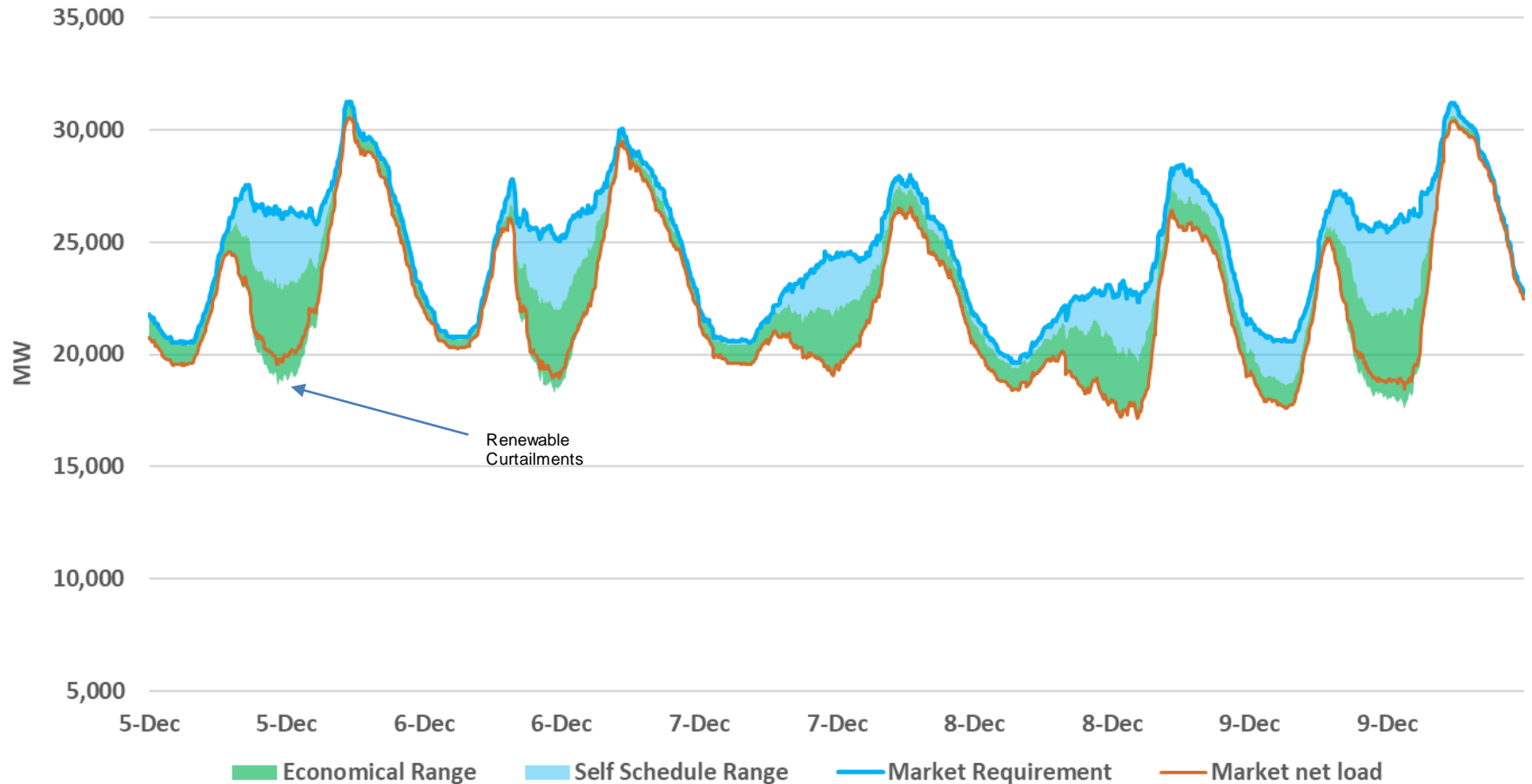
Data to Market

Persistence Method:

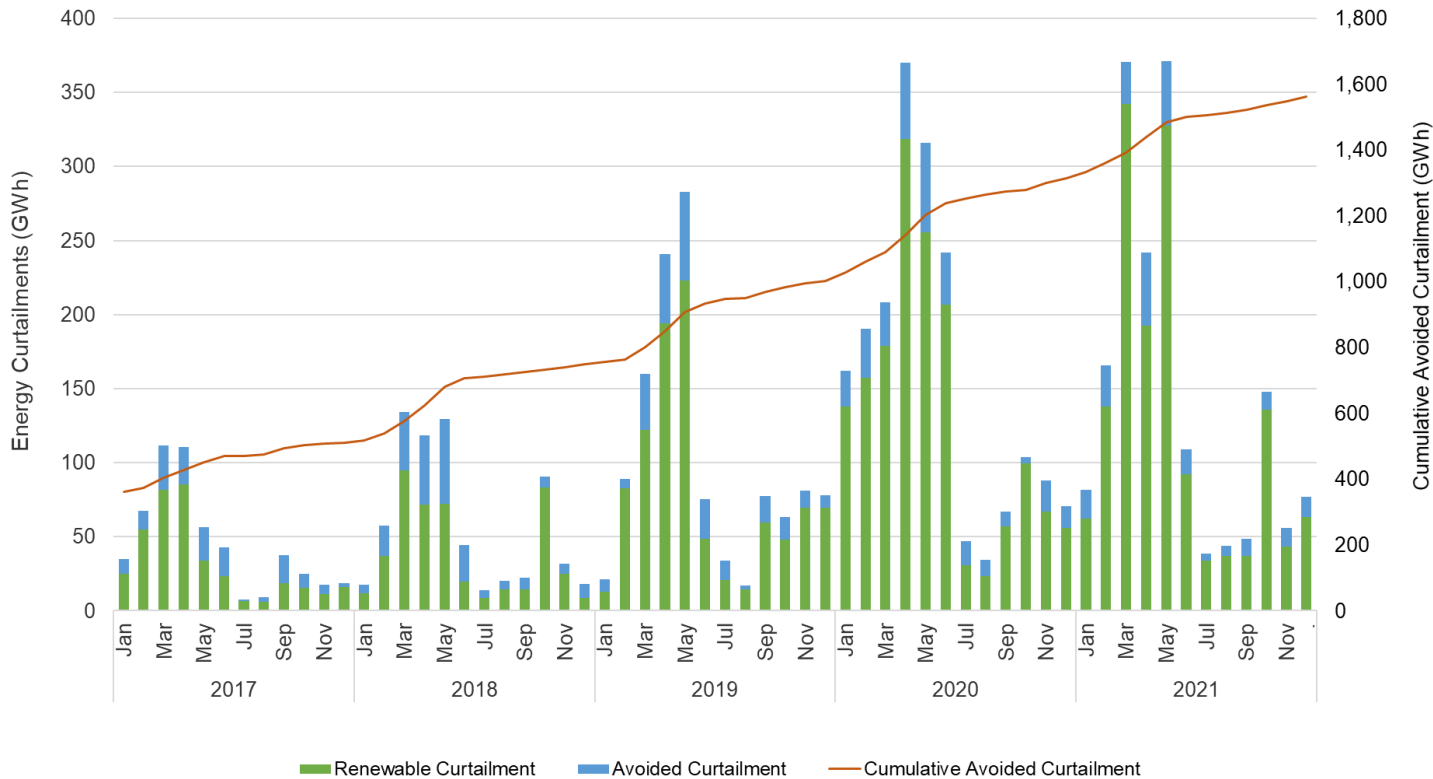
- More recent actuals are used in forecast
- 6+ minutes are eliminated from lag

Forecast calculated within the market, eliminating forecasting system & processing time needed outside of CAISO

Up to 50% of renewables is price responsive



RTD renewable curtailments exhibit a seasonal pattern



■ Renewable Curtailment
 ■ Avoided Curtailment
 — Cumulative Avoided Curtailment

