



Forming Weather-Aware Uncertainty Requirements

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Agenda

- CAISO Overview
- Challenges
 - Load/Demand
 - Large Scale Renewables
- Tools
 - Uncertainty Requirements
 - Imbalance
 - Flexible Ramp Product
 - Regulation Requirement
 - Expansion of Operational Forecasting Products



California ISO

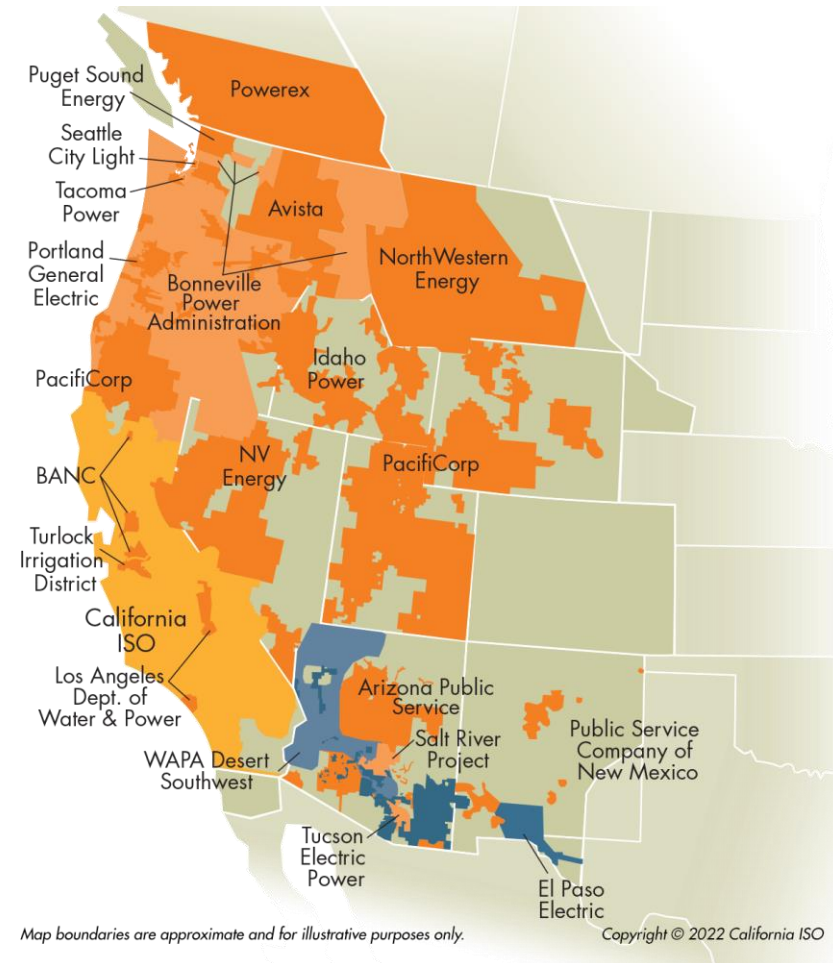
As a federally regulated nonprofit organization, the ISO manages the high-voltage electric grid.

50,270 MW record peak demand
(July 24, 2006)

224.8 million megawatt-hours of electricity delivered
(2020)

75,747 MW power plant capacity
Source: California Energy Commission

1,119 power plants
Source: California Energy Commission

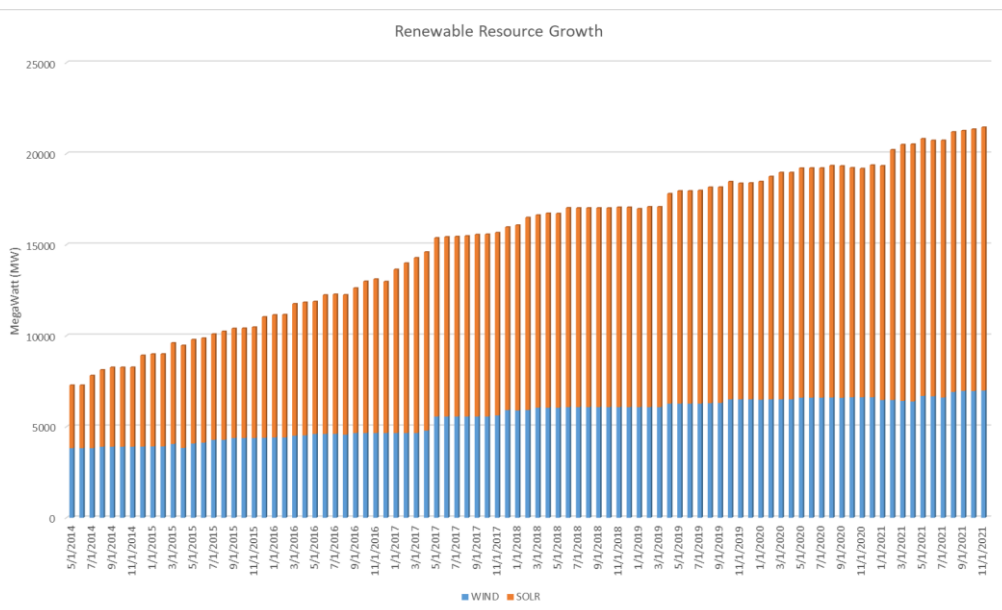


Renewable Portfolio Standard (RPS) goals

California requires all utilities to purchase energy that meets the state's aggressive renewable energy goal mandate.



- In 2030, the state's RPS requires 60 percent of the energy provided by utilities to be from a qualified renewable source
- By 2045, 100 percent of all energy provided to consumers must be from zero carbon resources



Current Renewable Penetration Facts

Historical statistics and records *(as of 04/01/2022)*



Solar peak NEW!

13,456 MW

Mar 24, 2022 at 2:32 p.m.

Previous record:

13,205 MW, May 27, 2021



Wind peak NEW!

6,265 MW

Mar 4, 2022 at 2:50 p.m.

Previous record:

6,178 MW, Feb 15, 2022



Peak renewables NEW!

serving load

96.4%

Mar 27, 2022 at 1:52 p.m.

Previous record:

94.5%, Apr 24, 2021



**Peak
net imports**

11,894 MW

Sep 21, 2019 at 6:53 p.m.



**Peak
demand**

50,270 MW

Jul 24, 2006 at 2:44 p.m.

Second highest:

50,116 MW, Sep 1, 2017



**Steepest ramp
over 3-hour period**

17,660 MW

Mar 11, 2022 starting at 2:59 p.m.

Second highest:

17,259 MW, Feb 28, 2021

¹ Based on 1-minute averages, and includes dynamic transfers. Values are subject to revision as data is refined.

² Indicates the highest amount of renewables serving peak electricity demand on any given day.

Currently Installed	Capacity
Number of Renewable Resources	500
MW Capacity Large Scale Renewables	21,500 MWs
MW Capacity Behind-the-Meter Solar	13,000 MWs

*Values are approximate as of November 2021

CHALLENGES

System and markets are evolving towards a non-deterministic environment

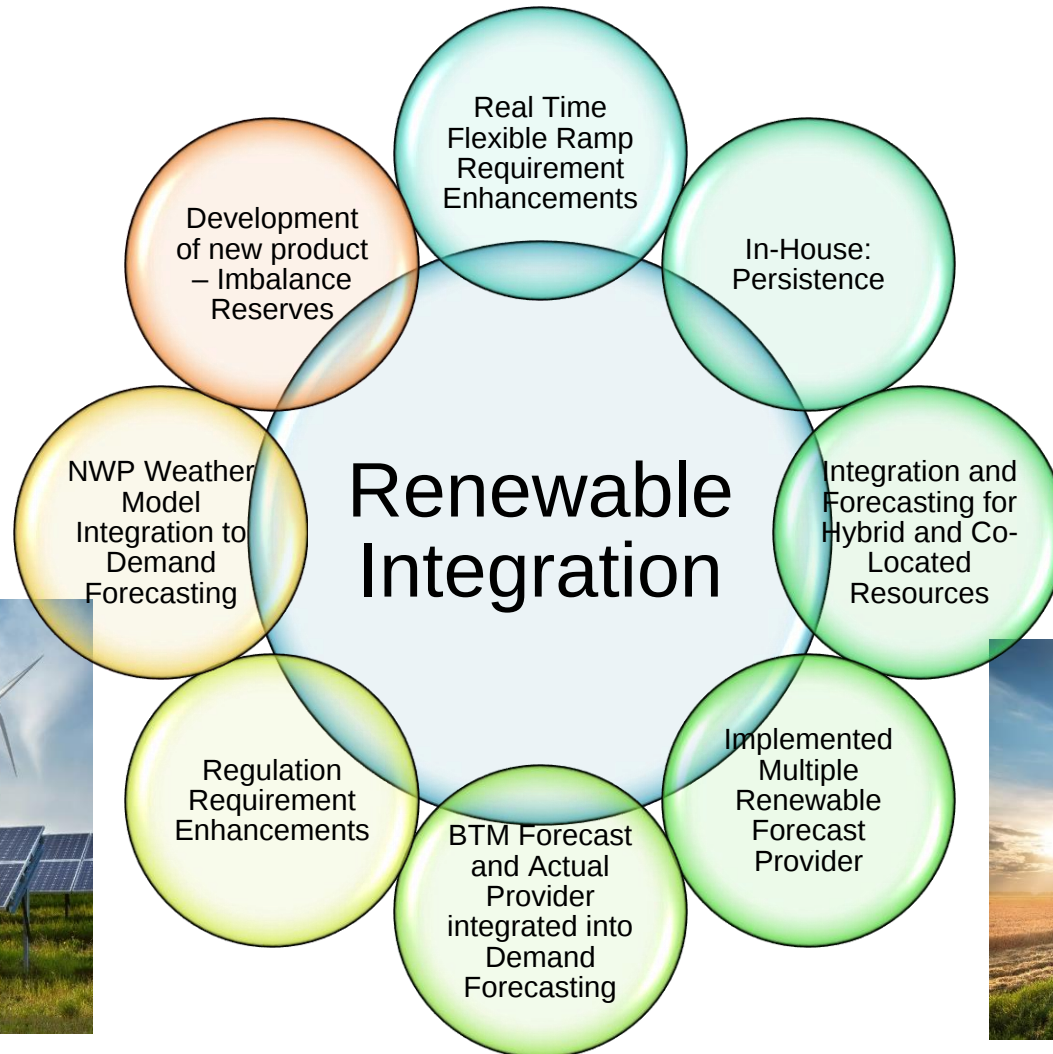
- Weather variables, such as cloud cover, introduce uncertainty components to multiple variables in the power system, including
 - Load forecast
 - Behind the meter generation
 - Large scaled wind and solar production
 - Regulation requirements
- CAISO still uses a deterministic market clearing process with deterministic inputs
- Different products and procedures are developed to assist in accounting for uncertainty

Operational Impacts



TOOLS

CAISO Forecasting Advancements in Support of High Penetrations of Renewable Resources

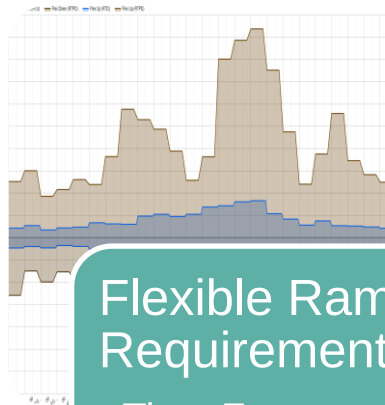


Net-Load Uncertainty Requirements



Imbalance Requirements

- Time Frame: DA to FMM
- Method: Quantile Regression



Flexible Ramp Requirements

- Time Frame: FMM to RTD
- Method: Quantile Regression



Regulation Requirements

- Time Frame: RTD to Actual
- Method: Combination

CAISO Proposed to use a Quantile Regression to Calculate Net Load Uncertainty Requirements

- Currently, a histogram methodology is used to procure capacity products like real-time flexible ramping product.
- Using a regression model based on forecasted amounts of load, wind, and solar will result in a more accurate requirement amount.
 - This model can be shaped to better capture variation of requirement to forecasted values

What is Quantile Regression?

- Quantile Regression estimates quantiles of a dependent variable, conditional on the values of a set of independent variables
- Preferred in Imbalance Reserve and RT Flex Ramp Requirement scenario to standard linear regression because the requirement is based on relatively extreme high and low (i.e. 2.5 and 97.5 percentile) observations of net load imbalances, as opposed to the average net load imbalance
- The Regressors (independent variables) include forecasted load, solar, and wind values, as well as operating hour and month.

Imbalance Reserves vs. Real-Time Flexible Ramping Product

Imbalance Reserves

- Hourly Product
- 15-minute dispatchable
- Biddable
- Covers granularity difference and uncertainty between DAM and FMM
- All awards are co-optimized and settled simultaneously

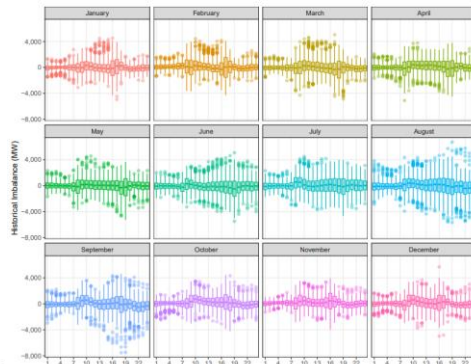
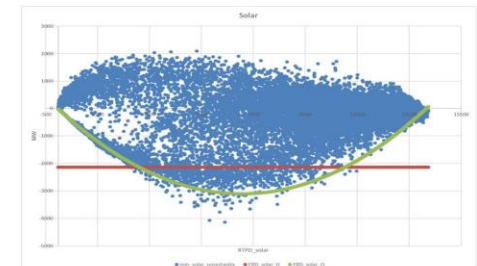


Figure 2: Hourly trend of Day-Ahead Imbalance Reserve.

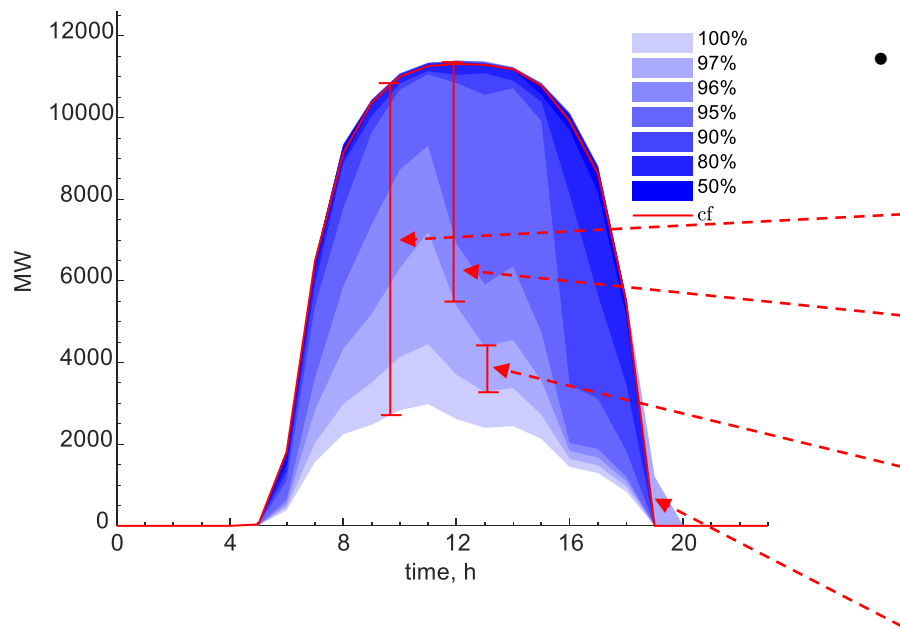
RT Flexible Ramping Product

- 15-minute product
- 5-minute dispatchable
- Not biddable
- Cover uncertainty from FMM to RTD
- Awards are calculated in successive runs and are only settled from the binding to the first advisory interval
- Demand Curve for uncertainty



Proposed methodology (green line) tracks more closely the solar production conditions, while current methodology (red line) is constant at any level of solar production

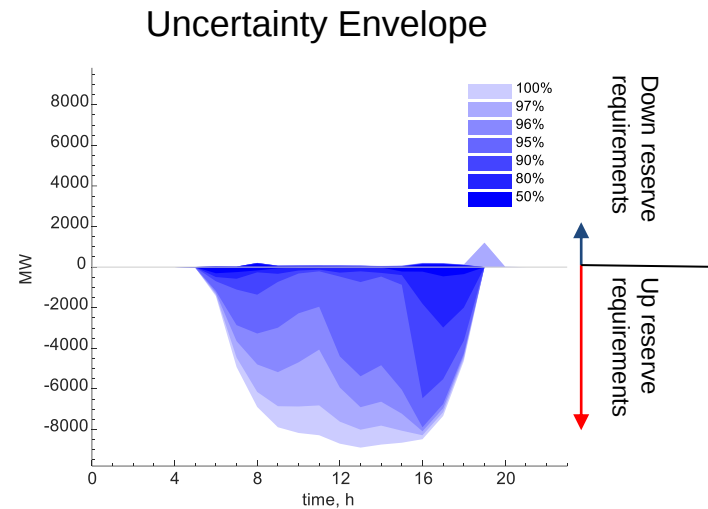
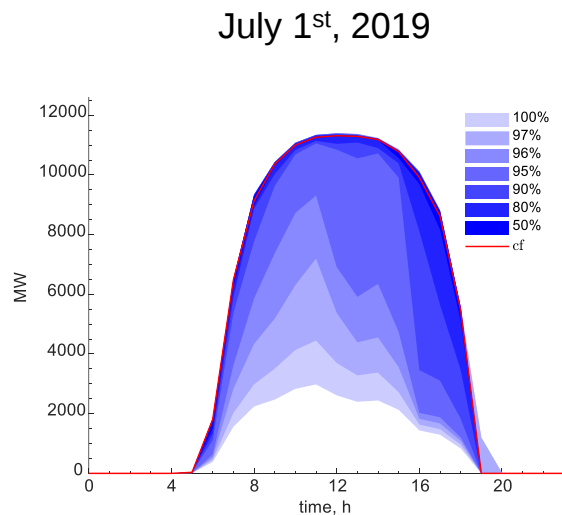
Anatomy of a Probabilistic Forecast



- Probabilistic forecasts provide users with valuable information on the possible scenarios of wind/solar generation
- It provides probabilistic thresholds in which the variables are expected to materialize:
 - A 100% threshold indicates total certainty of the variable being within the band
 - Lower probability thresholds indicate that the likelihood of the variable being within a narrower band (e.g., 90%)
 - Area between thresholds represent the probability of the variable materializing only in that space (e.g., $(100-95)/2 = 2.5\%$)
 - The redline represents the central expected forecast

Solar Probabilistic Forecasts

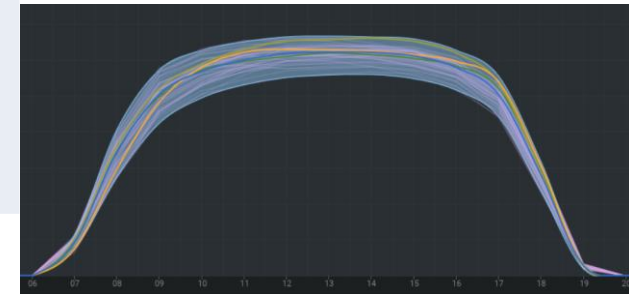
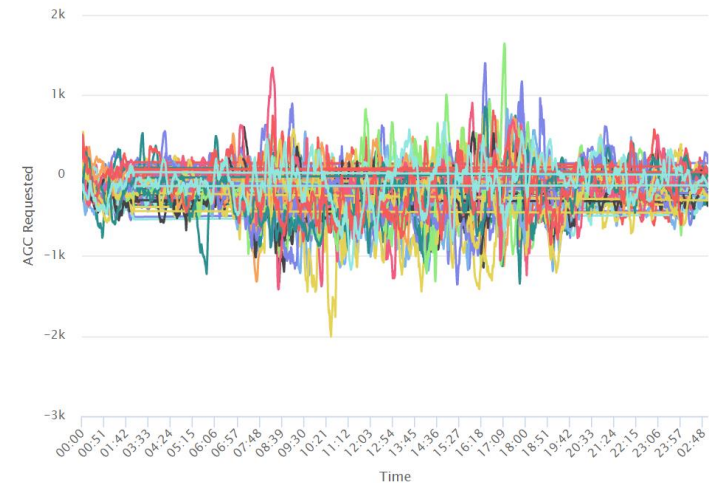
- Probabilistic forecasts for solar produced by UL as part of DOE-funded OPTSUN*
- Methods have been applied to the California ISO



* <https://www.energy.gov/sites/prod/files/2018/10/f56/Solar-Forecasting-2-Kickoff-EPRI.pdf>

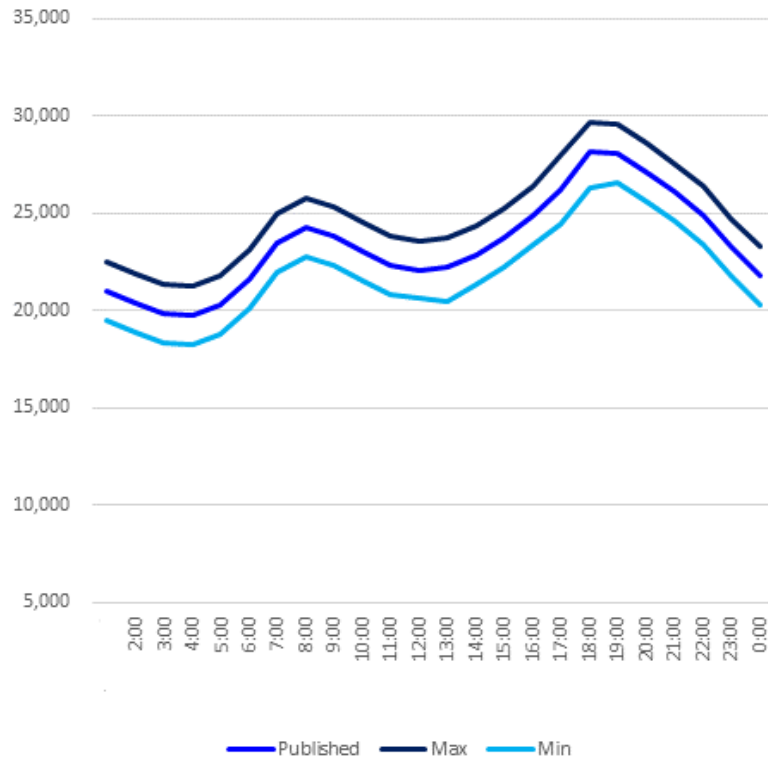
Regulation Requirement Enhancements

	Current
Tag used for Actual/Historical Data	ACE*, i.e. ACE combined with Regulation Dispatched
Historical Data Granularity	1 minute average data (extremes are not muted)
Historical Dataset	Monthly analysis run for 2 datasets: - Same month last year + most recent 30 days - Only most recent 30 days The max of both results is then taken for the recommendation during sunlight hours. This is intended to focus on the recent behavior without eliminating seasonal patterns from last year.
Unchanged	- Hourly values are determined by percentiles 95th percentile for Sunny (less volatility forecasted) 2.5% off each tail - 97.5% Up and 2.5% Down 98th percentile for Cloudy (more volatility forecasted) 1% off each tail – 99% up and 1% down - Base numbers updated at minimum monthly 95th/98th recommendation updated daily according to forecasted VER Volatility - Operations can adjust as needed - Due to weather, outages, software updates, AGC performance, last few days operational issues, etc.

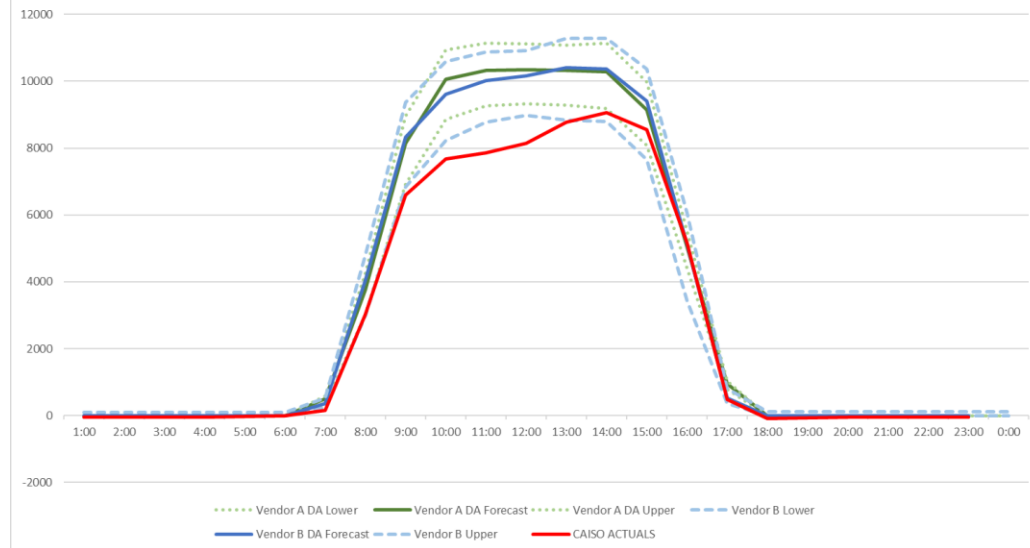


Creation and Use of Confidence Bands

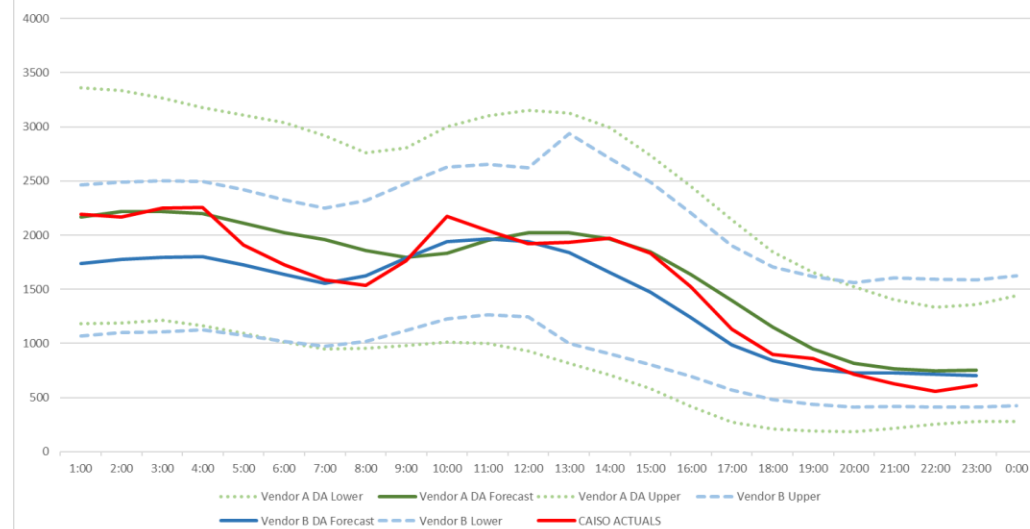
CAISO Confidence Bands



Solar Confidence Bands



Wind Uncertainty Band



Additional Material: Stakeholder Initiatives, Research, and Publications

- Stakeholder Initiatives:
 - Day Ahead Market Enhancements
 - Flexible Ramp Product Enhancements
 - Resource Sufficiency Evaluation Enhancements (Phase 1B)
- Research and Publications:
 - N. Costilla-Enriquez, M. A. Ortega-Vazquez, A. Tuohy, A. Motley, and R. Webb, "Operating Dynamic Reserve Dimensioning Using Probabilistic Forecasts," *IEEE Trans. Power Syst.*, Vol. XX, Issue X, pp., XXX. 2022.
[DOI] [arXiv]
 - DOE (EERE) funded projects "Operational Probabilistic Tools for Solar Uncertainty (OPTSUN)"
 - <https://www.energy.gov/sites/prod/files/2018/10/f56/Solar-Forecasting-2-Kickoff-EPRI.pdf>
 - https://www.energy.gov/sites/default/files/2019/10/f67/9%20Solar-Forecasting-2-Annual-Review_The-Johns-Hopkins-University.pdf