CAISO: Advances in the use of wind and solar forecasting

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G-PST/ESIG Webinar Series

Agenda

- History of renewable forecasting
- CAISO wind and solar forecasting
- Use of confidence bands in probabilistic renewable forecasts
- Optimization of forecasts from multiple renewable providers
- Renewable Resource evolution towards resource types of co-located and hybrid resources.
  - New data requirements

California ISO

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

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

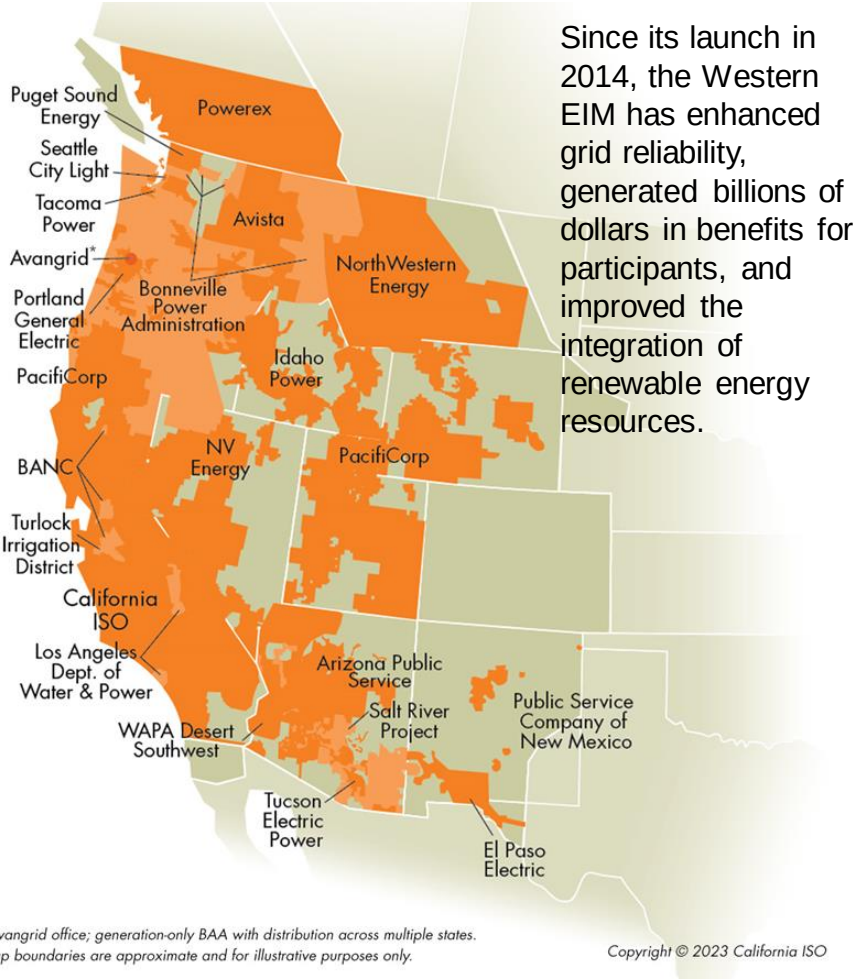
224.8 million megawatt-hours of electricity delivered (2020)

75,747 MW power plant capacity

Source: California Energy Commission

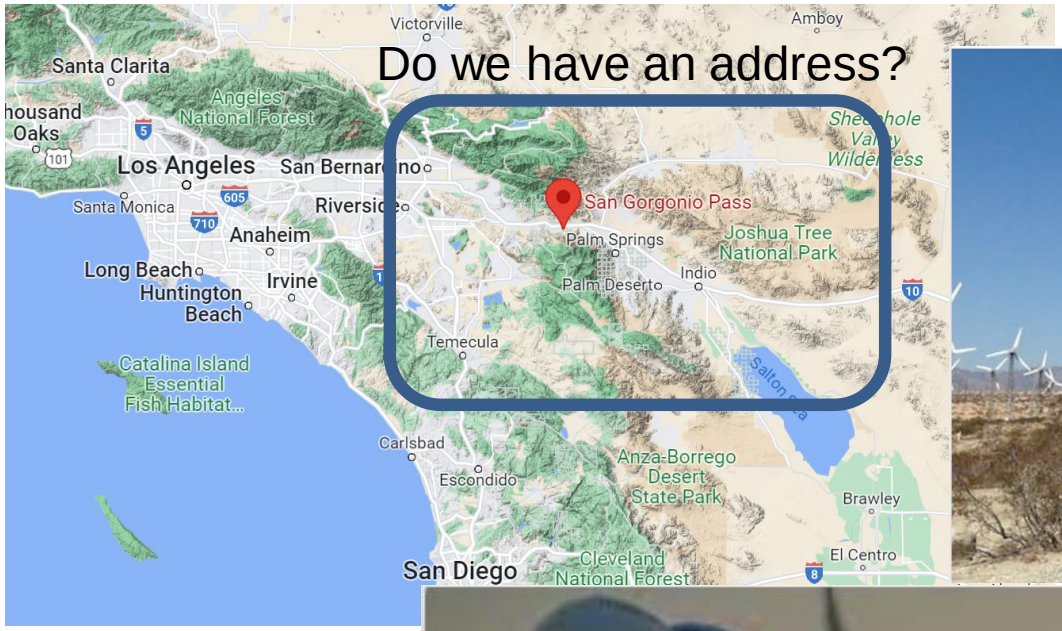
1,119 power plants

Source: California Energy Commission



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

How it all started – wind forecasting



Data Requirements to help forecast renewables are critical

- CAISO put into place **Participating Intermittent Resources** in **2003**
- Further refinements to renewable forecasting data requirements came with **FERC 764** in **2014** and with the **Hybrid/Co-Located** resource changes in **2021** and **2023**

A wind Eligible Intermittent Resource or Hybrid Resource with a wind generation component must provide the site information specified below in the manner and format as specified through the CAISO new resource implementation process. Latitude and Longitude should be in degrees/decimals using WGS84 geodetic datum only.

1. Park Potential (MW; numeric-float field [example: 100.5])
2. Resource Project Corner Coordinates in WGS84 format
3. Meteorological Station ID Numbers
4. Meteorological Station Coordinates in WGS84 format
5. Address
6. Resource ID
7. MW Generation Capacity
8. Plant Location (Latitude and Longitude in WGS84)
9. Lidar or Sodar (required)
10. Make (required; alphanumeric)
11. Model (required; alphanumeric)
12. Wind Speed (Anemometer) (required; alphanumeric)
13. Wind Direction (Anemometer) (required; alphanumeric)
14. Air Temperature (required; alphanumeric)
15. Barometric Pressure (required; alphanumeric)
16. Wind Turbine Group Numbers
17. Turbine Specifications:
18. Number of Turbines (numeric field)
19. Turbine Manufacturer (alphanumeric field)
20. Turbine Model (alphanumeric field)
21. Turbine Maximum Generation Capacity (numeric field)
22. Turbine Height Above Ground Level (numeric field)
23. Cut in Speed (numeric field; in m/s)
24. Cut Out Speed (numeric field; in m/s)
25. Cold Weather Package (Yes or No Dropdown)
26. Hot Weather Package (Yes or No Dropdown)
27. Low Temperature Cut Out (numeric field)
28. High Temperature Cut Out (numeric field)
29. Wind Turbine ID Numbers (alphanumeric field)
30. Elevation (numeric field; in meters)
31. Hub Height. (numeric field; in meters)
32. Turbine(s) Latitude(s) and Longitude(s) Coordinates (WGS84 Coordinate Field)
33. Turbine ID
34. Turbine Latitude and Longitude
35. Turbine Elevation
36. Turbine Hub Height
37. Turbine Group Number

Table Q-2 Solar Eligible Intermittent Resources Telemetry Data Points

Element	Device(s) Needed	Units	Accuracy
Wind Speed (Meter / Second)	Anemometer, wind vane and wind mast	m/s	± 2m/s
Wind Direction (Degrees - Zero North 90CW)	Anemometer, wind vane and wind mast	Degrees	± 5^0
Air Temperature (Degrees Celsius)	Temperature probe & shield for ambient temp	^{0}C	± 1^0
Barometric Pressure (hecto Pascals)	Barometer	hPA	± 60 hPa
Back Panel Temperature (Degree C)	Temperature probe for back panel temperature	^{0}C	± 1^0
Plane of Array Irradiance Watts\Meter Sq.	Pyranometer or Equivalent	W/m²	± 25 W/m²
Global Horizontal Irradiance Watts\Meter Sq.	Pyranometer or Equivalent	W/m²	± 25 W/m²
Direct Irradiance Watts\Meter Sq.	Pyranometer or Equivalent	W/m²	± 25 W/m²
Real Time Data		MWs*	
High Sustainable Limit (for Hybrid Resources with a solar generation component and solar EIRs that are a Co-located Resource		MWs**	

* Hybrid Resources with a solar generation component must provide MW values through telemetry for both the solar generation component and the overall Hybrid Resource

** High Sustainable Limit may be updated every 12 seconds.

Industry cross collaboration assists to obtain state of the art renewable forecasting

NOAA

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

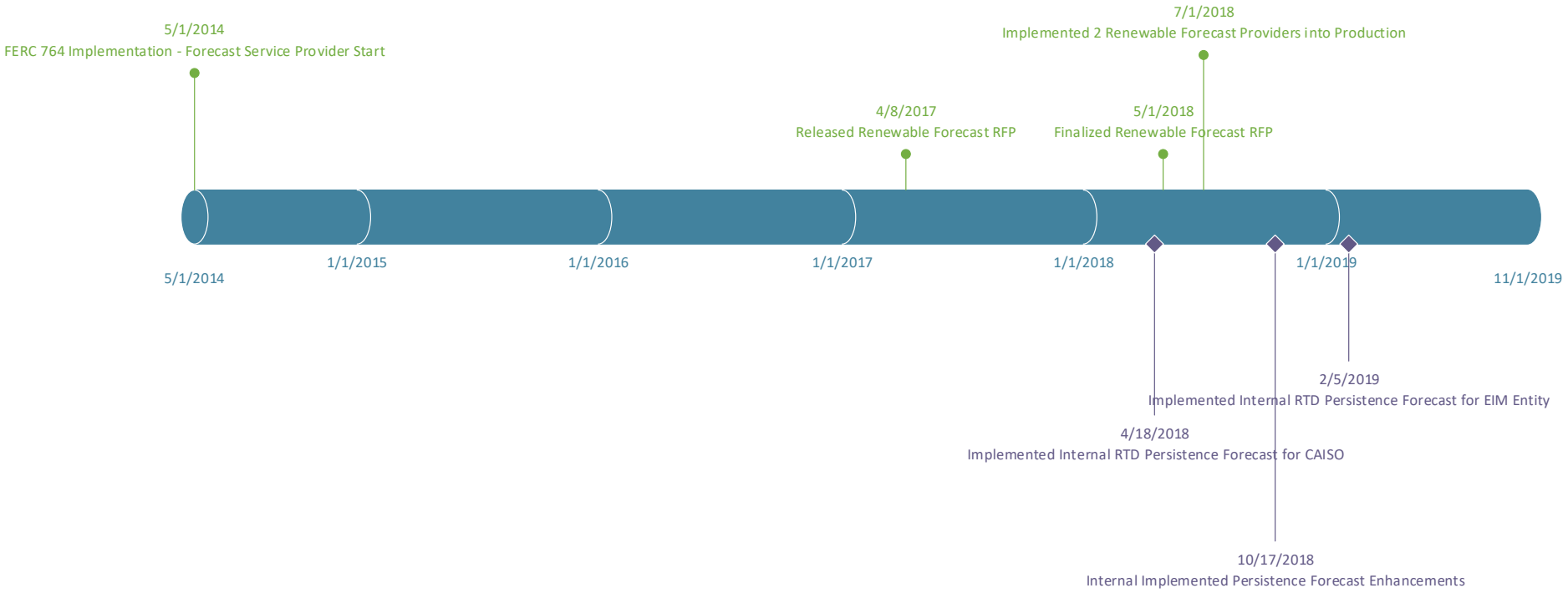
NCAR UCAR

STATE OF CALIFORNIA ENERGY COMMISSION SINCE 1975

U.S. DEPARTMENT OF ENERGY

AWS Truewind
POWERFUL SOLUTIONS®

Timeline of Key CAISO Renewable Forecast Enhancements



Current Renewable Penetration Facts

Historical statistics and records *(as of 9/06/2023)*

Solar peak NEW!
16,044 MW
Sept 6, 2023 at 12:18 p.m.
Previous record:
15,960 MW, July 6, 2023

Wind peak
6,465 MW
May 28, 2022 at 5:39 p.m.
Previous record:
6,265 MW, March 4, 2022

Peak percentage of renewables compared to demand
103.5%
May 8, 2022 at 3:39 p.m.
Previous record:
99.87%, April 30, 2022

Peak net imports
11,894 MW
Sept. 21, 2019 at 6:53 p.m.

Peak demand
52,061 MW
Sept. 6, 2022 at 4:57 p.m.
Second highest:
50,270 MW, July 24, 2006

Steepest 3-hour average ramp
20,326 MW
Feb. 15, 2023 starting at 3:00 p.m.
Second highest:
19,699 MW, Jan. 23, 2023

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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	509
MW Capacity Large Scale Renewables	25,899 MWs
MW Capacity Behind-the-Meter Solar	14,500 MWs

*Values are approximate as of September 2023

Wind & Solar Forecasting at CAISO


Tehachapi Pass

Eligible Intermittent Resources (EIR)

- Asset Registration Information
- Outage/De-Rate Schedules
- Real Time Generation Telemetry (MW)
- Real Time Telemetry for Meteorological Information
- High Sustainable Limit (HSL)
- Renewable dispatch/Curtailments
  - Operating Instructions


Topaz Solar Farm, San Luis Obispo County, California

Wind & Solar Forecast Service

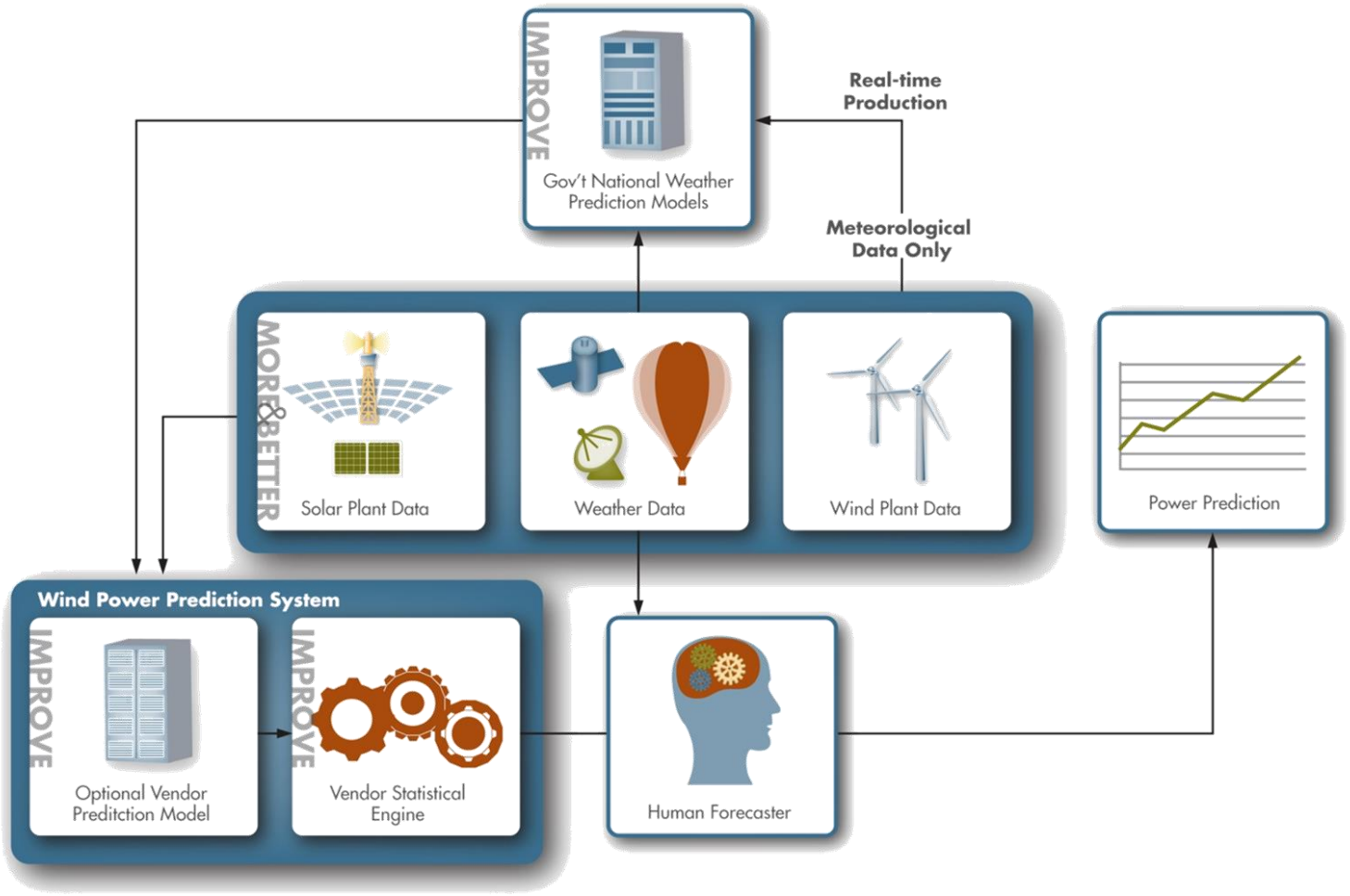
<u>Two Forecast Service Providers each provide:</u>

- **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 8 hours at a 5 minute granularity. Updated every 5 minutes
- One Provider Provides Probabilistic Forecasts used for risk assessment

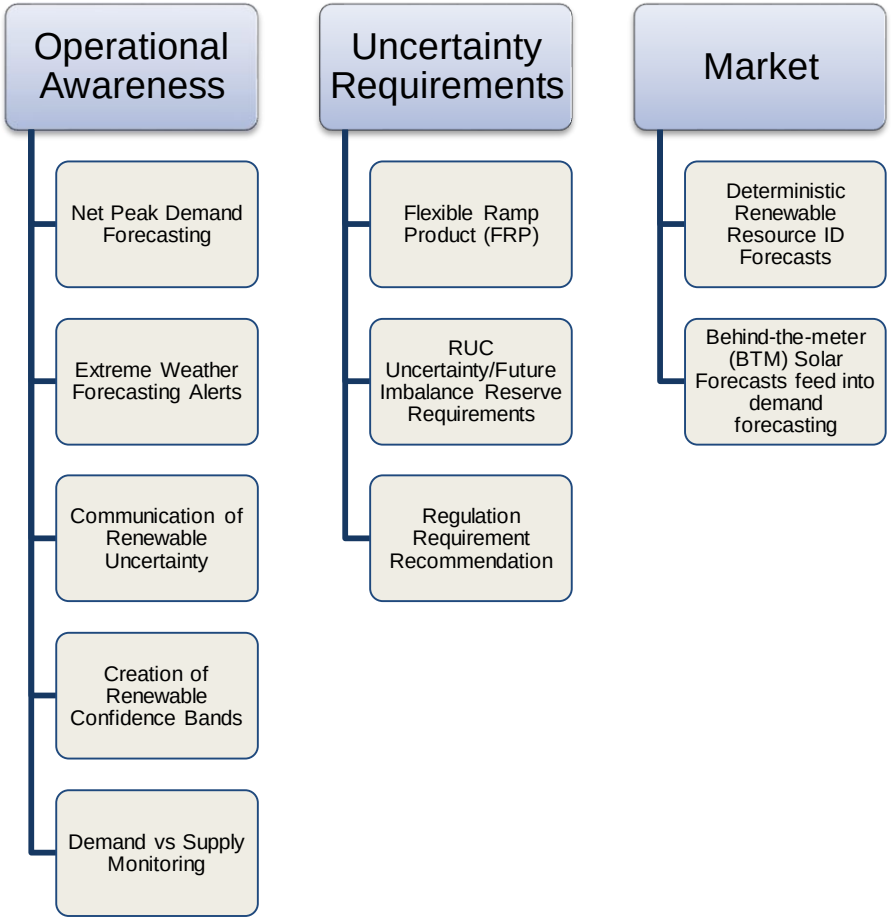
CAISO Systems

- 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 50% from FSP providers.

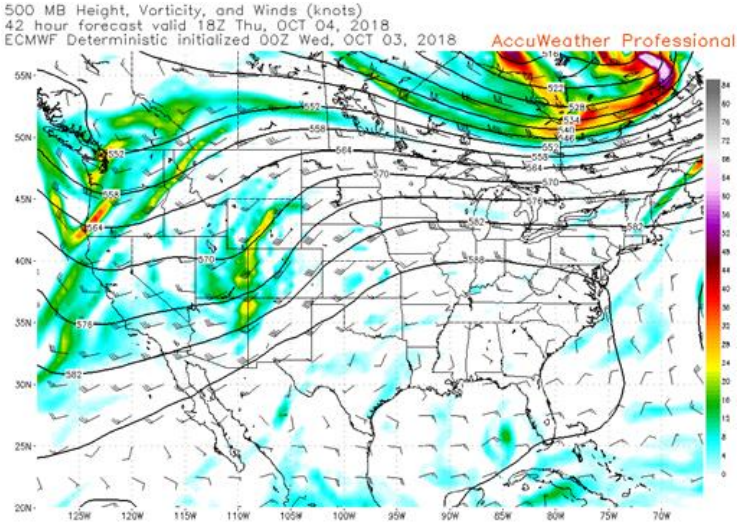
What is behind Renewable Forecasting?

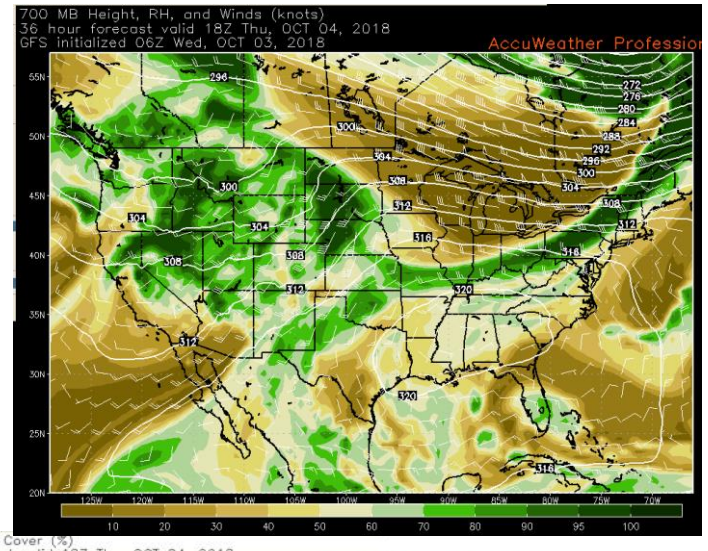


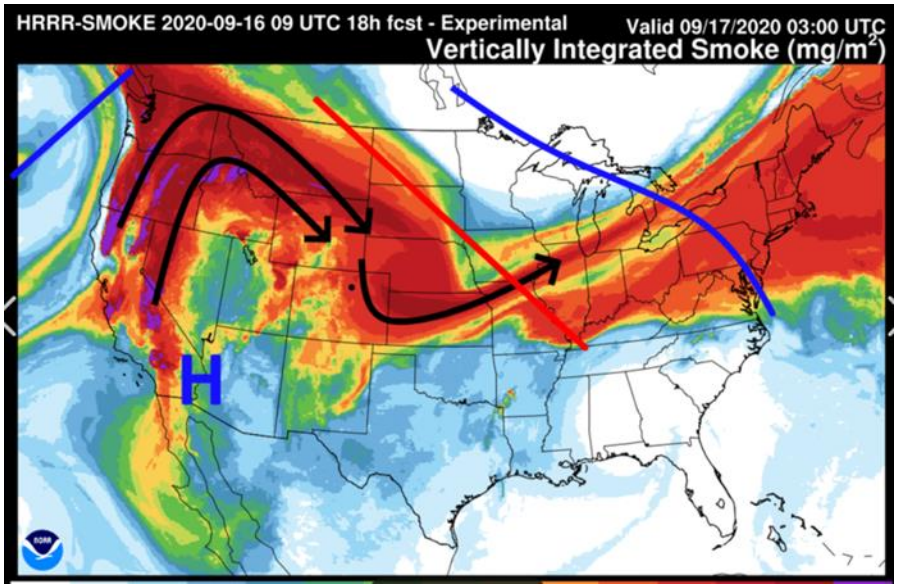
Where is renewable forecasting utilized in the CAISO systems and daily operations?

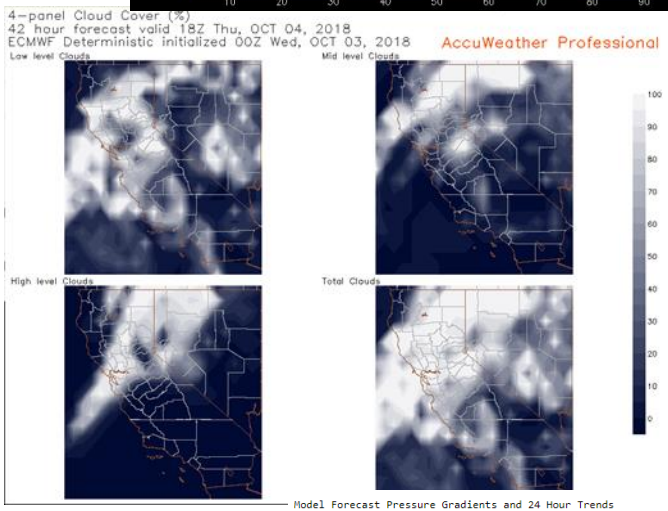


Renewable Forecast Tools







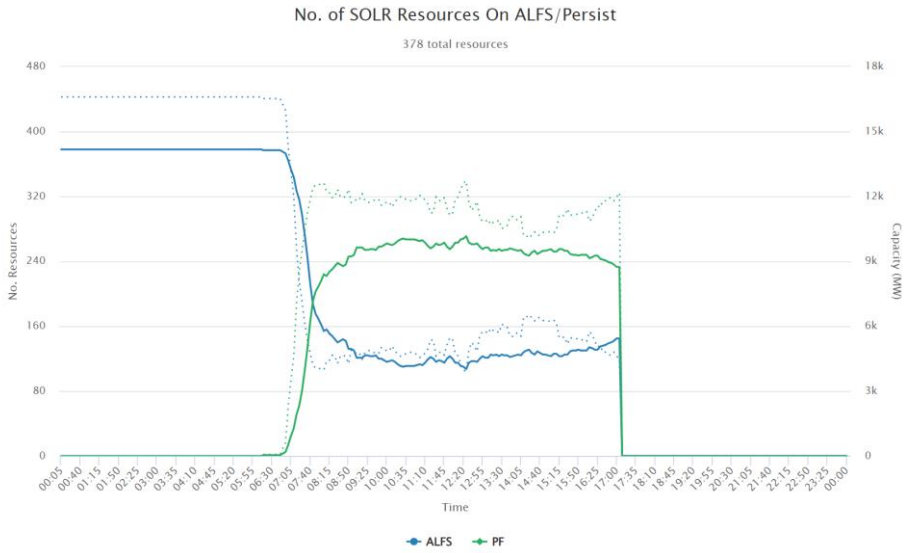


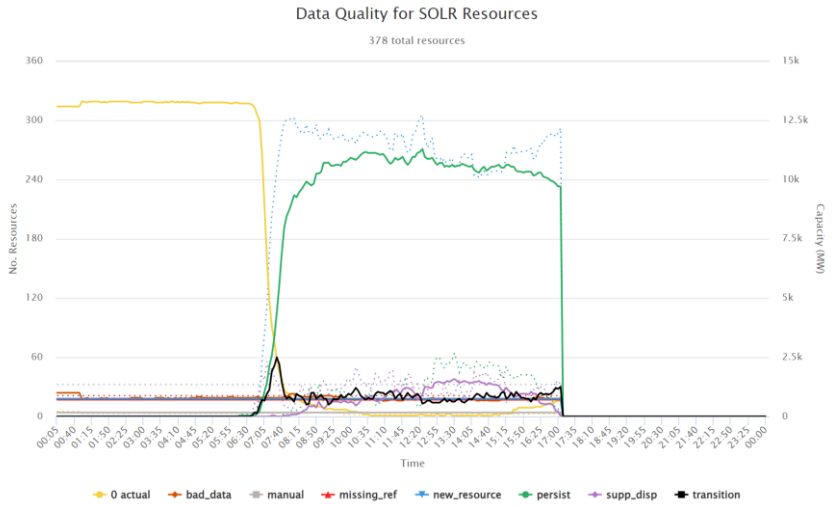
Model Forecast Pressure Gradients and 24 Hour Trends
Model/Run: ETA218 2018-10-03 12:00:00Z

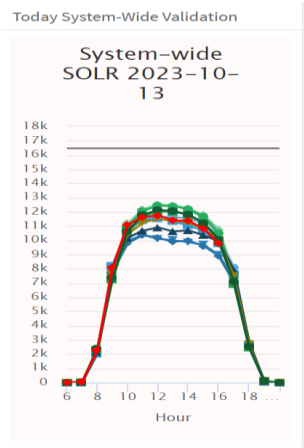
LAX-DAG

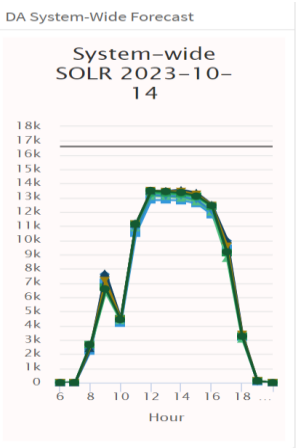
10/03/12Z	2.0		10/03/18Z	3.3		10/04/00Z	5.9	
10/04/12Z	0.9 /	-1.2	10/04/18Z	2.8 /	-0.5	10/05/00Z	4.7 /	-1.2
10/05/12Z	1.0 /	+0.1	10/05/18Z	1.7 /	-1.1	10/06/00Z	2.8 /	-1.9
10/06/12Z	-0.3 /	-1.3	10/06/18Z	2.2 /	+0.5	10/07/00Z	3.8 /	+1.0

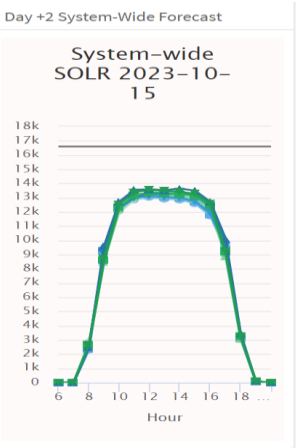
Renewable Forecast Monitoring

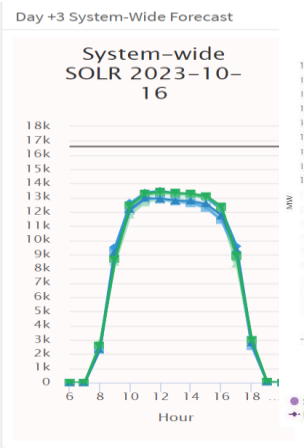


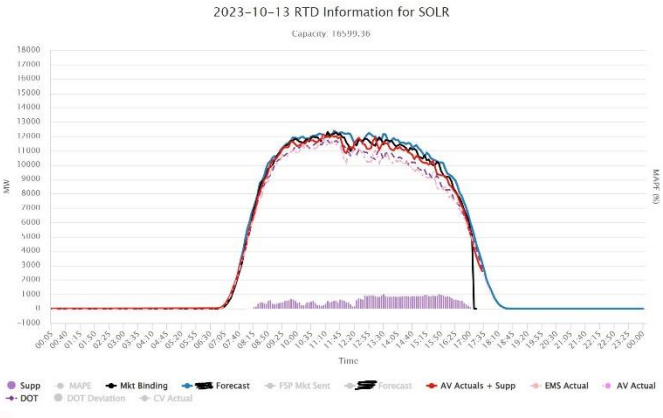








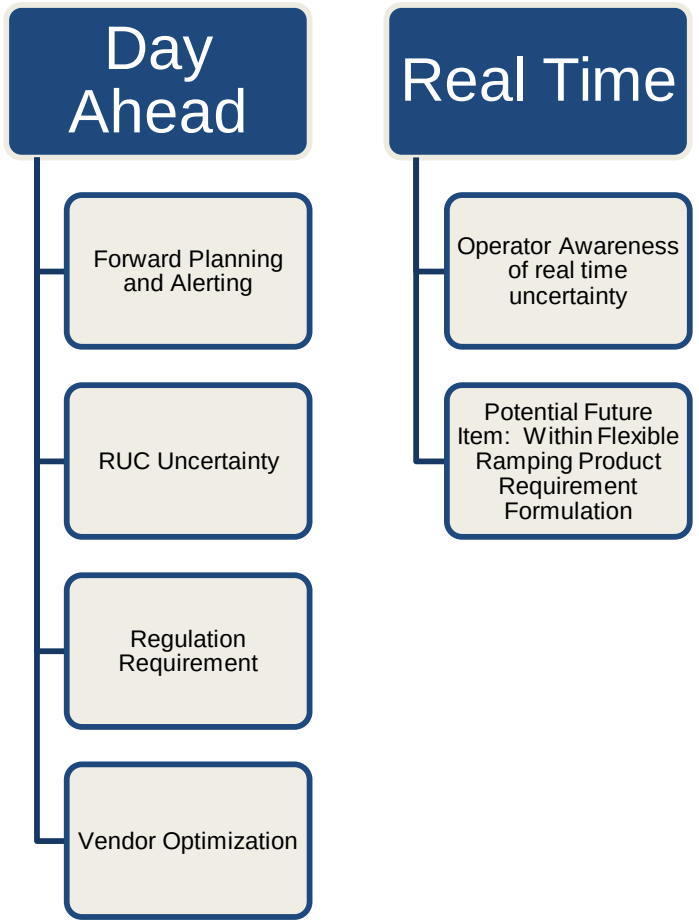




Deep dive into renewable use cases

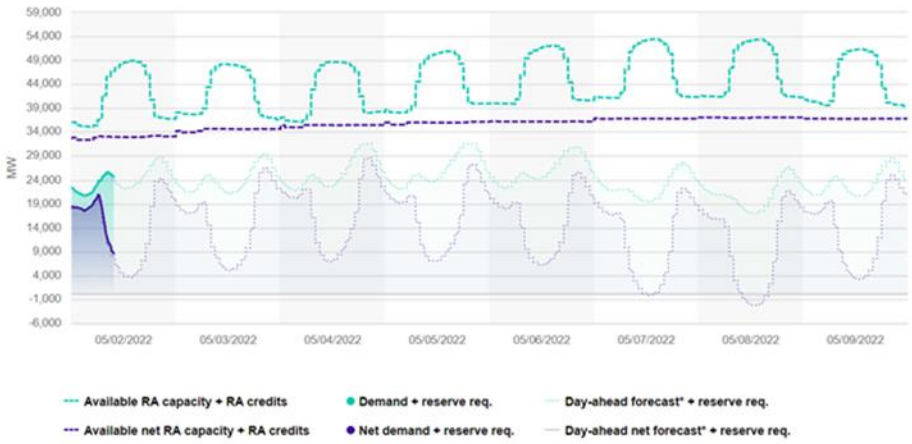
PROBABILISTIC FORECAST

Renewable Probabilistic Forecasting used fore situational awareness and uncertainty requirement formulations



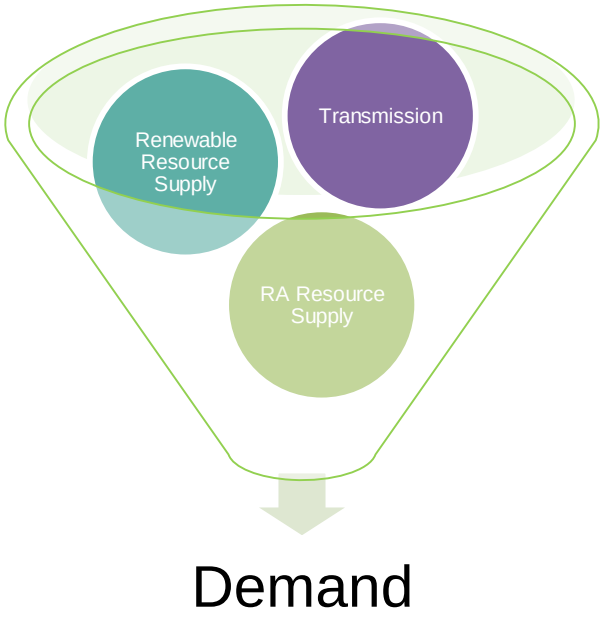
Forecasting Awareness and Transparency

- **Forecasting alerts** generated from **team of trained meteorologists** to identify extreme weather conditions up to 365 hours ahead of the event.
  - Weather, load, renewable, and fire forecasting/alerts
  - Forecasting and alerts cover CAISO & EIM areas, and the West at large



California ISO - Today's Outlook (caiso.com)

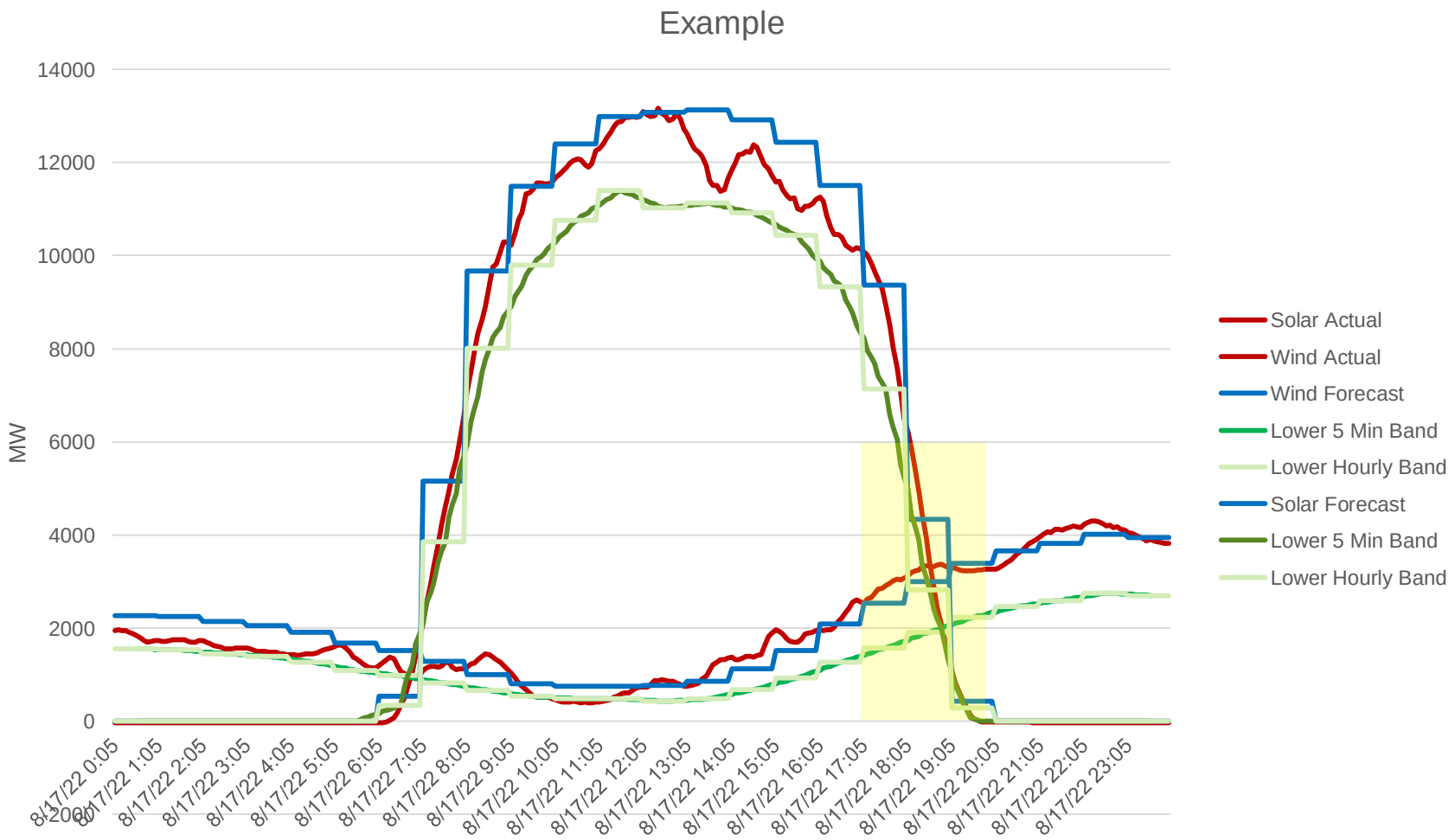
Assessing Weather Uncertainty Impact



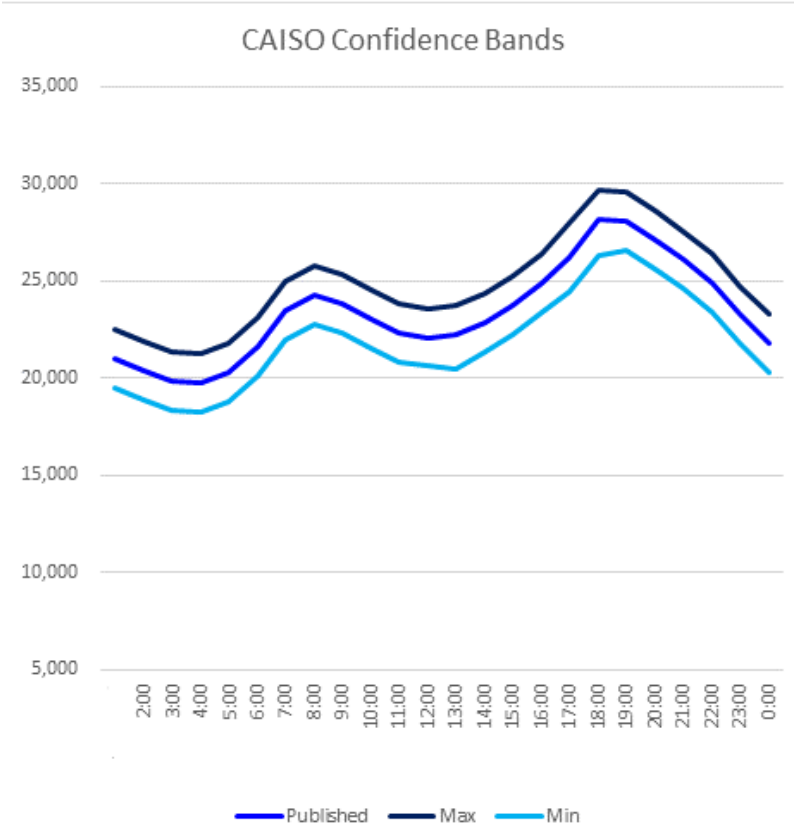
Creating an advanced warning system looking at key indicators of system health

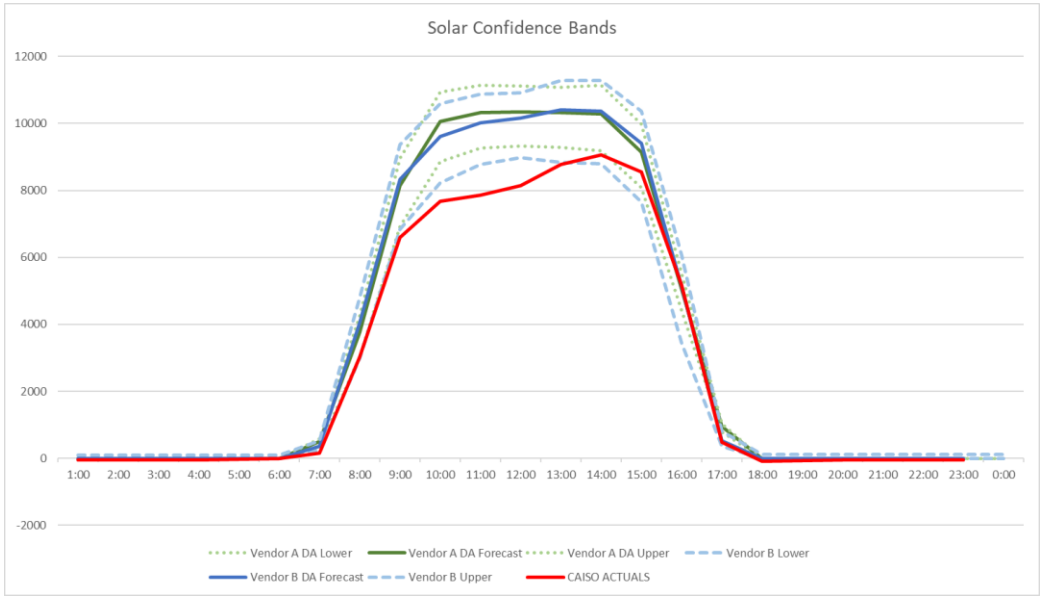
- The CAISO is monitoring and alerting on the following key elements in the 8-10 day horizon.
  - Load
  - Renewables
  - RA Resource Supply
    - Transmission Outages Impacting Resource Supply

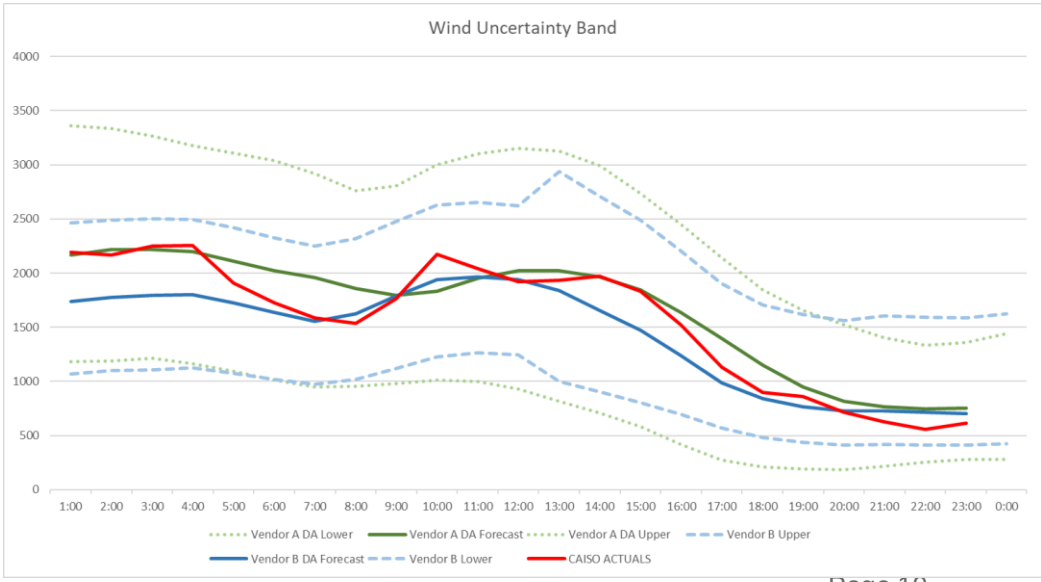
Renewable Resource Forecasting and Monitoring



The importance of net load forecasting



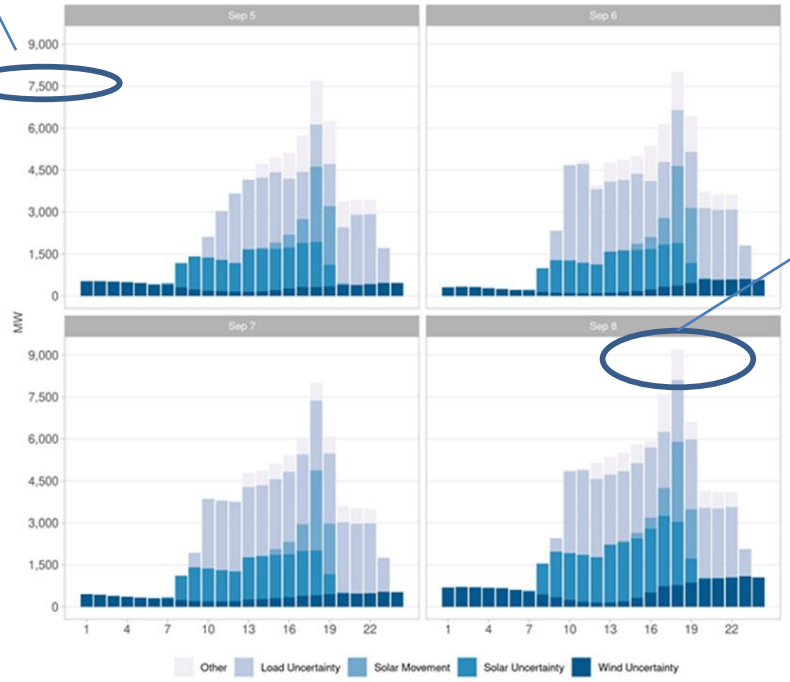




Additive approach resulted in **extra requirement** at peak and **poor coverage** off-peak

RUC Requirement Utilized

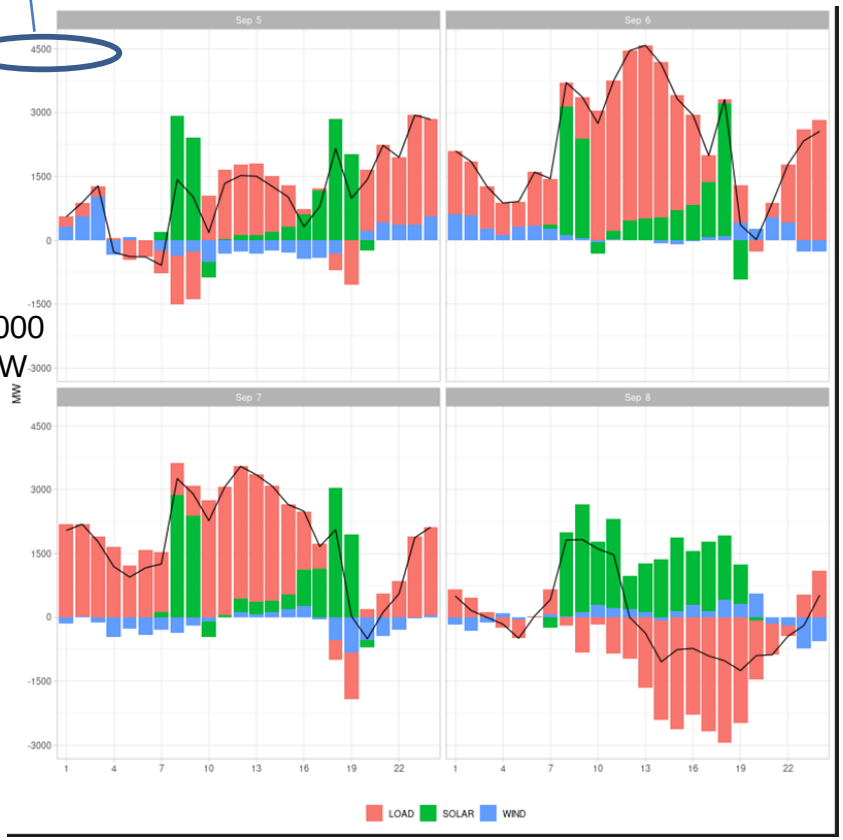
7500 MW



Realized Uncertainty Observed

4500 MW

>9000 MW

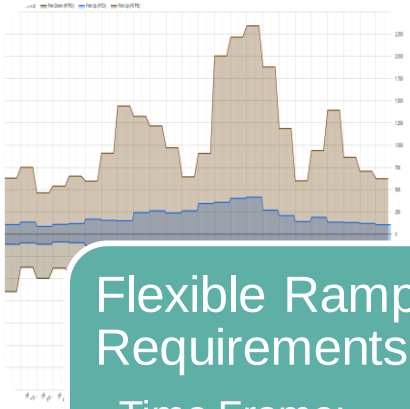


http://www.caiso.com/Documents/SummerMarketPerformanceReportforSeptember2022.pdf

Net-Load Uncertainty Requirements

Imbalance Requirements

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



Flexible Ramp Requirements

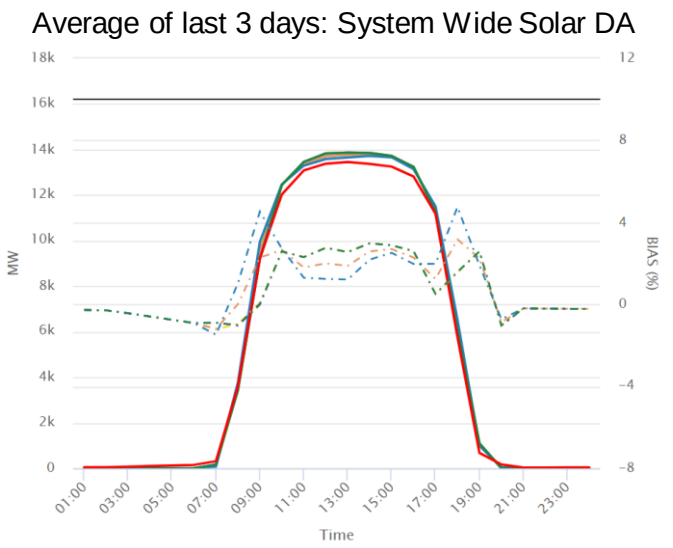
- Time Frame: FMM to RTD
- Method: Quantile Regression

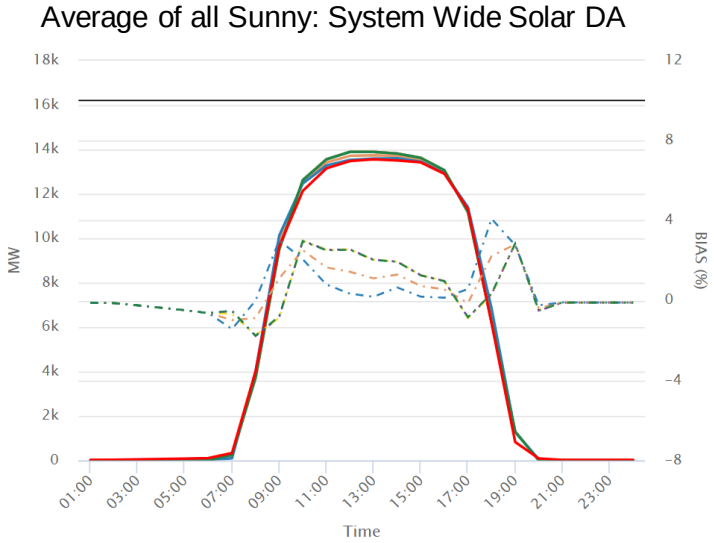
Regulation Requirements

- Time Frame: RTD to Actual
- Method: Combination

MULTIPLE VENDOR OPTIMIZATION

Integrating multiple renewable providers into daily forecasting



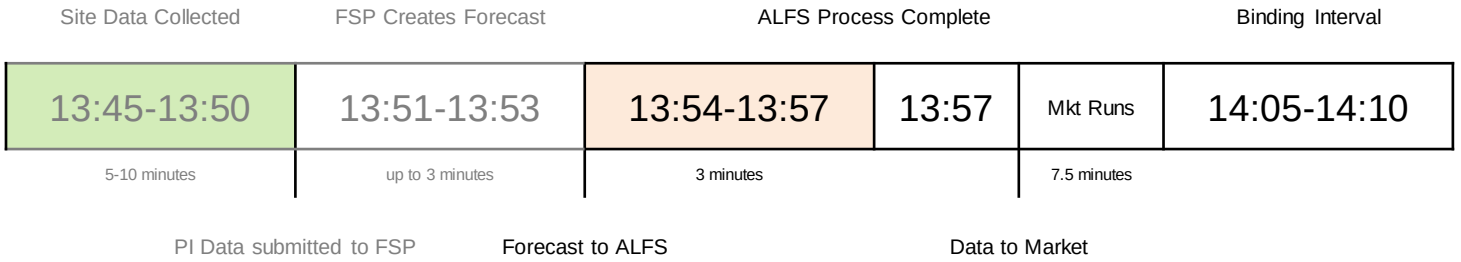


- CAISO currently has 3 renewable forecast service providers
  - 2 large scale wind/solar FSPs
  - 1 BTM Solar forecast provider
  - 1 BTM Solar actual provider

RENEWABLE FORECASTING IMPROVEMENTS

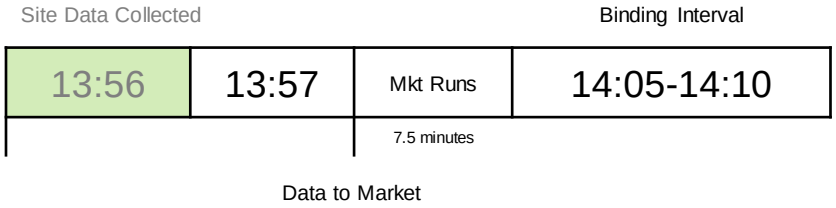
Internal CAISO Persistence-Based Renewable Forecast – Why was an internal RTD forecast needed?

Current:



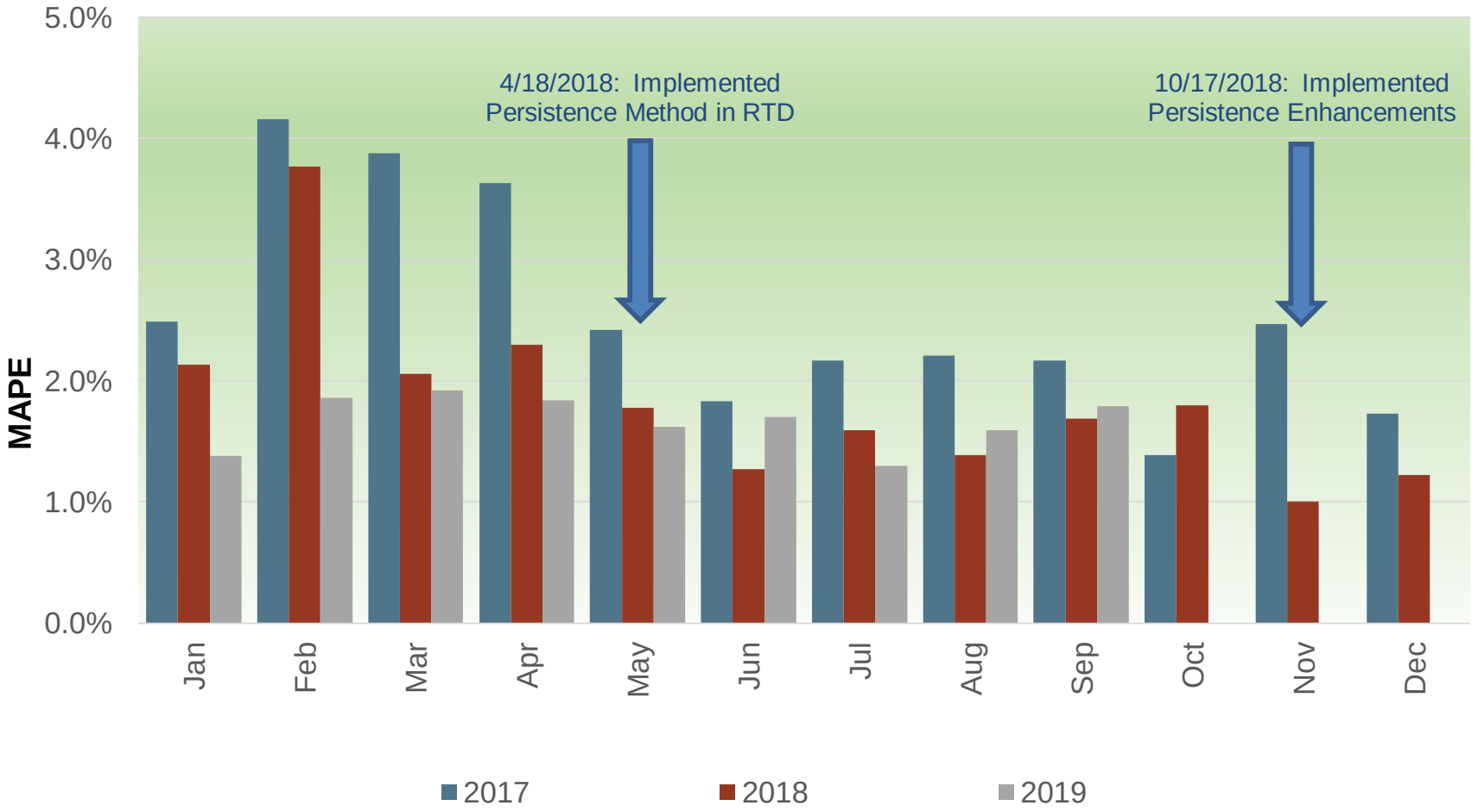
Persistence Method:

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



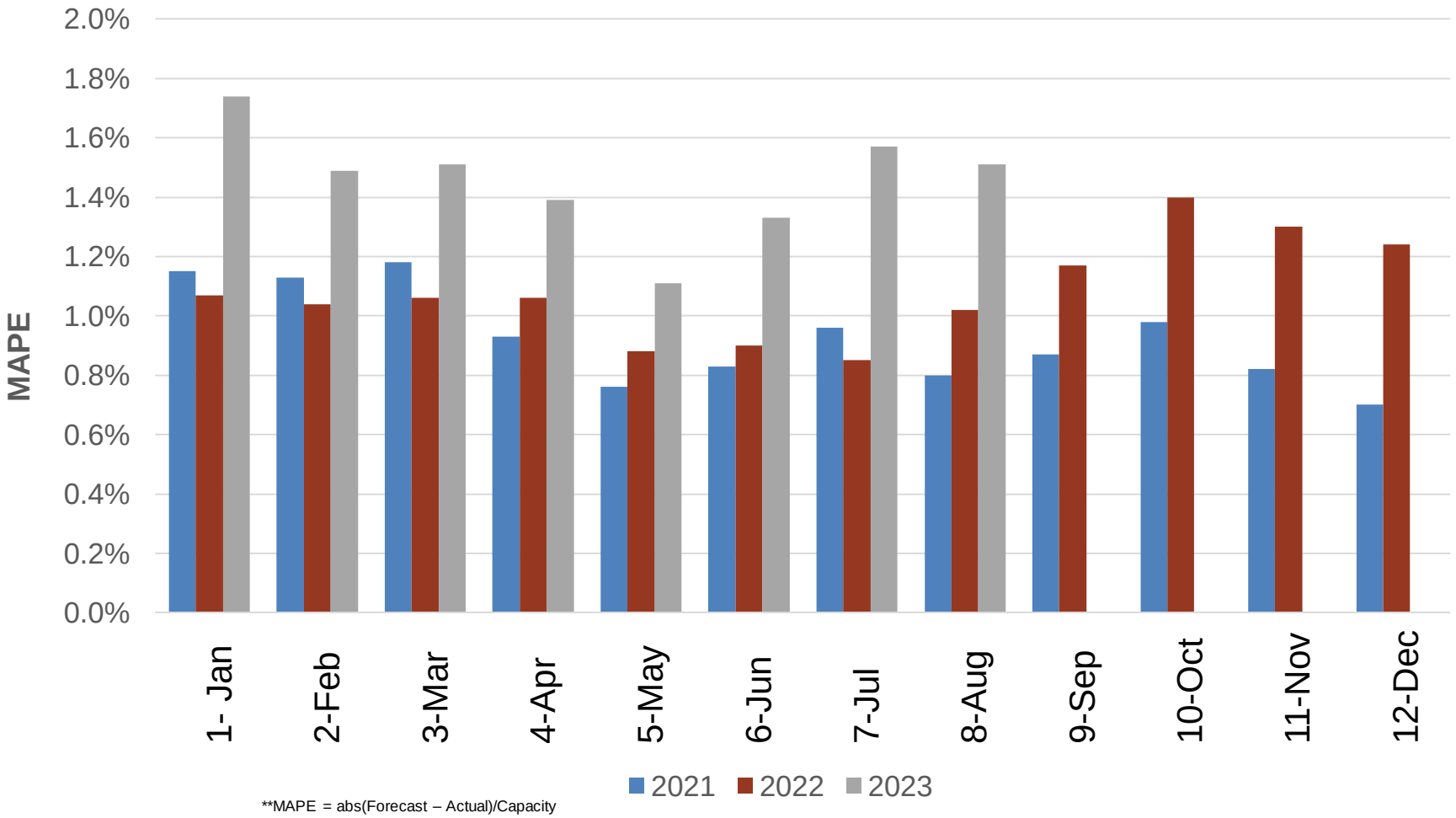
Forecast calculated in market, eliminating ALFS & processing time needed outside of CAISO

Real-time solar forecast accuracy



**2017 has been changed to track the RTD accuracy, i.e. the forecast made 7.5 minutes before the binding interval. The 2017 generation data used for accuracy calculation contains the economically dispatched MW.
**This forecast accuracy is pulled directly from the CAISO Forecasting System.
**MAPE = abs(Forecast – Actual)/Capacity

Latest: Real-time solar forecast accuracy



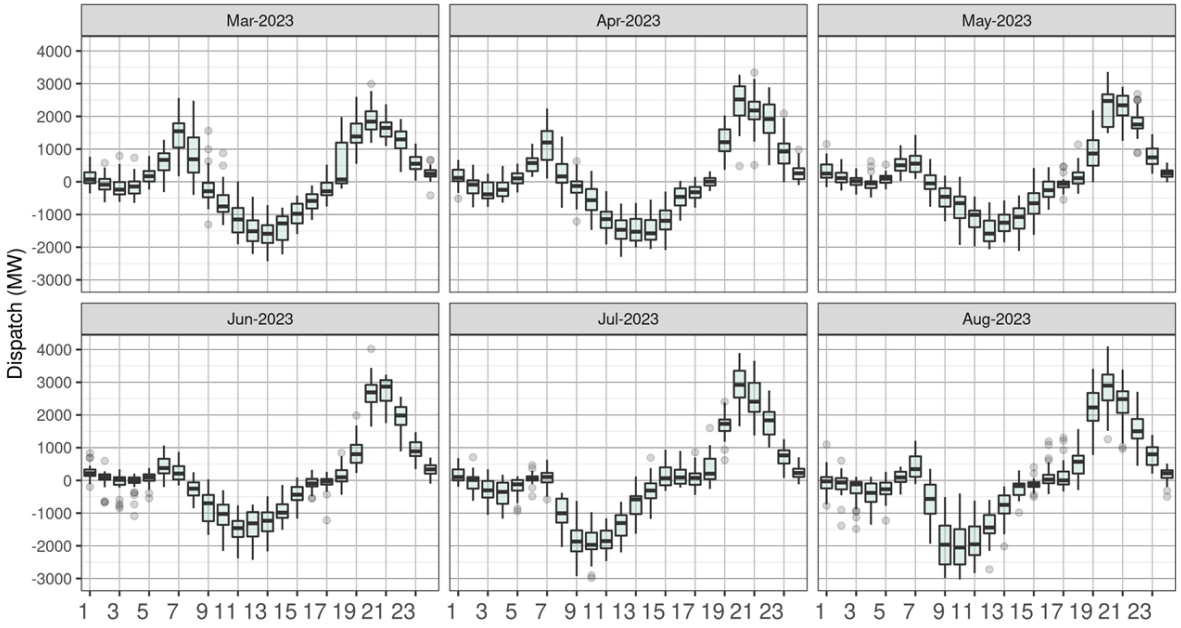
**MAPE = abs(Forecast – Actual)/Capacity

Hybrid and Co-Located

RENEWABLE RESOURCE EVOLUTION

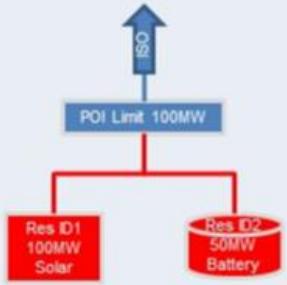
Storage

The energy storage industry is developing short- and long-duration storage options to serve both distribution and transmission systems.



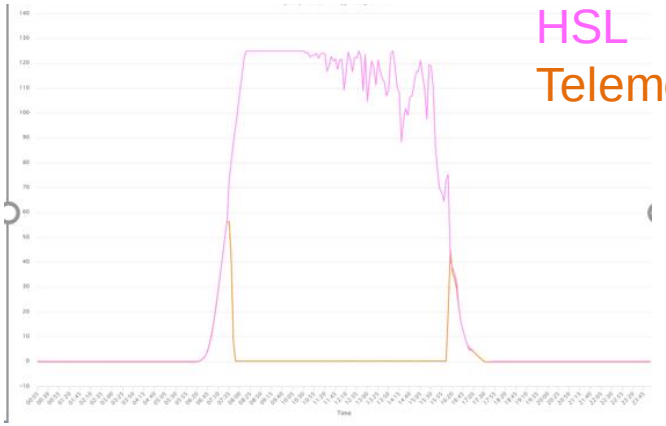
Rapid growth in storage technologies will require new forecasting techniques and market design to support market participation

- Hybrid Resource Initiative
  Phase 2C go-live 2023 & 2024
  - Phase 1 go-live was Dec 2020
  - Phase 2a go live was October 2021
  - Phase 2b go live was February 2023
- Expected to have 11,500 MW of renewable + storage by 2026
  - Based on Jan 2023 LSE survey
- CAISO provides wind and solar forecasting services:
  - Optional for hybrid renewables
  - Required for co-located

Hybrid vs. Co-located	Definition	Forecasting / Dispatch
Hybrid 	A Generating Unit, with a unique Resource ID at a single Point of Interconnection, with components that use different fuel sources or technologies.	• No aggregate forecast for hybrid • Hybrid expected to follow dispatch
Co-located 	A Generating Unit with a unique Resource ID that is part of a Generating Facility with other Generating	• VER component will be forecast • VER dispatched rules • Battery will dispatched and state of charge managed

New data request for hybrid and co-located resources to help with renewable forecasting: High Sustainable Limit (HSL)

- High Sustainable Limit (HSL):
  - Tariff definition: The instantaneous generating capability of a variable Generating Unit (or component thereof), provided to the CAISO through telemetry at the Generating Unit.
  - Calculated telemetered point provided to CAISO from the resource
  - The production of a renewable resource based on only the weather and resource properties
  - Essentially what the VER could produce without any market signals

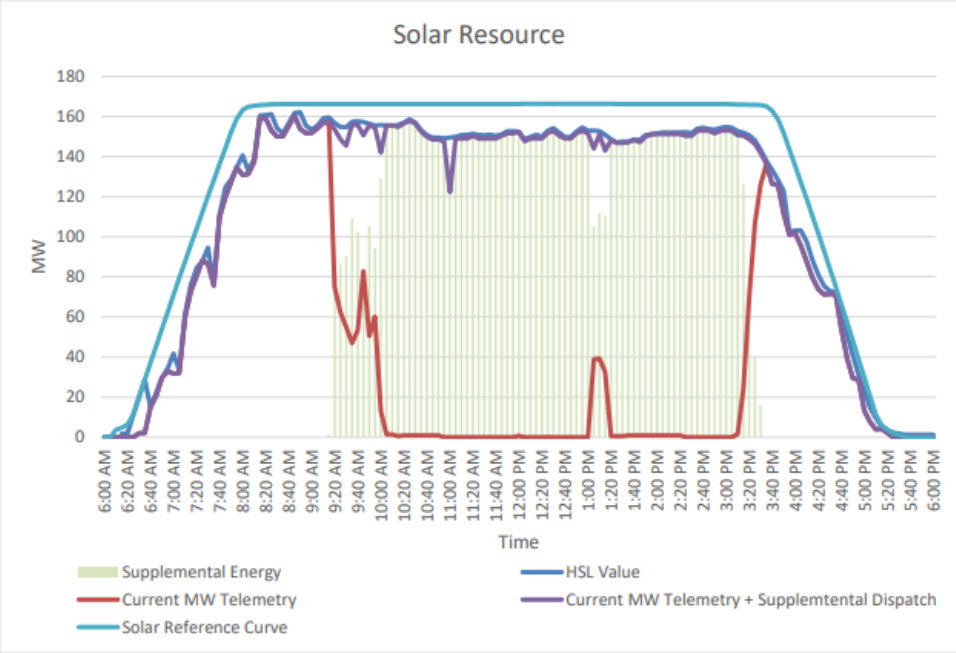


What is HSL used for?

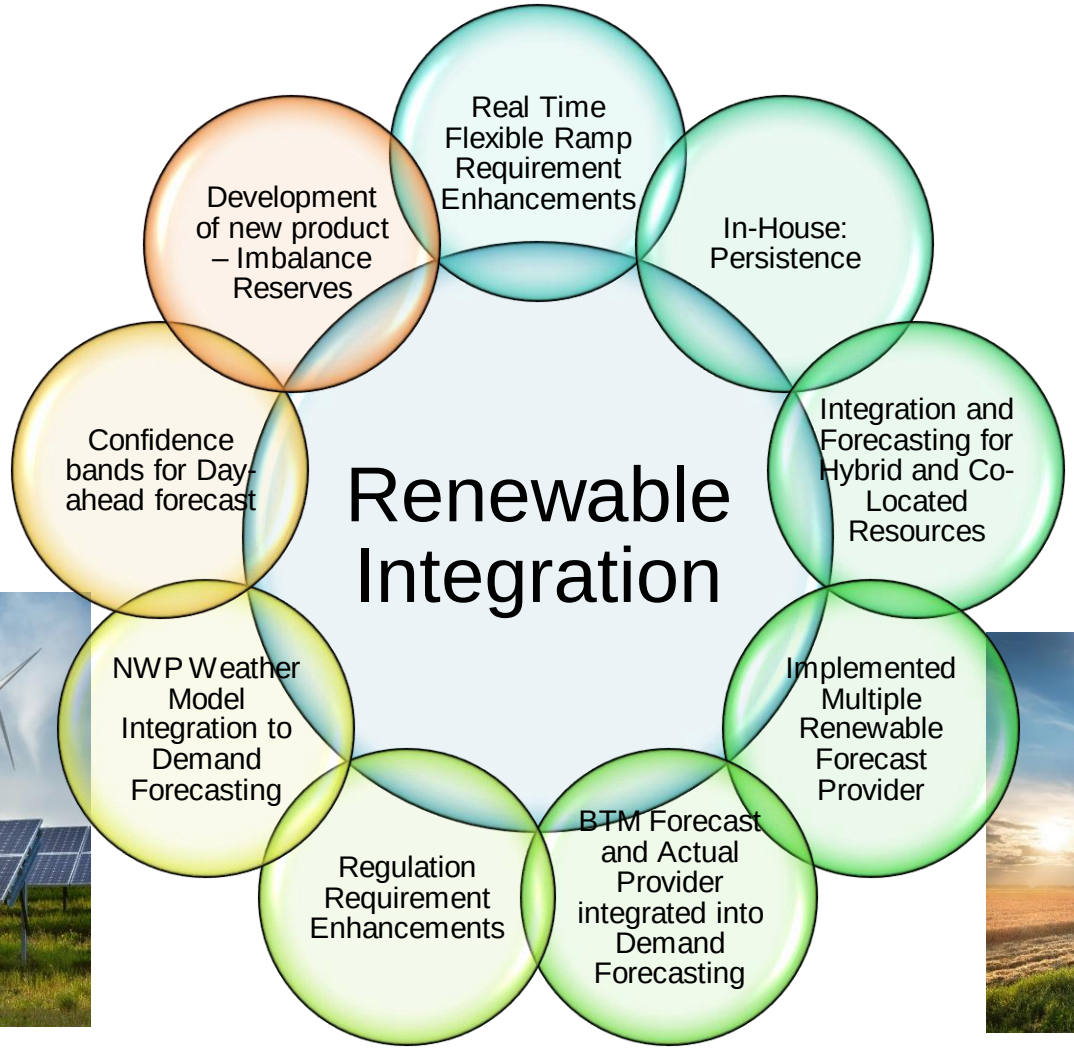
- Provided to the external forecast service providers (FSPs) to increase the number of good data intervals to train the forecast, especially during times of market dispatches impacting generation actuals.
- As data feed to persistence forecast
  - HSL persistence can remain on for all intervals as long as there is good HSL quality

Benefits of utilizing HSL in renewable forecast creation

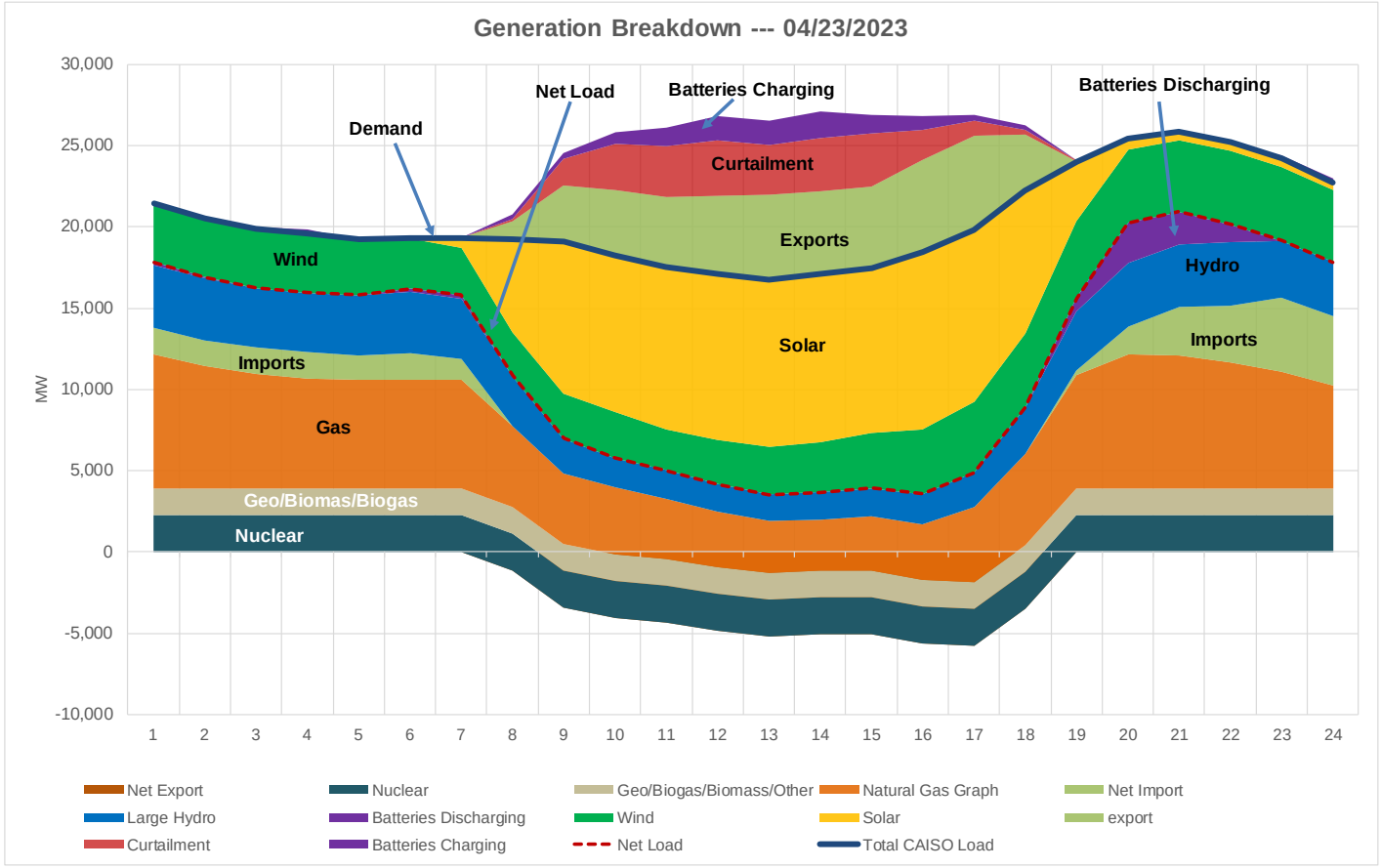
- HSL will not have market impacts in its telemetry – solely based off weather
  - No supplemental, ancillary services, operating instructions, etc.
- This will allow for a significant increase in the number of good telemetry periods for a resource to use in model training
  - Will still need some quality control on if the HSL telemetry is bad



CAISO Forecasting Advancements in Support of High Penetrations of Renewable Resources



Maximum load plus export served by non-carbon resources on Sunday, April 23, 2023 was 108%



Thank you!