ERCOT Wind and Solar Forecasting Developments – Status and Prospects

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Discussion Outline

- Overview of Renewable Forecast at ERCOT
- Updates on Recent Efforts Made to Improve Wind Forecast Performance and Usability
  - Extreme Weather Condition Forecast
  - Secondary Wind Forecast
  - Intra-hour Wind Forecast
- Ongoing and Thoughts on Future Direction for Further Improvements to Renewable Forecast

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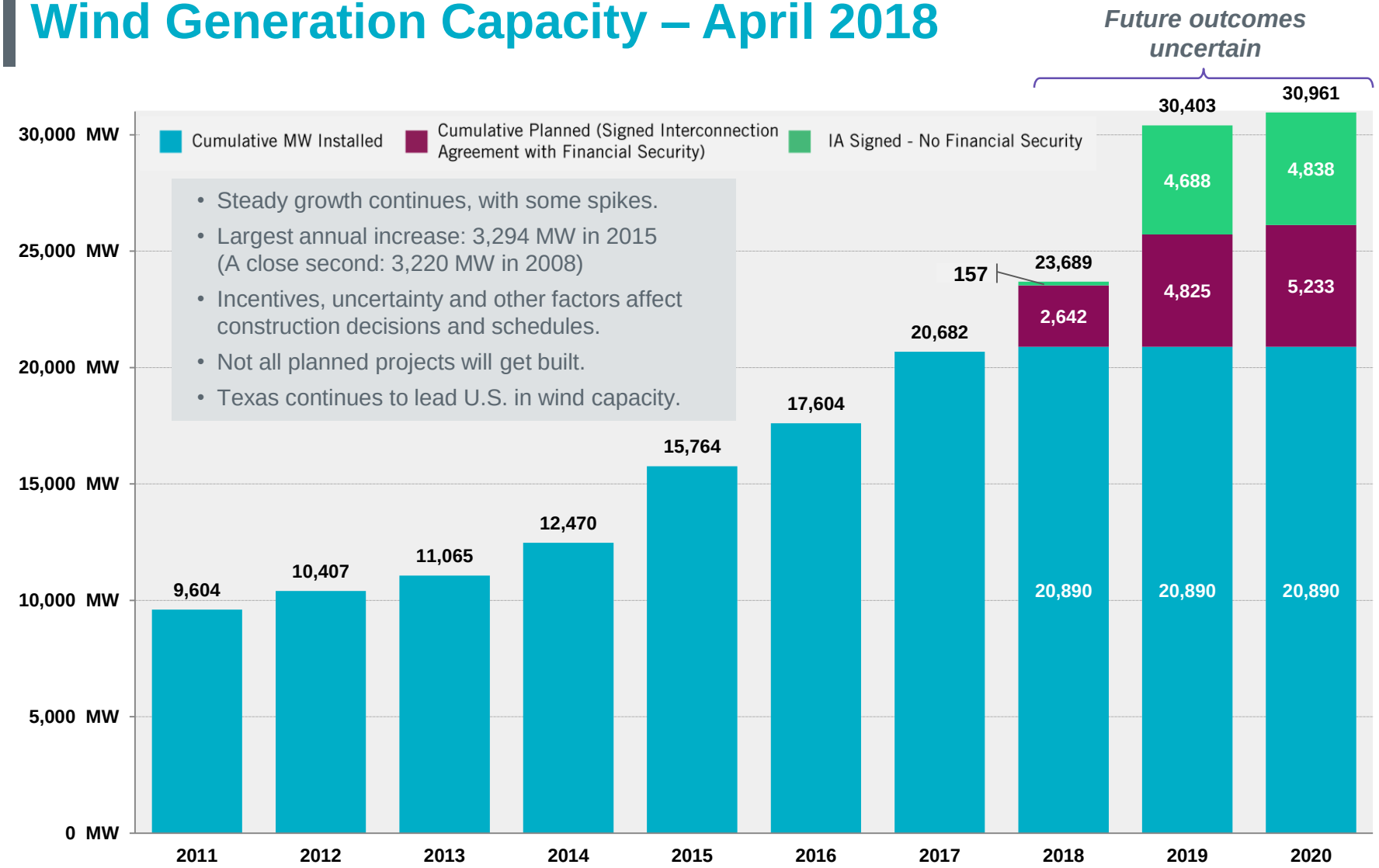
Overview of Renewable Forecast at ERCOT

Wind Generation Capacity – April 2018

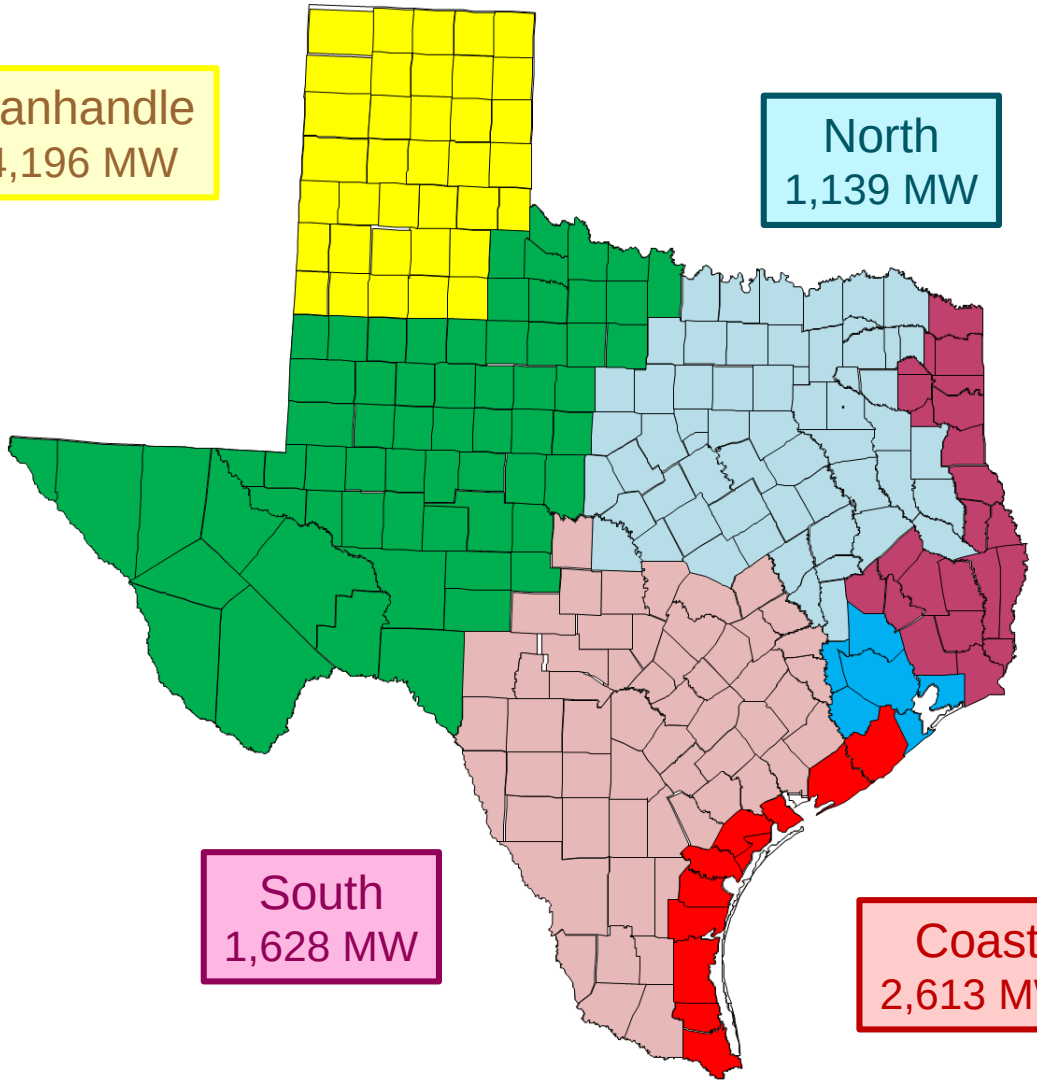


The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information is received. This chart reflects planned units in the calendar year of submission rather than installations by peak of year shown.

Financial security posted for funding interconnection facilities does not include CREZ security deposits, which are refunded to the Interconnecting Entity when an IA is signed.

As of April 30, 2018

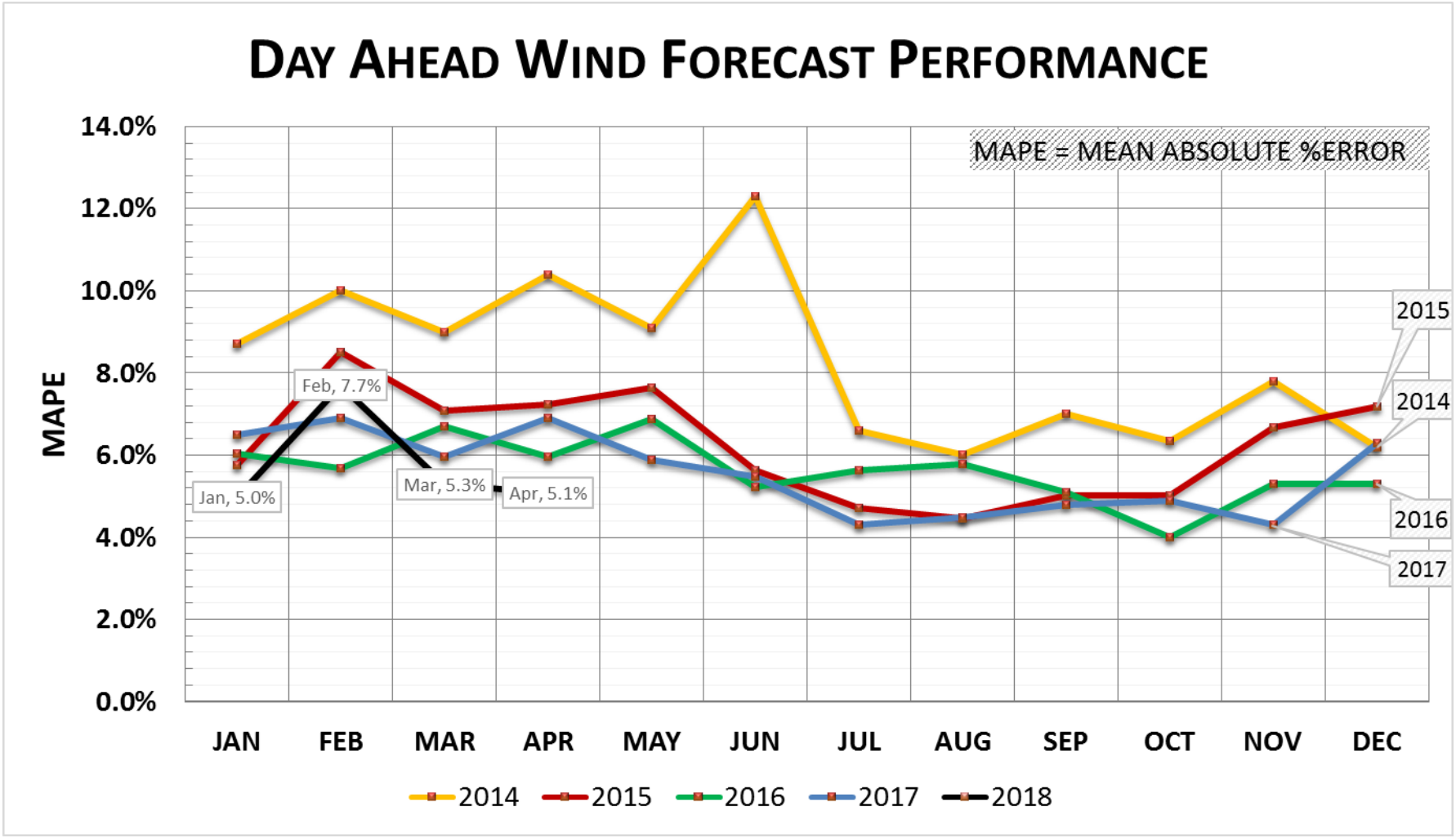
Wind Capacity By Region



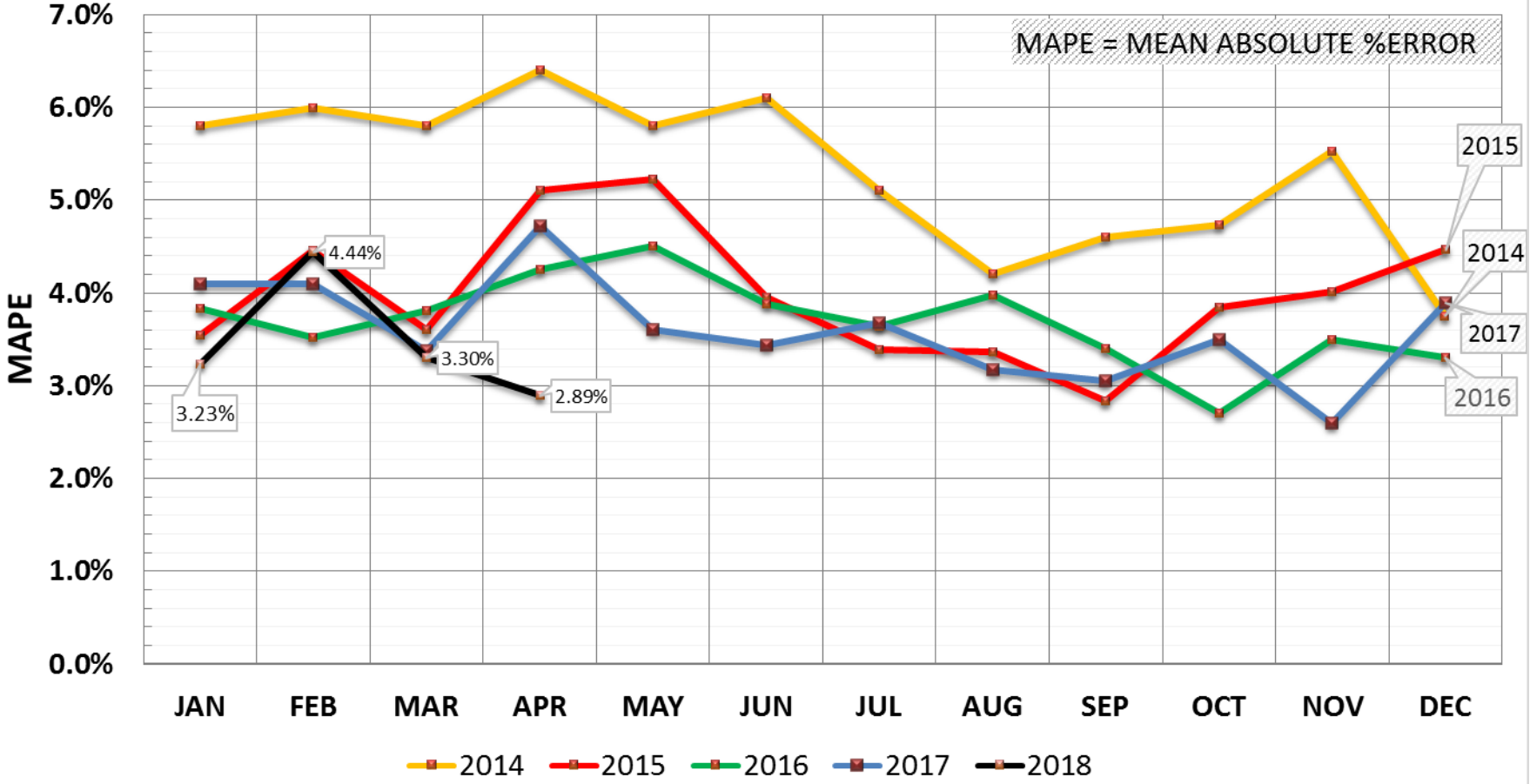
Wind Records

TIME	LOAD (MW)	WIND GENERATION (MW)	PENETRATION AT RECORD TIME
02/19/2018 22:05	37,435	**17,542**	46.86%
10/27/2017 04:00	28,418	15,408	**54.22** %

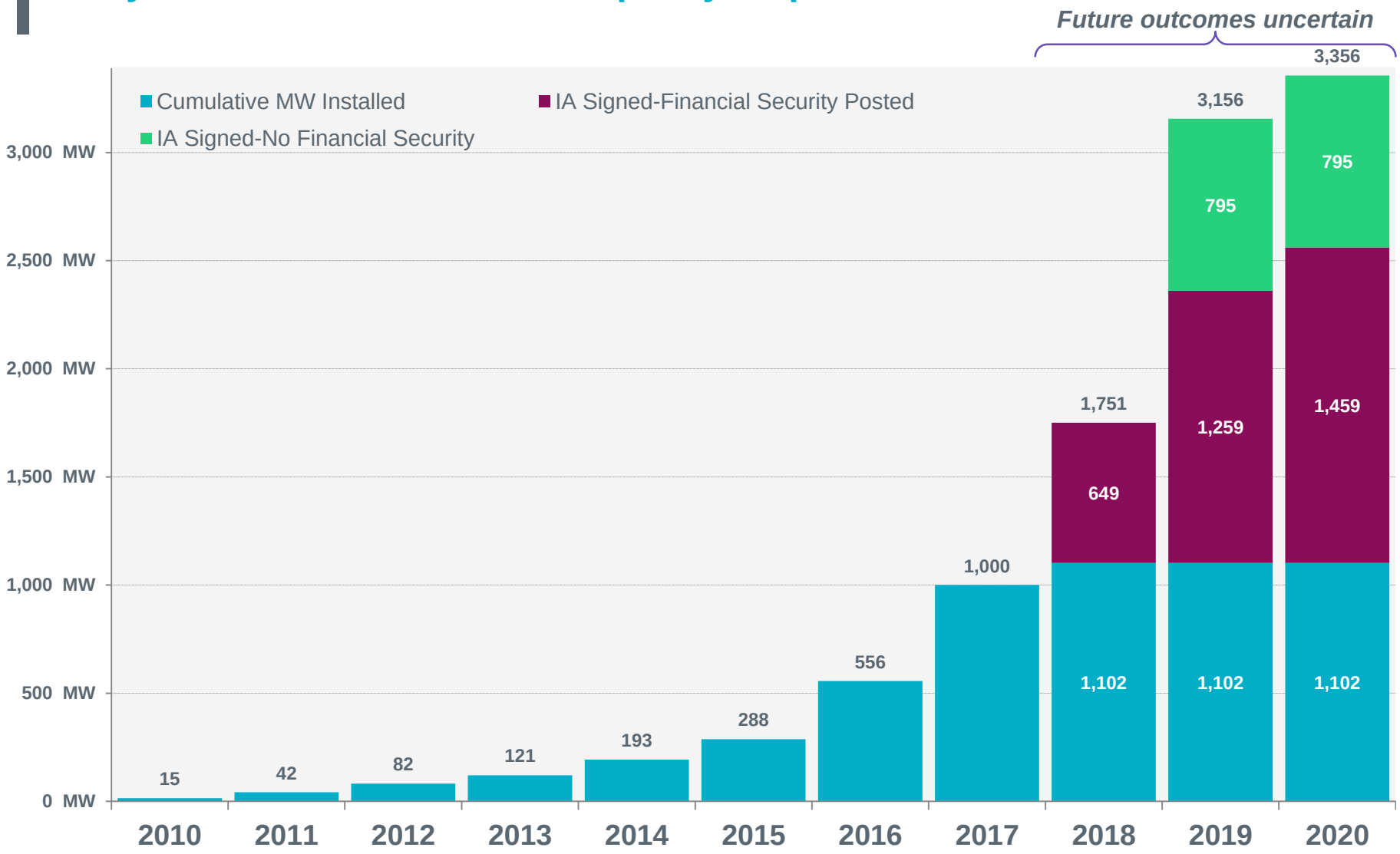
Day Ahead Wind Forecast Performance



Hour Ahead Wind Forecast Performance



Utility Scale Solar Generation Capacity – April 2018



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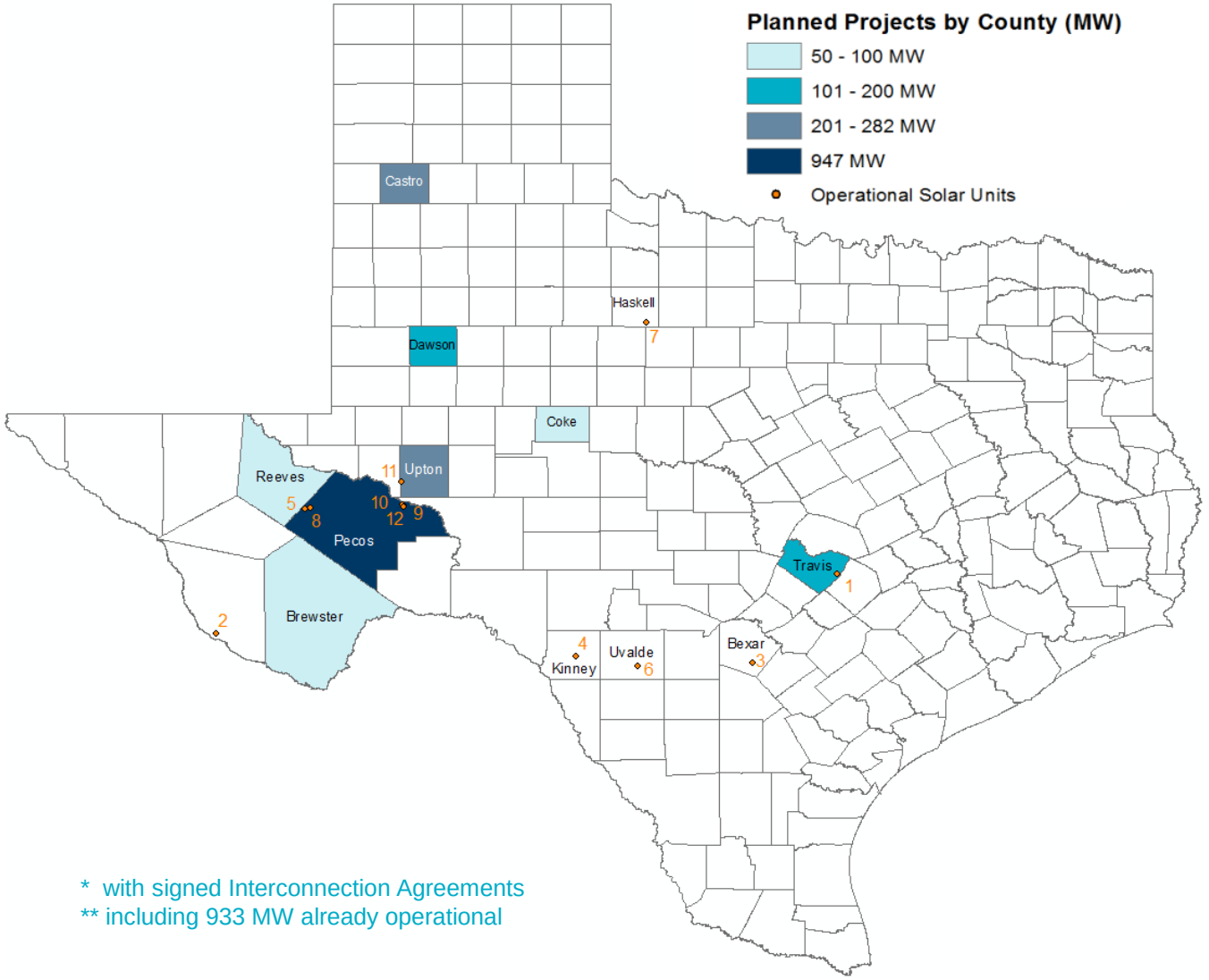
As of April 30, 2018

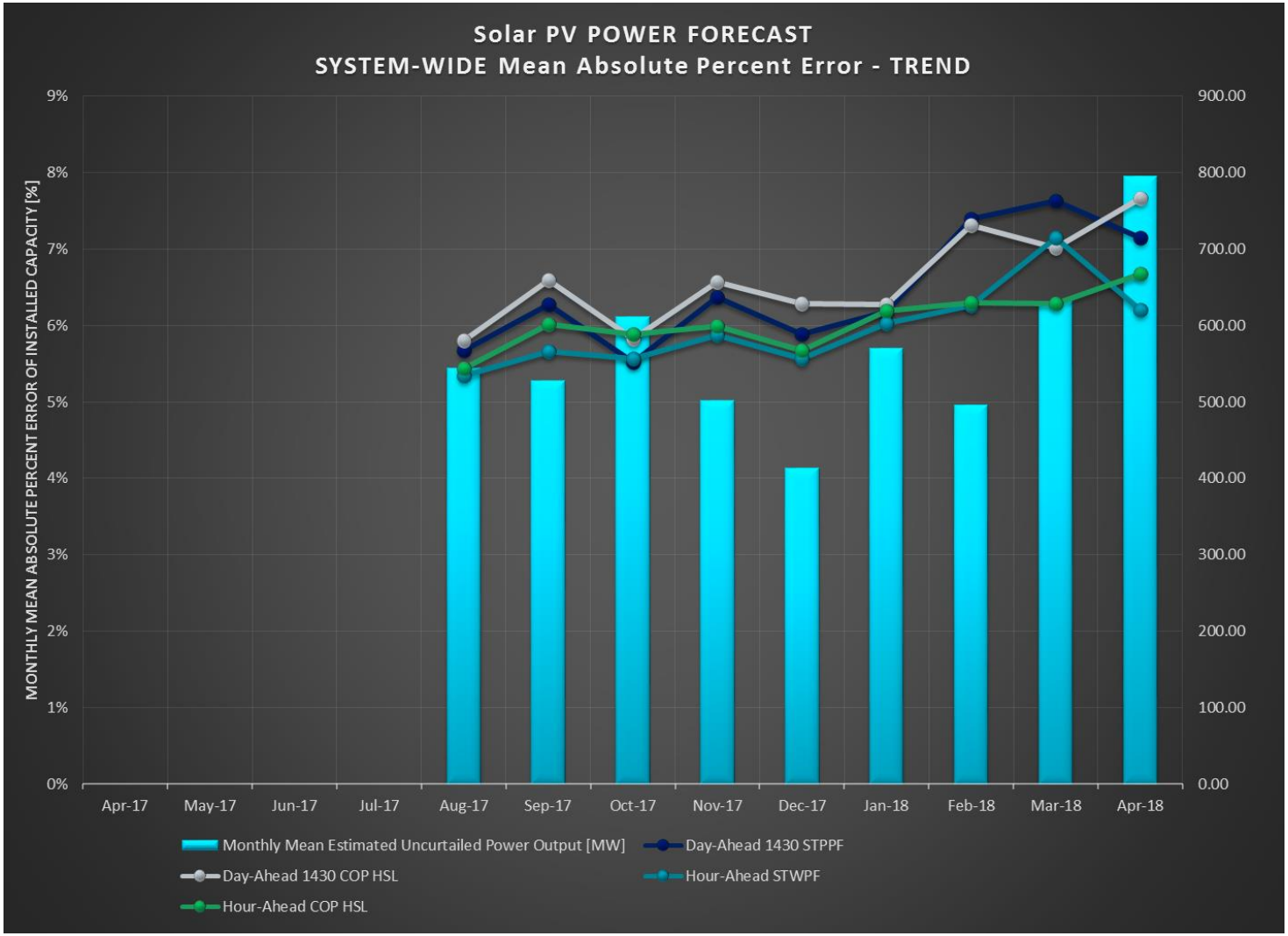
Operational and Planned Grid-Scale Solar Resources



* with signed Interconnection Agreements
** including 933 MW already operational

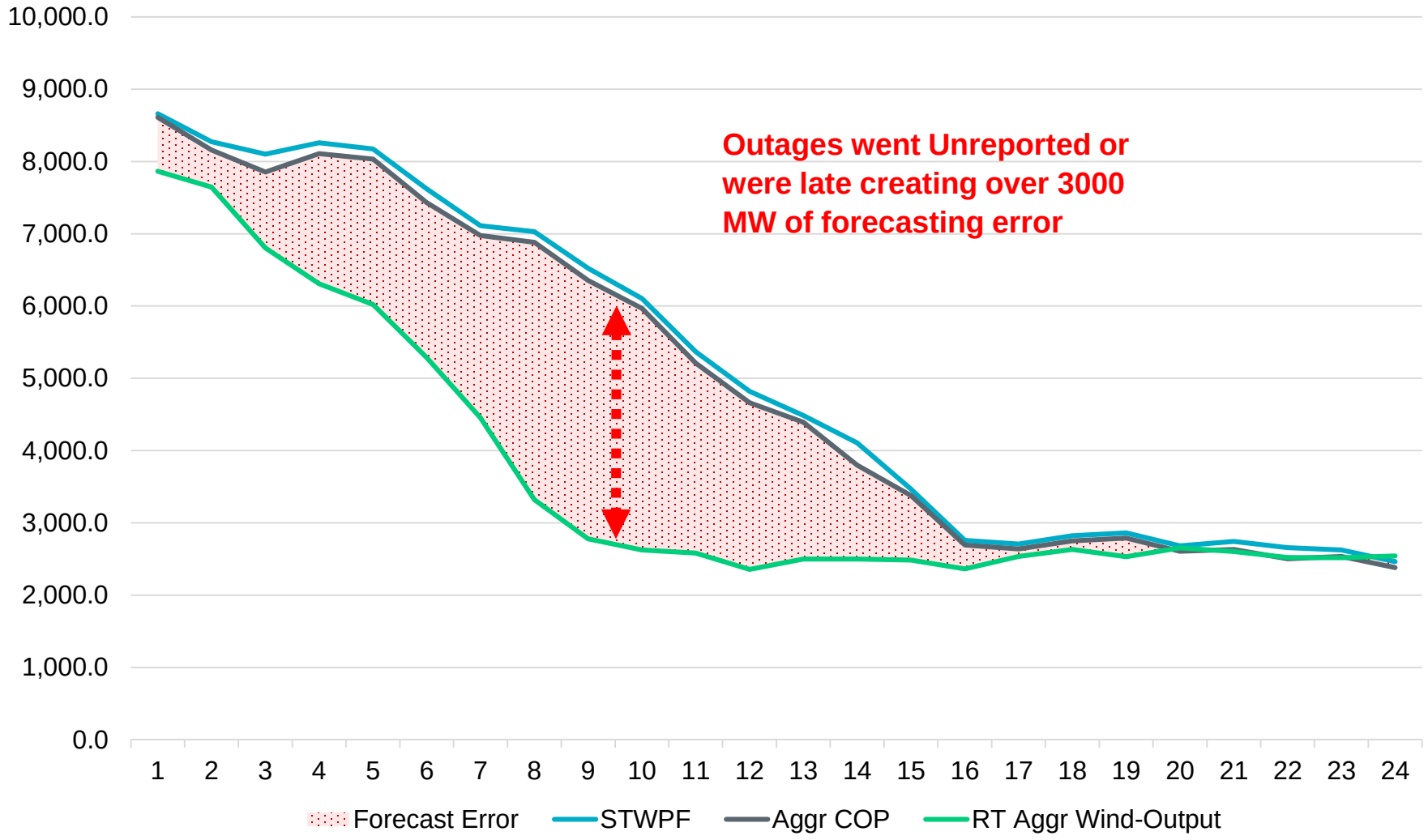
As of Nov 2017

PhotoVoltaic Generation Resource (PVGR) Forecast Performance



Extreme Weather Wind Forecast

Wind Turbine Icing and Forecasting Impact



Addressing the Wind Turbine Icing

- Use the following when a WGR is experiencing an icing related event,
  - Call the ERCOT Control Room and notify them.
    - Ensure the Plant has a Communication Plan to inform QSE & ERCOT of the event.
  - Continuously update the telemetry for number of turbines on and off (NTON and NTOFF) as conditions on the ground deteriorate.
  - If the outage/derate is expected to last greater than 2 hours, submit this into ERCOT's Outage Scheduler.
    - In comparison to turbine telemetry, Outage submissions have a greater impact in correcting the forecast.

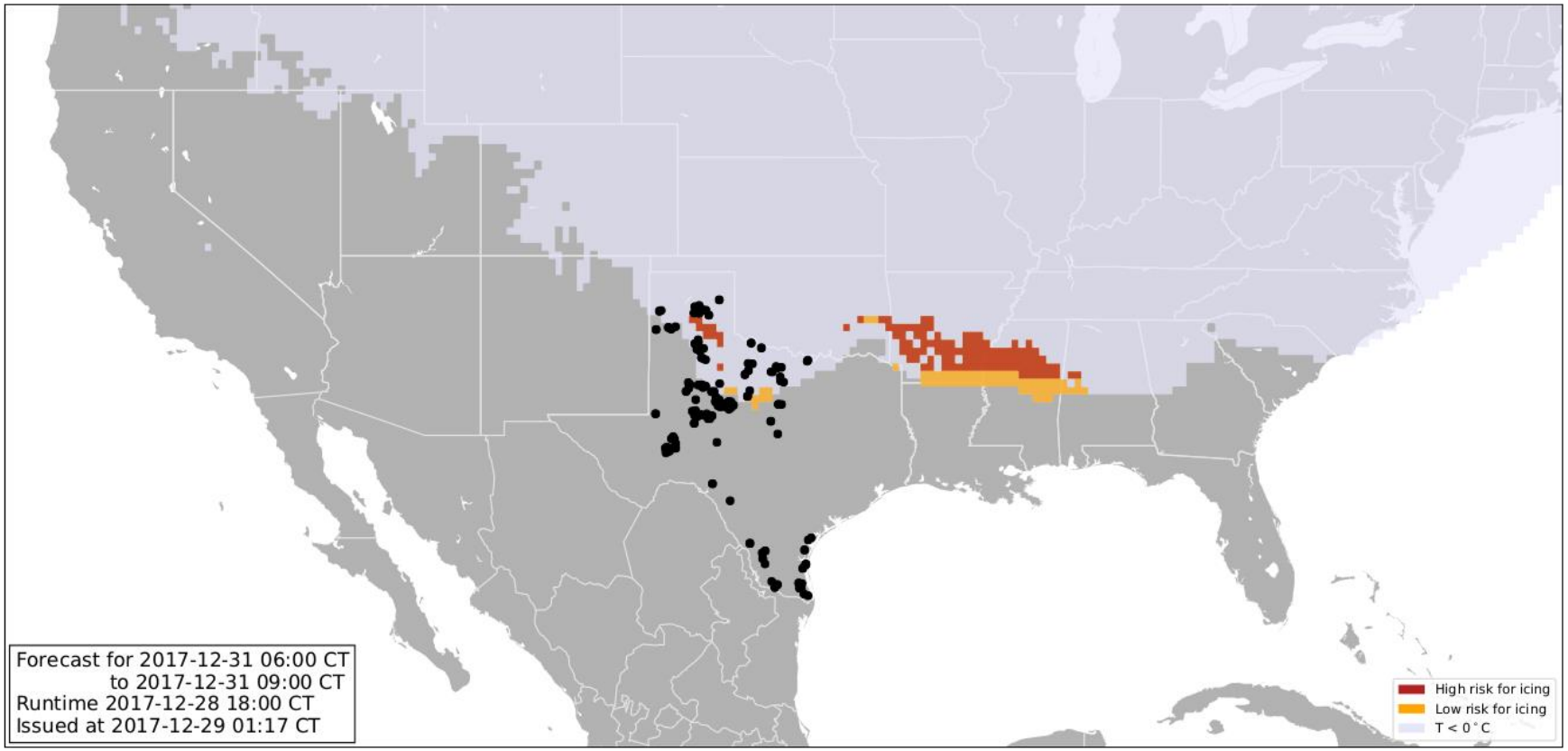
3.1.4.5 Notice of Forced Outage or Unavoidable Extension of Planned or Maintenance Outage Due to Unforeseen Events

(2) Any Forced Outage that occurs in Real-Time must be entered into the Outage Scheduler if it is to remain an Outage for longer than two hours.

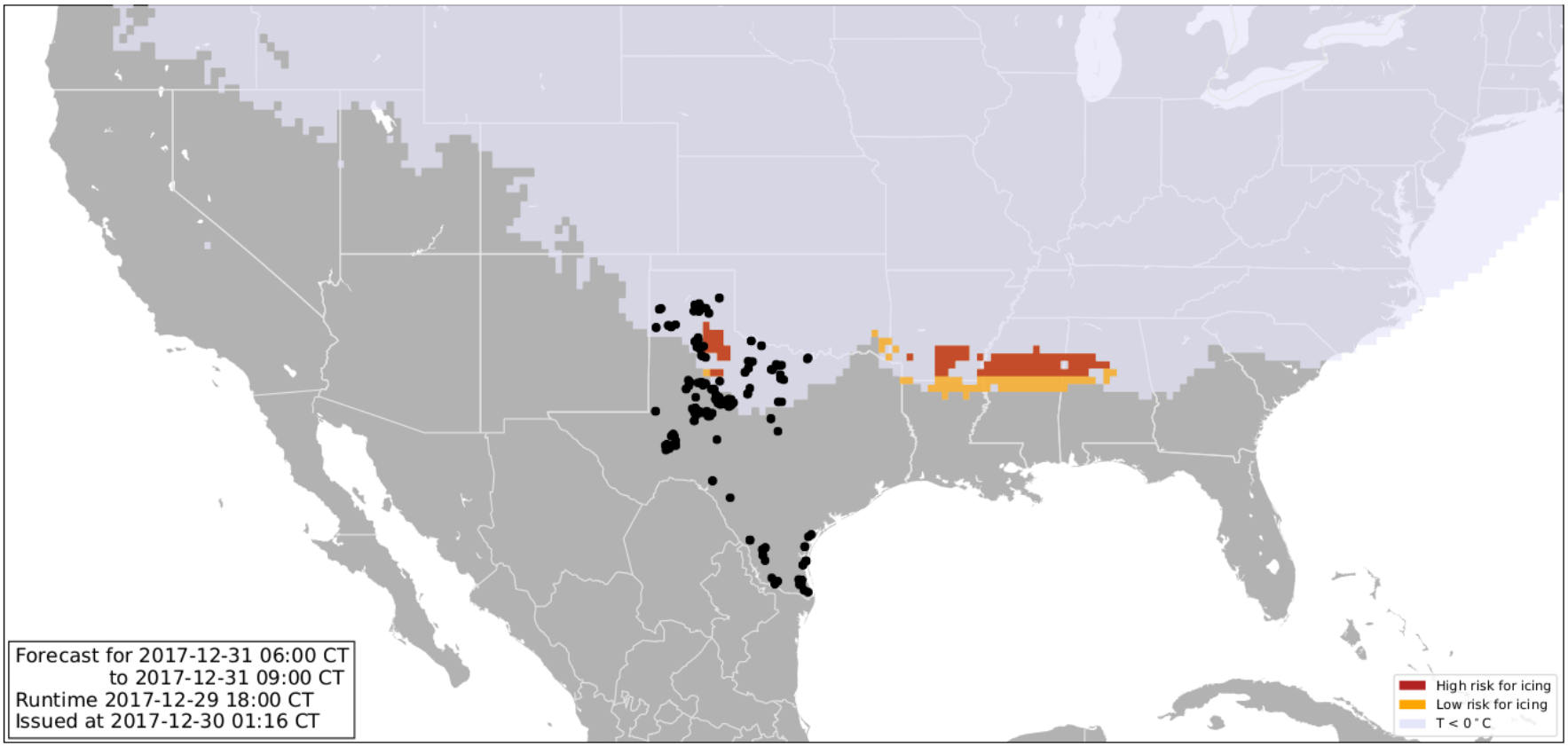
Dedicated Forecasting for Icing Conditions

- For the next 168 hours to predict the risk of incoming extreme weather events and the impact of extreme weather events over the wind generation potential for the aggregate ERCOT level, every Wind Region and each WGR.

Icing Report (2 days before)

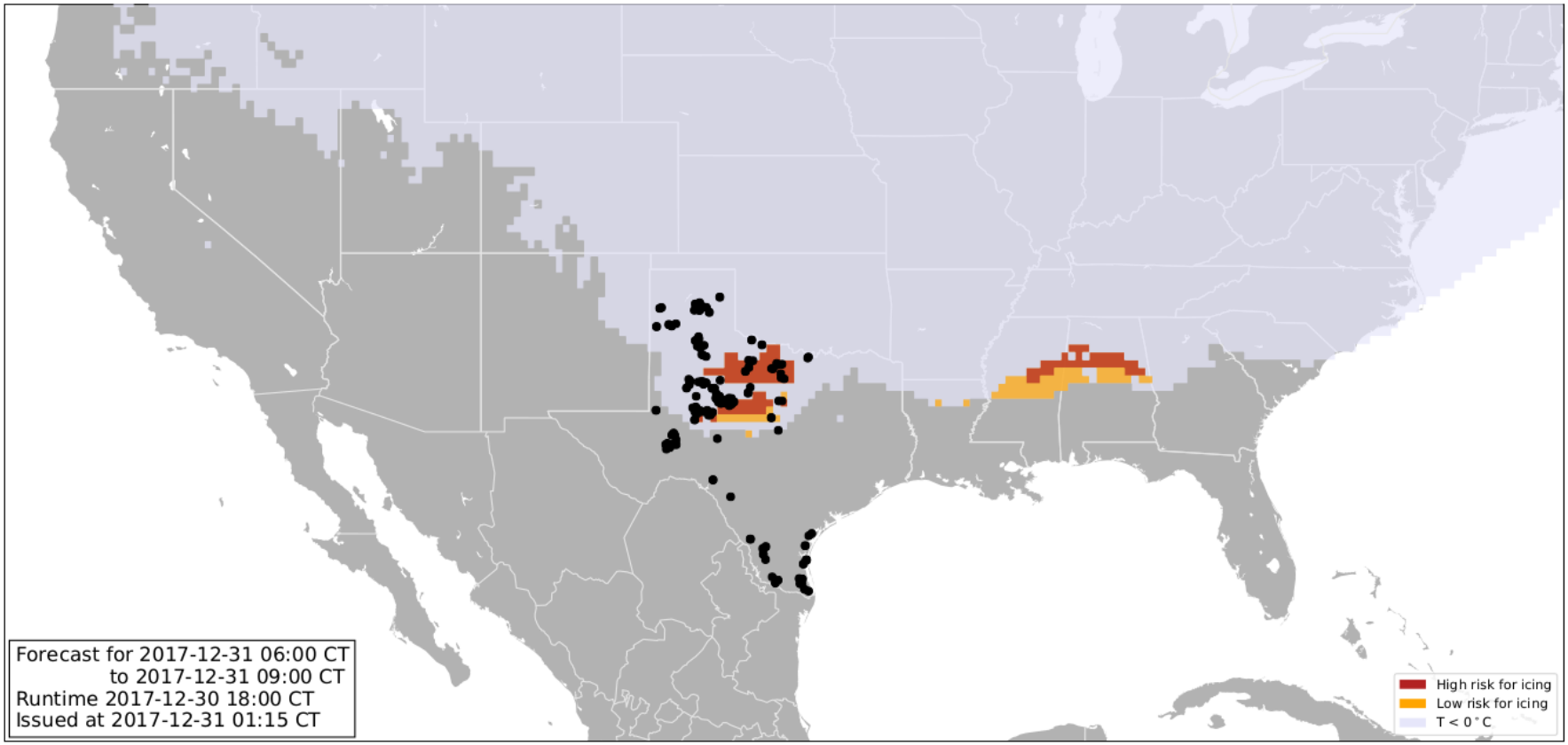


Icing Report (1 day before)



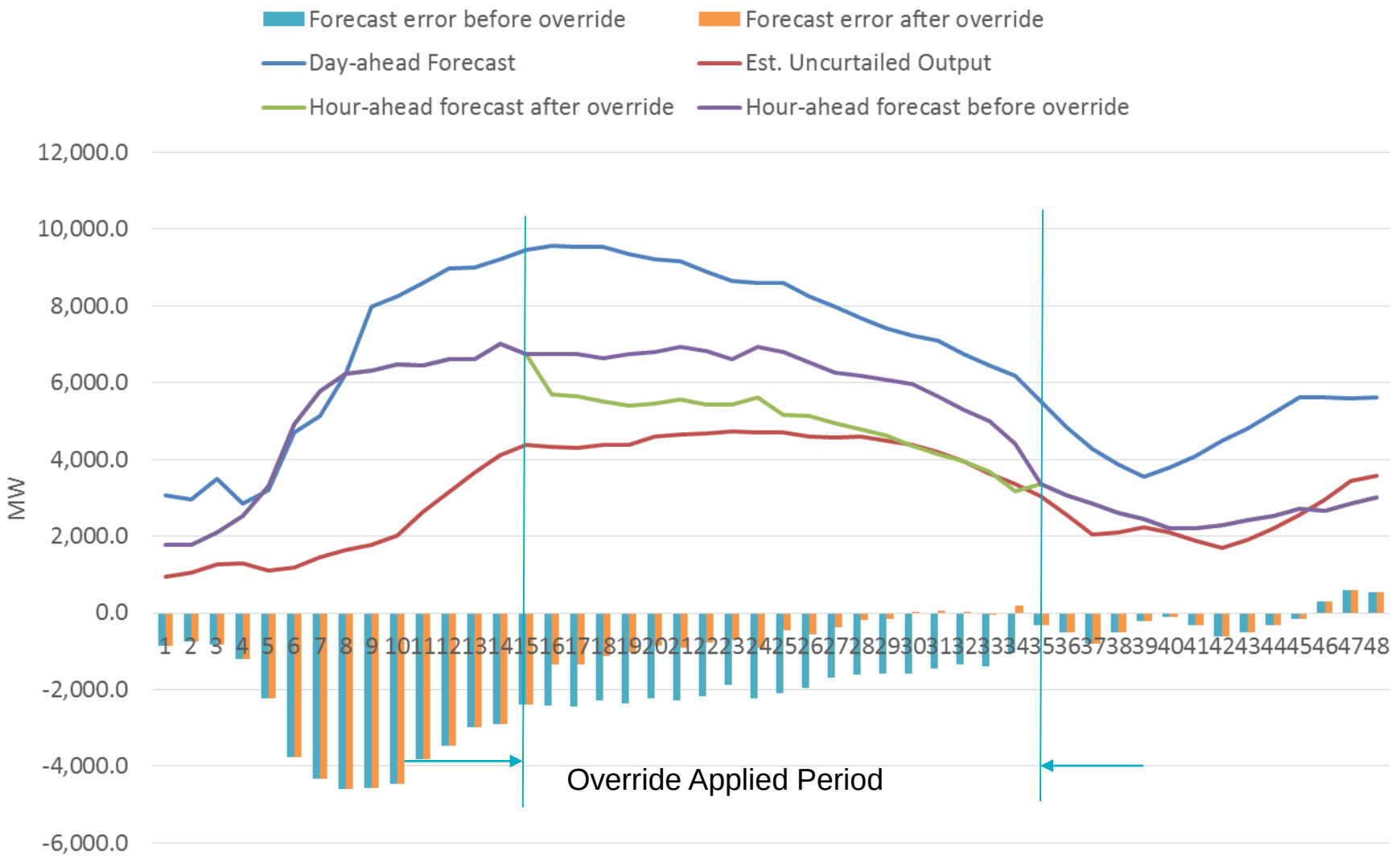
1 day before:
the icing conditions just changed a little in location but had a major impact in icing forecast for the single wind farms.

Icing Report (Same day)



here model changed in to forecast a larger area with icing conditions.

Override Capability to Provide More Flexibility

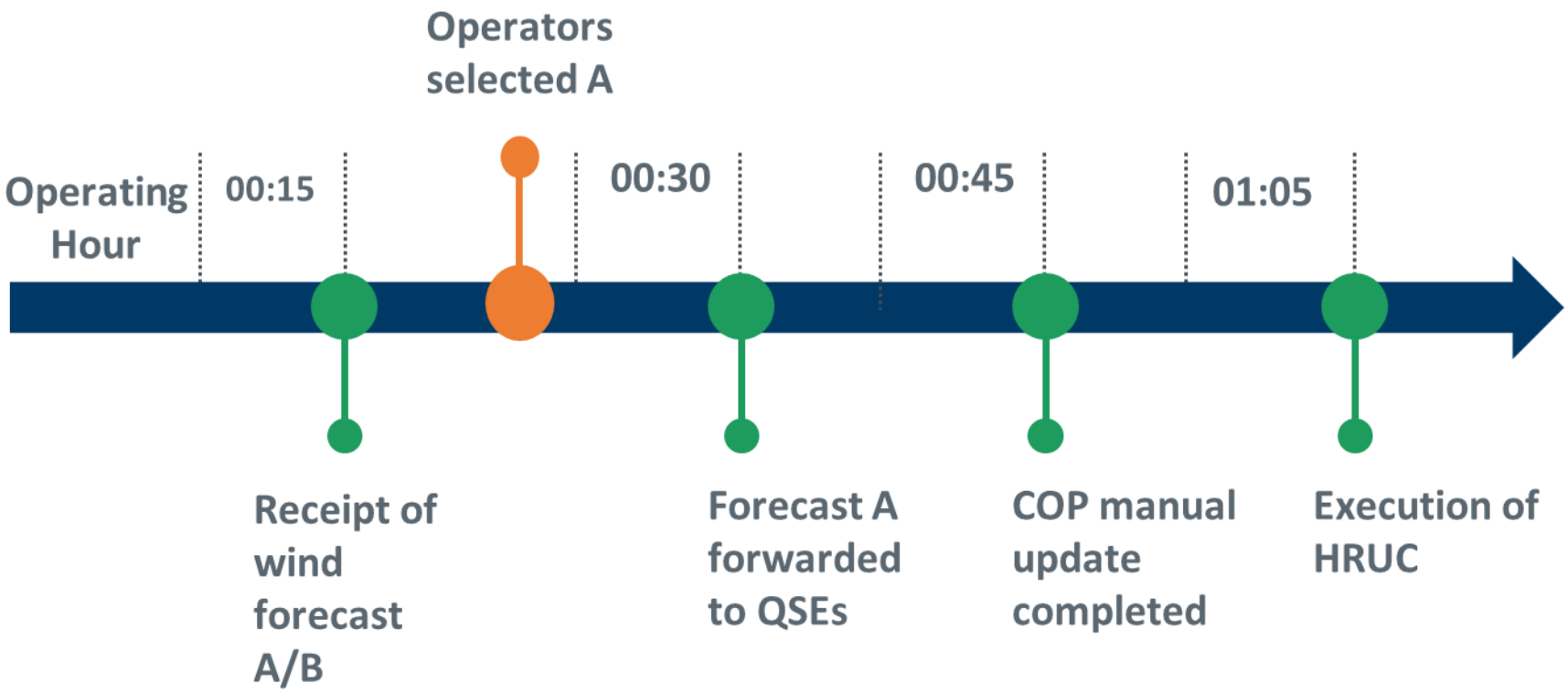


Secondary Wind Forecast Service

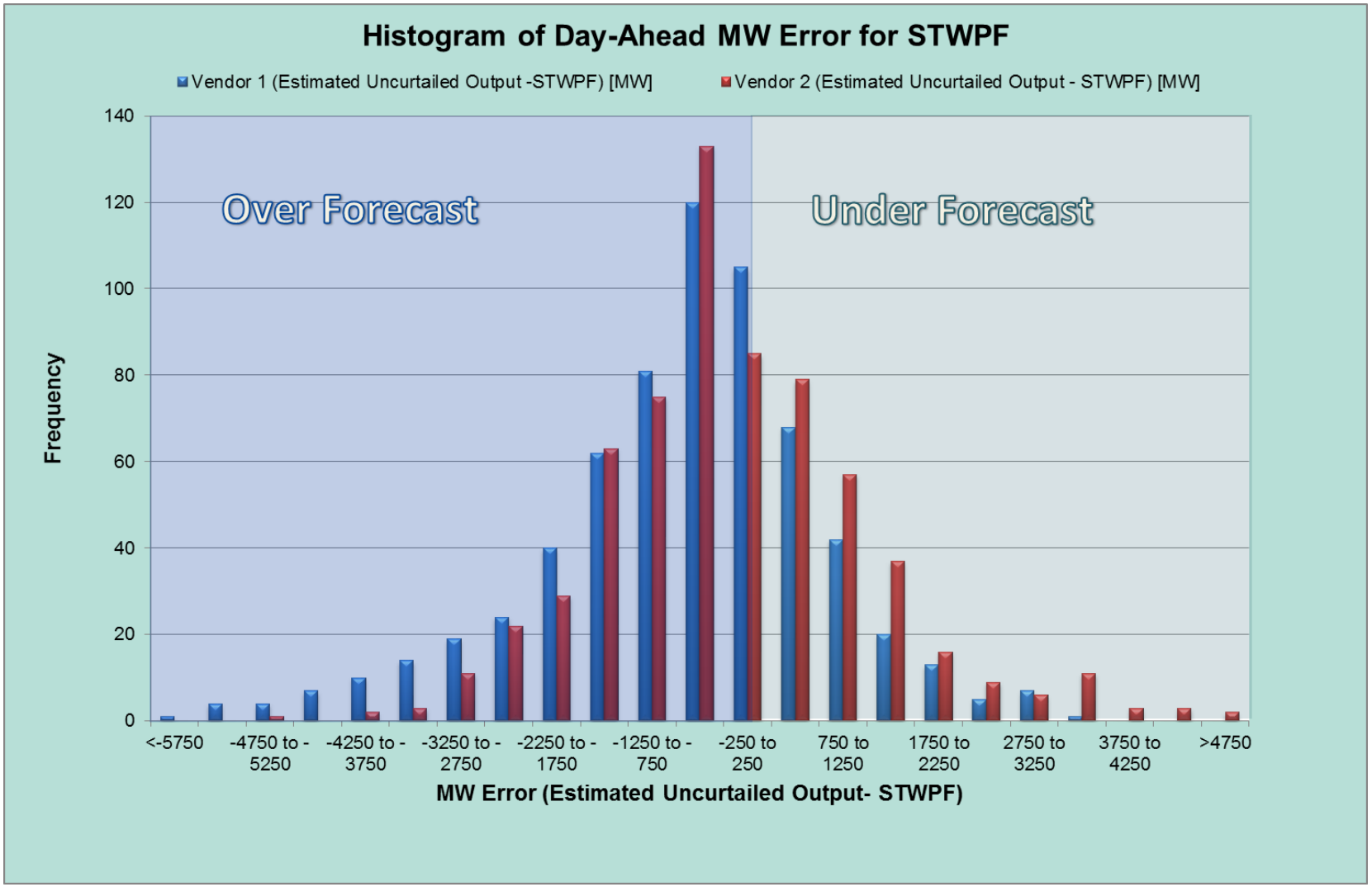
Secondary Wind Forecast

- Integrate the additional Wind Forecast into ERCOT's EMS and provide ERCOT the ability to "select" which Wind Forecast will be actively used in the Current Operating Plans (COPs) and in all look ahead studies.
  - Short Term Wind Power Forecast
  - Extreme Weather Conditions Forecast
  - Intra-hour Wind Forecast

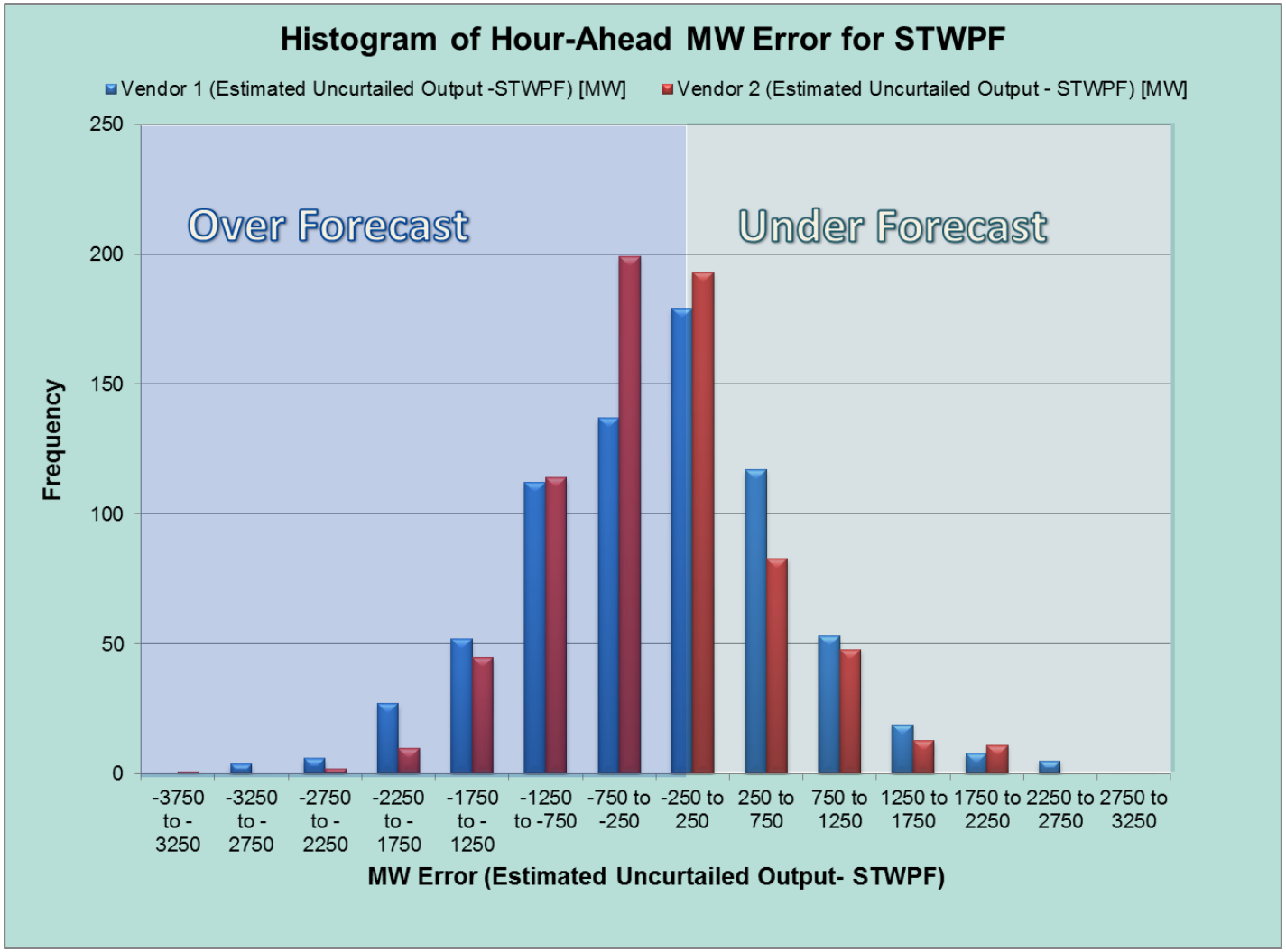
Forecast Selection Process



Histogram of Day-Ahead MW Error for STWPF (April 2018)



Histogram of Hour-Ahead MW Error for STWPF (April 2018)



Mixed Day-ahead Regional Wind Forecast

West+North	Panhandle	South+Coastal	Forecast Error (MAE)
Vendor 2	Vendor 2	Vendor 2	1073 MW
Vendor 1	Vendor 2	*Vendor 1*	934 MW (12.95% reduction in errors)
Vendor 2	*Vendor 1*	*Vendor 1*	1021 MW (4.85% reduction in errors)
Vendor 2	*Vendor 1*	Vendor 2	1016 MW (5.31% reduction in errors)

Mixed Hour-ahead Regional Wind Forecast

West+North	Panhandle	South+Coastal	Forecast Error (MAE)
Vendor 2	Vendor 2	Vendor 2	809 MW
Vendor 1	Vendor 2	*Vendor 1*	781 MW (3.46% reduction in errors)
Vendor 2	*Vendor 1*	*Vendor 1*	768 MW (5.07% reduction in errors)
Vendor 2	*Vendor 1*	Vendor 2	776 MW (4.08% reduction in errors)

5-min Intra-hour Wind Forecast

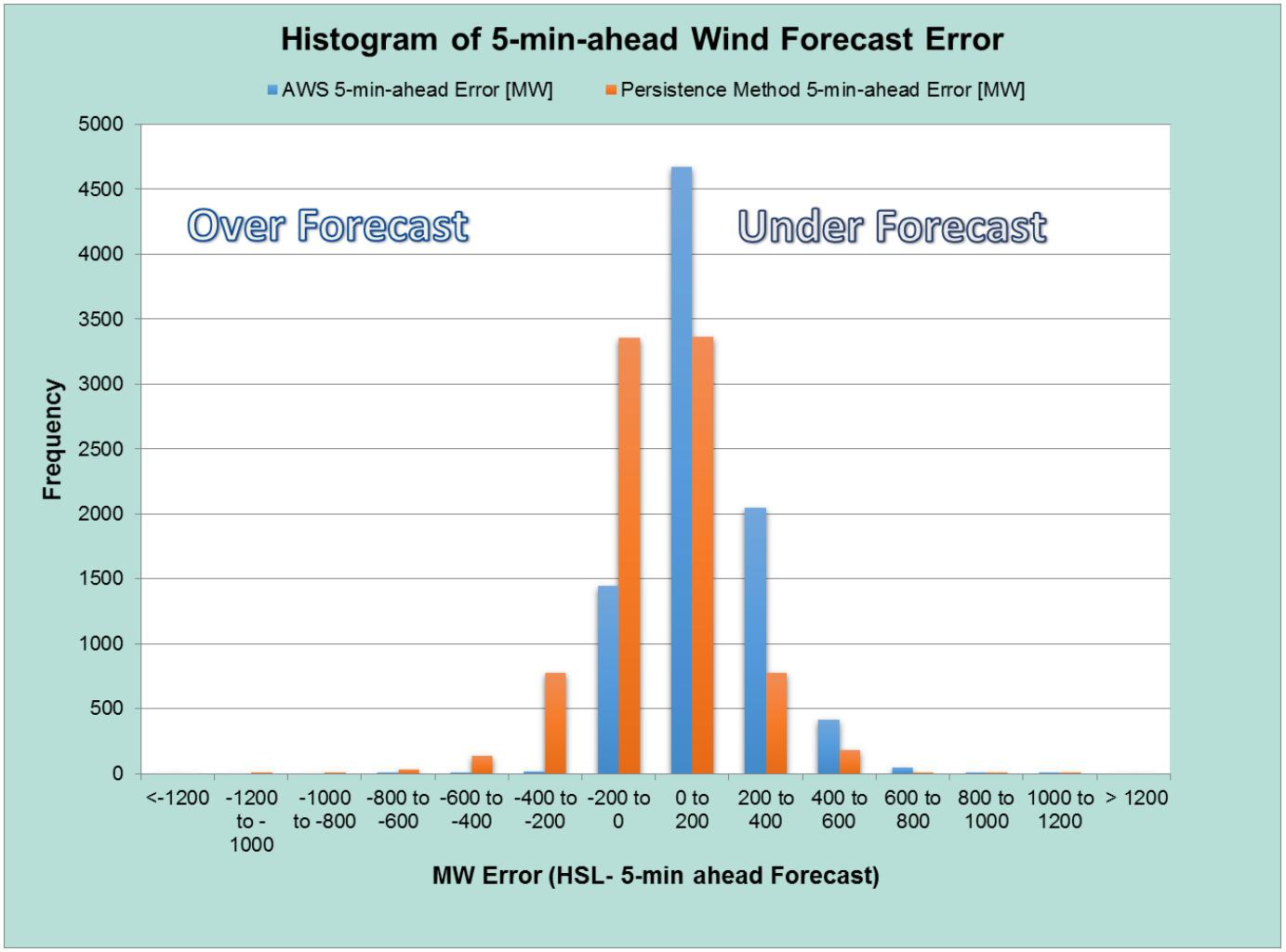
Integration of Intra-hour Wind Forecast

- Integrate into Generation To Be Dispatched (GTBD) calculation
  - The next 5-min Forecast can be integrated into GTBD to ensure SCED dispatch will preposition non-Wind units to offset the expected change in wind generation in the next 5-min

Generation To Be Dispatched = Total Gen + K1*10*System Load Frequency Bias + K2*[(net non-conforming Load) – (net filtered non-conforming Load)] + K3*5*PLDRR + K4*Regulation Deployed + K5*ACE Integral + K6*PWDRR

*The predicted wind ramp (PWDRR) is calculated from the intra-hour wind forecast separately in 1 minute granularity. This number will then be multiplied by 5 to capture the projected 5 minute wind ramp for the purpose of 5 minute SCED dispatch.

5-min-ahead Intra-hour Wind Forecast Performance



Pay for Performance

Goals

- Looking beyond just the average (MAPE)

- Increased focus on MW error
  - Keeping MW error at a reasonable level as capacity grows

- Improved vendor feedback on what matters via metrics
  - Minimize large and/or sustained errors
  - More focus on ramping, particularly down ramps
  - More focus on High Risk Periods

Proposed Method

"MUST MEET" Requirements

- Day Ahead MAPE < 10%
- Hour Ahead MAPE < 7%

- Highest DA MAPE in last 3 years is 8.5%
- Highest HA MAPE in last 3 years in 5.5%

Failure to Meet these metrics results in no "performance" payment.

"MUST MEET" 5 minute accuracy

- 15 min Ahead 60% of intervals better than persistence
- 30 min Ahead 75% of intervals better than persistence
- 60 min Ahead 85% of intervals better than persistence

Performance Metric #1 MAPE (15%)

- Day Ahead MAPE < 6%
- Hour Ahead MAPE < 3.9%

- 60% of DA MAPE scores since 2015 are less than 6% (which was the average MAPE)
- 60% of HA MAPE scores since 2015 are less than 3.9% (average MAPE was 3.85%)

Performance Metric #2 MW ERROR (35%)

- Day Ahead Avg. MW < 1100
- Hour Ahead MAPE < 700

- Median Avg. DA MW Error since 2015 was 1002. Median for 2017 was 1201.
- Median Avg. HA MW Error since 2015 was 657. Median for 2017 was 743.

Performance Metric #3 Scoring Metric (35%)

- Score < 500 or 500 less than monthly avg. (previous 2 years) – Immediate Loss
- Score > 500 and not 250 less than monthly avg. (previous 2 years) – Half of 35%
- Score > 1000 or 250 more than monthly avg. (previous 2 years) – All of 35%

- 2017 - Median: 757, Min: -285, Max: 1187
- 2016 - Median: 1369, Min: 645, Max: 2187
- 2015 - Median: 1136, Min: -202, Max: 2311

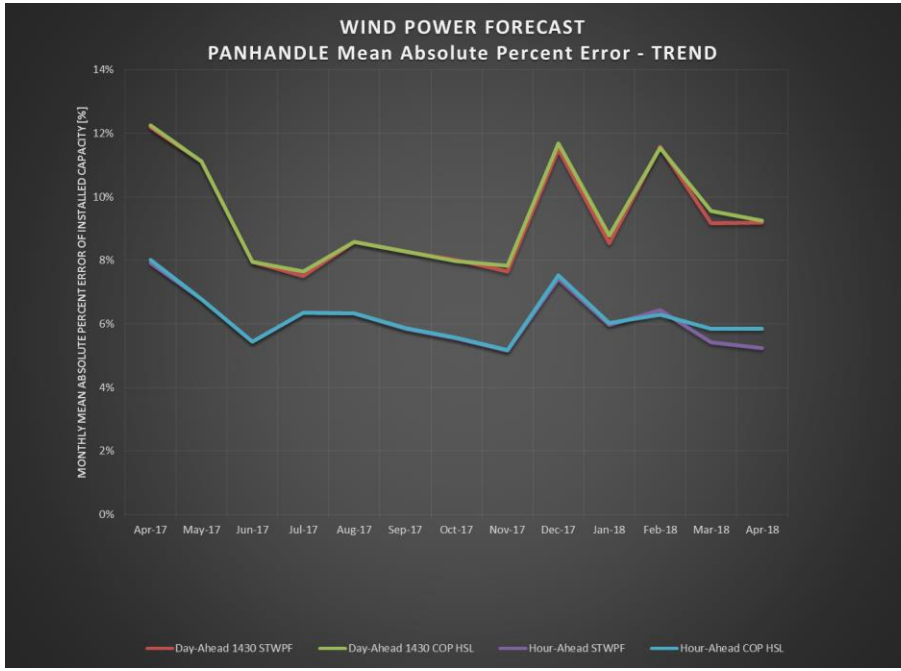
Performance Metric #4 5 minute accuracy (15%)

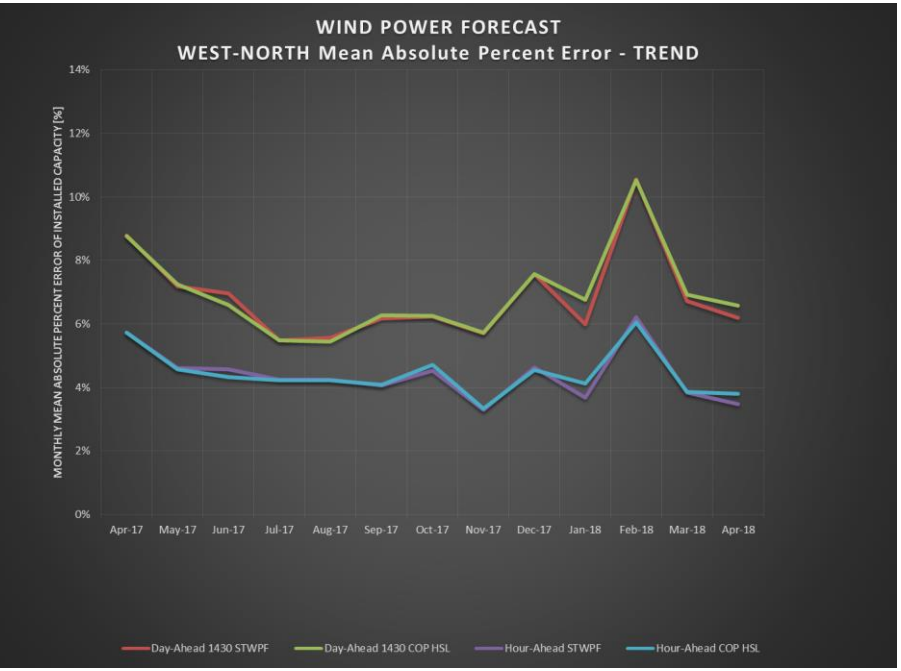
- 5 minute forecast monthly MAE is better than Persistence.
- 5 minute forecast better than persistence for 75% of intervals.

For Metric #3, might need to consider scores versus past month's performance rather than a specific number.

Ongoing Efforts And Thoughts On Future Direction

Panhandle Region Wind Forecast





Solar Uncertainty Management and Mitigation for Exceptional Reliability in Grid Operations (SUMMER-GO)

Technology Summary: The SUMMER-GO Team will design novel algorithms to create probabilistic solar power forecasts and automate their integration into power system operations. Adaptive reserves will dynamically adjust reserve levels conditional on meteorological and power system states. Risk-parity dispatch produces optimal dispatch strategies under uncertainty by cost-weighting solar generation scenarios.

Technology Outcomes: Adaptive reserves and risk-parity dispatch will reduce system operating costs while increasing system reliability. A situational awareness tool will help system operators understand the uncertainty in the solar power forecasts, and the impacts on operations.

Project Objectives and Approach: This project will bring probabilistic solar forecasts into ERCOT's real-time operation environment through automated reserve and dispatch tools that increase economic efficiency and improve system reliability. The adaptive reserves aim to reduce overall reserve levels by 25% while maintaining or improving system reliability. The risk-parity dispatch will automate the use of probabilistic forecast information in a 5-minute dispatch window. The situational awareness tool will present forecast uncertainty information that is relevant, timely, and allows for better decision making.

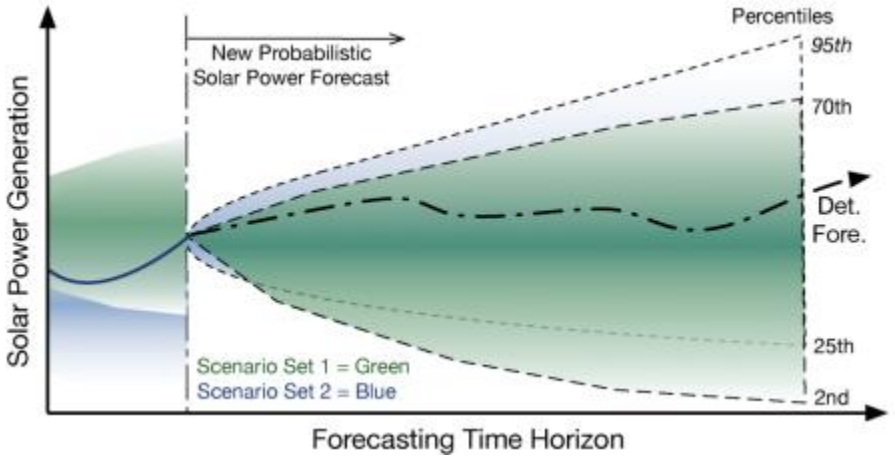
Team:

NREL NATIONAL RENEWABLE ENERGY LABORATORY

MDA

ercot

UT DALLAS



SUMMER-GO is a suite of tools that enable the incorporation of probabilistic solar forecasts into operations to improve system reliability and will be validated in ERCOT's real-time operational test system.

Questions?