



***The Impacts of Variable Generation
Forecasting in Determining Reserve
Needs and Value***

Nick Steffan
Operations Analysis

Sean Chang
Market Analysis

ESIG Forecasting Tutorial
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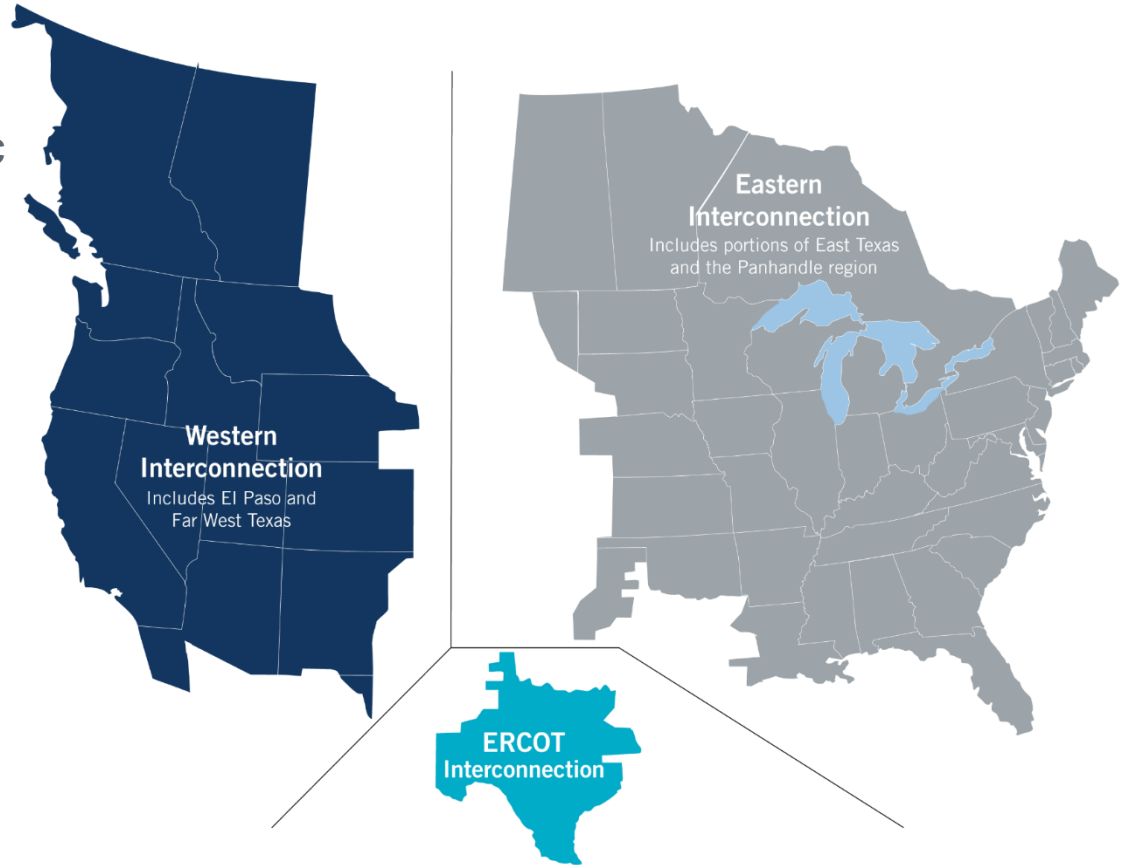
Outline

- Introduction to ERCOT
- Variable Generation Forecasts at ERCOT
- ERCOT's Ancillary Services
 - Regulation
 - Non-Spin
 - Responsive Reserve
- Market Impacts

What is ERCOT?

The Texas Legislature restructured the Texas electric market in 1999 and assigned ERCOT four primary responsibilities:

- **System Reliability**
- **Competitive Wholesale Market**
- **Open Access to Transmission**
- **Competitive Retail Market**



ERCOT is a nonprofit organization and regulated by the Public Utility Commission of Texas, with oversight by the Texas Legislature.

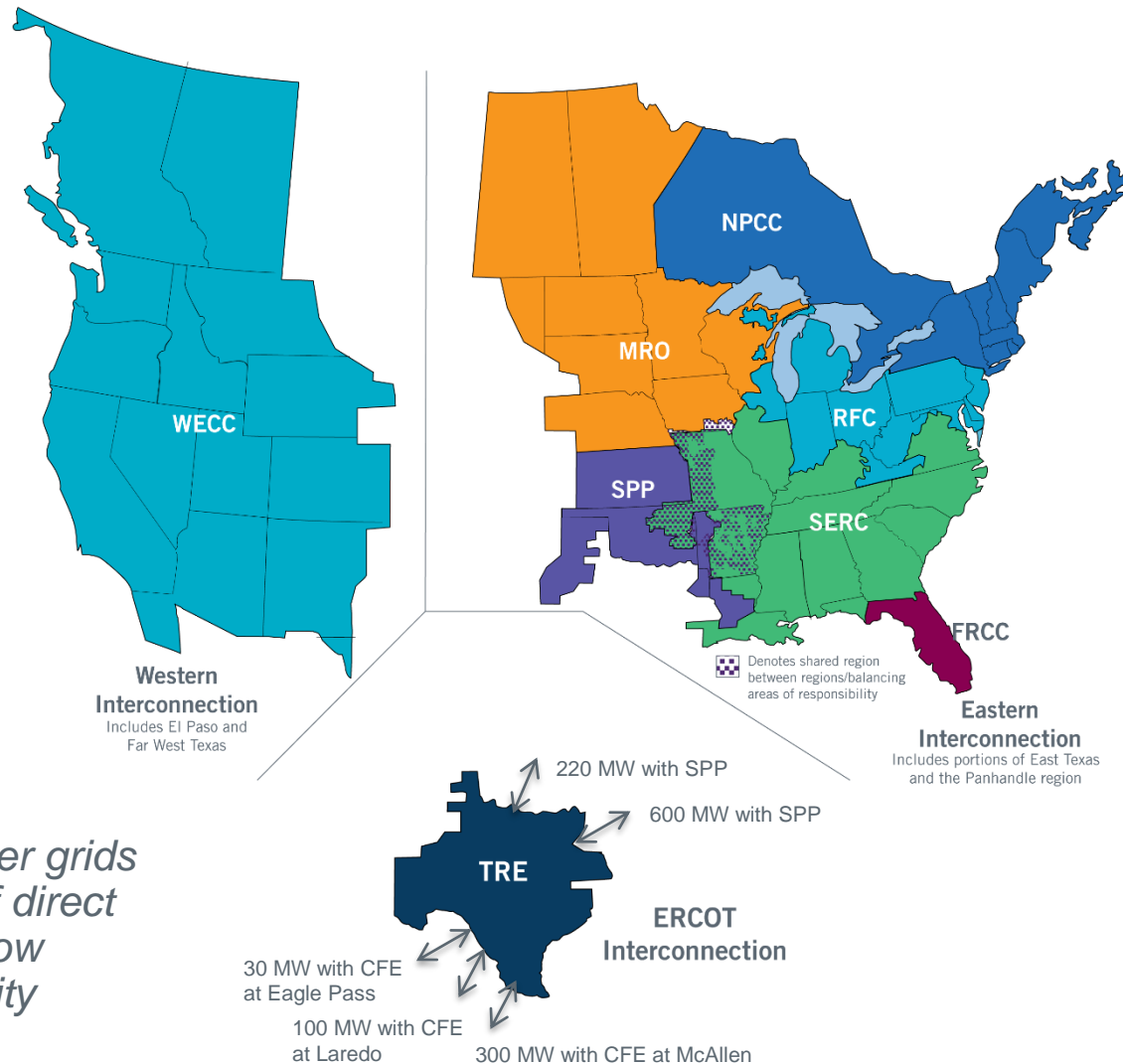
ERCOT is not a market participant and does not own generation or transmission/distribution wires.

The ERCOT Region

The interconnected electrical system serving most of Texas, with limited external connections

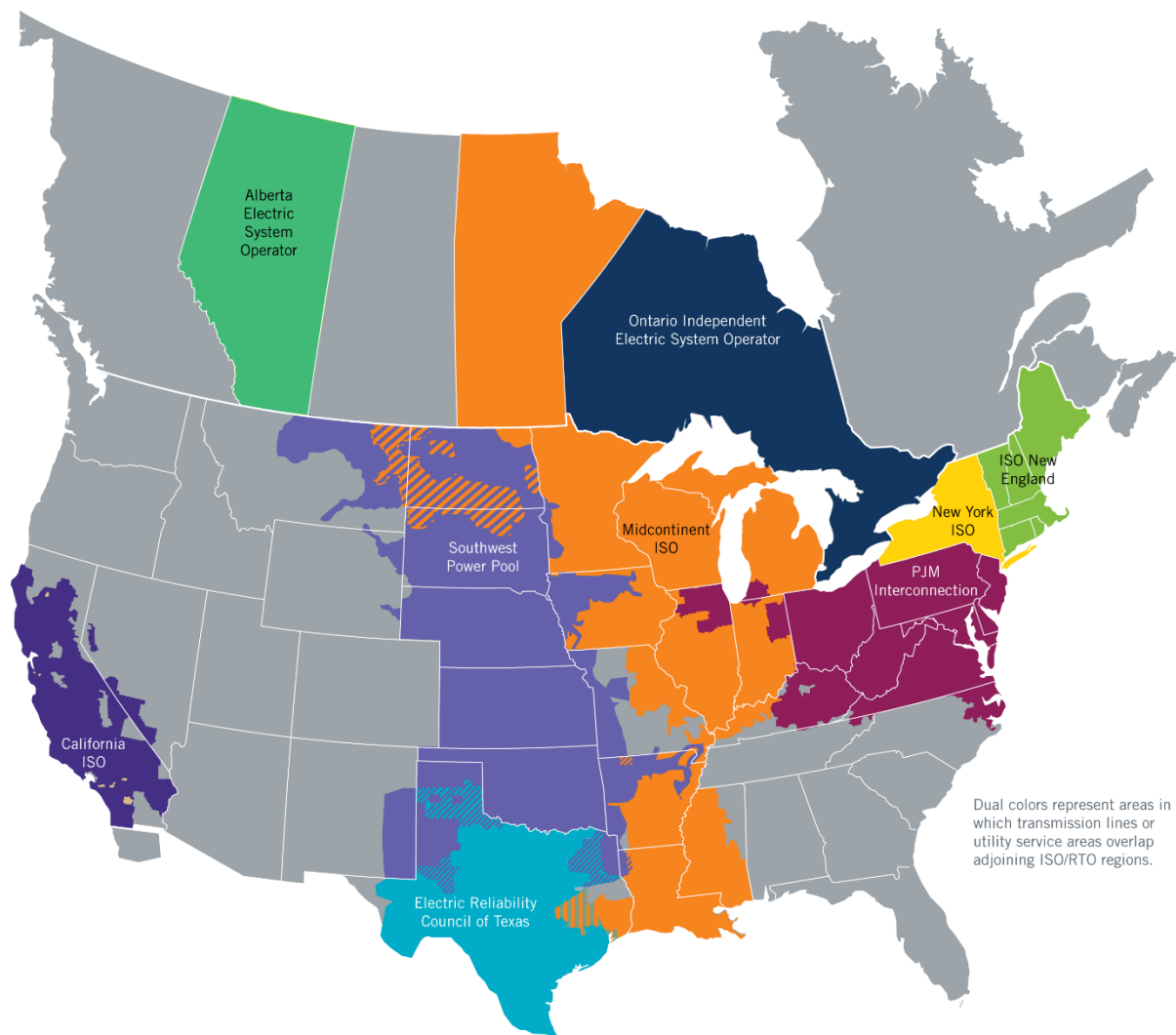
- 90% of Texas electric load; 75% of Texas land
- 71,110 MW peak, August 11, 2016
- More than 46,500 miles of transmission lines
- 570+ generation units

ERCOT connections to other grids are limited to ~1250 MW of direct current (DC) ties, which allow control over flow of electricity



ISOs and RTOs

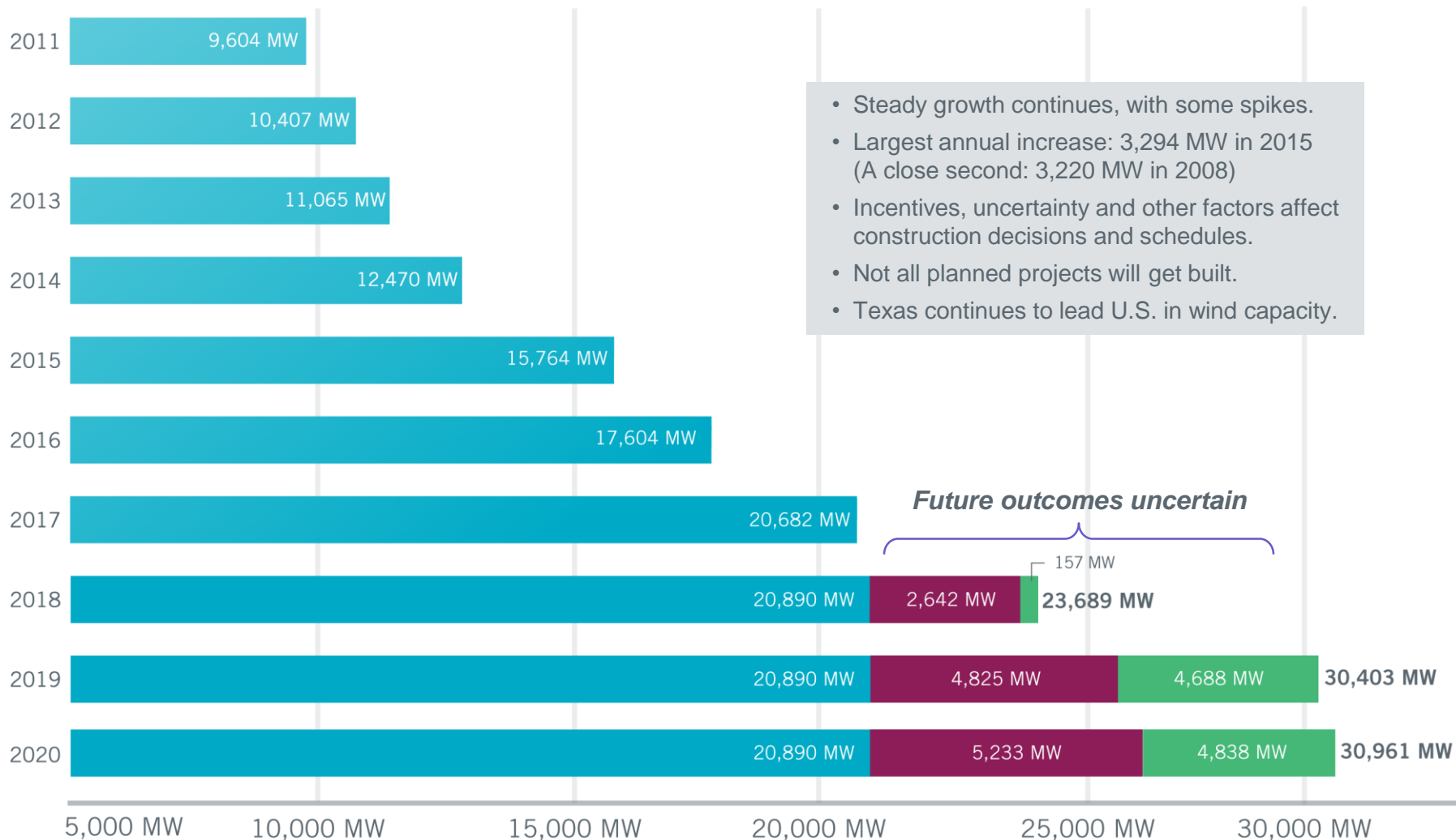
- ERCOT is one of nine **independent system operators** and **regional transmission organizations** in the U.S. and Canada.
- Together, ISO/RTOs serve about two-thirds of electric consumers in the U.S. and more than half of consumers in Canada.



Wind Generation Capacity – April 2018

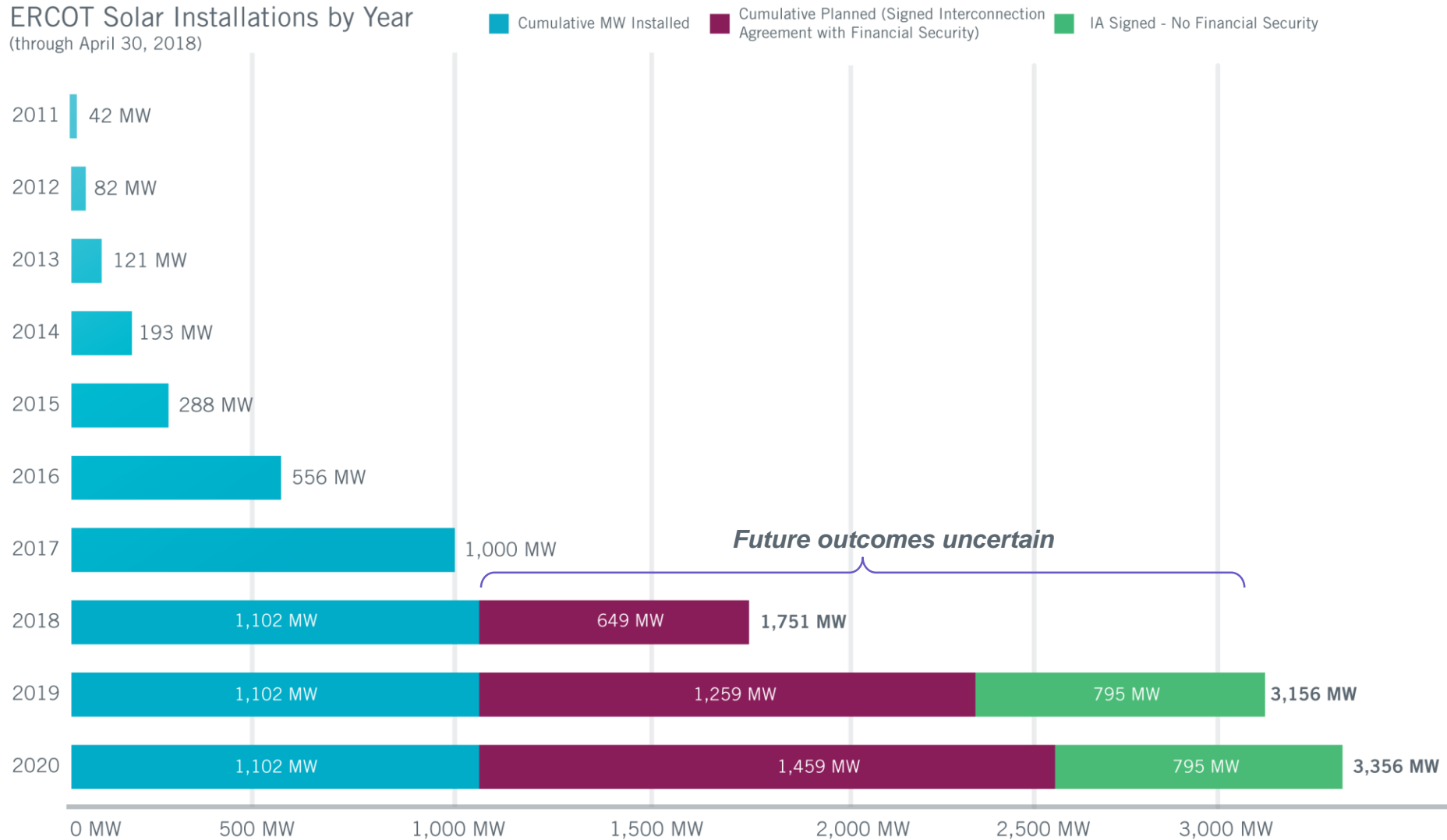
ERCOT Wind Installations by Year
(through April 30, 2018)

■ Cumulative MW Installed
 ■ Cumulative Planned (Signed Interconnection Agreement with Financial Security)
 ■ IA Signed - No Financial Security

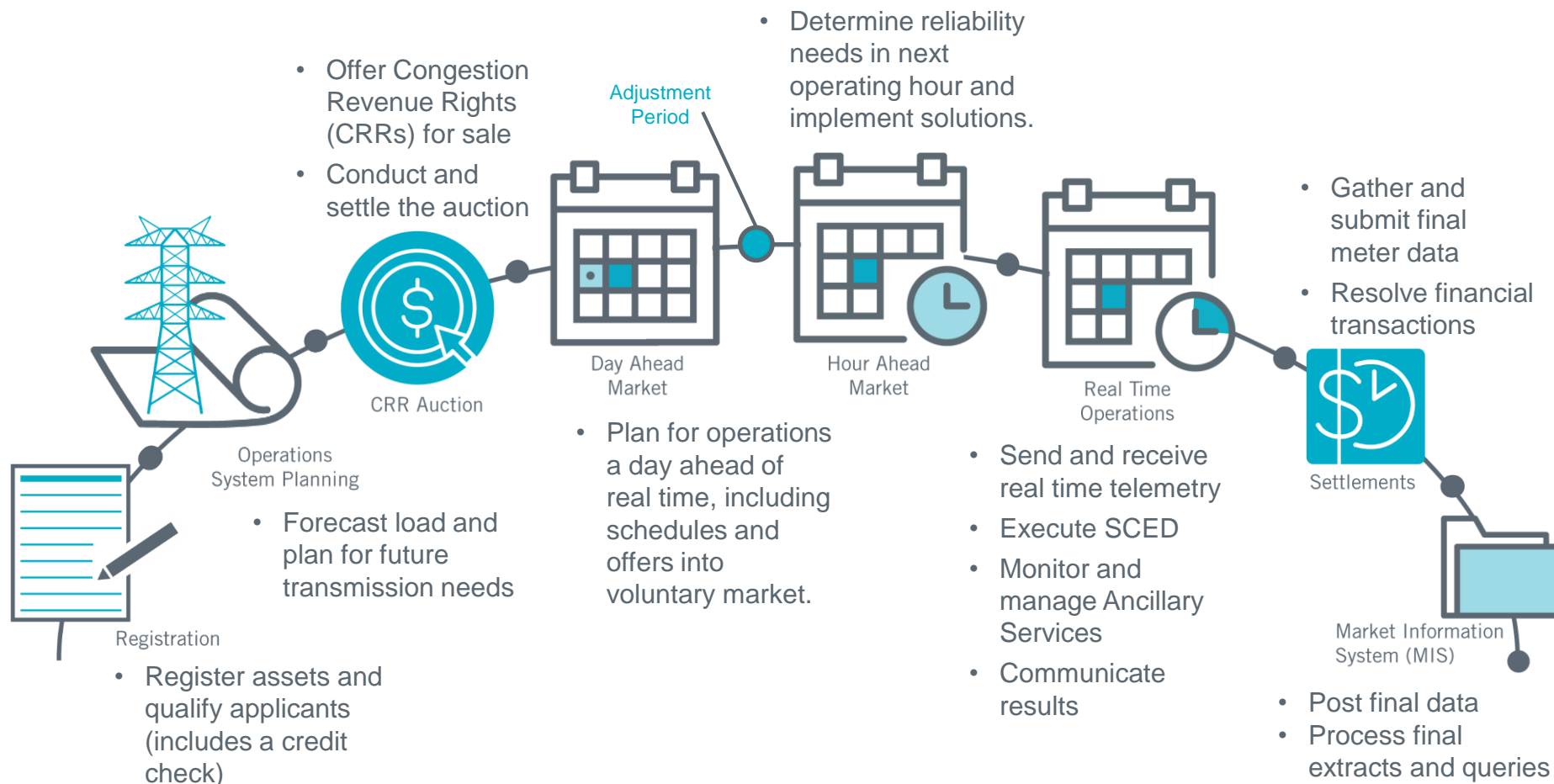


Utility Scale Solar Generation Capacity – April 2018

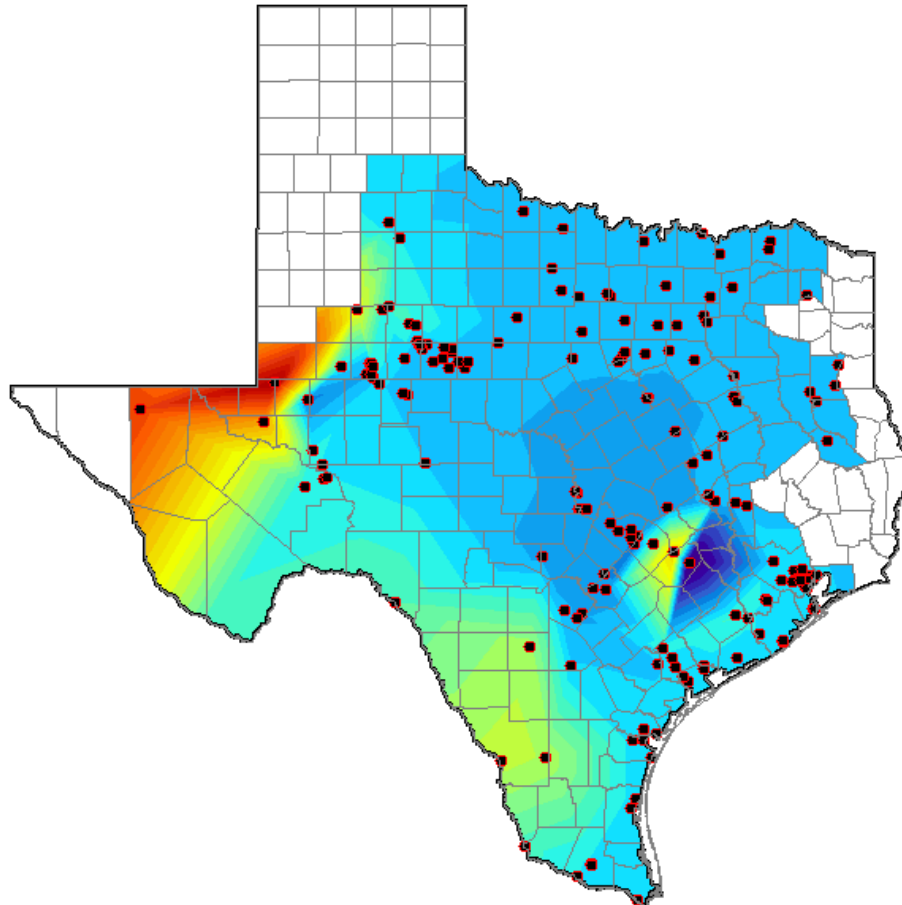
ERCOT Solar Installations by Year
(through April 30, 2018)



ERCOT Market Overview



Market operations at-a-glance



\$2.54 \$86.46

Prices



PUBLIC



Market participants may submit offers to buy and sell energy on an hourly basis in the voluntary Day-Ahead Market.



In the Real-Time Market, market participants submit offers to provide generation output and bring generation on-line as needed.



Every five minutes, ERCOT's Security-Constrained Economic Dispatch system selects the most efficient generation resource options to serve customer demand effectively within the limits of the transmission system.



Energy prices reflect the availability of resources during each interval, adjusting as needed to reflect the value of energy during scarcity conditions.



The Real-Time Market is settled every 15 minutes. Generators are paid settlement point prices, which reflect locational prices. Load-serving entities pay load zone prices, which can include costs associated with transmission congestion.

Variable Generation Forecasting at ERCOT

Direct Impacts

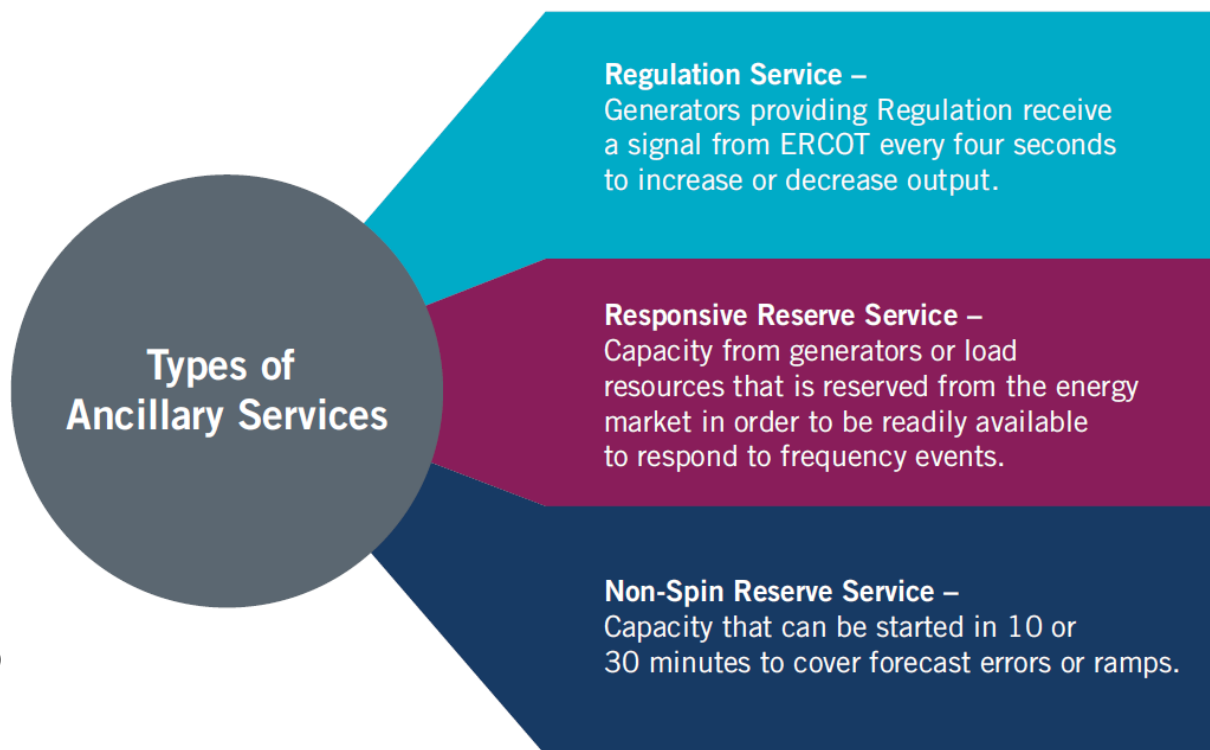
- Reliability Unit Commitment Processes
- Control Room Operations
- Non-Spin Ancillary Service Methodology
- Real-Time Reserve pricing

Indirect Impacts

- Not used directly in Day-Ahead Market, but forecasts influence market participant behavior
- Real-Time Market
- Indicative Pricing

Ancillary Services

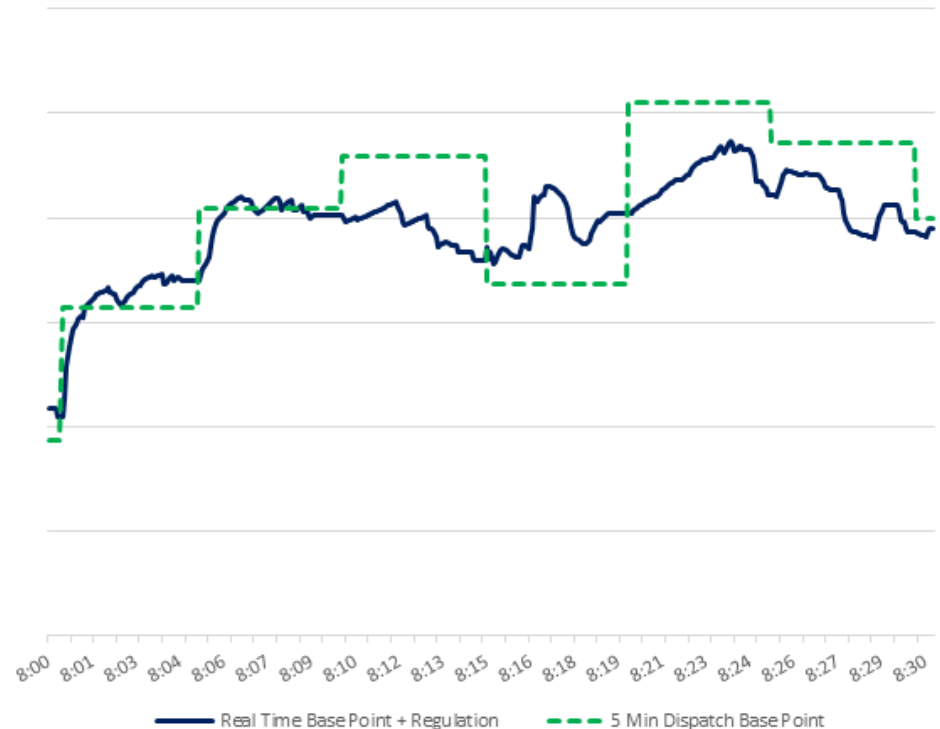
- Ancillary Services are procured in the Day-Ahead Market to ensure reserve capacity is available to address variability that cannot be covered by the five-minute energy market.
- ERCOT and its stakeholders continue to focus on the design of these services to provide resources that can maintain system reliability by responding quickly to sudden changes in load and generation output.



Over the last several years, ERCOT has made changes to how Ancillary Services are determined to better reflect system needs in different conditions.

Ancillary Services

- Load and generation are constantly changing, requiring continual rebalancing due to:
 - Daily load patterns
 - Instantaneous load variation
 - Changes in variable generation output
 - Generators tripping offline

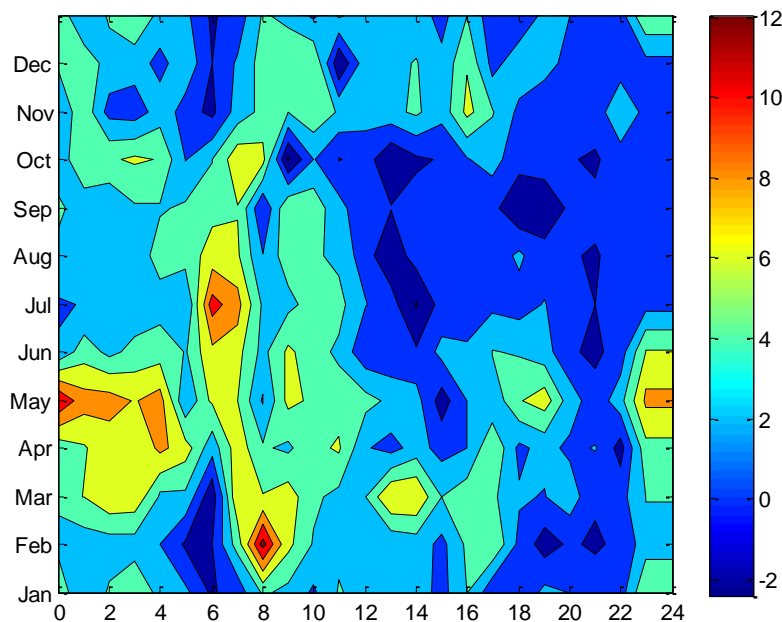


- Ancillary Services are procured to ensure sufficient resources are on-line, or able to be brought on-line in a timely manner, to balance the variability that cannot be covered by the 5-minute energy market.

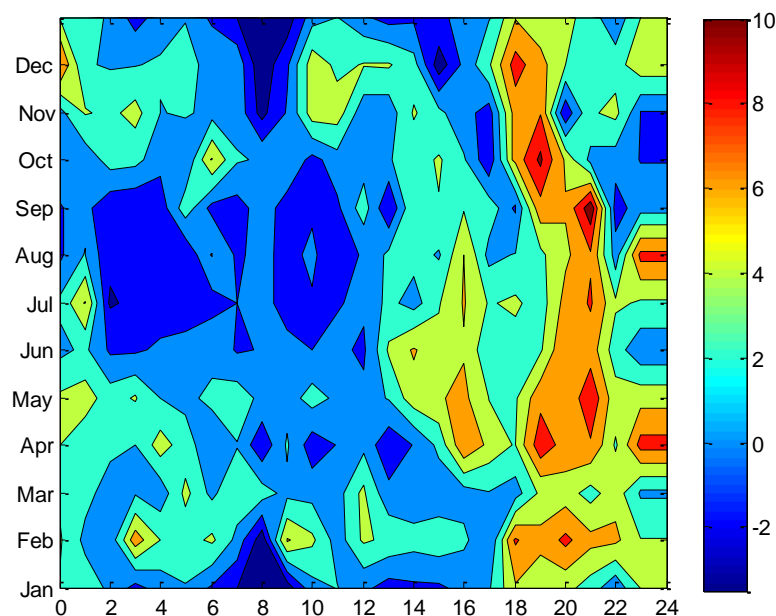
Regulation Service Methodology

- Regulation requirements are calculated to cover
 - 95th percentile of deployed regulation or **5-min net load variability** in the last two years
 - For 2018, 5-minute net load variability by includes solar generation (net load = load – wind generation – solar generation).
 - Incremental MWs are added (using GE tables) to account for additional variability that increasing Installed Wind capacity could bring through the year.
 - Adjustments may also be made based on historic **monthly** average CPS1 and 12-month rolling average scores.
 - CPS1 < 140%: 10% increase
 - CPS1 < 100%: 20% increase

Impact of Wind Generation on Regulation Services



Regulation-Up



Regulation-Down

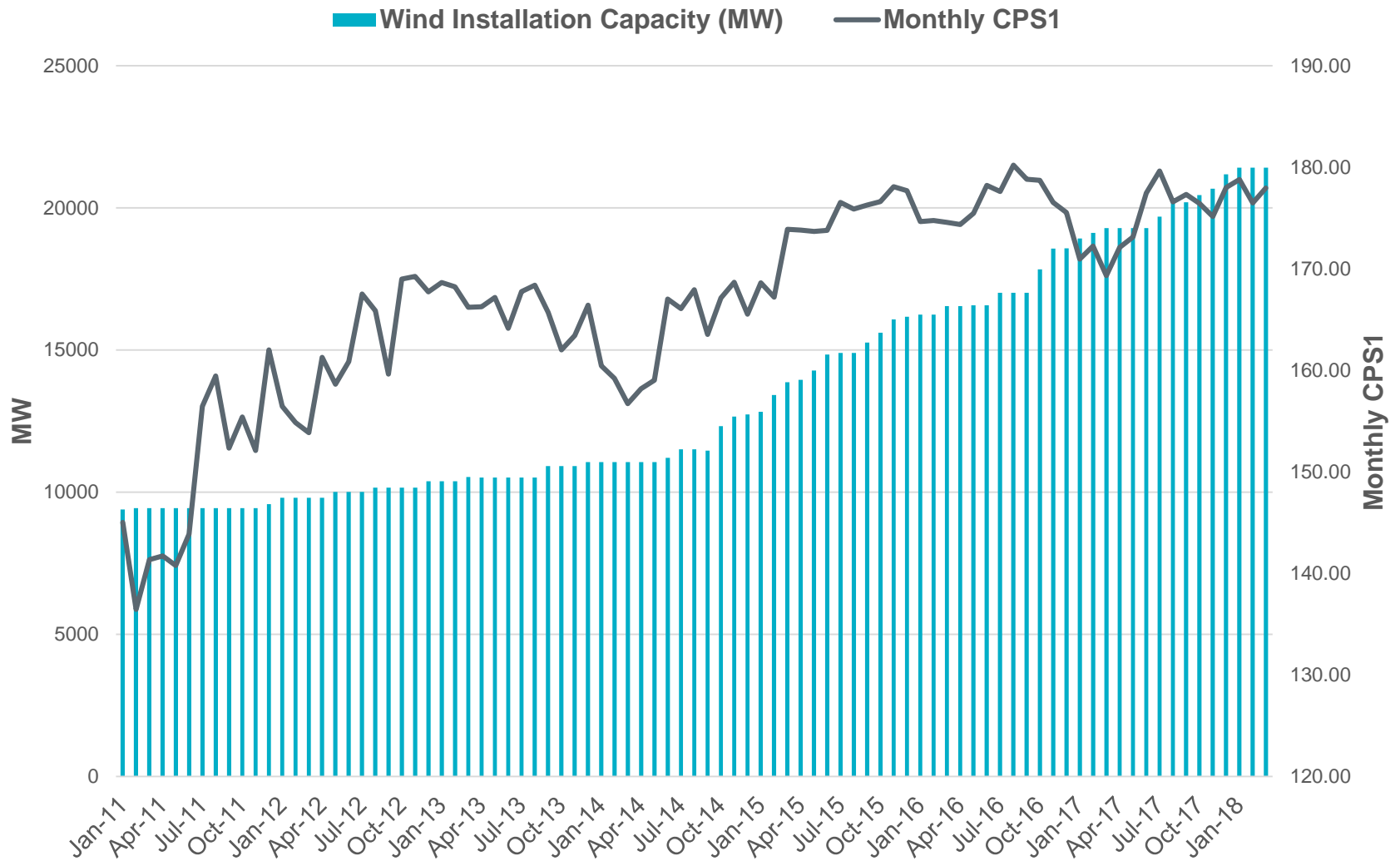
Incremental MW adjustment to Regulation Requirement, per 1000 MW of Incremental Wind Generation Capacity, to Account for Wind Capacity Growth

Integrating Renewables – Frequency Control

- All generation in ERCOT is required to provide governor response with a 5% droop setting with a deadband of 17 mHZ.
- Renewable resources started to assist in frequency control (by having an automatic response to frequency deviations) after 2010.
 - NERC's BAL-001-TRE regional standard was implemented starting April 1, 2015. This reduced Governor deadband for most resources including renewables from 36mHz to 17 mHZ.

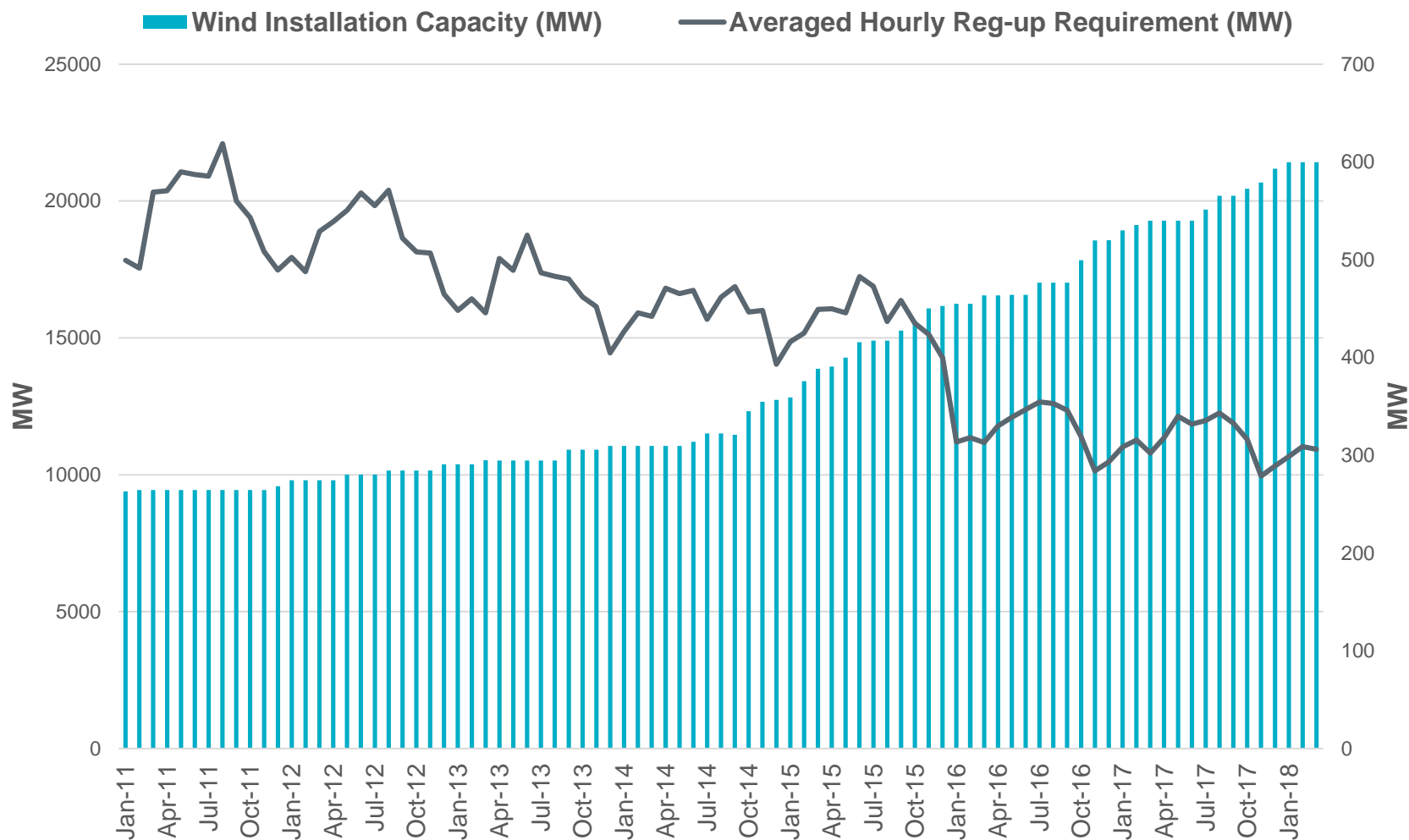
Trend of Monthly CPS1

Wind Installation Capacity (MW) v.s. Monthly CPS1

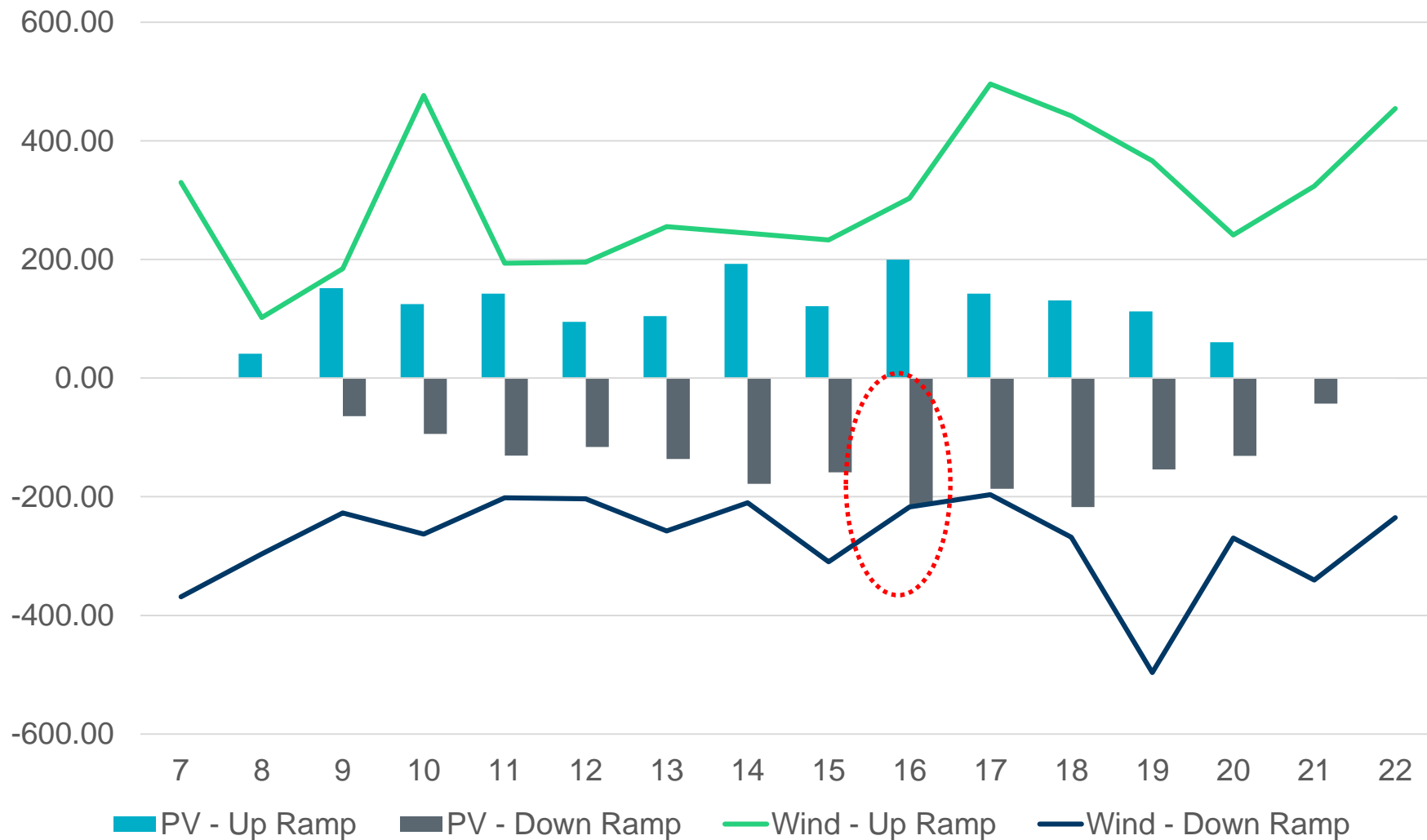


Wind Installed Capacity vs. Reg-Up Requirement

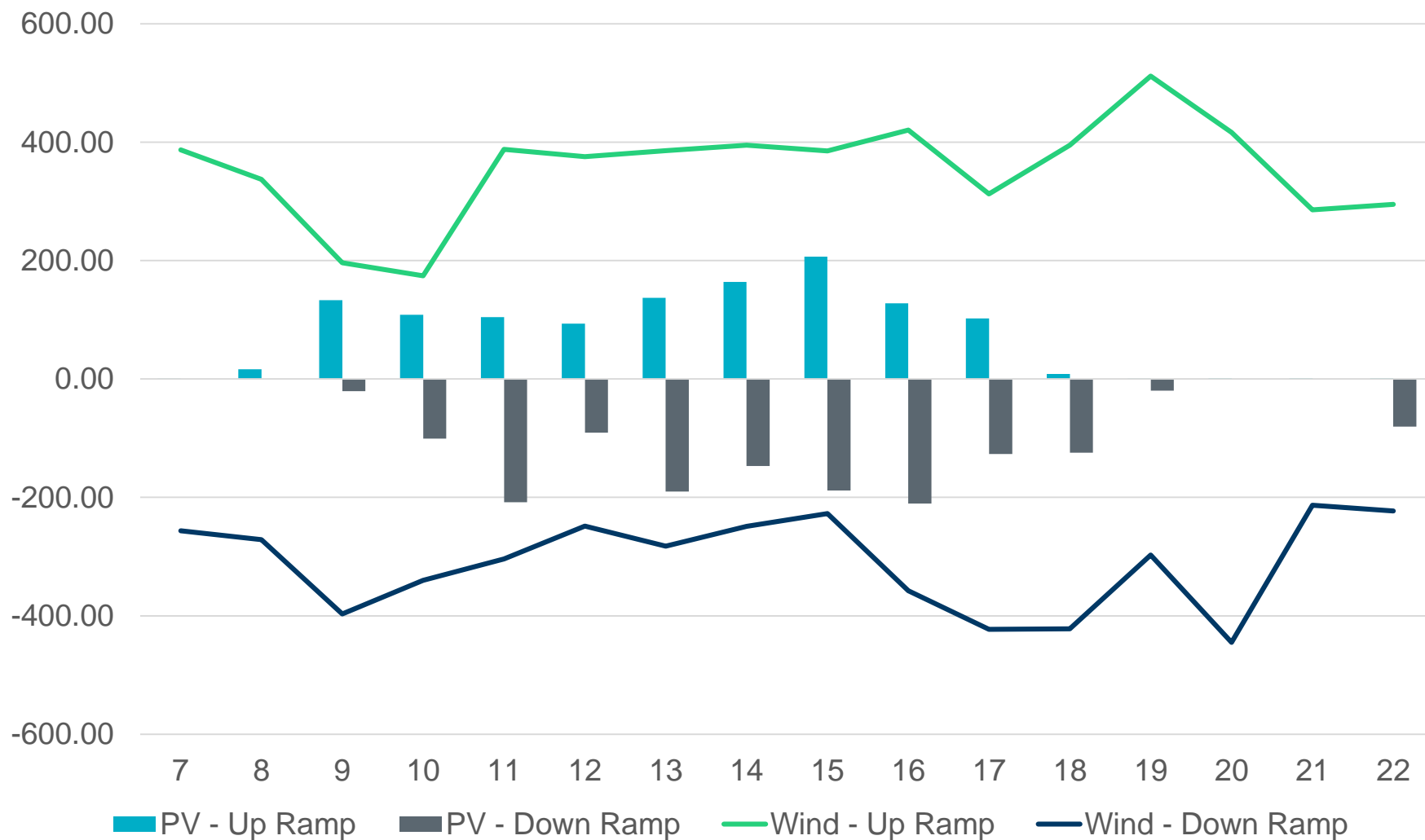
Wind Installation Capacity (MW) v.s. Averaged Hourly Reg-up Requirement



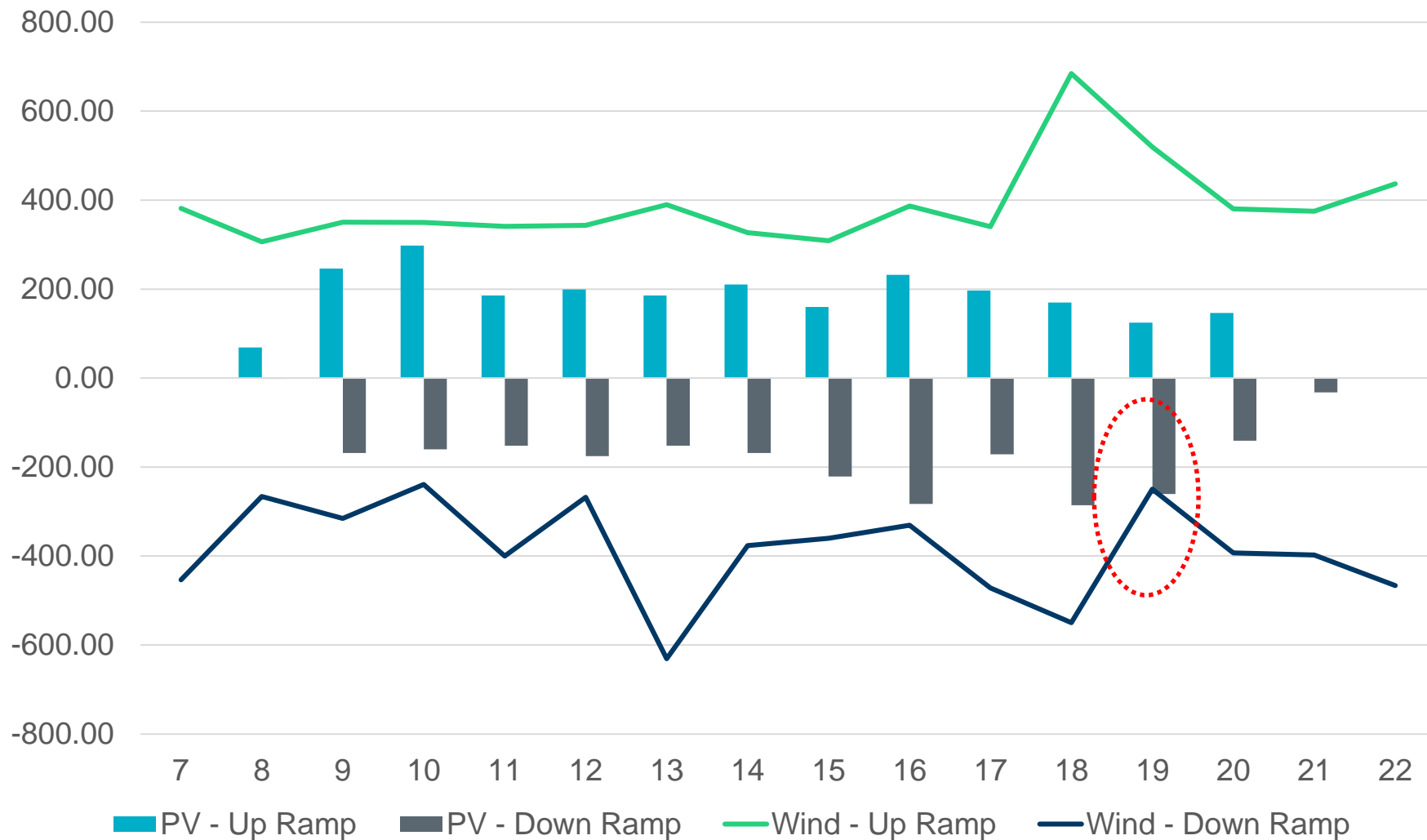
August 2017 - 5 Minute Max/Min Ramps



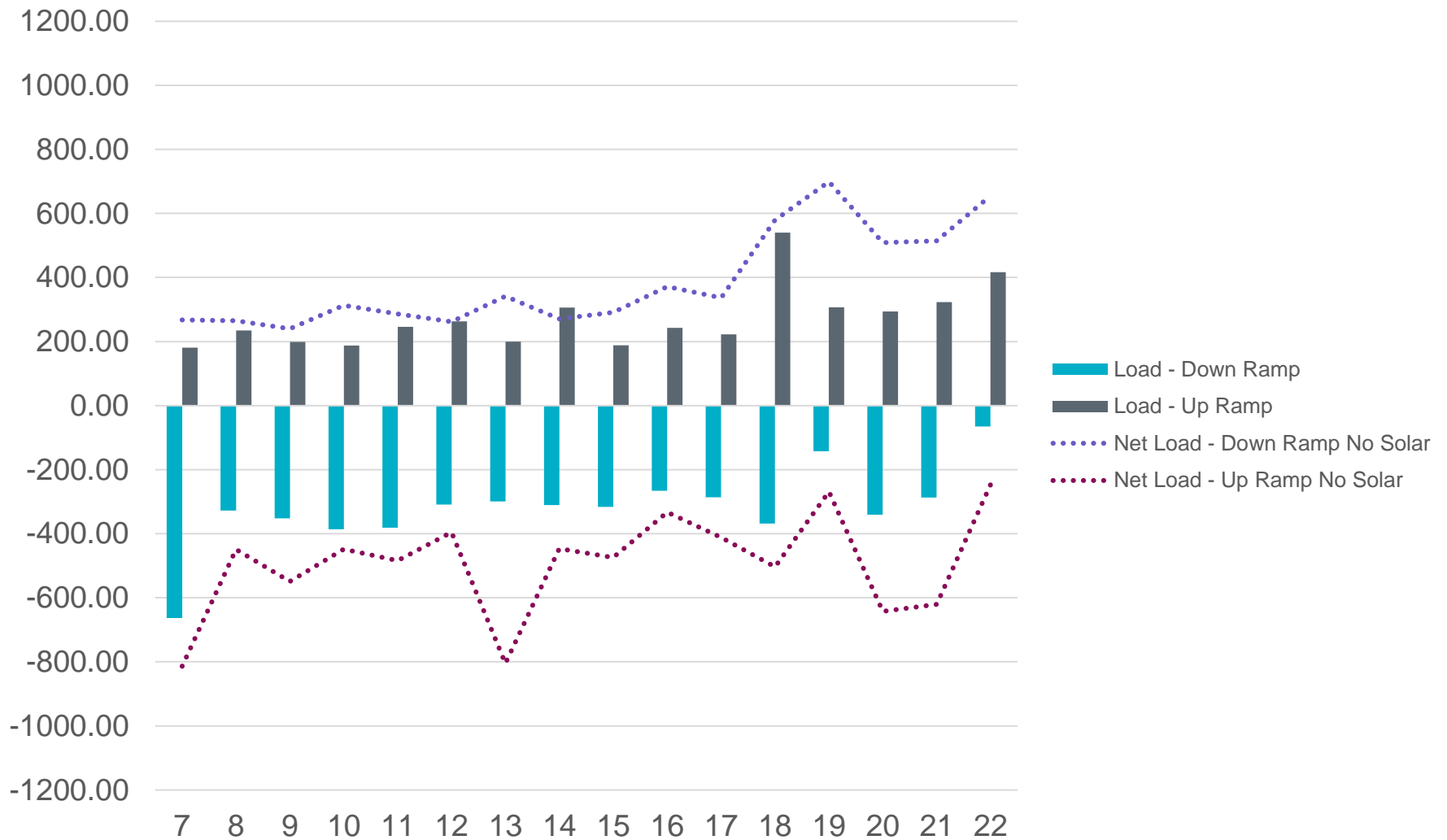
January 2018 - 5 Minute Max/Min Ramps



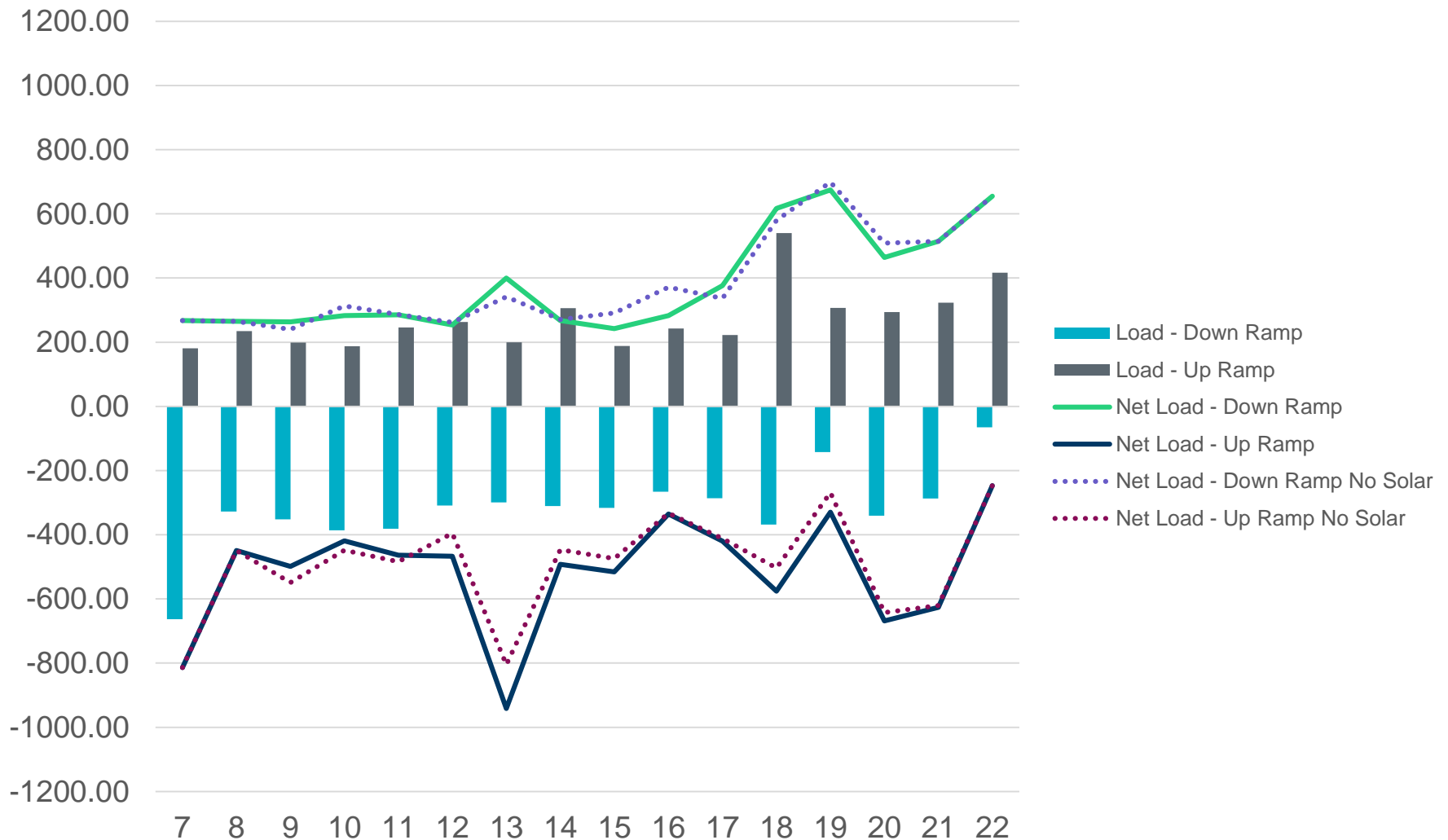
April 2018 - 5 Minute Max/Min Ramps



April 2018 Net Load Ramps



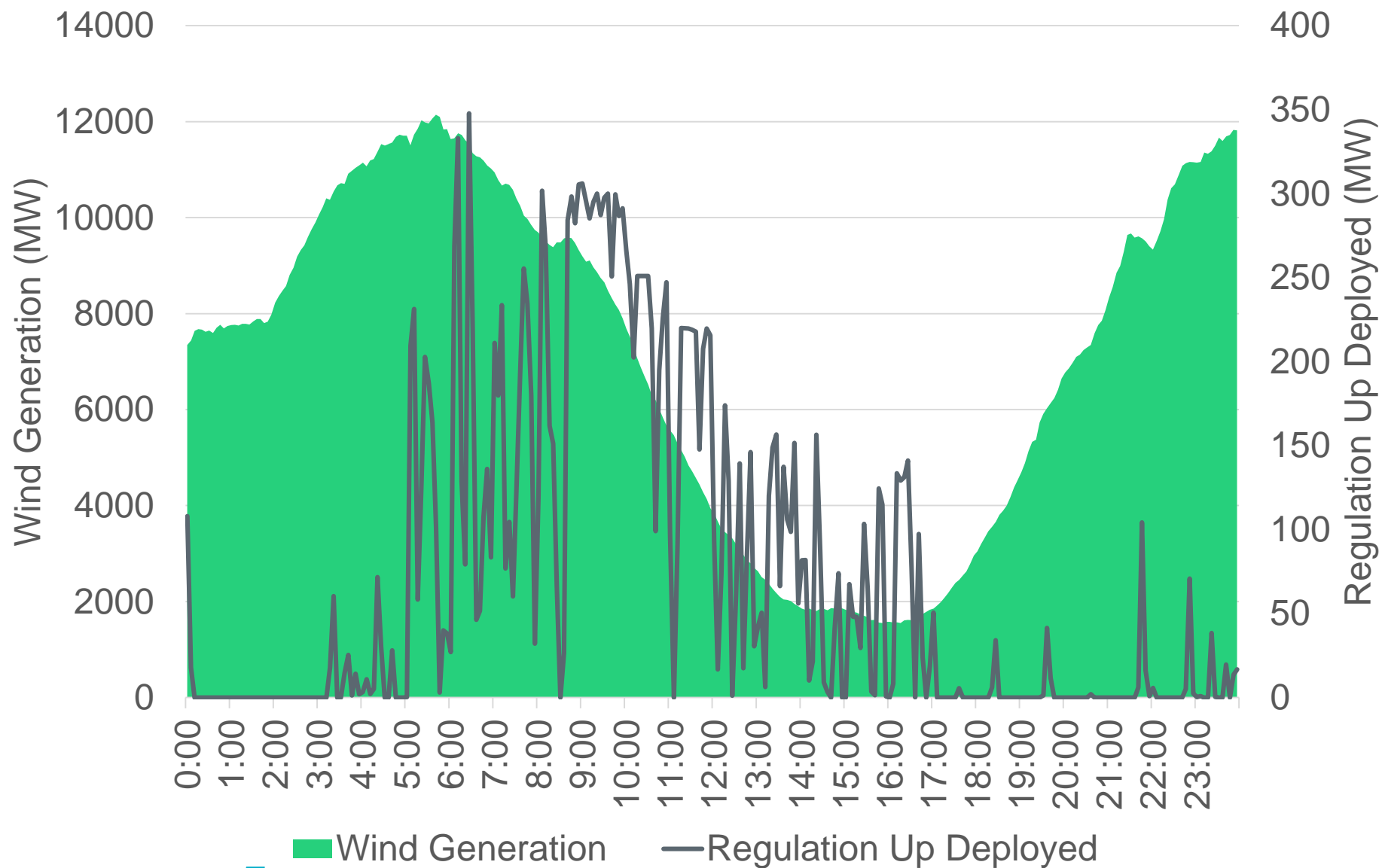
April 2018 Net Load Ramps - continued



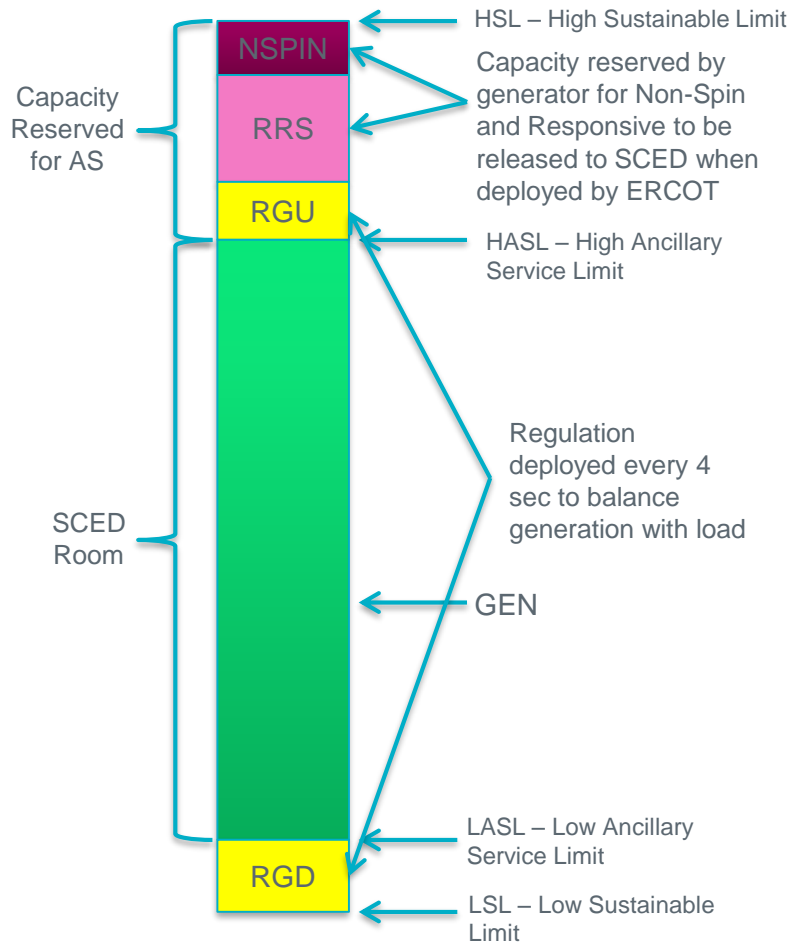
Real-Time Dispatch Impact

- ERCOT is looking into incorporating 5-minute variable generation forecasts into both Real-Time dispatch and its Regulation service procurement methodology
- Currently, SCED assumes persistence for variable generation resources
- Short term load forecast is the only forecast that is input into SCED
- Primary frequency control and regulation services must make up for any changes in variable generation

Example on Feb. 10, 2018



Non-Spin Reserve Service (NSRS)



What is NSRS?

- NSRS is an ancillary service provided by resources which can be deployed within 30 minutes.

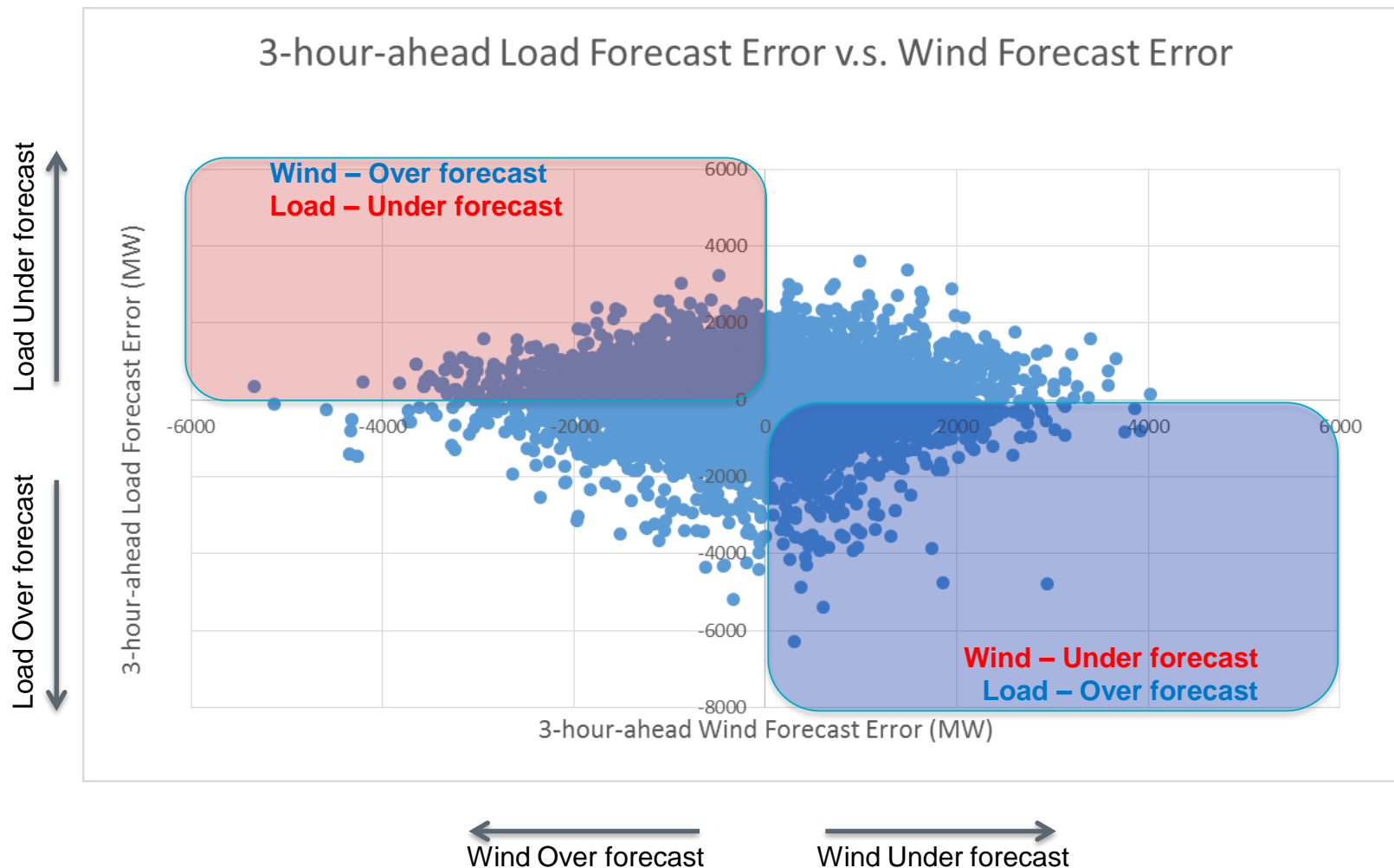
Why is it required?

- To recover reserves after major system disturbances.
- To cover for uncertainties in load and wind forecast.

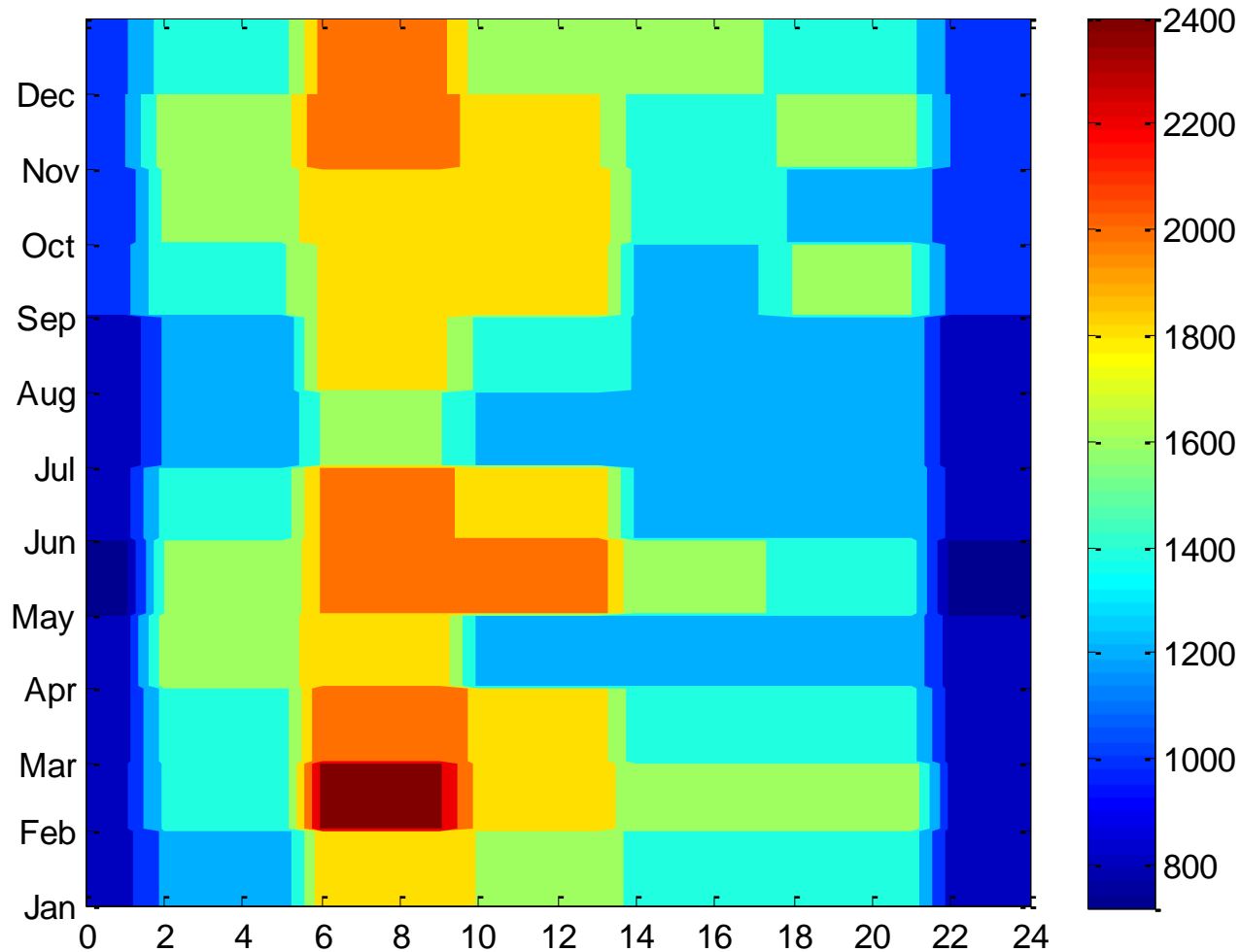
Non Spinning Reserve Methodology

- Non Spinning Reserve requirements are calculated to cover
 - Risk of net load ramp is computed for every 4-hour block in year.
 - Net load = Load - Wind Generation
 - Risk of Net load ramp = Change in Net Load over an hour divide by highest Net Load for season
 - **Base Requirement** is computed as 70th to 95th percentile of hourly Net Load uncertainty in previous three years.
 - Net load = Load - Wind Generation-HSL
 - Net load forecast = 3 Hour-Ahead Load Forecast – 3 Hour-Ahead Wind Forecast
 - Net load uncertainty = Net load – Net Load Forecast
 - 95th percentile used for periods with highest net load risk
 - 70th percentile used for periods with lowest net load risk
 - 1375 MW Floor is applied to On-peak hours (HE 7 thru 22)

Forecast Errors in 2016

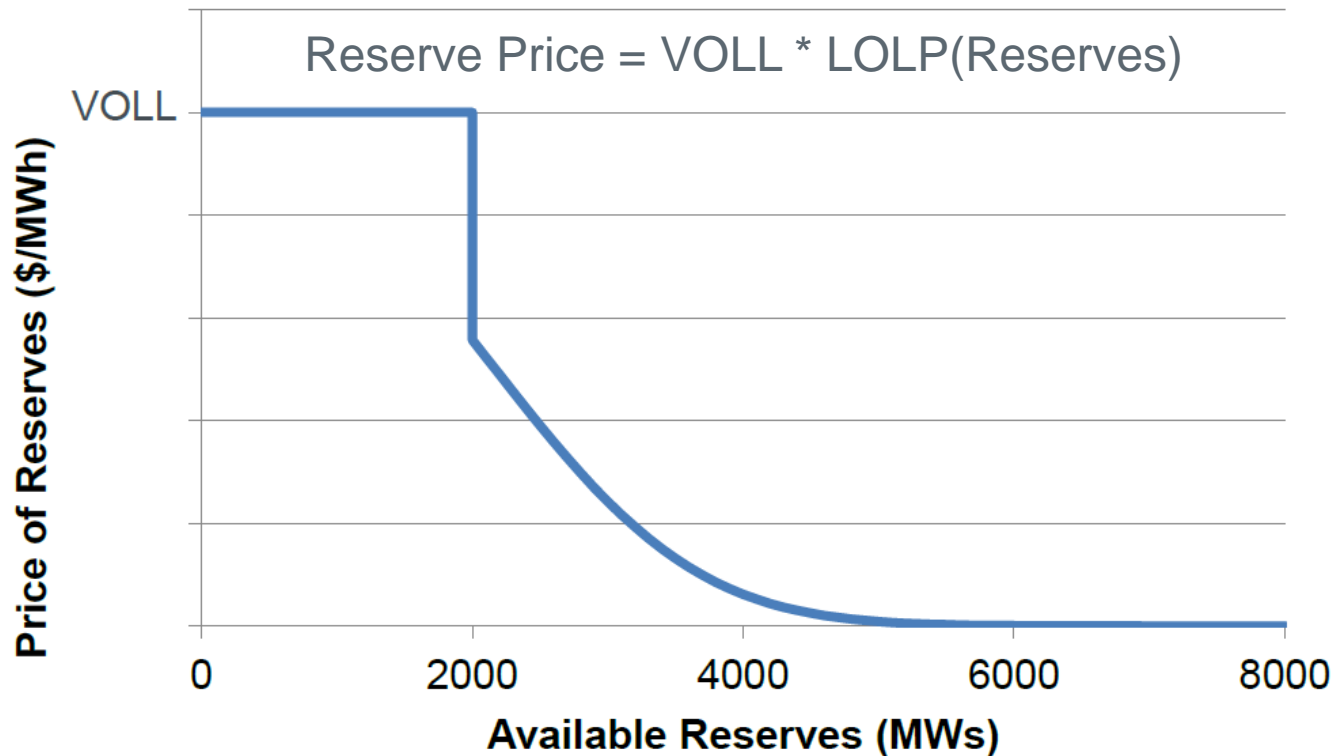


Minimum NSRS Requirement in 2017



Real-Time Reserve Pricing

- ERCOT uses a real-time reserve pricing mechanism called the Operating Reserve Demand Curve (ORDC)

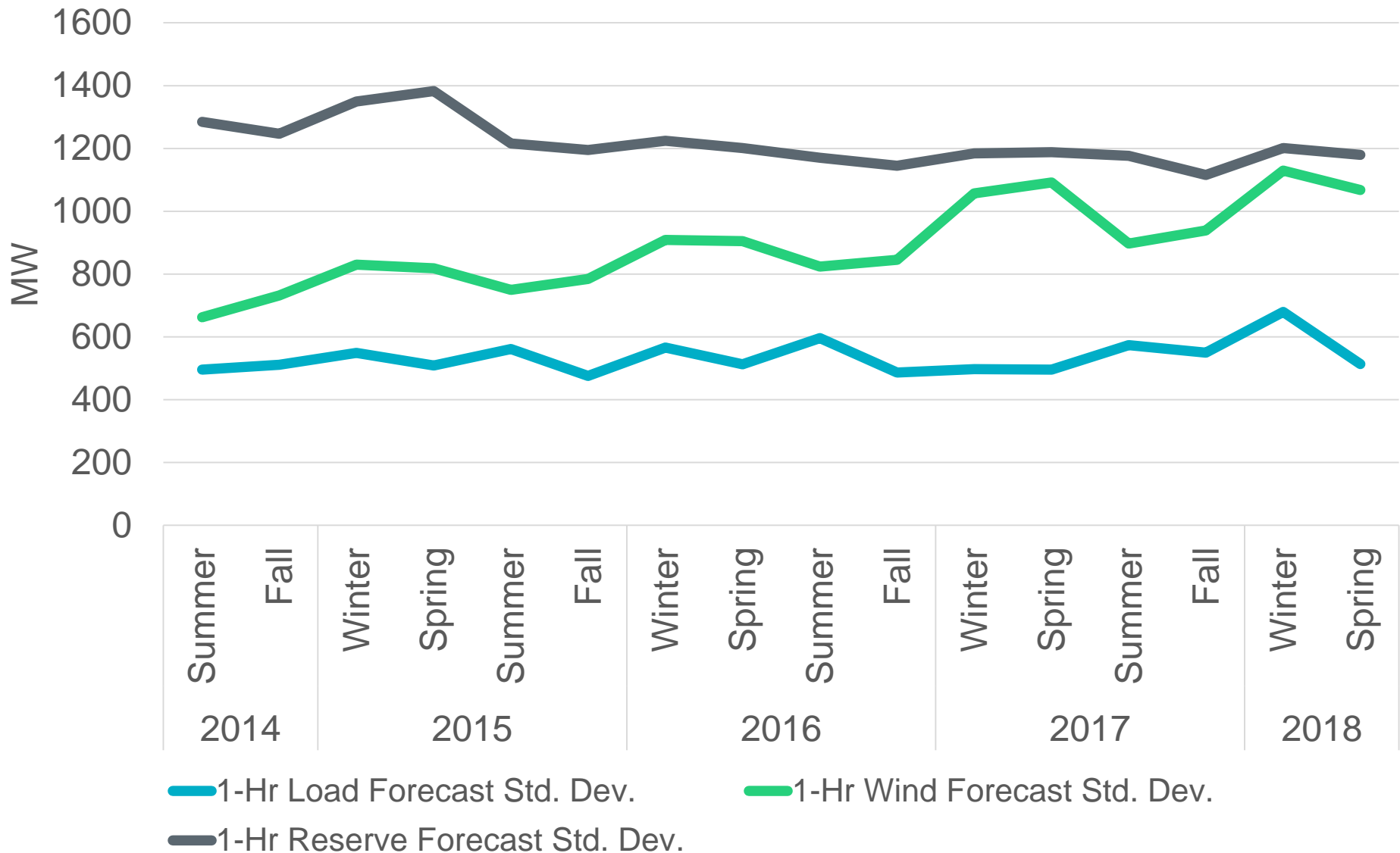


VOLL = Value of Lost Load (\$9,000/MWh in ERCOT)

LOLP(x) = Loss of Load Probability given X reserves

Note: Reserve Price calculation has been simplified

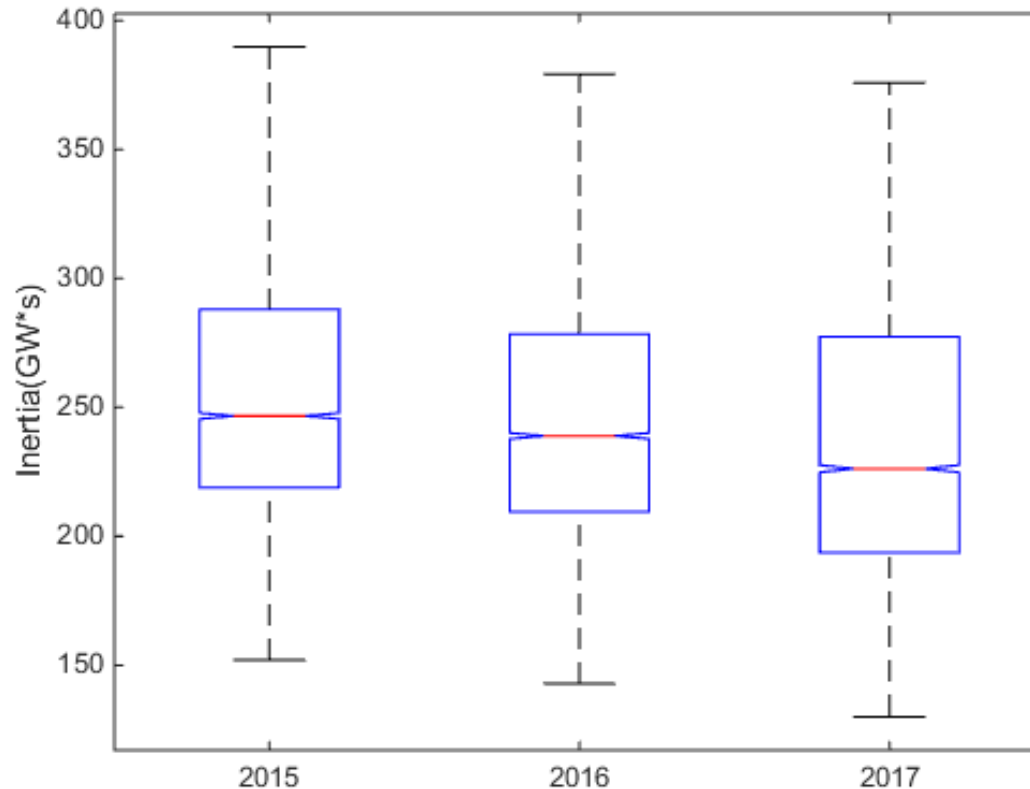
Comparing Forecast Errors



Ancillary Services – Responsive Reserves (RRS)

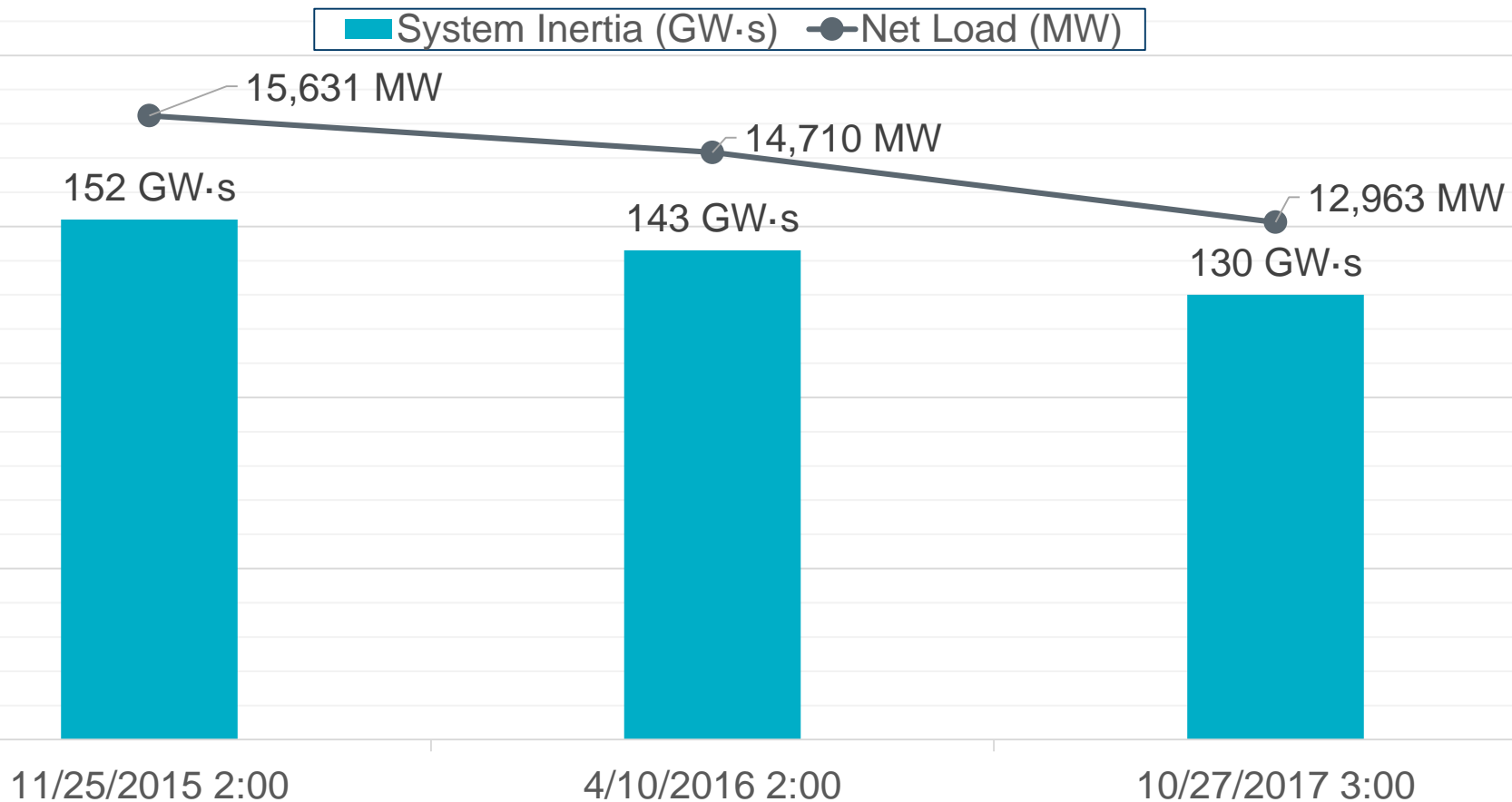
- Responsive Reserves are procured to ensure sufficient capacity is available to respond to frequency excursions due to unit trips
 - Capacity reserved from generators to provide governor response
 - Up to 60% of Responsive requirement can be provided by Load Resources on under-frequency relays (to trip when frequency decreases to 59.7 Hz for .5s)
 - Floor of 2300 MW
 - 70% of historic (last two years) system inertia conditions
- Since 2015, the Responsive Reserve procurement is based on expected system inertia.

System Inertia in ERCOT



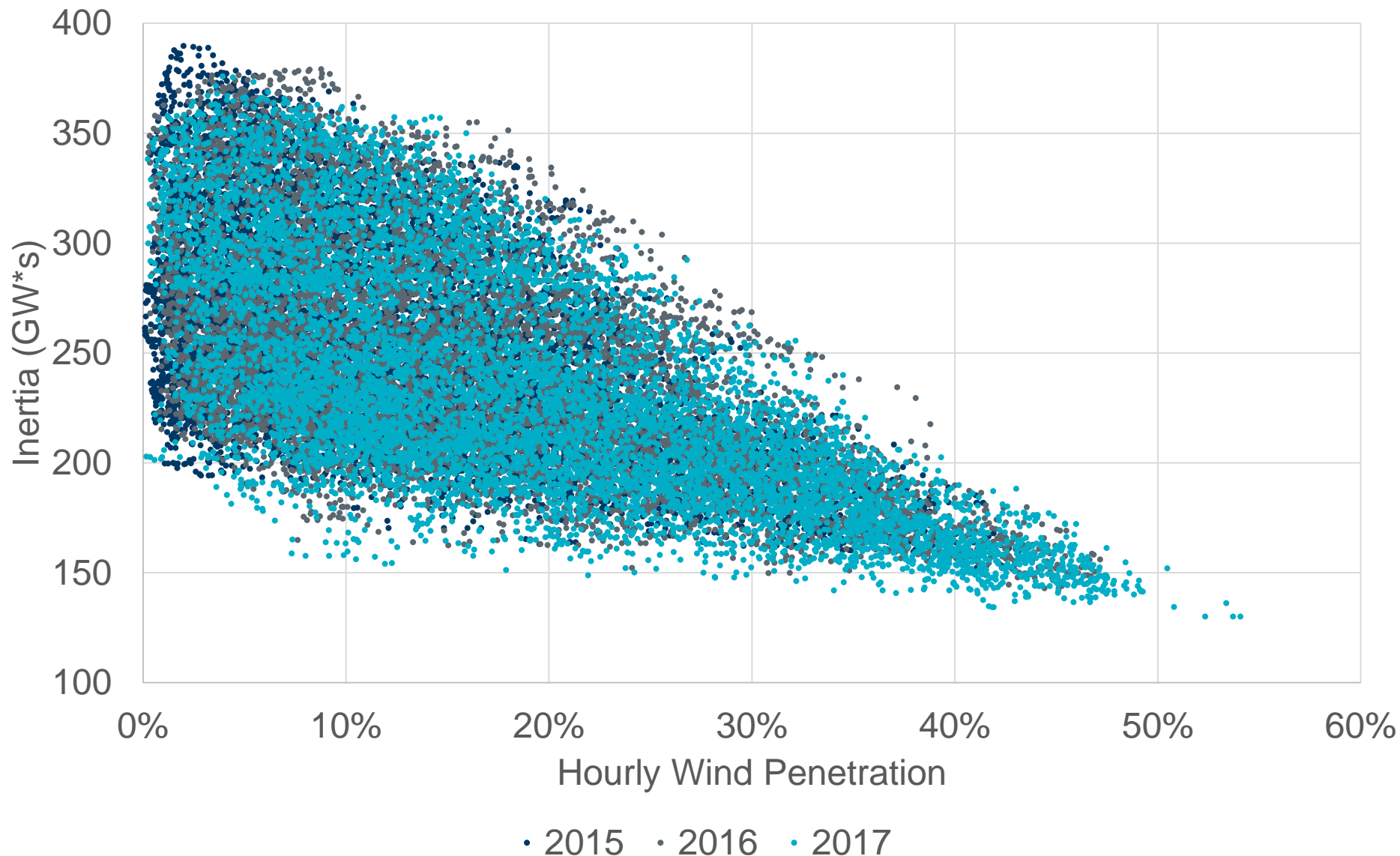
- Currently, the Critical Inertia Level for ERCOT appears to be around 100 GW-s (based on current operations and response characteristics of current resources)
- Rate of change of frequency at 100 GW-s would be high enough during the two largest unit trip that frequency would drop below 59.3 Hz

Inertia vs. Net Load at Moment of Minimum Inertia



Date	System Inertia (GW-s)	Load (MW)	Wind Gen (MW)	Net Load (MW)
11/25/2015 2:00	152	26,607	10,976	15,631
4/10/2016 2:00	143	26,801	12,091	14,710
10/27/2017 3:00	130	28,228	15,265	12,963

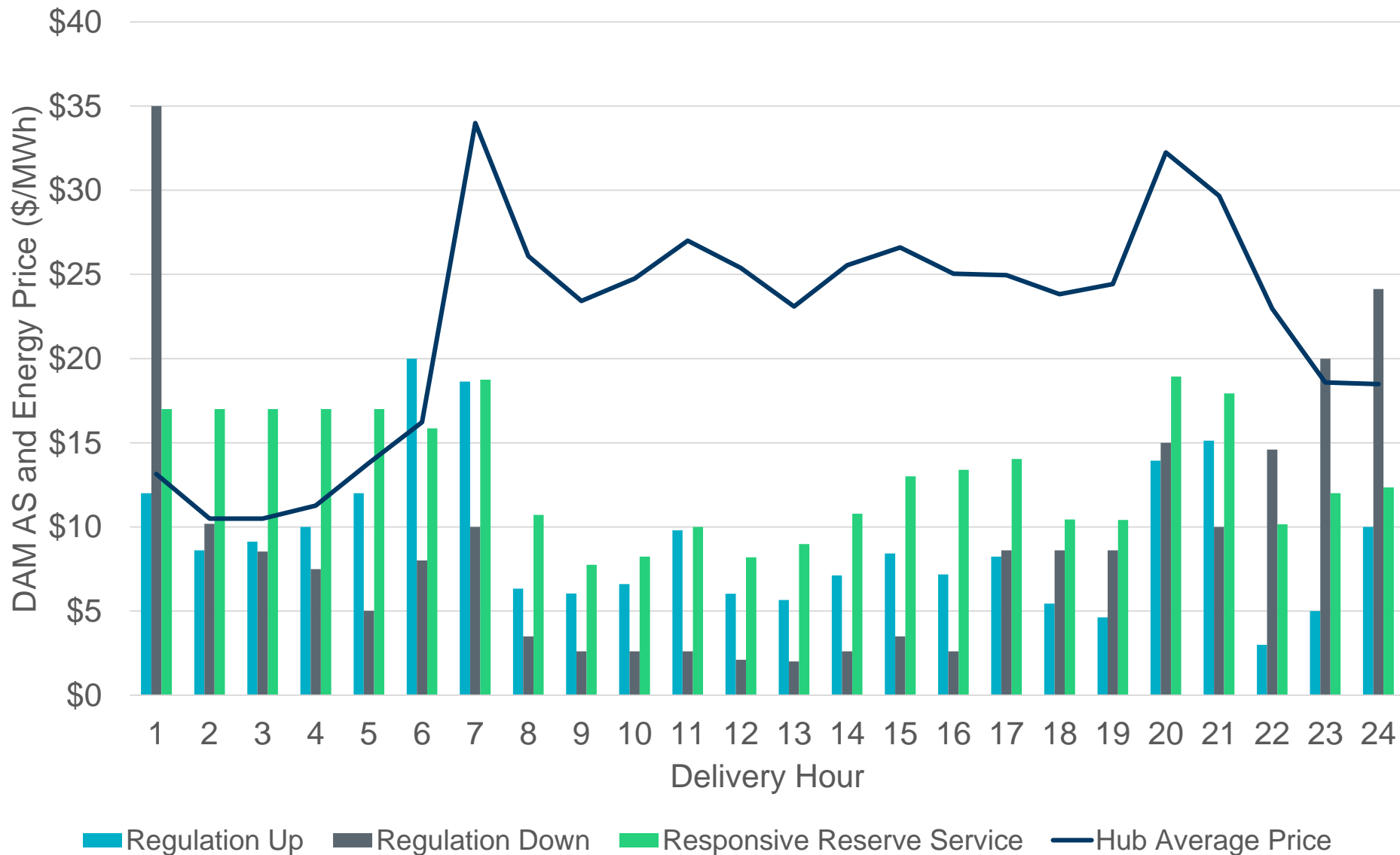
Correlation between Inertia and Wind Penetration (%)



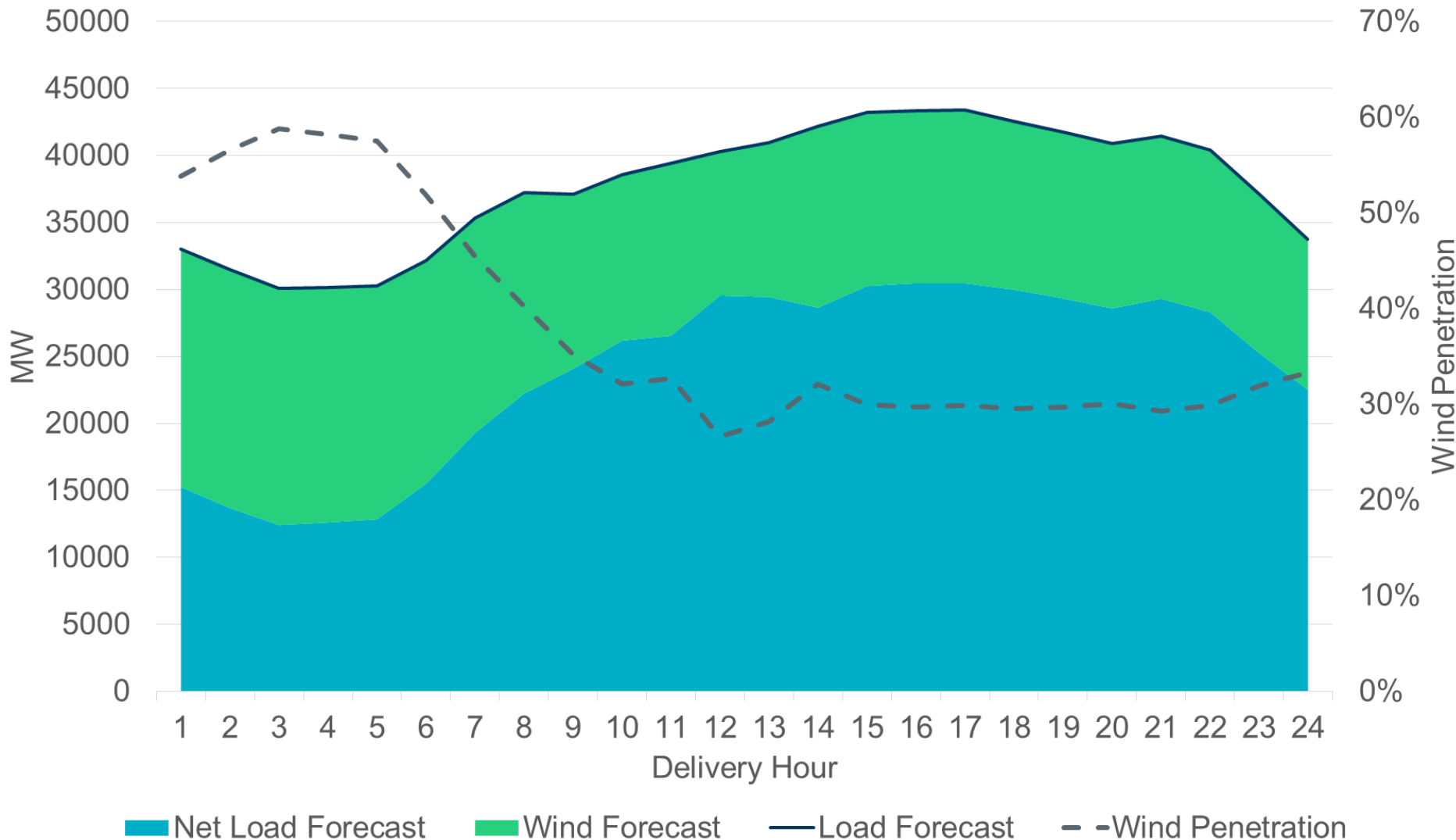
Day-Ahead Wind Forecast Impact on Day-Ahead Market



Day-Ahead Market Prices on April 3, 2018



Day-Ahead Forecast on April 3, 2018



Questions?