



Renewable Integration and Resiliency of the Power Grid

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Discussion Outline

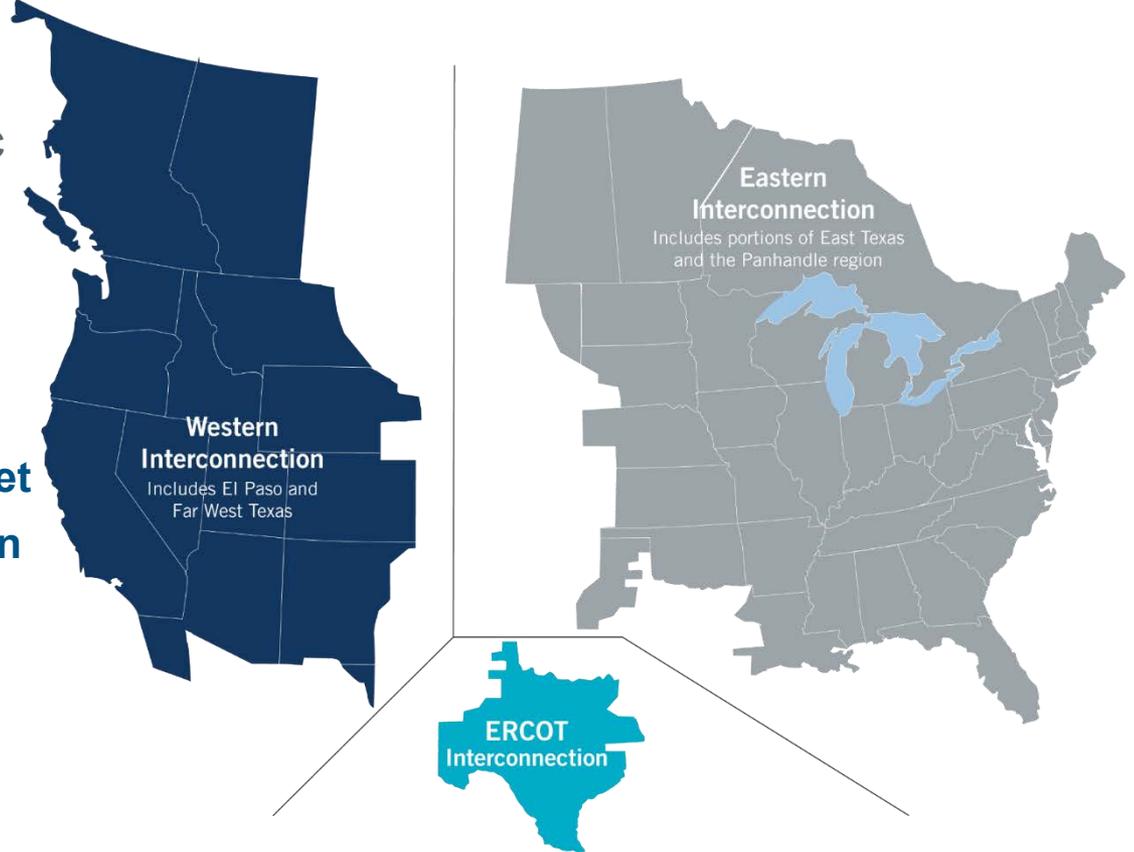
- An Introduction to ERCOT
 - Who we are & what we do
 - Renewables @ ERCOT
- Strategies to enhance Grid Resiliency
 - Transmission Networks
 - Grid Code
 - Renewable Forecasts
 - Ancillary Services i.e. Reserves



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.

Current Records

Peak Demand Record: 71,110 megawatts (MW)

- Aug. 11, 2016, 4-5 p.m.

Weekend Record: 66,921 MW

- Sunday, Aug. 7, 2016, 5-6 p.m.

Winter Peak Record: 59,650 MW

- Jan. 6, 2017, 6-7 p.m.

Wind Generation Records (instantaneous)

- Output: 16,141 MW
 - March 31, 2017, 8:56 p.m.
- Penetration (load served): 50%
 - March 23, 2017, 3:50 a.m.
 - Total Load = 28,780 MW

Recent Monthly Peak Demand Records

2017

- January: 59,650 MW (Jan. 6, 6-7 p.m.)

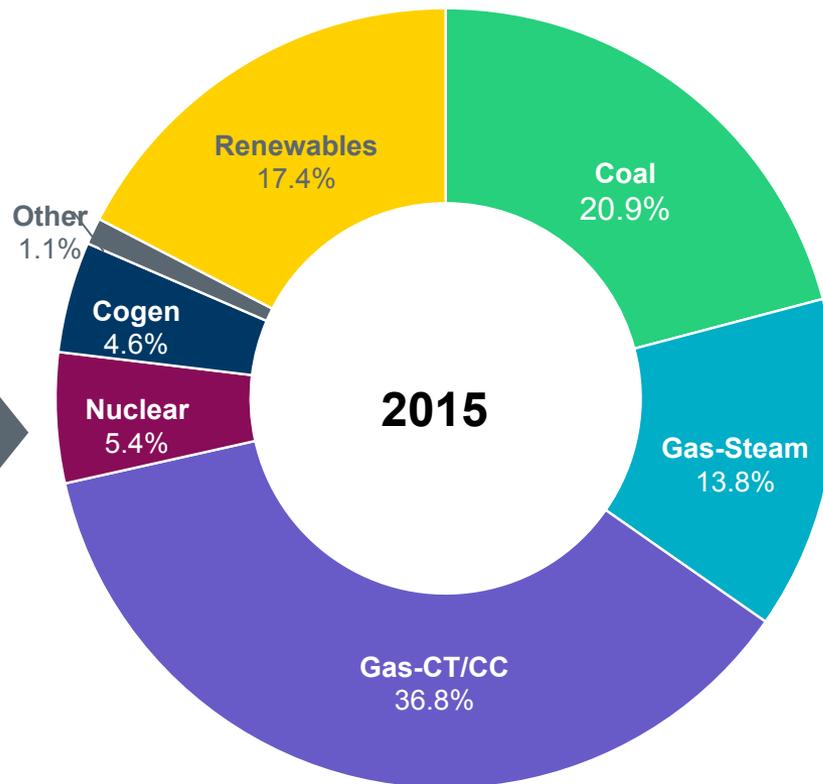
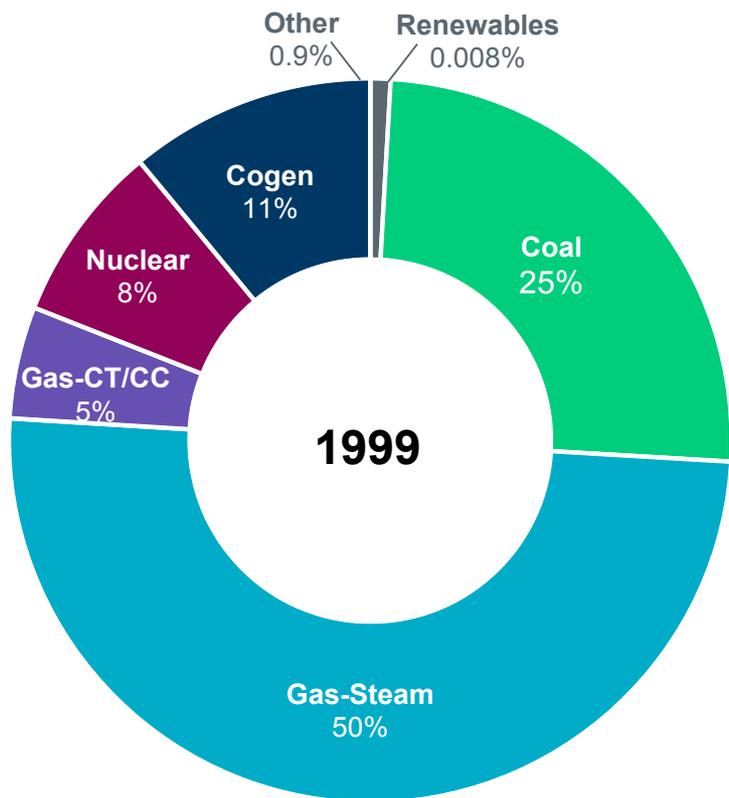
2016

- August: 71,110 MW
(All-time record)
- September: 66,949 MW (Sept. 19, 4-5 p.m.)
- October: 59,864 MW (Oct. 5, 4-5 p.m.)
- December: 57,932 MW (Dec. 19, 7-8 a.m.)

2015

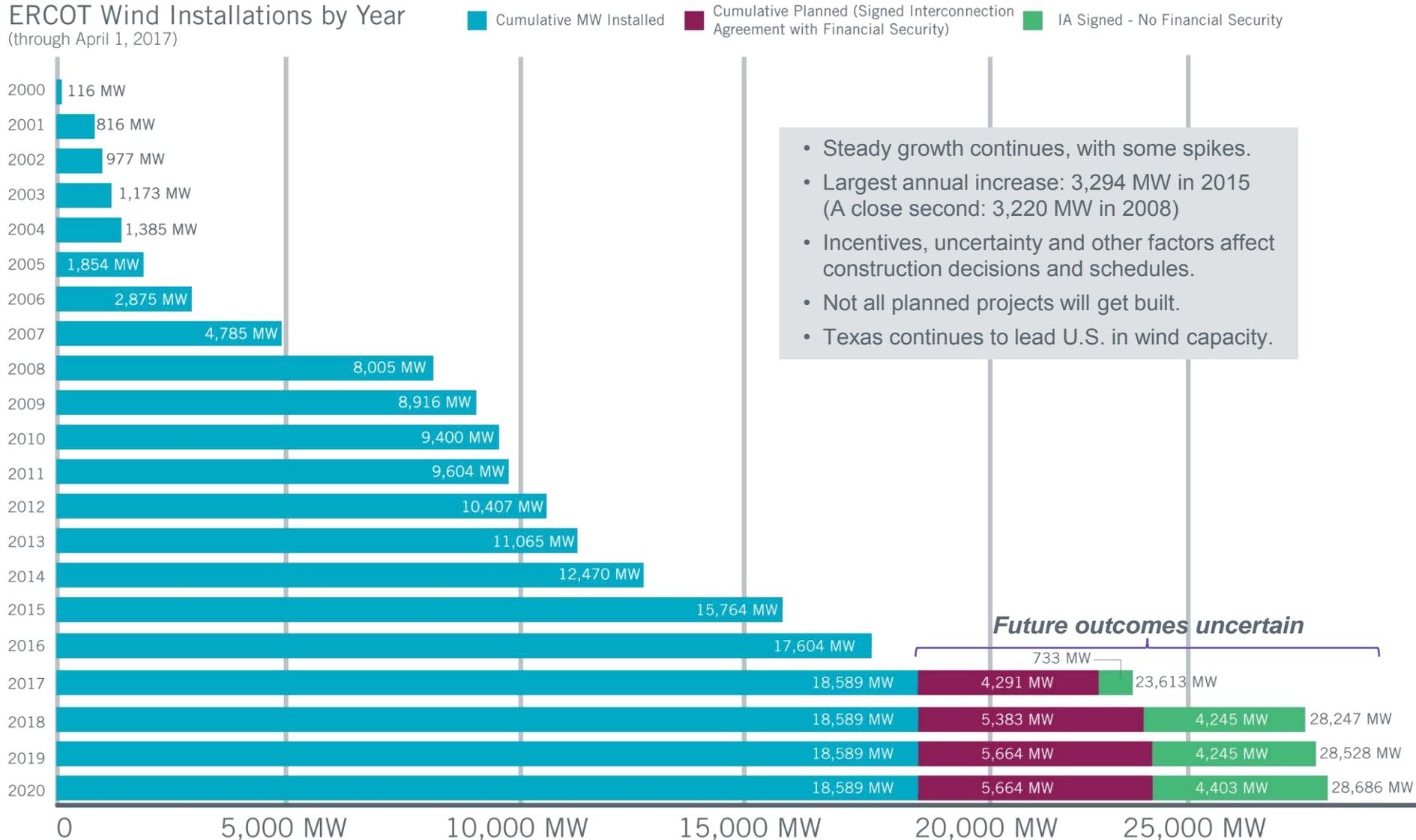
- July: 67,650 MW (July 30, 4-5 p.m.)

Changing Resource Mix – Installed Capacity



Wind Generation Capacity – March 2017

ERCOT Wind Installations by Year
(through April 1, 2017)



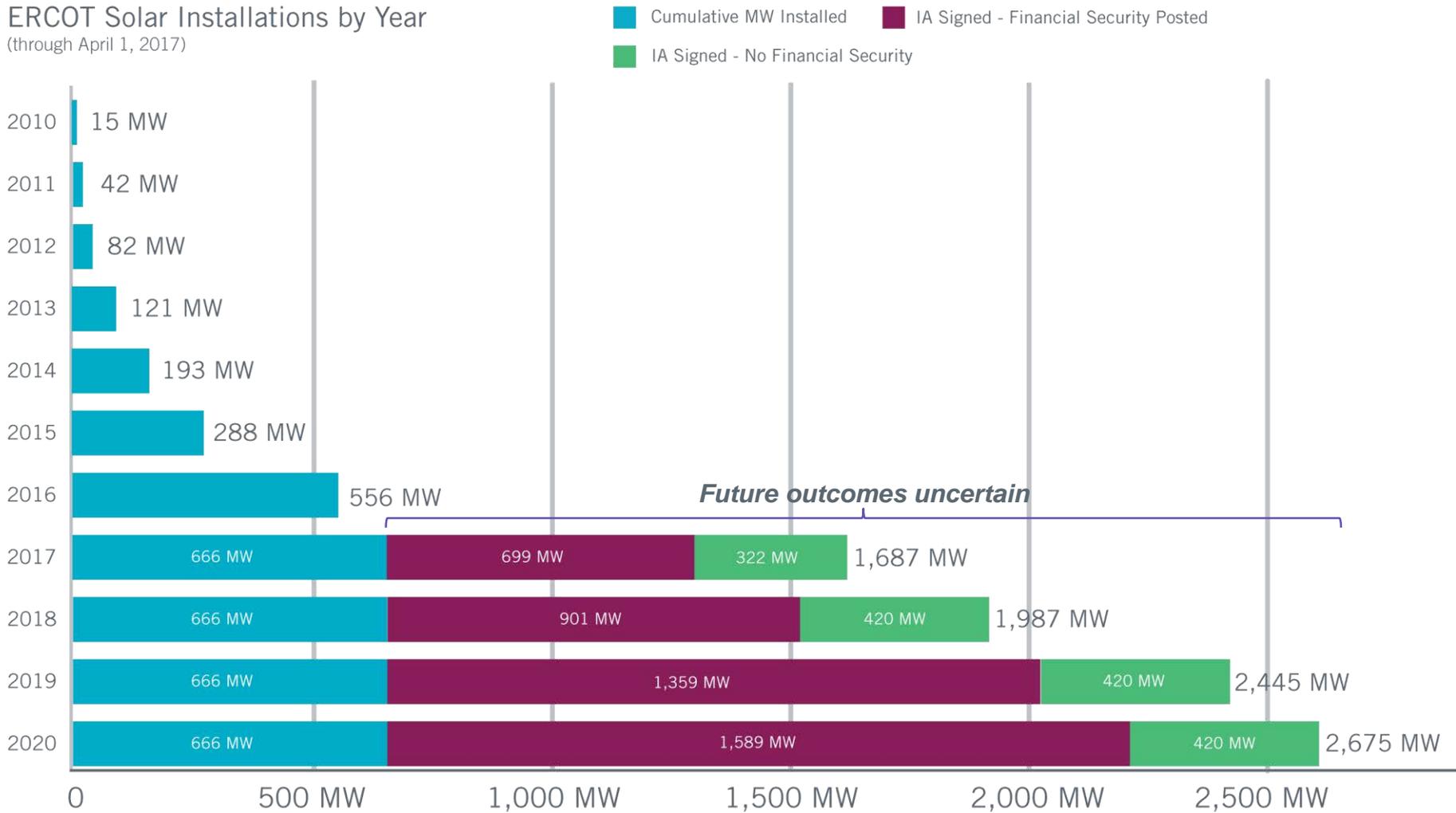
- Steady growth continues, with some spikes.
- Largest annual increase: 3,294 MW in 2015 (A close second: 3,220 MW in 2008)
- Incentives, uncertainty and other factors affect construction decisions and schedules.
- Not all planned projects will get built.
- Texas continues to lead U.S. in wind capacity.

Future outcomes uncertain



Utility Scale Solar Generation Capacity – March 2017

ERCOT Solar Installations by Year
(through April 1, 2017)

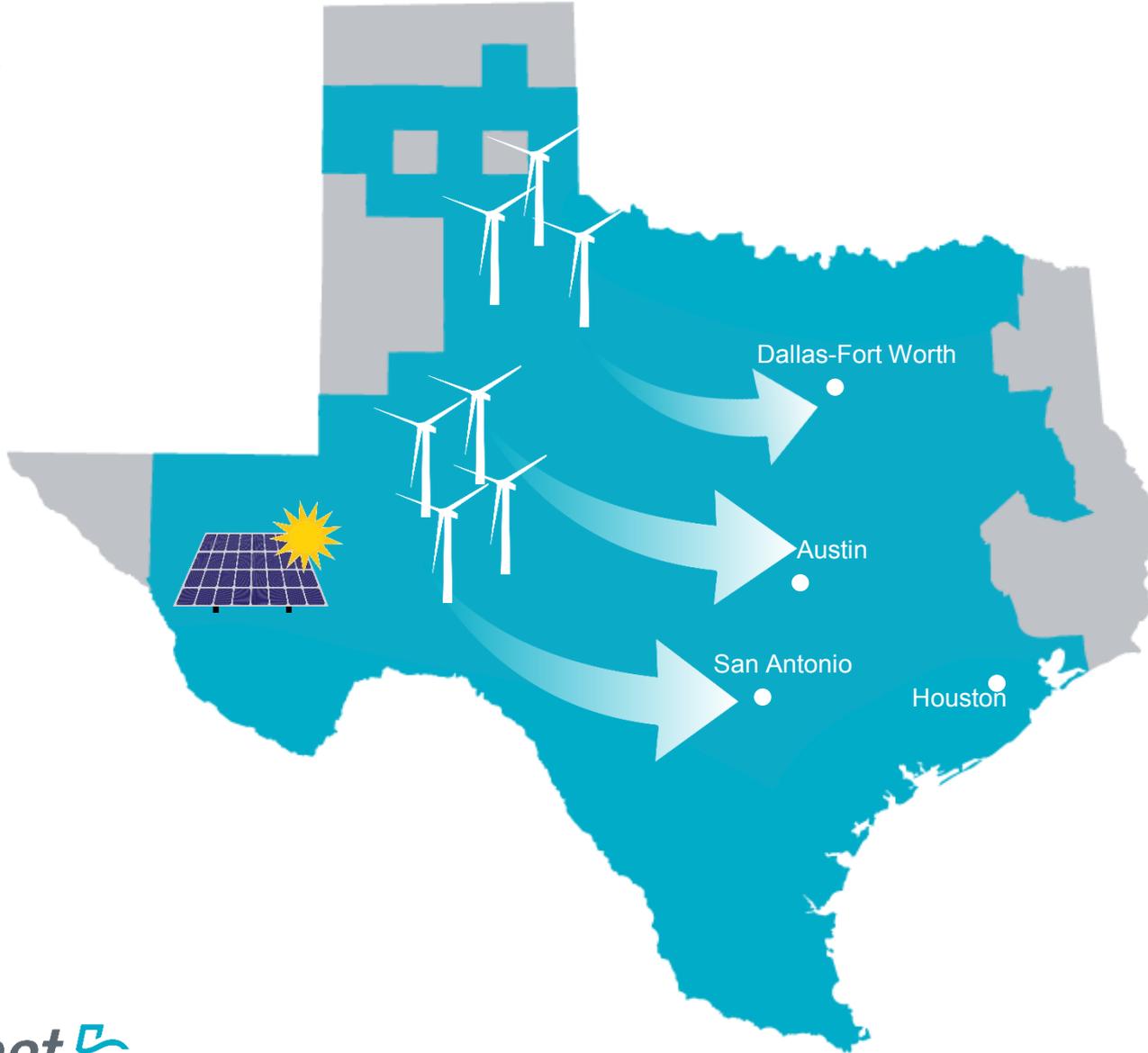


The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information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



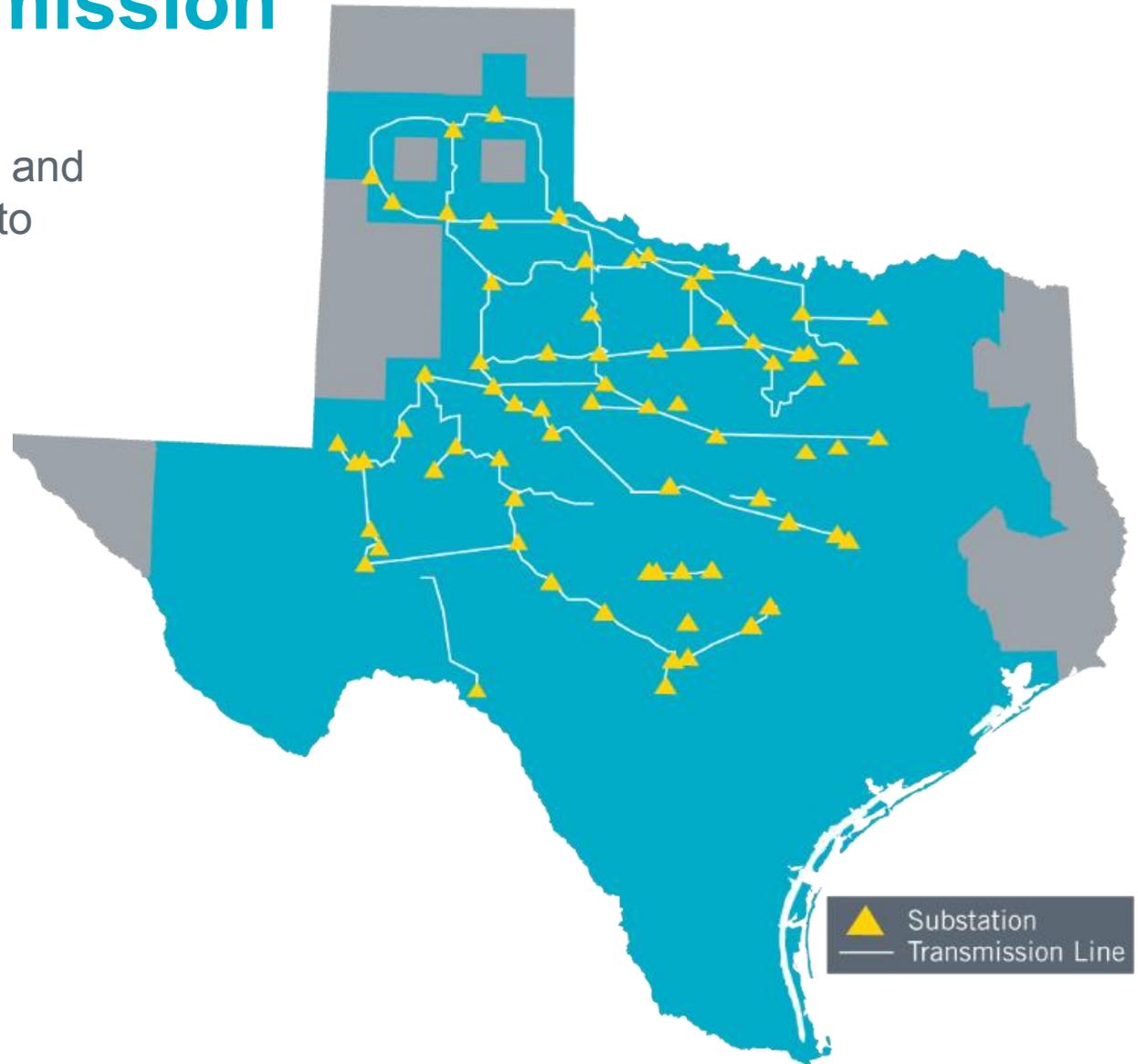
BUILDING TRANSMISSION NETWORKS

Moving Wind Energy from the West to East

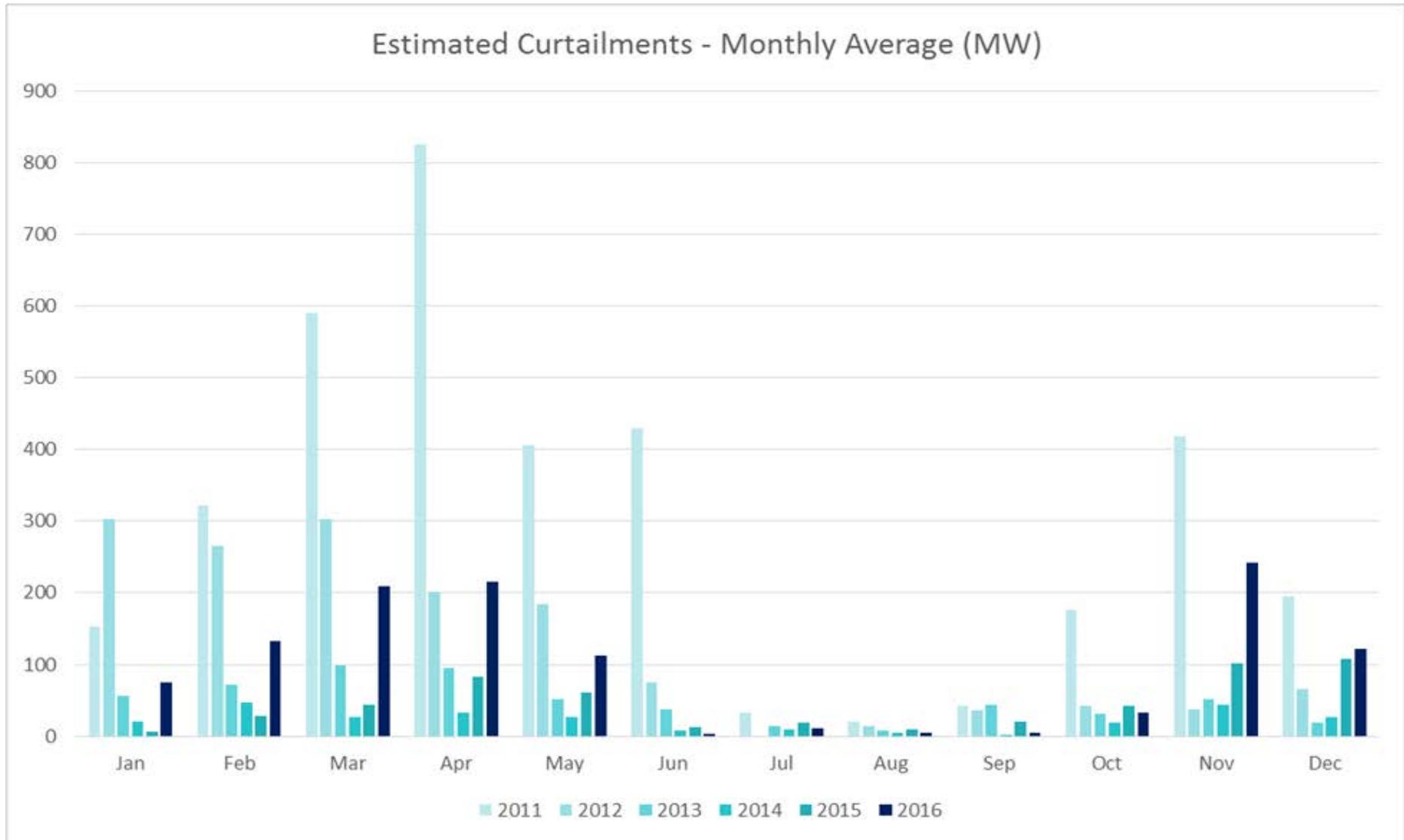


CREZ Transmission

Connecting West Texas and Panhandle wind power to the ERCOT grid



Estimated Curtailment – Monthly Average



ENHANCING GRID RESILIENCY

DEVELOPING ROBUST GRID CODES

Interconnection Requirements

INTERCONNECTION REQUIREMENTS

Frequency
Response

Voltage
Ride-through

Voltage
Support

Ramp Rate
Limitation

SYSTEM IMPACTS

Primary
Frequency
Control

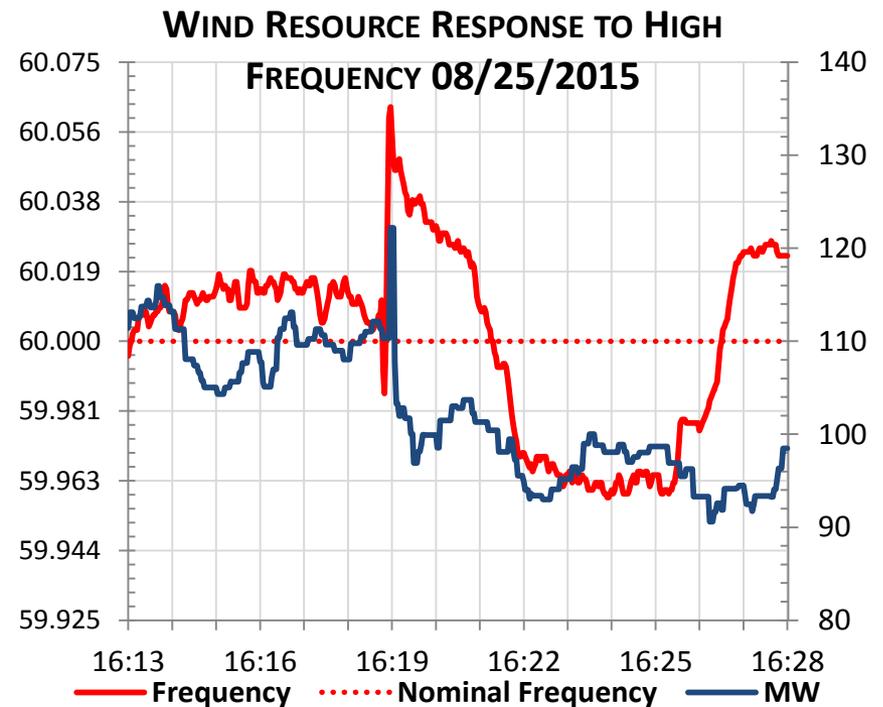
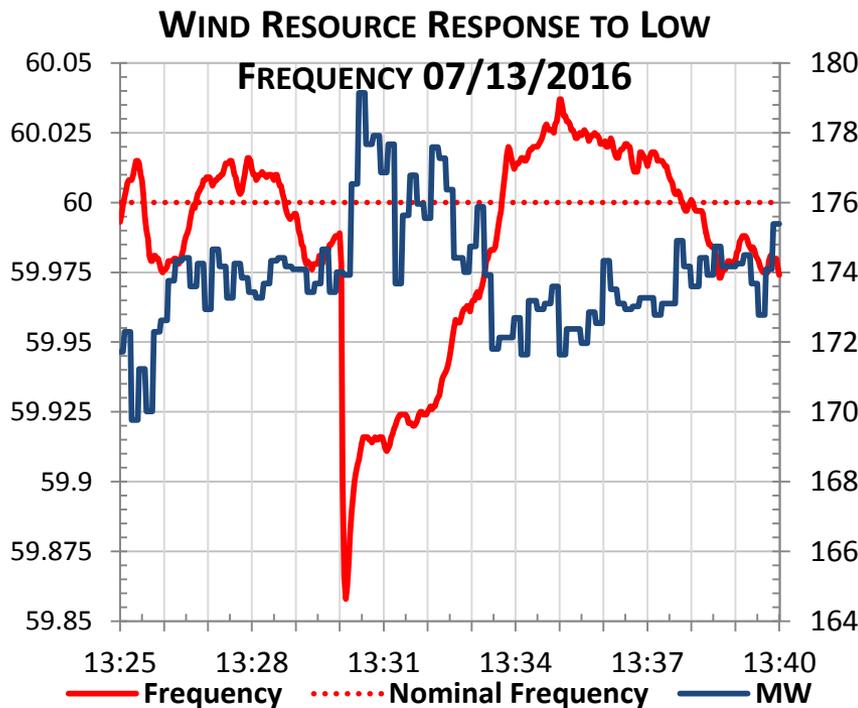
Secondary
Frequency
Control

Short Circuit
Ratio

Large
Ramps

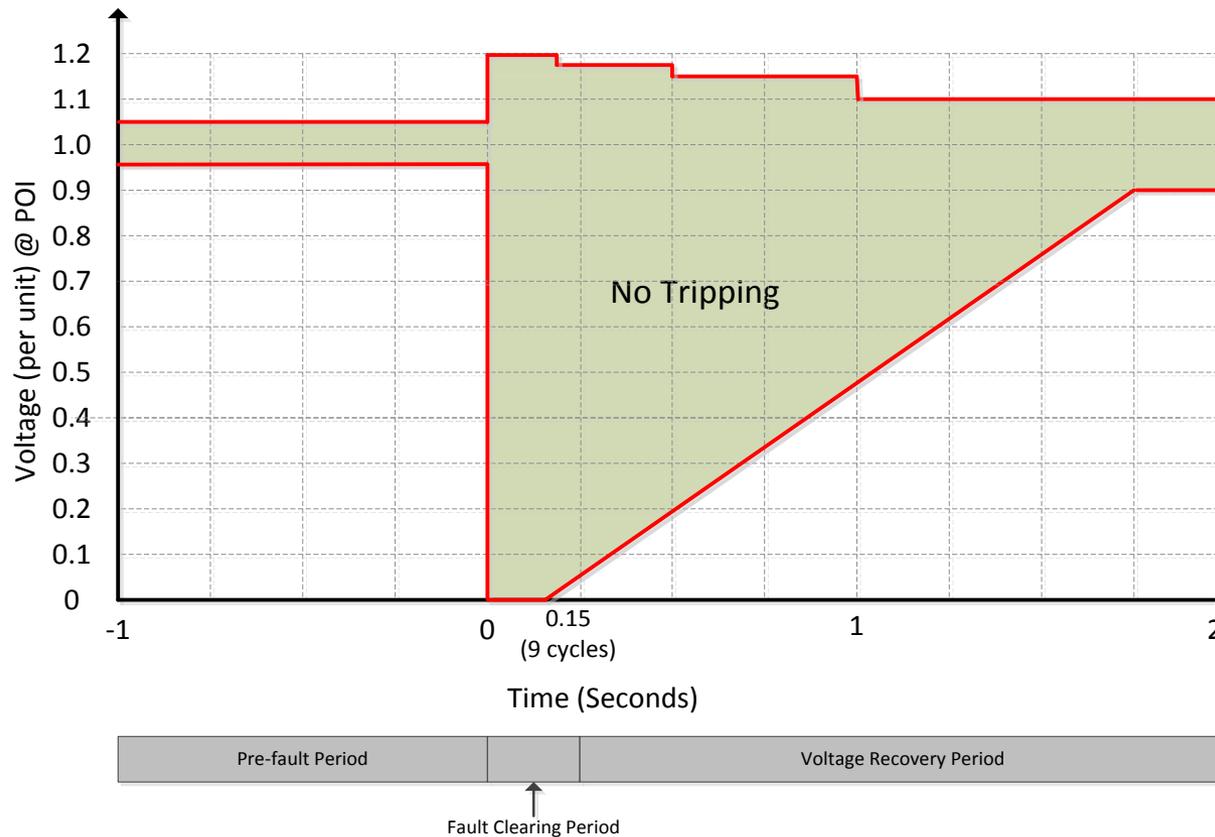
Frequency Control

- Renewable resources are required to assist in ERCOT's frequency control and provide a "governor-like" response (Primary Frequency Response) to frequency deviations.
 - Implemented NERC's BAL-001-TRE regional standard in 2015 which has reduced the Governor Dead-band for most resources including renewables from 36 mHz to 17 mHz.



Disturbance Ride Through

- Renewable resources are required to ride through i.e. stay online during abnormal disturbances in voltage and frequency.



Voltage Support Service

- Renewable resources that have an aggregated gross rating > 20MVA are required to provide Voltage Support.
- Renewable resources are required too have reactive power capability at all MW output levels at or above 10% of nameplate capacity.
 - Reactive Power profile is depicted graphically as a rectangle ((+/-) 0.328 * HSL)
 - This requirement can be met through a combination of the unit's dynamic leading/lagging capability and/or dynamic VAr capable devices.

3.15 Voltage Support

Each Generation Resource required to provide VSS shall comply with the following Reactive Power Requirements:

- a) An over-excited (lagging or producing) power factor capability of 0.95 or less determined at the generating unit's maximum net power to be supplied to the ERCOT Transmission Grid and the Generation Resource's set point in the Voltage Profile measured at the POI;
- b) An under-excited (leading or absorbing) power factor capability of 0.95 or less, determined at the generating unit's maximum net power to be supplied to the ERCOT Transmission Grid and the Generation Resource's set point in the Voltage Profile measured at the POI;
- c) Reactive Power capability shall be available at all MW output levels and may be met through a combination of the Generation Resource's Unit Reactive Limit (URL), which is the generating unit's dynamic leading and lagging operating capability, and/or dynamic VAr capable devices. This Reactive Power profile is depicted graphically as a rectangle. For Intermittent Renewable Resources (IRRs), the Reactive Power requirements shall be available at all MW output levels at or above 10% of the IRR's nameplate capacity. When an IRR is operating below 10% of its nameplate capacity and is unable to support voltage at the POI, ERCOT may require an IRR to disconnect from the ERCOT System for purposes of maintaining reliability

Ramp Rate Limitation

- Renewable resources are required to implement controls which limit per minute ramping to 20% of the unit's nameplate rating.

6.5.7.10 Intermittent Renewable Resource Ramp Rate Limitations

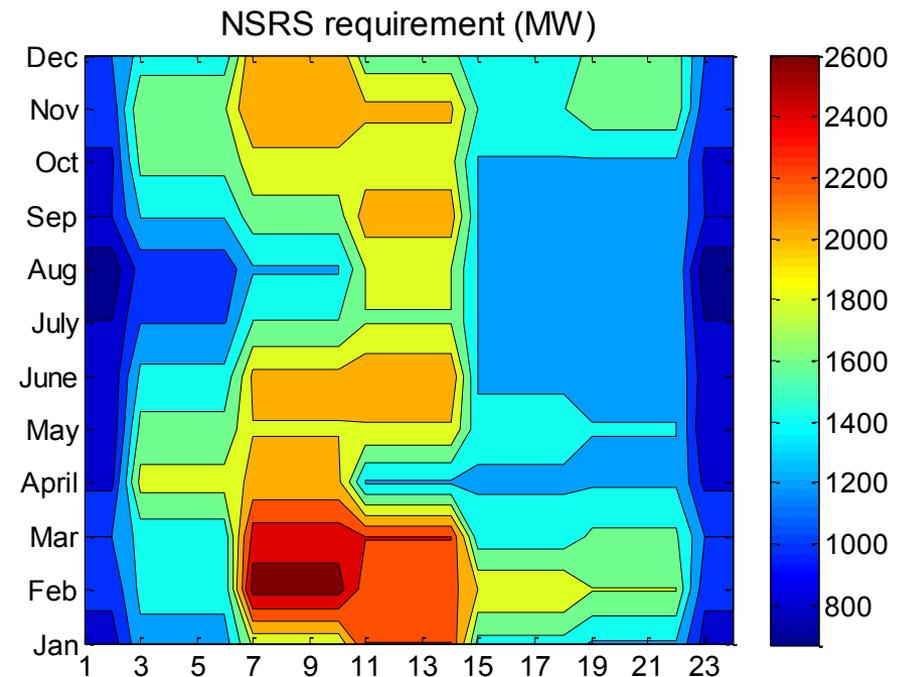
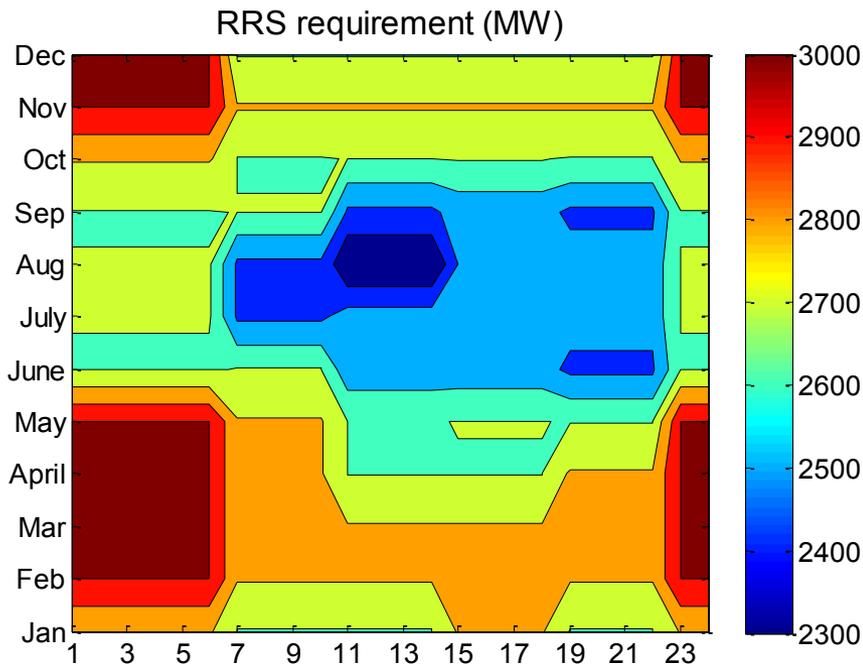
- 1) Each Intermittent Renewable Resource (IRR) that is part of a Standard Generation Interconnection Agreement (SGIA) signed on or after January 1, 2009 shall limit its ramp rate to **20% per minute of its nameplate rating (MWs)** as registered with ERCOT when responding to or released from an ERCOT deployment.
- 2) The requirement of paragraph (1) above does not apply during a Force Majeure Event or during intervals in which a decremental deployment instruction coincides with a demonstrated decrease in the available IRR.
- 3) Each IRR that is part of an SGIA signed on or before December 31, 2008 and that controls power output by means other than turbine stoppage shall limit its ramp rate to 20% per minute of its nameplate rating (MWs) as registered with ERCOT when responding to or released from an ERCOT deployment.

ENHANCING GRID RESILIENCY

**REFINING RESERVE DETERMINATION
METHODOLOGIES**

Ancillary Service Methodology

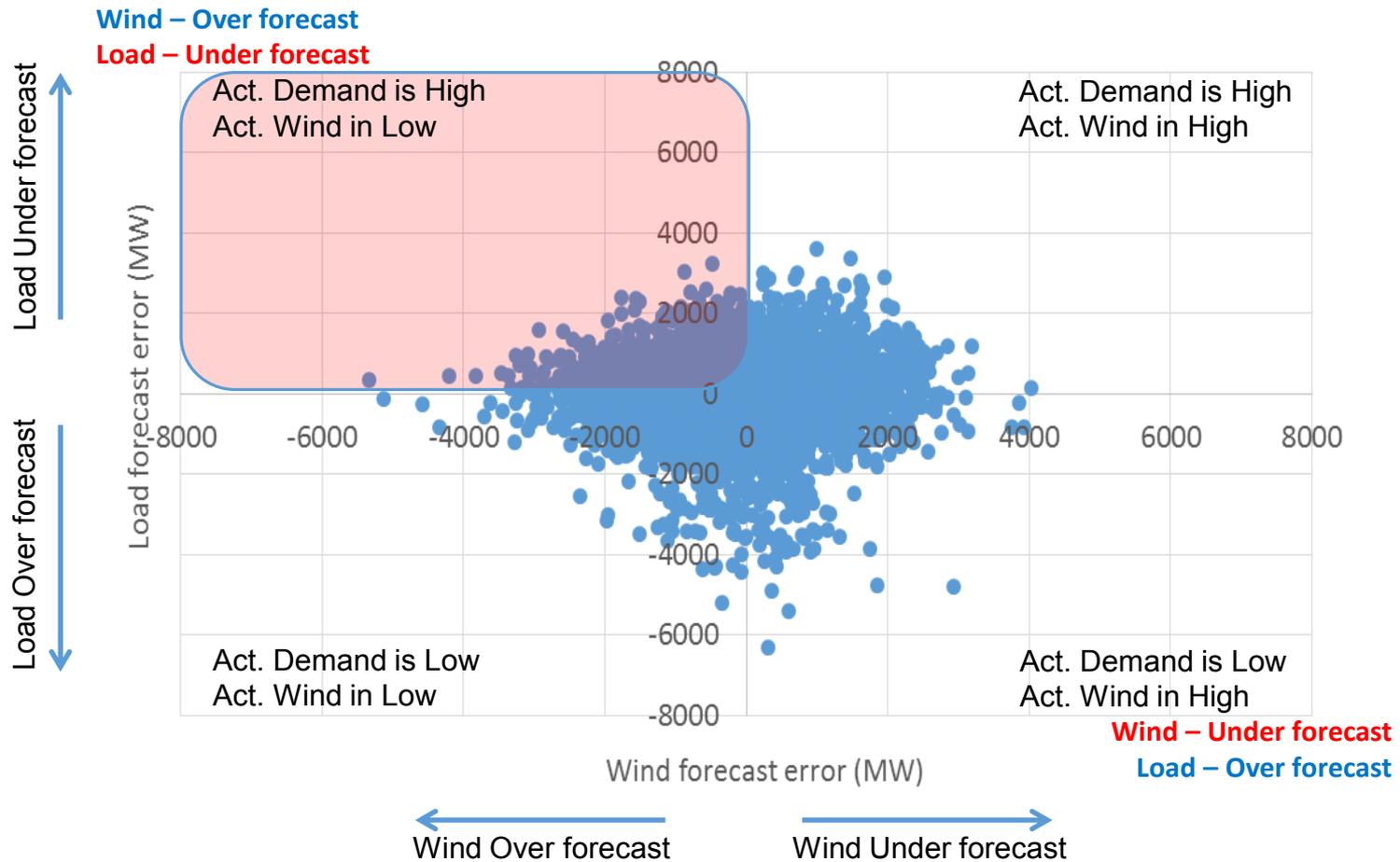
- Several changes have been made to methodology for determining reserves
 - Since 2017, Regulation Service is procured based on **historical variability of wind & solar**.
 - Since 2015, Responsive Reserve Service is procured based on **expected system inertia**.
 - Since 2016, Non-Spin Reserve Service is procured based on **risk of net load (load - wind) ramp and net load forecast error**.



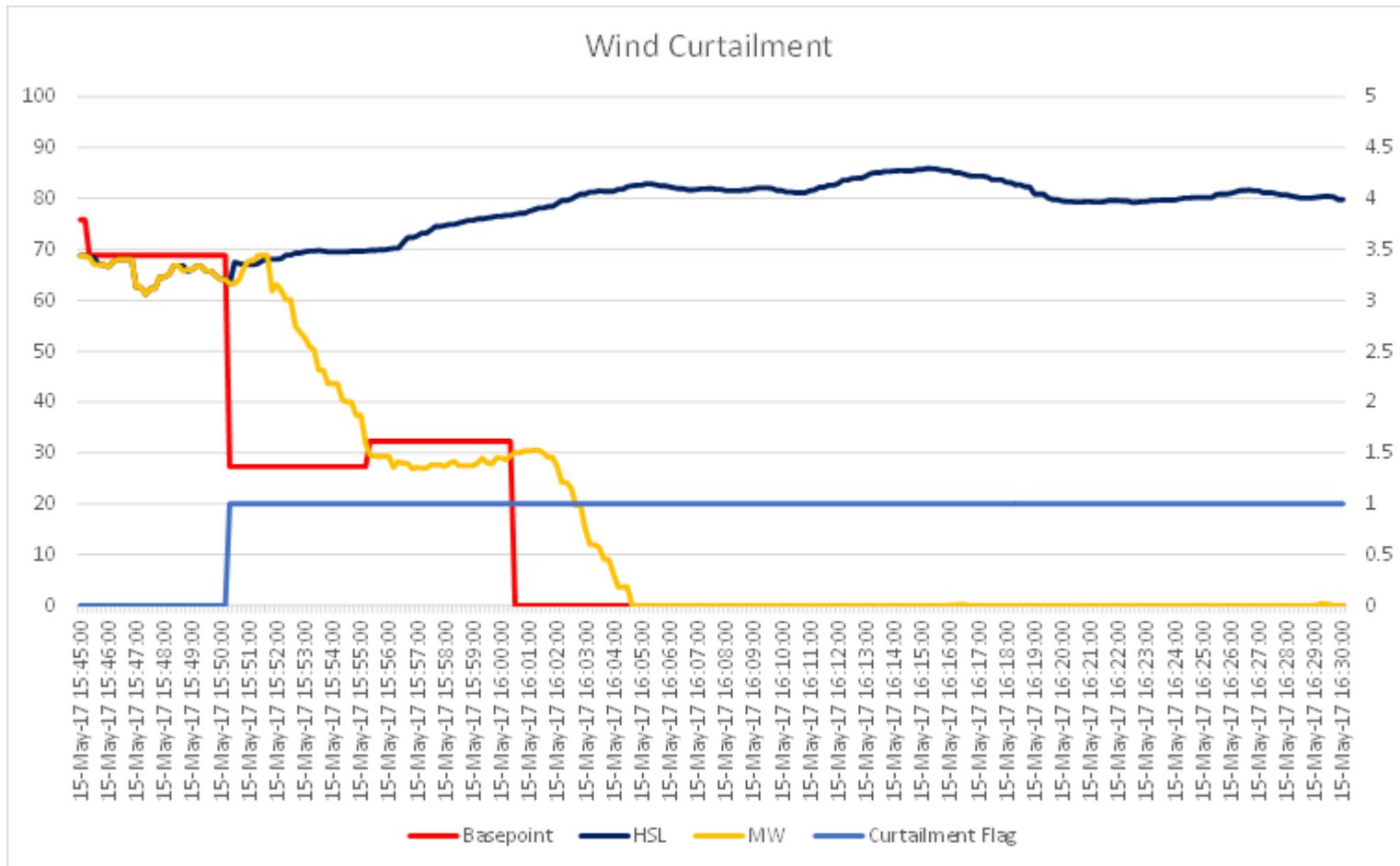
Responsive Reserves

- Responsive Reserves are procured to ensure sufficient capacity is available to respond to frequency disturbances due to unit trips
- ERCOT procures RRS to avoid triggering UFLS at 50.30 Hz for loss of two largest generators (2,750 MW).
 - Capacity reserved from generators to provide Primary Frequency Response (PFR)
 - ❑ Response must be proportional to frequency deviation using a droop setting no greater than 5%.
 - Up to 50% of Responsive requirement can be provided by Load Resources on under-frequency relays
 - ❑ Full response within 30 cycles

3-hour-ahead Forecast Error in 2016



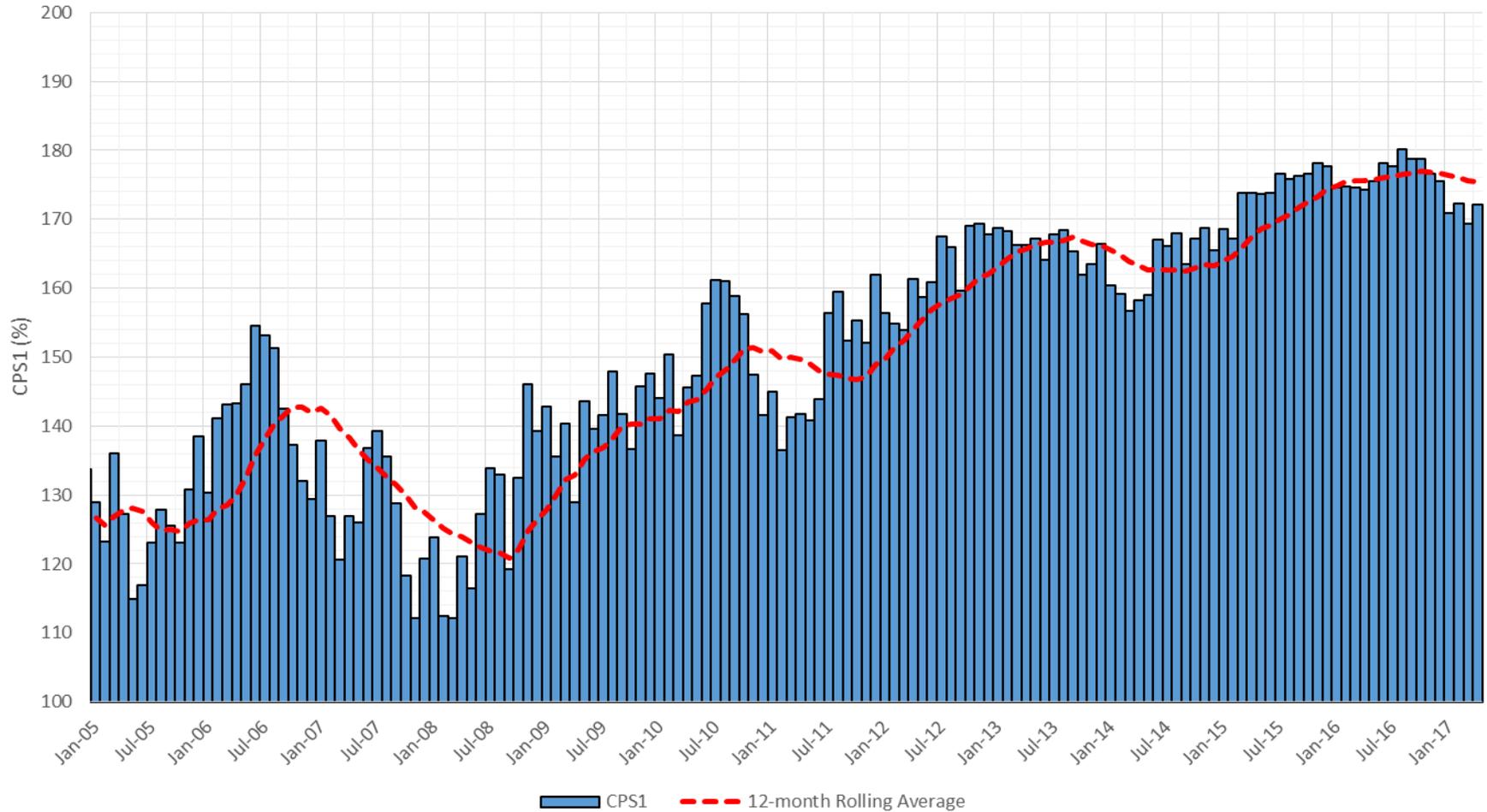
Real Time Curtailment of a WGR



Frequency Control & CPS1 Score

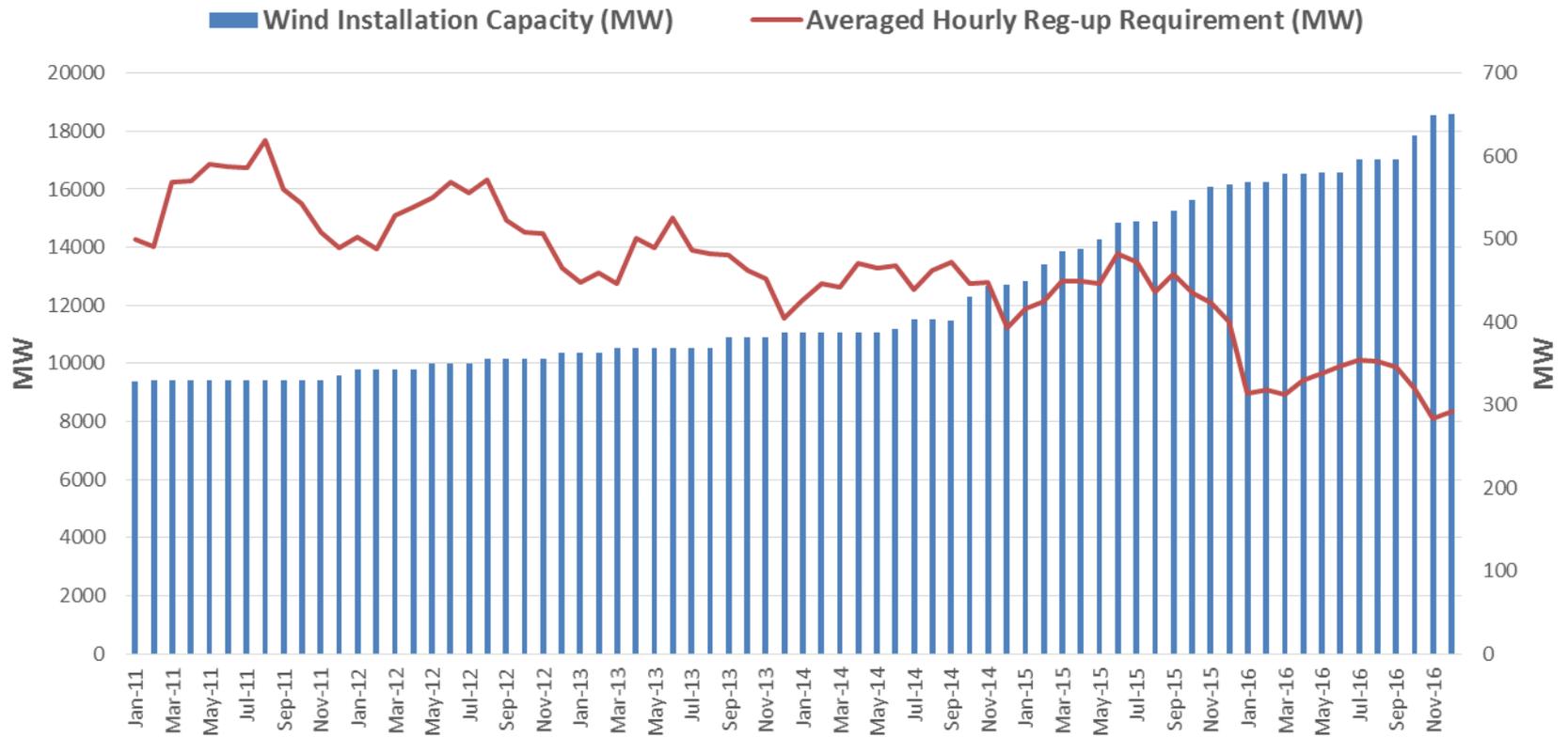
CPS1 12 Month Rolling Average = 175.47%

ERCOT CPS1 12-month Rolling Average



Wind Installed Capacity vs. Reg-Up Requirement

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



Reliability Risk Desk Goals

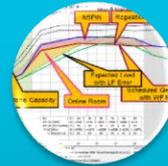
- Facilitate improved accuracy of renewable forecasts
 - Promote improved telemetry performance from wind/solar plants
 - Perform forecast adjustments during icing and other extreme weather events
- Maintain sufficient frequency responsive reserves
 - Confirm critical level of inertia is online
 - Ensure frequency responsive capacity is available to cover actual inertia conditions
- Maintain sufficient temporally available capacity to cover remaining forecast errors and net load ramps



1. Renewable Forecast and Extreme Weather Monitoring



2. Inertia Monitoring and RRS Sufficiency



3. Forecast Error Risk and NSRS Sufficiency



4. Intra-Hour Resource Monitoring

QUESTIONS?