# Integration of Renewable Generation in ERCOT

**Julia Matevosyan**
Lead Planning Engineer,
Resource Adequacy

**North European Energy Perspectives**
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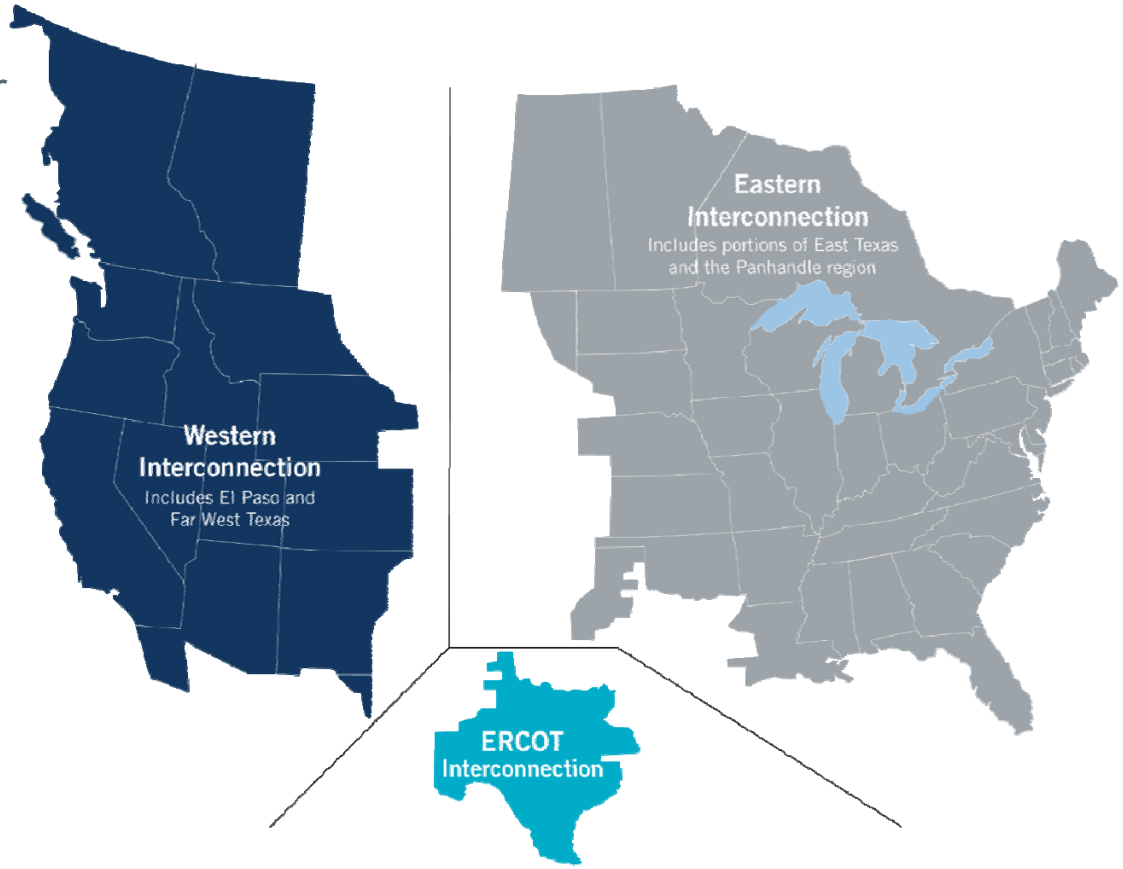
# Outline

- ERCOT System and Market Overview
- Renewable Integration / Balancing Challenge
- Key Takeaways

# What is ERCOT?

Independent System Operator (ISO) assigned with 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.

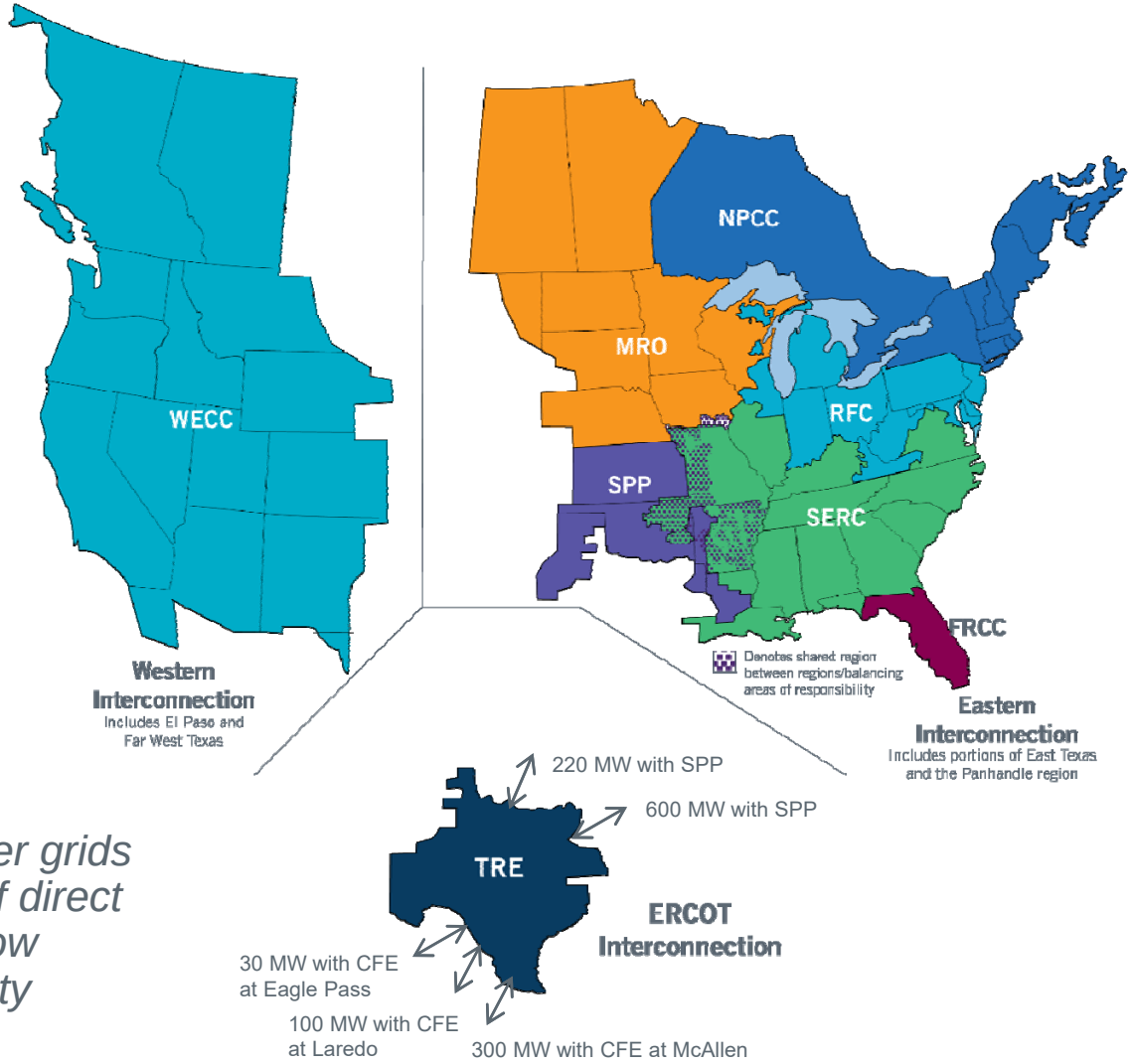
ERCOT is not a market participant and does not own generation or transmission/distribution wires.

# The ERCOT Region

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

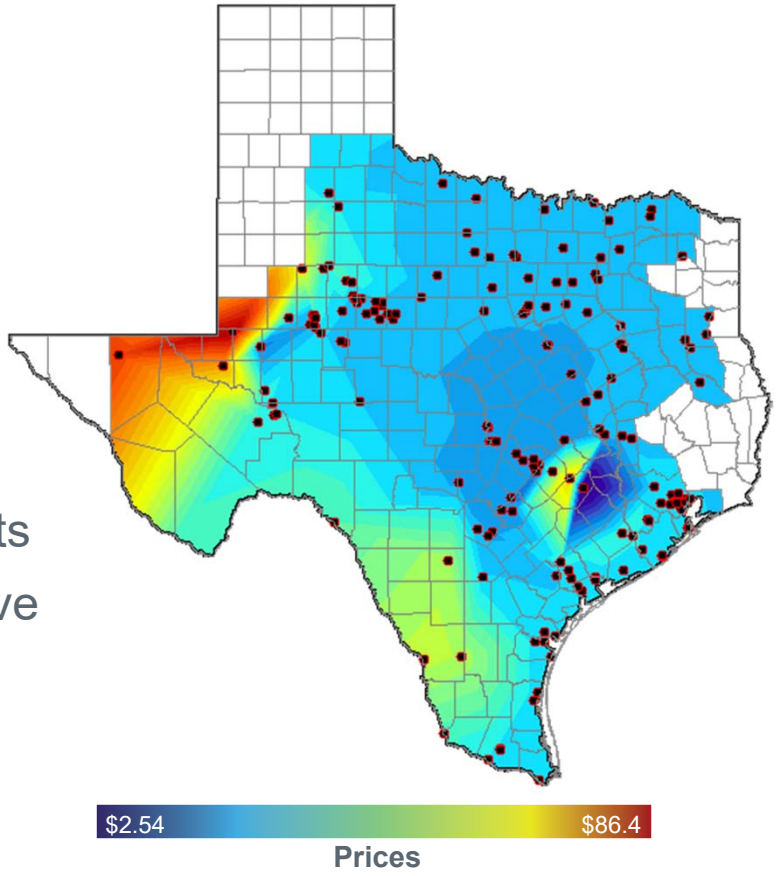
- 90% of Texas electric load; 75% of Texas land
- 71,110 MW peak, August 11, 2016
- More than 46,500 miles of transmission lines
- 570+ generation units

*ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over flow of electricity*



# Energy Market Construct

- No capacity market; $9000 price cap, with operating reserve scarcity adder
- Generator self-commitment; ERCOT makes residual reliability commitments
- Voluntary Day-Ahead Market (DAM); ancillary services procured in DAM, co-optimized with energy
- In Real- Time Market all generators (including renewables) submit offers for generation output
- Real-Time market clears every five minutes, using generation with the lowest bids to serve the load, subject to unit operational and transmission constraints
- All generators (including renewables) receive output level instructions and locational marginal prices



# 2017 Generation Capacity and Energy Use


## 2017 Generation Capacity

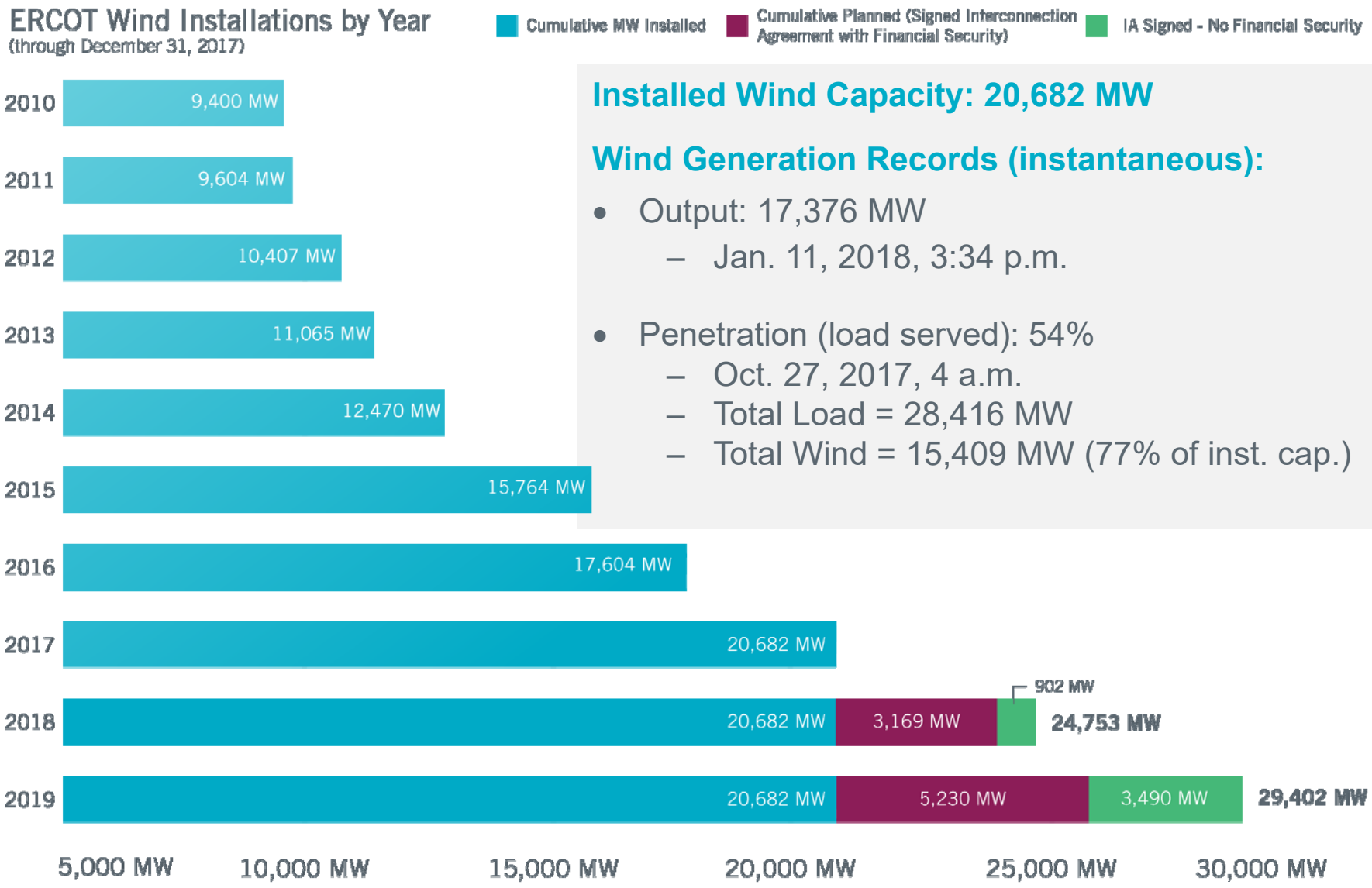
*Includes hydro and biomass


## 2017 Energy Use

357 billion kilowatt-hours of energy used in 2017. 1.6 percent more than 2016.

*Includes solar, hydro, petroleum coke, biomass, landfill gas, distillate fuel oil, net DC Tie and Block Load Transfer imports/exports, and an adjustment for Wholesale Storage Load

# Wind Generation Capacity – December 2017

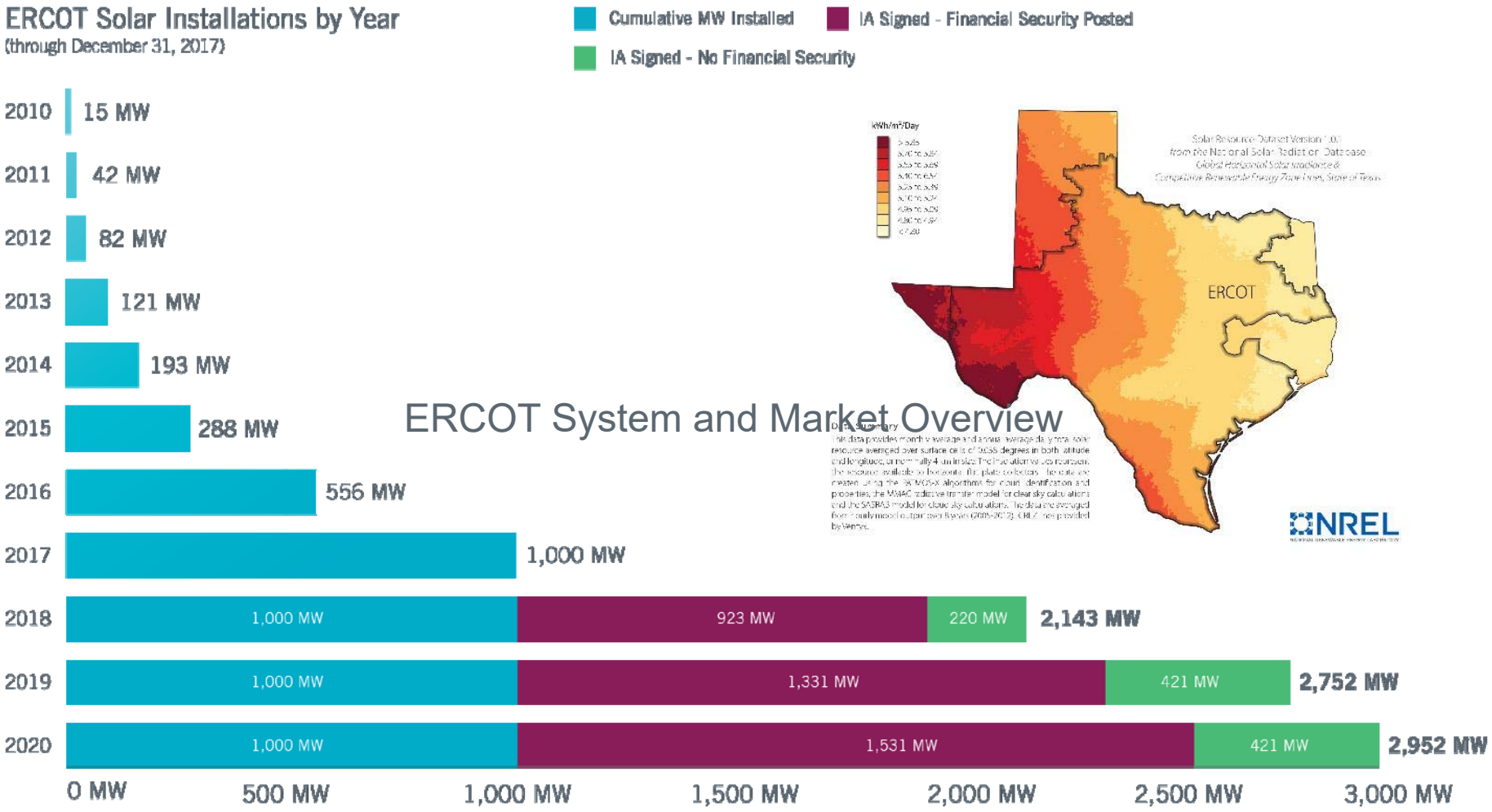



## Installed Wind Capacity: 20,682 MW

## Wind Generation Records (instantaneous):

- Output: 17,376 MW
  - Jan. 11, 2018, 3:34 p.m.
- Penetration (load served): 54%
  - Oct. 27, 2017, 4 a.m.
  - Total Load = 28,416 MW
  - Total Wind = 15,409 MW (77% of inst. cap.)

# Utility Scale Solar Generation Capacity – December 2017

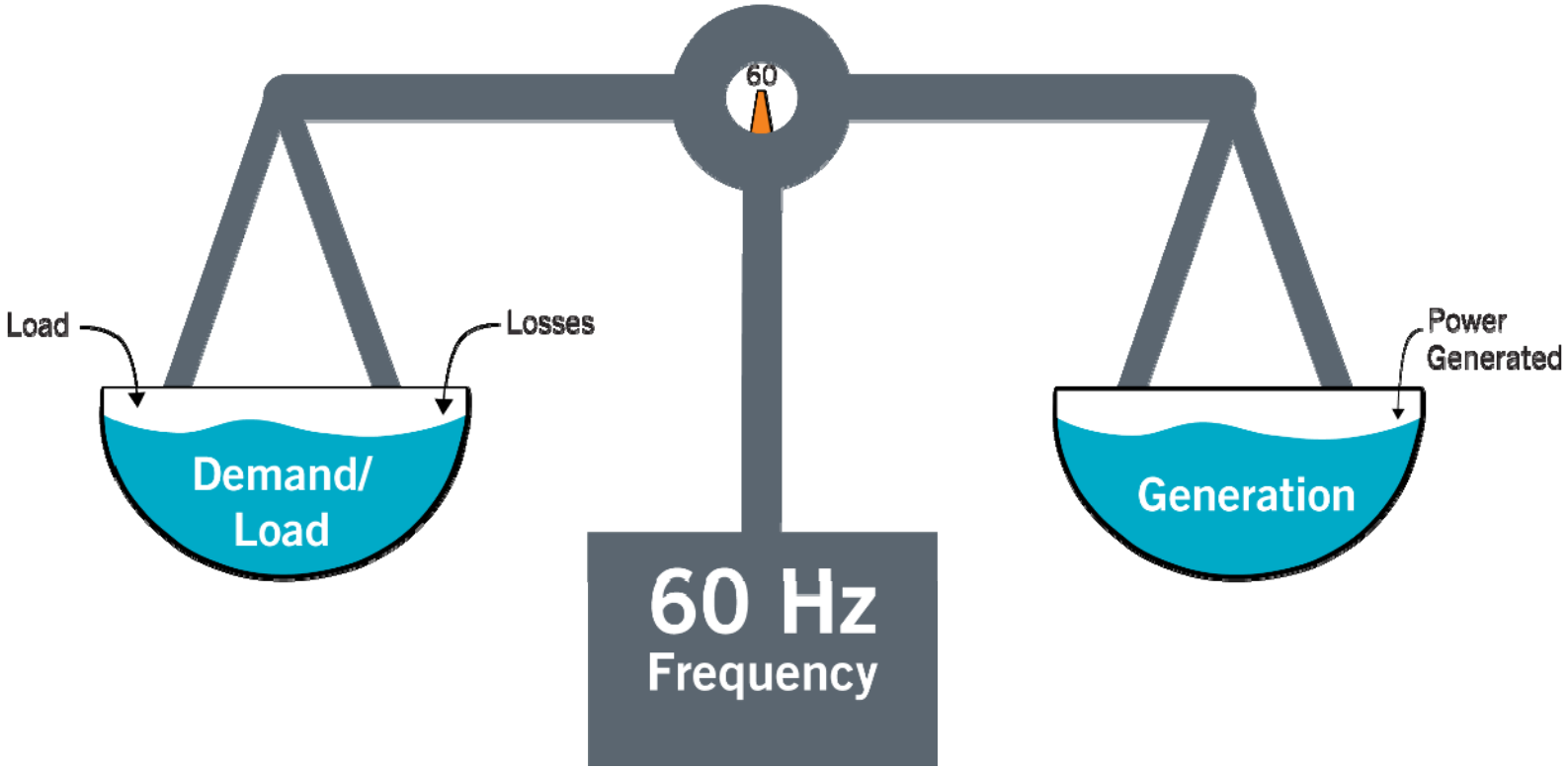



ERCOT System and Market Overview

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.

# Power Generation Must Match Power Demand

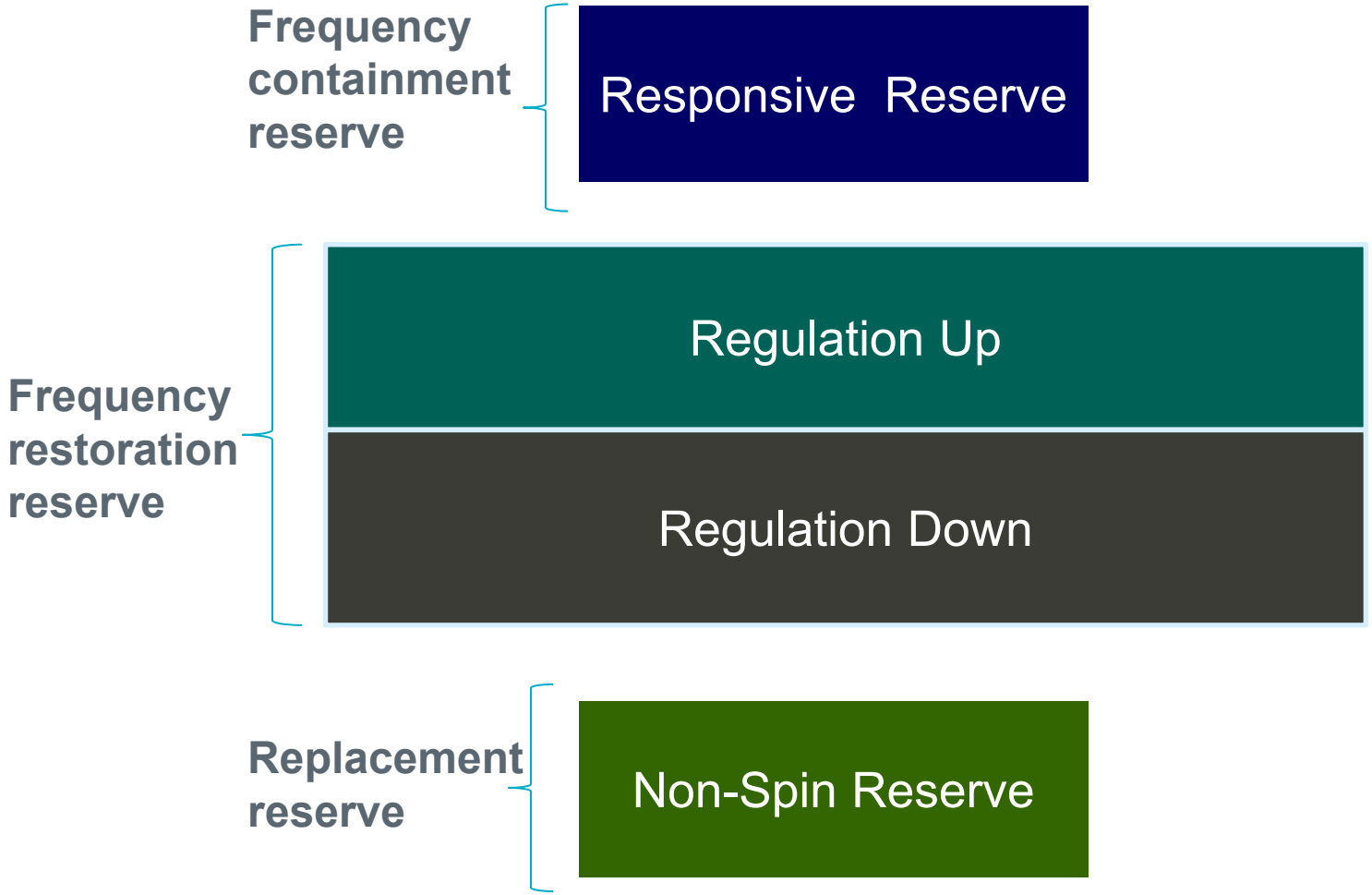
- The fundamental concept behind ERCOT operations is that generation has to match load at all times



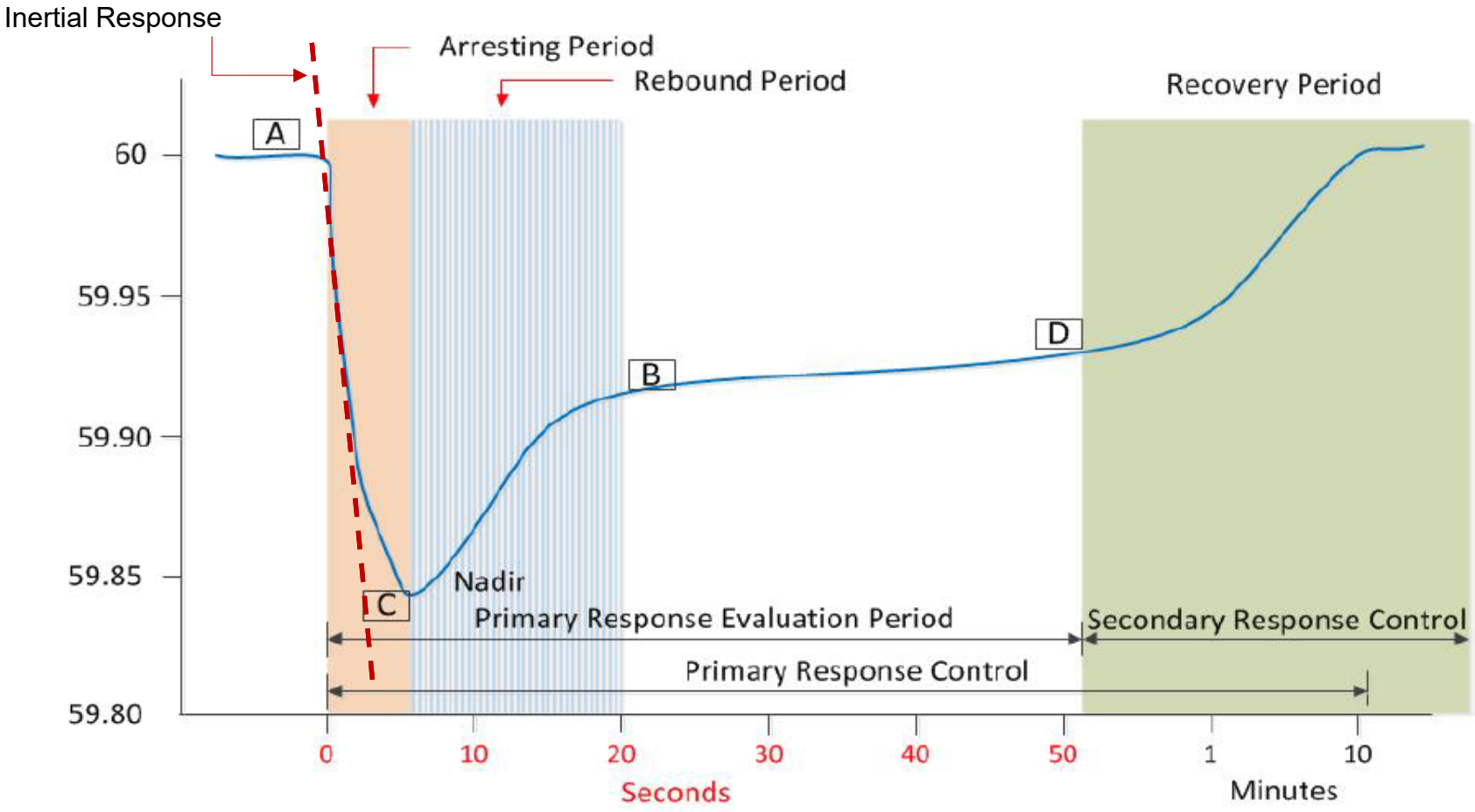
# Challenges of keeping balance with high amounts of wind and solar generation

- Frequency control with more generation from non-synchronous resources
- Variability of wind power production
- Uncertainty of wind and solar forecasts
- Wind, load and net load ramps

# Ancillary Services



# Frequency control after loss of generation



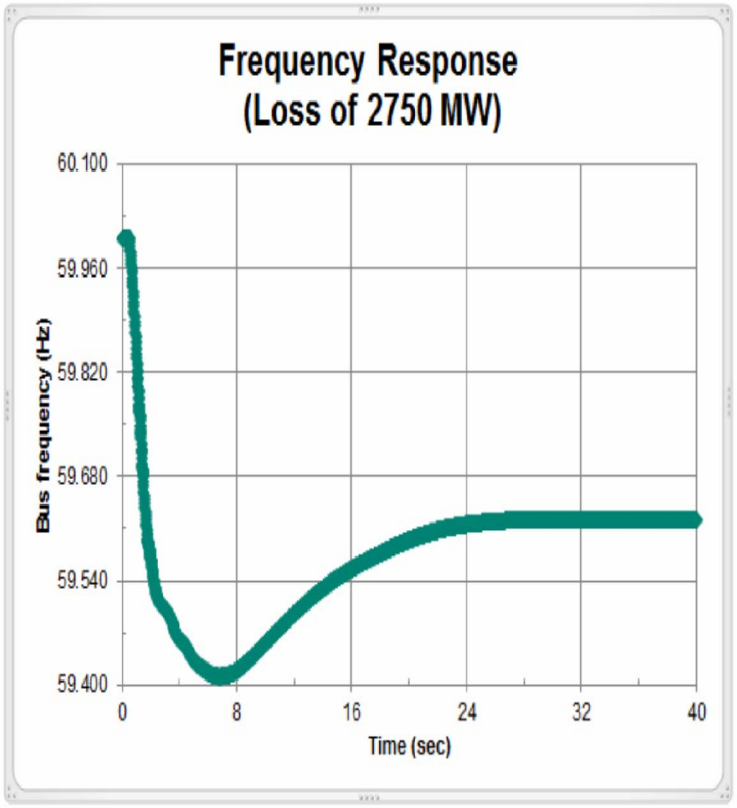
# Primary Frequency Response

- ERCOT is not synchronously interconnected with any other system, all resources have to participate in primary frequency support.
- All generators that are online (except nuclear) are required to have governor in service with set droop (MW/Hz) and frequency deadband.
- From March 2012 all wind and solar generation resources are also required to have governor-like response (to overfrequency when in operation, underfrequency when under curtailment).

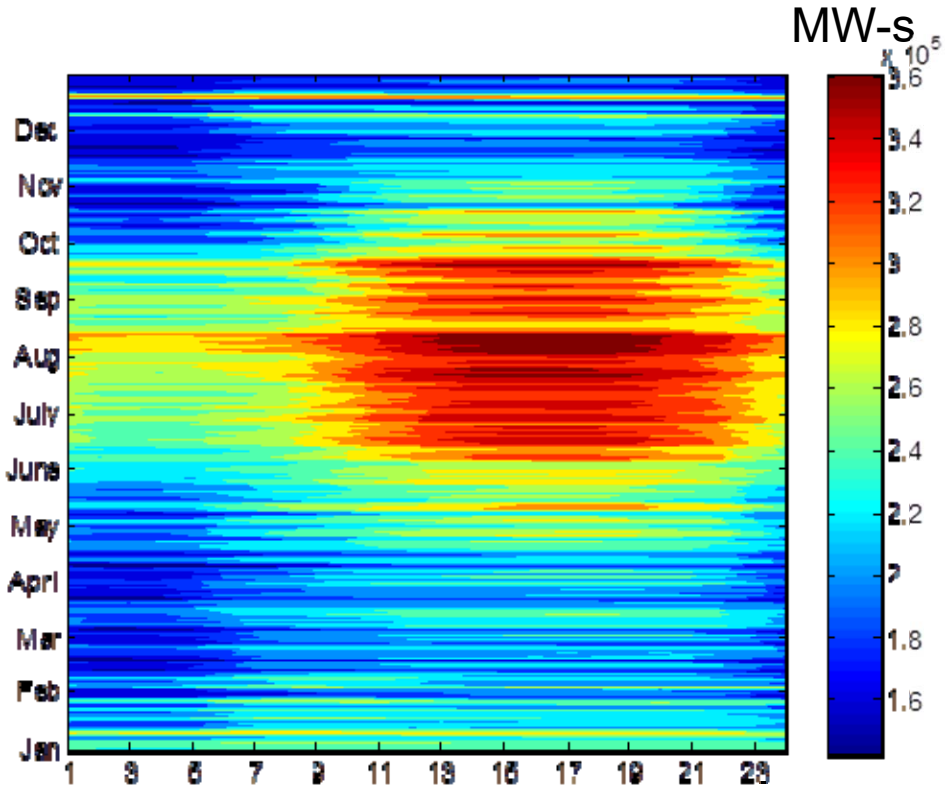
# Responsive Reserve Service (RRS)

Used to ensure sufficient capacity is available to respond to frequency excursions due to generation trips:

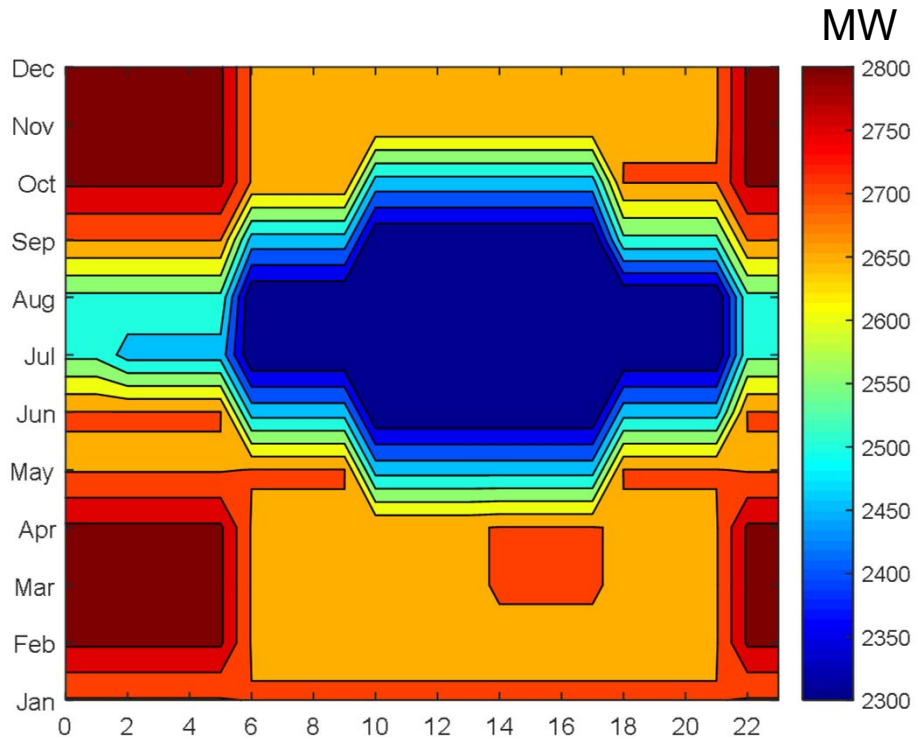
- Capacity reserved from generators to provide governor response
- Up to 50% of RRS requirement can be provided by Loads with underfrequency relays that trips at 59.7 Hz
- RRS are determined based on synchronous generation online (inertia)



# Inertia Impact on Hourly RRS Requirements



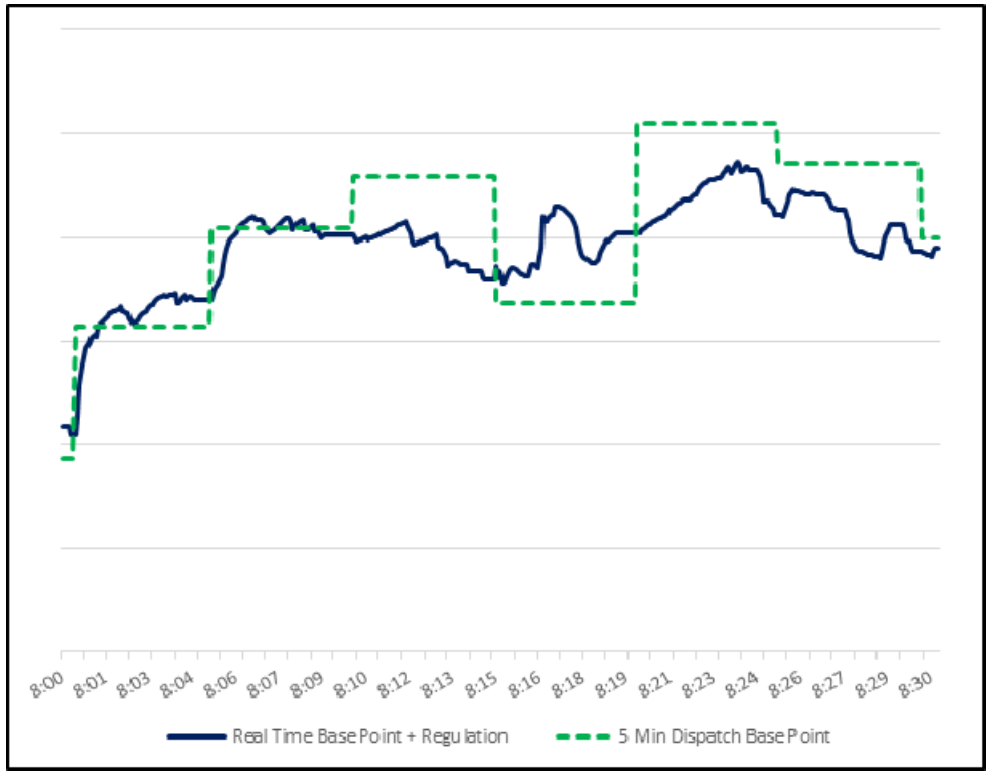

2016 Inertia Heat-Map



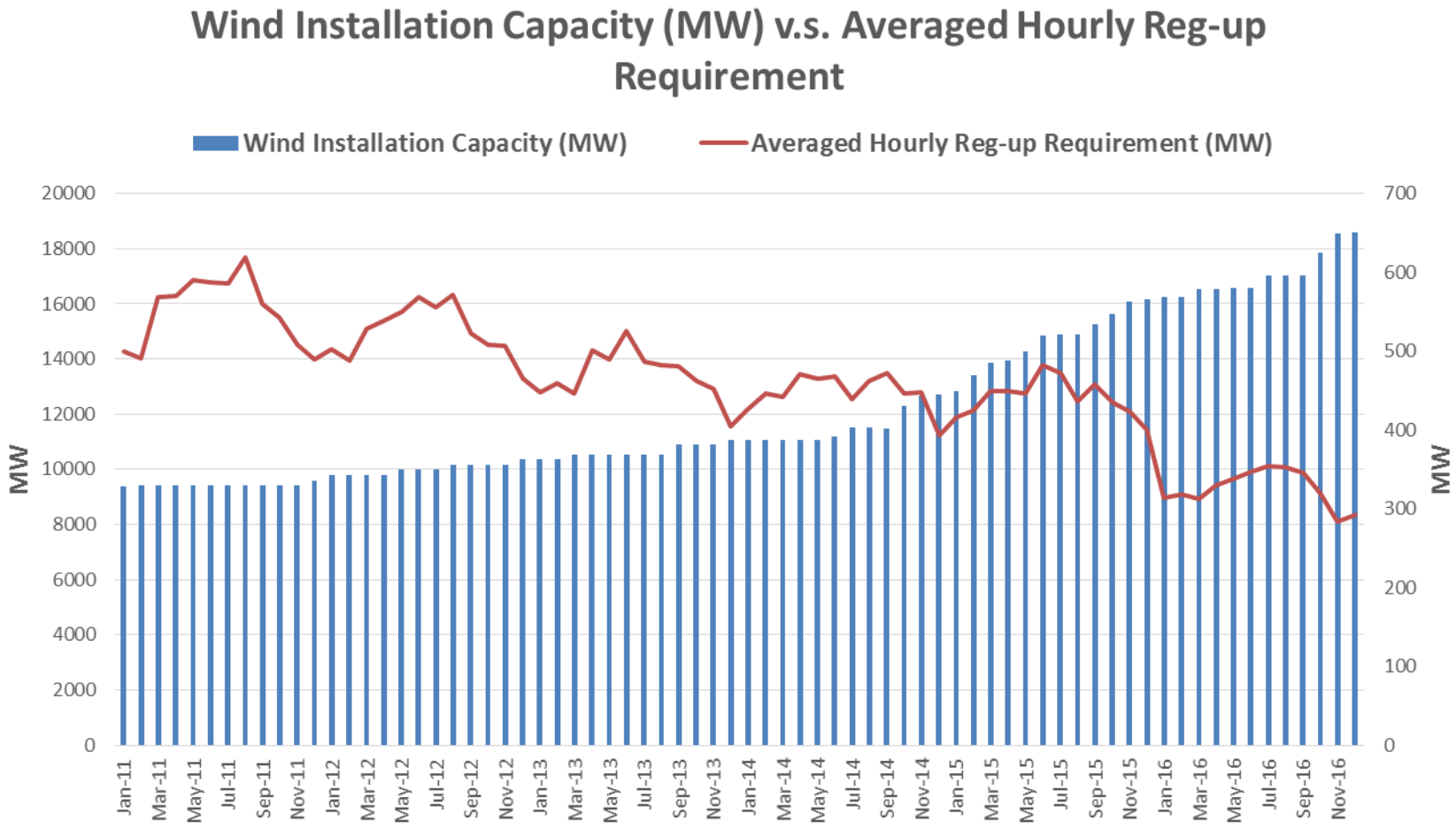

2017 Responsive Reserve Service Requirement

# Regulation (Up and Down)

- Provided from selected generators that receive AGC signal from ERCOT every 4 seconds to move up or down to maintain frequency between 5-minute dispatch intervals;
- Requirements are determined for every month every hour 1-24, based on historic 5-minute net-load variability

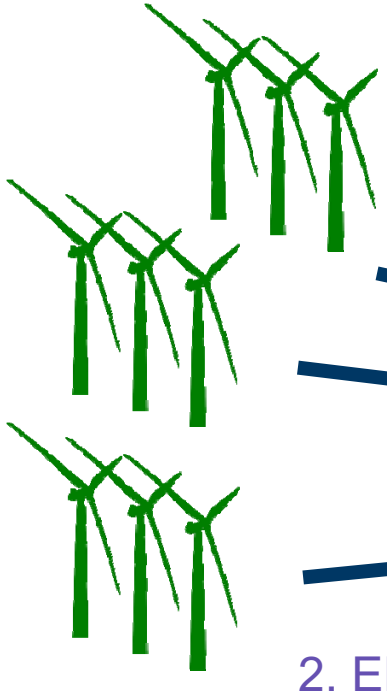


# Wind Installed Capacity vs. Regulation-Up Requirement




**As more wind has been added Regulation requirements have gone down!**

# ERCOT Wind Generation Forecast



1. Wind plants send site location, status, derate, and telemetered meterologic data to ERCOT

4. ERCOT uses 168-hour forecast to make operational decisions including unit commitment and dispatch

2. ERCOT sends information from wind plants to AWS Truepower

3. AWS Truepower computes and sends ERCOT a rolling 168-hour generation forecast for all wind plants

**AWS Truepower**

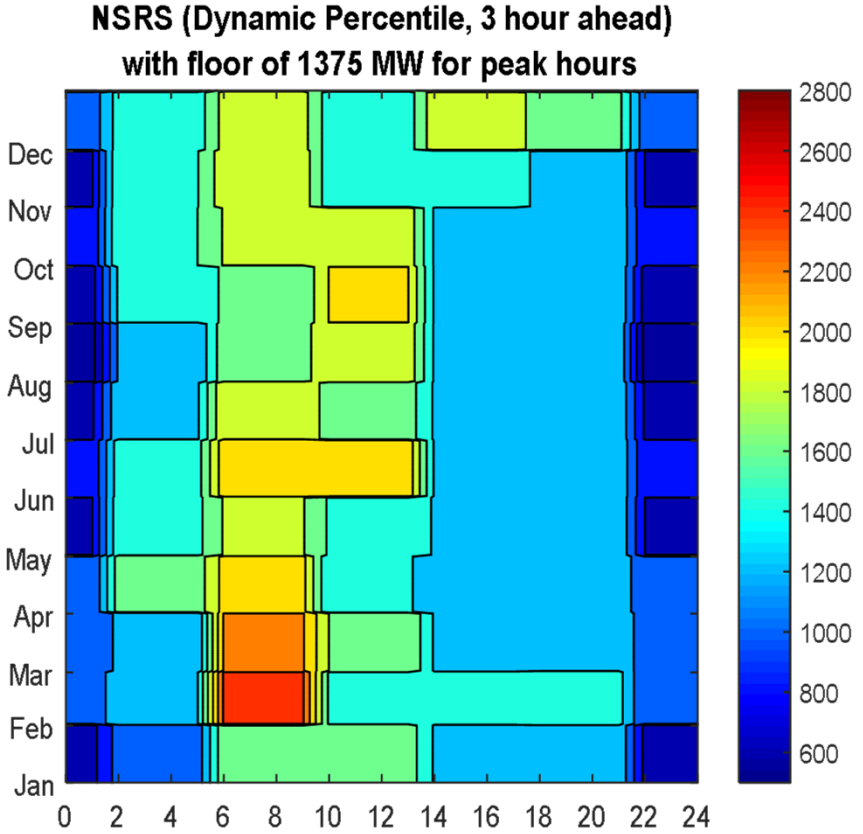
# Wind, Solar and Net Load Ramps

| | Max Ramp of Wind(MW) | Max Ramp of Load (MW) | Max Ramp of Netload (MW) |
|---|---|---|---|
| 15-min | 1333 | 2088 | 2481 |
| 60-min | 3842 | 6021 | 6853 |
| 180-min | 6659 | 14226 | 15885 |

* Based on 2015 data

# Ancillary Services – Non-Spin

- Used to ensure sufficient capacity is available to cover load/wind forecast errors or replace deployed RRS
  - 30 min deployment required but most provided by 10 min quick start or unloaded on-line generation
  - Must be dispatchable
- Quantity required varies based on historic 3-hour ahead forecast error and risk of large ramps.



# Reliability Risk Desk

- AS quantities are determined in December for each hour of the following year, based on expected conditions
- Actual conditions may vary from those assumed in this quantification
- ERCOT have added new desk in control room to monitor whether procured AS quantities are sufficient to cover relevant risks, given the system conditions expected over the next 24 hours:
  - Monitor renewable forecasts versus actual output
  - Monitor Inertia and resulting RRS requirements
  - Monitor sufficiency of Non-Spin to cover forecast error risk and net load ramps

# Key Takeaways

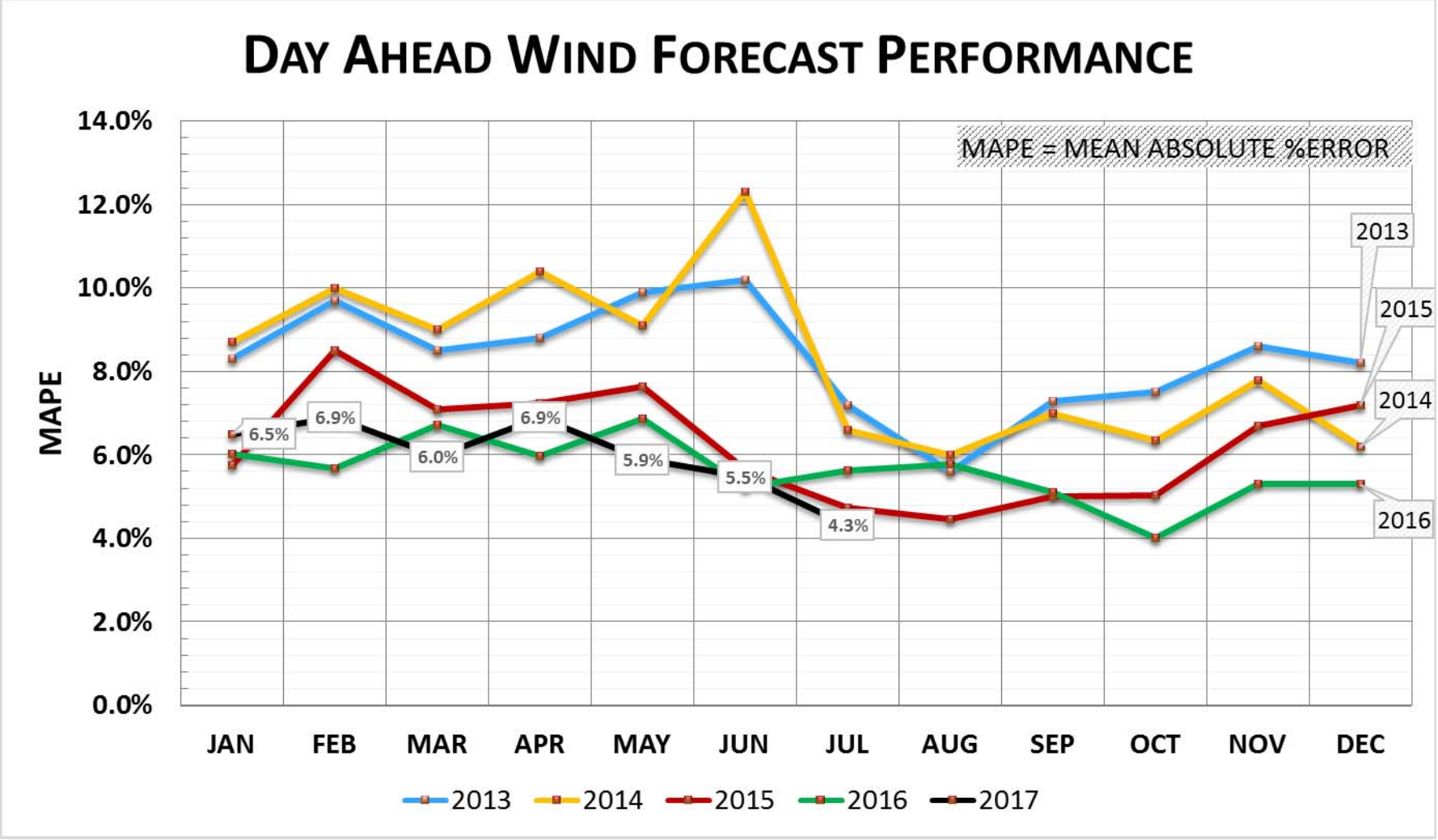
- System operators in areas with growing amounts of renewables facing challenges with system balancing (uncertainty, ramping, variability and frequency control;
- Accurate wind and solar generation forecasting is a key;
- Real time awareness tools in the control room are essential for efficient and reliable operation with high levels of renewables;
- Ancillary Services can satisfy essential reliability needs for the system
  - ERCOT uses market-based solutions as much as possible
- Some of the essential reliability requirements need to be implemented through grid codes. Modern renewable generation technology can provide grid support.

# Questions

Julia Matevosyan

jmatevosjana@ercot.com

# Wind Forecast Performance (Day-Ahead)



# Wind Forecast Performance (Hour-Ahead)