Recent ERCOT Developments in Applications of Uncertainty Forecasts to System Operations

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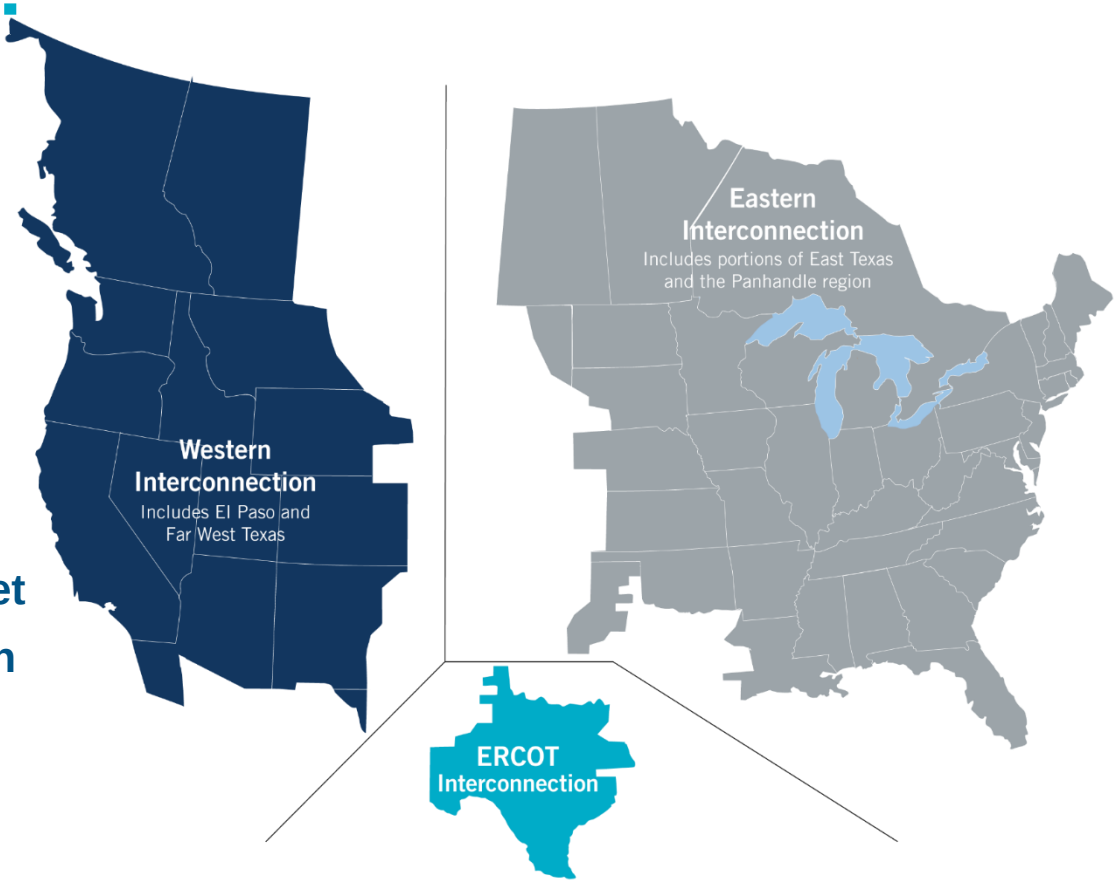
ERCOT

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**



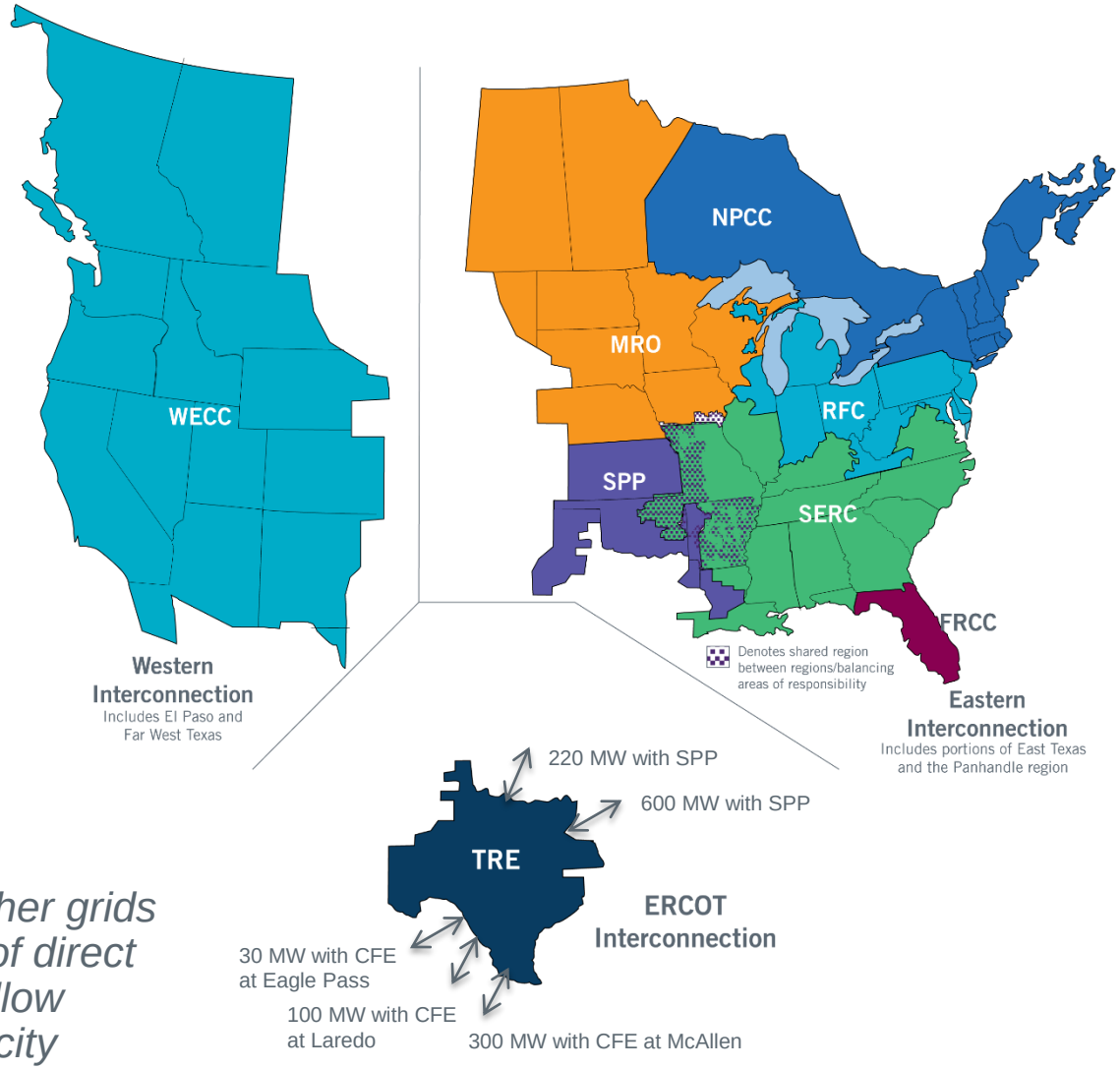
ERCOT is a nonprofit organization and regulated by the Public Utility Commission of Texas, with oversight by the Texas Legislature.

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

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.)

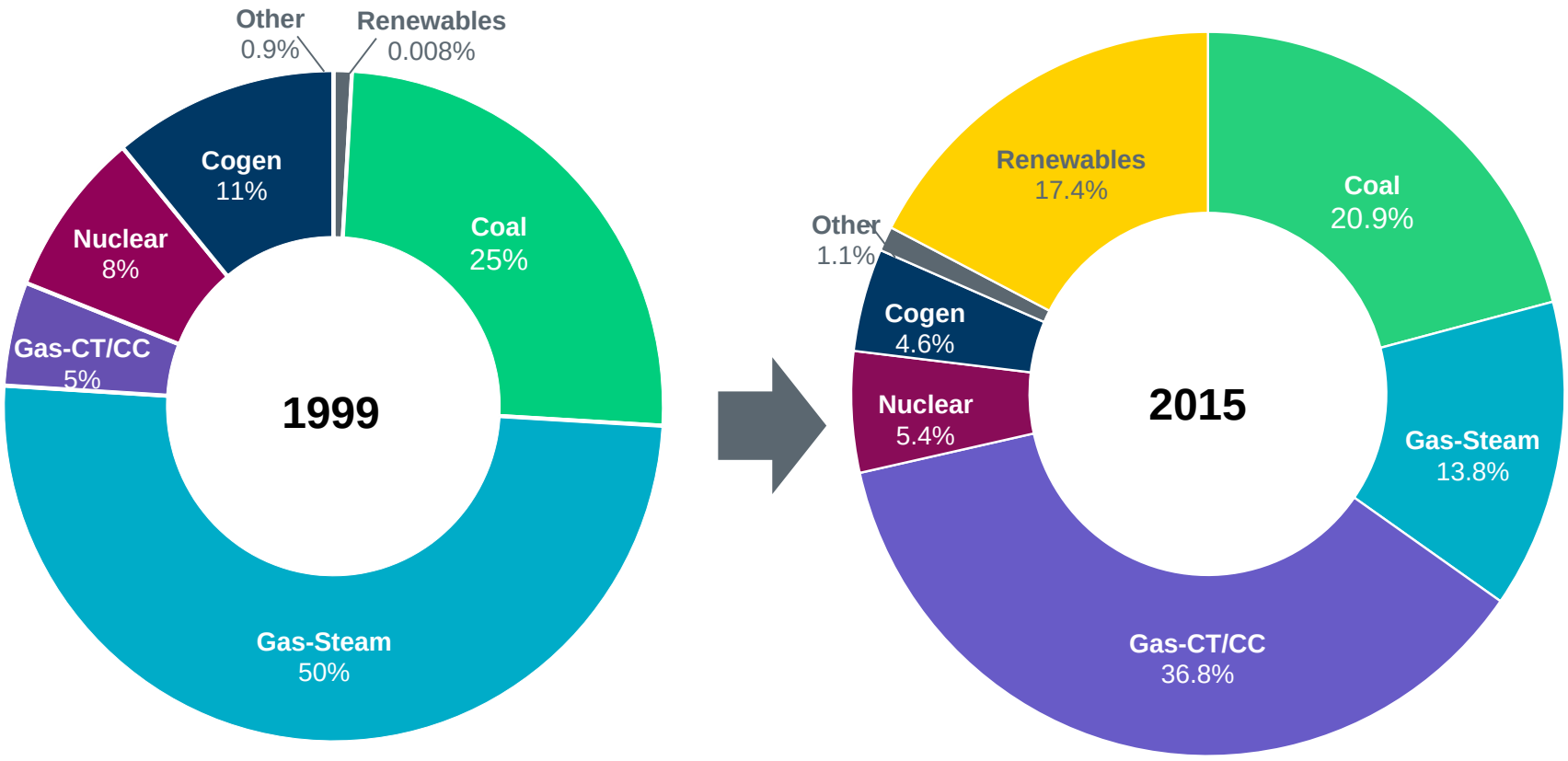
2016

- 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.)

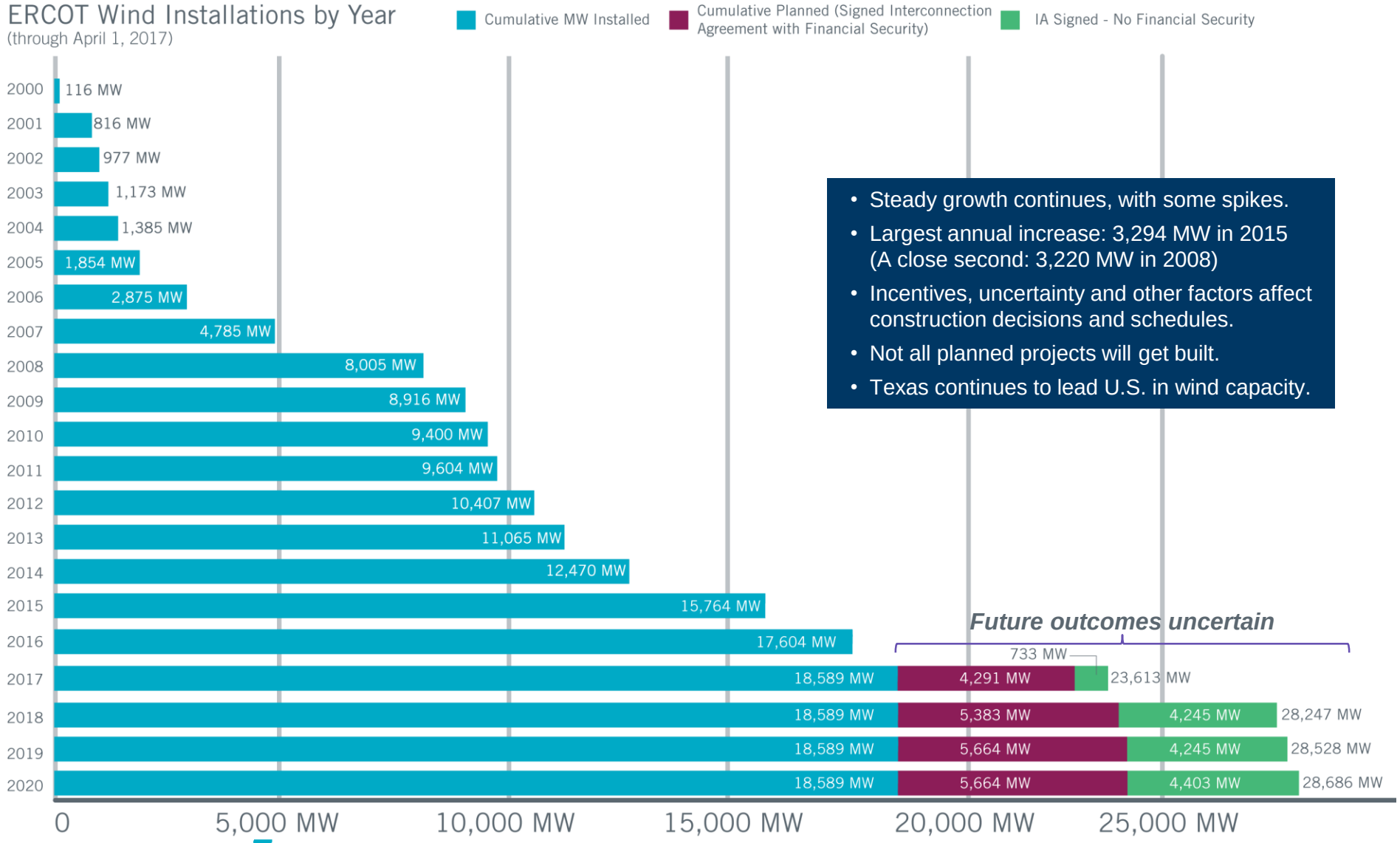
2015

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

Changing Resource Mix – Installed Capacity

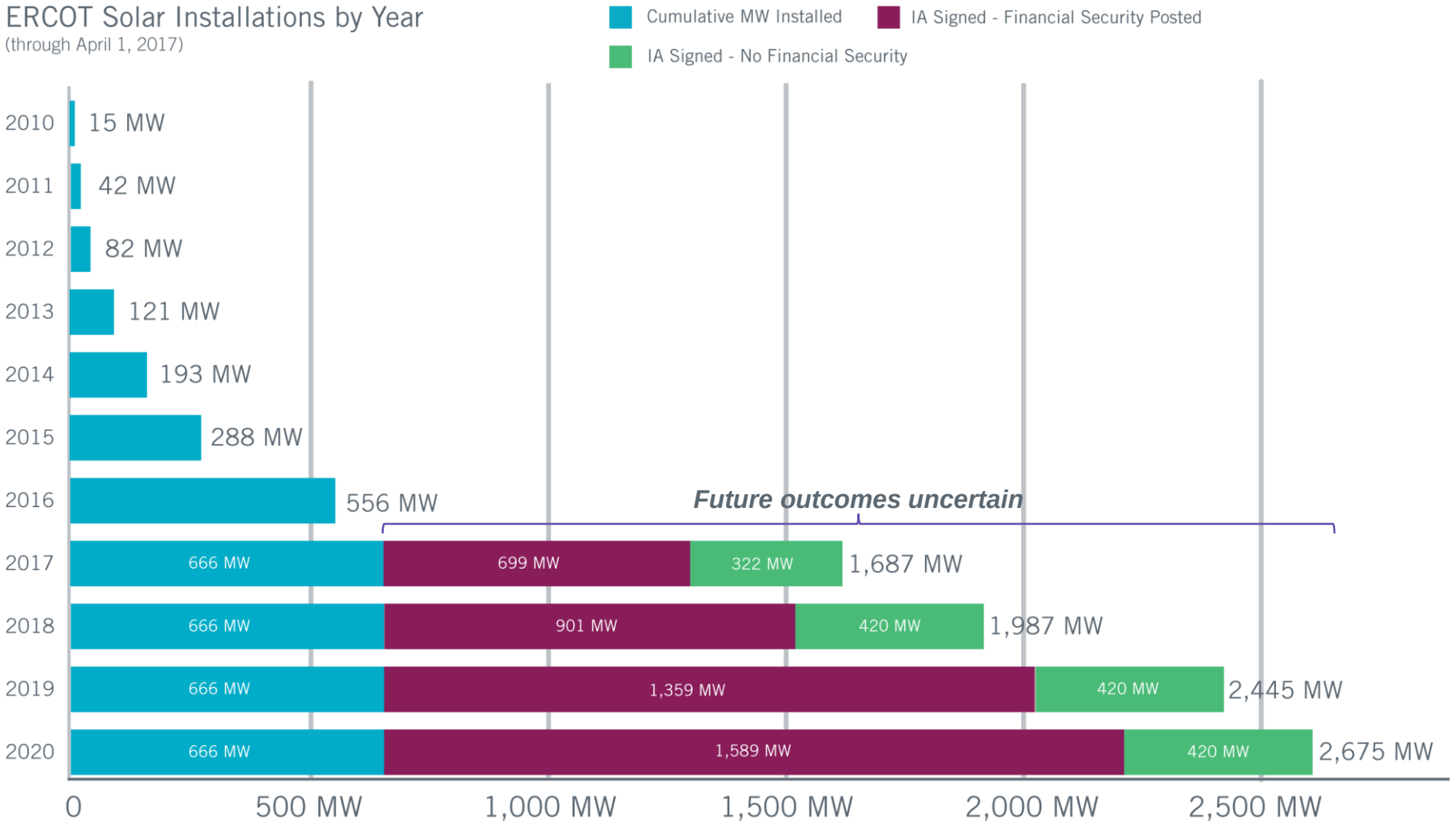


Wind Generation Capacity (March 2017)



- 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.

Utility Scale Solar Generation Capacity (March 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.

Wind & Solar Forecast

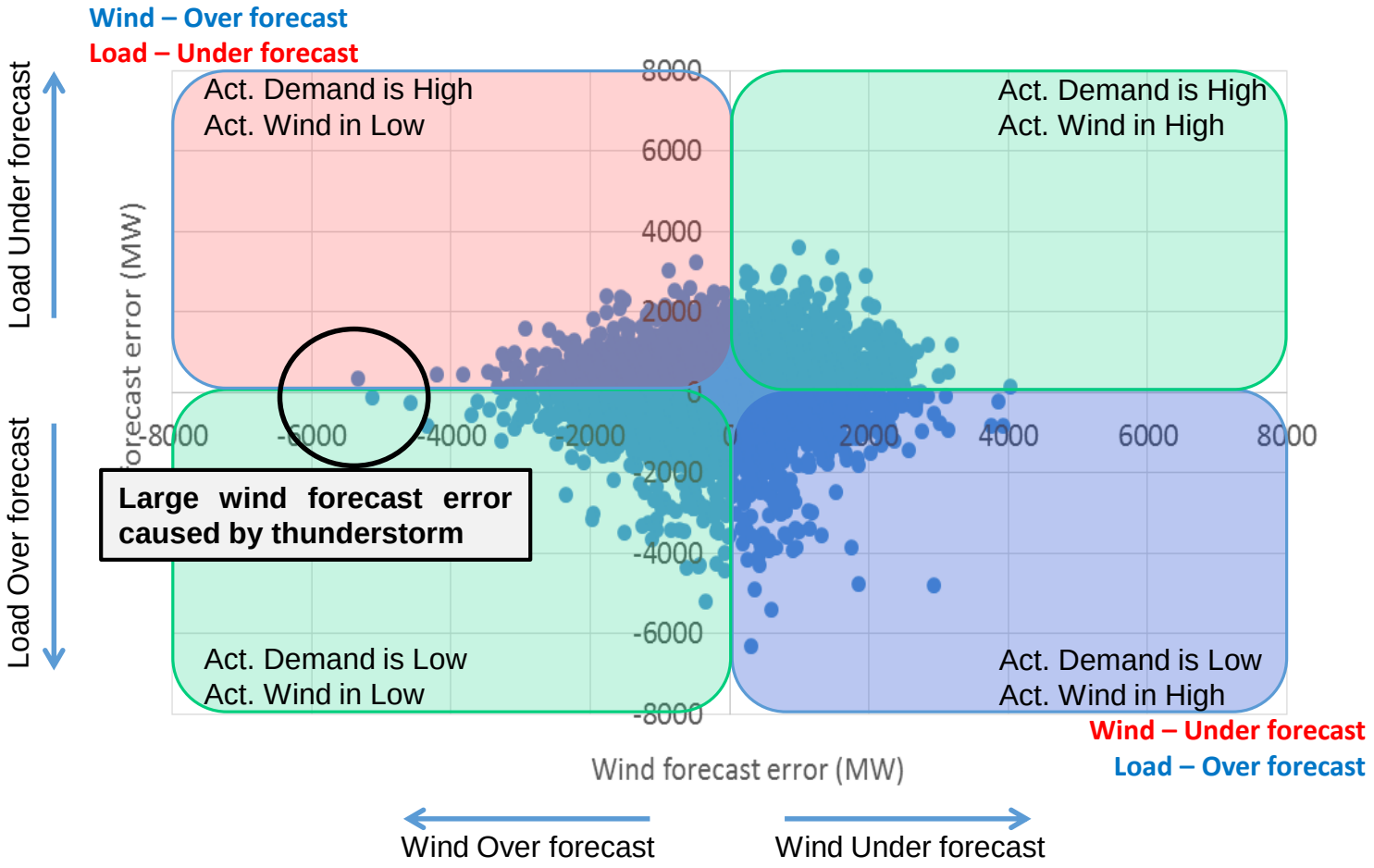
- A 168-hour rolling forecast; hourly resolution; for all Wind/Solar Resources.

- Wind Forecasting since 2009; changed from 48-hour to 168-hour in 2015
- Solar Forecasting since 2015.

- Primary Inputs,
  - site geo-location, met tower geo-location
  - Telemetered site specific output, meteorological data, status, turbine/*inverter* availability
  - Scheduled outages & de-rates
  - Generic power curves
  - Weather variables like wind speed/direction, *irradiance*, cloud cover, climatology
  - Numerical weather prediction

- Wind/Solar operators are required to report their planned operating capability (via Market tools) to be up to wind forecast for their resource.
  - Thus ensuring that (most recently) forecasted wind generation is factored into all look-ahead reliability analyses conducted

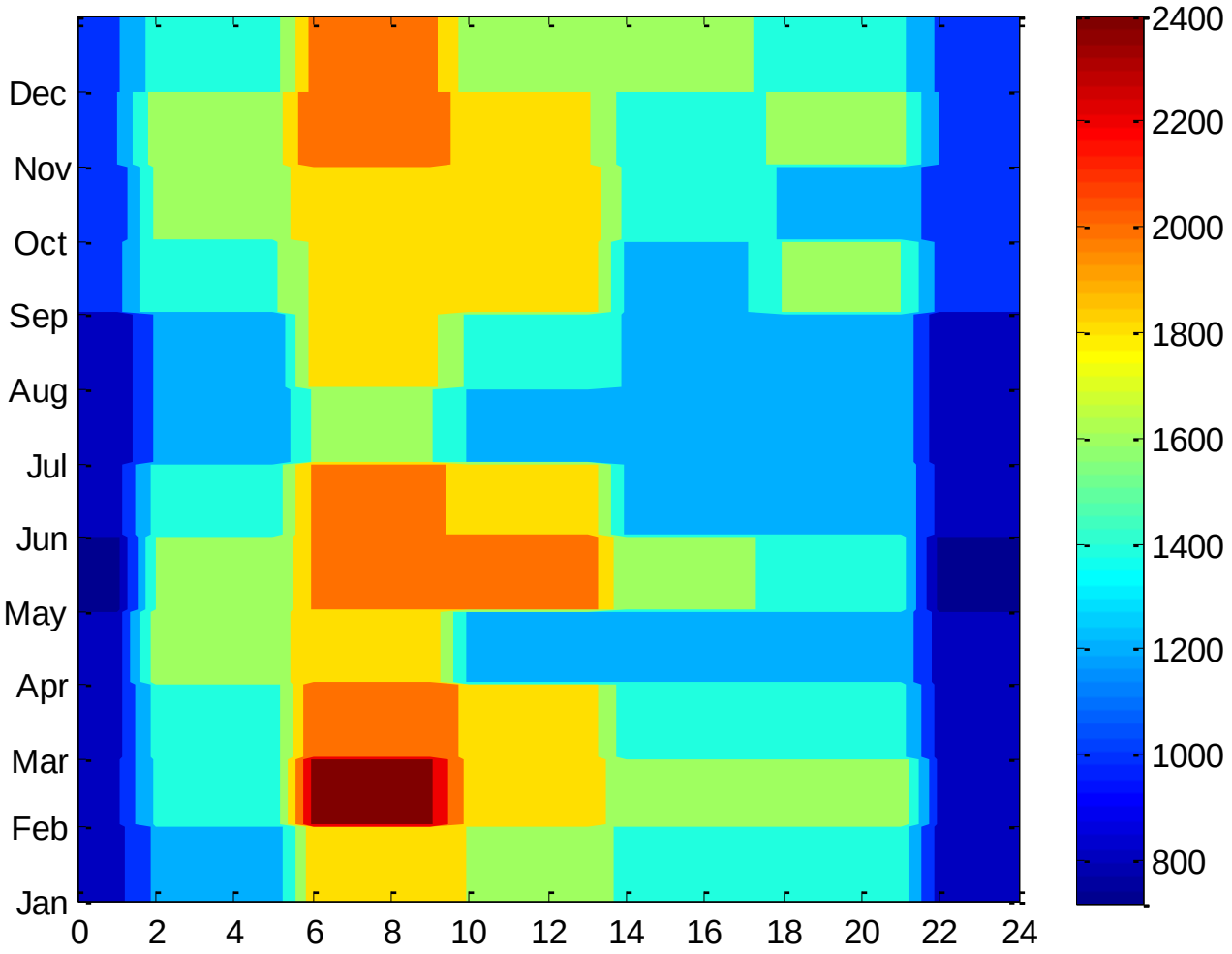
3-hour-ahead Forecast Error in 2016



Ancillary Services – Non-Spinning Reserve Service (NSRS)

- Non-spinning Reserve Service
  - 30 minute product that can be provided by unloaded capacity, offline Generators, and Load Resources
  - Wind power forecast error is one of the inputs used for calculating the requirement for this service

Minimum NSRS Requirement in 2017

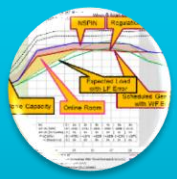


Reliability Risk Desk Goals

- 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

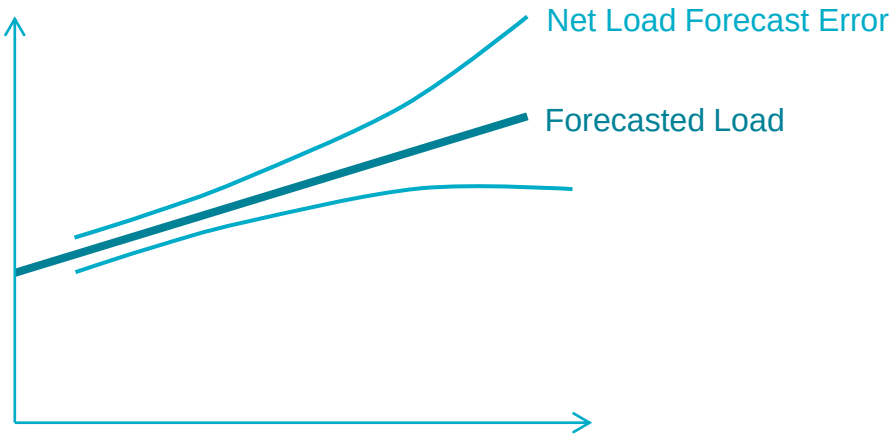


3. Forecast Error Risk and NSRS Sufficiency

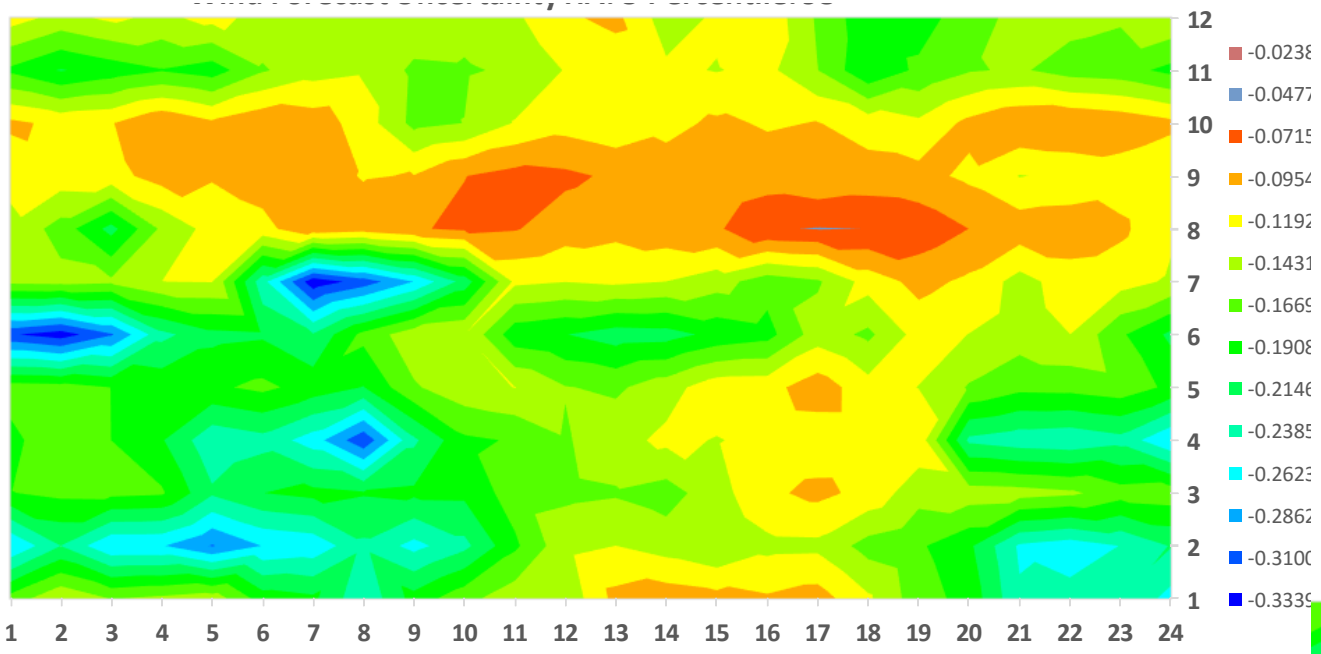
4. Intra-Hour Forecast Monitoring

Forecast Risk & NSRS Sufficiency Monitoring

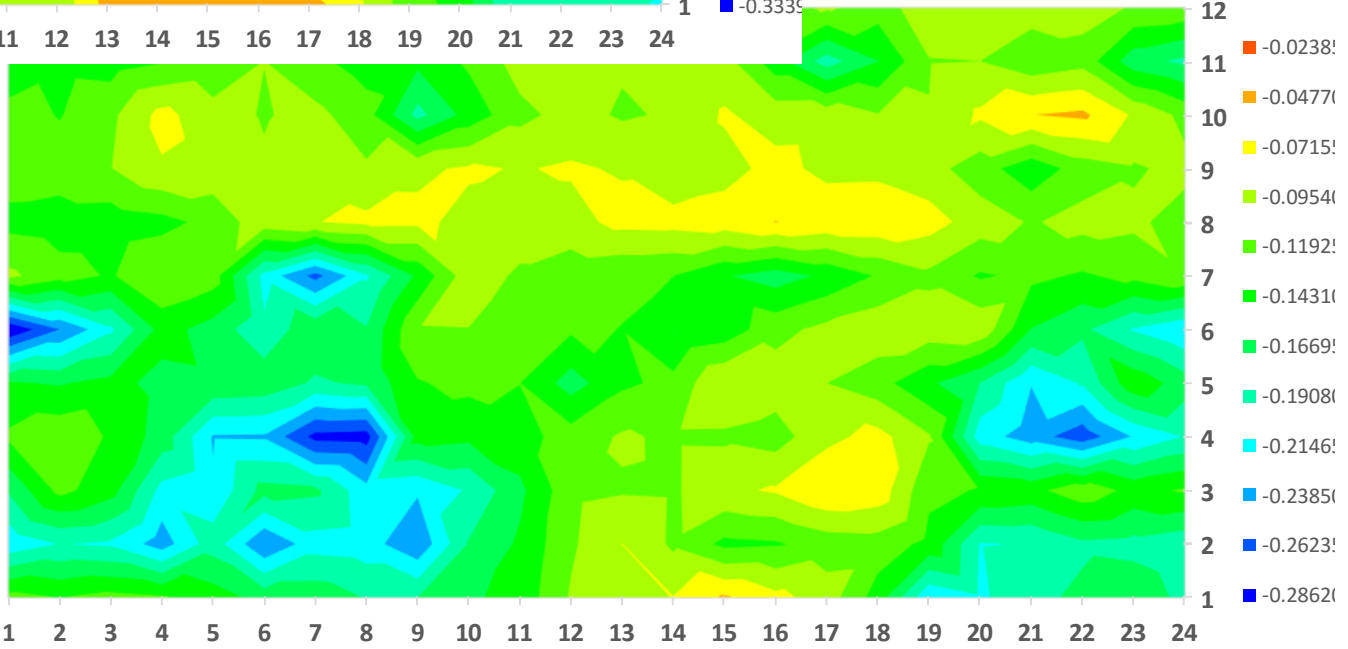
- Reliability Risk Desk will:
  - Monitor the adequacy of scheduled resources (COPs) to cover the forecasted load, ramp, and the uncertainty around each corresponding energy forecast for the next 6 hours and identify hours of insufficiency.
  - Retain sufficient NSRS in every hour to cover the higher of:
    - the current level of net load ramp risk or
    - the amount that will be needed, based on currently expected operating conditions, to restore frequency and recover contingency reserves



Uncertainty/Error of Wind Forecast

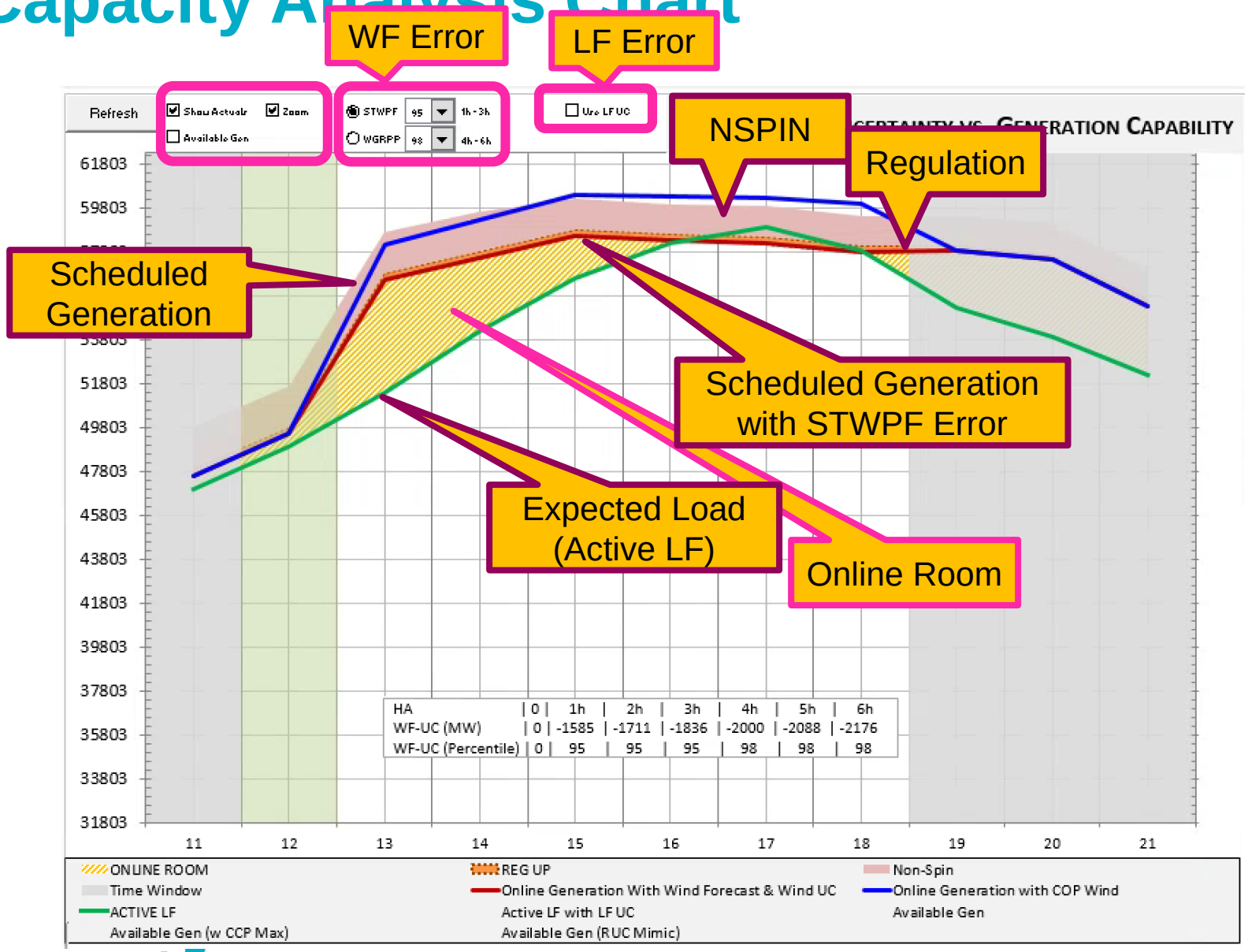


5 Hour Ahead Wind Forecast uncertainty



1 Hour Ahead Wind Forecast uncertainty

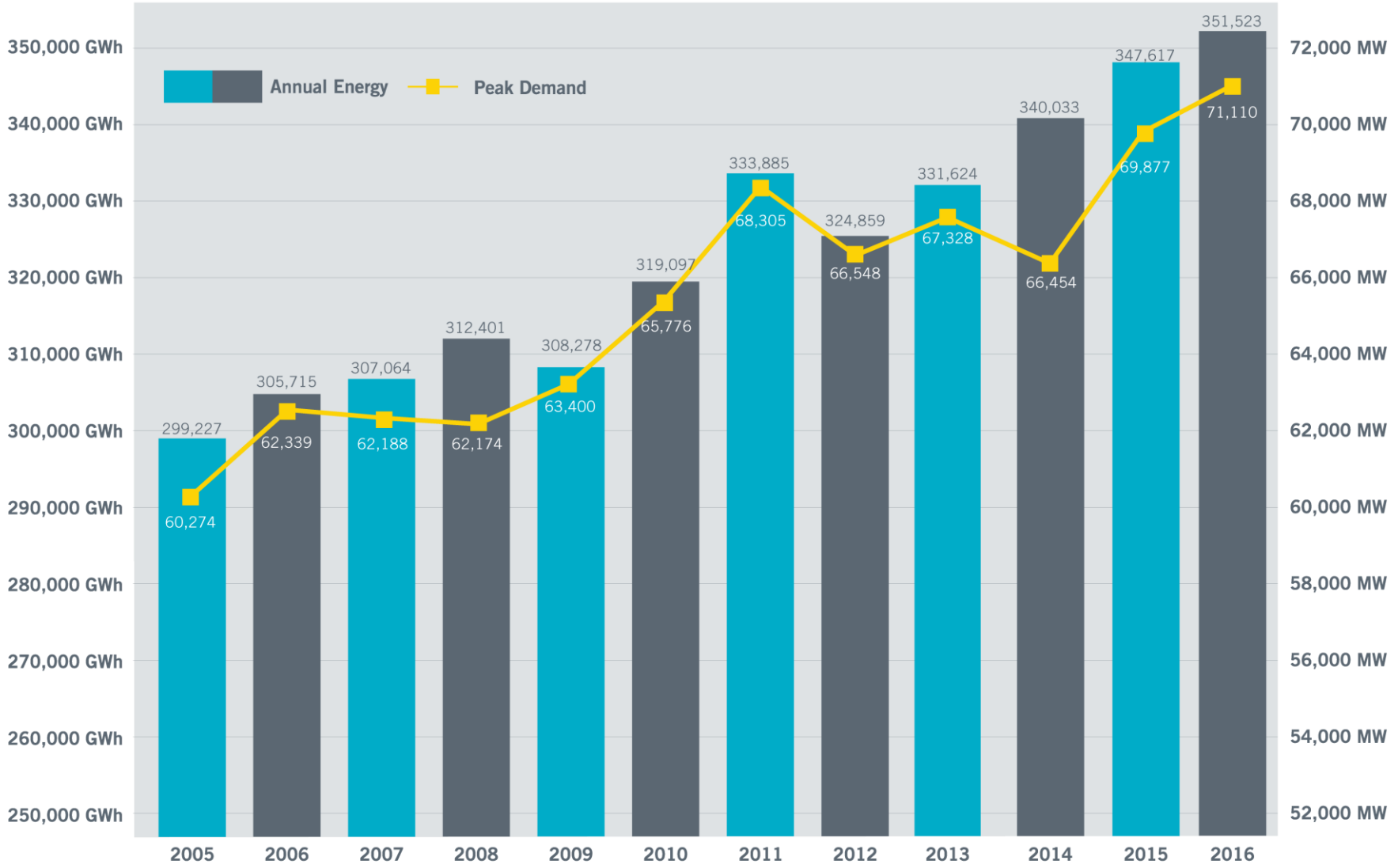
Capacity Analysis Chart



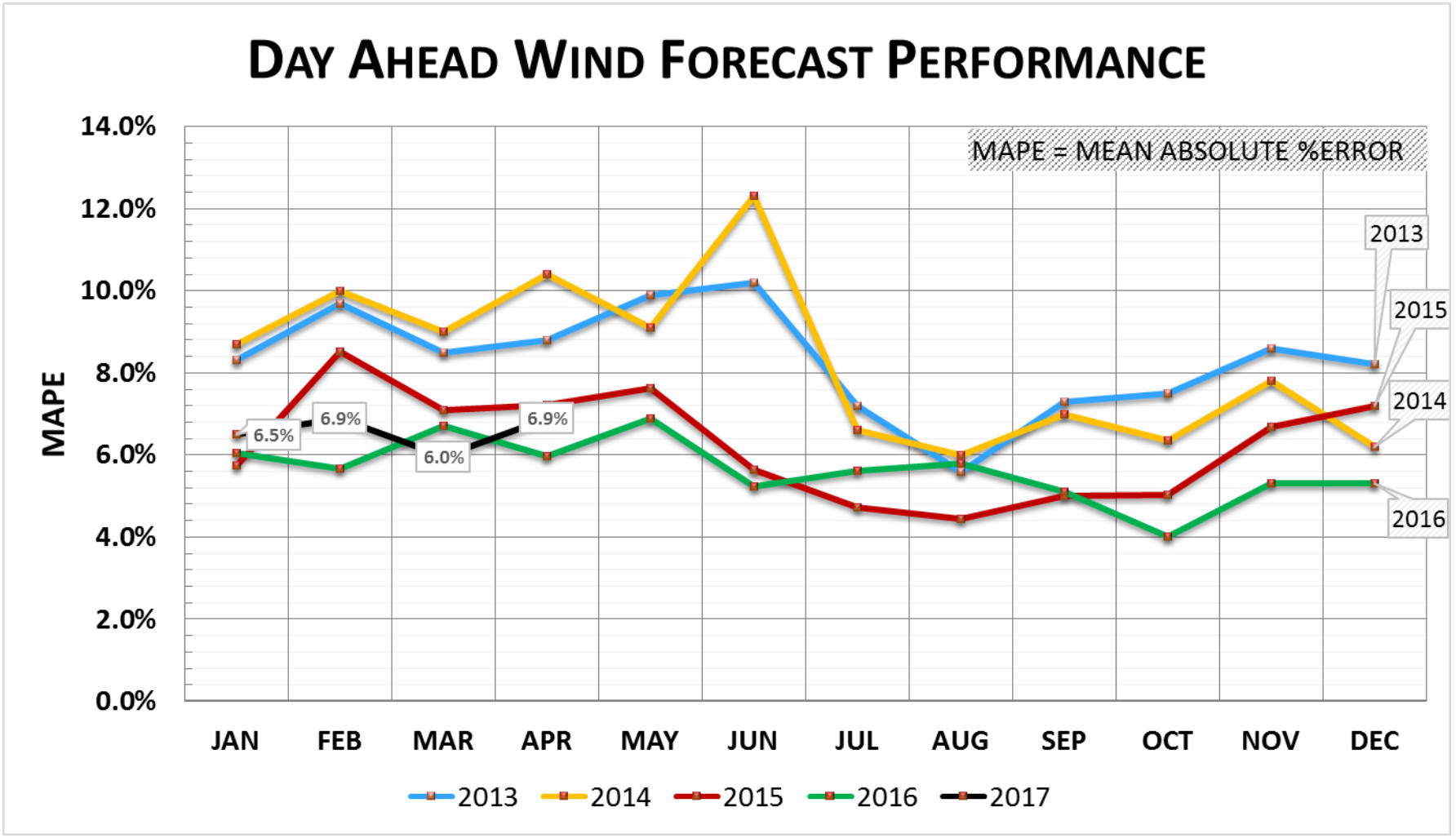
Discussion & Questions

APPENDIX

Annual Energy and Peak Demand (2005-2016)



Wind Forecast Performance (Day-Ahead)



Wind Forecast Performance (Hour-Ahead)