



Regional Impact of Renewables: ERCOT

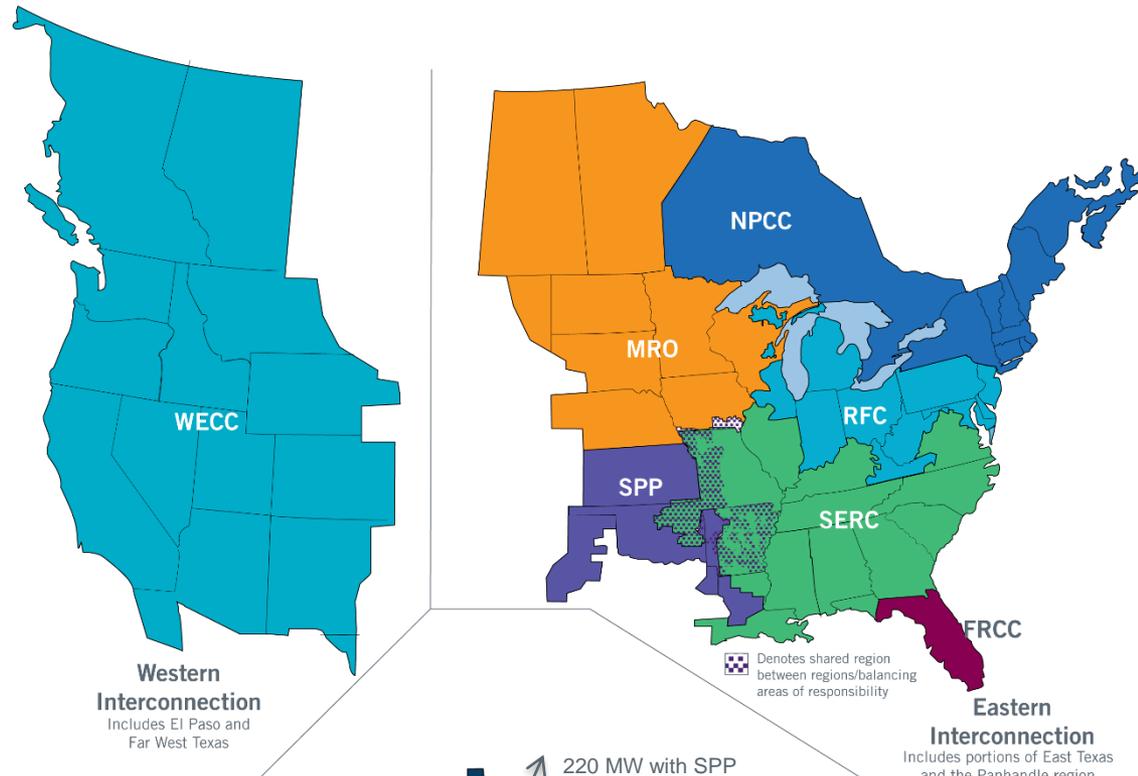
Kenan Ögelman
VP, Commercial Operations, ERCOT

February 1, 2018

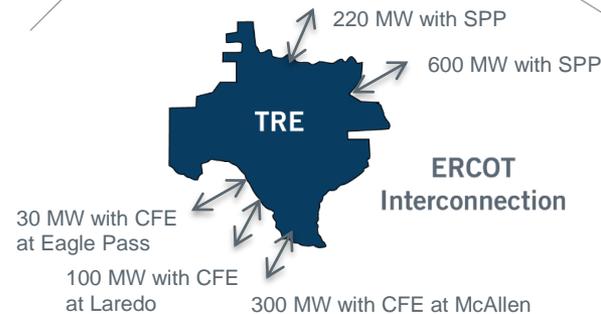
The ERCOT Region

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

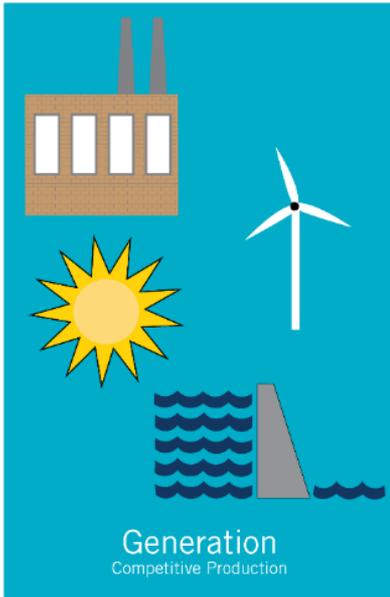
- 90% of Texas electric load; 75% of Texas land
- 71,110 MW peak, August 11, 2016
- More than 46,500 miles of transmission lines
- 570+ generation units



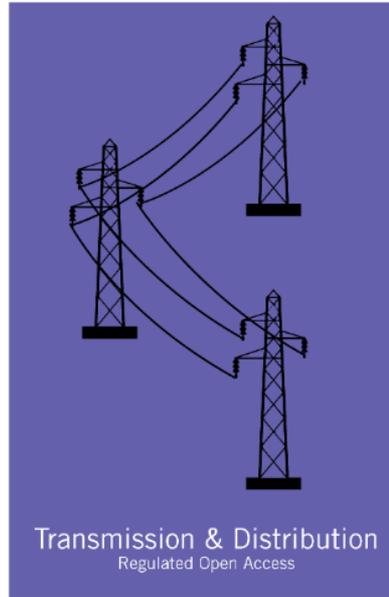
ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over flow of electricity



Texas Competitive Model



- Fully unbundled Wholesale market
- ERCOT operates a single Balancing Area
- 5-Minute security constrained economic dispatch with Day-Ahead and Ancillary Services markets
- Generators are paid Locational Marginal Prices (LMPs) at node.
- Load-serving entities pay averaged load-zone prices.
- Voluntary Day-Ahead Market



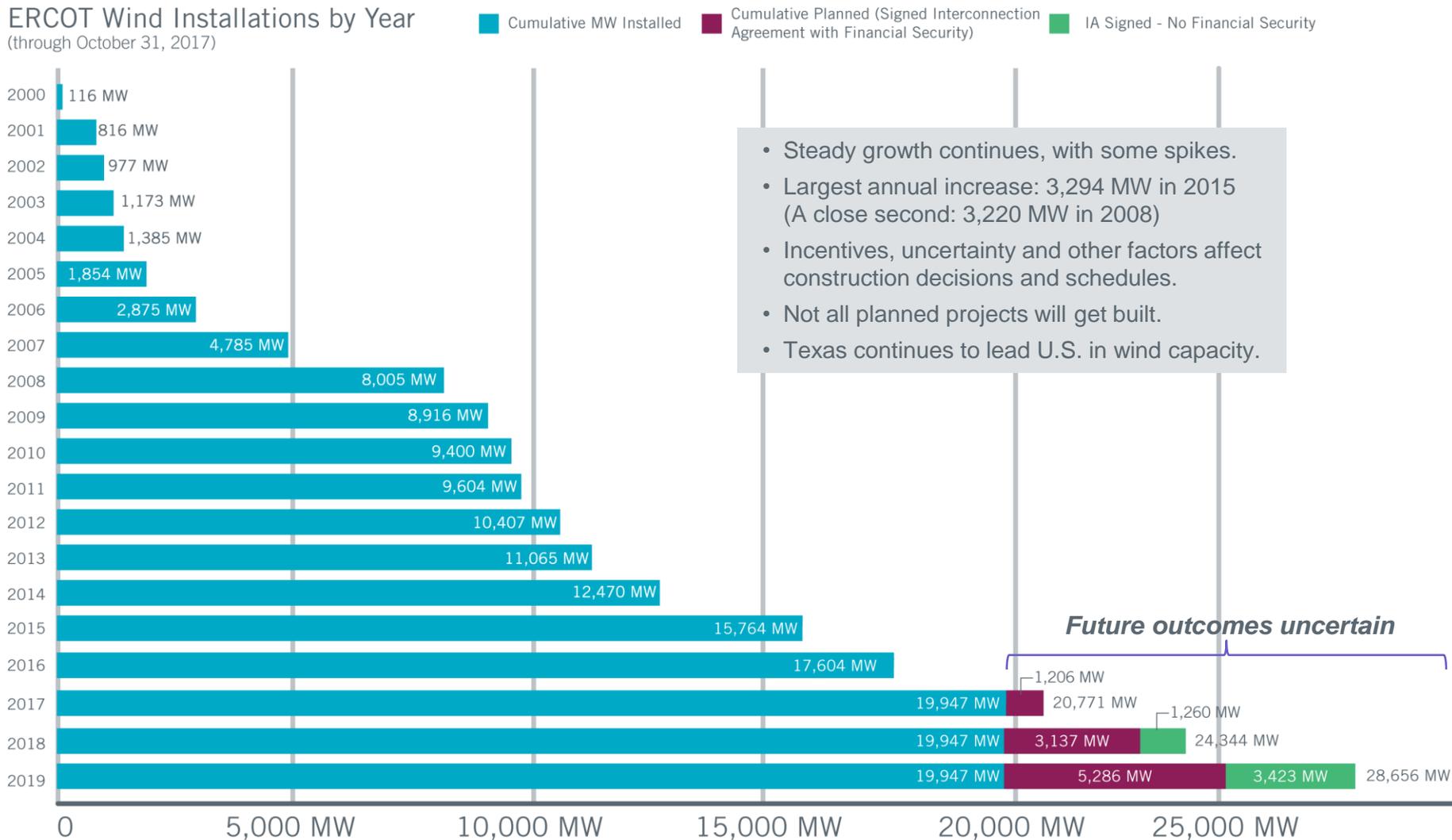
- Transmission and distribution lines and related facilities are owned and operated by regulated utilities.
 - Utilities are regulated by PUC.
- All transmission costs are rolled into a single postage stamp rate paid by load.
- No transmission service market.



- Full Retail competition for all customer types
Except in municipal and cooperative utility areas
Customers choose retail provider and terms of contract
Smart meters (which measure time of consumption) installed on all customer types – about 7 million meters

Wind Generation Capacity – October 2017

ERCOT Wind Installations by Year
(through October 31, 2017)



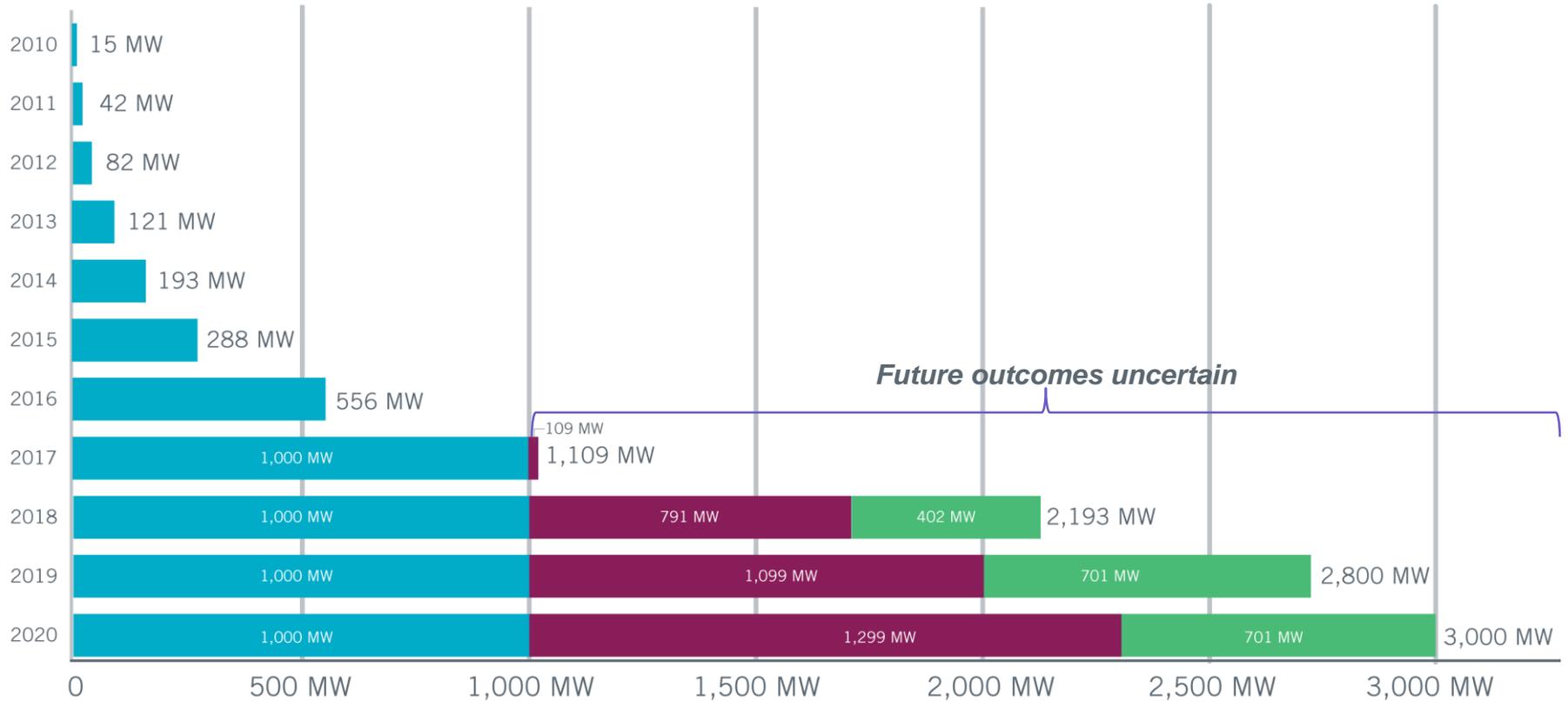
- Steady growth continues, with some spikes.
- Largest annual increase: 3,294 MW in 2015 (A close second: 3,220 MW in 2008)
- Incentives, uncertainty and other factors affect construction decisions and schedules.
- Not all planned projects will get built.
- Texas continues to lead U.S. in wind capacity.



Utility Scale Solar Generation Capacity – October 2017

ERCOT Solar Installations by Year
(through October 31, 2017)

■ Cumulative MW Installed
 ■ IA Signed - Financial Security Posted
■ IA Signed - No Financial Security

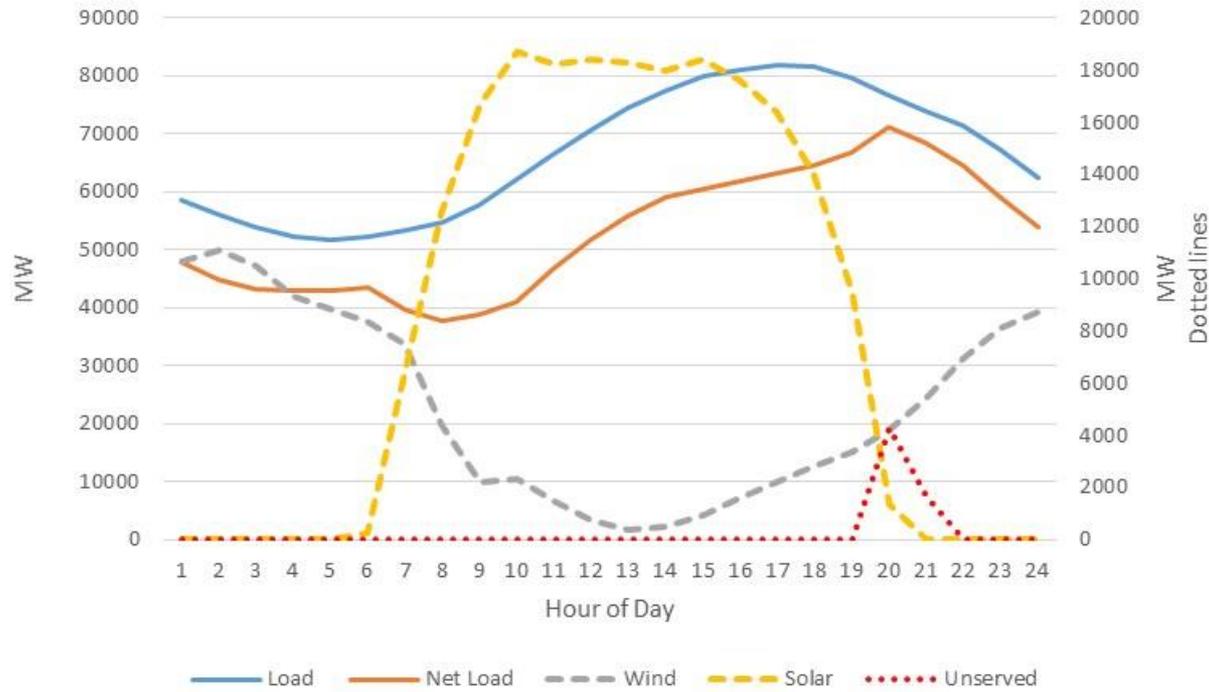


The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information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



A Future with High Solar and Wind Penetration

From the ERCOT Long Term System Assessment



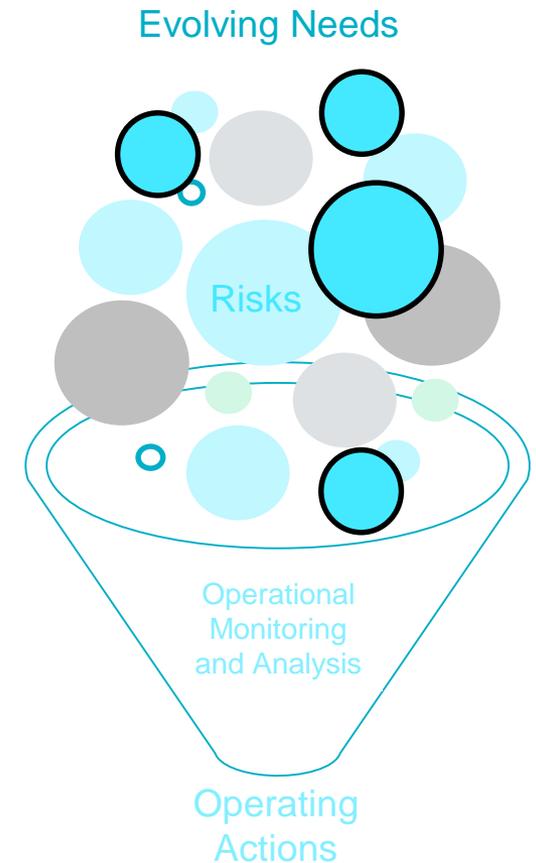
Problems associated with Generation Moving Further from Load

- Long line impedances are compensated with series capacitors which require system operators to monitor and protect against sub-synchronous oscillations.
- Moving power over long distances results in increased losses
- Voltage stability awareness and limits become more important as power is moved over longer distances.

ERCOT has made substantial investments in both people, technology, and infrastructure in order to mitigate these problems.

Reliability Risk Desk Addition in the Control Room

- Goal is improved quantitative analysis and dynamic consideration of particular risks:
 - Wind and Solar Forecast Errors
 - Net Load Ramps
 - Low Inertia
 - Variable Ancillary Service Needs
- Additional resources added in January 2017
 - One additional operator per shift
 - New monitoring and analytical tools



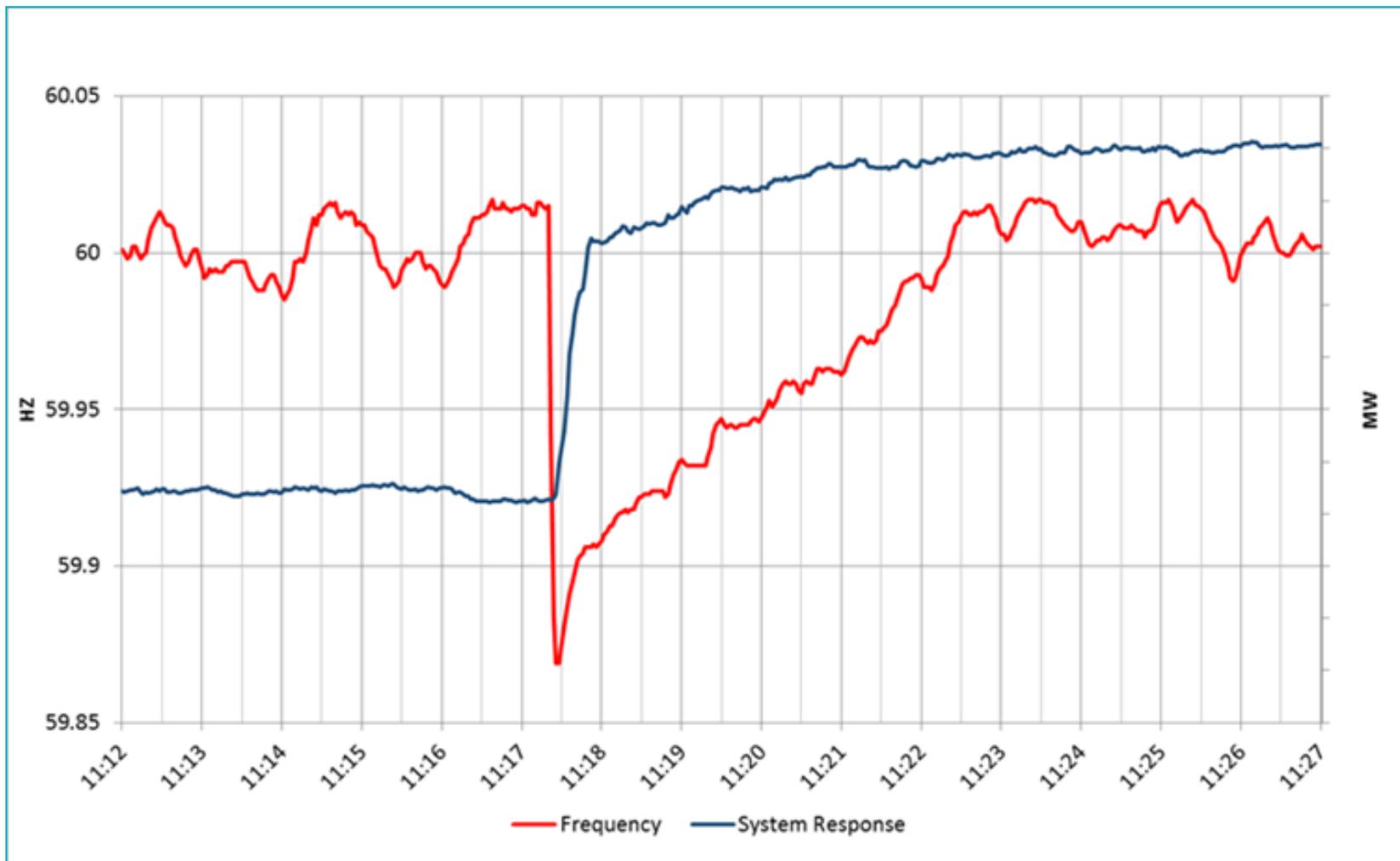
Challenge: Maintaining reliability with new resource mix

- During high wind/low load periods, the current bundled Ancillary Services framework will:
 - Keep higher cost generation online to provide Ancillary Services.
 - Extend and deepen negative price periods.
 - Curtail lower cost resources.
 - Result in increased Ancillary Services prices and produce overall higher costs.

The frequency of high-wind/low-load periods is increasing.

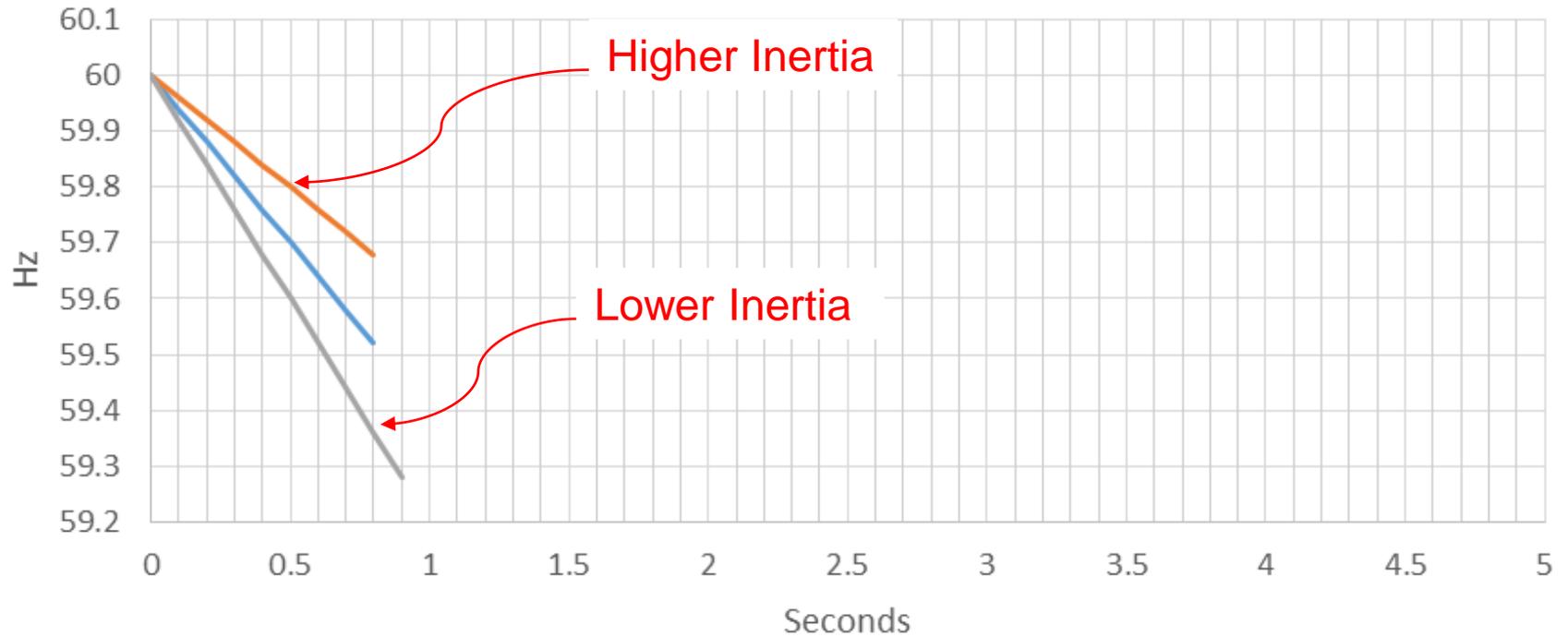
- In these periods ERCOT needs more flexible procurement and faster response from Ancillary Services.

System Response Following a Unit Trip



Inertial Effect on Frequency

Initial RoCoF for Same Unit Trip

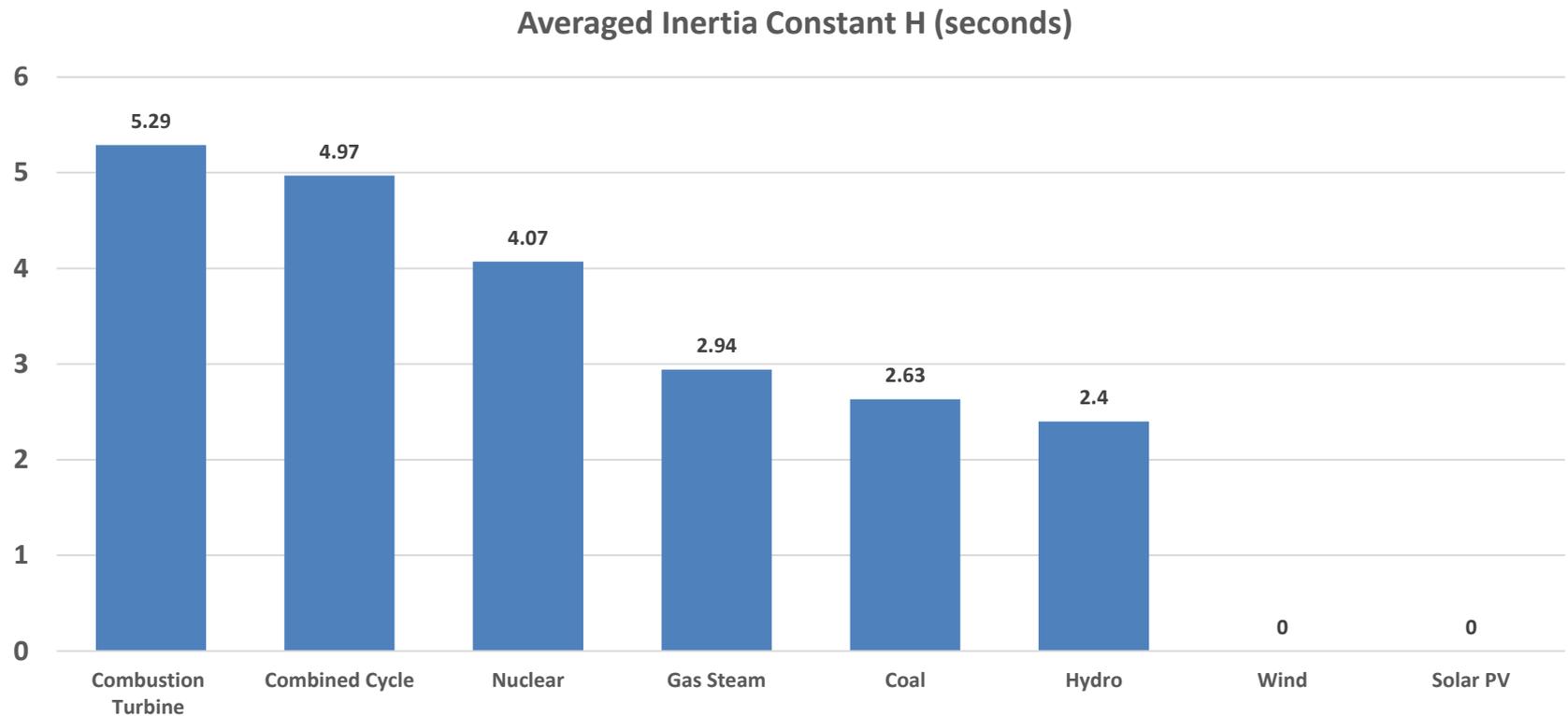


Important Frequency Response Role for Load Resources

- Load Resources (LR) providing RRS have underfrequency relays that respond in about 0.5 seconds after the frequency drops below the trigger level (currently 59.7Hz).
 - Load Resources once deployed may not recover as quickly. Once deployed ERCOT would need quick ramping resources deployed to help meet reliability standards.
- Governors of thermal generating units begin to respond “immediately” but will take 1-3 seconds to provide significant response (requires more steam or more combustion).

Impact of Coal Plant Retirements on System Inertia

- It depends on what takes their place.
 - If coal plants are replaced by combined cycle plants or combustion turbines, maybe not.



What about Distributed Energy Resources (DERs)

- DERs do not receive Locational Marginal Prices.
- DERs do not provide primary frequency response.
- DERs do not telemeter to ERCOT

Therefore, DERs are not price responsive from a reliability perspective, and cannot provide Ancillary Services.

ERCOT is working on these issues.