Emerging Grid Issues Briefing

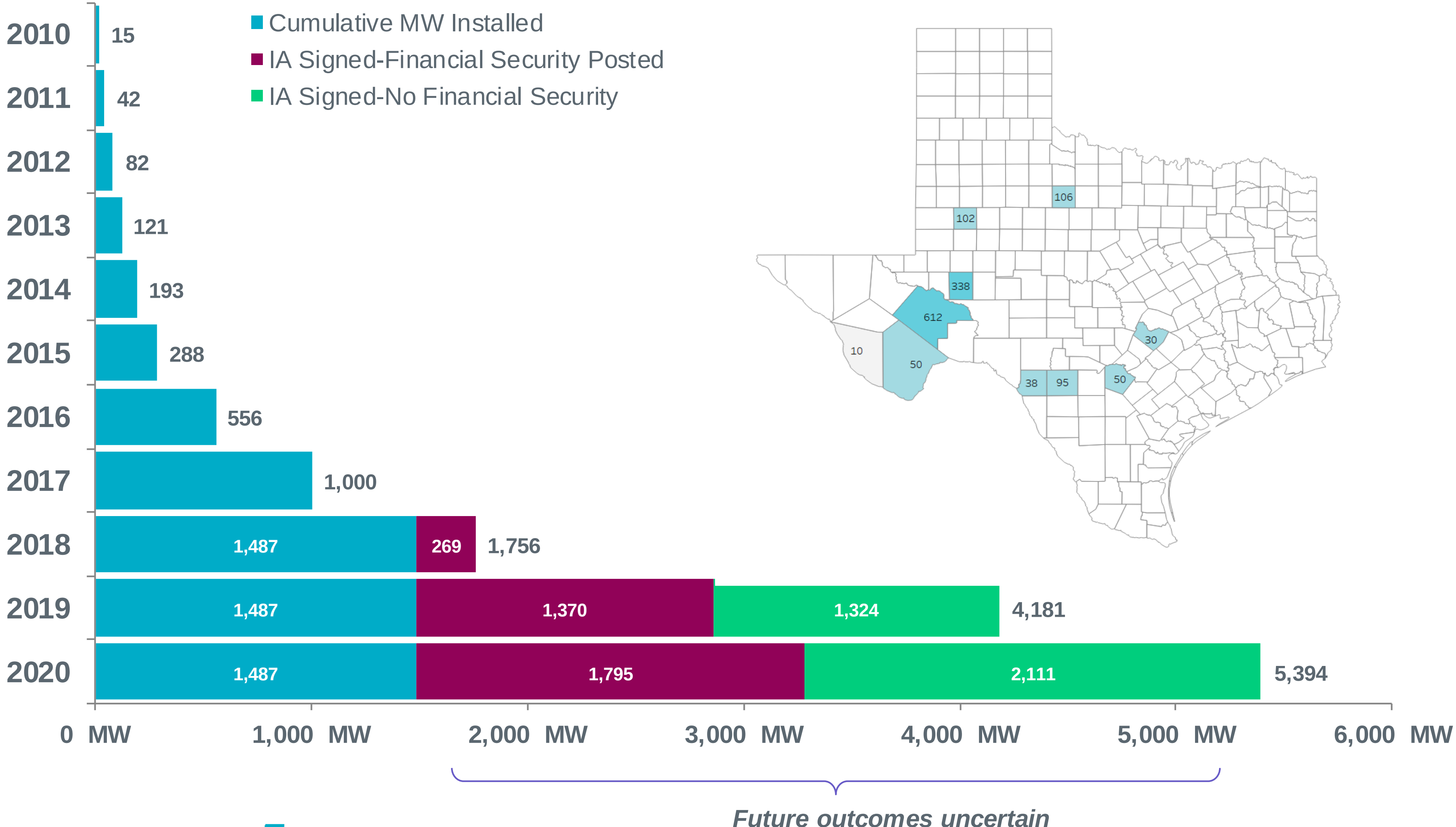
November 8, 2018

Agenda

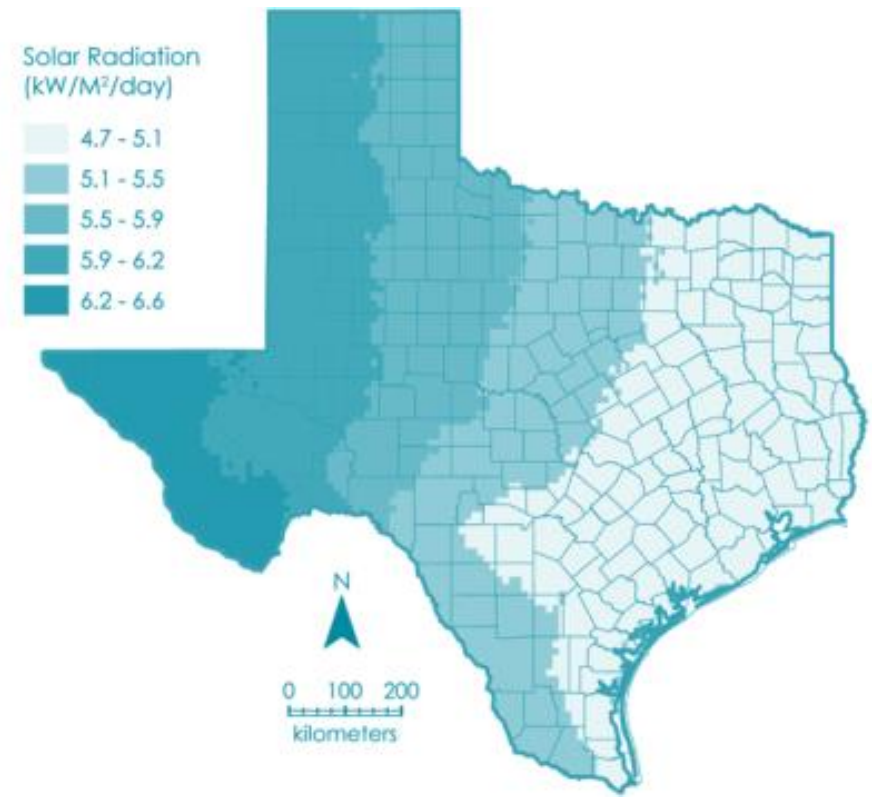
- ERCOT Forward Outlook
    - Bill Magness, President and Chief Executive Officer
- Future Resource Mix Changes
  - Solar Resources
    - Dan Woodfin, Senior Director, System Operations
    - Kenan Ögelman, Vice President, Commercial Operations
  - Distributed Energy Resources
    - Bill Blevins, Director, Grid Coordination
    - Kenan Ögelman, Vice President, Commercial Operations
  - Energy Storage
    - Warren Lasher, Senior Director, System Planning
- Transmission Supporting Load Growth
    - Warren Lasher, Senior Director, System Planning
- Cyber Security
    - Cheryl Mele, Senior Vice President and Chief Operating Officer

Solar Resources

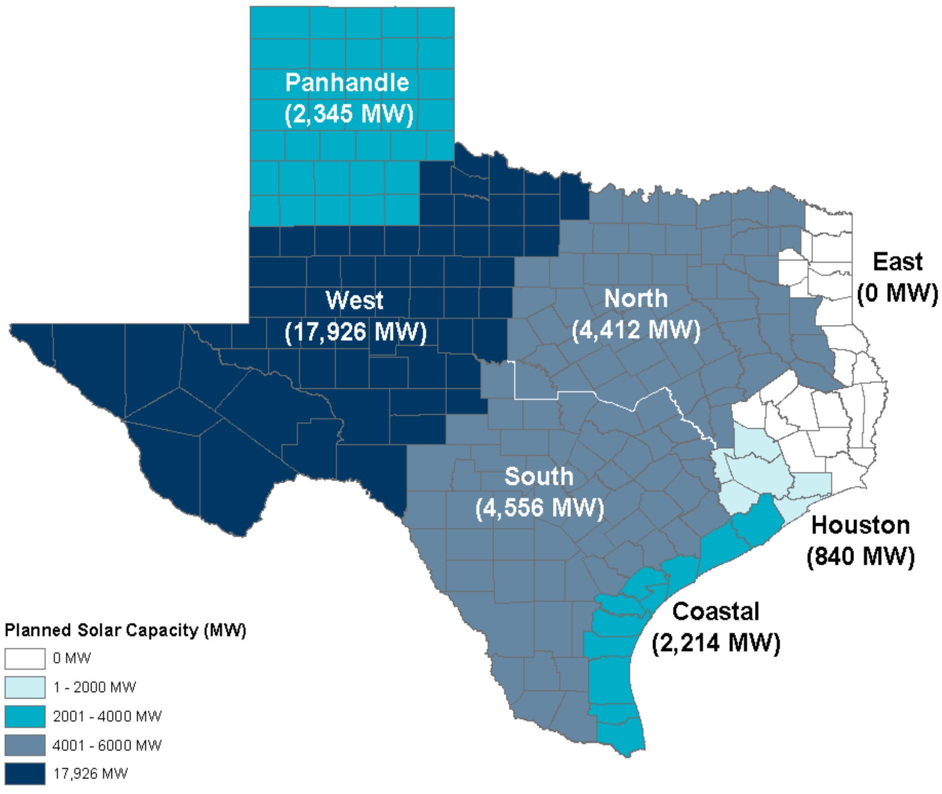
Utility-Scale Solar Generation Capacity – October 2018



Geographic Distribution of Solar Interconnection Requests

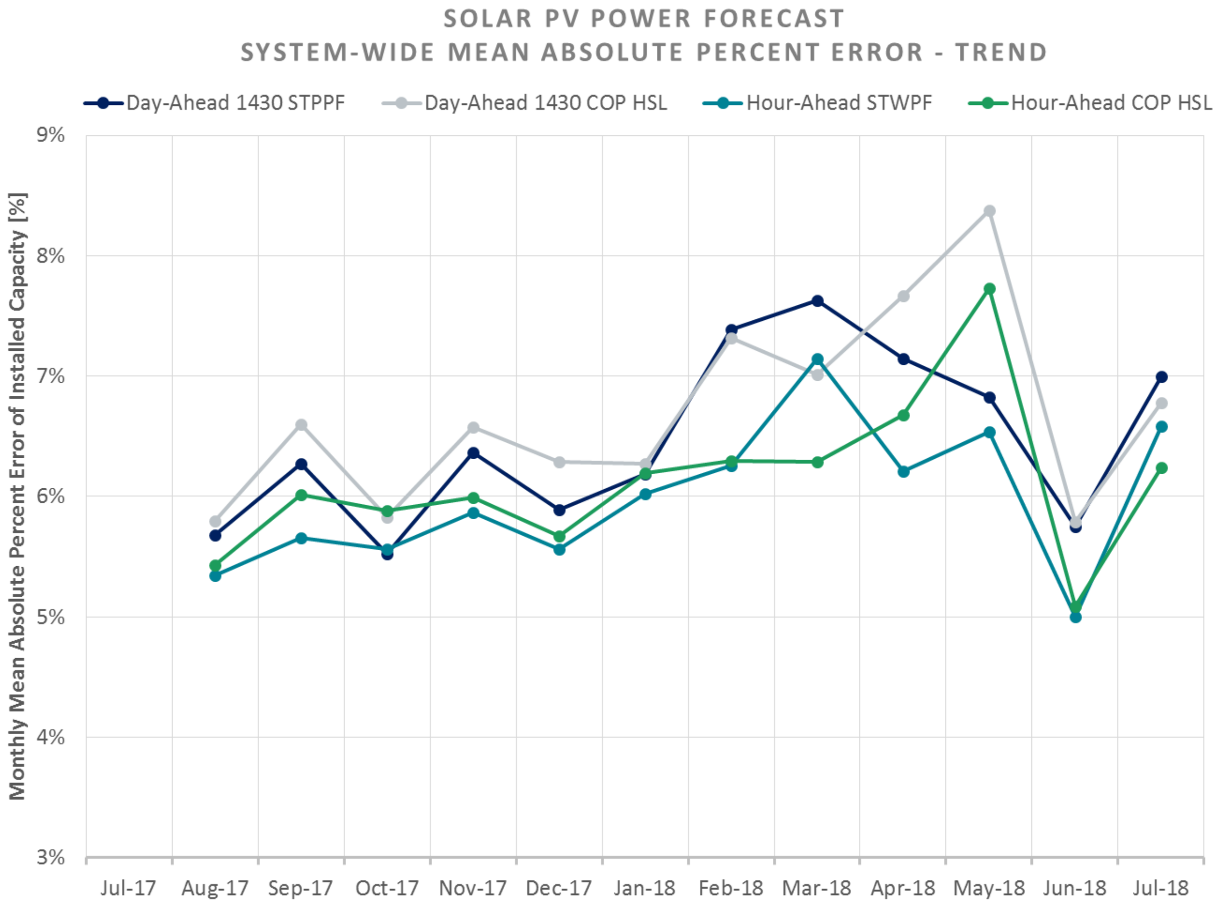


NREL Solar Irradiance Map



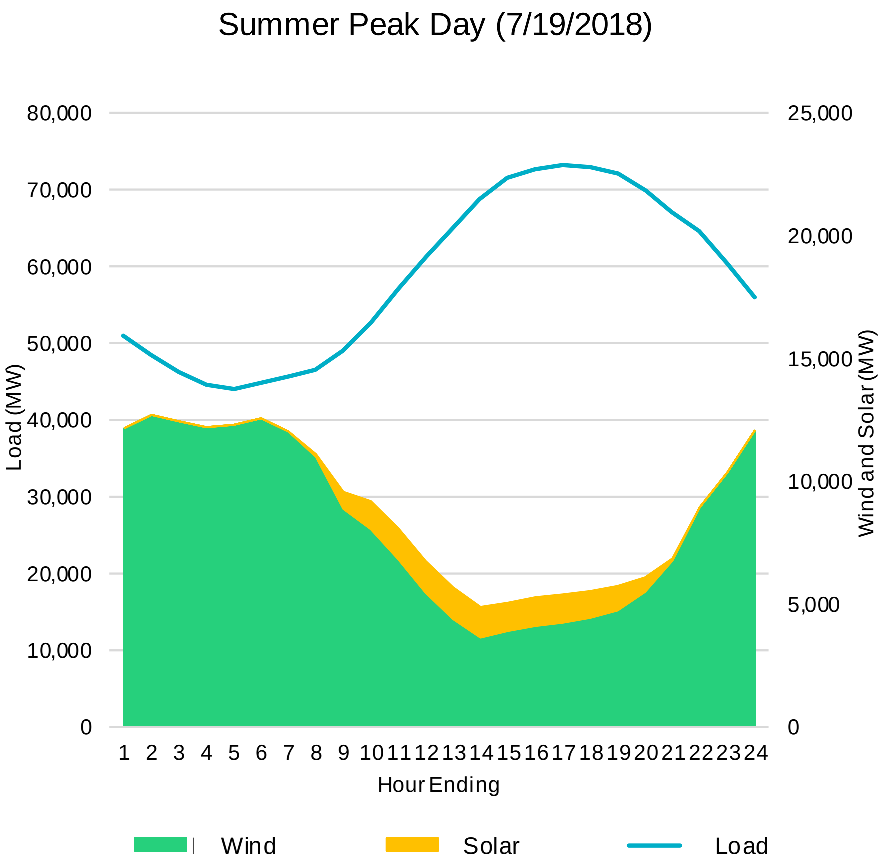
- Total Interconnection Requests at any stage of interconnection process as of October 2018
- Future outcome of these requests is uncertain

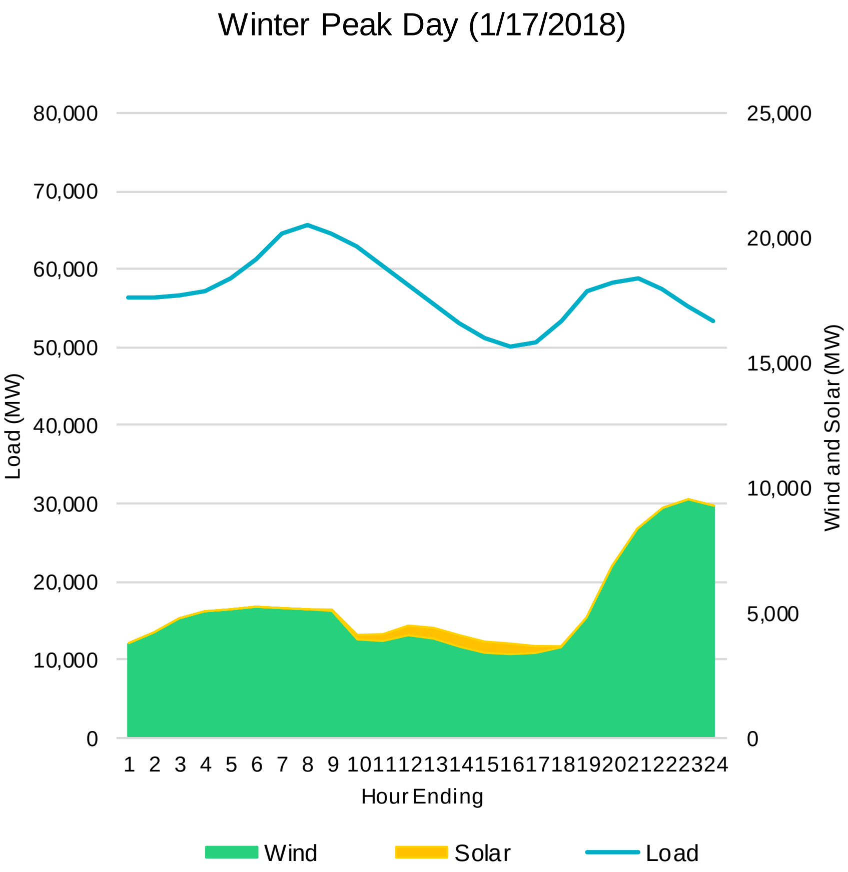
Solar Forecast Accuracy and Output Variability



- ERCOT has already implemented solar forecasting.
- Increasing geographic diversity will improve forecast and intra-hour variability.

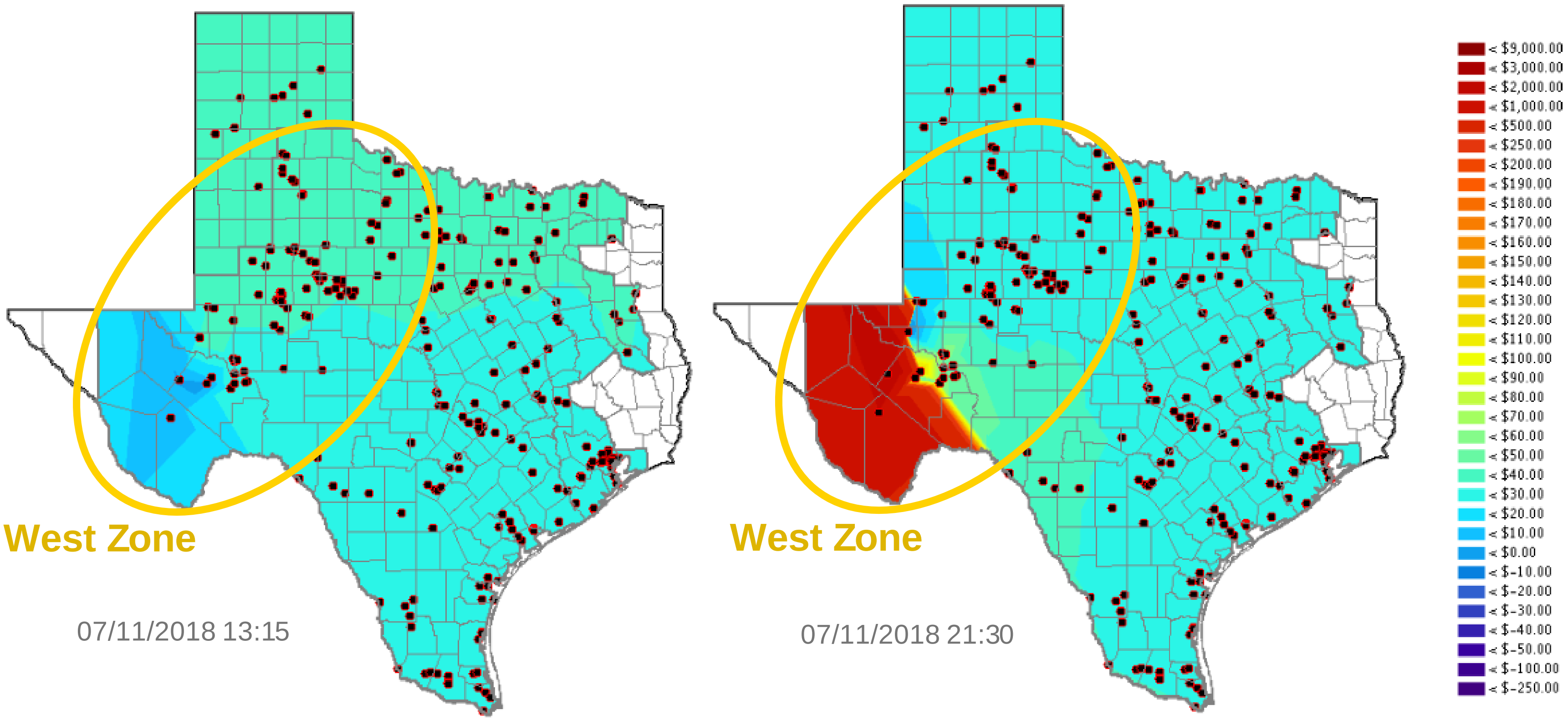
Pattern of Load, Wind and Solar on Peak Days





- Daily pattern of wind and solar generation is generally complementary
- Solar is more coincident with demand in summer

Congestion in the West: July 11, 2018



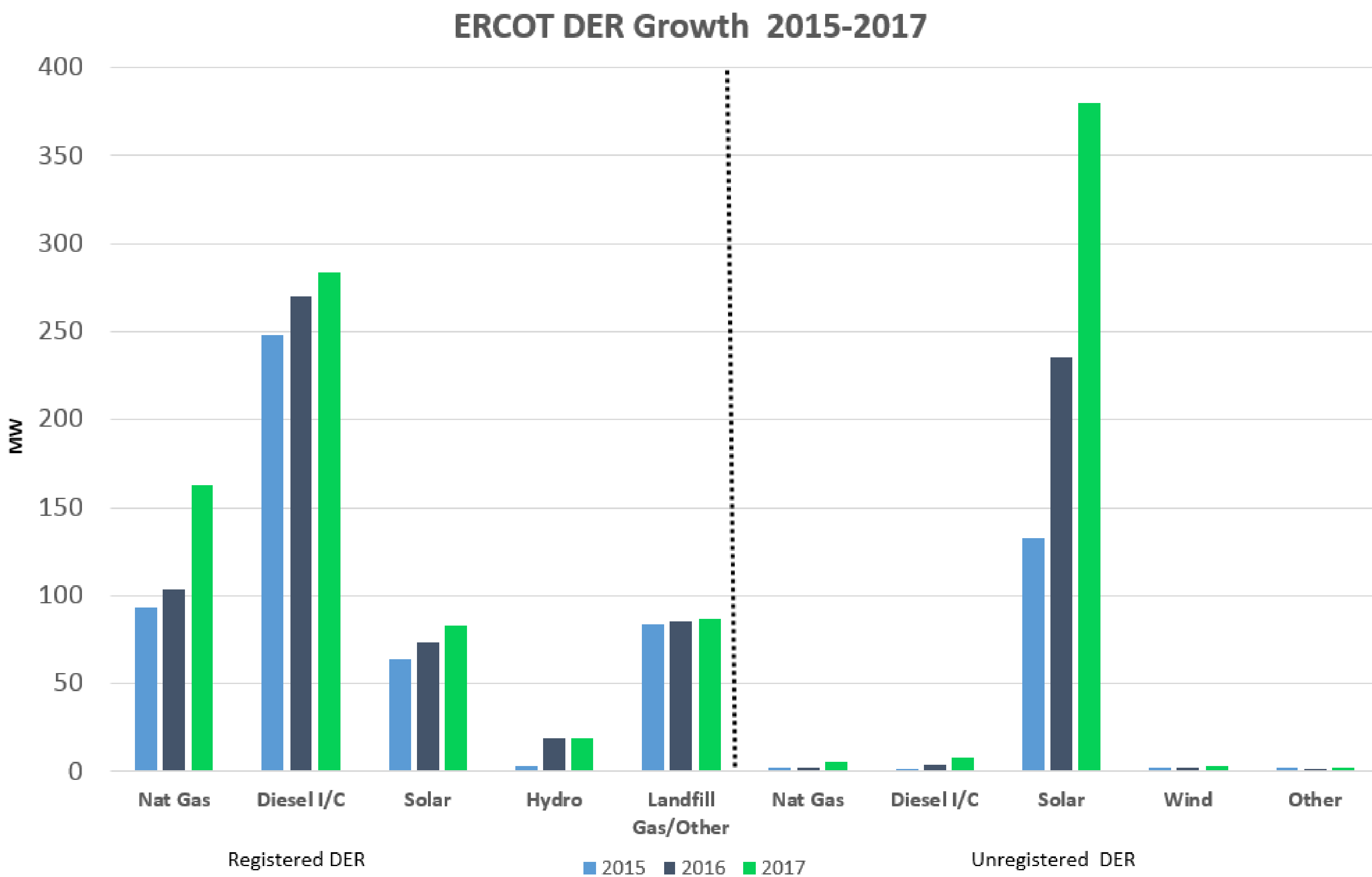
Transmission congestion drives large Locational Marginal Price (LMP) differences in the region

Distributed Energy Resources (DERs)

Distributed Energy Resources (DERs)

- DERs may include various technologies:
  - Gas/diesel
  - Wind/solar
  - Storage
- Historically, generation resources were only connected to the transmission system
- DERs are connected to the distribution system; ERCOT has limited visibility and interaction with distribution systems

Distributed Energy Resources in ERCOT



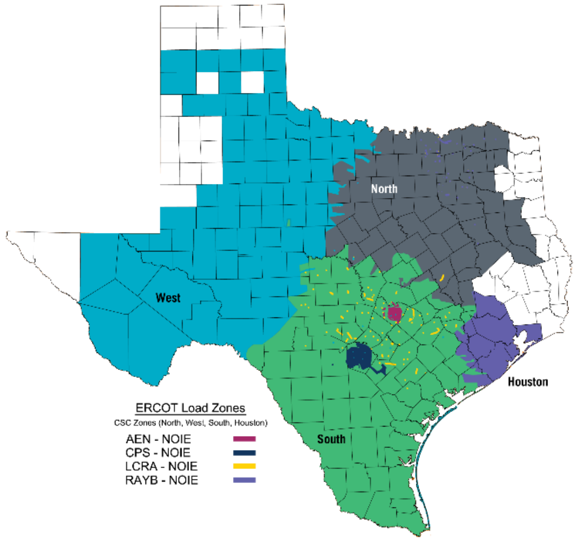
DER growth rate for 2015-2017 is 62%

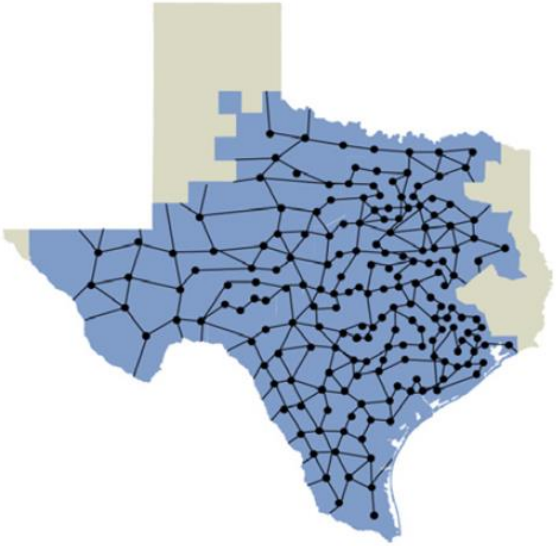
Current 2018 DER total is ~1,300 MWs and is expected to continue to grow

Integrating Registered Distributed Energy Resources

- To reliably operate and plan the ERCOT system, ERCOT is working on DER-related improvements:
  - **Visibility**: Worked with regulated Transmission/Distribution Service Providers to map some (93) of the existing registered DERs; working to map all registered DERs to transmission system load
  - **Reliability**: Working to provide locational price signals to registered DERs to support reliability and efficiency
  - **Planning**: Need reporting to properly capture capabilities and capacity from continued growth of DERs in planning processes

Prices Received by Distributed Energy Resources





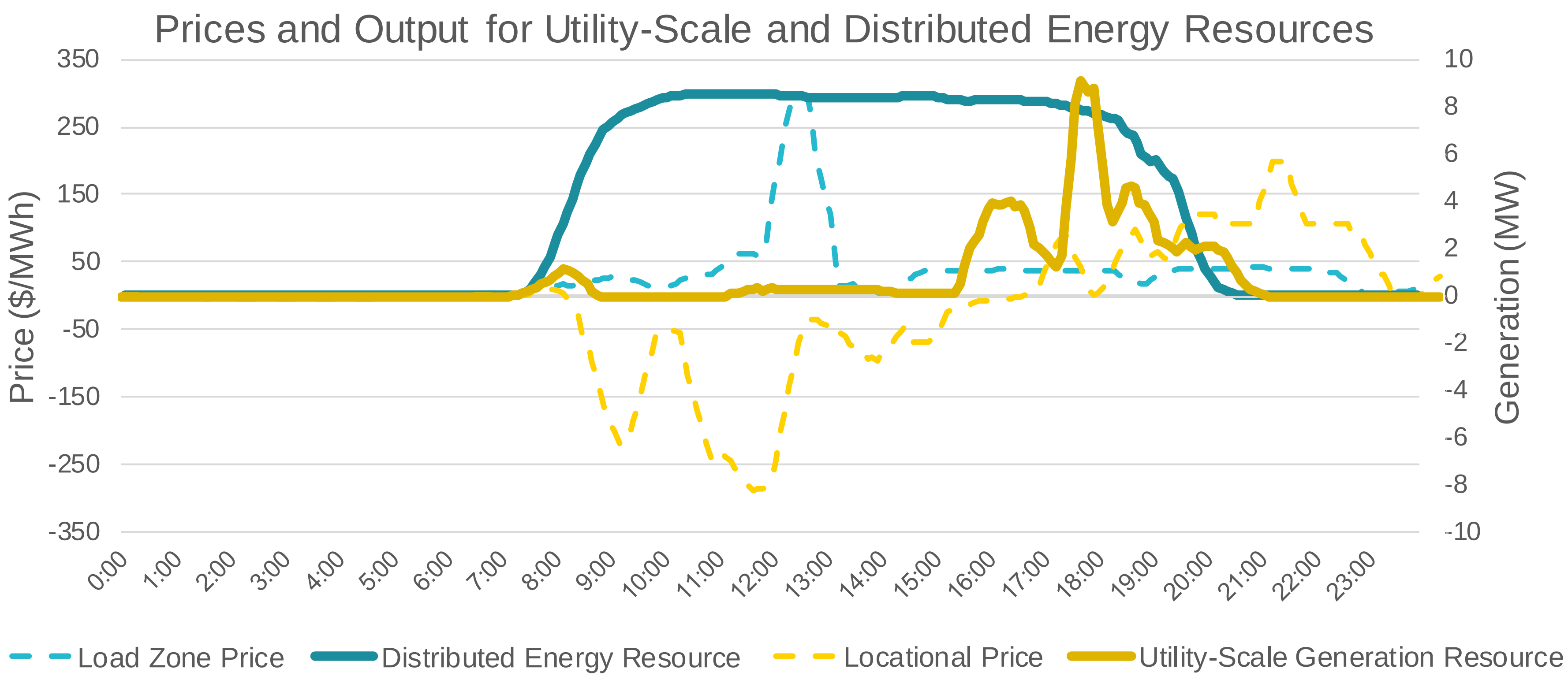
Current: Zonal Pricing

- DERs currently receive the zonal price.
- The Load Zone price is a weighted average of Locational Marginal Prices (LMPs) in the zone and does not fully reflect the local reliability need.

Future: Nodal Pricing

- Grid-scale resources that receive the locational price may have to overcompensate if nearby generation does not respond to local price signals.
- A LMP represents the value of energy at a specific location.
- Nodal prices better reflect the local reliability need.
- Registered DERs should receive a LMP in the future.

Zonal Pricing of DERs Results in Inefficient Price Signals



- In this instance, a DER solar facility does not receive negative locational prices; instead, it receives the Load Zone price, which does not dip below zero. Consequently, the DER solar facility does not lower its output.
- A grid-scale solar generation resource receives the LMP at its location, and in this example, lowers output accordingly when LMPs go negative.

Energy Storage

Why is Energy Storage of Interest?

- Energy storage (batteries) can be used for a variety of grid and customer applications:
  - Store energy at a resource
  - Arbitrage energy prices
  - Provide grid-level Ancillary Services
  - Defer or eliminate the need for transmission/distribution upgrades
  - Allow customers to reduce peak demand (to save on demand and/or transmission charges)
  - Provide high reliability at customer location
  - Enable micro-grid capability
  - Provide fuel for electric transportation
- Energy storage is scalable
  - A Tesla PowerWall has a maximum output of 5 to 7 kW
  - Some battery facilities are greater than 200 MW
- Energy storage can take energy from variable generation (wind and solar) and provide a dispatchable resource
- Costs of battery technologies are declining rapidly

Current Storage Activity in ERCOT and Beyond

- Currently, ~89 MW of battery storage resources are registered with ERCOT and participating in ERCOT Ancillary Services markets.
  - There are smaller DER battery systems that are not registered with ERCOT.
  - There also is a 4 MW battery in Presidio, TX, which was installed to improve customer reliability at the end of a 60-mile radial transmission line.[1]
- Approximately 1,889 MW of battery storage capacity is being studied in the ERCOT resource interconnection queue.
- In September 2016, American Electric Power applied to install batteries at two distribution substations in lieu of more costly system upgrades. The PUCT is reviewing the use of batteries as grid upgrades in Project No. 48023 (initial comments were submitted last week).
- FERC jurisdictional electric markets are subject to FERC Order No. 841, which requires increased access to energy, Ancillary Services and capacity markets for battery resources.

[1](Approved by the Public Utility Commission of Texas [PUCT] in April 2009 [Docket No. 35994].)

Integrating Energy Storage

Focus on increasing visibility and decreasing barriers to entry

- Develop increased system awareness of storage device operation and limitations in the control room
- Identify and reduce barriers to energy and Ancillary Services markets
- Adapt ERCOT system models to facilitate integration of storage technologies

Approach needs to be adaptable – we don't know how the technology will develop in our market

Transmission Supporting Load Growth

Transmission Development in West Texas

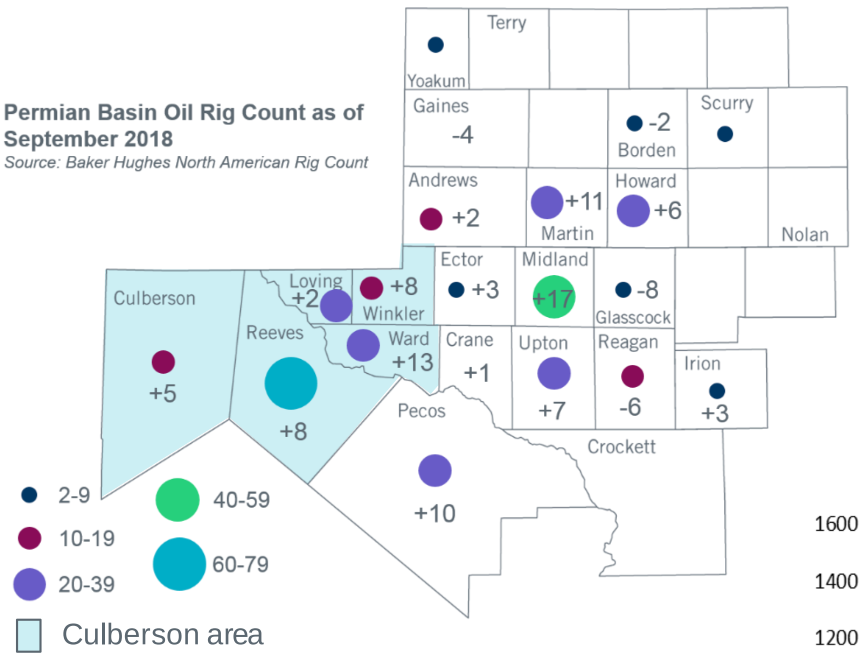
- Providing reliable electric service to meet the needs of oil and gas development in West Texas is a challenge.
  - Existing infrastructure was not designed for recent increases in customer demand.
  - Predicting the amount and location of future customer oil and gas demand growth is difficult.
  - Major transmission projects take five years to plan and build. Many oil and gas development companies have 18-month planning horizons.
  - Transmission upgrades, line maintenance and connecting new customers typically require line outages, which temporarily reduces existing available transmission capacity.

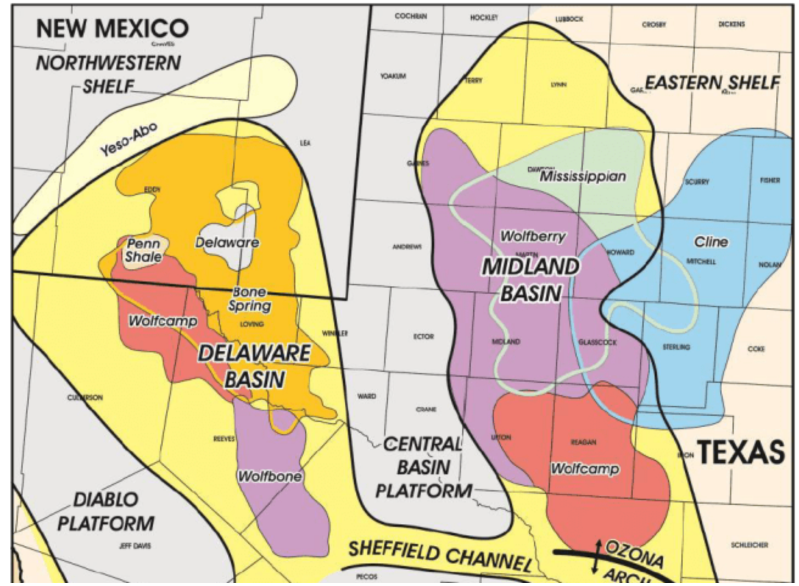
Culberson County Area Electricity Demand Growth

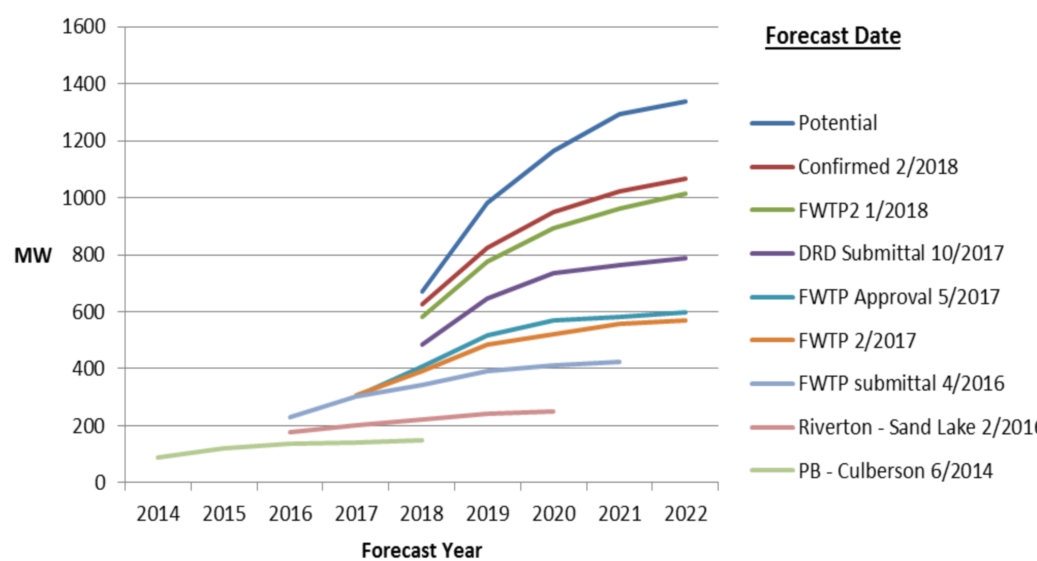
Permian Basin Rig Count

Permian Basin Oil Rig Count as of September 2018

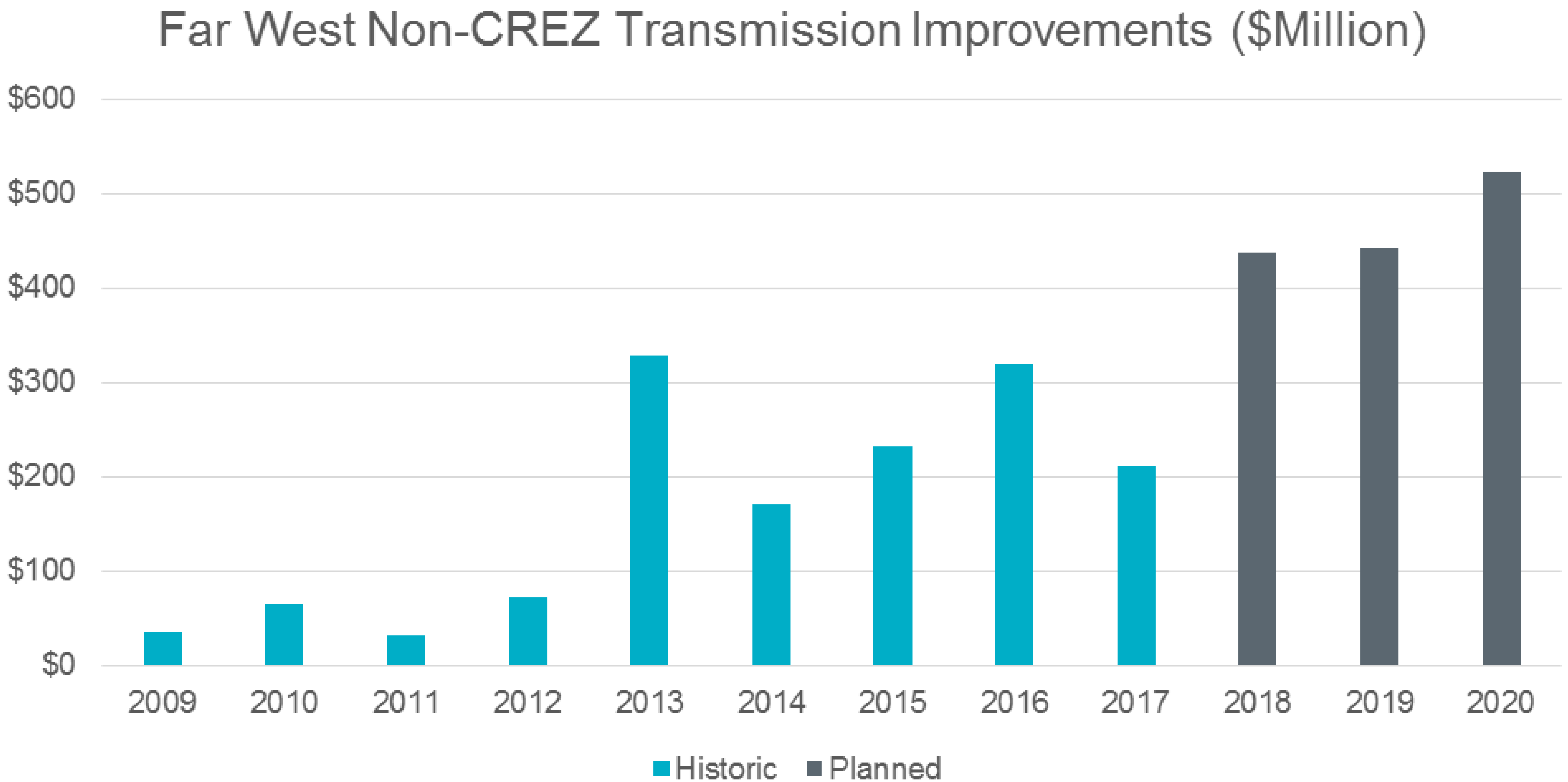
Source: Baker Hughes North American Rig Count





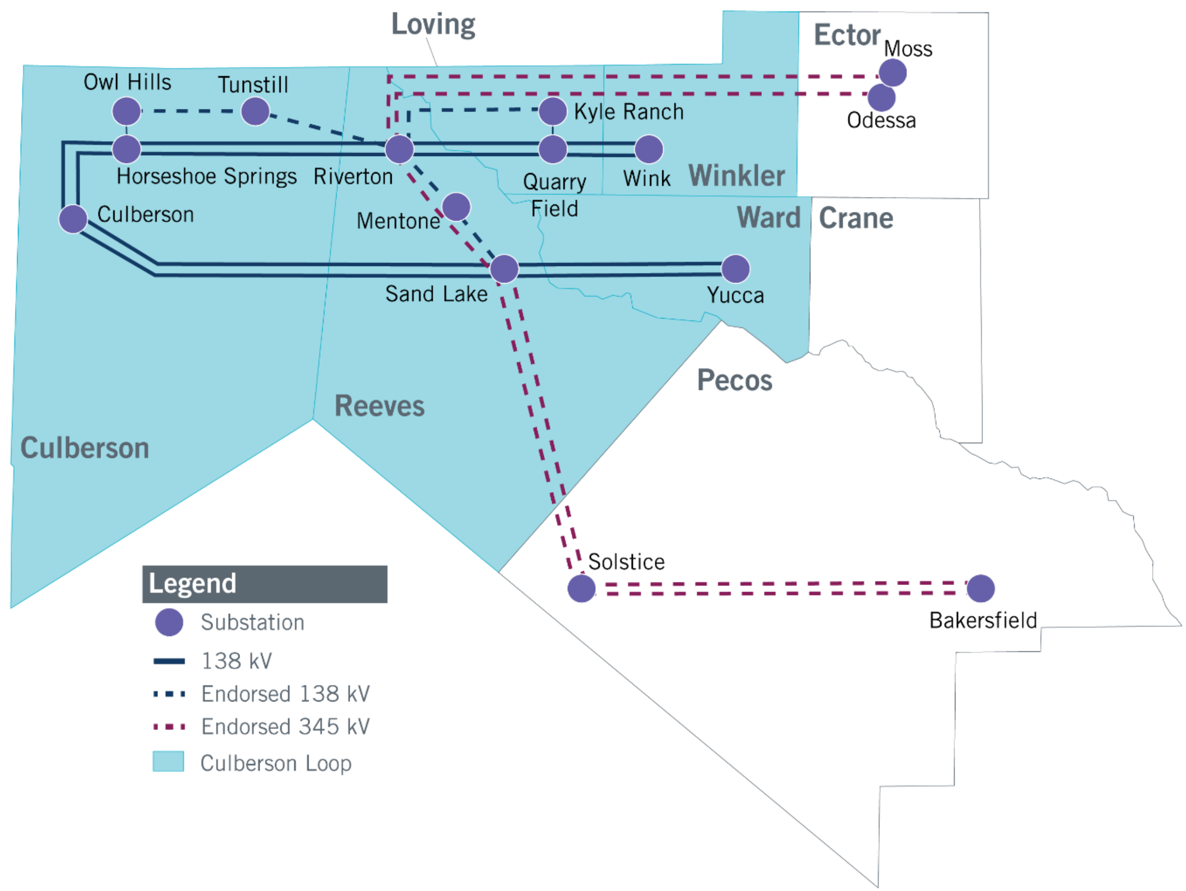


Transmission Development



Future Transmission Development

- The ERCOT Board of Directors recently endorsed a major transmission project in West Texas to ensure continued grid reliability in the region.
- This project should be fully constructed by April 2021.

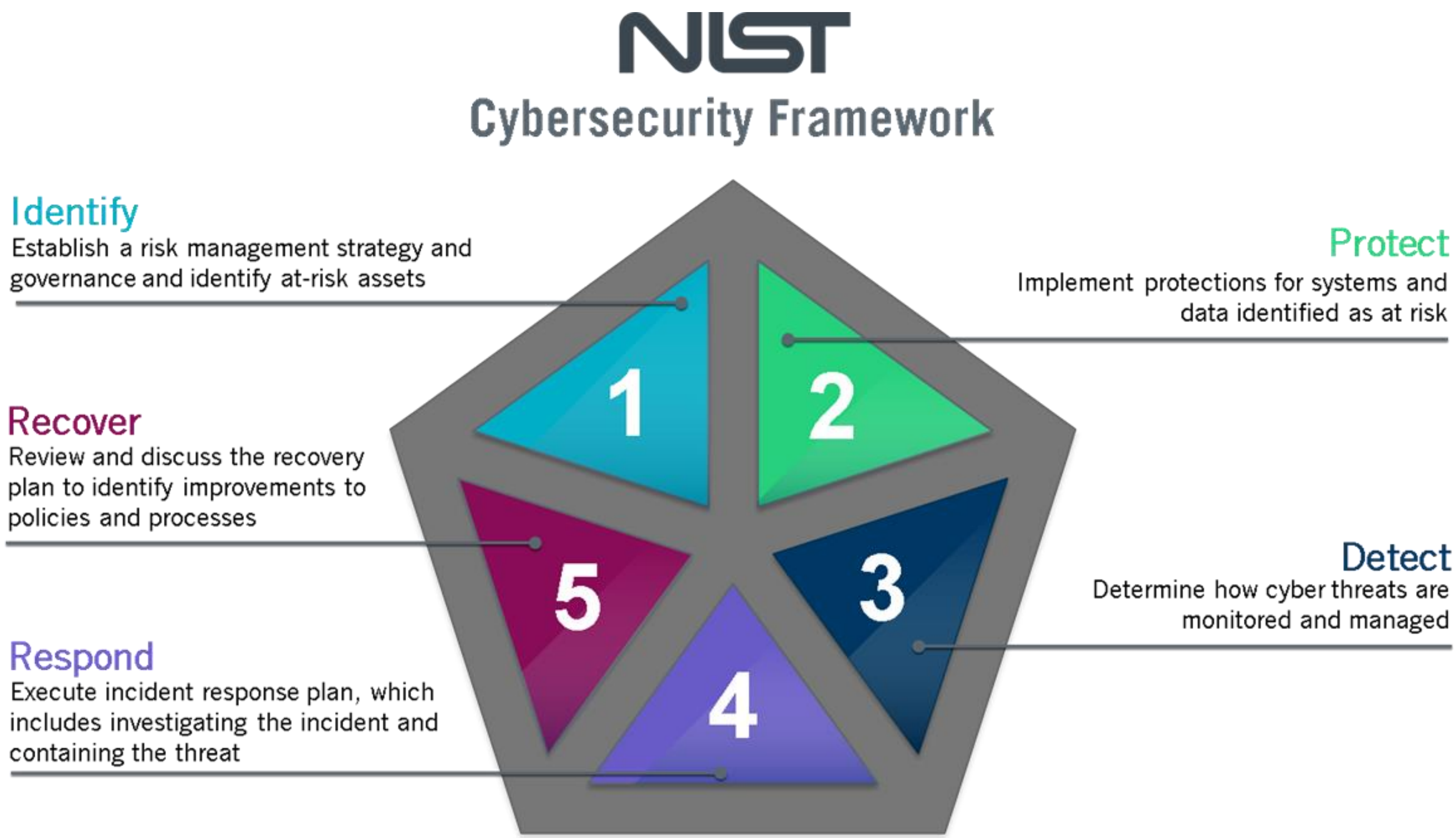


Cyber Security

ERCOT Cyber & Physical Security Program

- ERCOT has strong executive management support for security.
- ERCOT has a dedicated and integrated cyber/physical security organization and established strategy.
- ERCOT uses layered cyber and physical security architectures known as a defense-in-depth strategy, along with careful monitoring.
- ERCOT is committed to external collaboration with relevant government agencies, law enforcement, industry and national labs to enhance its and the industry's security posture.

Security Protection Approach



National Institute of Standards and Technology

Grid Security Collaboration

Federal/National	State	Industry	National Labs
US-CERT United States Computer Emergency Readiness Team	Public Utility Commission of Texas	North American Transmission Forum	INL Idaho National Laboratory
ICS-CERT Industrial Control Systems Cyber Emergency Response Team	Department of Public Safety Texas	EPRI Electric Power Research Institute	Pacific Northwest National Laboratory
National Electric Sector Cybersecurity Organization	DIR Dept. of Information Resources	IRC ISO/RTO Council	Sandia National Laboratories
NERC North American Electric Reliability Corporation	Texas Cybersecurity Council Building a More Secure and Prosperous Texas	ercot	Argonne National Laboratory
E-ISAC™ Electricity Information Sharing and Analysis Center		• Critical Infrastructure Protection Working Group (CIPWG) • Grid Resilience Working Group (GRWG)	
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