Report on Existing and Potential Electric System Constraints and Needs

December 2020

Key Takeaways

- In recent years, the ERCOT system has experienced a **significant increase in wind and solar generation** and a decline in fossil fuel plants. This trend is expected to continue over the next 15 years. Maintaining system reliability with a changing resource mix requires ERCOT to continually adapt its planning and operational practices.

- Residential and commercial **demand continues to grow** throughout the ERCOT system, most notably in major load centers. There is also **large industrial demand growth** along the coast and in West Texas. ERCOT has been improving its processes to account for hard-to-forecast load additions such as oil and gas in the Permian Basin and electric vehicle hubs.

- The growth of wind and solar generation in both **West Texas** and **South Texas** has resulted in **stability limits** on the generation in those areas. ERCOT studies show that potential transmission projects to relieve these constraints must be designed as **holistic solutions,** to allow the power to be reliably exported from these regions and deliver it to load centers.

- The purpose of transmission is to move power from generators to loads. Load growth and changes in the resource mix in ERCOT have led to an **increase in transmission** construction and overall transmission costs. **However, the annual cost of transmission per energy use has been dropping since 2017**.

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About ERCOT Transmission Planning

ERCOT supervises and exercises comprehensive independent authority over the planning of transmission projects for the ERCOT system as outlined in PURA and Public Utility Commission of Texas (PUCT) Substantive Rules. The PUCT Substantive Rules further indicate that the independent organization (IO) shall evaluate and make a recommendation to the PUCT as to the need for any transmission facility over which the IO has comprehensive transmission planning authority. ERCOT examines the need for proposed transmission projects based on ERCOT planning criteria and NERC Reliability Standards. Once a project need has been identified, ERCOT evaluates project alternatives based on cost-effectiveness, long-term system needs and other factors.

The ERCOT Nodal Protocols and Planning Guide describe the practices and procedures through which ERCOT meets its requirements related to system planning under PURA, PUCT Substantive Rules, and North American Electric Reliability Corporation (NERC) Reliability Standards.

ERCOT annually performs a planning assessment of the transmission system that is primarily based on three sets of studies:

- The Regional Transmission Plan (RTP) addresses region-wide reliability and economic transmission needs and includes the recommendation of specific planned improvements to meet those needs for the upcoming six years. The public version of the 2020 RTP report is posted on the ERCOT website at: http://www.ercot.com/gridinfo/planning.
- The Long-Term System Assessment (LTSA) uses scenario-analysis techniques to assess the potential needs of the ERCOT system up to 15 years into the future. The role of the LTSA is to provide a roadmap for future transmission system expansion and identify long-term trends that should be considered in near-term planning. The biennial LTSA study is completed in even-numbered years. The 2020 Long-Term System Assessment report is posted on the ERCOT website at: http://www.ercot.com/gridinfo/planning.
- Stability studies are performed to assess the angular stability, voltage stability, and frequency response of the ERCOT system. Due to the security-related sensitive nature of the information contained in these study reports, they are not published on the ERCOT website.

Recent Constraints

Top 10 constraints on the ERCOT system

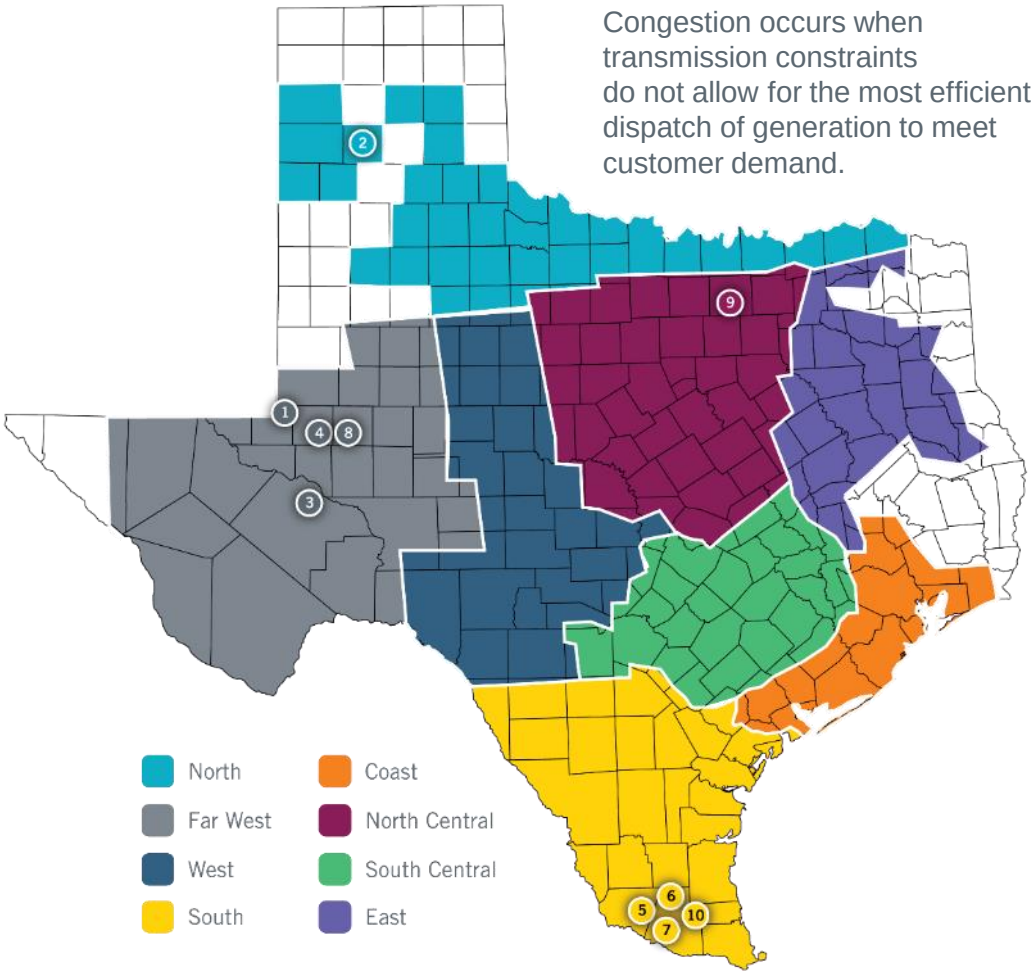
Oct. 2019 to Sept. 2020, based on real-time data

Map	Constraint	Congestion Rent*	Outage Related?
1	Andrews County South - Amoco Three Bar Tap - Dollarhide - No Trees Switch 138-kV Lines	$463 M	
2	Panhandle Export	$131 M	Planned
3	Rio Pecos – Fort Stockton & Rio Pecos – 16th Street 138-kV Lines	$85 M	Construction
4	Odessa EHV - Trigas Odessa Tap & Odessa - Odessa North 138-kV Lines	$73 M	Construction
5	Hidalgo Energy Center - Azteca Sub 138-kV Line	$62 M	Hurricane Hanna
6	North Edinburg 345/138-kV Transformer	$50 M	
7	Weslaco Switch - North Alamo 138-kV Line	$36 M	Hurricane Hanna
8	Odessa EHV 345/138-kV Transformer	$33 M	Construction
9	West - TI 138-kV Line	$31 M	Planned
10	Key Switch - North McAllen 138-kV Line	$30 M	Hurricane Hanna

All constraints have planned projects that will mitigate the congestion.

*Congestion rent indicates areas of the system where economic transmission projects may be beneficial. It is not an indication of whether a project to reduce specific congestion would or would not meet the ERCOT economic planning criteria.

Congestion occurs when transmission constraints do not allow for the most efficient dispatch of generation to meet customer demand.

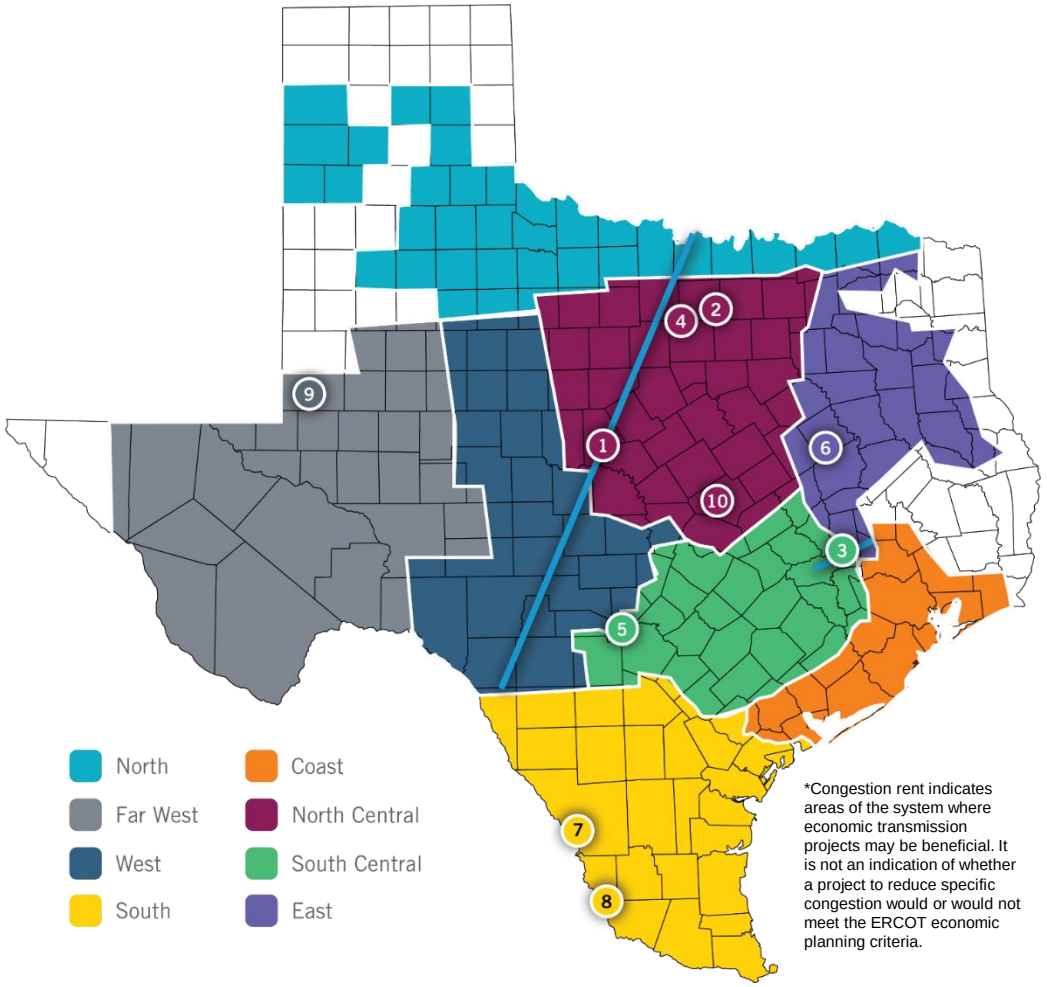


Projected Constraints

Top 10 projected constraints on the ERCOT system for 2022 and 2025

Based on economic analysis conducted for the 2020 RTP

Map	Constraint	Congestion Rent* 2022	Congestion Rent* 2025
1	West Texas Export Interface	$224.8M	$259.9M
2	West TNP to TI TNP 138-kV Line	$28.3M	$97.4M
3	North to Houston Interface	$38.6M	$78.4M
4	Hicks Switch to Alliance Switch 345-kV Line	$99.9M	-
5	Medina Lake to Tally Road 138-kV Line	$38.5M	$50.2M
6	Big Brown to Jewett 345-kV Line	$28.2M	$25.5M
7	Laredo VFT North to Las Cruces 138-kV Line	$24.7M	$28.5M
8	Lobo to North Edinburg Interface	$19.0M	$34.2M
9	Andrews North to Exxon Means Tap 138-kV Line	$27.6M	$22.8M
10	Killeen Switch to Salado Switch 345-kV Line	$19.3M	$17.0M



*Congestion rent indicates areas of the system where economic transmission projects may be beneficial. It is not an indication of whether a project to reduce specific congestion would or would not meet the ERCOT economic planning criteria.

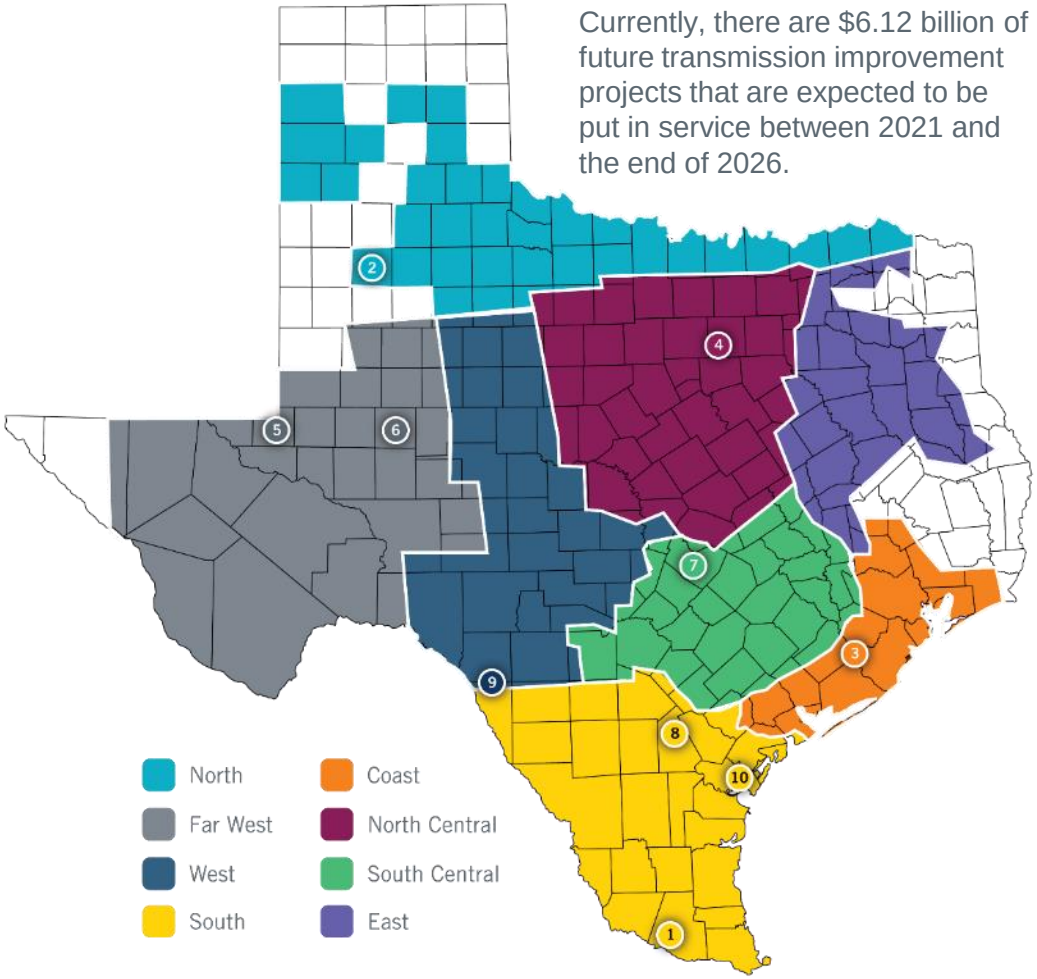
Planned Improvements

Top 10 significant improvements on the ERCOT system

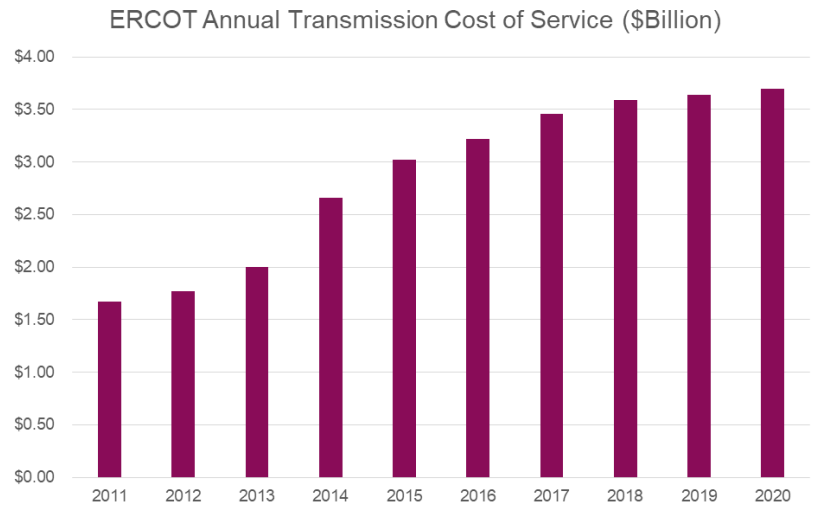
Projects planned for completion within the next six years

Map	Transmission Improvement	In-Service
1	New Stewart Road 345-kV Station with 345/138-kV Transformers and Shunt Reactor	2021
2	New Ogallala – Blackwater Draw, Blackwater Draw – Folsom Point, Blackwater Draw – Double Mountain, and Double Mountain – Fiddlewood Switch – Farmland 345-kV Lines	2021
3	New Bailey – Jones Creek 345-kV Double-Circuit Line	2021
4	Upgrade Saginaw Switch – Eagle Mountain 138-kV Double-Circuit Line	2021
5	New Quarry Field 345/138-kV Station with 345/138-kV Transformers	2021
6	New Bearkat – Longshore 345-kV Line	2022
7	New Hornsby 345-kV Station	2022
8	New Borglum 138/69-kV Station with 138/69-kV Transformer, Convert Beeville – Three Rivers 69-kV Line to 138-kV, and New Tuleta – Beeville 138/69-kV Double Circuit Line	2022
9	New Brackettville – Escondido 138-kV Line	2023
10	Corpus Christi North Shore Project	2024

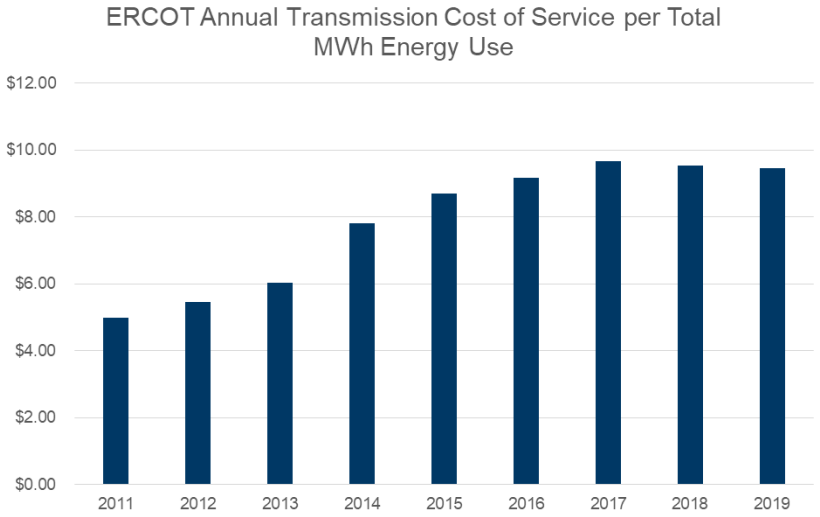
Currently, there are $6.12 billion of future transmission improvement projects that are expected to be put in service between 2021 and the end of 2026.

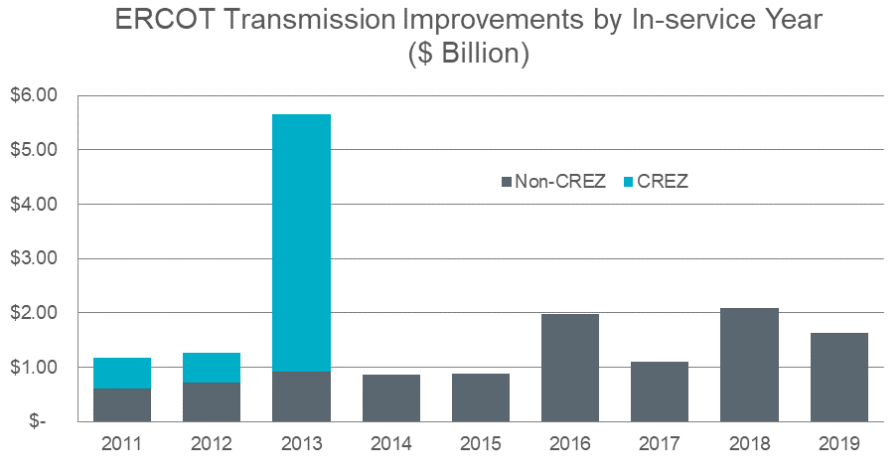


Transmission Cost Trends



ERCOT annual Transmission Cost of Service (TCOS) and the corresponding investment in transmission improvements have been fairly consistent over the past several years. However, TCOS per total energy use has been dropping since 2017.

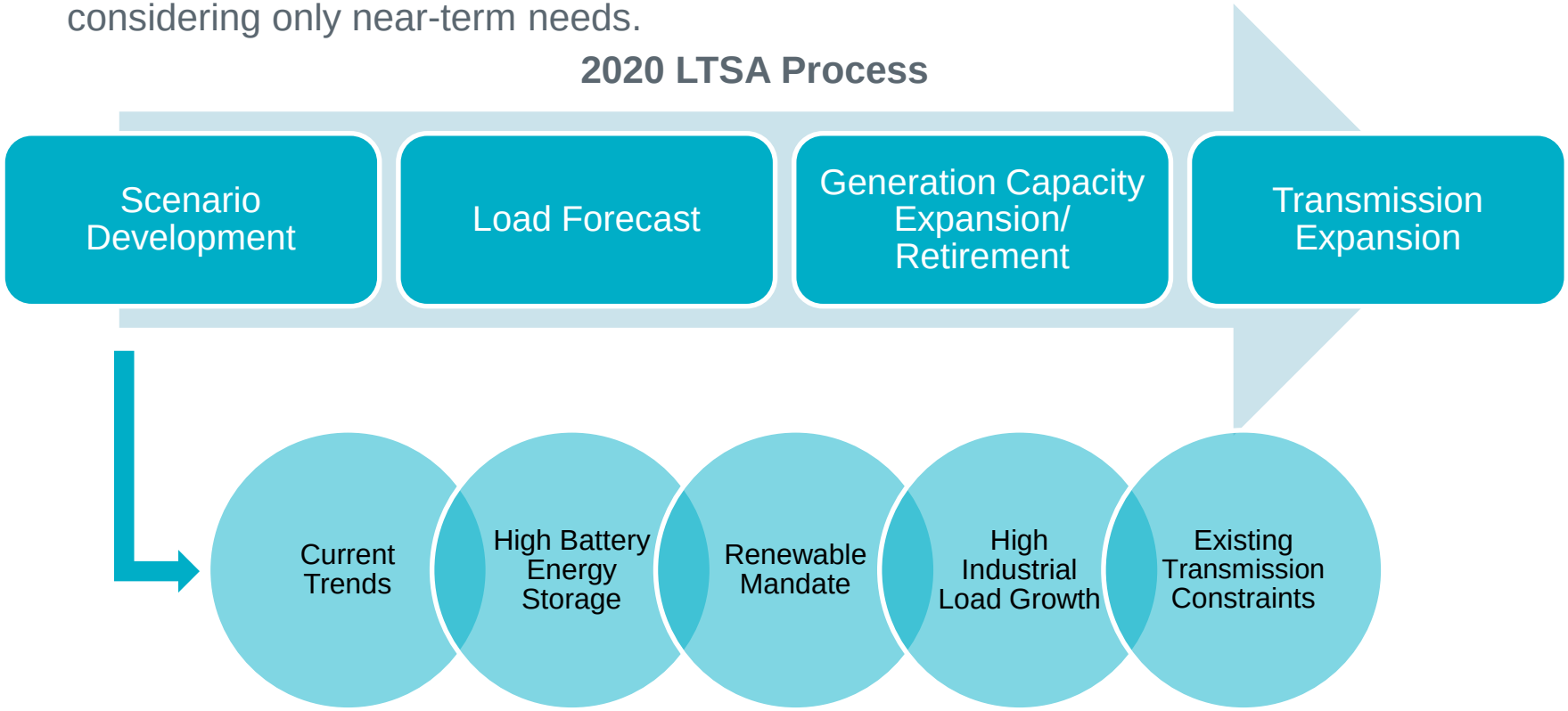




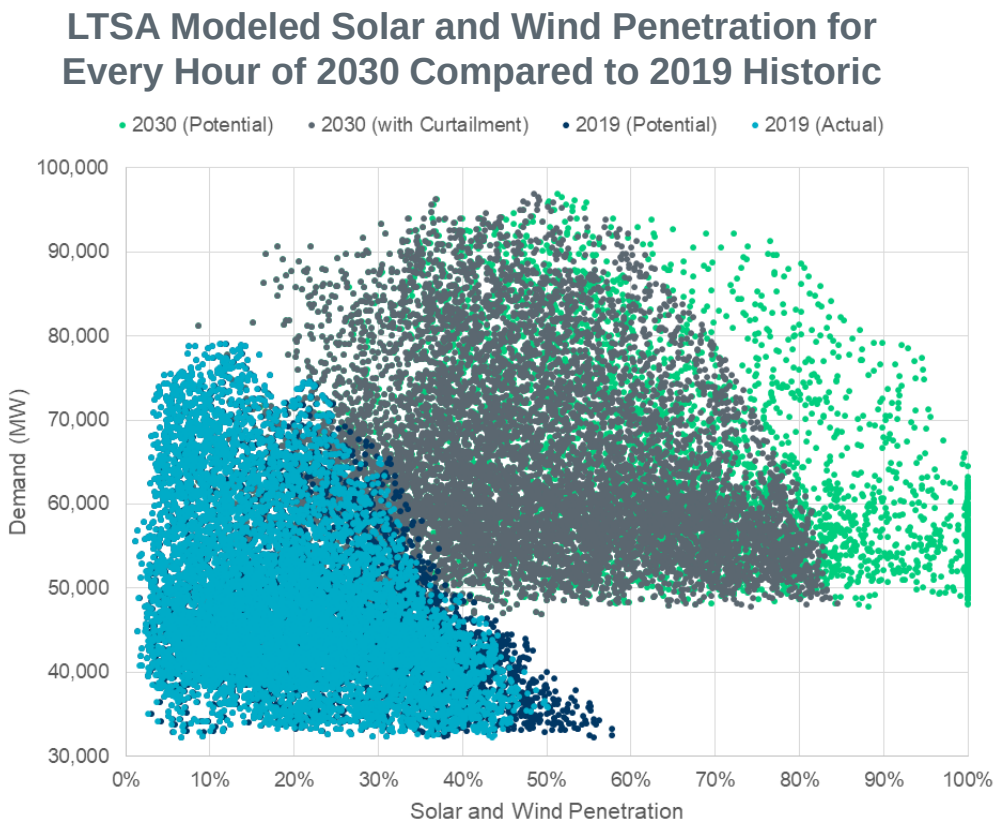
2020 Long-Term System Assessment (LTSA)

- ERCOT's 2020 LTSA analyzed potential system needs through 2035.
- ERCOT analyzes different future scenarios in its long-term planning process to account for the inherent uncertainty of planning the transmission system beyond six years. The goal of using scenarios in the LTSA is to identify upgrades that are advantageous across a range of scenarios, or more economical than upgrades that are determined when considering only near-term needs.

2020 LTSA Process



2020 LTSA Renewable Generation Penetration

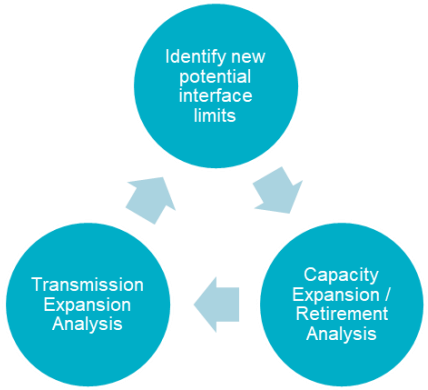


Renewable penetration is defined as the percentage of total demand at any given time that is being served by solar and wind generation. The "potential" penetration is based on the available wind and solar irradiance while the "actual" and "with curtailment" values include transmission constraints and other reliability limitations.

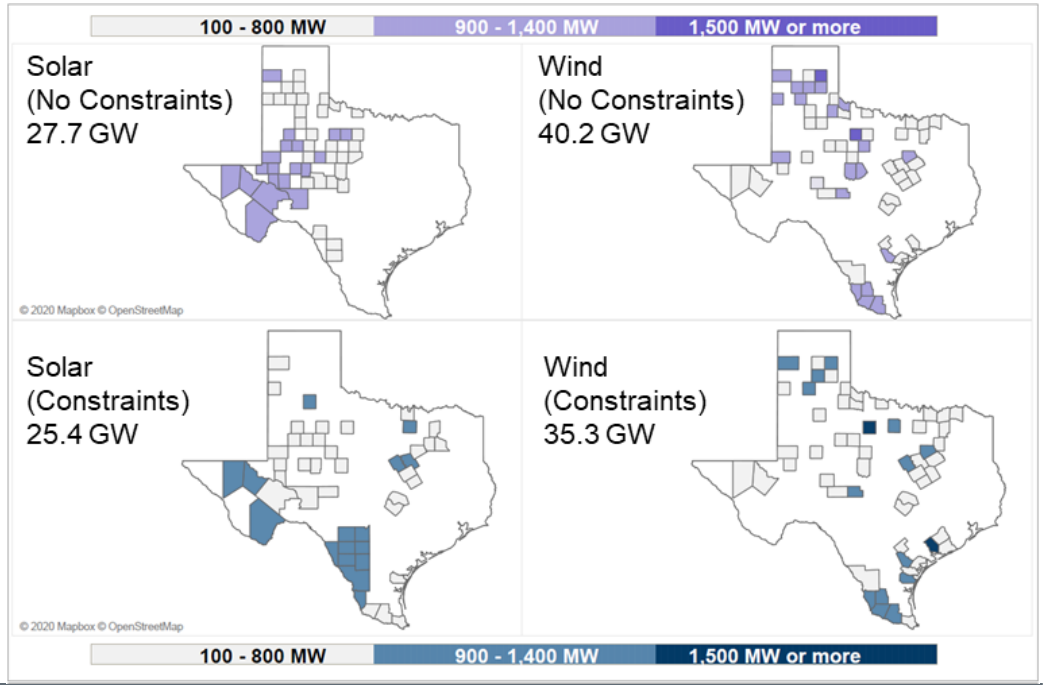
- The results for the LTSA capacity expansion and retirement analysis showed ~21 GW of thermal generation retired and significant growth of solar, wind, and combined cycle generation in all five scenarios.
- The growth in solar and wind caused significantly higher penetrations of renewable generation compared to recent years.
- Historically, the most stressed system conditions – from both resource scarcity and transmission security standpoints – have been during summer afternoons. In all five scenarios studied, stressed system conditions were observed at other times of the day and on days throughout the year due to the changed resource mix.

2020 LTSA Transmission Limit Impacts on Generation

- For the Current Trends Scenario, ERCOT conducted two iterations of capacity expansion/ retirement analysis considering transmission constraints.
- The results showed that transmission constraints could lead to:
  - Less wind and solar generation capacity being constructed
  - New wind and solar generation being located closer to load centers and, as a result, farther from the most resource-rich regions
  - Increased utilization of natural gas generation and battery energy storage
  - Fewer capacity additions overall



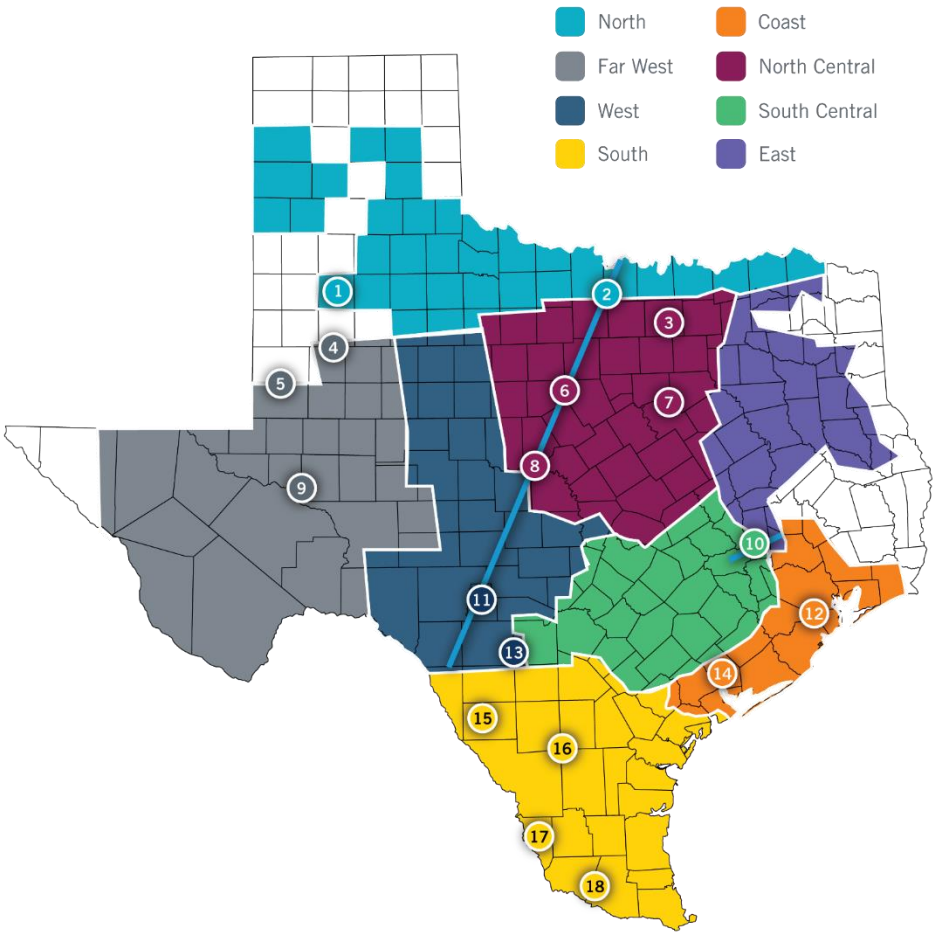
Comparison of Wind and Solar Generation Expansion
(Current Trends, 2035)



2020 LTSA Transmission Expansion

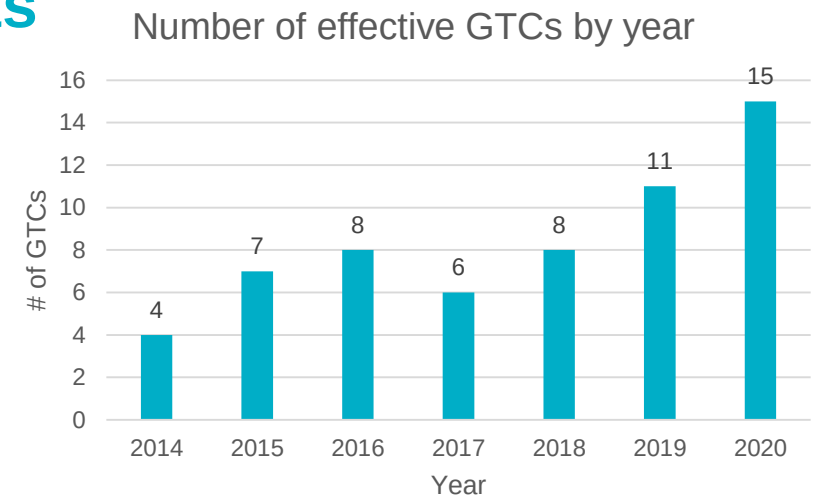
- Holistic solutions addressing both regional limits on the long-distance transfer of power and local constraints closer to urban demand centers are required to accommodate high transfers of generation from West Texas.
- The need for transmission improvements is driven both by the location of new generation and trends in customer demand growth.
- Large industrial load additions in both rural and urban areas can increase the need for major transmission improvements.
- Times of use and flexibility of customer demand are shifting as new technologies are adopted.
- Evaluation of system conditions other than peak load is becoming increasingly important.

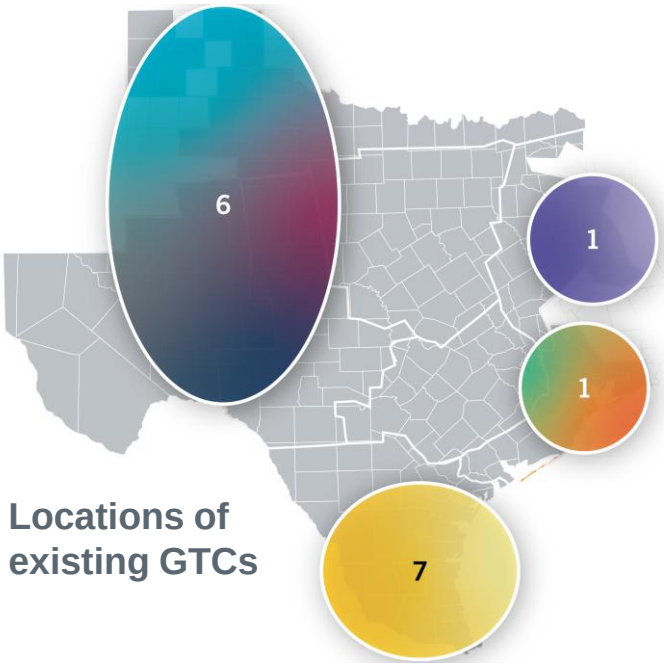
Locations of Transmission Improvements Identified for the Current Trends Scenario, 2035



Increasing Stability Constraints

- As of October 31, 2020, there were 48 GW of renewable generation (~35.4 GW wind and ~12.4 GW solar) planned to be in service by the end of 2021.
- Much of the growth in renewable generation is concentrated in West Texas and South Texas, contributing to stability constraints associated with the long-distance transfer of power from these areas to urban load centers.
- These stability constraints can limit power transfers below the physical thermal ratings of the individual transmission lines.
- A Generic Transmission Constraint (GTC) is a tool that ERCOT uses to manage stability limitations in real-time operations.
- ERCOT has seen an increase in stability constraints in recent years, particularly in West Texas and South Texas, which has led to an overall increase in the number of GTCs.

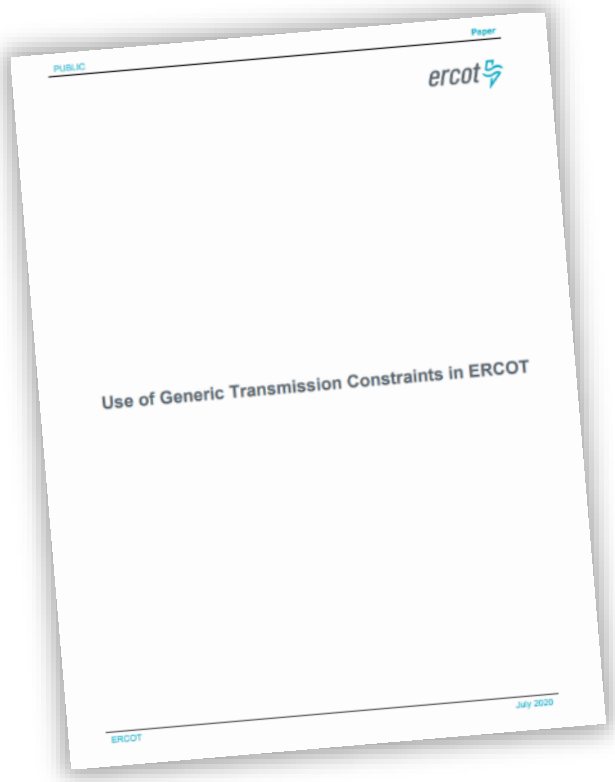




Locations of existing GTCs

Increasing Stability Constraints

- ERCOT hosted two workshops in 2020 related to GTCs. The intent of these workshops was to:
  - Help stakeholders better understand stability challenges being observed in ERCOT studies,
  - Explain the need/use of GTCs to manage stability constraints, and
  - Discuss options to relieve stability constraints.
- ERCOT, in consultation with TSPs, develops an exit alternative that would allow each GTC to be retired. Most GTC exit alternatives require significant transmission upgrades.
- Typically, the transmission upgrades associated with GTC exit alternatives are considered as potential economic-driven projects and can be recommended if they meet the economic planning criteria for new projects.
- ERCOT will continue to work with stakeholders to identify potential improvement ideas to reduce the impacts of stability constraints.

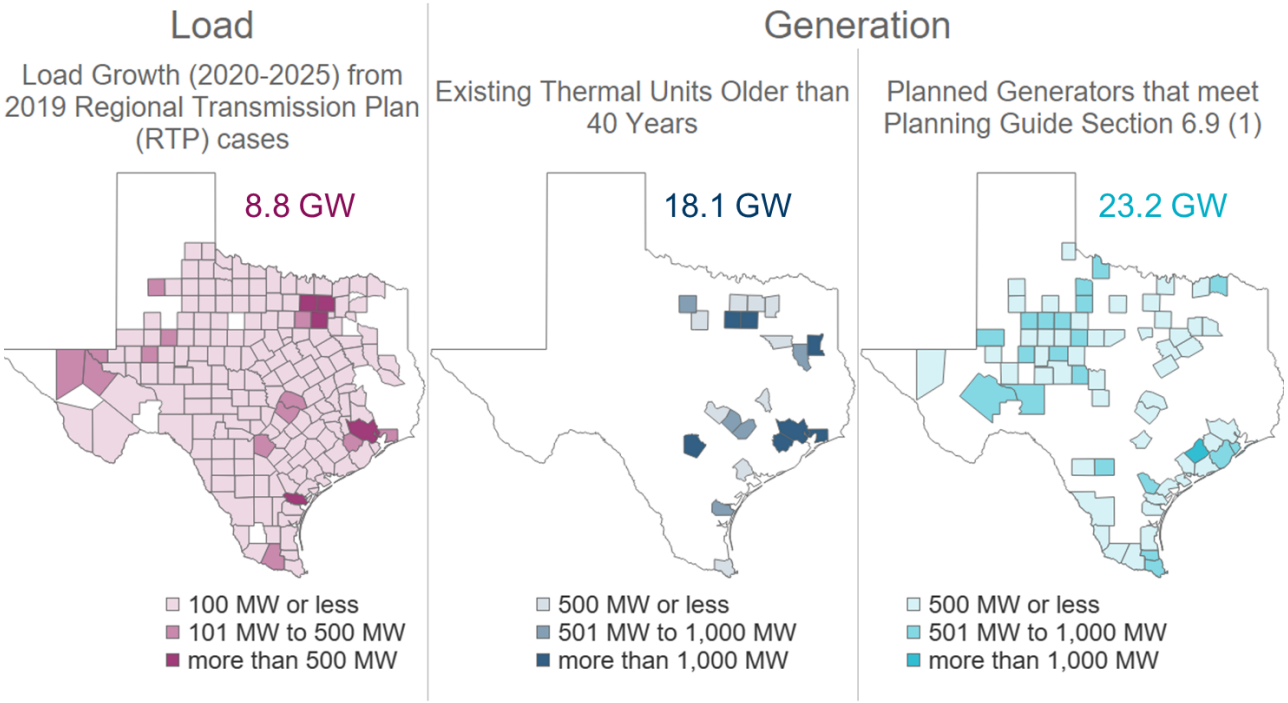


- ERCOT developed a GTC whitepaper in 2020 to help stakeholders understand ERCOT's management of stability constraints.

  The whitepaper is posted at: http://www.ercot.com/content/wcm/lists/197392/The_Use_of_GTCs_in_ERCOT_July_2020.pdf.

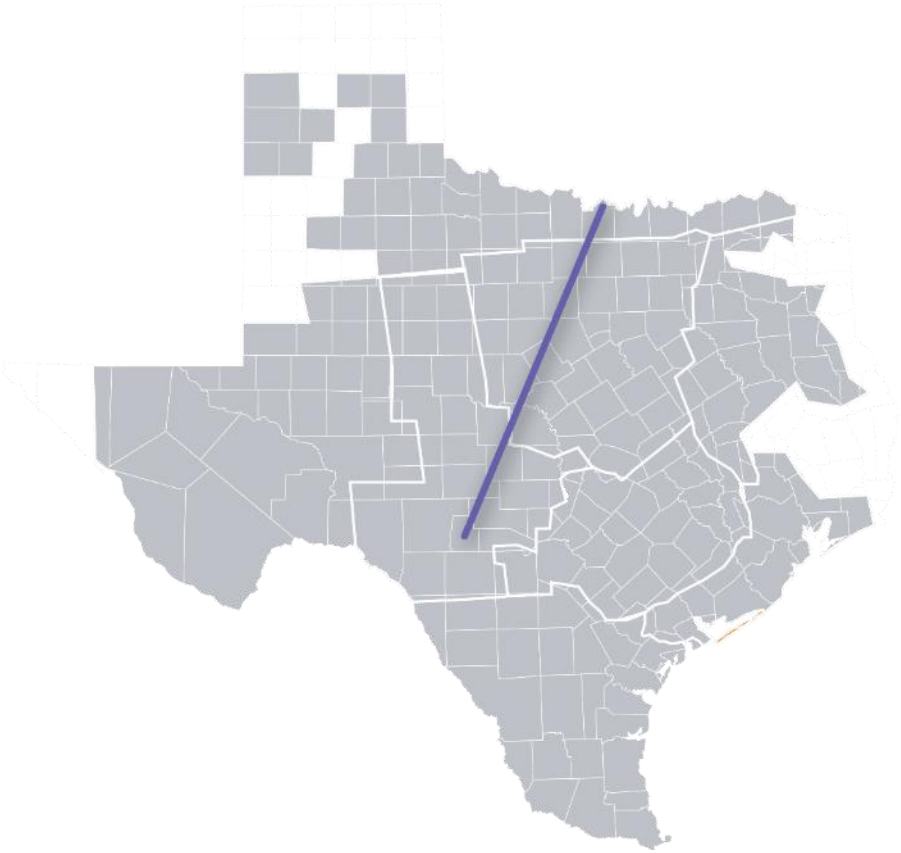
Need for Holistic Solutions

- Increased transfers from renewable-rich regions to load centers, continued load growth, and the retirement of thermal generation closer to load centers also contribute to an increase in transmission constraints near load centers.
- The full benefit of new transfer paths to relieve stability-related export constraints cannot be realized without corresponding relief to local transmission constraints.
- Holistic solutions that address both stability constraints and downstream local transmission constraints are needed.



Existing thermal unit capacities are from the Final Winter 2020/21 SARA report and planned generation capacities are from the October 2020 GIS report. http://www.ercot.com/gridinfo/resource

West Texas Export

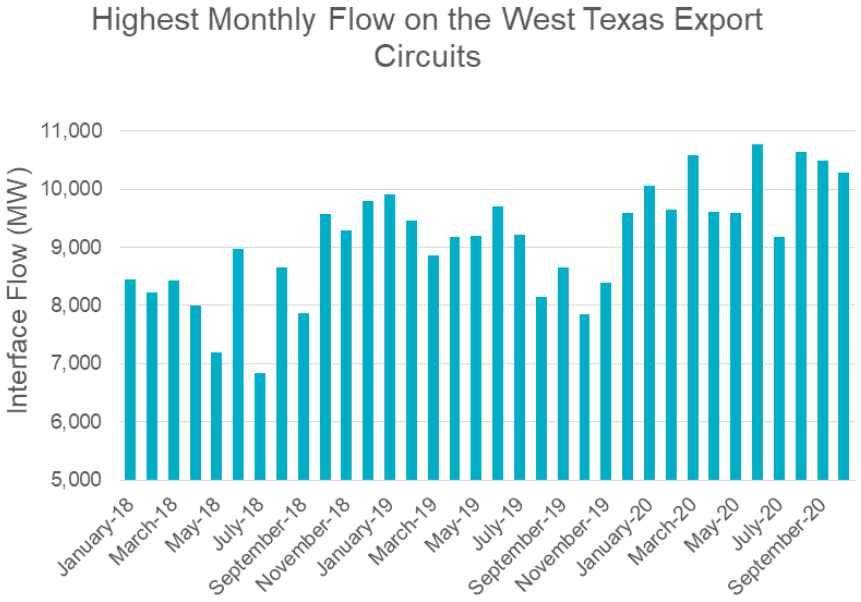


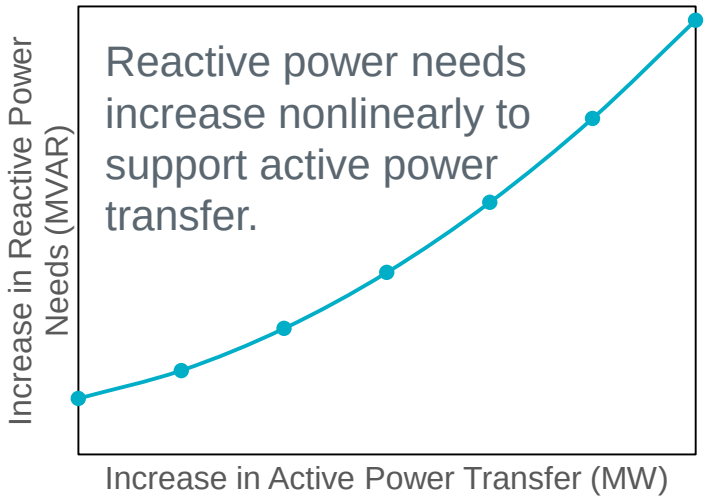
Approximate Location of the West Texas Export GTC Interface

- Renewable generation in West Texas is expected to exceed 33 GW by 2021.
- ERCOT planning studies, including the 2020 West Texas Export Stability Assessment, have identified a stability constraint that will limit the transfer of power from West Texas to ERCOT load centers.
- Both the 2020 RTP and the 2020 LTSA indicate that this West Texas Export constraint is expected to have the highest amount of congestion rent in the future if transmission improvements are not implemented.
- ERCOT established the West Texas Export GTC in October 2020 to manage the stability constraint in real-time operations. Under normal conditions, the current GTC limit is 11,660 MW.
- The transmission circuits used to monitor West Texas exports and the limit could change over time as the system evolves.

West Texas Export

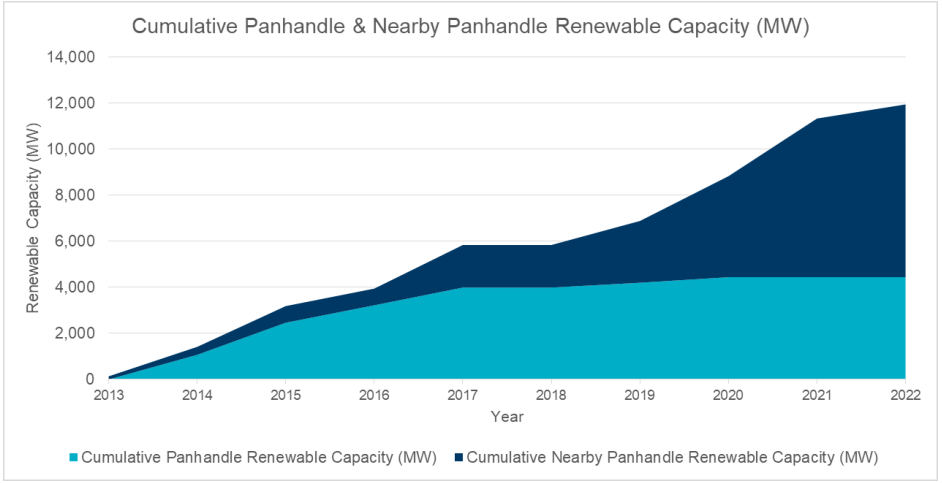
- ERCOT initiated the West Texas Export Special Study in late 2020 to develop a roadmap of transmission improvements that will allow more power transfers from West Texas to ERCOT load centers. The potential options being evaluated include, but are not limited to:
  - Long-distance, extra-high voltage transmission circuits, including 345-kV or above
  - Voltage Source Converter-HVDC circuits
  - Dynamic reactive devices
- Due to the nature of the West Texas export stability constraint, it is expected that relatively short lead time dynamic reactive devices alone will not significantly improve the stability constraints.
- The study is expected to be completed in 2021.

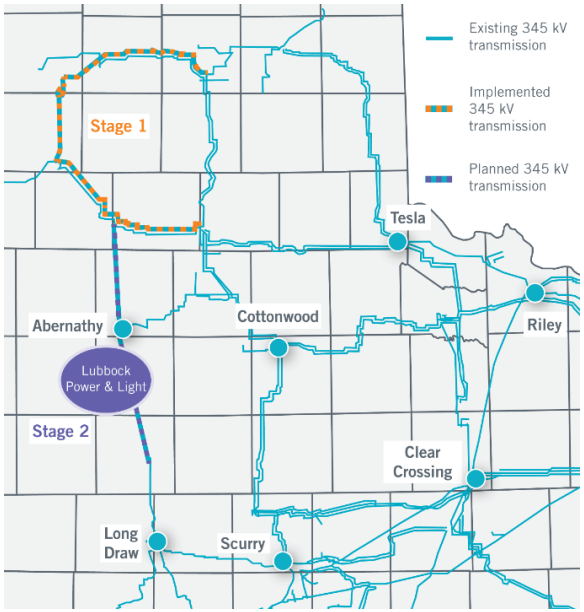




Panhandle Renewable Development and Improvements

- Exports of power from the Panhandle region were limited by stability constraints throughout 2020.
- In 2014, ERCOT created a holistic roadmap[1] of potential future transmission system improvements to increase the stability limits.
- In recent years, ERCOT has performed annual stability assessments of the region, accounting for generation additions within and 'nearby' the Panhandle. The key findings from the 2020 assessment include:
  - More than 11 GW of renewable generation are scheduled to connect to this area by 2022.
  - The new circuits needed to integrated Lubbock Power and Light customers will improve the power transfer capability from the Panhandle region.
- ERCOT will continue to evaluate the system and options to maintain stability and improve the transfer capability.



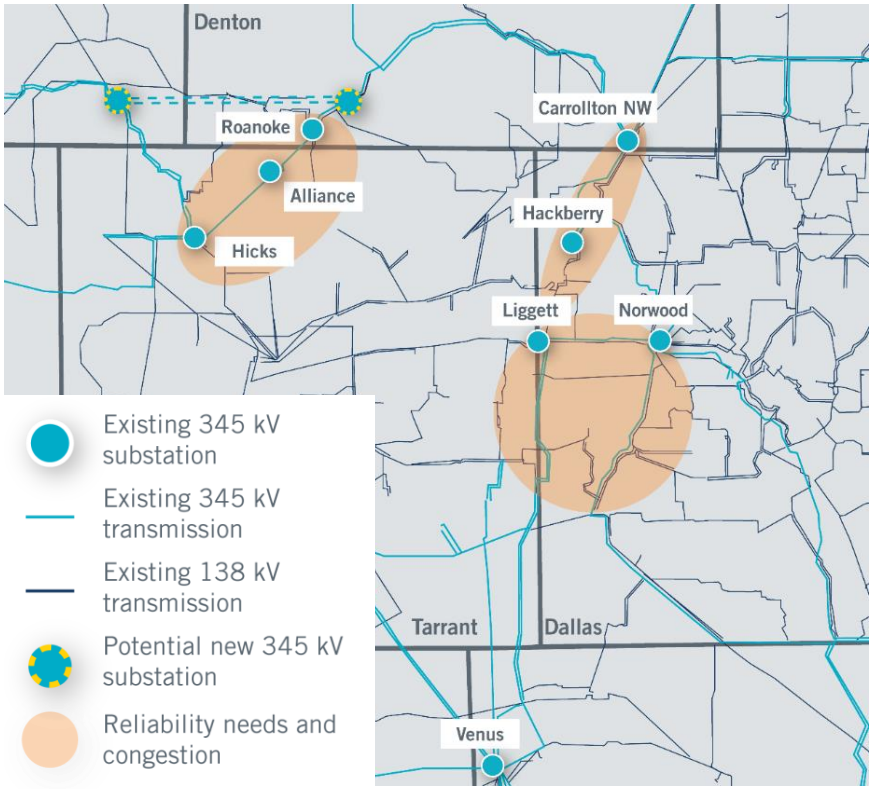


From the roadmap, Stage 1 improvements were placed into service in 2018, and a variation of Stage 2 improvements are planned to be placed into service in 2021, corresponding with the ERCOT integration of Lubbock Power and Light.

1 http://www.ercot.com/content/news/presentations/2014/Panhandle%20Renewable%20Energy%20Zone%20Study%20Report.pdf

Dallas-Fort Worth Area

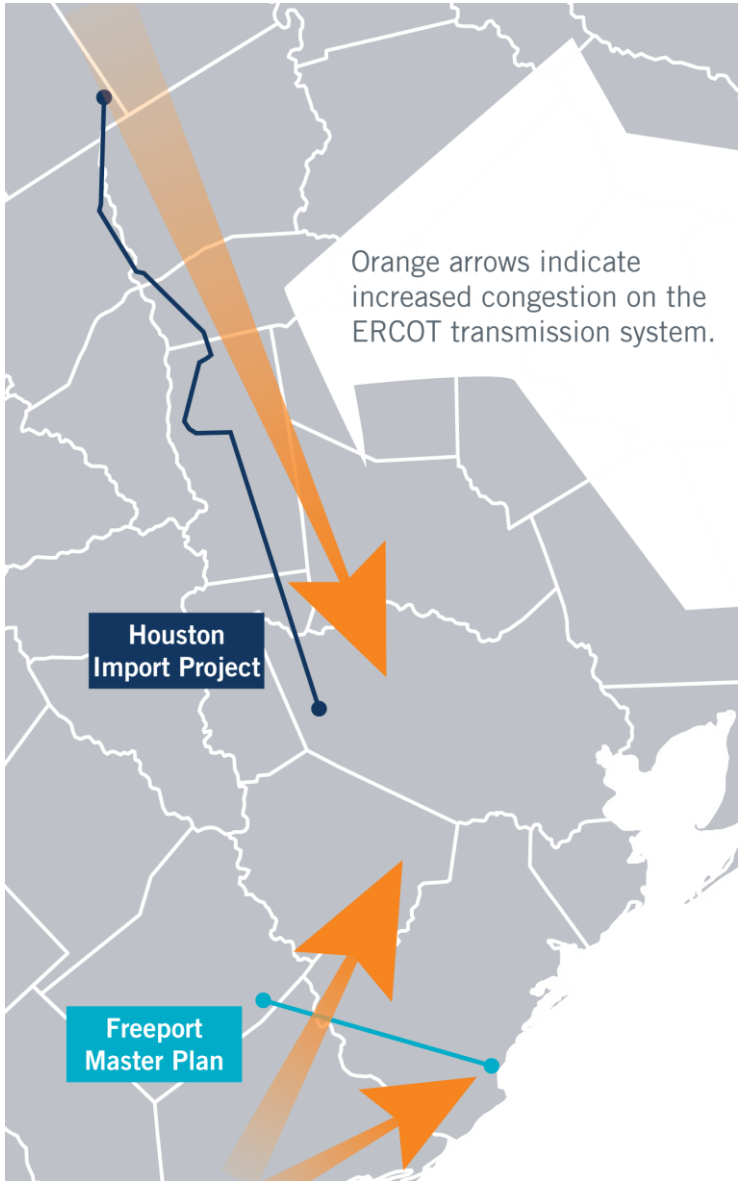
- The combination of generation development northwest of the Dallas-Fort Worth area and load growth within the area is expected to exceed transmission capacity in this region.
- The **2020 RTP** identified both reliability needs and significant congestion in the northwest Dallas-Fort Worth area, requiring a new transmission path.
  - ERCOT and TSPs are continuing to evaluate project options.
  - Additional reliability needs were identified within the central part of the Dallas-Fort Worth area.
  - Future RPG submittals for projects to meet these needs are expected.



- Some of the most highly-congested circuits identified in the **2020 LTSA** were also in the Dallas-Fort Worth area. The potential need for new transfer paths from the Panhandle region into central Dallas-Fort Worth, and the need for new extra-high voltage circuits across the area were identified across multiple scenarios.

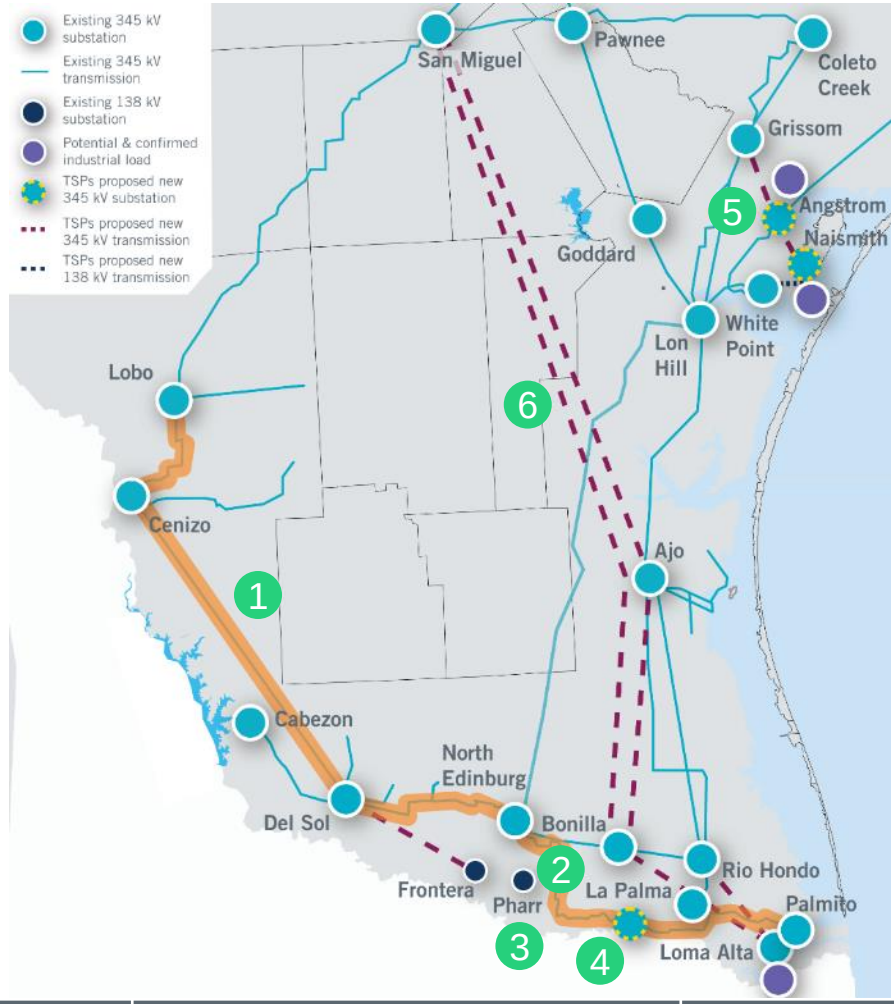
Houston / Freeport Area

- The Houston Import Project went into service in 2018.
- The Freeport Master Plan Project was endorsed in 2017 and is expected to be completed in 2021.
- The 2014 Houston Import Project study indicated additional upgrades would be needed by 2027 to continue to meet reliability criteria.
- The **2020 RTP** indicated increasing amounts of congestion on the transmission lines importing power into the Houston and Freeport areas in coming years.
- Recent planning studies have indicated that increased exports from West Texas will increase congestion on the transmission lines importing power into the Houston and Freeport area.



South Texas

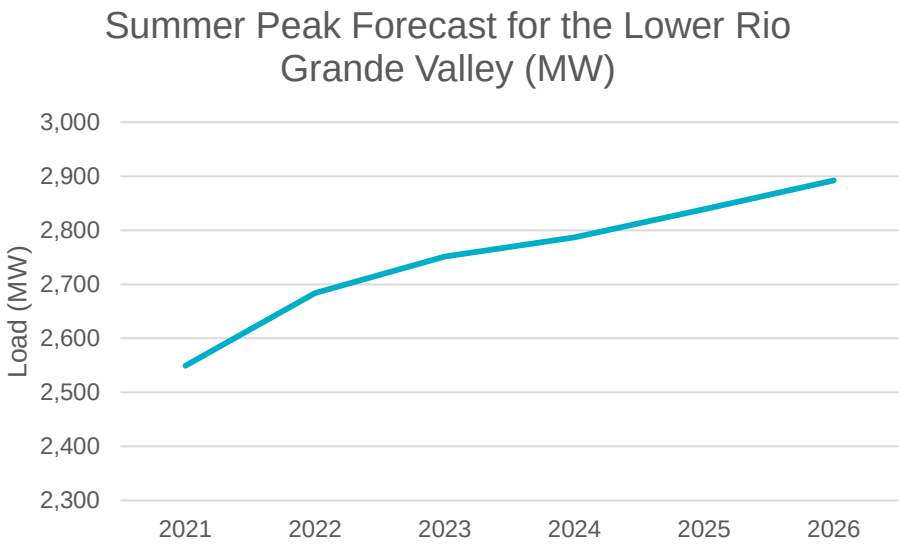
- The Lower Rio Grande Valley (LRGV) and Cross Valley Projects were placed into service in 2016 to meet reliability needs. The LRGV Dynamic Reactive Additions were placed into service in 2018, also to meet area reliability needs.
- Recently, there have been several confirmed and prospective industrial load additions planned for South Texas, including Liquefied Natural Gas facilities.
- In 2020, the ERCOT Board of Directors endorsed the Corpus Christi North Shore project, which includes new 345-kV lines to meet reliability needs for confirmed industrial load additions of approximately 1,100 MW.
- ERCOT is also reviewing the need for additional import capability into the LRGV for potential LNG facilities in the Brownsville area.

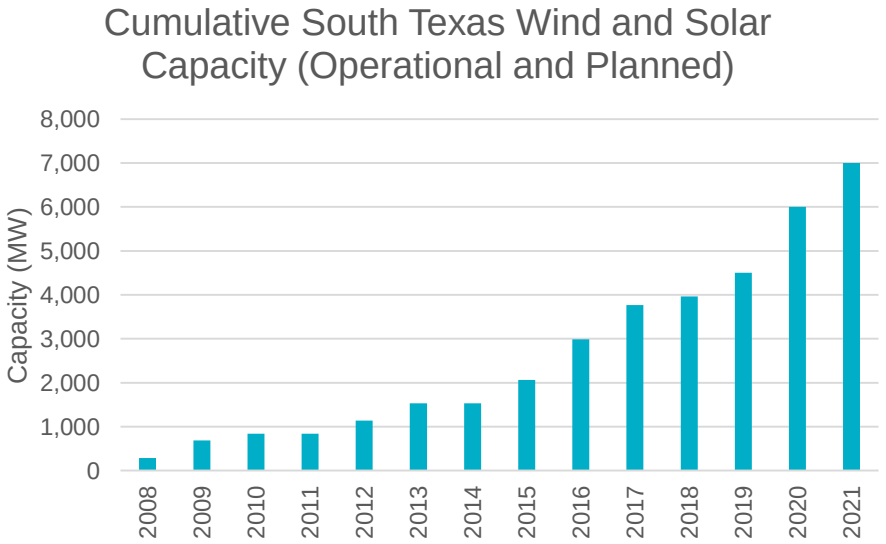


Map	Project Name	In-Service Date
1	Lower Rio Grande Valley Project	June 2016
2	Cross Valley Project	June 2016
3	LRGV Area Transmission Improvements project	Dec. 2018
4	Stewart Road: Construct 345-kV cut-in	June 2021
5	Corpus Christi North Shore Project	Apr. 2024
6	LRGV Import Project	Pending

South Texas

- The LRGV is projected to have an average annual peak demand growth of ~2.5%.
- In addition to studying the need for transmission to support LRGV load growth, ERCOT expects the area to experience stability constraints related to exporting power during times of low demand and high renewable generation output.
- In recent years, there has been a significant increase in new generation, mainly wind and solar, connected in the South Texas region. The cumulative wind and solar generation capacity is expected to reach ~7 GW by 2021.
- Seven of the 15 existing GTCs used to manage stability constraints are located in South Texas.
- This area is also susceptible to tropical storm and hurricane related outages. Three of the top ten constraints on the ERCOT system in 2020 were caused by outages related to Hurricane Hanna storm damage.





Far West Load Growth

>250

Far West 2019-2020 Peak Load Growth (MW)

4,588

Far West 2020 Peak Load (MW), Exceeding 4,500 for the first time in 2020

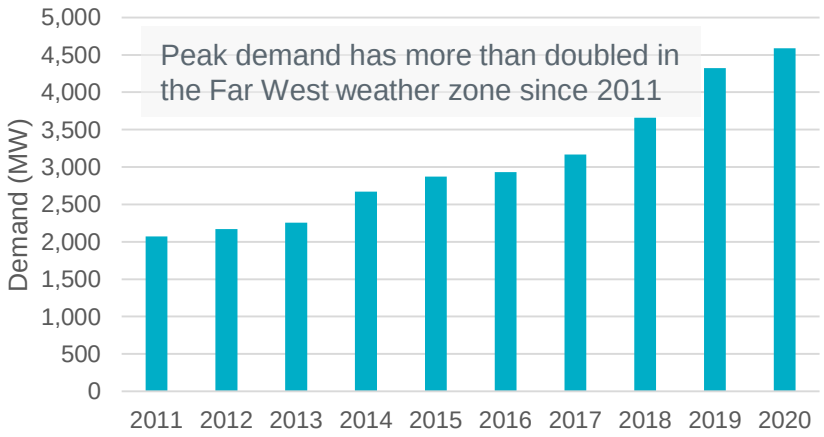
~9.6%

Far West 2011-2020 Annual Peak Load Growth Rate

~1.5%

ERCOT System-wide 2011-2020 Annual Peak Load Growth Rate

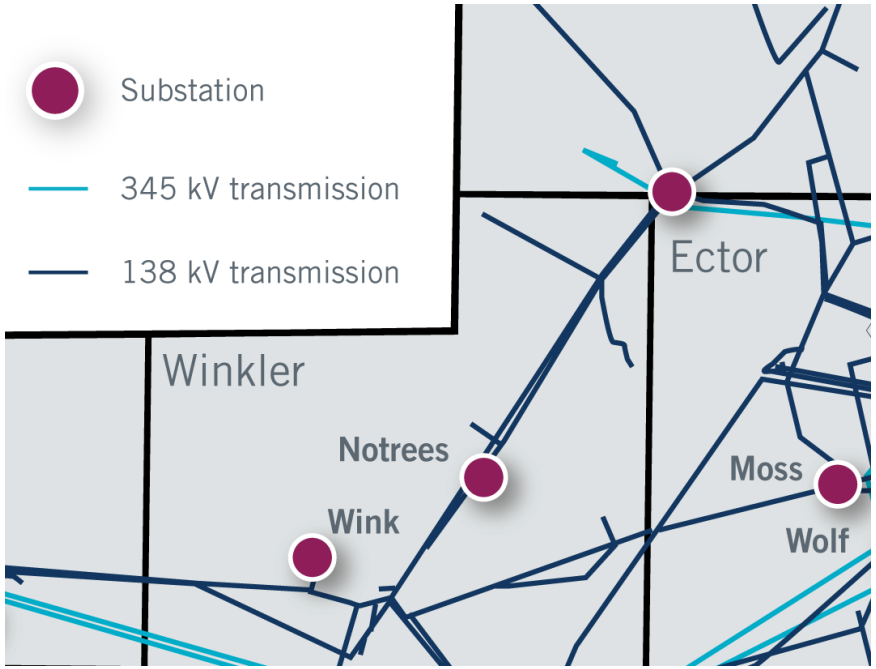
Far West Weather Zone Peak Demand



- The Far West Weather Zone in ERCOT encompasses most of the Texas portion of the Permian Basin oil field.
- Load growth in the Far West Weather Zone, which experienced a new peak in July 2020, continues to outpace growth in the rest of the ERCOT system due to oil and gas activity in the region.
- ERCOT expects growth in the region to continue into the future.

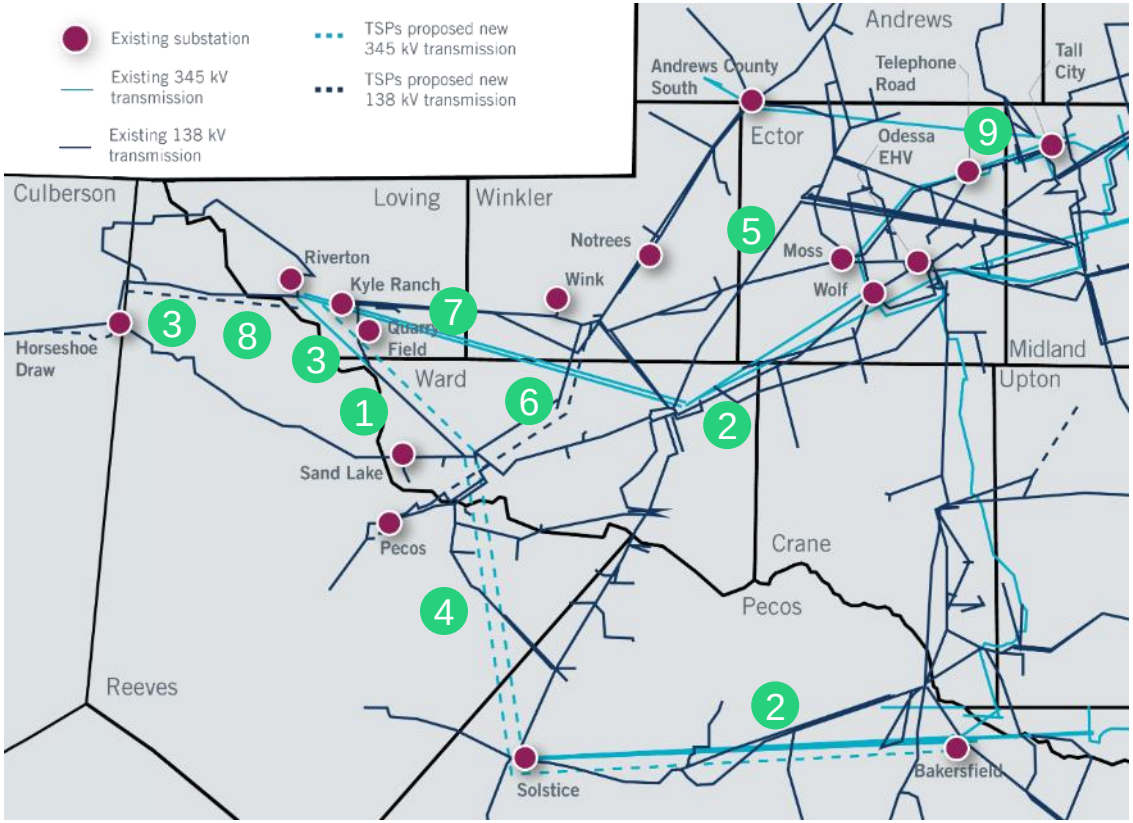
Andrews County South-No Trees Switch Congestion

- The highest congestion on the ERCOT system in 2020 was experienced on the Andrews County South-Amoco Three Bar Tap-Dollarhide-No Trees Switch 138-kV line located in Far West Texas.
- The congestion was caused by high loading on the circuits supplying Delaware Basin oil and gas load during times of low renewable generation output in the area.
- A planned upgrade of the congested 138-kV line was completed in spring 2020, and no additional congestion was experienced on this path after this upgrade.



Recent Transmission Improvements in Far West Texas

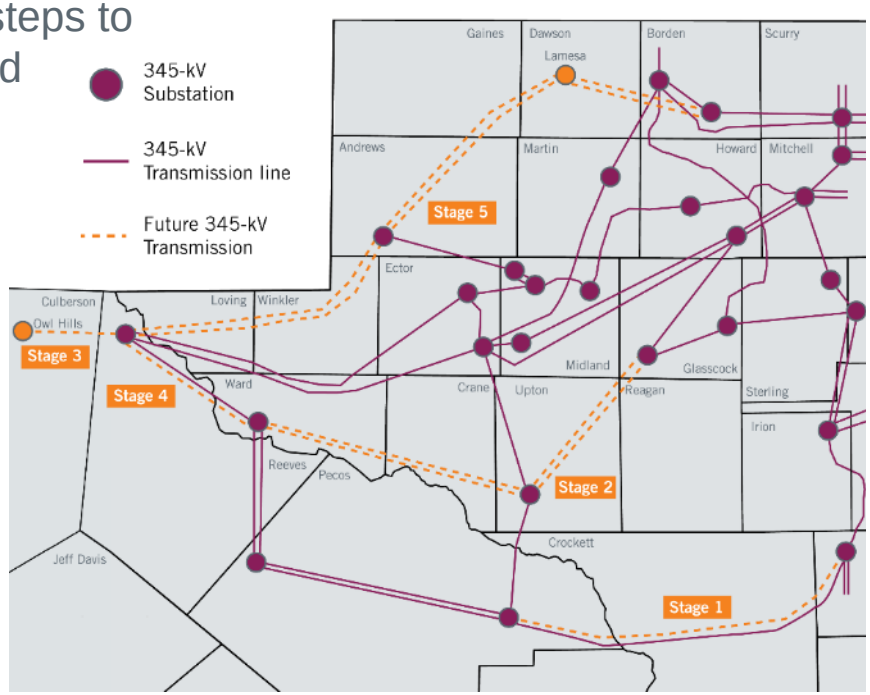
- Several large transmission improvement projects have been implemented recently or are under construction to address congestion resulting from the significant load growth in Far West Texas, particularly in the Delaware Basin area.



Map	Transmission Improvement Project	Anticipated Service Date
1	Riverton-Sand Lake 138-kV line (new)	Dec. 2019
2	Far West Texas Project 1.0 (New Odessa-Riverton and Bakersfield-Solstice 345-kV lines)	Dec. 2020
3, 4	Far West Texas Project 2.0 Dynamic Reactive Devices and Riverton-Sand Lake-Solstice 345-kV and Kyle Ranch-Riverton, Horseshoe Springs-Riverton 138-kV	May 2019 to Dec. 2020
5	Wolf to Moss 138-kV Line High Temperature Upgrade	Mar. 2020
	Permian Basin Area Upgrades	May 2020
6	Ward and Winkler County Transmission Improvement Project	Dec. 2021
7	Quarry Field 345-kV Switch Project	May 2021
Not shown	Big Spring - Buzzard Draw 69-kV Line Conversion to 138-kV	Nov. 2021
8	Horseshoe Springs Switch – Riverton Switch 138-kV Second Circuit Project	May 2021
9	Tall City – Telephone Road 138-kV Line Rebuild Project	Fall 2021

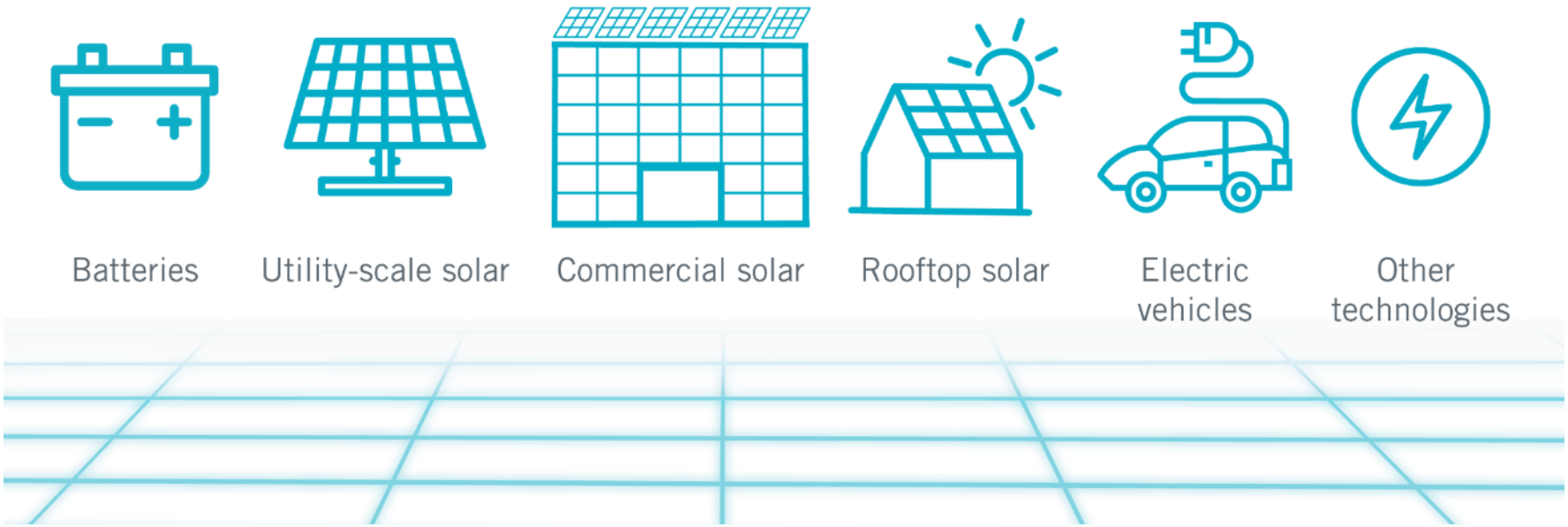
Far West Load Growth Planned Improvements

- The Delaware Basin comprises an eight county area in the western portion of the Far West Weather Zone.
- In 2019, ERCOT completed a five-stage roadmap for potential 345-kV transmission improvements that may be needed to support continued load growth in the Delaware Basin.
- As identified through the 2020 Regional Transmission Plan, the forecasted 2026 summer peak demand in the Delaware Basin exceeds the trigger point of Stage 1 upgrade (adding a second circuit on the existing Big Hill – Bakersfield 345-kV line). The TSPs associated with this project are currently analyzing next steps to ensure the improvements can be implemented in time to meet the system needs.
- In 2020, Oncor released a study conducted by IHS Markit that forecasts Permian Basin oil and gas load growth through 2030.
- ERCOT, Oncor and other area TSPs are reviewing the results of this study to identify needed 138-kV transmission circuits that will be required to serve oil and gas customers.



Planning for the Changing Grid

- Over the next several years, Distribution Energy Resources (DGRs), Energy Storage Resources (ESRs), electric vehicles (EVs) and load flexibility are expected to increase significantly.
- ERCOT is implementing process improvements today to plan for these changes going forward.



Contacts and Links

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Users must obtain a digital certificate for access to this area. Folders in this area include data, procedures, reports and maps for both operations and planning purposes. Helpful information that can be found on this site includes the following:

- Generation Project Interconnection Information
- Regional Planning Group Information
- Steady-State Base Cases