2020 Regional Transmission Plan

Document Revisions

Date	Version	Description
12/20/2020	1	
06/29/2021	2	Updated short circuit analysis CAPs based on latest stakeholder inputs.

Executive Summary

The 2020 Regional Transmission Plan (RTP) is the result of a coordinated planning process performed by ERCOT System Planning with extensive review and input by NERC-registered Transmission Planners (TPs), Transmission Owners (TOs), and other stakeholders. The RTP addresses ERCOT System reliability and economic transmission needs for years 2022 through 2026. This report documents the results of the assessment, in part, to comply with the requirements of NERC Reliability Standards, ERCOT Nodal Protocols, and the ERCOT Planning Guide.

The reliability analysis was performed over a six-year planning horizon; years one through five representing the near-term horizon and year six representing the long-term horizon. The 2020 RTP assessed ERCOT's steady-state transmission needs under summer peak and off-peak conditions. In addition to the seasonal variations, the RTP also included various sensitivities to address uncertainty involved in the transmission planning process. The reliability analysis in the 2020 RTP included:

- Steady-state contingency analysis to identify criteria violations based on NERC Reliability Standards and ERCOT planning criteria.
- Short-circuit analysis to identify over-dutied circuit breakers in the near-term planning horizon.
- Cascading analysis to identify potential system cascading conditions.

Following the reliability assessment, ERCOT, in collaboration with TPs, developed Corrective Action Plans (CAPs) to address the reliability criteria violations identified in this assessment. These plans included, but were not limited to, upgrades or addition of new transmission facilities and new constraint management plans.

The majority of planned improvements identified in the 2020 RTP are 138-kV and 345-kV upgrades. The projects identified as 345-kV upgrades consist of new substations, line additions, line upgrades, new 345/138-kV transformers, 345/138-kV transformer upgrades, and reactor additions. The majority of the projects were newly identified in the 2020 RTP.

ERCOT identified the following noteworthy reliability projects in the 2020 RTP:

- Dallas-Fort Worth import project in Wise and Tarrant Counties. This project is a placeholder project for reliability issues identified in the 2020 RTP. ERCOT and TPs will continue the analysis of the area after the conclusion of the 2020 RTP.
- Midland area transmission improvement in Midland County. This project is a placeholder project for reliability issues identified in the 2020 RTP. ERCOT and TPs will continue the analysis of the area after the conclusion of the 2020 RTP.
- Nacogdoches Southeast to Herty North Switch to Lufkin Switch 345-kV loop in Angelina and Nacogdoches Counties. This project is a placeholder project for the Oncor "Nacogdoches

Southeast Switch – Redland Switch – Lufkin Switch 345 kV Loop" project that is currently under Regional Planning Group (RPG) review.

- Venus Switch to Navarro 345-kV line upgrade in Ellis and Navarro Counties.
- Venus Switch 345/138-kV transformer addition in Ellis County.
- West Denton 345/138-kV transformer addition in Denton County. This project is a placeholder project for the reliability issues identified in the 2020 RTP. ERCOT and TPs will continue the analysis of the area after the conclusion of the 2020 RTP.
- Eagle Mountain 345/138-kV transformer upgrades in Tarrant County.
- Liggett to Hackberry 138-kV to 345-kV line conversion in Dallas County. This project is a placeholder project for the reliability issues identified in the 2020 RTP. ERCOT and TPs will continue the analysis of the area after the conclusion of the 2020 RTP.

The 2020 RTP also included an economic assessment of the ERCOT transmission system for years 2022 and 2025. Through this assessment, ERCOT identified transmission congestion and tested various transmission improvements to address this congestion in a cost-effective manner (as defined by ERCOT's economic planning criteria). Noteworthy results from 2020 RTP economic analysis include:

- Accelerating the in-service date for the RPG-approved Pelican to Whitepoint 138-kV line upgrade to 2022 met the economic planning criteria.
- A placeholder economic project to resolve congestion in the Bearkat area is included in the final 2025 economic case. This placeholder project is related to the Midland Area Transmission Improvement Project identified in the 2020 RTP reliability analysis. Multiple options showed sufficient production cost savings to meet the economic planning criteria. ERCOT and the affected TPs are continuing to evaluate options that address both the economic and reliability needs identified in the 2020 RTP analysis. Future RPG project submittals related to this work are expected.
- Analysis of several study areas did not result in projects that met the economic planning criteria for 2022, but had more production cost savings in 2025. While ERCOT is not making any project recommendations for those areas as part of the 2020 RTP, specific project options have been identified for reevaluation in future economic planning studies, including the 2021 RTP.

The project completion years stated in the 2020 RTP Report were chosen to address reliability and economic needs in a timely manner. The TOs are expected to meet these project completion dates, but lead-times necessary to implement projects based on factors such as availability of construction clearances, the time required to receive regulatory or governmental approvals, equipment availability, land acquisition, and resource constraints may result in different project completion dates. The reliability projects stated in the RTP do not represent ERCOT's endorsement of the projects. Instead, they represent the suggested CAPs for the reliability criteria violations identified under the system conditions studied in the RTP. The scope of projects identified in the RTP may change if further analysis by ERCOT or the TPs indicate better alternatives or a need to modify the projects due to changes in expected generation, load forecasts, or other system conditions. TPs should perform studies to confirm the need with the latest system conditions and develop applicable reliability projects to resolve any reliability criteria violations. For projects that are subject to ERCOT Nodal Protocols Section 3.11.4, Regional Planning Group Project Review Process, a review shall be conducted in accordance with the process described therein. For a project that is under Regional Planning Group (RPG) review when the RTP is developed, a placeholder project will be used if the need is identified. However, that does not represent ERCOT's endorsement. Projects requiring RPG endorsement will be reviewed in future assessments (where sufficient lead-time exists), such as future RTPs, to ensure the identified system facilities are still needed.

The TOs will provide ERCOT additional details on project scope, project cost, and an implementation schedule with completion date(s) for each identified project. This information from the TOs may be provided through further RPG review and/or Transmission Project Information Tracking (TPIT) updates in accordance with ERCOT Planning Guide Section 6.4.1.

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1. 2020 Regional Transmission Plan

This report documents the RTP assessment performed by ERCOT System Planning. It is intended, in part, to satisfy ERCOT's requirements under NERC Reliability Standards, ERCOT Nodal Protocols Section 3.11, and ERCOT Planning Guide Sections 3 and 4.

The RTP study is conducted annually for the entire ERCOT System. The 2020 RTP's near-term and long-term planning horizon analysis evaluated the reliability needs of the ERCOT transmission system for the years 2022, 2023, 2025, and 2026. As required by NERC Reliability Standard TPL-001-4, the 2020 RTP included a steady-state analysis of summer peak conditions for years 2022 (year 2), 2023 (year 3) and 2025 (year 5) and off-peak conditions for 2023 (year 3), and a short-circuit analysis of summer peak conditions for years 2023 (year 3) and 2025 (year 5). The 2020 RTP also included steady-state analyses for 2026 (year 6), representing the long-term planning horizon. The year six, or 2026, was selected based on the rationale that most of ERCOT transmission upgrades can be completed within five to six years from the date when the need is identified. In addition to analyzing the reliability needs of the system, the 2020 RTP also evaluated economic/efficiency needs of the ERCOT system for 2022 and 2025.

1.1. Stakeholder Involvement

The development of the RTP is a collaborative process. ERCOT worked with NERC-registered TPs, TOs, and other stakeholders to develop the input assumptions and the scope of technical studies that define the RTP. These assumptions are described in the RTP Scope and Process document and were presented to the stakeholder community at Regional Planning Group (RPG) meetings. The RTP Scope and Process document and input assumptions can be found in Appendices A, B, and C. Stakeholders were provided routine updates on the input assumptions and supporting analysis performed for the 2020 RTP in monthly RPG meetings. Feedback and comments from the RPG were incorporated into the RTP Scope and Process document.

The RPG is responsible for reviewing and providing comments on new transmission projects in the ERCOT Region. Under ERCOT Nodal Protocols Section 3.11.3, participation in the RPG is required of all Transmission Service Providers and is open to all Market Participants, consumers, other stakeholders, and Public Utility Commission of Texas (PUCT) Staff.

ERCOT worked with TPs, TOs, and other stakeholders to study the existing system, identify system upgrades and new transmission projects to ensure continued system reliability, and address projected system congestion.

1.2. Standards and Regulations

The RTP assessment was conducted based on requirements in NERC Reliability Standards, ERCOT Nodal Protocols, and the ERCOT Planning Guide.

ERCOT performed its steady-state reliability assessment in accordance with NERC Reliability Standard TPL-001-4, Transmission System Planning Performance Requirements. A portion of the RTP assessment also addressed some requirements in Reliability Standards FAC-002[1] and IRO-017.[2]

ERCOT Nodal Protocols Section 3.10.8.4(3) requires ERCOT to identify additional Transmission Elements that have a high probability of providing significant added economic efficiency to the ERCOT market through the use of Dynamic Ratings and request such Dynamic Ratings from the associated ERCOT Transmission Service Provider (TSP). This report identifies such Transmission Elements as part of its economic analysis. ERCOT Nodal Protocols Section 3.11.5 specifies the economic planning criteria used to evaluate the cost-effectiveness of projects in the RTP.

The RTP assessment adheres to ERCOT Planning Guide Section 3.1.1.2, which provides guidelines regarding completion of the RTP. This section requires that ERCOT complete and publish the final RTP report no later than December 31 each year. Additionally, ERCOT Planning Guide Section 4 and ERCOT Nodal Protocols Section 3.11.2 specify the transmission planning criteria to be used in the RTP assessment.

1.3. Confidentiality and Report Posting

The RTP report is shared with internal and external stakeholders. One redacted version of the RTP is created by removing, at a minimum, any confidential data such as the list of long lead time equipment. This report is shared with ERCOT stakeholders via the MIS Secure area. A second, further redacted version of the RTP report is posted to the ERCOT public website.

[1] FAC-002, Requirement R4
[2] IRO-017, Requirements R3 and R4

2. 2020 Regional Transmission Plan Process

The RTP study process is described in Figure 1. The initial start cases to be used in the reliability analysis were prepared in the case-conditioning stage. The case conditioning step in the 2020 RTP also included the use of the "bounded-higher-of" methodology to determine appropriate weather zone load levels for the RTP study. The details of this methodology can be found in ERCOT Planning Guide Section 3.1.7. Following case conditioning, a reliability analysis was conducted on the base case to determine the CAPs needed to meet ERCOT and NERC reliability requirements. In addition to the base case, the 2020 RTP also included sensitivity cases, a short-circuit analysis, a cascade analysis, and a multiple element outage analysis as required by NERC Reliability Standard TPL-001-4. An economic analysis was also conducted to identify transmission projects that allow reliability criteria to be met at a lower total cost. The detailed scope, process, and input assumptions used in conducting both reliability and economic analyses are available in Appendices A, B, and C.

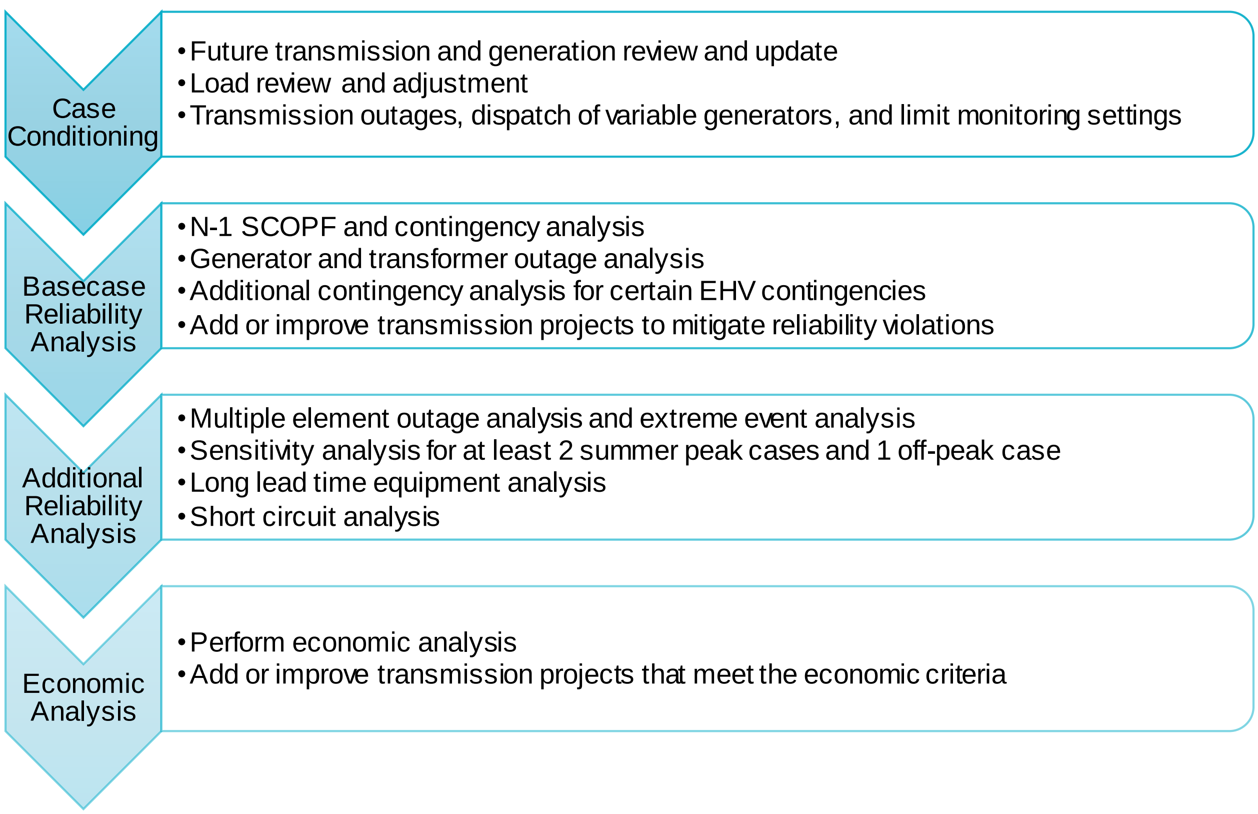


Figure 1: 2020 RTP Transmission Planning Process

ERCOT utilized the following software tools while performing the 2020 RTP:

- PSS/E version 33 was used to develop the conditioned cases.
- PowerWorld version 21 with Security Constrained Optimal Power Flow (SCOPF) and its SIMAUTO functionality were used to perform AC SCOPF analysis and to run generator and transformer outage analysis.
- PowerWorld version 21, and Physical and Operational Margin (POM) application suite version 2020 were used to screen critical contingencies while evaluating P3 (Generator outage) and P6-2 (Transformer outage) planning events.
- POM application suite version 2019 and 2020 including POM suite – Optimal Mitigation Measures (OPM) and Potential Cascading Modes (PCM) were used to perform load shed analysis, multiple element outage analysis, and cascade analysis to identify critical events as candidates for detailed analysis in PowerWorld version 21.
- UPLAN version 10.4 was used to perform security-constrained economic analysis.

2.1. Reliability Analysis

The reliability analysis in the 2020 RTP was focused on the steady-state portion of NERC Reliability Standard TPL-001-4 and the ERCOT Planning Guide. The purpose of reliability analysis was to identify potential criteria violations and CAPs that may be used to resolve them. The RTP analysis included Security Constrained Optimal Power Flow (SCOPF) to identify unresolvable constraints. Loading and voltage levels at Bulk Electric System (BES) elements were monitored for all NERC Planning Events, including Extreme Events. ERCOT staff developed CAPs in collaboration with TPs to mitigate criteria violations in accordance with the NERC and ERCOT performance requirements.

The 2020 RTP reliability analysis included the following studies:

- SCOPF: Security Constrained Optimal Power Flow (SCOPF) was used to perform basic power flow and Contingency Analysis (CA) for P0, P1, P2-1, and P7 contingencies. The SCOPF used generation cost data and other system constraints to give an optimal generation dispatch and unit commitment while maintaining the reliability of the system. In this analysis, the software simulated the removal of all elements of Protection System and other automatic controls following the contingency event.
- Contingency Analysis: Basic CA routines in the power flow software were used to test P2-2, P2-3, P2-4, P4, P5, and Extreme Event contingencies.
- Multiple Element Contingency Analysis: Planning events P3 and P6 involve a first and second level contingency analysis; such events were tested using multiple element contingency analysis. During this analysis, loss of elements due to first contingency was followed by acceptable system adjustments, before testing the effect of the second contingency event. The list of acceptable system adjustments included system reconfiguration, changes in voltage

schedule, and re-dispatch of generation. Other contingency events such as P4, P5, and Extreme Events, which involved simultaneous removal of multiple elements, were also analyzed. Extreme Events associated with the disruption of gas pipelines were also included.

- Cascading Analysis: Cascading analysis was conducted to test all Planning and Extreme Events where a facility may be loaded above its relay loadabilty rating prior to allowed load shed. In this analysis, the software simulated the removal of all elements of Protection System and other automatic controls following the contingency event. This included tripping of generators and transmission elements which were loaded beyond their relay loadability limits. These contingencies were screened to detect potential cascade events for more detailed analysis.
- Short Circuit Analysis: In accordance with the agreement between ERCOT and TPs in the ERCOT region as required by NERC Reliability Standard TPL-001-4, Requirement R7 (revised in May 2020), ERCOT performed the short-circuit analysis in order to determine short-circuit currents for Resource Entity (RE)-owned facilities. The results of the short-circuit analysis included the magnitude of short-circuit current and the source impedance associated with each fault. These results were communicated to the NERC Registered Generator Owners (GOs). GOs completed a review of study results, acknowledged the findings, and provided a list of over-dutied circuit breakers and CAPs. In addition, GOs also confirmed the continued validity and implementation status of the facilities identified in the previous RTP.
- Long Lead Time Equipment Analysis: Under Requirement 2.1.5 of NERC Reliability Standard TPL-001-4, the impact of the possible unavailability of major transmission equipment with a lead time of one year or more was studied. The studies were performed with an initial condition of the identified long lead time equipment modeled as out of service, followed by P0, P1, and P2 contingency events. The list of long lead time equipment was developed based on TO feedback. The results of such analysis were communicated to the appropriate TOs.
- Sensitivity Analysis: ERCOT selected the summer peak conditions of 2022 and 2025 and off-peak conditions of 2023 for sensitivity analyses as required by Requirement 2.1.4 of NERC Reliability Standard TPL-001-4. ERCOT prepared the sensitivity cases by varying the following set of input assumptions:

    - High renewable output with coincident summer peak conditions for years 2022 and 2025
    - High renewable penetration condition for the 2023 off-peak case
    - No wind and no solar (offline) conditions for West/Far West study region for 2022 and 2025 summer peak cases

The sensitivity analyses were performed with all identified reliability solutions from the base case analysis to evaluate the effectiveness and robustness of the base case solutions under the stressed system conditions.

For both the high renewable output summer peak and the high renewable penetration off peak sensitivity analysis, the following approaches were utilized:

- Renewable curtailment was allowed to alleviate reliability criteria violations.
- No renewable curtailment was allowed to identify potential needs to accommodate the assumed level of penetration.

2.1.1 CAP Development

Under the ERCOT Planning Guide, reliability projects are those system improvements (projects) that are needed to meet NERC Reliability Standards or ERCOT planning criteria, which could not otherwise be met by any possible re-dispatch of existing or planned generation. In order to develop this list of projects, grid simulation software was utilized which included the removal of all protection system elements and other automatic controls following the contingency event. These elements included devices designed to provide steady-state control of electrical system quantities, such as load tap changing transformers, phase-shifting transformers, switched capacitors, and inductors.

A list of potential CAPs, or reliability projects, along with the corresponding limiting elements and contingencies were communicated to the appropriate TP and/or TO. TPs and TOs reviewed the initial list of reliability-driven projects for their technical feasibility and estimated the year of completion (taking into account necessary lead-times). In some cases, the TOs also provided project alternatives. In the instance that a project was not feasible in time, ERCOT designed a Constraint Management Plan to mitigate the criteria violations until the permanent CAP could be put in-service. These mitigation actions were developed in collaboration with TPs and further communicated to ERCOT Operations. Intermediate and final results were posted on the ERCOT MIS Secure area and presented to stakeholders at regularly scheduled RPG meetings in order to solicit comments and suggestions.

2.1.2 System Operating Limit (SOL) Identification

The ERCOT SOL Methodology was used to determine if additional SOLs were needed in the planning horizon. Per the criteria, a new SOL was identified if results of the reliability analysis of the base case resulted in any of the following:

- Voltage instability (resulting in uncontrolled voltage collapse).
- Cascading or uncontrolled separation or islanding.

2.2. Economic Analysis

ERCOT conducted an economic analysis to identify system improvements that would allow ERCOT to meet NERC Reliability Standards and ERCOT planning criteria at a lower total cost (total system variable production cost plus carrying cost of new transmission projects) than the continued dispatch of higher cost generation.

To identify such efficiency-driven projects, ERCOT prepared a production cost model for years 2022 and 2025. Details on the production cost models developed for the 2020 RTP can be found in Appendix D and N.

According to the economic planning criteria described in ERCOT Nodal Protocols Section 3.11.2(5), ERCOT recommends economic projects if the annual production cost savings exceed the first-year annual revenue requirement for the project. Based on the recent review of current market conditions, the first-year annual revenue requirement for a project was assumed to be 13.2% of the estimated project cost.

3. Findings from Reliability Analysis

3.1. Reliability Projects and Constraint Management Plans

The primary purpose of the 2020 RTP reliability analysis was to identify reliability criteria violations and potential CAPs to resolve them. Overall, the base reliability analysis identified a need for 50 CAPs. The detailed list of criteria violations and resulting CAPs can be found in Appendix E. Figure 2 illustrates the geographic location of the identified CAPs. The legend linking reliability projects and their associated map indices can be found in Appendix F.

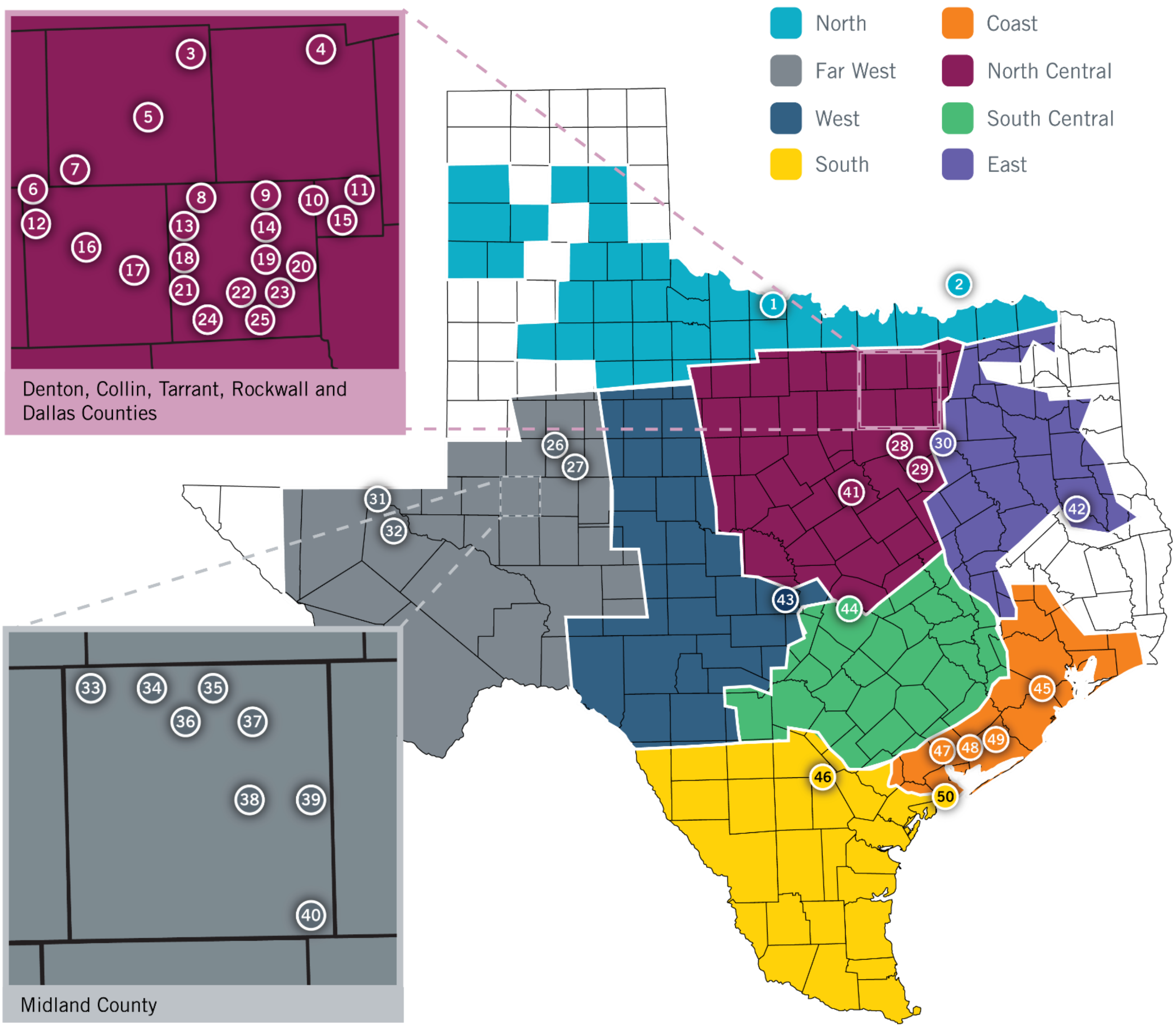


Figure 2: Geographic locations of CAPs identified in the 2020 RTP

Figures 3 and 4 summarize the type of projects, their geographic locations, and voltage levels. Figure 5 distinguishes between projects that were newly identified in the 2020 RTP and projects that were identified in previous ERCOT planning studies or TSP studies.

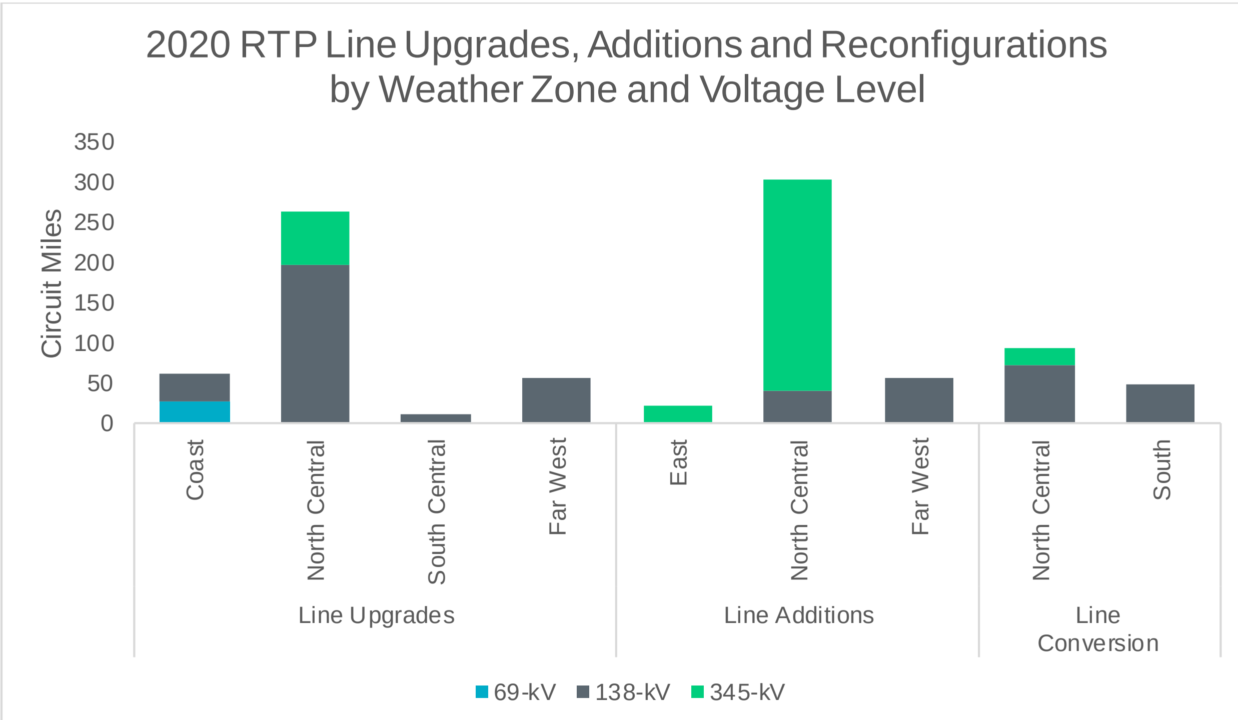


Figure 3: 2020 RTP transmission line project types by weather zone and voltage level

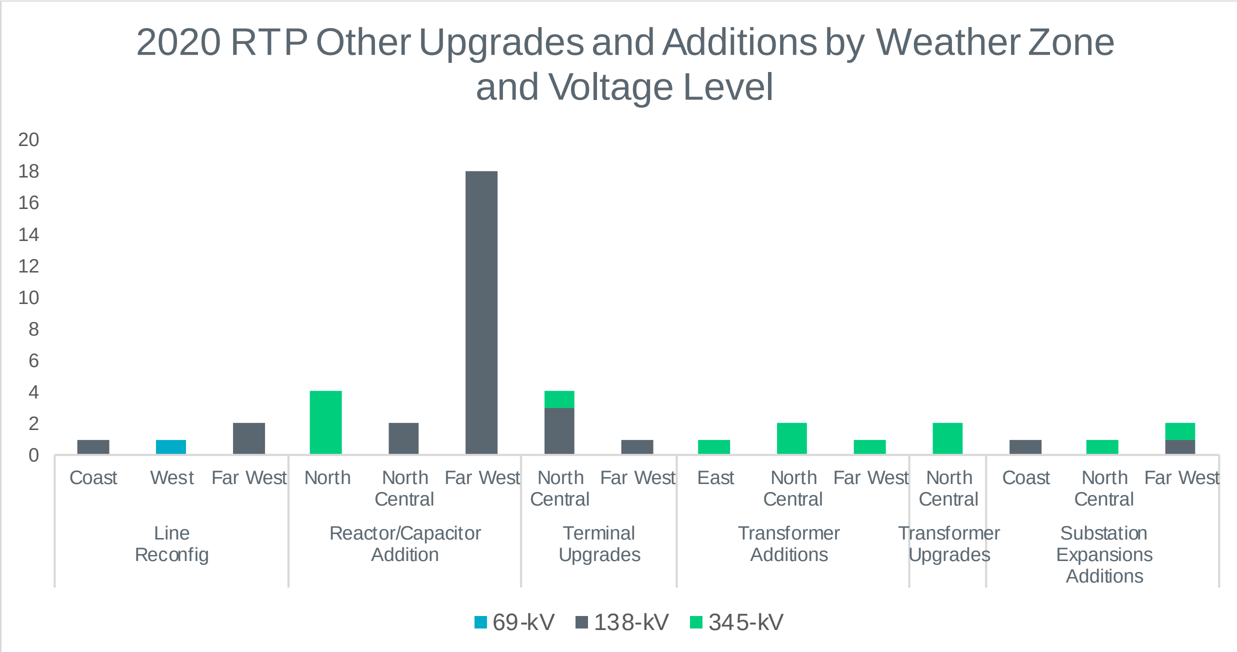


Figure 4: 2020 RTP other upgrades and additions by weather zone and voltage level

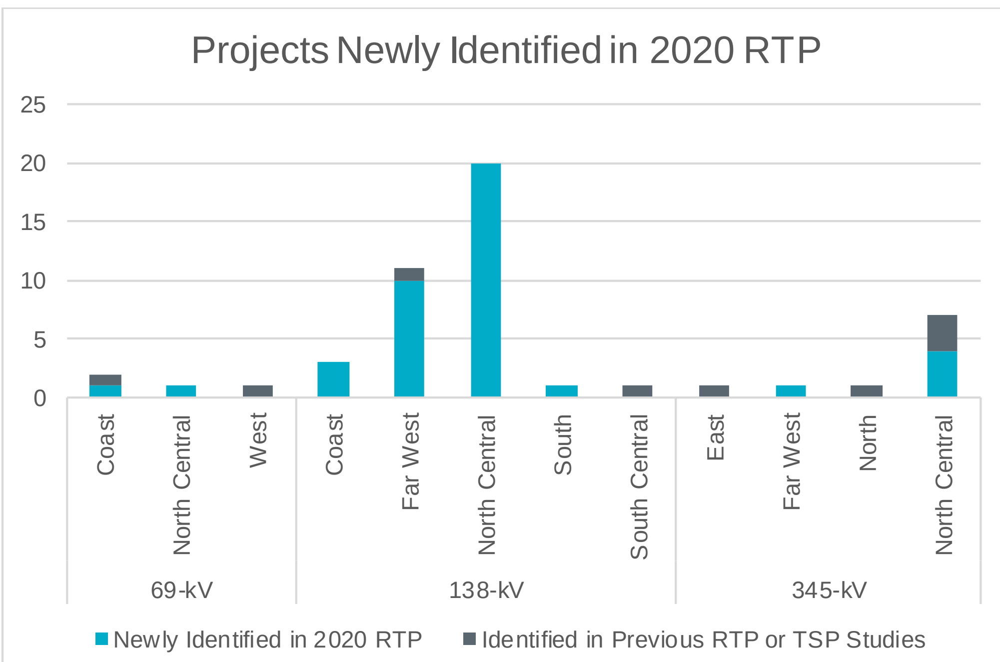


Figure 5: Projects newly identified in 2020 RTP versus projects previously identified

The CAPs identified in the 2020 RTP included transmission upgrades that may not be completed prior to the need for the project due to lead-time challenges. ERCOT, in collaboration with TPs, identified five potential Constraint Management Plans (CMPs) as placeholder mitigating actions which will be reviewed in the operations planning horizon by ERCOT and TOs. The list and details of the CMPs identified in the 2020 RTP can be found in Appendix G.

In addition to this reliability analysis, a multiple element outage analysis was conducted for contingencies where non-consequential load shed is allowed under NERC Reliability Standard TPL-001-4, Table 1. This analysis consisted of 1) corrective action analysis, which identified mitigation measures (such as transformer tap setting changes, switching actions, generator re-dispatch, and load shed) to resolve any overloads and over/under voltage issues resulting from such contingencies; and 2) cascading analysis, which identified any contingencies that could result in potential cascade events.

Several Planning Events and Extreme Events were screened for detailed analysis. However, further investigation performed by ERCOT and affected TPs indicated that none of the events result in cascading conditions. ERCOT also studied the loss of multiple generating stations due to the disruption of gas pipelines. The results of the multiple element outage analysis are documented in Appendix H. This appendix includes the list of critical contingencies identified as a result of this analysis and CAPs or recommendations necessary to mitigate the impact of these contingencies. No new SOLs were identified in the 2020 RTP reliability analysis.

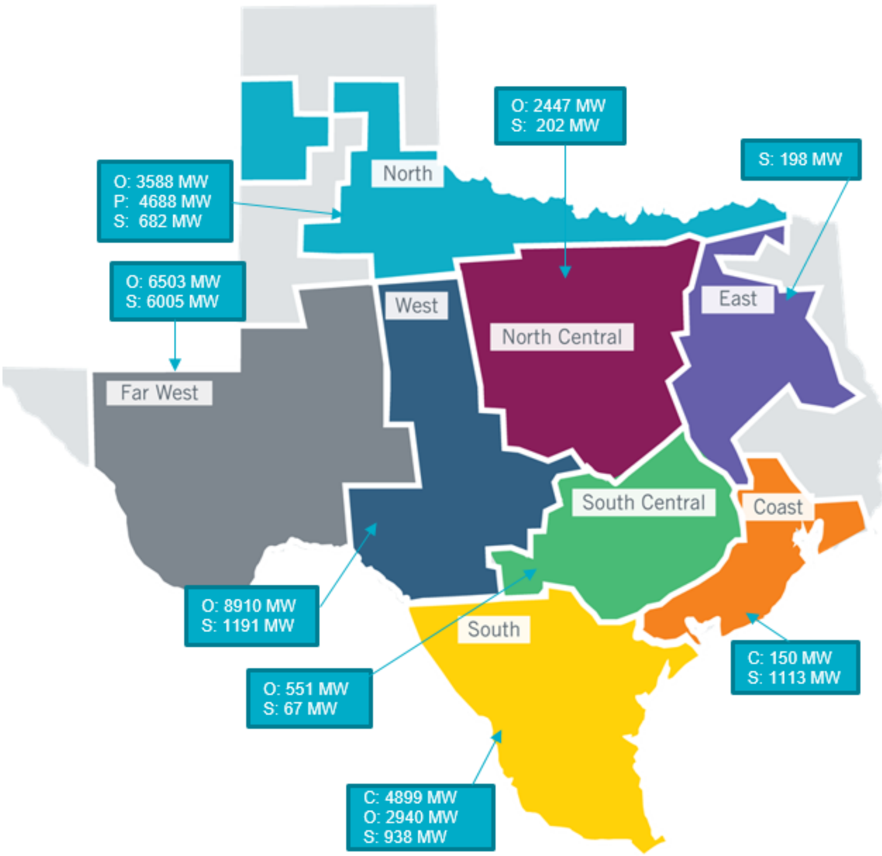
In addition to the above analysis, per ERCOT Planning Guide Section 3.1.1.2(3), the 2020 RTP analysis also included development of a list of transmission facilities that were loaded above 95% of their applicable ratings under normal and contingency events (loss of single generating unit, transmission circuit, transformer, or common tower outage). This list is attached to the report as Appendix I.

3.2. Sensitivity Analysis

While the ERCOT region continues with the strong trend of wind development, solar development has also experienced rapid growth over the past couple of years. By 2022, the total capacity of operational solar and the planned solar projects that have met ERCOT Planning Guide 6.9(1) requirements will exceed 10 GW, which is approximately 2.5 times the currently installed solar capacity. In addition, there will be close to 35 GW of wind capacity by 2022 including both the operational wind and the planned wind projects that have met Planning Guide 6.9(1) requirements. With around 45 GW of renewables expected to be in service by 2022, it is crucial to understand their impact on the ERCOT system under various system conditions to prepare for the challenges they may bring to the transmission system, which is the focus of the 2020 RTP sensitivity analysis.

The purpose of this portion of the study was to evaluate the effectiveness and robustness of the base case reliability projects under stressed system conditions.

While the load centers in the ERCOT region are mainly located in the Coast, North Central, and South Central weather zones, the majority of the renewables are located in the West, Far West, North, and South weather zones, far from the load centers. The geographic location of the renewable generation included in the 2020 RTP is illustrated in Figure 6.



Legend	Description	Capacity (MW)
C	Coastal Wind	5,049
O	Other Wind	24,939
P	Panhandle Wind	4,688
S	Solar	10,395

Figure 6: 2020 RTP renewable location and capacity

Under high renewable output/penetration conditions, potential voltage and export issues may occur due to high reactive power losses caused by long distance power transfers. Based on the analysis of historical renewable generation data, high renewable output can happen under various system load conditions including both summer peak load conditions and shoulder month light load conditions. High renewable output sensitivities for both 2022 and 2025 coincident summer peak load conditions, and 2023 light load conditions were studied in the 2020 RTP.

These sensitivity analyses were studied using the two following approaches:

- Renewable curtailment allowed to alleviate reliability criteria violations – Transmission projects were identified to resolve any remaining reliability criteria violations that could not be resolved by a simultaneously feasible, security constrained dispatch. The sensitivity analyses using this approach were used to satisfy NERC Reliability Standard TPL-001-4.
- No renewable curtailment allowed to identify potential needs to accommodate the assumed level of penetration – Potential transmission solutions identified are not considered as CAPs under NERC Reliability Standard TPL-001-4. Instead, they will serve as possible candidates for economic analysis to be assessed further. Only P1, P2.1, P7, P3, and P6.2 contingency analysis were performed.

In addition to the high renewable output sensitivity analysis, ERCOT also analyzed the system impact of the unavailability of renewables under summer peak load conditions in the West/Far West study region, which represents high net load conditions when renewables are not available, but system load is still high. Both wind and solar generators were assumed offline with reactive capability unavailable. Static reactive devices, such as capacitor banks, at renewable generator sites were utilized as needed in this sensitivity analysis. The West/Far West study region was selected due to the high oil and gas load in the region, which typically remain flat throughout the day. This sensitivity analysis is intended to help understand potential import challenges in the West/Far West region under these extreme conditions. Only P1, P2.1, P7, P3, and P6.2 contingency analysis were performed for this particular sensitivity analysis.

3.2.1 High Renewable Output Coincident Summer Peak Study Results

The high renewable coincident summer peak sensitivity analysis started with maintaining the renewable penetration level at 26.9% and 25.6% for the 2022 and 2025 cases, respectively. While increased renewable generation output in the resource rich weather zones did significantly increase the West Texas export interface flow, no region-wide transfer issues were observed. Instead, the issues identified were all related to the export of renewables from local generation pockets when a portion of the export path was lost under various contingencies. These generation pockets included Andrews County, Edwards County, and the Lower Rio Grande Valley. Potential solutions to accommodate the assumed renewable penetration level were developed, in addition to acceptable mitigation actions such as voltage schedule changes, tap setting changes, and generation re-dispatch other than renewables. In one instance the potential solution included the acceleration of a portion of an approved RPG project.

All observed overloads can be alleviated by curtailing renewable generation output in those local areas. Since renewable curtailment is a valid mitigation action in operations and in planning, the identified transmission solutions will serve as economic project candidates for future economic analysis, rather than being required for reliability purposes. Two CMPs identified in the base cases were also needed for this sensitivity analysis when renewable curtailment was not utilized.

A detailed list of findings identified in this sensitivity analysis is provided in Appendix J.

3.2.2 High Renewable Penetration Light Load Study Results

In the high renewable off peak sensitivity analysis, ERCOT started the case with 35 GW of renewable output. In order to respect various stability limits, the renewable output was reduced to approximately 27 GW, corresponding to a 62.3% renewable penetration level, to serve as the start case for this sensitivity analysis. The start case had both the West Texas export interface and the North Edinburg to Lobo interface loaded close to 100% of their modeled limits. With this assumed penetration level, a few P7 contingencies involving the loss of part of the West Texas export path resulted in unsolved power flow. Adding an additional West Texas export path – for example, from West to South Central or from West to North Central – was needed to resolve the observed issues. ERCOT also identified some additional local transmission solutions to facilitate wind and solar export, in addition to acceptable mitigation actions such as voltage schedule changes, tap setting changes, and generation re-dispatch other than wind and solar. The local transmission solutions were mainly located in the South and West Weather Zones. All of the reliability issues observed could be resolved by utilizing renewable curtailment. Since renewable curtailment is a valid mitigation action in operations and in planning, the identified transmission solutions will serve as economic project candidates for further economic analysis, rather than being required for reliability purposes.

A detailed list of findings identified in this sensitivity analysis is provided in Appendix J.

3.2.3 No Wind No Solar West/Far West Study Results

Almost half of the renewable capacity included in the 2020 RTP is located in the West/Far West study region. With the assumed solar and wind dispatch in the base case reliability study, the generation available in the West/Far West study region was able to supply the total load in the region, which was slightly below 10.5 GW in 2025, with minimal import from other regions. However, with all wind and solar modeled offline, most of the load in the West/far West region had to be served by imports from other regions. The unavailability of the renewable resources not only stressed the import to the West/Far West region, but also greatly depressed voltages in the region due to the loss of close to 8 GVAr of reactive power support from renewable units. The limitations on the West/Far West import paths, especially the import paths into Far West, and the significant loss of reactive power support became the prominent issues to resolve under the assumed conditions.

The purpose of this sensitivity was to provide understanding of potential system impacts under the assumed extreme system conditions. The key takeaways from this sensitivity analysis are summarized below. Please note that these findings do not represent ERCOT's recommendations for any specific transmission solutions, but are rather intended to further the understanding of the challenges the area faces under various system conditions

- Some transmission solutions identified in the "ERCOT Delaware Basin Load Integration Study"[3], including new 345-kV right ways, were found to be able to facilitate import into the study region under the studied conditions.
- Some transmission solutions identified by the 2020 Long Term System Assessment (LTSA) were also found to be able to facilitate import into the study region.
- Some local transmission enhancements were found to be helpful to alleviate non-import related local issues.

ERCOT plans to continue to evaluate the needs of the Far West region under conditions where the capacity of local generation to serve load is limited.

3.3. Short Circuit Analysis

As indicated in Section 2.3, ERCOT conducted the short-circuit analysis for Resource Entity-owned facilities for 2023 and 2025 summer peak conditions using the system protection future year base

[3] http://www.ercot.com/gridinfo/planning

cases and shared the results with GOs. GOs reviewed the fault duty information to identify buses with over-dutied breakers along with CAPs.

Table 1 provides a summary of the results of the short-circuit analysis. Based on the review and comments provided by GOs, one bus was identified as having over-dutied breakers. The study cases and details of the results can be found in Appendix K.

Table 1: Summary of Short-circuit Analysis

Magnitude of Fault Current	Number of buses (3-phase fault)		Number of buses (single-line to ground fault)	
	2023	2025	2023	2025
Below 40 kA	505	505	523	524
40 kA ~ 60 kA	70	71	49	48
More than 60 kA	11	10	14	14

3.4. Long Lead Time Equipment Analysis

In response to ERCOT's request, the TOs provided a list of long lead time equipment based on their spare equipment strategies. All TO-provided, BES, long lead time equipment outages were studied to determine the impact of unavailability of such equipment for an extended period of time. This analysis was conducted for 2022, 2023, 2025, and 2026 summer peak conditions, along with 2023 off-peak conditions. Overall, 26 unique 345/138-kV transformers, 11 unique 345-kV reactive devices, and two 345-kV synchronous condensers and their transformers were identified as long lead time equipment. NERC category P0, P1, and P2 contingencies were studied. The results were shared with the respective TPs. The list of long lead time equipment and study results are provided in Appendix L.

4. Economic Analysis

The 2020 RTP economic analysis was performed using production cost simulation runs for the years 2022 and 2025. The input assumptions and starting congestion for both years are presented in Appendix D. Figures 7 and 8 show the top constraints seen in 2022 and 2025, respectively. The size of each bubble represents the relative capacity of the congested element.

The Pelican to Whitepoint 138-kV line experienced a significant amount of congestion in the 2022 case. This congestion was not observed in the 2025 case because an upgrade of the line is included in the ERCOT Board-approved Corpus Christi North Shore RPG project and was included in the 2025 economic start case. The line upgrade was tested in the 2022 economic case and met the economic planning criteria. ERCOT recommends that the construction timeline for the Pelican to Whitepoint 138-kV line upgrade be accelerated to 2022.

Similar to the Pelican to Whitepoint 138-kV line, the 345-kV line from Alliance to Hicks Switch was congested in 2022, but not in 2025. This is due to the inclusion in the 2025 economic case of the Dallas-Fort Worth import project, which serves as a placeholder addressing reliability needs identified in the 2020 RTP. ERCOT and TPs are continuing to evaluate project options that address both the economic and reliability needs identified in the northwest Dallas-Fort Worth area.

The West Texas export interface experienced the top congestion in both the 2022 and 2025 study years. While several options to relieve congestion across the interface were evaluated as part of the 2020 RTP economic analysis, none met the economic planning criteria at this time. One factor that impacted the production cost savings resulting from additional export paths was the relationship between increased power flow across the interface and increased congestion near load centers as a result of that increased power transfer. For example, 2020 RTP economic analysis showed that increasing the West Texas export transfer limit also increased congestion on import paths into the Houston and Freeport areas. Holistic solutions addressing both the transfer limit and congestion close to load centers are needed in order for the full benefit of new transfer paths to be realized. To that end, ERCOT began work on a Long-Term West Texas Export Special Study in the fourth quarter of 2020. This study will include both stability and economic analysis to determine a roadmap for addressing the West Texas export stability limit and interrelated local constraints near load centers. The results of the special study will inform future economic planning analysis, including the 2021 RTP.

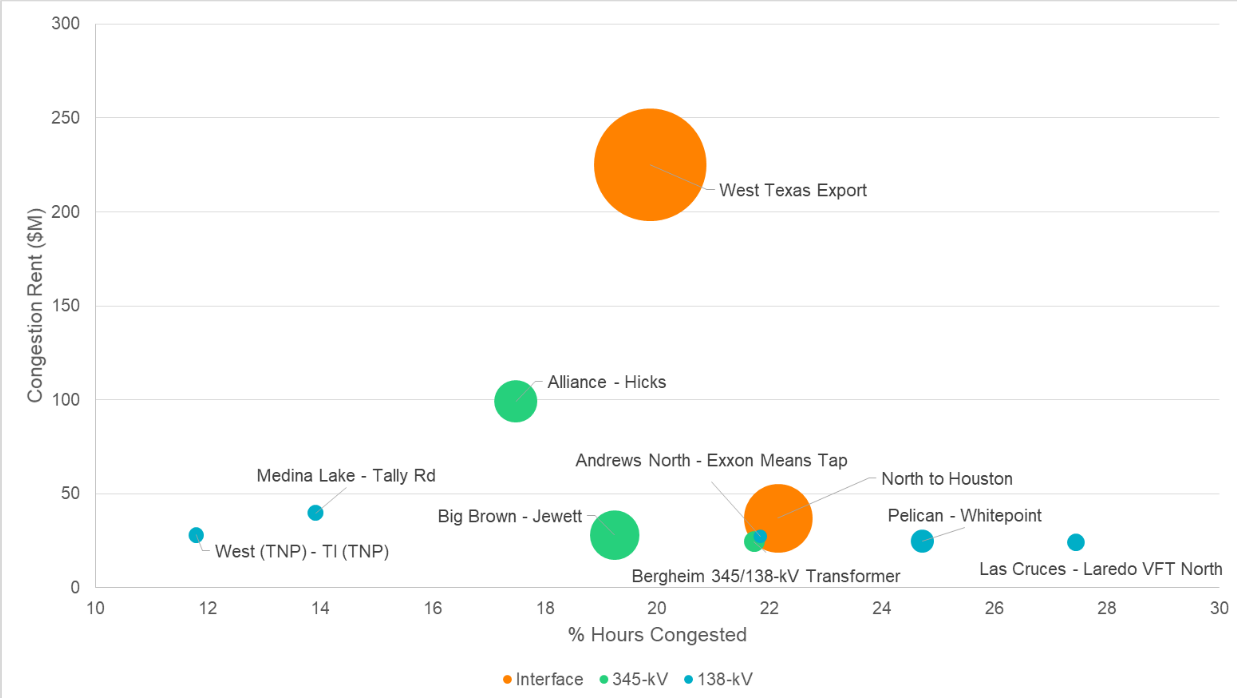


Figure 7: Top Constraints in 2022

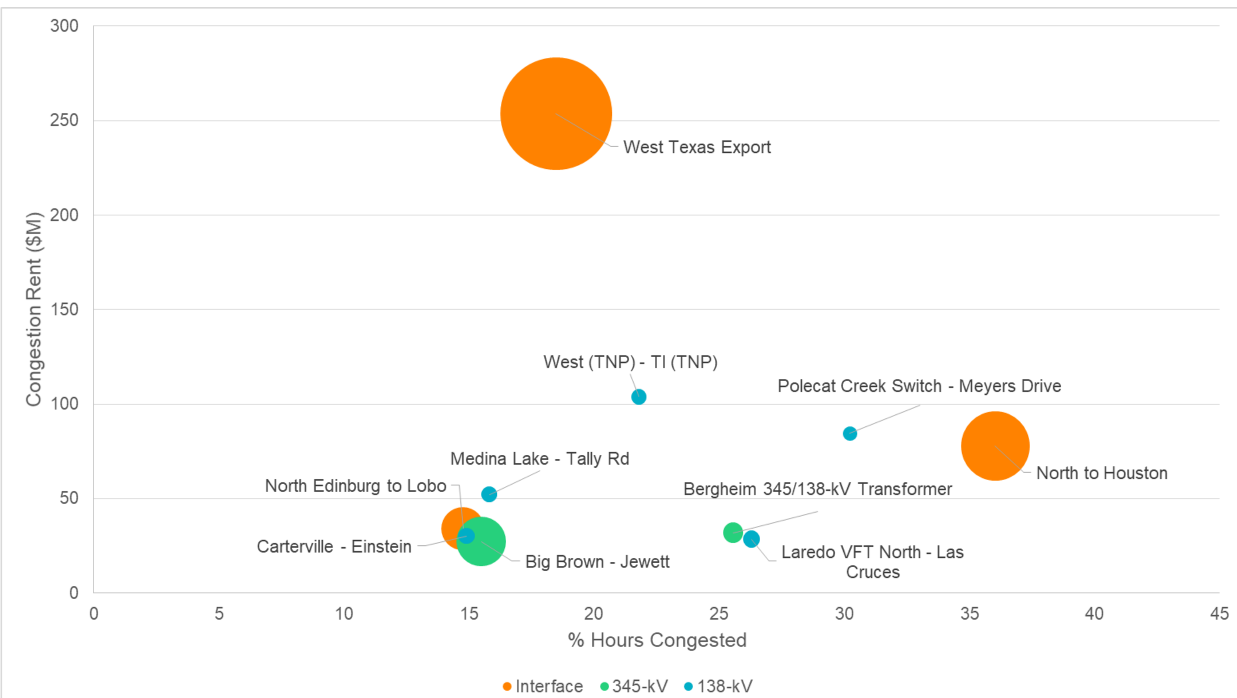


Figure 8: Top Constraints in 2025

Full details of the economic analysis conducted as part of the 2020 RTP, including results for transmission improvements that were evaluated, can be found in Appendix M. The input data and final congestion tables from the 2020 RTP can be found in Appendix N.

Finally, as required by ERCOT Nodal Protocols Section 3.10.8.4(3), ERCOT identified additional Transmission Elements that have a high probability of providing significant added economic efficiency to the ERCOT market through the use of dynamic ratings. Dynamic ratings for the identified elements (listed in Appendix O) have been requested from the associated TOs.

5. Appendices

Index	Description	Document	Access
A	RTP Scope and Process Document	Appendix_A_2020_RTP_Scope_and_Process_Final.pdf <file included in the public version>	Public
B	Input assumptions for the 2020 RTP reliability analysis	Appendix_B_2020_RTP_Reliability_Input_Assumptions.xlsx <file included in the public version>	Public
C	Input assumptions for the 2020 RTP economic analysis	Appendix_C_2020_RTP_Economic_Input_Assumptions.xlsx <file included in the public version>	Public
D	Economic analysis start case input and annual constraints	Appendix_D_2020_RTP_Economics_Start_Case_Inputs_Annual_Contraints.zip <file available in MIS Secure Area>	MIS Secure
E	Reliability Driven Projects	Appendix_E_2020_RTP_Reliability_Projects_Public.xlsx <file included in the public version>	Public
F	Project locations	Appendix_F_2020_RTP_Project_Locations.pdf <file included in the public version>	Public
G	Constraint Management Plans	Appendix_G_2020_RTP_ConstrainstManagementPlans.xlsx <file available in MIS Secure Area>	MIS Secure
H	Multiple element outage analysis	Appendix_H_2020_RTP_MultipleElementContingencyStudyReportI.docx <file available in MIS Secure Area>	MIS Secure
I	Facilities loaded over 95%	Appendix_I_2020_RTP_95%_Exceedance_PG31123.xlsx <file available in MIS Secure Area>	MIS Secure
J	Sensitivity Analysis Results	Appendix_J_2020_RTP_Sensitivity_Projects.xlsx <file available in MIS Secure Area>	MIS Secure
K	Short circuit Analysis	Appendix_K_2020_RTP_ShortCircuitStudyCases_DetailedResults.docx <file available in MIS Secure Area>	MIS Secure
L	Long lead time equipment analysis	Appendix_L_2020_RTP_LongLeadTimeEquipment.docx (File is ERCOT-Confidential)	N/A
M	Economic Analysis	Appendix_M_2020_RTP_Economic_Analysis.docx <file included in the public version>	Public
N	Economic analysis final case input and annual constraints	Appendix_N_2020_RTP_Economics_Final_Case_Inputs_Annual_Contraints.zip <file available in MIS Secure Area>	MIS Secure
O	Transmission elements proposed to be dynamically rated	Appendix_O_2020_RTP_DynRating_NP3_10_8_4.xlsx <file available in MIS Secure Area>	MIS Secure