2021 Regional Transmission Plan

Document Revisions

Date	Version	Description
12/23/2021	1	Initial version
05/23/2022	2	Corrected a couple typos in the report

Executive Summary

The 2021 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 transmission needs for years 2023 through 2027. This report documents the results of the assessment, in part, to comply with the requirements of NERC Reliability Standards, ERCOT 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 2021 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 2021 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 2021 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. In the 2021 RTP, ERCOT adopted the Permian Basin load forecast from the IHS Markit Study[1], which included the load forecast for all but four counties in the Far West weather zone and five adjacent counties in the West weather zone. The reliability analysis in the 2021 RTP identified various reliability projects to accommodate the interconnection of the loads, which were also identified in the ERCOT the Permian Basin Load Interconnection Study[2].

ERCOT identified the following noteworthy reliability projects in the 2021 RTP:

[1] https://www.ercot.com/files/docs/2020/11/27/27706_ERCOT_Letter_to_Commissioners_-_Follow-up_Status_Update_on_Permian....pdf

[2] https://www.ercot.com/files/docs/2021/12/08/ERCOT_Permian_Basin_Load_Interconnection_Study_Public.zip

- New Bearkat to North McCamey to Sand Lake 345-kV double-circuit line addition in Glasscock, Upton, Crane, and Winkler Counties. This project was also identified as the Stage 2 transmission enhancement in the ERCOT Delaware Basin Load Integration Study,[3] and as an ERCOT preferred project in the ERCOT Permian Basin Load Interconnection Study. The 2021 RTP identified the need for this project starting in summer 2026 to resolve voltage collapse issues and other observed reliability violations. The summer 2026 peak load of 4,340 MW in Delaware Basin also exceeded the load triggering point of 4,022 MW identified in the Delaware Basin Load Integration Study.
- Midland County Northwest to Midland East to Falcon Seaboard to Morgan Creek to Tonkawa Switch 345-kV existing circuit rebuild and second circuit addition in Midland, Howard, Mitchell, and Scurry Counties. This project was also identified as an ERCOT preferred project in the Permian Basin Load Interconnection Study.
- Morgan Creek to Longshore 345-kV line upgrade in Mitchell and Howard Counties. This project was also identified as an ERCOT preferred project in the Permian Basin Load Interconnection Study.
- Quail Switch to Odessa 345-kV line upgrade in Ector County. This project was also identified as an ERCOT preferred project in the Permian Basin Load Interconnection Study.
- IH20 345-kV substation expansion and new 345/138-kV transformer additions with the Solstice to Sand Lake 345-kV existing double-circuit line loop in at the expanded IH20 345-kV substation in Winkler and Pecos Counties. This project was also identified as an ERCOT preferred project in the Permian Basin Load Interconnection Study.
- Howard Road and Beck Road 345-kV substation expansion with new 345/138-kV transformer additions, and Howard Road to San Miguel 345-kV double-circuit line addition in Bexar and Atascosa counties. The “Howard Road 345/138 kV Switching Station Project” submitted by CPS Energy was accepted by the ERCOT Regional Planning Group (RPG) in December 2021 as a first step in addressing the reliability needs in the area. The other portions of this RTP project serve as a placeholder for the remaining reliability needs identified. ERCOT and TSPs will continue to evaluate additional project options. Additional RPG submittals for projects to meet the remaining reliability needs are expected.
- Bowman 345/138-kV transformer upgrades in Archer County.
- Pebble Creek area upgrade project in Dallas and Ellis Counties, which includes the addition of the new Pebble Creek North 345-kV station with the Cedar Hill to Watermill 345-kV double-circuit line looped into the new station and two 345/138-kV transformers added at the new Pebble Creek North station along with related 138-kV line additions and upgrades.

[3] http://www.ercot.com/content/wcm/lists/172485/ERCOT_Delaware_Basin_Load_Integration_Study_Public_Version.zip

- Epco 345-kV substation expansion and new 345/138-kV transformer addition in Collin County. Similar reliability needs were identified in 2020 RTP, additional options were studied in the 2021 RTP based on TSP feedback. Based on the study results three options were identified to resolve the identified reliability issues. All the options identified by the 2021 RTP serve as placeholder projects for the reliability issues identified. ERCOT and TSPs will continue to evaluate additional project options after the conclusion of the 2021 RTP. Future RPG submittals for projects to meet the reliability needs are expected.
- Roanoke area upgrade project in Wise and Tarrant Counties. Similar reliability needs were identified in 2020 RTP and additional options were studied in the 2021 RTP based on TSP feedback. Based on the study results two options were identified to resolve the identified reliability issues. Both options involve 345-kV substation additions, 345/138-kV transformer additions, 345-kV line additions, and the loop-in of existing 345-kV lines into the new 345-kV substations. All of the options identified by the 2021 RTP serve as placeholder projects for the reliability issues identified. ERCOT and TSPs will continue to evaluate additional project options. Future RPG submittals for projects to meet the remaining reliability needs are expected.
- Liggett to Norwood 138-kV to 345-kV line conversion in Dallas County. Similar reliability needs were also identified in 2020 RTP. This is a placeholder project for the reliability issues identified in the 2021 RTP, and is subject to further feasibility review by the TP.

The 2021 RTP also included an economic assessment of the ERCOT transmission system for years 2023 and 2026. Through this assessment, ERCOT identified projected transmission constraints and lines recommended for dynamic rating.

The project completion years stated in the 2021 RTP report were chosen to address reliability 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 projects identified in the RTP do not represent ERCOT's endorsement of the projects. Instead, they represent 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 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. 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.

Table of Contents

1. 2021 Regional Transmission Plan

This report documents the 2021 Regional Transmission Plan (RTP) assessment performed by ERCOT System Planning. It is intended, in part, to satisfy ERCOT's requirements under NERC Reliability Standards, ERCOT Protocols Section 3.11, and ERCOT Planning Guide Sections 3 and 4.

The RTP study is conducted annually for the entire ERCOT System. The 2021 RTP's near-term and long-term planning horizon analysis evaluated the reliability needs of the ERCOT transmission system for the years 2023, 2024, 2026, and 2027. As required by NERC Reliability Standard TPL-001-4, the 2021 RTP included a steady-state analysis of summer peak conditions for years 2023 (year 2), 2024 (year 3), and 2026 (year 5); and off-peak conditions for 2024 (year 3); and a short-circuit analysis of summer peak conditions for 2024 (year 3). The 2021 RTP also included steady-state analysis of summer peak conditions for 2027 (year 6), representing the long-term planning horizon. Year six, or 2027, 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 2021 RTP also evaluated projected congestion on the ERCOT system for years 2023 and 2026.

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, C, and D. Stakeholders were provided routine updates on the input assumptions and supporting analysis performed for the 2021 RTP in 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 proposed transmission projects in the ERCOT Region. Under ERCOT 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 and to identify system upgrades and new transmission projects to ensure continued system reliability.

1.2. Standards and Regulations

The RTP assessment was conducted based on requirements in NERC Reliability Standards, ERCOT 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 NERC Reliability Standards FAC-002[4] and IRO-017.[5]

ERCOT 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.

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 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 public version of the RTP report is also created by removing, at a minimum, any confidential data and ERCOT Critical Energy Infrastructure Information (ECEII). This report is posted to the ERCOT website.

[4] FAC-002, Requirement R4
[5] IRO-017, Requirements R3 and R4

2. 2021 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 2021 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. In the 2021 RTP, the West and Far West weather zones adopted the IHS Markit study Permian Basin load forecast. 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 2021 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 projected congestion and lines recommended for Dynamic Rating. The detailed scope, process, and input assumptions used in conducting both reliability and economic analyses are available in Appendices A, B, C, and D.

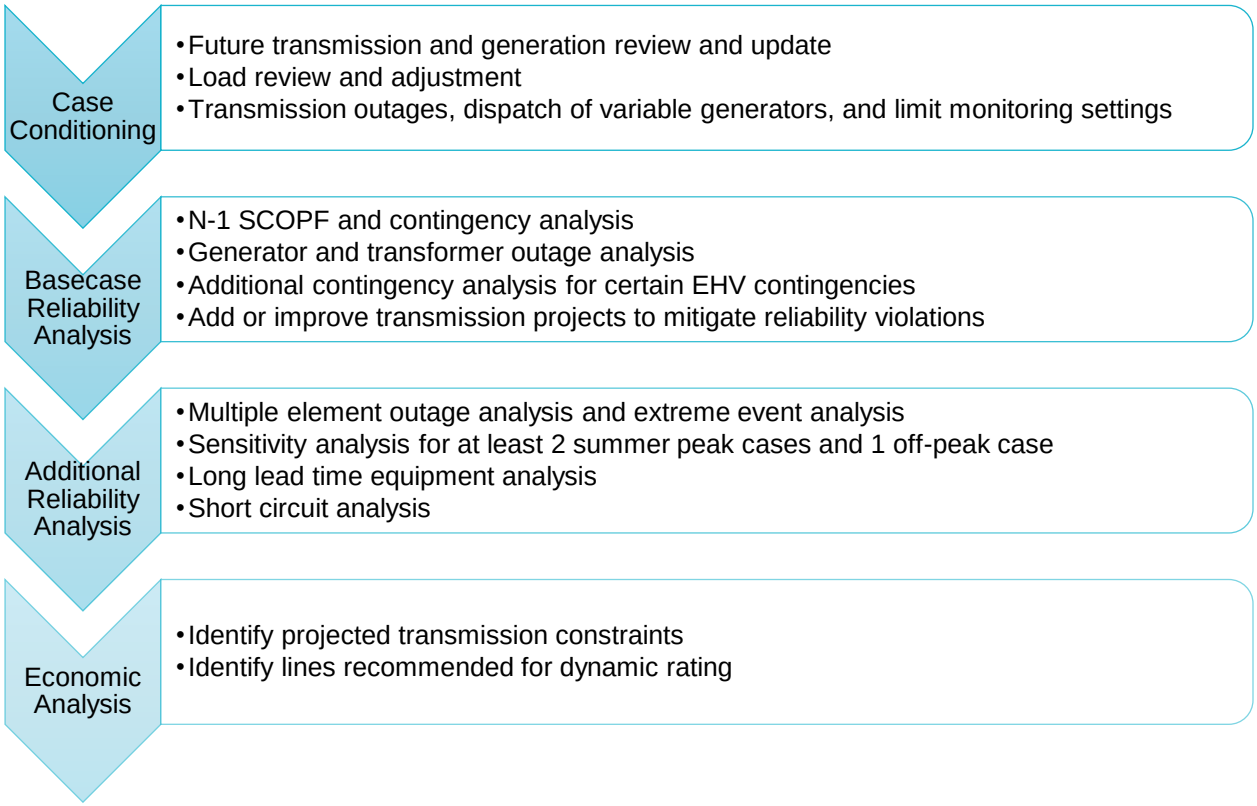

Figure 1: 2021 RTP Transmission Planning Process

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 was used to screen critical contingencies while evaluating P3 (generator outage) and P6-2 (transformer outage) planning events.
- POM application suite version 2021 including POM suite – Optimal Mitigation Measures (OPM) and Potential Cascading Modes (PCM) were used to perform 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. Adoption of Permian Basin Load Forecast from IHS Markit Study

West Texas has experienced rapid load growth in the past several years due to significant growth of oil and gas production in the area. The average annual load growth rate was observed to be approximately 12% from 2016 through 2021. The rapid load growth coupled with the short lead time of oil and gas load interconnection requests has imposed significant challenges in transmission planning to reliably integrate the growing oil and gas load. Both ERCOT and TSPs serving West Texas oil and gas load have been working diligently to better understand oil and gas activities and growth, and better prepare for potential long lead time transmission enhancements needed to reliably serve the fast-growing loads.

ERCOT completed the Delaware Basin Load Integration Study with extensive input from TSPs in 2019, and identified a five-stage transmission upgrade road map to reliably serve different levels of Delaware Basin load. In addition, both ERCOT and TSPs have also evaluated West Texas oil and gas load growth at a more granular level. In April 2020, a TSP-sponsored IHS Markit study report for Permian Basin load forecast was published, which was based on an in-depth analysis of the oil and gas activities in the Permian Basin, and provided the load forecast with more granularity. The Permian Basin load forecasted in the IHS Markit study was reviewed by ERCOT and TSPs serving the load within the Permian Basin area, and was determined to be appropriate for use in the 2021 RTP. The adoption of the Permian Basin load forecast from the IHS Markit study in the 2021 RTP was also presented at RPG meetings for stakeholder comment.

The Permian Basin load forecast from the IHS Markit study included all but four counties in the Far West weather zone and five adjacent counties in the West weather zone. The counties and load forecast from 2022 to 2030 associated with the Permian Basin area can be found in Table 1 and Figure 2, respectively.

Table 1: Permian Basin Counties

County	Weather Zone
Andrews	Far West
Borden	Far West
Crane	Far West
Crockett	Far West
Culberson	Far West
Dawson	Far West
Ector	Far West
Glasscock	Far West
Howard	Far West
Irion	West
Loving	Far West
Martin	Far West
Midland	Far West
Mitchell	West
Pecos	Far West
Reagan	Far West
Reeves	Far West
Schleicher	West
Scurry	West
Sterling	West
Upton	Far West
Ward	Far West
Winkler	Far West

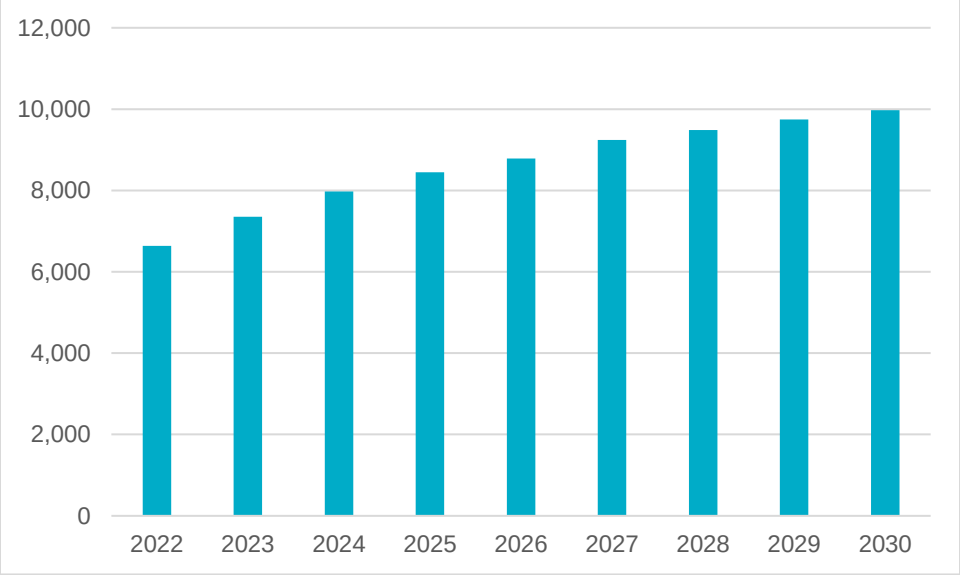

Figure 2: IHS Markit Study Permian Basin Summer Peak Load Forecast (MW)

While a large portion of the Permian Basin loads can be served from exiting or planned substations, there are also projected new loads that require new interconnections to the existing transmission system. In the 2021 RTP, the new load interconnection was assumed to be consistent with the ERCOT Permian Basin Load Interconnection Study. The new load-serving stations and their connections to the existing transmission system can be found in Appendix C.

2.2. Reliability Analysis

The reliability analysis in the 2021 RTP was focused on the steady-state portion requirements 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 2021 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 planning events. 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, and P5 planning events; and extreme events.
- 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 the 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 and P5 planning events; 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 loadability rating before mitigation measures can be taken. 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 TOs.
- Sensitivity Analysis: ERCOT selected the summer peak conditions of 2023 and 2026 and off-peak conditions of 2024 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:
    - Deliverability Assessment Under ERCOT Coincident Summer Peak Load Conditions for years 2023 and 2026: Identify potential transmission upgrades needed to ensure that Generation Resources utilizing nuclear, coal and lignite, combined cycle, gas/oil steam, or combustion turbine technologies; and Energy Storage Resources (ESRs) with a minimum duration of 4 hours at their maximum discharge capability, were not limited by transmission constraints from a reliability perspective.
    - Stressed Resource Availability condition for the 2024 off-peak case: Identify potential challenges with limited Resource availability due to high planned outages for conventional generators and the unavailability of renewable Resources.

  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.

2.2.1. 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 simultaneously-feasible, security-constrained re-dispatch of existing and 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 on-load tap-changing transformers, phase-shifting transformers, and switched capacitors and reactors.

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 year of completion (taking into account necessary lead times). In some cases, the TOs also provided project alternatives. In instances where it is not feasible to construct a project prior to the identified date of need, ERCOT designed Constraint Management Plans (CMP) to mitigate the criteria violations until the permanent CAP can 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.

2.2.2. 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.

2.3. Economic Analysis

ERCOT conducted an economic analysis to identify projected congestion and lines recommended for dynamic rating. To conduct this analysis, ERCOT prepared production cost models for years 2023 and 2026. Details on the production cost models developed for the 2021 RTP can be found in Appendices E and N.

3. Findings from Reliability Analysis

3.1. Reliability Projects and Constraint Management Plans

The primary purpose of the 2021 RTP reliability analysis was to identify reliability criteria violations and potential CAPs to resolve them. Overall, the base reliability analysis identified a need for 67 CAPs. The detailed list of criteria violations and resulting CAPs can be found in Appendix F. Figure 3 illustrates the geographic location of the identified CAPs. The legend linking reliability projects and their associated map indices can be found in Appendix G.

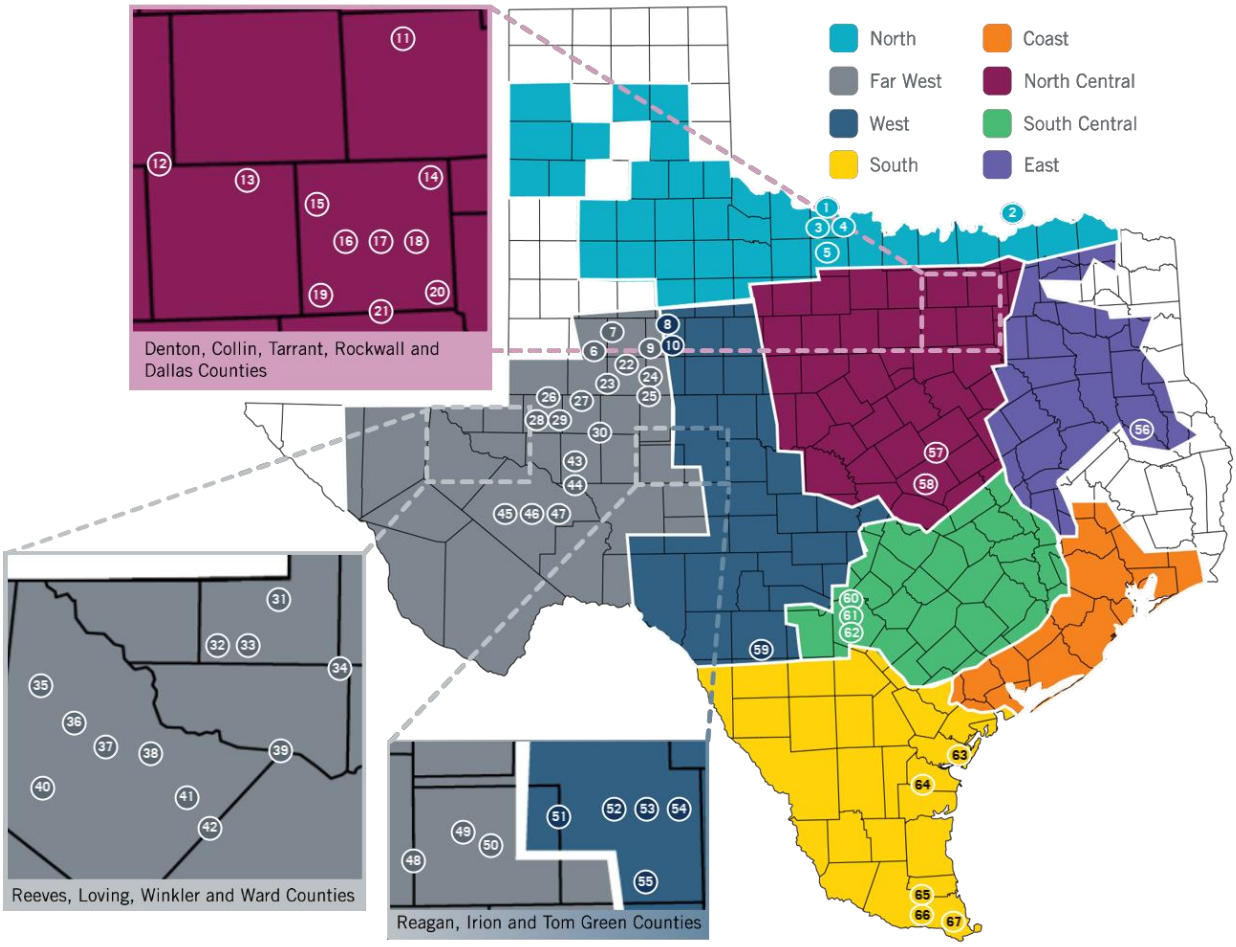

Figure 3: Geographic Locations of CAPs Identified in the 2021 RTP

Figures 4[6] and 5 summarize the types of projects, their geographic locations, and associated voltage levels. Figure 6[7] distinguishes between projects that were newly identified in the 2021 RTP and projects that were identified in previous ERCOT planning studies or TSP studies.

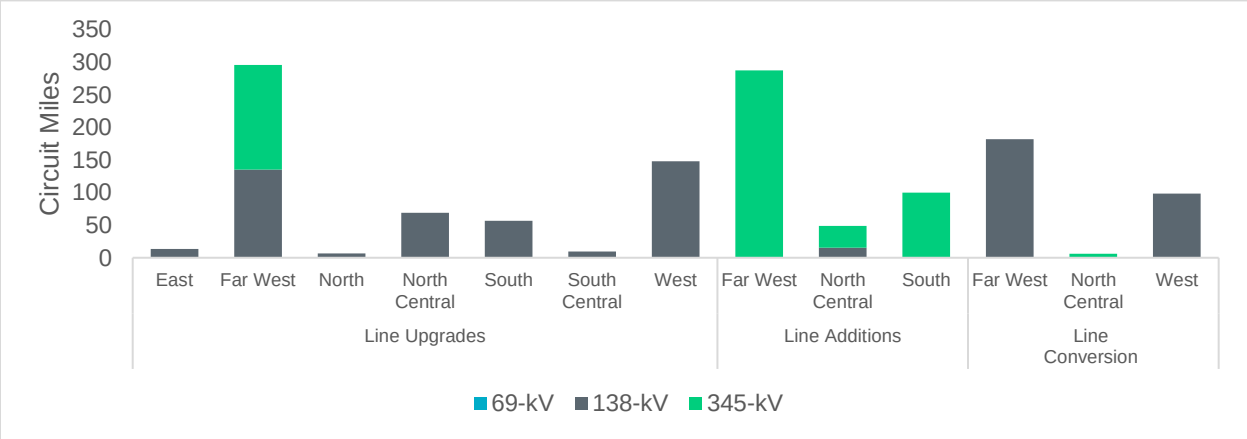

Figure 4: 2021 RTP Transmission Line Project Types by Weather Zone and Voltage Level

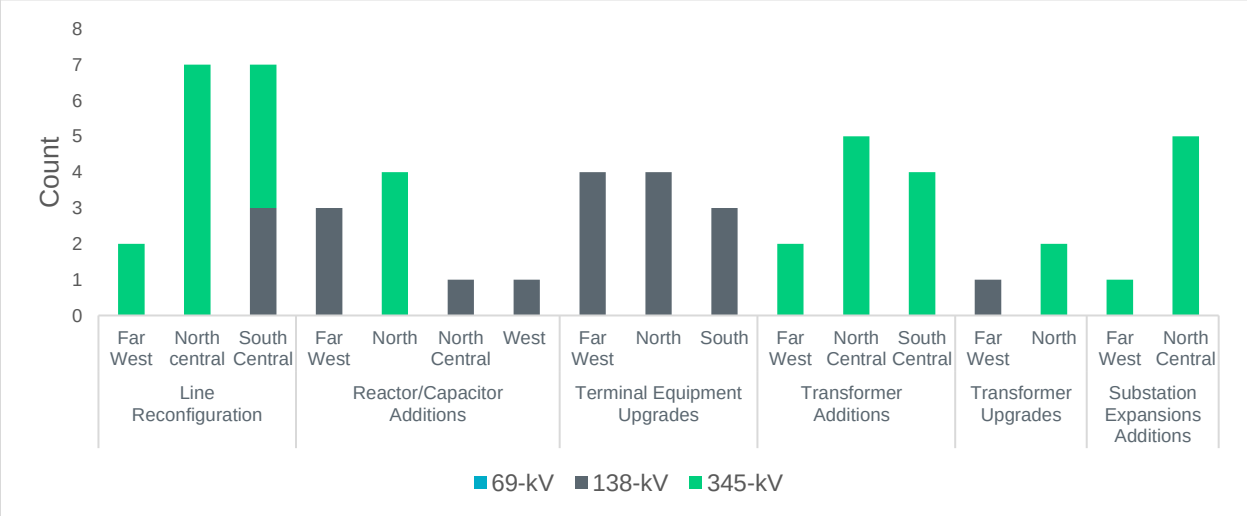

Figure 5: 2021 RTP Other Upgrades and Additions by Weather Zone and Voltage Level

[6] The 69-kV to 138-kV line conversion was included in the 138-kV category.
[7] The projects, which were also identified in ERCOT Permian Basin Load Interconnection Study, were included as newly identified projects.

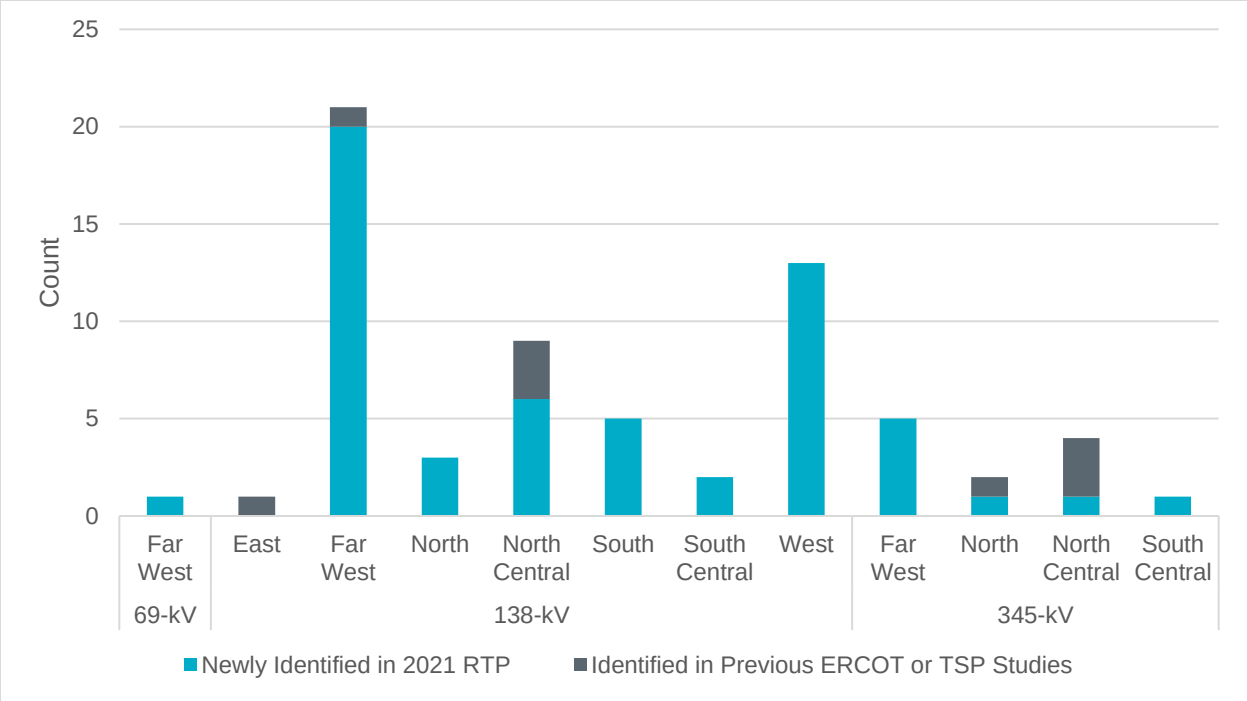

Figure 6: Projects Newly Identified in the 2021 RTP versus Projects Previously Identified

The CAPs identified in the 2021 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 three potential 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 2021 RTP can be found in Appendix H.

3.1.1. West Texas Study Findings

As described in Section 2.1, the Permian Basin load forecast from the IHS Markit study was adopted in the 2021 RTP. The IHS Markit study forecasted that electric demand in Permian Basin will nearly double by 2030. The total Permian Basin load forecast adopted for year 2027, which is the furthest out year studied in the 2021 RTP, is 9,244 MW. Besides the forecasted demand that can be served from the existing and planned substations, there are 118 projected new loads served from new stations through new interconnections to the existing transmission grid by year 2027. In the 2021 RTP, those new load serving stations are mostly radially connected to the existing system, which is consistent with the ERCOT Permian Basin Load Interconnection Study. The new load connection information can be found in Appendix C. The focus of the 2021 RTP was on the system impacts from loads served from both existing and planned substations, and the new substations with assumed connections. Since the oil and gas loads do not vary throughout the day, the condition without any solar generators available was also analyzed to ensure that all West and Far West loads can be served reliably.

Overall, 40 reliability projects were identified for the West and Far West study region. Among them, 5 345-kV transmission upgrades/additions were identified. All 5 projects were also identified by the

ERCOT Permian Basin Load Interconnection Study as preferred projects. These projects are summarized below:

- New Bearkat to North McCamey to Sand Lake 345-kV double-circuit line addition in Glasscock, Upton, Crane, and Winkler Counties. This project was also identified as the Stage 2 transmission enhancement in the ERCOT Delaware Basin Load Integration Study transmission roadmap. The 2021 RTP identified the need for this project starting in summer 2026 to resolve voltage collapse issues and other observed reliability violations. The summer 2026 peak load of 4,340 MW in Delaware Basin also exceeded the load triggering point of 4,022 MW identified in the Delaware Basin Load Integration study.
- Midland County Northwest to Midland East to Falcon Seaboard to Morgan Creek to Tonkawa Switch 345-kV existing circuit rebuild and second circuit addition in Midland, Howard, Mitchell, and Scurry Counties.
- Morgan Creek to Longshore 345-kV line upgrade in Mitchell and Howard Counties.
- Quail Switch to Odessa 345-kV line upgrade in Ector County.
- IH20 345-kV substation expansion and new 345/138-kV transformer additions with the Solstice to Sand Lake 345-kV existing double-circuit line loop in at the expanded IH20 345-kV substation in Winkler and Pecos Counties.

3.1.2. San Antonio Area Study Findings

In the 2021 RTP, a group of generators were taken out of service in the RTP base cases prior to receiving a Notification of Suspension of Operations (NSO) based on the Resource Entities notifications and public statements about their intention to retire those Generation Resources in accordance with Planning Guide Section 3.1.4.1.1(4). The list of affected Generation Resources can be found in the "Generation Resources Unavailable in Planning Studies Prior to NSO" document[8] posted on the ERCOT website. Some generators may have filed NSOs after the start of the 2021 RTP. The total MW capacity affected in each study year for the 2021 RTP is listed in Table 2 below.

Table 2: Capacity of Generation Resources Taken Out of Service Prior to NSO

Study Year	Total Capacity Affected (MW)
2023	420
2024 MIN	420
2024	420
2026	1279
2027	2354

8 https://www.ercot.com/misapp/GetReports.do?reportTypeId=16603&reportTitle=Generation%20Resources%20Unavailable%20in%20Planning%20Studies%20Prio%20to%20NSO&showHTMLView=&mimicKey

The expected Generation Resource retirements coupled with robust load growth in the San Antonio area resulted in reliability challenges in the area, including thermal overloads of 345/138-kV transformers at Cagnon and Hill Country stations, and 138-kV line overloads in the area northeast of San Antonio. The reliability needs are illustrated in Figure 7.

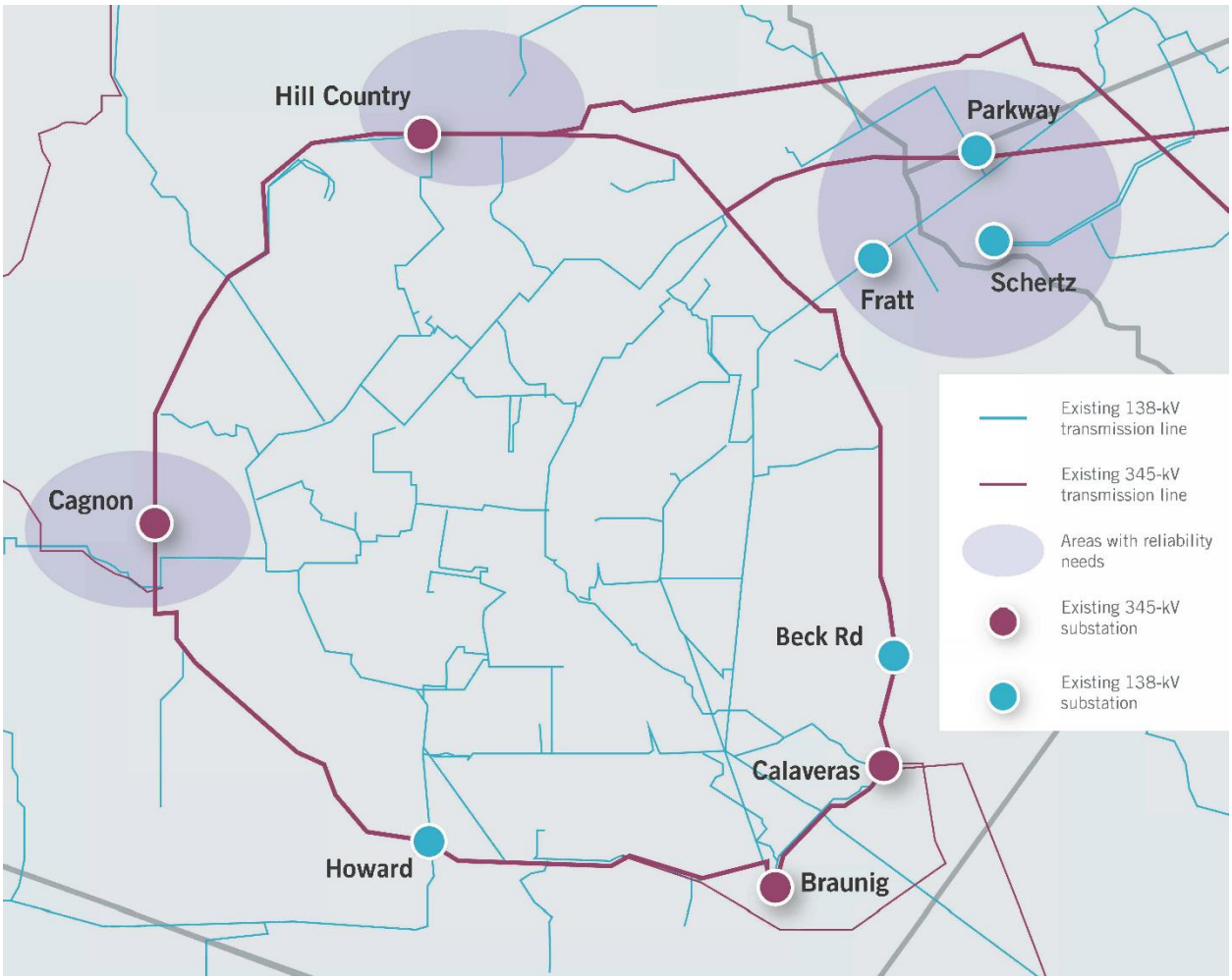

Figure 7: San Antonio Area Reliability Needs

In order to address the reliability needs observed, a placeholder project was used in the 2021 RTP, which includes expansion of the Howard Road and Beck Road 345-kV substations, new 345/138-kV transformer additions at those stations, and the Howard Road to San Miguel 345-kV double-circuit line addition. The Howard Road 345-kV substation expansion and 345/138-kV transformer additions at the expanded Howard Road substation were needed by summer 2026, while the rest of the upgrades were needed by summer 2027. The “Howard Road 345/138 kV Switching Station Project” submitted by CPS Energy was accepted by RPG in December 2021 as a first step in addressing the reliability needs in the area. The other portions of this RTP project serve as a placeholder for the remaining reliability needs identified. ERCOT and TSPs will continue to evaluate additional project options. Additional RPG submittals for projects to meet the remaining reliability needs are expected.

3.1.3. Other Findings

In addition to the reliability analysis summarized in previous sections, a multiple element outage analysis was conducted for contingencies where non-consequential load loss is allowed under NERC Reliability Standard TPL-001-4, Table 1. This analysis consisted of:

- 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
- cascading analysis, which identified any contingencies that could result in potential cascade events.

Some planning events and extreme events were screened for detailed analysis, and 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 I. 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 2021 RTP reliability analysis.

In addition to the above analysis, per ERCOT Planning Guide Section 3.1.1.2(3), the 2021 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 J.

3.2. Sensitivity Analysis

Understanding the challenges under various system conditions has become increasingly important with the changing grid, which includes not only resource mix changes related to rapid growth of wind, solar, and energy storage resources and increased coal and gas generator retirement, but also to changes on the demand side with robust oil and gas activity in west Texas, increased interest in cryptocurrency mining facility development, and the expected increase in electrical vehicle (EV) adoption. As part of ERCOT's efforts to address the challenges posed by the changing grid, sensitivity analysis is performed as part of the RTP each year. In past RTPs, sensitivities have been performed with various renewable generation output assumptions different from the base case analysis for both the on-peak and off-peak analysis, and with various assumptions for West Texas oil and gas loads. In the 2021 RTP, besides varying the renewable generation output assumptions, the sensitivity analysis also further stressed the system with increased limitations on conventional generation resource availability due to planned outages for off-peak conditions, and evaluated potential transmission needs to ensure full deliverability of nuclear, coal, natural gas, and energy storage resources with at least four hours of duration at their maximum discharge capability under on-peak system conditions. The detailed assumptions and study results are summarized in the following sections and are also available in Appendices B and K, respectively.

3.2.1. Deliverability Assessment Under ERCOT Coincident Summer Peak Load Conditions

The on-peak sensitivity analysis was performed for years 2023 and 2026 under ERCOT coincident summer peak load conditions. The focus of this sensitivity analysis was to identify any additional reliability needs in order to ensure the full deliverability of Resources meeting the following criteria:

- Generation Resources utilizing nuclear, coal and lignite, combined cycle, gas/oil steam, or combustion turbine technologies and
- Energy Storage Resources (ESRs) with a minimum duration of 4 hours at their maximum discharge capability.

The total MW capacity of the Generation Resources meeting the above criteria for each weather zone can be found in Figure 8.

Figure 8: Generation Resource Capacity Meeting Defined Criteria by Weather Zone

In this sensitivity analysis, the Resources meeting the defined criteria were assumed to generate at their maximum capacities and were not re-dispatched to alleviate transmission constraints, while

Resources not meeting the criteria were re-dispatched, as needed, to alleviate transmission constraints.

The study results showed that additional local transmission upgrades were needed to ensure the full deliverability of Resources meeting the criteria defined for this sensitivity. The transmission upgrades were concentrated in the East, North Central, and South weather zones. The affected counties are:

- Cherokee, Rusk, and Smith Counties in the East weather zone
- Dallas, Ellis, and Bosque Counties in the North Central weather zone
- San Patricio County in the South weather zone

All of the identified transmission upgrades were needed for both study years 2023 and 2026 under the conditions studied in this sensitivity analysis. The detailed results can be found in Appendix K.

3.2.2. Stressed Resource Availability Under Off-Peak Load Conditions

In the 2024 off-peak sensitivity analysis, the 2021 RTP focused on understanding potential challenges associated with stressed Resource availability. The following assumptions were made in this sensitivity analysis in terms of Resource availability:

- renewable generation including both wind and solar were assumed to be offline;
- ESRs were assumed to be offline; and
- approximately 14 GW of conventional generation capacity were assumed to be offline due to planned outages.

The total conventional generation capacity affected by planned outages was selected based on historical data analysis. The planned outage generation capacity in each weather zone is illustrated in Figure 9. The total system load was assumed to be 58 GW in this sensitivity analysis.

Figure 9: Planned Outages Capacity by Weather Zone

The study results showed that additional local transmission upgrades were needed to ensure system reliability under the conditions studied.

The transmission upgrades were concentrated in the East, North Central, and West weather zones. The affected counties are:

- Henderson County in the East weather zone;
- Denton County in the North Central weather zone; and
- Edwards County in the West weather zone.

The detailed results can be found in Appendix K.

3.3. Short Circuit Analysis

As indicated in Section 2.2, ERCOT conducted short-circuit analysis for Resource Entity-owned facilities for 2024 summer peak conditions based on the system protection future year base case and shared the results with GOs. GOs reviewed the fault duty information to identify buses with over-dutied breakers along with CAPs.

Table 3 provides a summary of the results of the short-circuit analysis. The study cases and details of the results can be found in Appendix L.

Table 3: Summary of Short-circuit Analysis

Magnitude of Fault Current		Number of buses (3-phase fault)	Number of buses (single-line-to-ground fault)
Below 40 kA		457	467
40 kA ~ 60 kA		75	61
More than 60 kA		1	5

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 2023, 2026, and 2027 summer peak conditions, along with 2024 off-peak conditions. Overall, 30 unique 345/138-kV transformers, 3 unique 345/115-kV transformers, 14 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 planning events were studied. The results were shared with the respective TPs. The list of long lead time equipment and study results are provided in Appendix M.

4. Economic Analysis

The 2021 RTP economic analysis was performed using production cost simulation runs for years 2023 and 2026. The input data and final congestion tables from the 2021 RTP can be found in Appendices D and E. Table 4 provides a system summary of 2021 RTP economic analysis for years 2023 and 2026.

Table 4: System Summary of 2023 and 2026[9]

Description	Unit	2023	2026
Coincident Peak Load	MW	82,966	85,490
Peak Net Load[10]	MW	67,964	70,492
Minimum Net Load[10]	MW	10,337	11,323
Annual Served Demand	GWh	464,695	488,349
Annual Storage Charging	GWh	419	496
Annual Transmission Losses	GWh	13,277	13,443
Annual Generation	GWh	478,390	502,288
Load-Weighted Average LMP	$/MWh	23.30	25.61

Figure 10 shows the renewable penetration for the 2023 and 2026 study years. Renewable penetration is defined as the total amount of demand at any given time that is served by wind and solar generation. It appears possible that there may be hours when all ERCOT demand could theoretically be served by wind and solar resources. However, thermal and stability constraints on the transmission system and unit commitment limitations caused the grid simulation software to curtail available wind and solar output. Figures 11 and 12 summarize monthly production and curtailment for wind and solar generation, respectively.

[9] All results are based on the 2013 historical weather year
[10] Hourly Net Load = Hourly Load Forecast – Hourly Wind Output – Hourly Solar Output

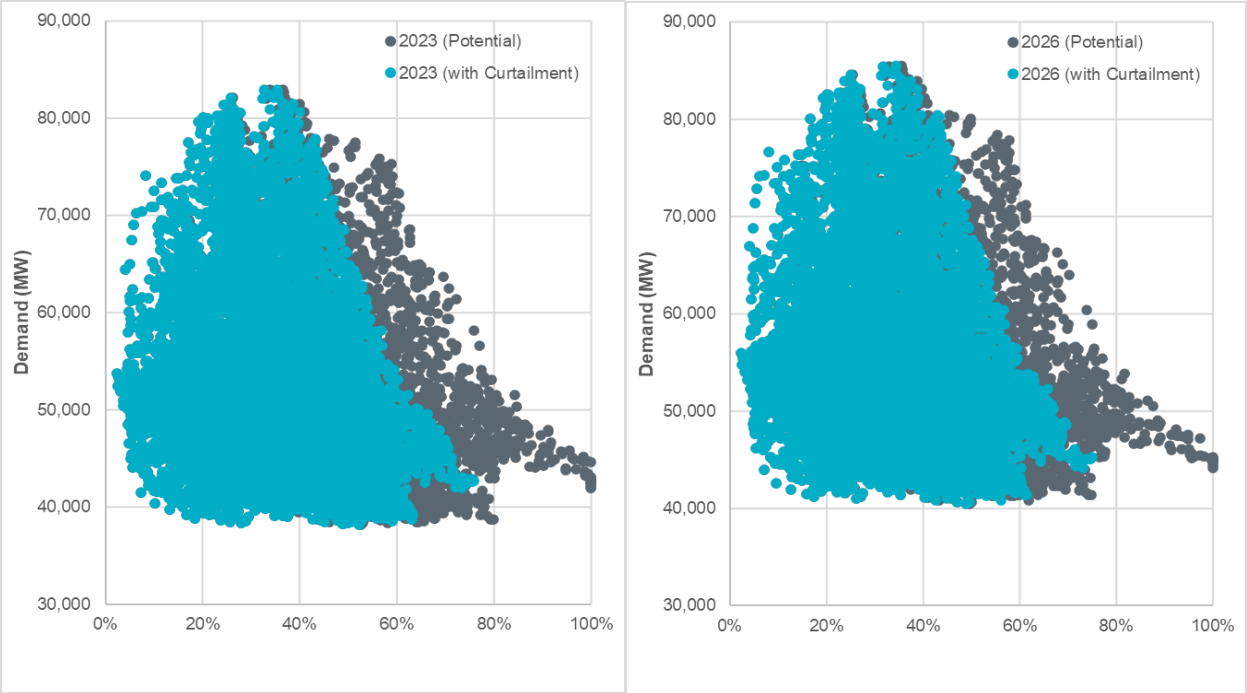

Figure 10: Wind and Solar Penetration

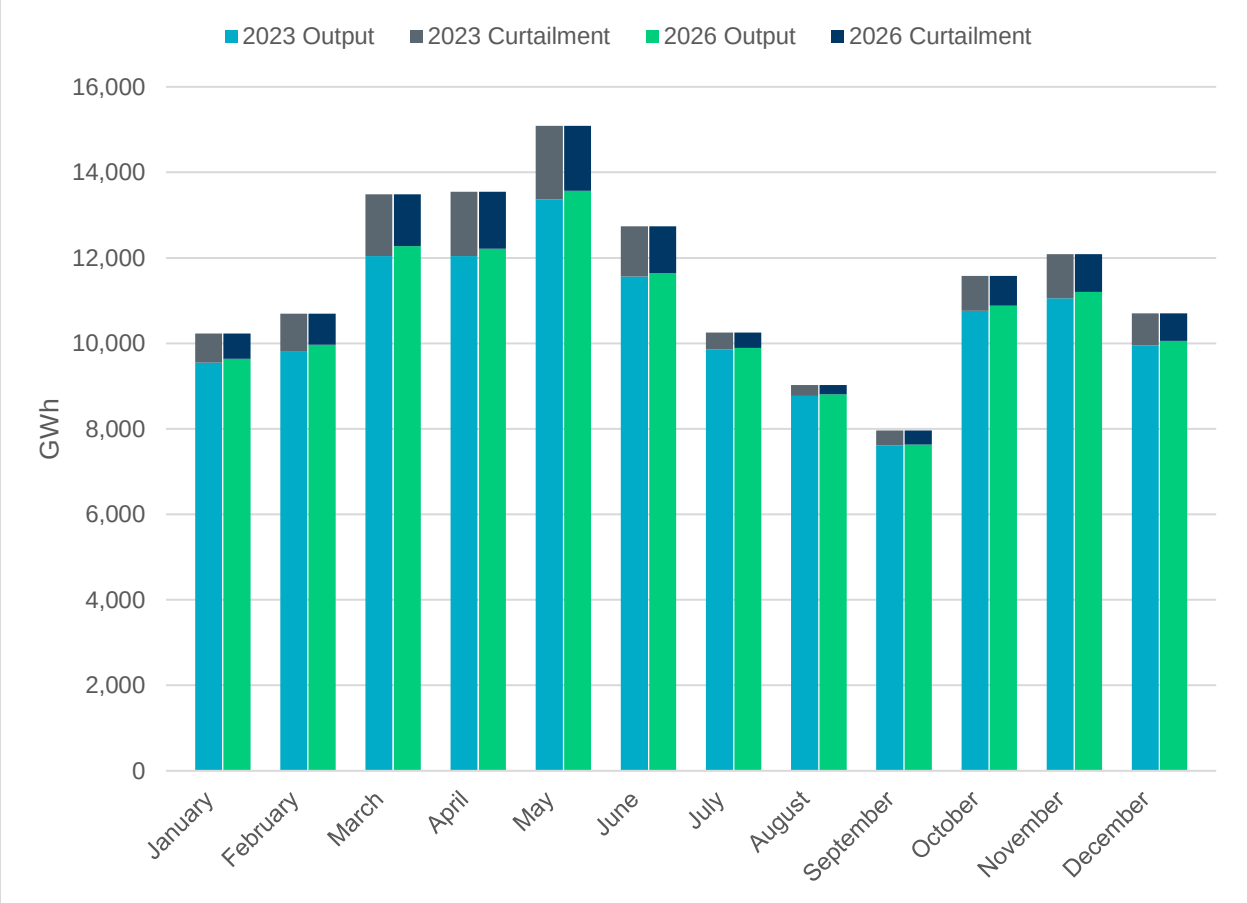

Figure 11: Wind Production and Curtailment

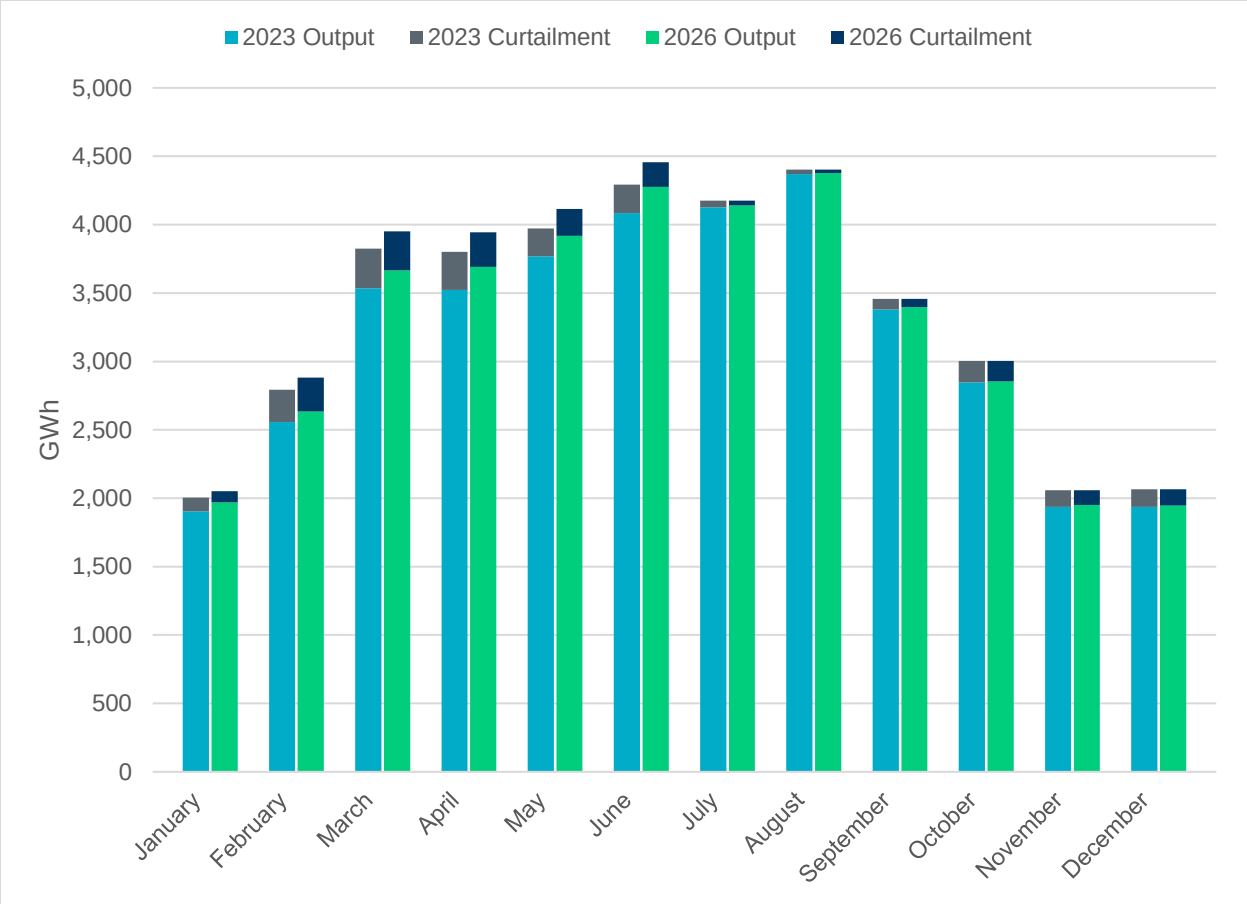

Figure 12: Solar Production and Curtailment

Figures 13 and 14 show the top constraints seen in 2023 and 2026, respectively. The size of each bubble represents the relative capacity of each congested element over the study period.

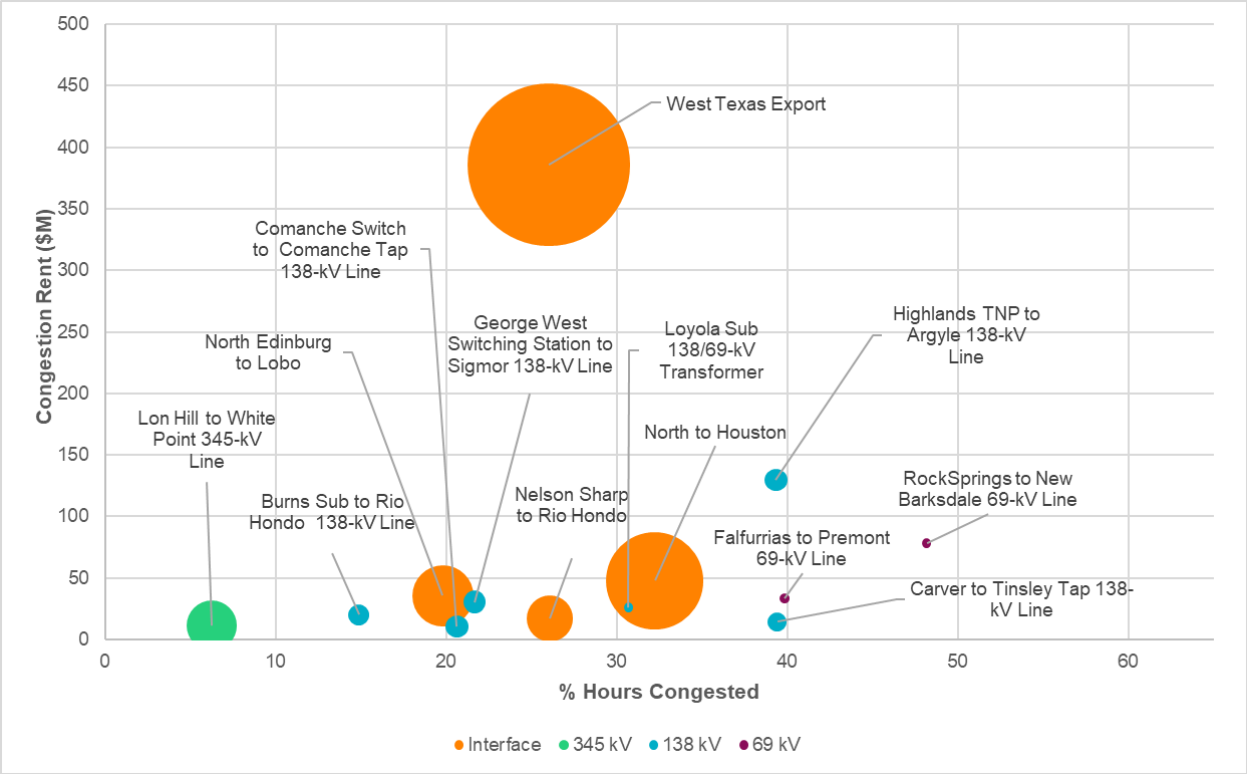

Figure 13: Top Constraints in 2023

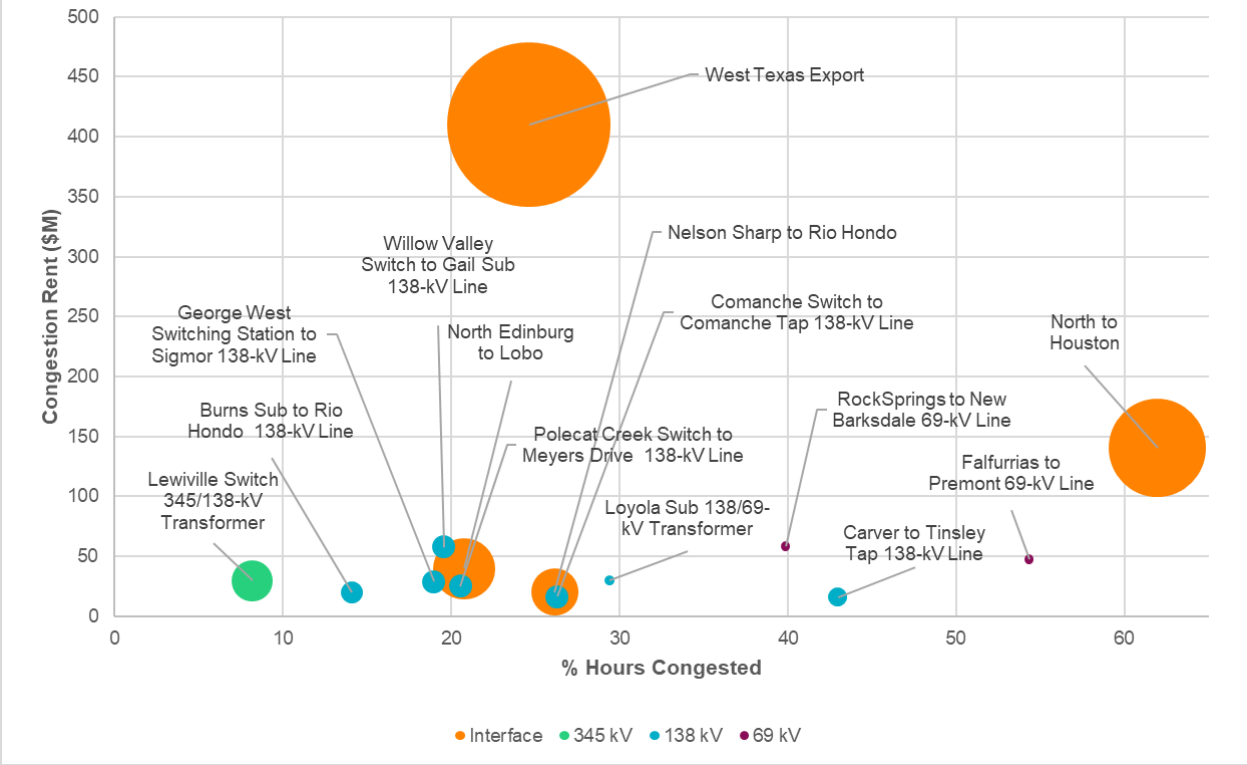

Figure 14: Top Constraints in 2026

Similar to the 2020 RTP economic analysis, the West Texas export interface was the top congested element observed for both the 2023 and 2026 study years. The interface limit used in the 2021 RTP was 11,016 MW based on preliminary results from ERCOT's Long-Term West Texas Export Special Study – a higher limit than that utilized for the 2020 RTP. The interface was congested approximately 26% and 24.6% of hours in the 2023 and 2026 study years, respectively. Potential improvements to alleviate congestion on the West Texas export interface informed by the results of the Long-Term West Texas Export Special Study may be evaluated in future RTP economic analysis.

The placeholder Dallas-Fort Worth Import Project identified in the 2020 RTP was included in both the 2023 and 2026 study years for the 2021 RTP. With the project in place, congestion previously observed in the Alliance and Hicks Switch area in the 2020 RTP was not present in the 2021 RTP economic analysis results and more power could be delivered through the Dallas-Fort Worth area. However, congestion observed on the Highlands TNP to Argyle 138-kV line under the loss of Lewisville Switch to Krum West and Lewisville Switch to Roanoke 345-kV double-circuit line and on one of the Lewisville Switch 345/138-kV transformers under the loss of the Northwest Carrollton to Lewisville Switch 345-kV double-circuit line resulted from the increased power transfers attributable to the Dallas-Fort Worth Import Project. An alternative to the Dallas-Fort Worth Import Project is expected to be submitted for RPG review. ERCOT will continue to evaluate project options that address both the economic and reliability needs identified in the northwest Dallas-Fort Worth area.

The North to Houston interface was modelled with hourly profiles based on historical data in the 2021 RTP economic analysis. High congestion was observed in both the 2023 and 2026 study years on the North to Houston interface, with the interface congested 32.2% and 62% of hours in the 2023 and 2026 study years, respectively. The congestion was driven by both West Texas renewable generation and load growth within the Houston area. These results are consistent with real-time congestion on the North to Houston interface throughout 2021.

Due to increasing renewable generation in the Lower Rio Grande Valley (LRGV) area, the North Edinburg to Lobo interface and Nelson Sharpe to Rio Hondo interface experienced high congestion in both real-time operations and the 2021 RTP economic study. It was observed that the North Edinburg to Lobo interface was congested 19.8% and 20.8% of hours in the 2023 and 2026 study years, respectively. The Nelson Sharpe to Rio Hondo interface was congested 26.1% and 26.2% of hours in the 2023 and 2026 study years, respectively. The 138-kV line from Rio Hondo to Burns, which is located within the LRGV, was also highly congested in both the 2023 and 2026 study years. These observations are consistent with the findings identified by the 2020 RTP. Congestion in the area is driven primarily by the contingency involving the common tower loss of the North Edinburg to Bonilla 345-kV line and the 138-kV line from Bonilla to South Santa Rosa. The primary 345-kV path was removed as part of the contingency, and the result was heavy congestion along the parallel 138-kV path to the west.

The ERCOT Board of Directors recently endorsed the preferred long-term improvement option for the Lower Rio Grande Valley (LGRV) System Enhancement Project. The Public Utility Commission of Texas (PUCT) also recently ordered the construction of a new second circuit on the double-circuit

capable 345-kV transmission line that runs from San Miguel to Palmito and new transmission facilities to close the loop from Palmito to North Edinburg. Those improvements for the LGRV area will inform future economic planning analysis.

Finally, as required by ERCOT 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 using 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_2021_RTP_Scope_and_Process_Final.pdf <file included in the public version>	Public
B	Input assumptions for the 2021 RTP reliability analysis	Appendix_B_2021_RTP_Reliability_Input_Assumptions.xlsx <file included in the public version>	Public
C	WFW IHS new load interconnection	Appendix_C_WFW_IHS_New_Load_Interconnection.xlsx <file available in the MIS Secure Area>	MIS Secure
D	Input assumptions for the 2021 RTP economic analysis	Appendix_D_2021_RTP_Economic_Input_Assumptions.xlsx <file included in the public version>	Public
E	Economic analysis start case input and annual constraints	Appendix_E_2021_RTP_Economics_Start_Case_Inputs_Annual_Contraints.zip <file available in the MIS Secure Area>	MIS Secure
F	Reliability Driven Projects	Appendix_F_2021_RTP_Reliability_Projects_Public.xlsx <file included in the public version>	Public
G	Project locations	Appendix_G_2021_RTP_Project_Locations.pdf <file included in the public version>	Public
H	Constraint Management Plans	Appendix_H_2021_RTP_ConstrainstManagementPlans.xlsx <file available in the MIS Secure Area>	MIS Secure
I	Multiple element outage analysis	Appendix_I_2021_RTP_MultipleElementContingencyStudyReportI.docx <file available in the MIS Secure Area>	MIS Secure
J	Facilities loaded over 95%	Appendix_J_2021_RTP_95%_Exceedance_PG31123.xlsx <file available in the MIS Secure Area>	MIS Secure
K	Sensitivity Analysis Results	Appendix_K_2021_RTP_Sensitivity_Projects.xlsx <file available in the MIS Secure Area>	MIS Secure
L	Short circuit Analysis	Appendix_L_2021_RTP_ShortCircuitStudyCases_DetailedResults.docx <file available in the MIS Secure Area>	MIS Secure
M	Long lead time equipment analysis	Appendix_M_2021_RTP_LongLeadTimeEquipment.docx	N/A
N	Economic analysis final case input and annual constraints	Appendix_N_2021_RTP_Economics_Final_Case_Inputs_Annual_Contraints.zip <file available in the MIS Secure Area>	MIS Secure
O	Transmission elements proposed to be dynamically rated	Appendix_O_2021_RTP_DynRating_NP3_10_8_4.xlsx <file available in the MIS Secure Area>	MIS Secure