Public

TEXAS RE

Ensuring electric reliability for Texans

2024 RELIABILITY PERFORMANCE AND REGIONAL RISK ASSESSMENT

JUNE 2025

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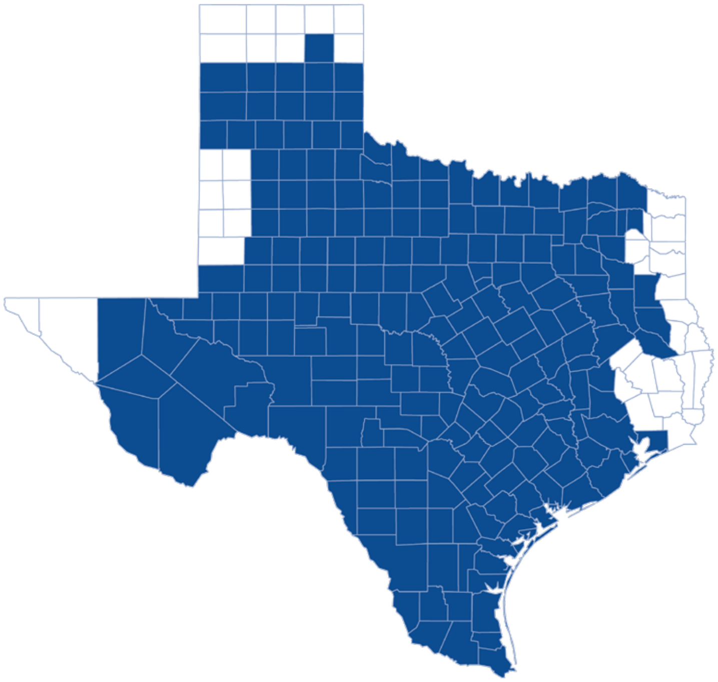
INTRODUCTION

Electricity is essential in our daily lives for the health and safety of our communities. As part of its mission, Texas Reliability Entity, Inc. (Texas RE) periodically assesses and reports on the reliability and adequacy of the Bulk Power System (BPS) within the Texas Interconnection (also known as the Electric Reliability Council of Texas [ERCOT] Interconnection). The Assessment of Reliability Performance annually compiles analyses for the previous year and this document is the 2024 report of that analysis.

The goals of this report are to paint the overall BPS reliability picture with historical context, identify current and future risk areas, and prioritize them to promote actionable results for reliability improvement.

This report provides insight into areas where reliability goals can be more effectively achieved by addressing key measurable components of BPS reliability. Additionally, it aligns data and facts reported from multiple sources with full information transparency. This report provides insight into the current state of reliability in the Texas RE Region. Its purpose is to inform policy makers and other stakeholders, elevate identified risks to grid reliability, and prioritize focus areas for future outreach by Texas RE.



TEXAS RE'S MISSION

To assure efficient and effective reduction of risks to the reliability and security of the Bulk Power System within the ERCOT Interconnection.

DATA SOURCES

TADS
Transmission Availability Data System

GADS
Generation Availability Data System

DADS
Demand Response Availability Data System

MIDAS
Misoperation Information Data Analysis System

EVENT REPORTS
OE-417,
NERC EOP-004,
& NERC Events Analysis

Frequency Control Performance and Primary Frequency Response

ERCOT ISO Data and Reports

TEXAS RE
Ensuring electric reliability for Texans

EXECUTIVE SUMMARY

Electricity is the key driver of modern life and the foundation of our digital future. The North American BPS faces mounting resource adequacy challenges from surging demand growth to power our increasingly electrified economies combined with thermal generator retirements. The Texas RE/ERCOT Region (hereafter "Region") is at the forefront of these changes. The Region is forecasting unprecedented load growth that is primarily driven by the integration of large loads associated with new data centers and artificial intelligence (AI) services, as well as increased demand from the oil and gas sectors. ERCOT currently forecasts an additional 70.5 GW of new load could be interconnected to the system by 2028. While the full amount of forecasted load may not materialize, the sheer amount of new demand represents a significant challenge that will require a comprehensive and proactive response to ensure electricity continues reliably flowing to Texans. This report concludes that reserve margin issues associated with large load growth represent an actionable performance trend, and the disorganized integration of large loads constitutes the largest increased risk to the Region.

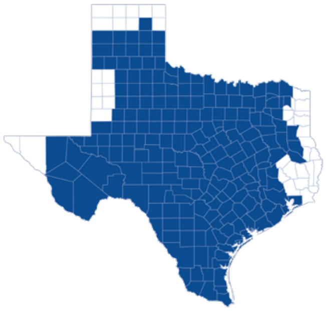
The generation necessary to meet this demand in the Region continues to evolve toward variable generation resources and energy storage, and away from dispatchable fossil-fueled machines. Over the past five years, the total energy from solar generation has increased 996 percent, while energy from coal resources has declined 25 percent. Variable energy resources (wind and solar) served 34.8 percent of total energy in the Region in 2024 and experienced a peak hourly penetration of nearly 75 percent in March. The total energy contribution from variable resources will likely increase in the near term. As of December 2024, ERCOT projects solar generation capacity to nearly double over the next two years. Similarly, storage capacity neared 10 GW in 2024 and is forecasted to almost triple to 27.5 GW during the next two years. The increasing dependence on variable, inverter-based resources (IBRs) has brought an array of efforts at the state and federal levels to ensure IBRs provide reliable and predictable performance. These efforts will be vital to support reliability in 2025 and beyond.

The Region's reliability performance remains strong while navigating these challenges. The Texas Interconnection demonstrates adequate reliability for normal operating conditions and when subjected to contingencies within planned parameters. The Region's resources managed extended high summer peak periods in 2024 (as in recent years), helped by new solar generation and energy storage. Annual energy production increased (alongside renewable generation output and peak renewable penetration levels) to meet projected peak loads. As a result, the Region did not experience any Energy Emergency Alerts related to insufficient responsive reserves in 2024.

Multiple extreme events have tested the grid's ability to maintain appropriate reliability and adequacy levels. The continued and coordinated efforts at both the state and federal levels to harden the grid, increase its resiliency, and respond to winterization challenges have reduced the overall likelihood of a major impact from winter storms. These efforts demonstrate the important progress that has been made, but continued vigilance is required. Extreme heat and cold events, drought, and storms will continue to test the resilience of the grid to withstand and recover from these events.

Reliability and security risks to the electric grid continue to grow. Throughout 2024, the work to address those challenges moved forward at an unprecedented pace. These collective efforts from industry and policymakers, state and federal regulators, and across critical infrastructure sectors is the backbone of maintaining the reliable electric service expected by Texans.

TEXAS INTERCONNECTION AT A GLANCE



BY THE NUMBERS

REGISTERED ENTITIES	367
Distribution Providers	36
Generator Owners	286
Generator Operators	208
Transmission Owners	28
Transmission Operators	21
Transmission Planners	26

Generating Units	> 1,250
Miles of Transmission	> 54,100
Population Served	> 27 Million
Percentage of Texas Load	90%
MW Peak Demand	85,508
Renewable Penetration Record	75.0%

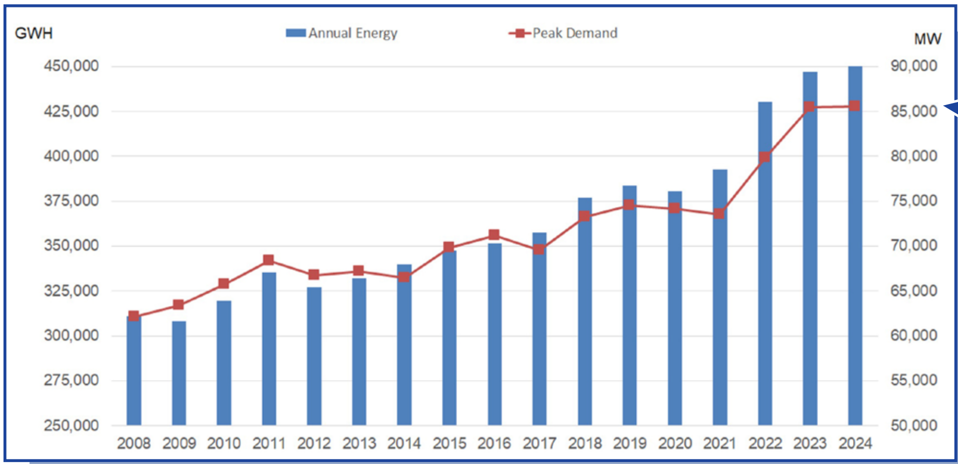
CAPACITY AND GENERATION — FIVE YEAR CHANGE

FUEL SOURCE	2019 (MW)	2024 (MW)	% Change	2019 (MWH)	2024 (MWH)	% Change
Coal	15,065	14,713	- 2%	77,857	58,317	- 25%
Natural Gas	52,329	67,059	+ 28%	181,770	204,389	+ 12%
Wind	28,373	38,911	+ 37%	76,708	111,744	+ 46%
Solar	3,738	27,157	+ 627%	4,398	48,222	+ 996%
Hydro	553	583	+ 5%	956	461	- 52%
Nuclear	4,973	5,268	+ 6%	41,314	38,733	- 6%
Storage	363	9,863	+ 2,617%	-	- 2,814	-
Other	169	172	+ 2%	1,056	2,525	+ 139%

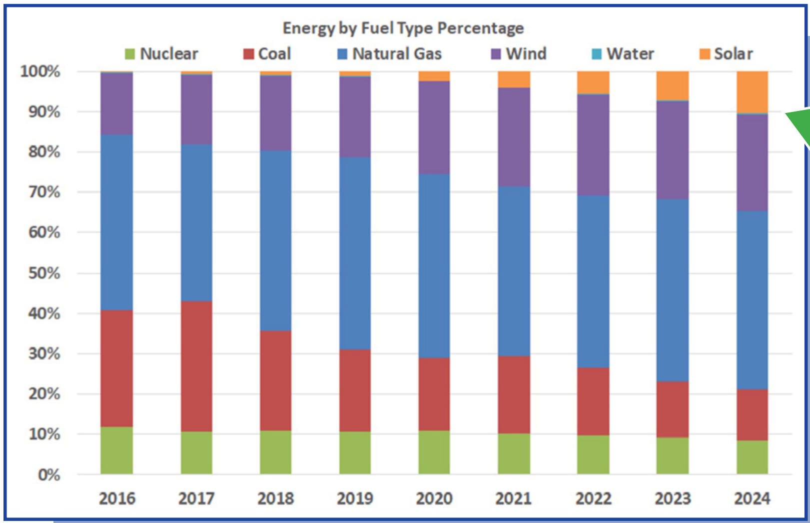
TRANSMISSION — FIVE YEAR CHANGE (BASED ON TADS DATA)

VOLTAGE	2019 (Circuit Miles)	2024 (Circuit Miles)	% Change
345 kV	17,358	21,448	+ 24%
138 kV	25,895	29,898	+ 15%

DEMAND AND ENERGY
2024 AT A GLANCE

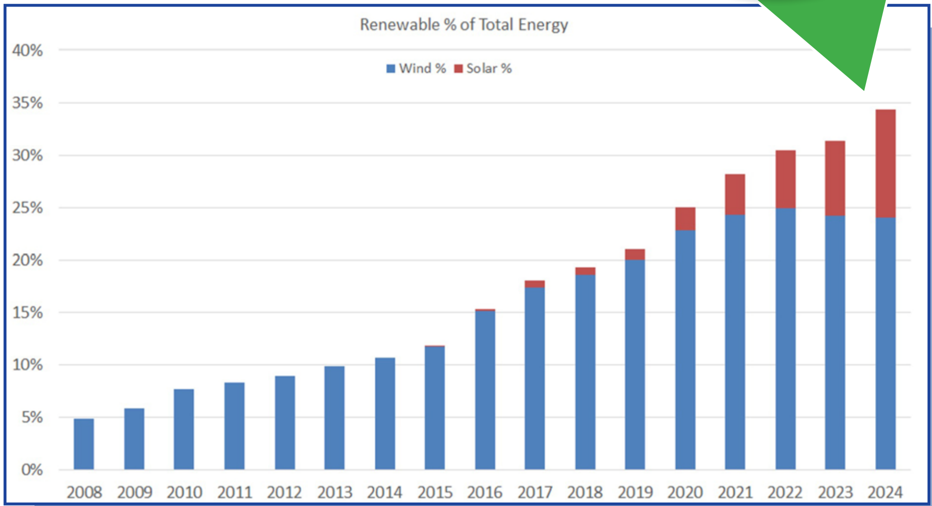


SUMMER PEAK DEMAND:
85,245 MW
on 8/20/2024



PEAK HOURLY RENEWABLE GENETRATION:
38,497 on
7/31/2024

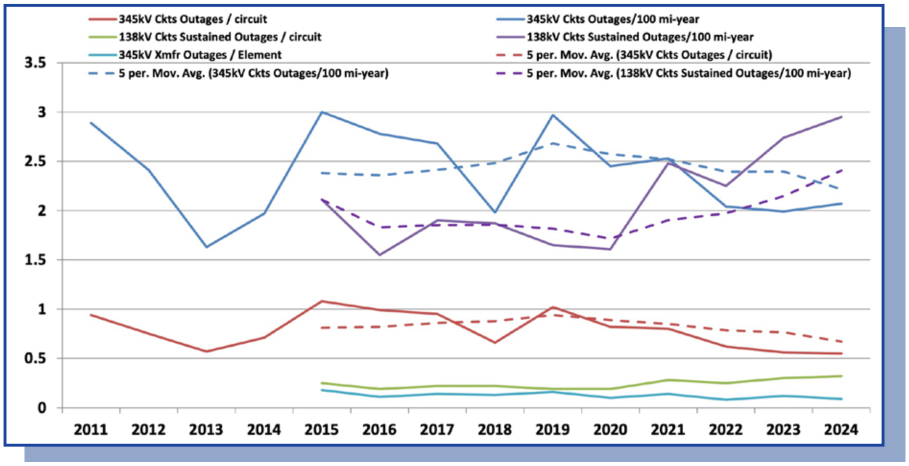
RENEWABLE ENERGY SERVED:
34.8% of total
energy in 2024



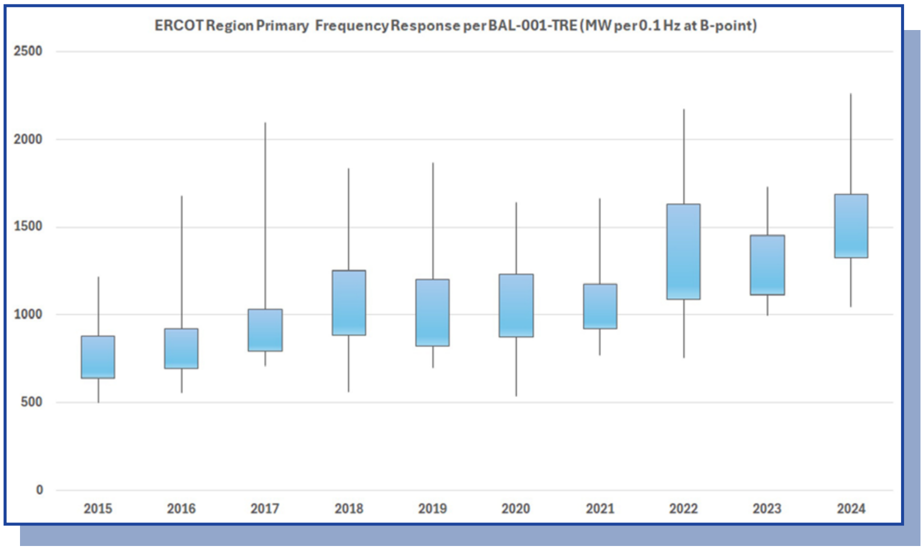
PEAK HOURLY RENEWABLE PENERATION:
74.97% on
3/29/2024

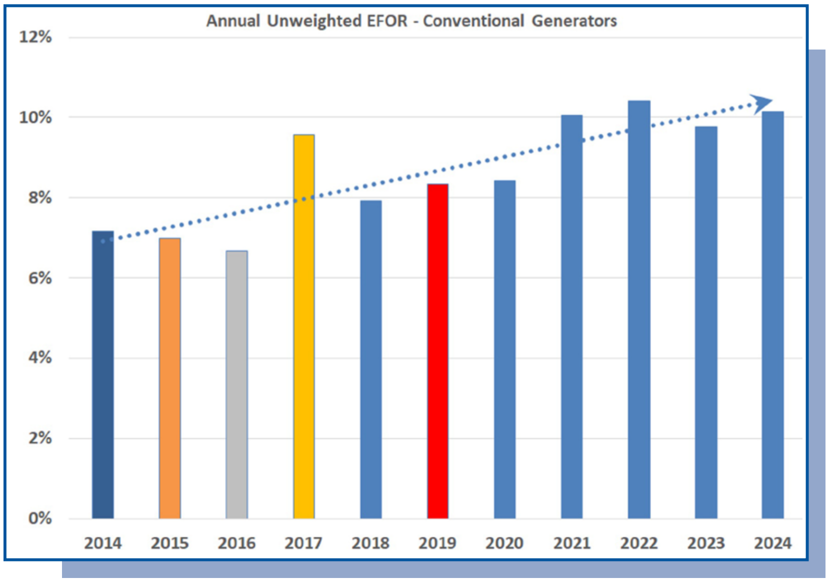
RELIABILITY

2024 AT A GLANCE

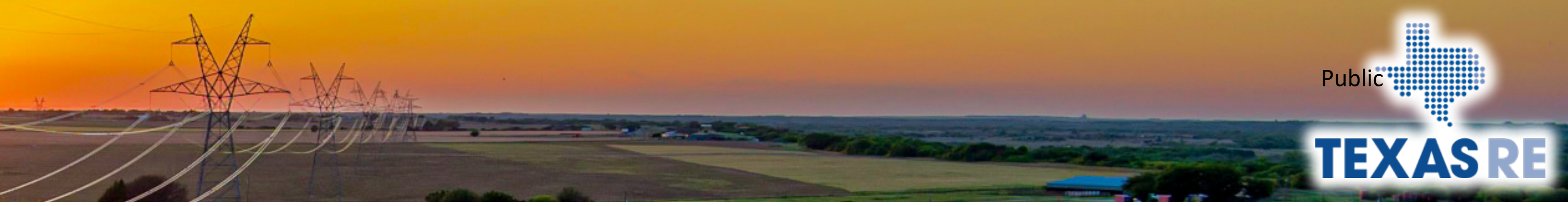


PRIMARY FREQUENCY RESPONSE:
1,552 MW/0.1Hz for for 2024 vs. NERC Obligation of 395 MW/0.1Hz





	2024	2023
CONTROL PERFORMANCE STANDARD 1 (CPS1)	175.5	175.2
TADS 345kV CIRCUIT AUTOMATIC OUTAGE RATE PER 100 MILES	2.07	2.00
PROTECTION SYSTEM MISOPERATION RATE	4.3%	4.6%
GENERATION AVAILABILITY DATA SYSTEM (GADS) EQUIVALENT FORCED OUTAGE RATE (EFOR) UNWEIGHTEED	10.1%	9.8%



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Texas RE continuously evaluates existing and emerging risks to the Texas Interconnection in developing its risk-based programs. Based on the review of significant risks in 2024, Texas RE again focused on risk mitigation activities in three key reliability areas:

- Grid transformation and IBR performance
- Extreme events resiliency and winterization
- Cyber and physical security

GRID TRANSFORMATION

In 2024, Texas RE supported activities to reduce risks for IBR performance and study the interregional transfer capability with prudent additions to address resource deficiencies. Texas RE also monitored numerous state-level activities to address resource adequacy issues, the changing resource mix, transmission needs, and the risks associated with large loads.

ONGOING EFFORTS TO REDUCE RISKS FROM INVERTER-BASED RESOURCES

The May/June 2021 and June 2022 Odessa disturbance events and the subsequent publication of joint reports from Texas RE, North American Electric Reliability Corporation (NERC), and ERCOT staff represented a key turning point in the understanding of (and efforts to mitigate) operational risks from inverter-based resources. This touched off a wave of activities at the state and national levels (rooted in the specific recommendations from the reports) that focused on mitigating risks from IBR resource ride-through and modeling accuracy, among others. The recommendations also informed Texas RE's outreach activities over the past several years.

At the federal level, the NERC standards process mandated by Federal Energy Regulatory Commission (FERC) Order 901 has progressed at a blistering pace. This order directed NERC to develop new or modified Reliability Standards that address reliability gaps related to IBRs in the following areas: data sharing; model validation; planning and operational studies; and performance requirements. In 2024, NERC filed new IBR standards for disturbance monitoring (PRC-028-1), IBR frequency and voltage ride-through requirements (PRC-029-1), and unexpected IBR event mitigation (PRC-030-1). Standards development efforts will continue into 2025 on verification of IBR models (MOD-026), IBR modeling framework (TOP-003, MOD-032, and IRO-010), and IBR system model validation (MOD-033).

At the state level, ERCOT has taken great strides to reduce the risk posed by IBR disturbances. In 2023, ERCOT proposed Nodal Operating Guide Revision Requests (NOGRR) 245 and 255 to adopt more stringent ride-through requirements as well as data recording and monitoring

2024 IN REVIEW

requirements for IBRs. Texas RE submitted comments in favor of ERCOT's proposal to adopt frequency and voltage ride-through requirements for IBRs, as well as presented information to the ERCOT Technical Advisory Committee (TAC) in May 2024 on the Odessa events and federal standards development process. NOGRR 255 was approved in July and NOGRR 245 in September. ERCOT further approved changes to its planning guides to establish new requirements for dynamic modeling of IBRs.

While the efforts to reduce risks from IBRs evolved and expanded in 2024, smaller scale system disturbances continued. ERCOT identified seven disturbances associated with IBR ride-through issues in 2024, highlighting the fact that the risks still remain. The purpose of the alert was to gather information from Bulk Electric System (BES)-connected IBRs to understand the extent of condition of IBR dynamic modeling to inform mitigations for observed deficiencies. The data collection effort included responses from over 1,600 generation facilities, seventeen different inverter manufacturers, and over 185,000 MW of IBR capacity (wind, solar, and battery storage). Within the Region, data was collected from over 375 generation facilities and over 53,000 MW of wind, solar, and battery storage capacity. Like the previous Level 2 alert, feedback from industry (Generator Owners (GOs), consultants, original equipment manufacturers (OEMs), etc.) indicated that GOs are reliant upon OEMs and consultants to keep the requested data and information up-to-date.

Date	Description	Facility	Pre-Disturbance MW	Post-Disturbance MW	MW Loss	Turbines or Inverters Tripped
1/16/2024	South Wind, A-C fault, 3 cycle clearing	Six Facilities	776	657	119	15
3/5/2024	West Tx Solar, B-C fault, 3.5 cycle clearing	Four Facilities	585	331	254	20
5/22/2024	Temple tornado, 3 phase fault, Multiple faults	One Facility	75	0	75	35
5/23/2024	Coastal Wind, A-G fault, 3 cycle clearing	Five Facilities	711	602	109	40
6/2/2024	Panhandle Wind, C-G fault, 3 cycle clearing	Three Facilities	648	536	112	30
7/24/2024	Coastal Wind, C-G fault, 3 cycle clearing	One Facility	27	6	21	34
9/21/2024	Panhandle Wind, B-G fault, 3 cycle clearing	Three Facilities	559	88	471	198

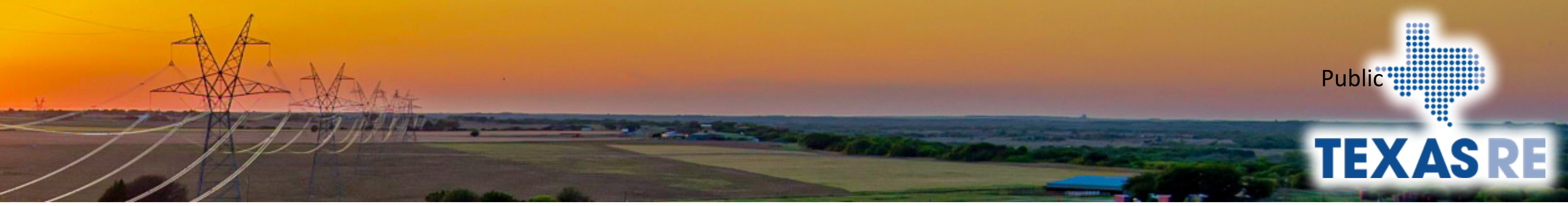
Western Electricity Coordinating Council (WECC) also documented four large IBR disturbances in 2024 that met the NERC Event Analysis criteria, with the largest being a loss of 1,046 MW. Each of these events were associated with a normally cleared transmission fault.

In June 2024, NERC issued a Level 2 Alert on Inverter-Based Resource Model Quality Deficiencies. The

Further, multiple major GOs expressed that obtaining fundamental site information (such as basic plant controller settings) was difficult and time-consuming.

Other key findings from the Level 2 Alert included:

1. Many GOs indicated that they did not have the requested data readily available. This hampers future NERC event analyses and raises questions

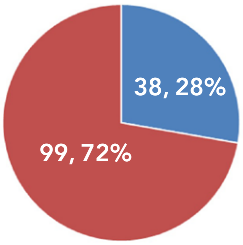


on the quality of the data submitted by GOs for study in the planning processes. This supports the findings from the previous Level 2 Alert: Inverter-Based Resource Performance Issues and indicates knowledge on how IBR plants operate on the BPS and a failure to improve data acquisition and management processes.

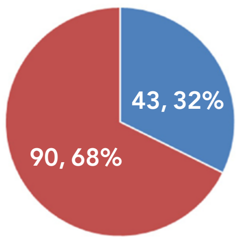
2. The systemic deficiencies observed in this alert analysis indicate that the interconnection process requirements are insufficient. Enhancing requirements and study procedures (to be recommended in an upcoming level 3 alert) could significantly mitigate these deficiencies.
3. Approximately two-thirds (66 percent) of the protection settings used by the respondent GOs are not set to provide the maximum capability of the inverters. This creates a significant artificial limitation of overall ride-through capability of BPS-connected solar photovoltaic (PV) facilities.
4. Approximately 20 percent of the facilities use a "triangle" (0.95 power factor (PF) limit) facility capability, meaning a significant amount of underused reactive capability exists on the BPS.
5. Inconsistency in dynamic model data has been observed across different sources. GOs reported as-left settings and modeling data, and submitted dynamic model data files (e.g., .dyd and .dyr files), and dynamic model data from interconnection-wide cases. Transmission Planners (TPs) and Planning Coordinators (PCs) can address the inconsistency by enhancing requirements and quality-check processes for existing and new models.

Another significant issue noted in the responses was that as-left control settings in the field did not match model parameter settings. This is reflected in the data below for the units in the Region.

High Voltage Threshold Settings Model vs Reported	# of Facilities	%
As-left control setting matches model parameter	38	28%
As-left control setting does not match model parameter	99	72%
Total	137	100%



Low Voltage Threshold Settings Model vs Reported	# of Facilities	%
As-left control setting matches model parameter	43	32%
As-left control setting does not match model parameter	90	68%
Total	133	100%



As-left control setting matches model parameter

As-left control setting does not match model parameter

NERC INTERREGIONAL TRANSFER CAPABILITY STUDY (ITCS)

Congress directed NERC to conduct the Interregional Transfer Capability Study (ITCS) in the Fiscal Responsibility Act of 2023. The study was performed in collaboration with NERC's six Regional Entities, transmitting utilities across North America, and interested stakeholders. The ITCS identified locations between neighboring transmission planning regions where enhanced transfer capability would strengthen grid reliability. The study also concluded that transmission upgrades alone will not fully address all risks for energy deficiencies in a Transmission Planning Region. A broader set of solutions should be considered, emphasizing the need for local resources, energy efficiency, demand-side management, and storage solutions. A diverse and flexible approach enables tailored solutions specific to each region's vulnerabilities, risk tolerance, economics, and policies.

[1]*FERC Order No. 901: Final Rule; Reliability Standards to Address Inverter-Based Resources under RM22-12 (Oct. 19, 2023) ("FERC Order No. 901").*

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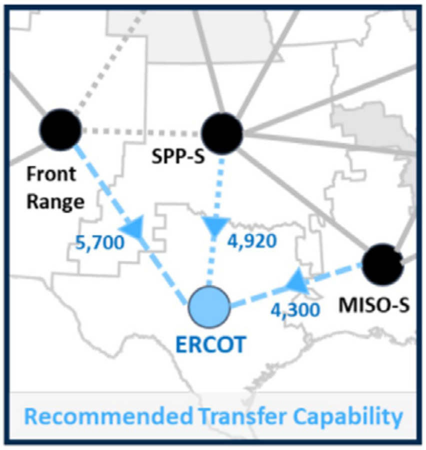
The study did not address economic, siting, political, or environmental impacts. The final document was filed with FERC on November 19, 2024.

For the Texas Interconnection, the study identified the need for an additional 14,100 MW of transfer capability to resolve potential energy deficiencies during extreme weather conditions. This particularly reflected the extreme shortfall conditions that occurred during Winter Storm Uri in 2021.

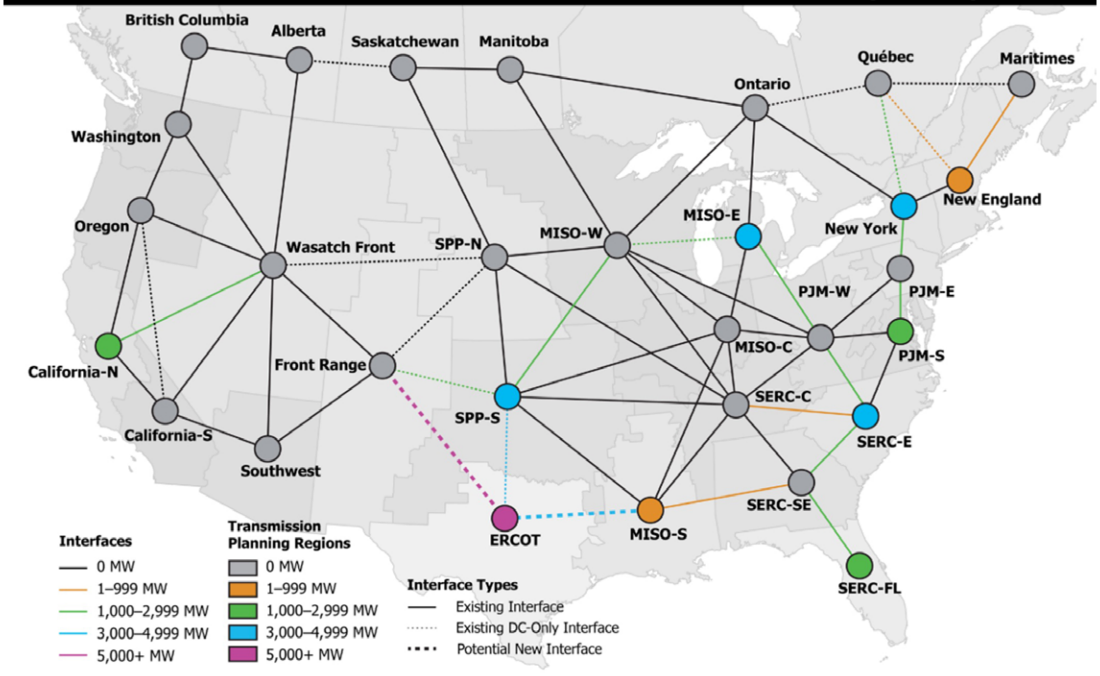
The other key findings of the study were:

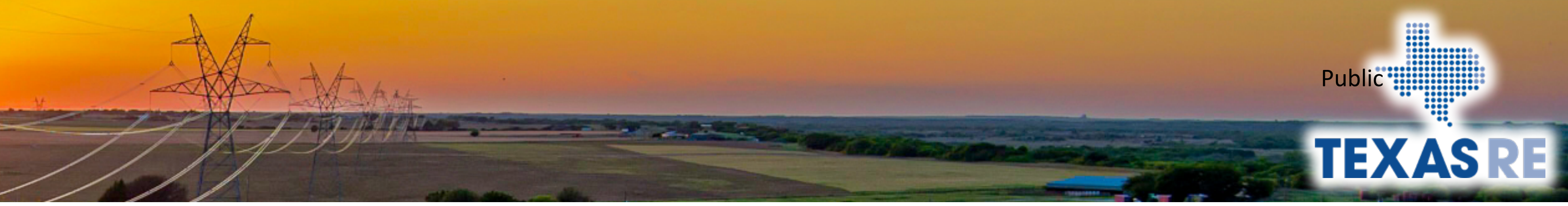
- Energy deficiencies were identified in ERCOT for seven of the 12 weather years studied.
- Import capability needed during extreme conditions varied significantly across the country—there is no one-size-fits-all answer.
- An additional 35 gigawatts of transfer capability across the United States was identified as being beneficial for addressing energy deficits.
- There are numerous barriers to realizing the benefits of interregional transmission in a timely manner.
- Some identified transmission needs could be alleviated by projects already in the planning, permitting, or construction phases.
- Higher than expected generation retirements (without replacement capacity) would lead to increased energy deficiencies and potentially more transfer capability needed than recommended in this study.
- Transmission upgrades alone may not fully address all risks and a broader set of solutions should be considered, balancing the opportunity for local resources, demand-side management, and storage solutions.



It is important to note that the ITCS focused exclusively on addressing reliability issues through interregional transfers. However, the potential reliability challenges posed by extreme weather conditions could also be addressed through intraregional transmission projects (including projects already in the planning, permitting, and construction phases) and through the addition of new generation within the Texas Interconnection. To that end,

Prudent additions are based on 2033 resource mix and other study assumptions





a number of important initiatives are underway at the state level such as the Permian Basin transmission study and Texas Energy Fund projects highlighted below that are focused on addressing the resource adequacy issues identified in the ITCS. Texas RE will continue to monitor these efforts to bolster the interconnection's overall reliability.

TEXAS ENERGY FUND PROJECTS

The Texas Energy Fund (TEF) was created by the Texas Legislature through Senate Bill 2627 (the Powering Texas Forward Act) to provide grants and loans financing the construction, maintenance, modernization, and operation of electric facilities in Texas with a focus on incentivizing new dispatchable resources. The In-ERCOT Generation Loan Program application period closed on July 27, 2024. The Public Utility Commission of Texas (PUCT) advanced a recommended portfolio of 9,781 MW of potential new dispatchable generation at the August 29, 2024, Open Meeting.

PUBLIC UTILITY COMMISSION RELIABILITY STANDARD

In August 2024, the PUCT adopted a reliability standard for the ERCOT Region. The requirements of the standard were based on language from Senate Bill 3. To remain in compliance with the rule, the ERCOT Region must meet three criteria:

- A grid outage resulting from inadequate power supply to meet demand must be expected to occur no more than once per ten years on average.
- A potential grid outage resulting from inadequate power supply to meet demand must be expected to last less than 12 hours.
- The amount of electricity lost during any hour of a potential outage resulting from inadequate power supply to meet demand must be expected to be less than the amount of electricity that can be safely rotated during an outage.

The final rule also establishes the process beginning in January 2026 for ERCOT to conduct a probability-based assessment every three years. It will determine whether the power system is meeting the reliability standard and is expected to continue meeting the standard for the next three years. If ERCOT determines that the system fails to meet the reliability standard, it must include in its report to the Commission recommended changes to the ERCOT market design that could address the deficiency and outline the potential cost of those changes.

IMPROVEMENTS IN PRIMARY FREQUENCY RESPONSE FROM BATTERY STORAGE INTEGRATION

The growth in battery resources has exploded from 1,300 MW at the end of 2021 to over 10,000 MW at the end of 2024. Over that same period, battery resources have taken over the ERCOT ancillary services market, pushing out gas and coal units that have traditionally supplied these services. Batteries are particularly well-suited to provide ancillary service products that require a fast response time quicker than baseload generators can.

In 2023 and 2024, the inherent capability of battery resources began to manifest itself into noticeable improvements in primary frequency response. The last two years have seen marked improvements in datapoints such as the trending over time of frequency responsive headroom, nadir frequency points during generation unit trips, and interconnection level droop response. Time trend analyses show that total frequency responsive headroom is increasing year-over-year. Simultaneously, frequency responsive headroom on thermal generation is decreasing, with batteries making up the gap. Time trends also show that nadir frequencies are improving (i.e., getting higher) over time for the same size unit trips versus historical data. This means that the system

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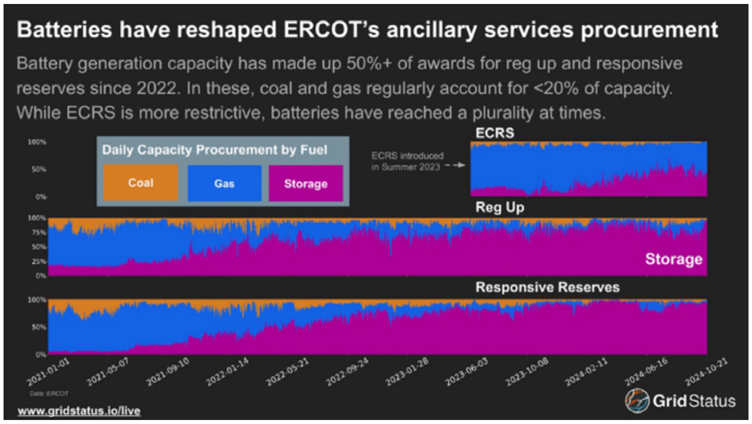
frequency decay during sudden generation unit trips is being arrested faster and at a higher frequency than in previous years—primarily due to the fast response time from battery resources.



EXTREME EVENTS RESILIENCY & WINTERIZATION

Texas RE monitors and prioritizes risk mitigation activities addressing extreme events resiliency and generator winter readiness. Texas RE supported implementation of the new federal winterization standards (EOP-012), conducted outreach with affected entities, and initiated a new winterization site visit program. The thermal generation fleet in the Texas Interconnection performed well during Winter Storm Heather in January 2024, continuing the positive results from the sustained focus on winterization at the state and national levels.

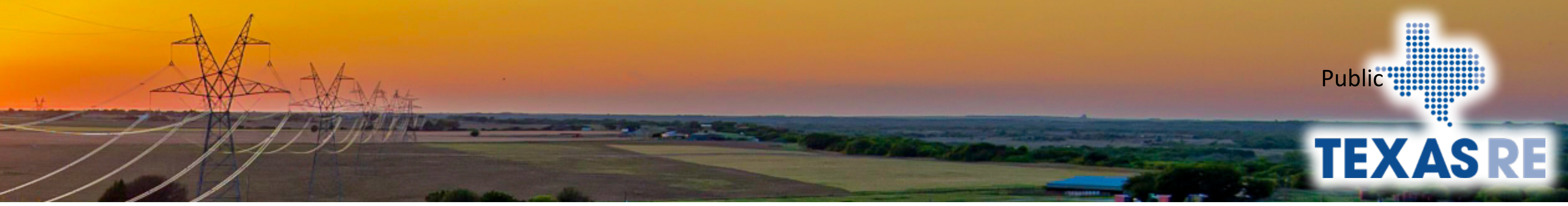
The Texas Interconnection experienced multiple extreme weather events in 2024. While these events did not significantly affect the BPS (demonstrating improved generator performance), they did impact local distribution systems, particularly in the Houston area.

Key events included:

JANUARY 13-16, 2024, WINTER STORM HEATHER

Winter Storm Heather originated as an extratropical cyclone over the northeastern Pacific Ocean on January 12, moving ashore the following day. Widespread, significant, and deadly impacts were observed from coast to coast in the U.S. as areas that normally don't receive frozen precipitation were affected adversely. Prior to the arrival of the winter storm, Texas state officials assured residents that the power grid was fully prepared to cope with the weather. Public appeals were issued for energy conservation, Operating Condition Notices (OCN) and advisories were issued for extreme cold weather, and one emergency notice was issued for frozen precipitation impacting generation resources in the San Angelo area. A new all-time winter peak demand record of 78,314 MW was set on January 16, 2024, at the hour ending 0800.

The thermal generation fleet performed well, demonstrating the benefits of the focus on implementing weatherization mitigation measures and requirements the past several years. Outages were lower than the projected seasonal average for the thermal fleet. Approximately 3,000 MW of incremental forced outages and derates occurred during Heather.



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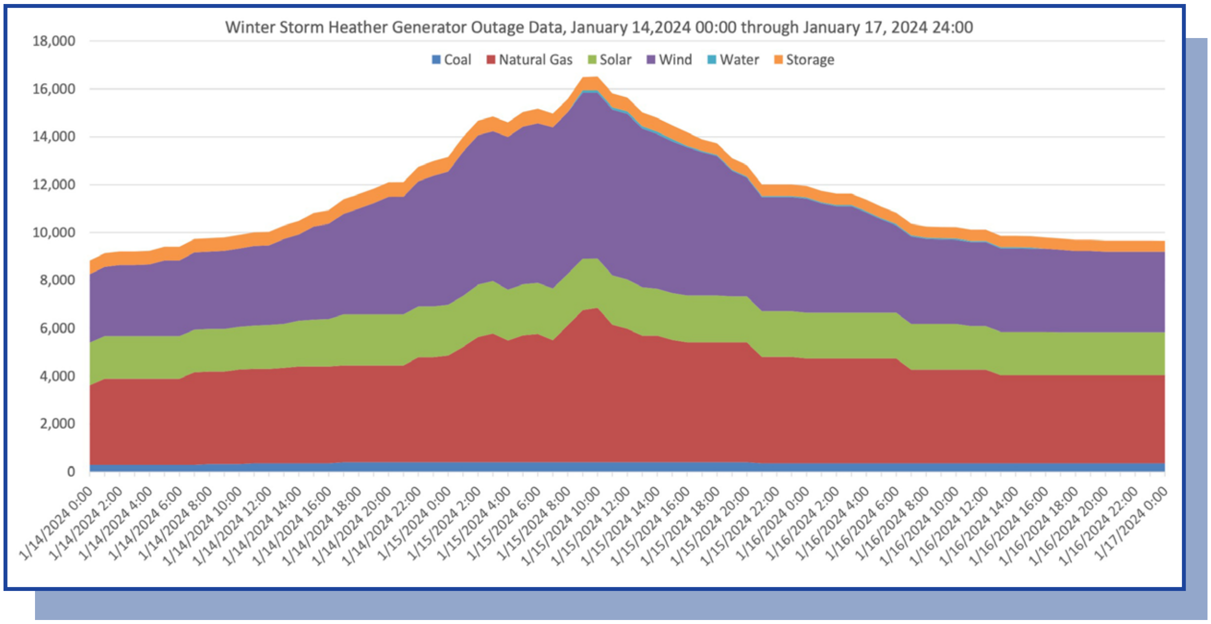
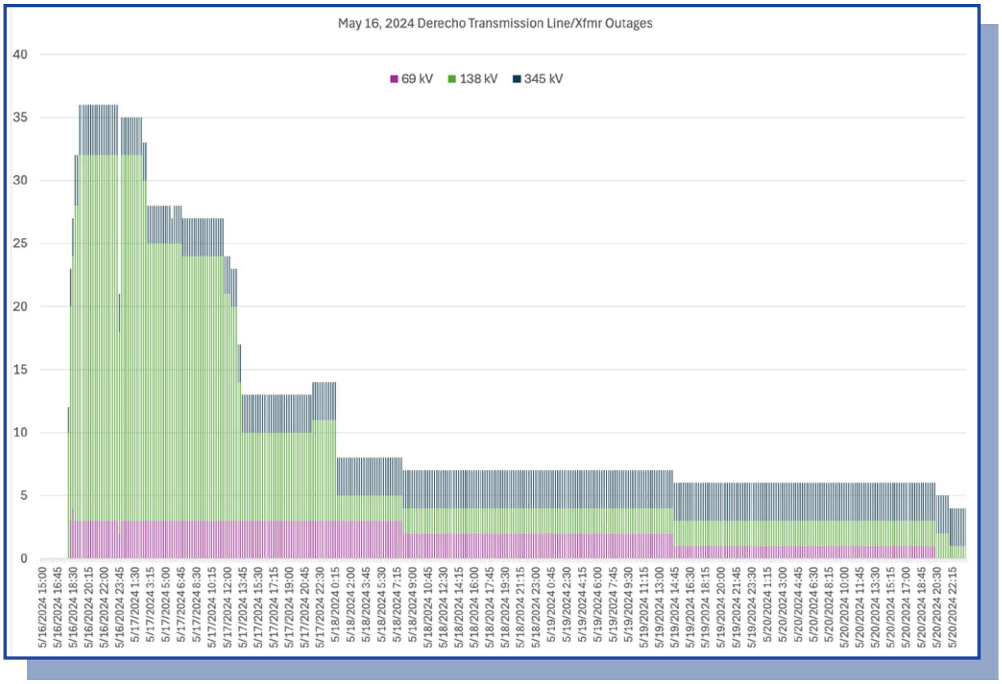
The overall level of forced outages for thermal resources was in the range of 7,000 MW, which included approximately 4,000 MW in forced outages prior to Heather. This is in comparison to approximately 14,000 MW of forced outages for the thermal fleet during 2022's Winter Storm Elliott. The system also experienced gas curtailments and restrictions in North Texas during Winter Storm Heather, with an approximate net loss of 1,700 MW in available generation capacity.



MAY 16-17, 2024, HOUSTON DERECHO

From the evening of May 16, 2024, to midday May 17, 2024, a derecho[1] struck the U. S. from Southeast Texas to Florida and caused widespread damage, particularly in the Houston metropolitan area. The storm produced wind gusts of up to 100 mph in Downtown Houston (the windows of many high-rise buildings were blown out and the wall of a brick building collapsed) and was the most damaging wind event to affect Houston in 25 years. The derecho also caused extensive damage to transmission towers and lines. More than a million customers lost power in the greater Houston area and nearby counties as a result of the high winds.



[1] *Derecho defined as "a large fast-moving complex of thunderstorms with powerful straight-line winds that cause widespread destruction."*

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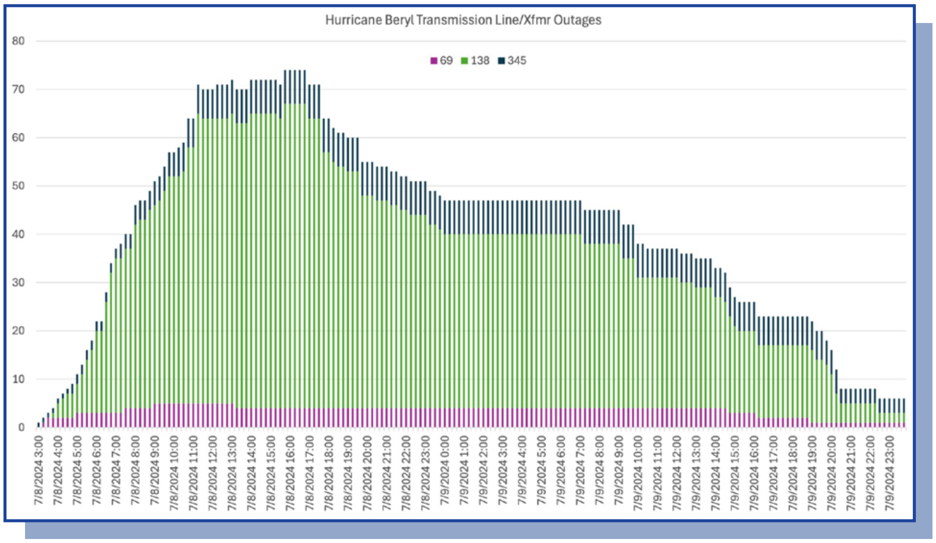
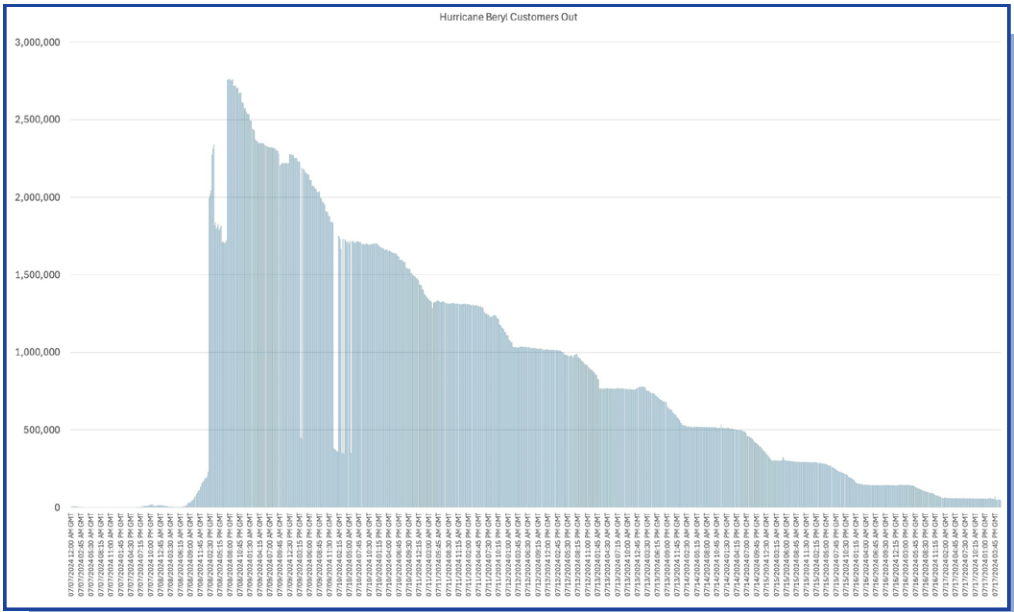
JULY 8-10, 2024, HURRICANE BERYL

On July 8, 2024, Hurricane Beryl made landfall near Matagorda, Texas, with the east side of the eyewall impacting Brazoria County. It produced wind gusts over 60–70 mph with a peak gust of 97 mph in



Brazoria. Houston was directly impacted by Beryl's eyewall with 2.7 million households and businesses losing power. At least ten transmission towers were knocked down and many distribution lines were damaged. Over eight inches of rain fell



in and around Houston, with a peak rainfall amount for the state west-southwest of the city at 13.55 inches. There were 16 confirmed tornadoes in Texas and the state issued severe weather disaster declarations for 121 of its 254 counties.

2024 IN REVIEW

CYBER & PHYSICAL SECURITY

Operational security remains an essential foundation for a highly reliable and secure electric grid. Global conflicts threaten BPS cybersecurity and domestic terrorists aim to disrupt normal operations of the grid. In 2024, BPS facilities in the Region experienced minimal impact from cyber and physical security events. Nevertheless, the electric industry faces an unprecedented number of threats including direct attack vectors and supply chain vulnerabilities.

Across North America, there is also a noticeable trend with low impact BES Cyber Systems (BCS). Entities have struggled with the implementation of their security programs, particularly in connection with remote access controls. As noted in the **2024 CIP Themes and Lessons Learned Report**, a compromise of such assets could create localized issues. An individual low impact asset could (a) serve as a channel to attack other assets or (b) be used to conduct reconnaissance. The potential risk to the BES multiplies in scenarios where several low impact assets are compromised in a coordinated attack. Given the significant growth of low-impact assets (which are often associated with new, dispersed generation facilities), Texas RE is increasingly emphasizing sound cyber and physical security practices at these facilities as part of its compliance and outreach efforts.

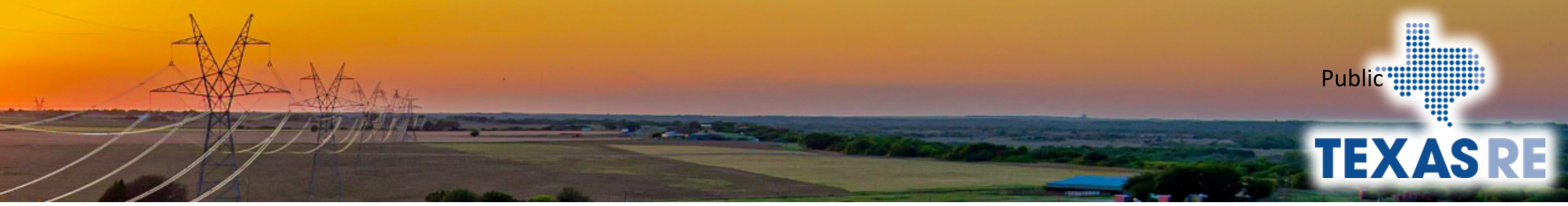
Remote access risks continue to be further magnified by the increasing use of dispersed management systems, including third-party owned Control Centers that monitor and control dispersed generation resources. The reliance on third parties to perform backup Control Center (or even routine maintenance) activities could pose risks if not properly implemented or understood. Similarly, the shift from on-premises client/server business models to cloud-based off-premises solutions further emphasizes the need for appropriate cyber and physical security controls implementation. Finally, supply chain concerns and the challenges of identifying and securing increasingly complex device components represent continued reliability and security issues.

The increased penetration of artificial intelligence (AI) in the electric utility industry, while promising, demands robust mitigation strategies for risks including: cybersecurity vulnerabilities, data privacy, algorithmic errors, and potential for misuse. This is why Texas RE has added "Artificial Intelligence" as a new risk element for 2025, is focused on identifying sound security practices, and shares these recommendations with stakeholders.

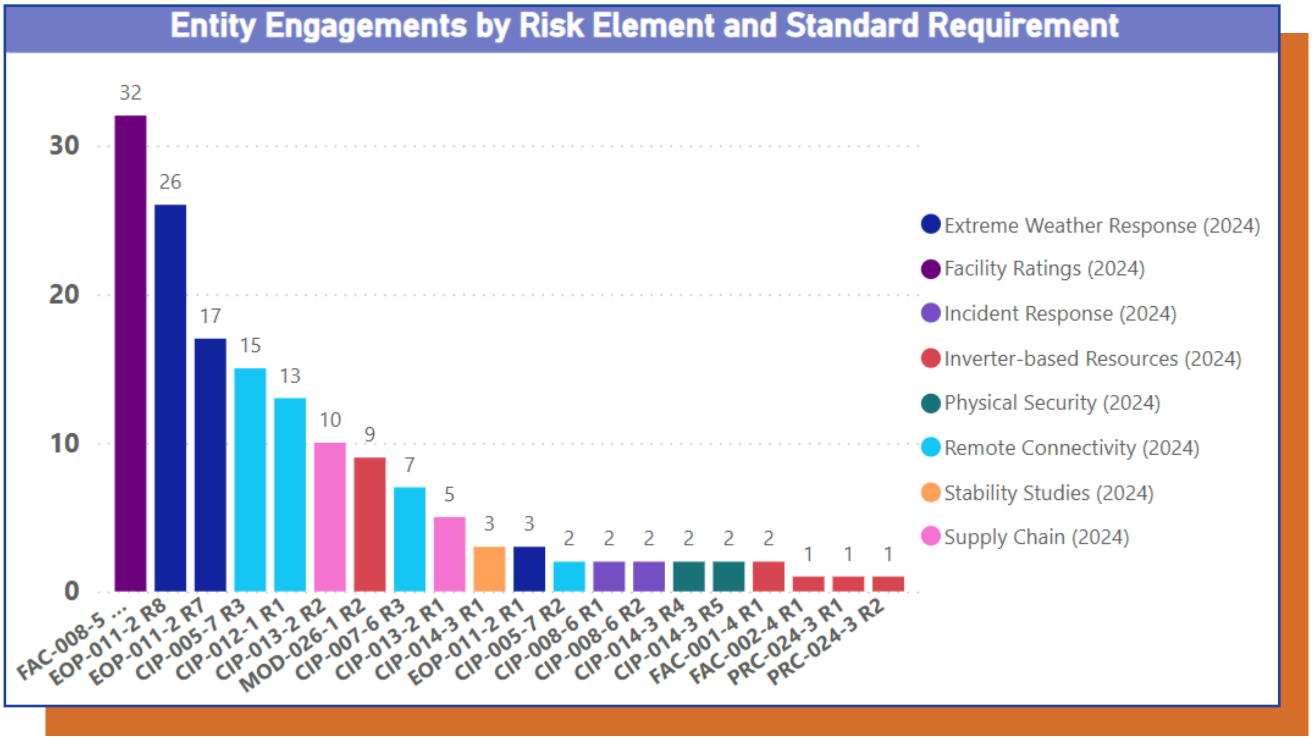
TEXAS RE'S 2024 RISK MITIGATION HIGHLIGHTS

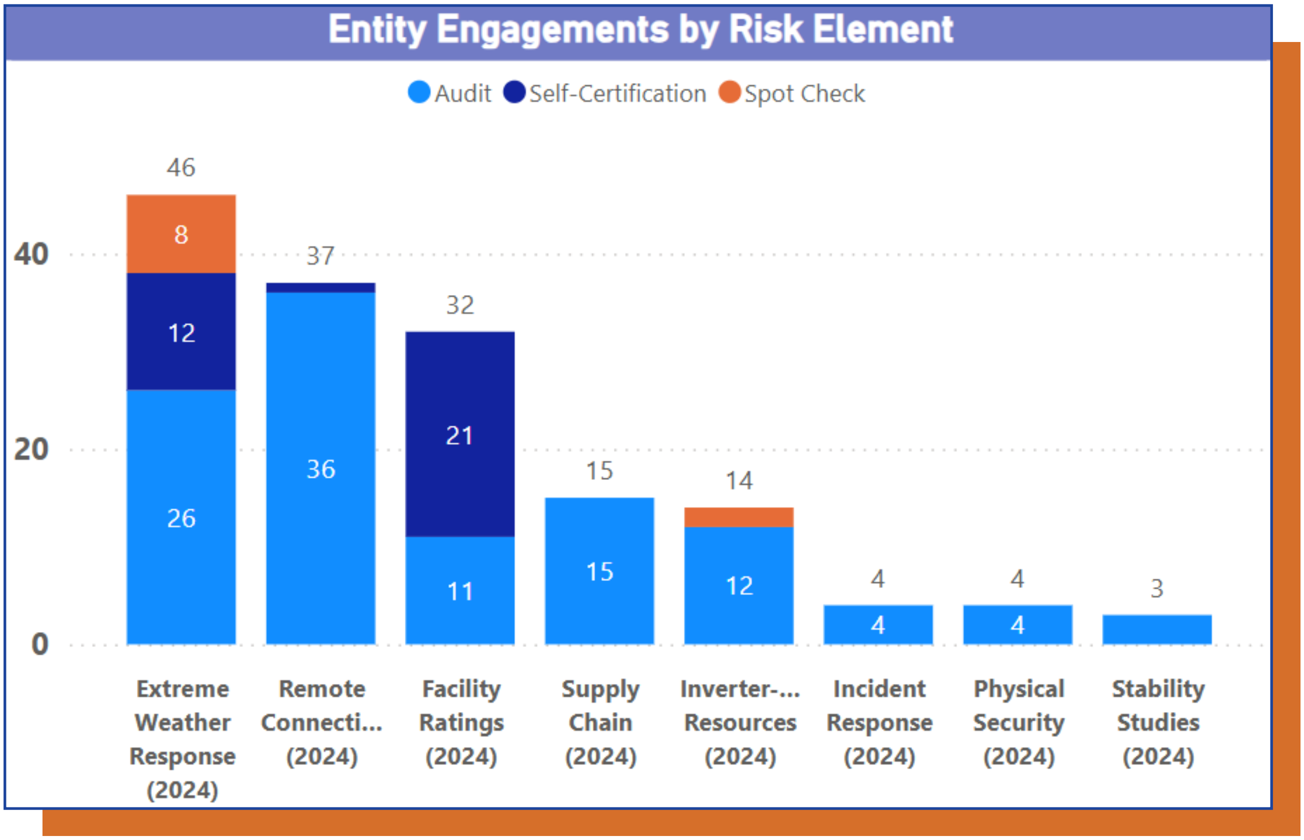
Texas RE identified multiple risk focus areas to prioritize the mitigation of risks across its reliability and compliance programs. The table below summarizes some of Texas RE's key 2024 activities related to these risk focus areas.

FOCUS AREA	OUTREACH HIGHLIGHTS	ENGAGEMENTS
Extreme Weather & Resource Weatherization	• January 2024 Talk with Texas RE on FERC Blackstart Report • October 2024 Texas RE workshop on winter weatherization	• Engaged 46 entities on the cold weather Reliability Standards, including site visits and walk downs.
IBR Ride-through	• January 2024 comments in support of ERCOT's proposed NOGRR245 • March 2024 Talk with Texas RE on State initiatives related to inverter-based resources • May 2024 Talk with Texas RE on IBR registration • May 2024 presentation at the ERCOT TAC meeting on IBR ride-through events and initiatives at the federal level • July 2024 Talk with Texas RE on challenges presented by integration of IBRs • August 2024 Talk with Texas RE on IBR data collection and reports	• Engaged 14 entities that included modeling Standards and IBRs.
Physical Security, Remote Access, & Supply Chain	• February 2024 Talk with Texas RE on Cyber Security Incident Response Plans • March 2024 Talk with Texas RE on GridEx VII report • April 2024 Talk with Texas RE on the MOVEit vulnerability • June 2024 Talk with Texas RE on supply chain management • July 2024 Talk with Texas RE on current cybersecurity threats • July 2024 Talk with Texas RE on zero trust architecture • August 2024 Texas RE Cyber and Physical Security Workshop • September 2024 Talk with Texas RE on the PUCT Cyber Outreach Program • September 2024 Talk with Texas RE on renewable supply chain management • November 2024 Talk with Texas RE on remote connectivity	• Engaged 37 entities that included requirements associated with remote connectivity. • Engaged 15 entities that included a supply chain area of focus. • Engaged four entities that included a physical security focus.
Provision of Essential Reliability Services from a Changing Resource Mix	• May 2024 Talk with Texas RE on new generator registration requirements • October 2024 presentation at Texas RE's New Generator Workshop on understanding generator obligations • November 2024 NERC webinar on Inverter-Based Resource registration and performance	• Engaged 14 entities that included modeling Standards and IBRs.
Energy Availability	• January 2024 Talk with Texas RE on NERC reliability assessments • May 2024 Talk with Texas RE on the summer outlook • October 2024 Talk with Texas RE on electric and natural gas coordination • NERC/ERO program initiated to conduct annual independent energy availability probabilistic studies	• N/A
Gas Supply Restrictions During Cold Weather	• April 2024 Talk with Texas RE on the Natural Gas & Power Industry Reliability Alliance • Texas RE's 2024 Winter Weatherization workshop including updates on developments at the Railroad Commission in connection with natural gas facility winterization requirements	• N/A
Inaccurate Resource Modeling	• NERC Alert published in IBR model quality issues • Texas RE provided outreach on the Alert to ERCOT stakeholders in early 2025	• Engaged 14 entities that included modeling Standards and IBRs.
Facility Ratings	• August 2024 presentation to NSRF on the Texas RE facility walk down process, best practices and lessons learned • Two October 2024 presentations at Texas RE's New Generator Workshop on facility rating internal controls and best practices • November 2024 presentation at Texas RE's Fall Workshop on common and high-risk violations	• Engaged 32 entities that included modeling Standards and IBRs.
Integration of Large Flexible Loads	• NERC Large Load Task Force initiated	• N/A



TEXAS RE'S 2024 RISK MITIGATION HIGHLIGHTS





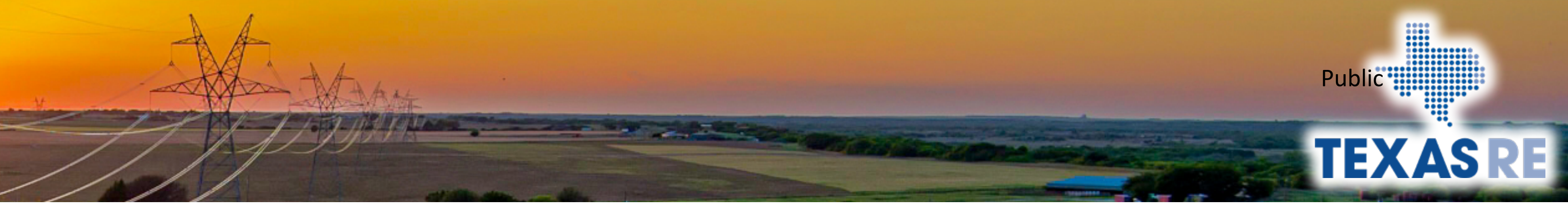
Public

2024 PERFORMANCE METRICS

Texas RE utilizes key performance indicators to evaluate how effectively the Region is meeting targeted electric reliability objectives. The table below describes these indicators, how they are measured, the target values, and an assessment of the state of each.

IMPROVING	STABLE OR NO CHANGE	MONITORING	ACTIONABLE
Improving trend compared to previous four years or improved event performance of observed conditions.	Minimal or no change compared to previous four years.	Declining trend compared to previous four years or specific negative event performance issues.	Declining trend for two or more consecutive years or significant negative event performance.

Key Performance Indicator with Description	2024 Performance & Trend Results
Resource Adequacy Measures potential resource adequacy issues by analysis of planning reserve margin and energy emergency alerts.	• Reserve margins show resource deficiencies due to integration of large loads (Actionable) • Resource weatherization resulted in sustained performance during cold weather events (Stable or No Change)
Transmission Performance Measures transmission performance by analysis of transmission outage rates and Interconnection Reliability Operating Limits (IROL) exceedances.	• 345 kV & 138 kV transmission outage rates (Stable or No Change) • IROL Exceedances (Improving)
Resource Performance Measures generation performance by analysis of generator outage rates, primary frequency response, and balancing contingency events.	• Resource outages/gas restrictions during cold weather • EFOR decreased in 2024, long term rate increase (Stable or No Change) • Primary frequency response • No balancing contingency event failures (Improving)
Grid Transformation Measures potential issues related to grid transformation by analysis of system inertia and ramping.	• Solar ramp magnitudes continue to increase • Voltage ride through for IBRs and large loads (Monitoring) • Inertia levels are stabilizing • Synchronous generator retirements slowed (Stable or No Change)
Protection System Performance Measures Protection System Performance by analysis of Protection System Misoperations.	• Misoperations due to incorrect settings continued to decrease in 2024 (Stable or No Change) • Misoperation rate decreased in 2024, remains less than overall NERC Misoperation rate (Stable or No Change)
Human Performance Measures transmission outages, generation outages, and Protection System Misoperations caused by human error.	• Reduction in transmission and generation outage rates from human error (Improving) • Human error primary causal factor in Misoperations and events (Monitoring)
Situational Awareness Measures situational awareness by analysis of state estimator convergence rates, event analysis, and telemetry performance.	• Eight loss of situational awareness events (up from four) (Monitoring) • State estimator convergence rate (Stable or No Change)



2024 KEY FINDINGS

Texas RE continually evaluates risks to grid reliability in its Region through long-term and seasonal reliability assessments, event analyses, situational awareness, tracking reliability indicators, real-time performance monitoring, and planning observations. The 2024 Reliability Performance and Regional Risk Assessment report provides a high-level overview of the data collected in the Region in 2024. It includes:

- Overview of 2024's numbers
- Associated historical data
- The current state of the Interconnection
- Observations for the future of Texas RE's Region

To gauge reliability of the Region and turn that data into actionable information, Texas RE assessed data and historical trends in these areas:

GRID TRANSFORMATION

- Resource Adequacy and Performance
- Bulk Power System Planning
- Protection and Control Systems
- Situational Awareness Challenges
- Human Performance
- Changing Resource Mix

RESILIENCE TO EXTREME EVENTS

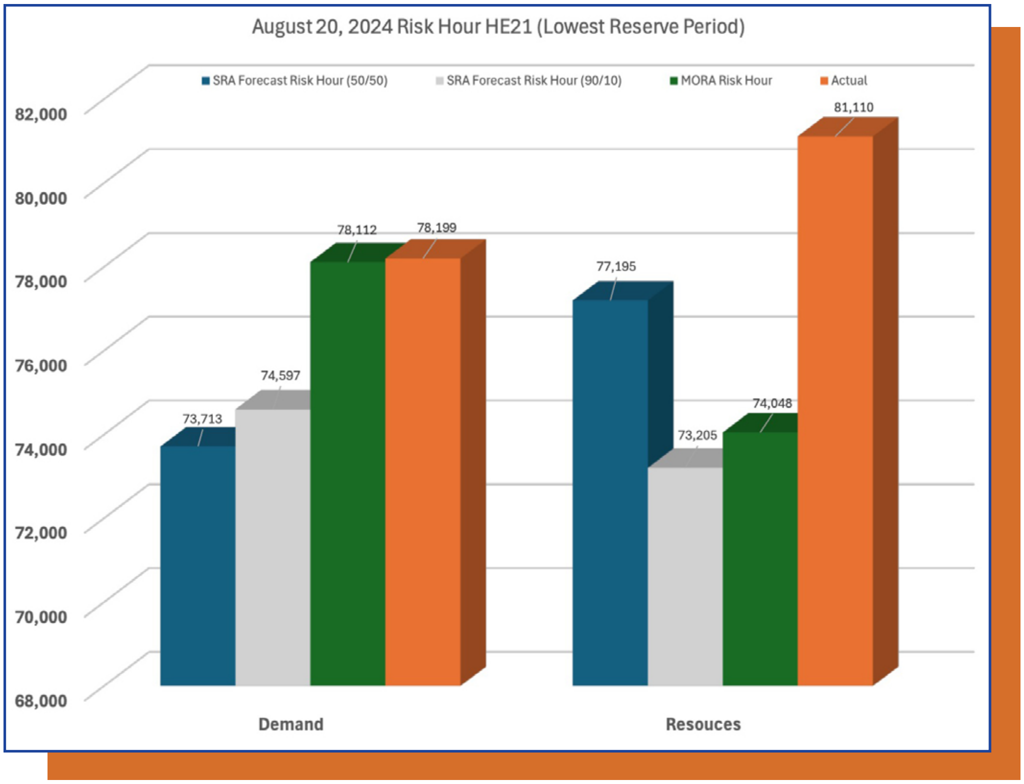
SECURITY RISKS

- Cyber
- Physical

CRITICAL INFRASTRUCTURE INTERDEPENDENCIES

RESOURCE ADEQUACY & PERFORMANCE

Throughout 2024, ERCOT maintained sufficient operating reserves. The Region did not experience any instances in which Physical Responsive Capacity (PRC) declined below ERCOT's defined Advisory, Watch, or EEA levels. ERCOT had sufficient resources to meet the actual peak of over 85 GW in August 2024. Hour-ending (HE) 21 had the highest probability of capacity deficiencies during the summer after the evening solar down ramp. The lowest hourly reserve period during the high-risk hour occurred on August 20, 2024. ERCOT maintained sufficient resources during this period (see graphic to left).



As noted in Texas RE's previous assessments, ERCOT no longer has sufficient dispatchable resources to meet projected 50/50 and extreme peak loads. The pace of dispatchable resource retirements slowed significantly in 2024 from previous years, and an additional 560 MW of dispatchable resources were approved for commercial operation this past year. Efforts to incentivize additional dispatchable generation through the TEF are underway, with a recommended portfolio of slightly less than 10 GW of dispatchable resources identified for grants and incentives. Further legislation may also spur the development of additional dispatchable resources.

Projected Peak:	82,333 MW
Actual Peak:	85,245 MW
Renewable % at Peak:	27.9%
Max Hourly Wind:	27,667 MW
Max Hourly Solar:	21,589 MW
Max Hour Renewable%:	75.0%
Advisories (PRC <3000):	0
Watches (PRC <2500):	0
EEA (PRC <2300):	0

At the same time, Texas RE continues to observe significant growth in renewable generation resources. The addition of 5,350 MW of solar resources and 2,100 MW of wind resources in 2024 improved margins during peak demand hours. Battery resources injected over 4,000 MW during evening solar down ramp hours or prior to the morning load ramp. Additionally, 3,900 MW of new battery resources contributed to maintaining the balance between load and generation during solar ramp periods and at other times with low renewable generation output. Batteries and other energy storage options will continue to play a key role, especially for shorter duration needs. These trends are expected to continue with approximately 49,000 MW of additional renewable and storage resources expected by the end of 2027. These additions will continue to drive changes in how ERCOT manages generation. Combined wind and solar generation curtailments exceeded 8,363 gigawatt-hours (GWh) in 2024, which represented a slight decrease from 2023.

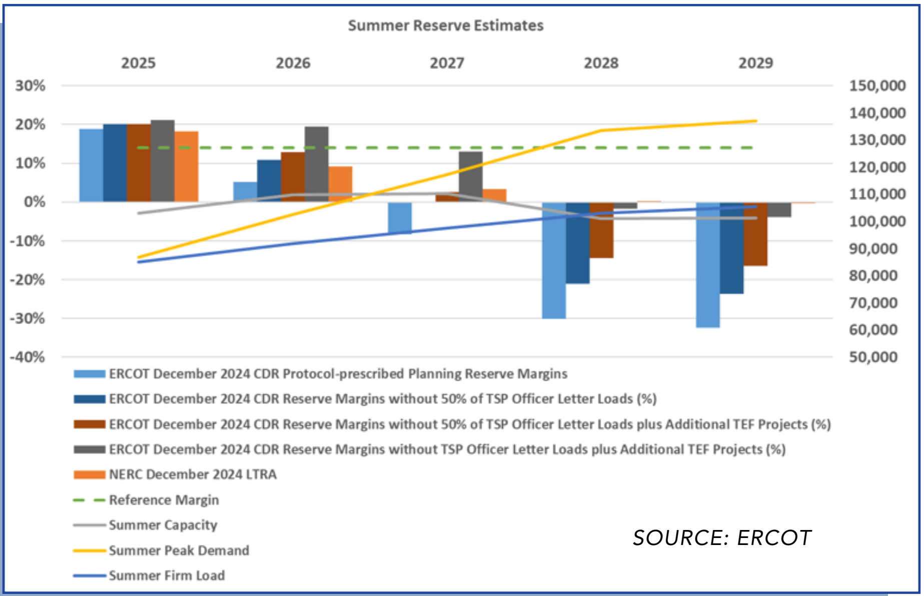
RESOURCE ADEQUACY & PERFORMANCE

Despite this continued positive and reliable performance, Texas RE has elevated concerns regarding resource adequacy in the future due to the potential integration of a significant number of large loads. Current large load interconnection requests indicate that up to 70,500 MW of new load resources could interconnect by 2028. While a significant number of these resources will likely not materialize, the rapid increase in load on the system presents substantial forward-looking challenges.

ERCOT's Capacity, Demand, and Reserves (CDR) report indicates that planning reserve margins for 2025 through 2029 decrease significantly from year to year, and cross over to negative values in 2026 and 2027 depending on the season. The summer margins for the peak Net Load hours are lower than for the peak Load hours due mainly to decreasing solar generation availability in the early evening when loads are still high. The decreases are mainly due to:

- The addition of new forecasted Loads reported by Transmission Service Providers (TSPs), dominated by large consumers such as data centers, industrial/oil & gas production facilities, and cryptocurrency mining operations.
- ERCOT assumes all Loads other than Large Flexible Loads (i.e., cryptocurrency mining) are considered firm Loads. Firm Loads are Loads that will remain on when entering emergency conditions. Large Flexible Loads are responsive to real time prices and can reduce consumption or turn off quickly before emergency conditions.
- The summer peak Net Load hour margin enters negative territory beginning summer 2026, while the peak Load hour margin enters negative territory beginning summer 2027. The lower margins for the peak Net Load hour relative to those for the peak Load hour mainly reflect the lower reliability contribution of solar generation during the evening hours when the peak Net Load occurs.
- The lower and sharply downward trajectory of the margins is due to:
  1. High load growth largely driven by new Loads reported by TSPs
  2. A lower capacity contribution from wind and solar resources due to the switch to Effective Load Carrying Capability (ELCC)
  3. Fewer planned resources that result from applying additional eligibility criteria to be included in planning reserve margins
  4. Inclusion of planned unit retirements publicly announced but not officially reported as a planned retirement to ERCOT

RESOURCE ADEQUACY & PERFORMANCE



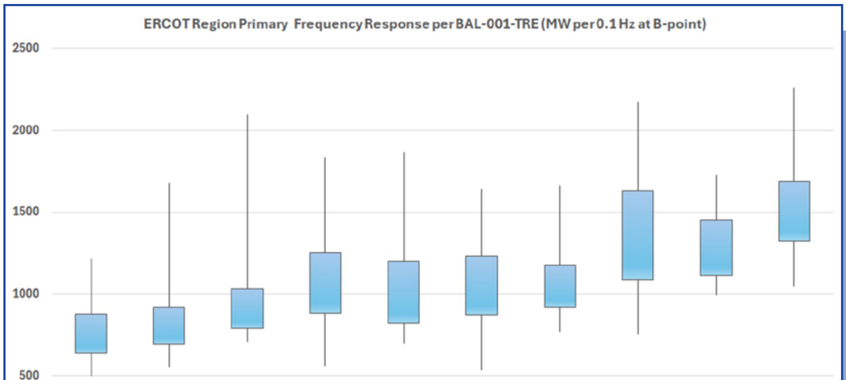
SOURCE: ERCOT

Beginning in 2022, the capabilities of battery resources began to show noticeable improvements in primary frequency response. The system frequency decay during sudden generation unit trips is being arrested faster and at a higher frequency than in previous years, primarily due to the fast response time from battery resources.

Solar facilities greater than 100 MW began mandatory reporting in GADS-Solar in 2024. Solar facilities greater than 20 MW will begin mandatory reporting in GADS-Solar in 2025. GADS-Solar provides similar metrics as GADS to compare unit-level and fleet-level performance.

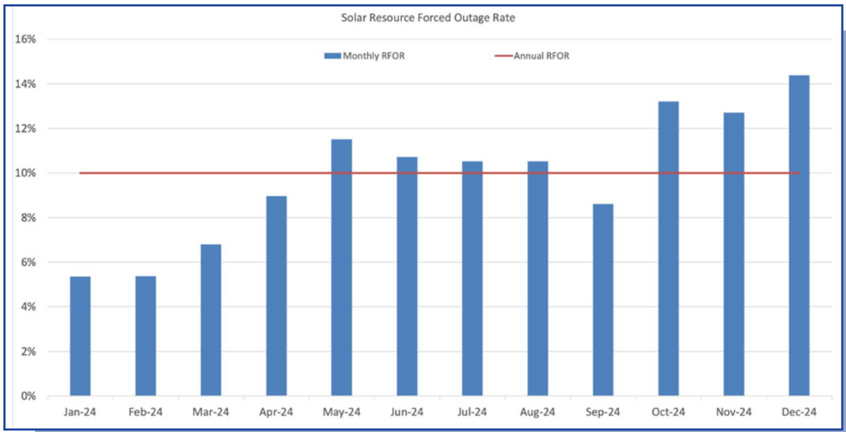
In 2024, 81 solar facilities in the Region and sub-groups submitted a total of 744 unit-months of data in GADS-Solar. Net solar generation reported was 22,759.8 GWh, or 47.2 percent of the total solar generation for the year. Resource-level metrics look at the resource as a whole. GADS-Solar inverter outage data reporting for 2024 included 2,206 component outage reports totaling 22,643 inverter-hours of forced, planned, or maintenance outage duration, with an estimated production loss of 16,248.6 GWh

A summary of key performance metrics for the ERCOT solar generators for 2024 is provided in the following table.



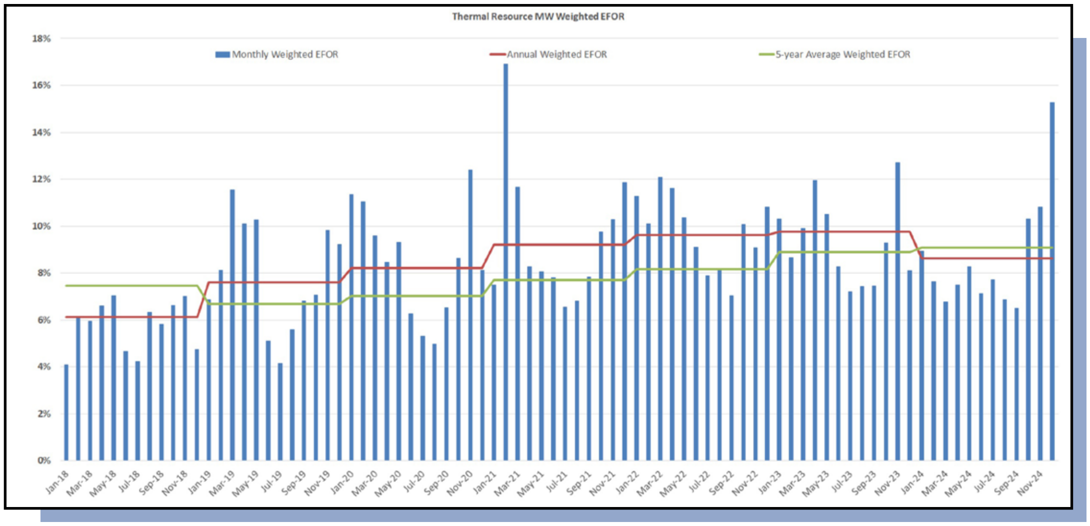
Primary frequency response continues to improve and far exceed NERC requirements due to integration of battery resources minimums.

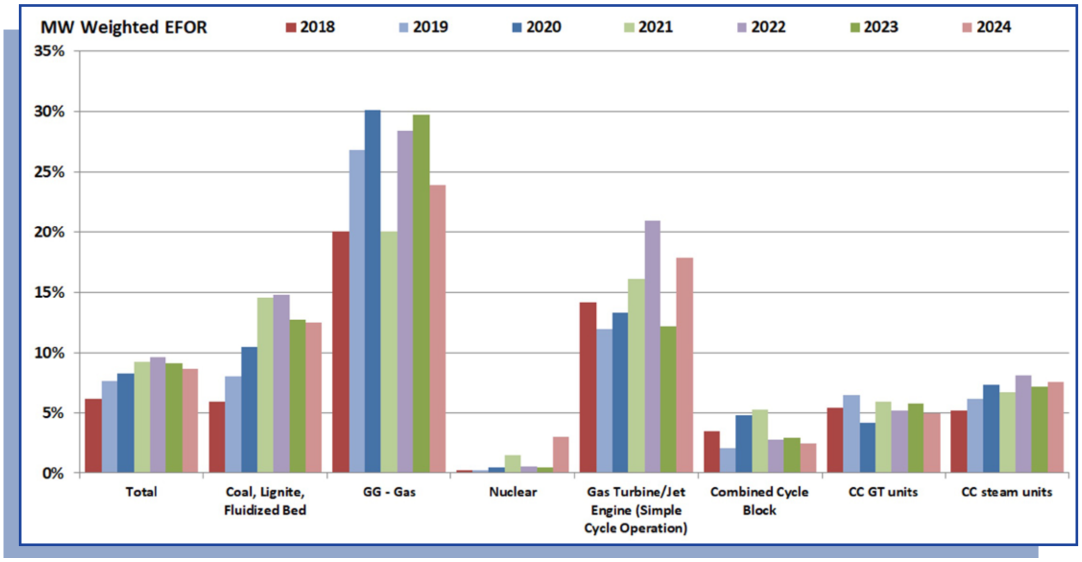
Metric: ERCOT Region GADS-Solar Data	2024
Net Capacity Factor (RNCF)	17.6%
Resource Generating Factor (RGF)	42.6%
Resource Forced Outage Rate (RFOR)	10.0%
Equipment Forced Outage Rate (EFOR)	4.4%
Resource Scheduled Outage Rate (RSOR)	0.3%
Performance Index (PI)	79.5%
Resource Availability Factor (RAF)	95.0%



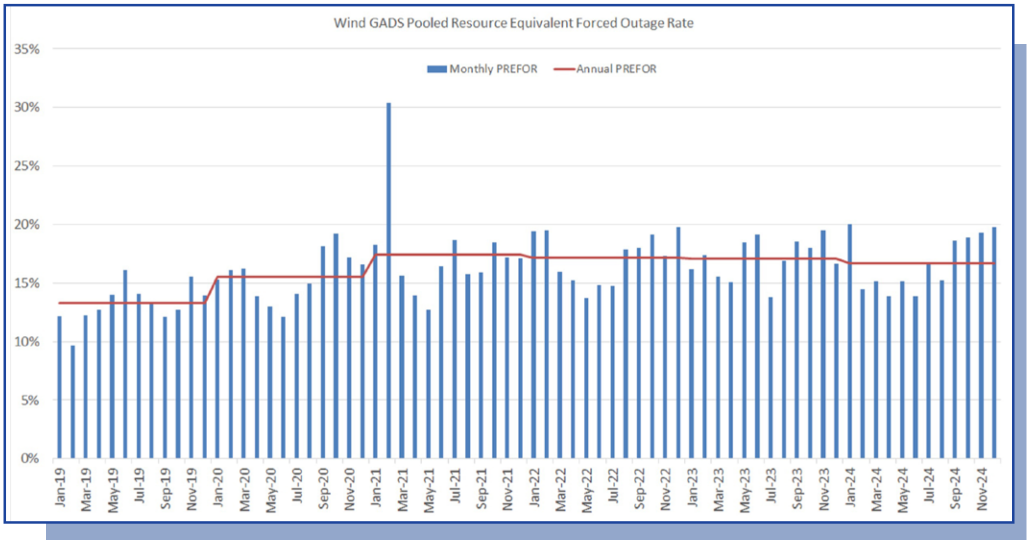
RESOURCE ADEQUACY & PERFORMANCE

The MW-weighted EFOR for thermal resources was 8.6 percent in 2024, which was a slight drop from 9.1 percent in 2023. However, the long-term five-year trends continue to show an increasing rate.





GADS Wind Resource EFOR was 16.2 percent in 2024, a slight decrease from 17.1 percent in 2023.



RESOURCE ADEQUACY & PERFORMANCE

2024 HIGHLIGHTS FROM THE ANALYSIS OF RESOURCE ADEQUACY AND PERFORMANCE INCLUDE:

- Primary Frequency Response achieved a rolling average of 1,552 MW/0.1 Hz for 2024 versus NERC Obligation of 395 MW/0.1 Hz.
- No Reportable Balancing Contingency Event Recovery Period failures occurred in 2024.
- No Reportable Balancing Contingency Events greater than the Most Severe Single Contingency (MSSC) occurred in 2024.
- An IROL was exceeded three times (totaling nine minutes) in 2024.

AREAS TO MONITOR INCLUDE:

- Weatherization of generation resources will continue to be a primary focus for the foreseeable future.
- Implementation of new NERC Standard requirement changes to improve voltage ride-through for IBRs is a primary focus in 2025.
- GADS EFOR (unweighted) for thermal resources was 10.1 percent for 2024, which was a small increase from 9.8 percent in 2023. The MW-weighted EFOR for thermal resources was 8.6 percent in 2024, which was a small drop from 9.1 percent in 2023. However, the long-term five-year trends continue to show an increasing rate.
- GADS Wind Resource EFOR was 16.2 percent in 2024, a slight decrease from 17.1 percent in 2023.
- For the inaugural year of GADS Solar data collection, the aggregate Resource Forced Outage Rate (RFOR) was 10 percent in 2024.

BULK POWER SYSTEM PLANNING

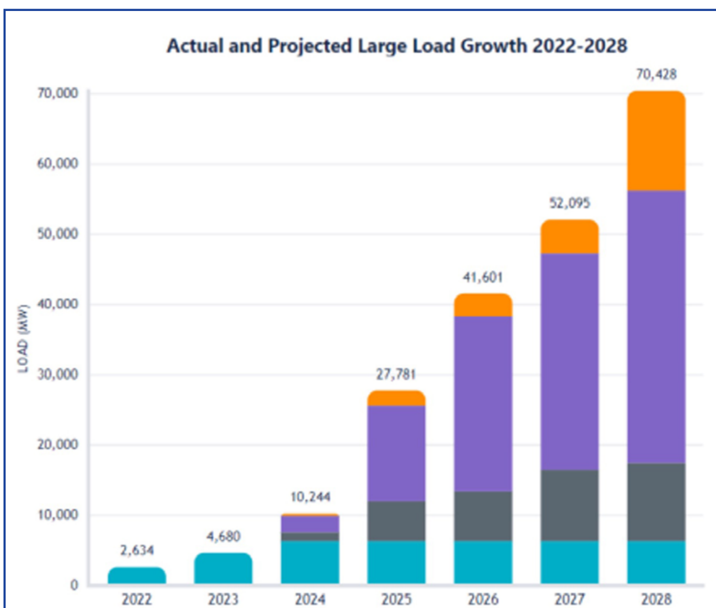
The 2024 NERC Long-Term Reliability Assessment (LTRA) shows a planning reserve margin above the 13.75 percent reference margin for the next five years in the Region. However, ERCOT's December 2024 Capacity, Demand and Reserves (CDR) report shows negative reserve margins as early as 2026 due to the inclusion of large loads dominated by data centers, oil and gas production facilities, and cryptocurrency facilities. In the December 2024 CDR report, ERCOT expanded the scope of the Long-Term Load Forecast (LTLF) to incorporate additional new large loads with a TSP or Distribution Service Provider (DSP) officer letter.

LARGE LOAD INTEGRATION

The Region has experienced continued rapid load growth from data centers, industrial oil and gas production facilities, and other cryptocurrency mining operations. Current large load interconnection request queues indicate such load totals could reach up to 70,500 MW by the end of 2028. As of December 2024, approximately 6,297 MW have been approved to energize, and 11,127 MW have had their planning studies approved by ERCOT. The remaining loads are undergoing ERCOT review or have had no studies submitted.

Integration of these loads has resulted in modifications to existing methodologies, such as load forecasts, to capture aspects of flexibility and price responsiveness more accurately. This is demonstrated by a new assumption in the long-term load forecast methodology that credits large flexible loads for a 15 percent curtailment during on-peak hours based on this price sensitivity. Continuous efforts are being made to further improve the accuracy of these forecasts and incorporate bitcoin mining economic models to better predict load ramps due to price response. ERCOT has proposed Nodal Protocol Revision Request (NPRR) 1234 and Planning Guide Revision Request (PGRR) 115 to formalize the interconnection process for large loads and establish operational standards to maintain reliability.

It is expected that increasing numbers of large loads (75 MW or more, like data centers) will be connecting to the ERCOT grid. Policymakers and industry are discussing requirements for large loads to be demand-flexible during periods of grid scarcity. In the Texas Legislature, Senate Bill 6 was signed into law by Governor Abbott in June 2025. This bill creates requirements for large loads, including planning requirements, financial security requirements, net metering requirements for large loads integrated behind generator points of interconnection, and demand management/ demand respond requirements.*



SOURCE: ERCOT

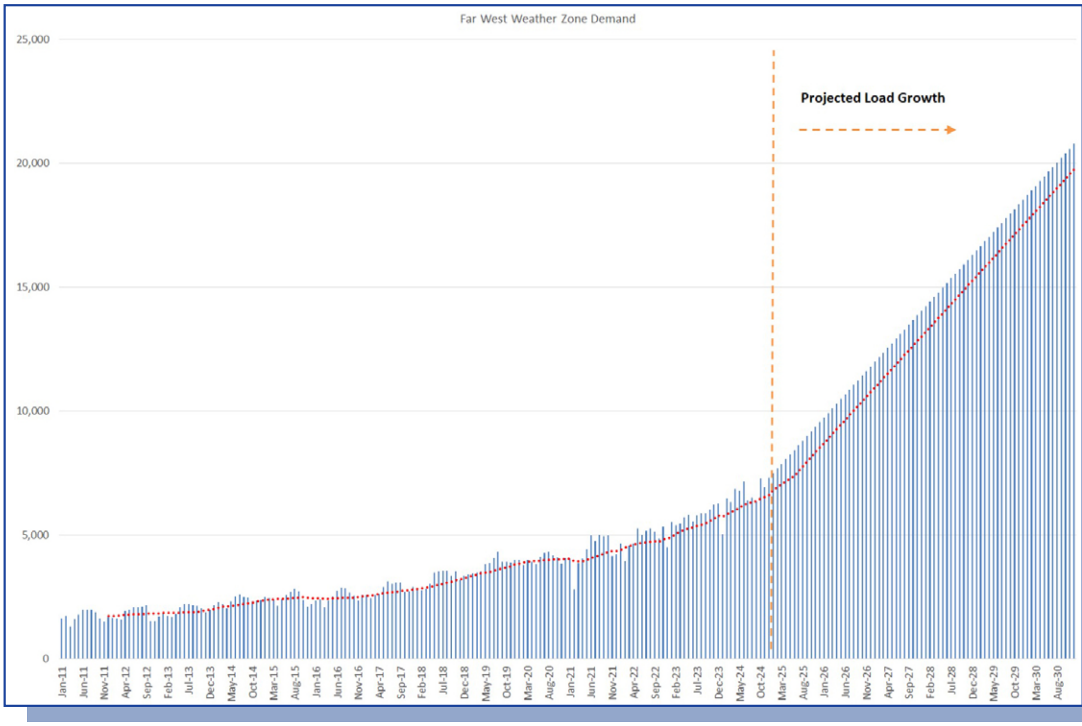
ERCOT's Large Flexible Load Task Force (LFLTF) is an on-going effort to address the risks associated with integration of these large loads. In 2024, NERC also initiated a Large Load Task Force. These task forces are evaluating key issues such as the extent to which these loads will impact system frequency in the event of rapid and unpredictable load ramping, the failure to ride through voltage disturbances, modeling practices, and possible NERC/ERCOT registration.

This text originally referred to Senate Bill 6 as being in the legislative process and was updated to reflect its passage and being signed into law.

BULK POWER SYSTEM PLANNING

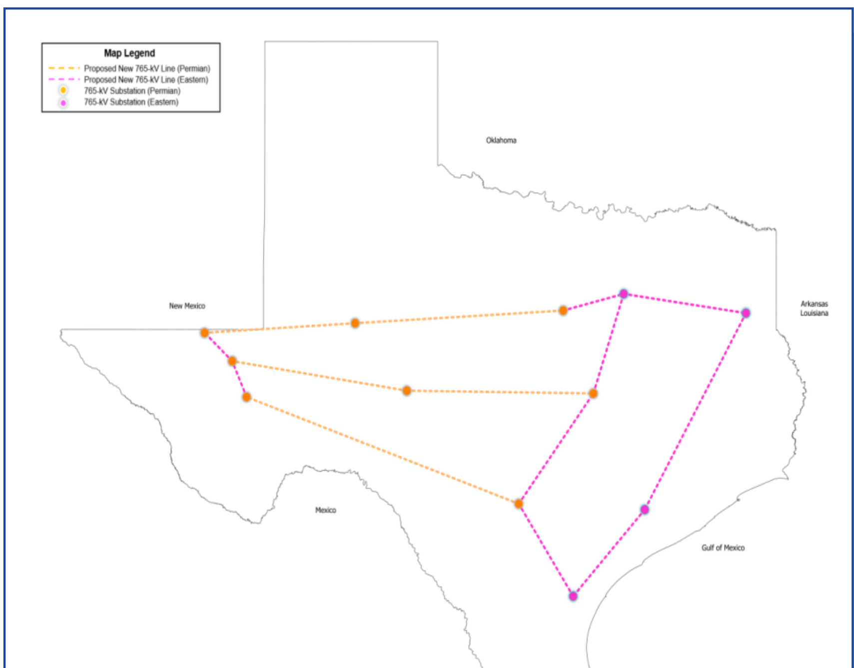
WEST TEXAS LOAD GROWTH AND 765 KV INFRASTRUCTURE PROPOSALS

In the 2024 Regional Transmission Plan (RTP), the Far West weather zone load is forecasted to approach 18 GW by 2029 and exceed 20 GW by 2030 under summer peak conditions. This is attributed to the projected oil and gas load along with other large loads seeking to be connected. The 2024 RTP incorporated the projects designated under the Permian Basin Reliability Plan as directed by the PUCT to ensure that these forecasted loads are served as well as to meet the reliability needs in West Texas.



The reliability of the grid is heavily reliant on the timely completion of planned transmission projects. This is shown in the list of over 270 reliability projects listed in the 2024 ERCOT Regional Transmission Plan. Increasing amounts of generation that are physically distant from load are straining transmission capacity and increasing reliance on remote generation to serve load.

As part of the 2024 Regional Transmission Plan, ERCOT considered a 765 kV infrastructure proposal as an alternative to the traditional 345 kV solutions in order to meet the unprecedented increase in forecasted load growth in Texas. ERCOT prepared a comprehensive comparison of the benefits and merits of a 345 kV transmission plan versus a 765 kV solution and shared this with stakeholders at a workshop in January 2025. ERCOT also developed the Permian Basin Reliability Plan study, which identified both local transmission needs and import needs with 345 kV and 765 kV options. PUCT issued an order approving the Permian Basin Reliability Plan in October 2024. The PUCT approved the 765 kV plan in April 2025.

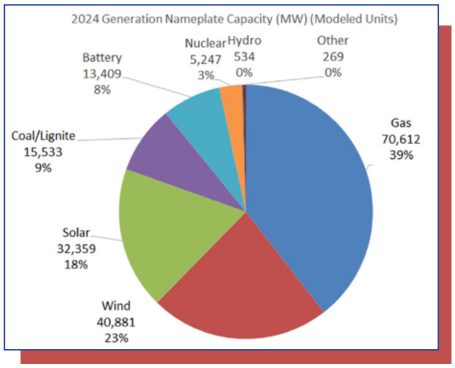


SOURCE: ERCOT

BULK POWER SYSTEM PLANNING

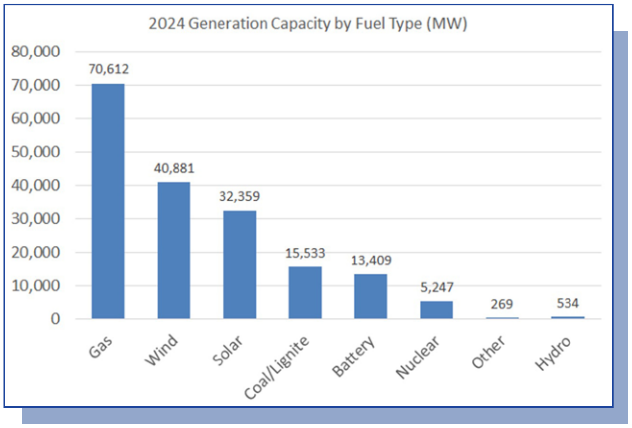
2024 HIGHLIGHTS FROM THE ANALYSIS OF BULK POWER SYSTEM PLANNING INCLUDE:

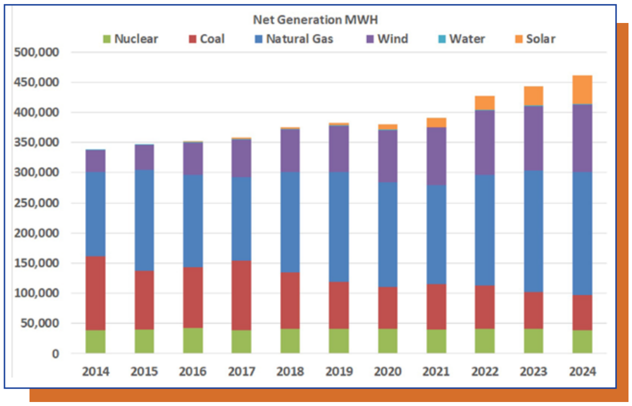
- Summer Peak: Actual 85,245 MW versus projected 82,333 MW
- Winter Peak: Actual 78,349 MW versus projected 71,717 MW
- Renewable Percentage of Total Load at Summer Peak: 27.9 percent
- Peak hourly wind generation: 27,667 MW on June 17, 2024
- Peak hourly solar generation: 21,588 MW on September 8, 2024
- Peak hourly renewable penetration: 74.97 percent on March 29, 2024

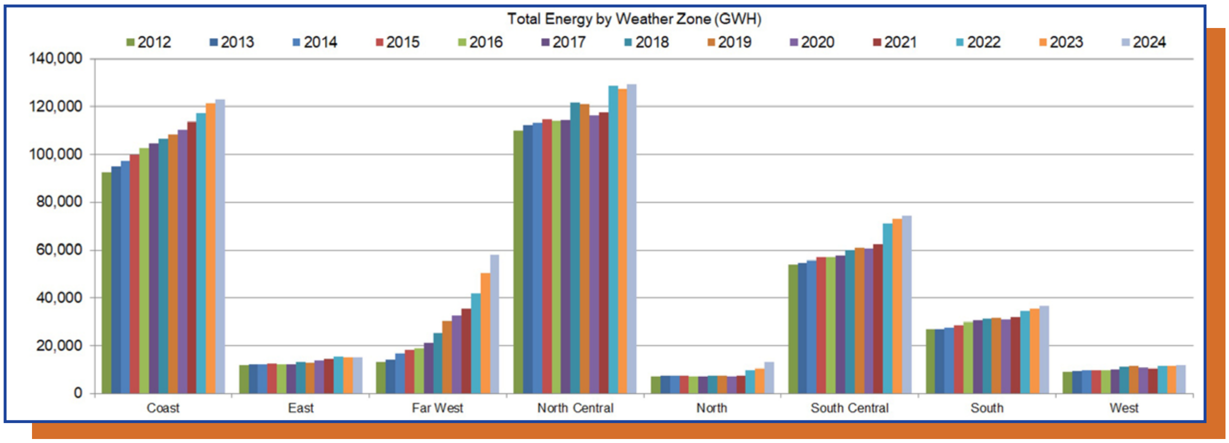


AREAS TO MONITOR INCLUDE:

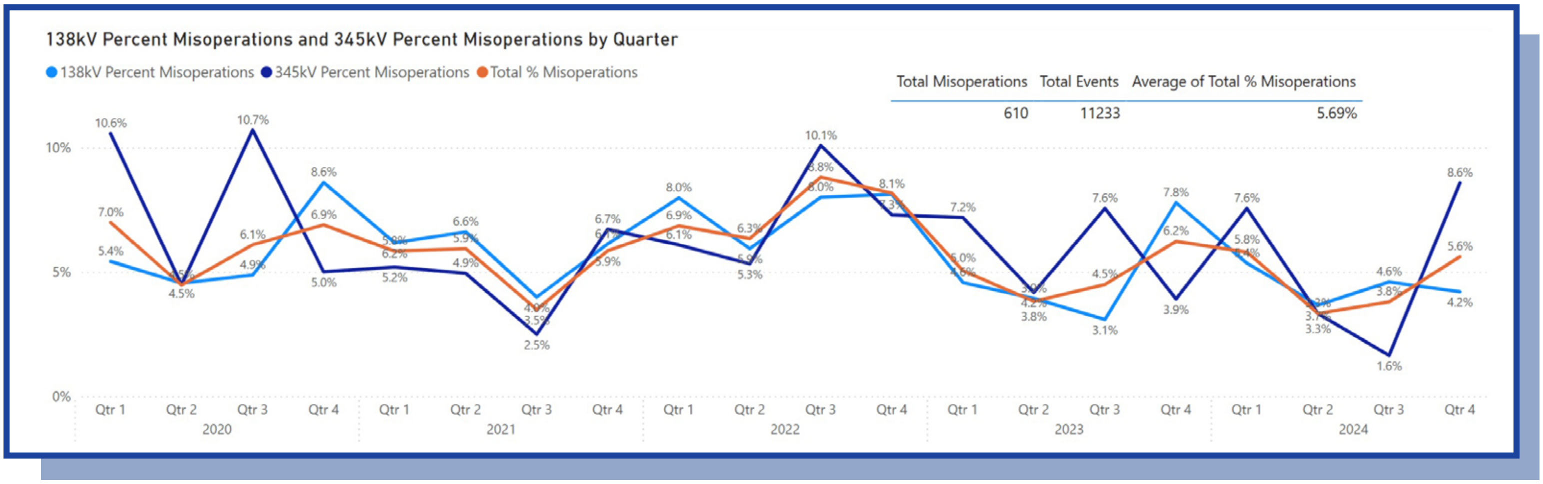
- As of December 2024, ERCOT projections indicate utility-scale solar generation will almost double to over 57,560 MW, wind generation will increase nine percent to more than 43,960 MW, and storage resources will increase 275 percent to over 27,560 MW during the next two years (based on current signed generation interconnect agreements with financial security).
- Projected growth of distributed and non-modeled generation is steadily increasing. ERCOT had 2,095 MW of non-modeled generation capacity and 2,805 MW of unregistered distributed generation resources (DGR) at the end of 2024. Estimates for the contribution at peak from unregistered rooftop PV in ERCOT's December 2024 Capacity, Demand and Reserves report project growth from 1,463 MW in 2025 up to 2,649 MW by 2027.
- Energy growth rates in the Coastal, South Central, and Far West Weather zones continue to drive the overall Region demand, increasing by 4.4 percent in the last year. Overall, the Region's energy growth increased by 3.8 percent year-over-year.
- Transmission solutions for load growth will be monitored and reviewed. Inclusion of these transmission projects into future reliability assessments is critical.





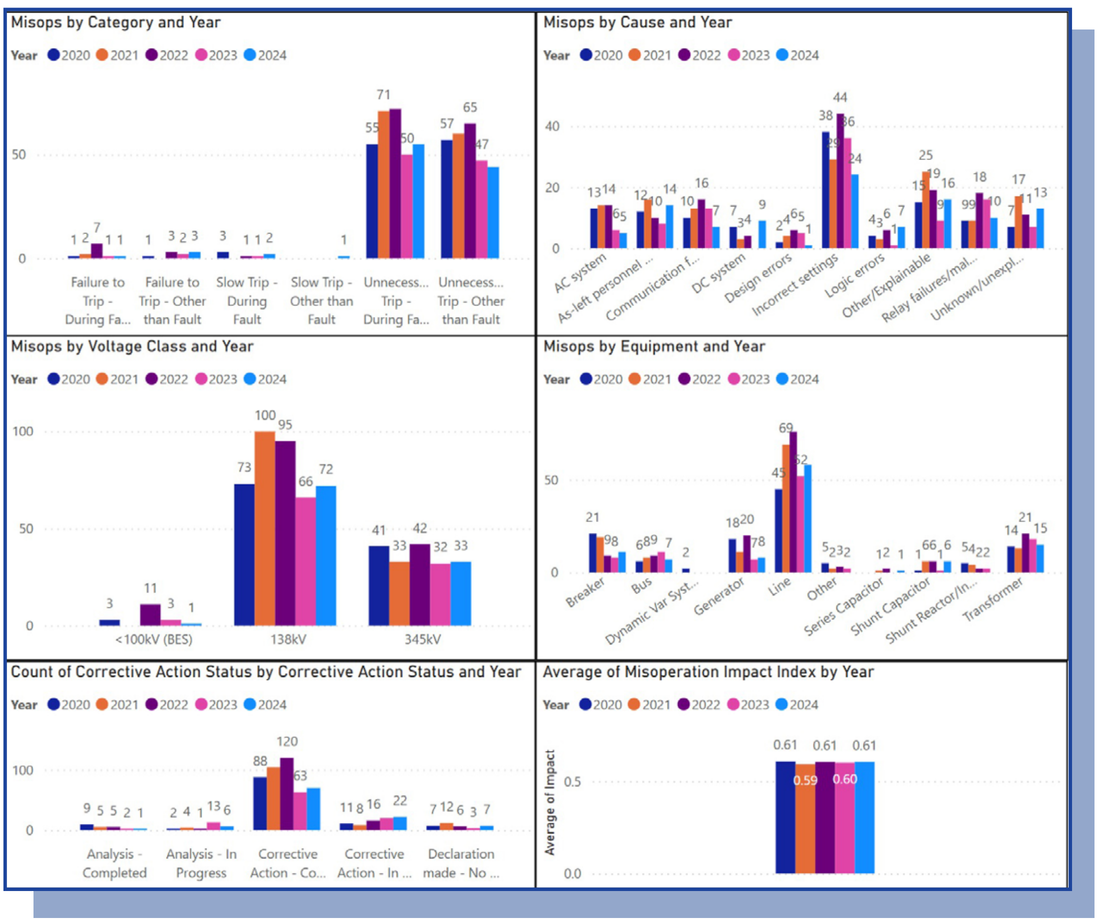


PROTECTION & CONTROL SYSTEMS



2024 HIGHLIGHTS FROM THE ANALYSIS OF PROTECTION SYSTEM MISOPERATIONS INCLUDE:

- Since January 2020, the overall transmission system Protection System Misoperation rate has gradually declined, from 6.0 percent in 2020 to 4.3 percent in 2024. The five-year Misoperation rate from 2020-2024 was 5.4 percent.
- In 2024, three main categories account for 58 percent of the total Misoperations: incorrect settings/logic/design (30 percent), other/explainable (15 percent), and as-left personnel errors (13 percent). Incorrect settings continue to be the largest category of Misoperations over the past five years.
- Misoperations due to AC systems, relay failures, communication failures, and incorrect settings decreased in 2024 compared to 2023.
- Misoperations due to AC systems and communication failures continue to show a positive downward trend.
- Corrective actions were completed or are in-progress for approximately 87 percent of Misoperations that occurred in 2024.



PROTECTION & CONTROL SYSTEMS

AREAS TO MONITOR INCLUDE:

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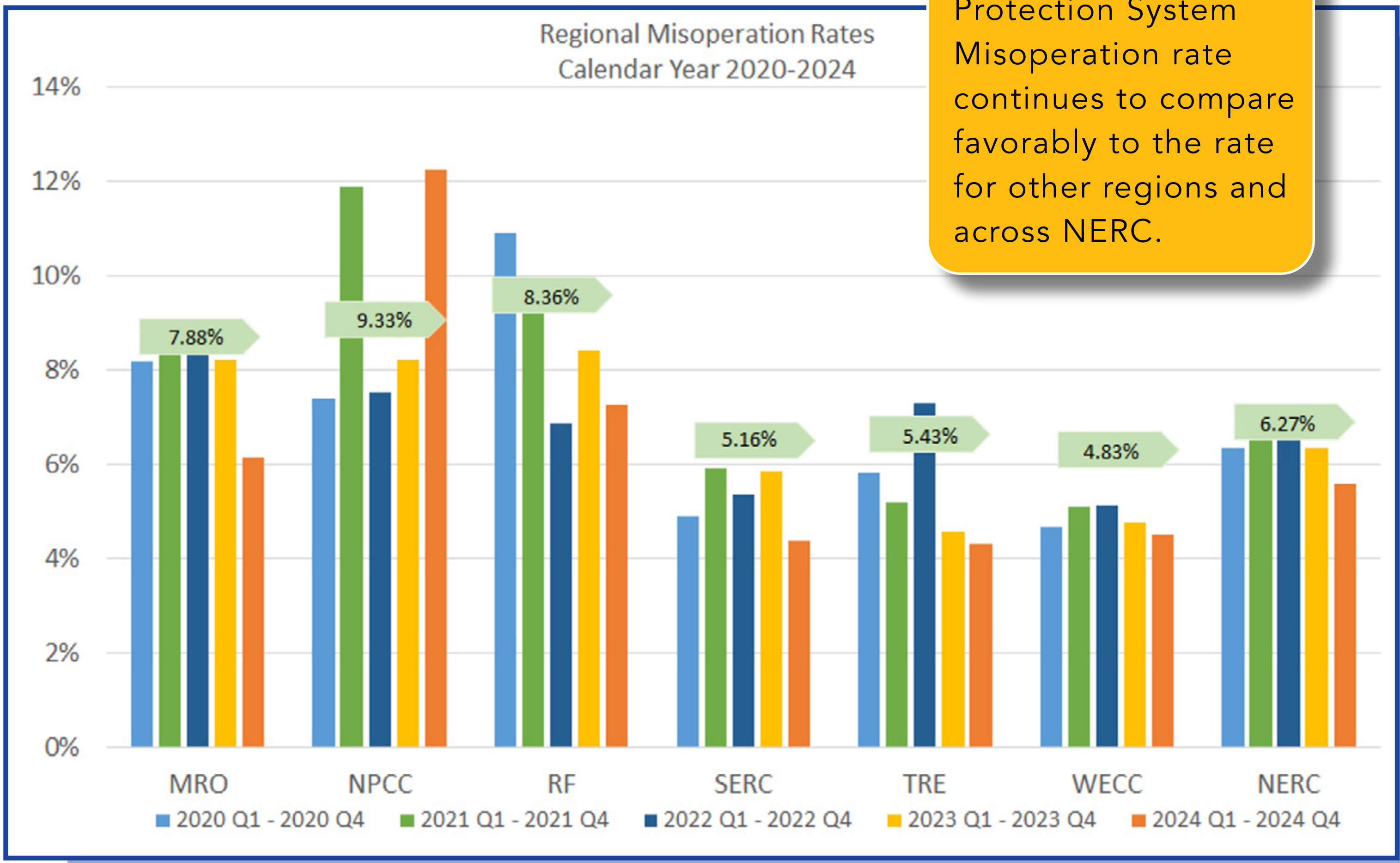
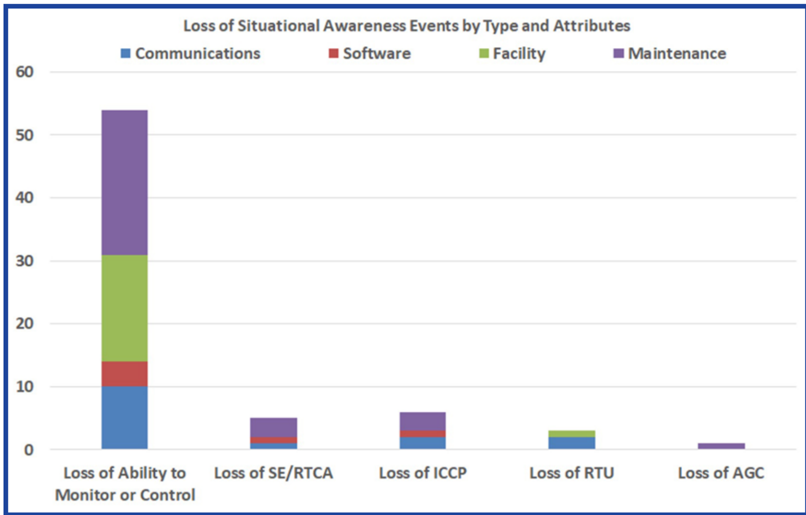
- Misoperations due to AC systems, relay failures, communication failures, and incorrect settings decreased in 2024 compared to 2023.
- Misoperations due to AC systems and communication failures continue to show a positive downward trend.
- Corrective actions were completed or are in-progress for approximately 87 percent of Misoperations that occurred in 2024.

Protection System Misoperations were not a contributing factor in any system events in 2024 categorized under the NERC events analysis process.

The Texas RE Region Protection System Misoperation rate continues to compare favorably to the rate for other regions and across NERC.



SITUATIONAL AWARENESS CHALLENGES

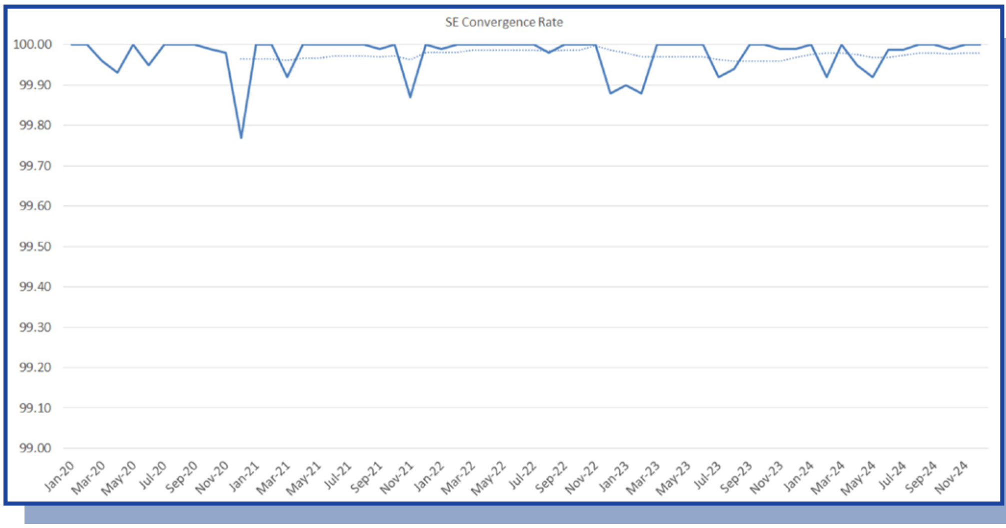


LOSS OF SITUATIONAL AWARENESS EVENTS ARE BROKEN DOWN INTO SEVERAL CATEGORIES BY THE CAUSE OF THE EVENT. THESE ARE:

- Loss of ability to monitor or control
- Loss of State Estimator (SE) or Real-time Contingency Analysis (RTCA)
- Loss of Inter-Control Center Communication Protocol (ICCP) links
- Loss of remote terminal units (RTUs)
- Loss of Automatic Generation Control (AGC)

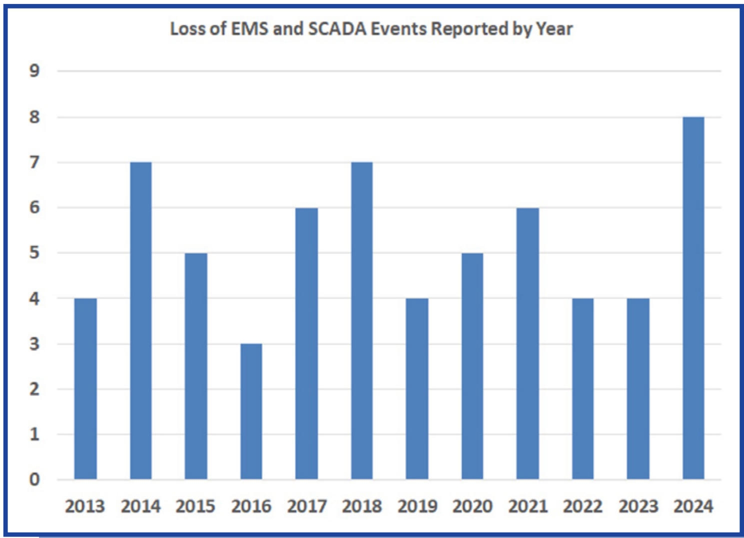
2024 HIGHLIGHTS FROM THE ANALYSIS OF LOSS OF SITUATIONAL AWARENESS INCLUDE:

- Convergence rates for ERCOT's state estimator continue to surpass the goal of 97 percent, exceeding 99.98 percent in 2024.
- Telemetry availability rates remain stable at approximately 96 percent overall.



AREAS TO MONITOR INCLUDE:

- A total of eight Category 1 loss of System Control and Data Acquisition (SCADA) or Energy Management System (EMS) events were reviewed in 2024 at Transmission Operators' control facilities. Average duration was approximately 56 minutes. Two events were caused by external cyber-related incidents, and one event was caused by the loss of external ICCP data links.



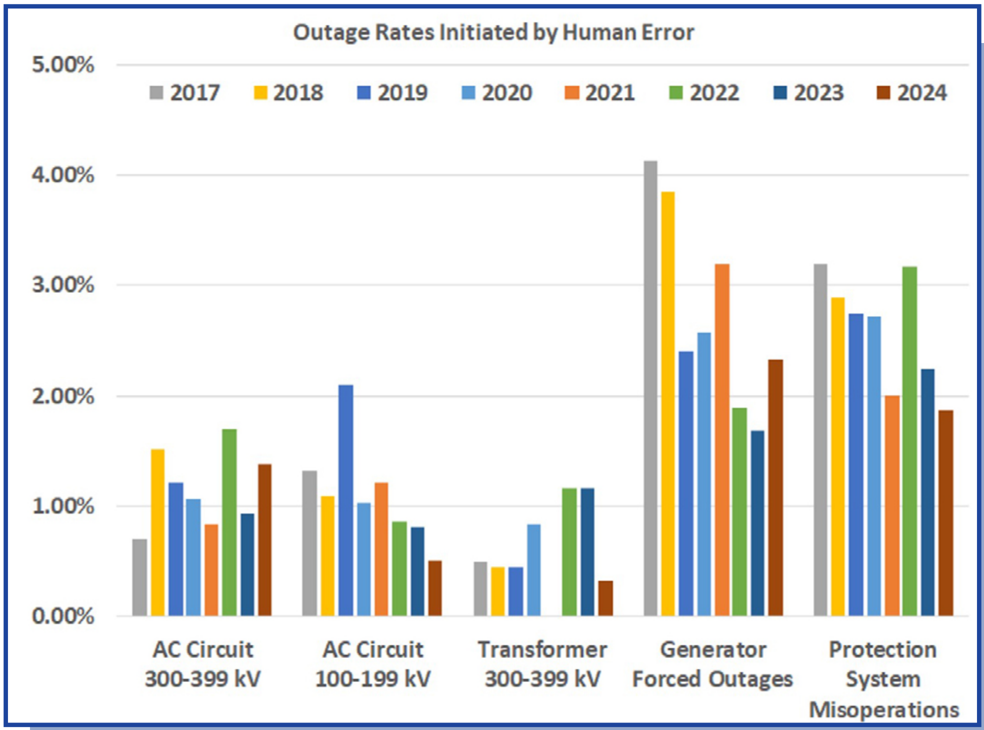
HUMAN PERFORMANCE

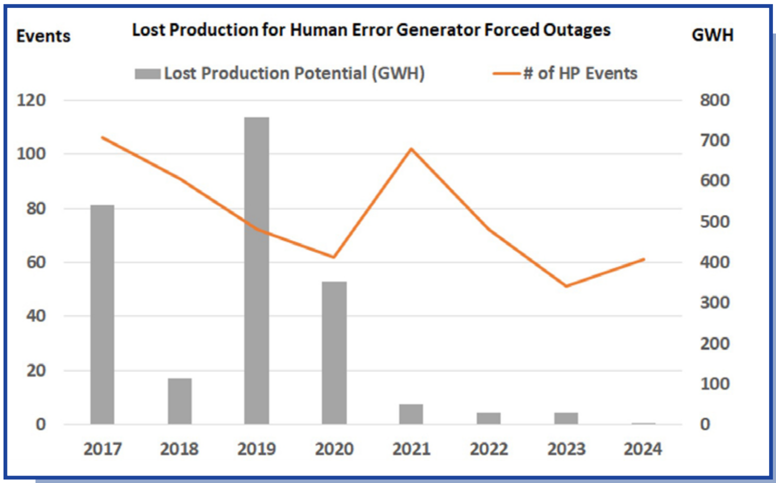
2024 HIGHLIGHTS FROM THE ANALYSIS OF HUMAN PERFORMANCE INCLUDE:

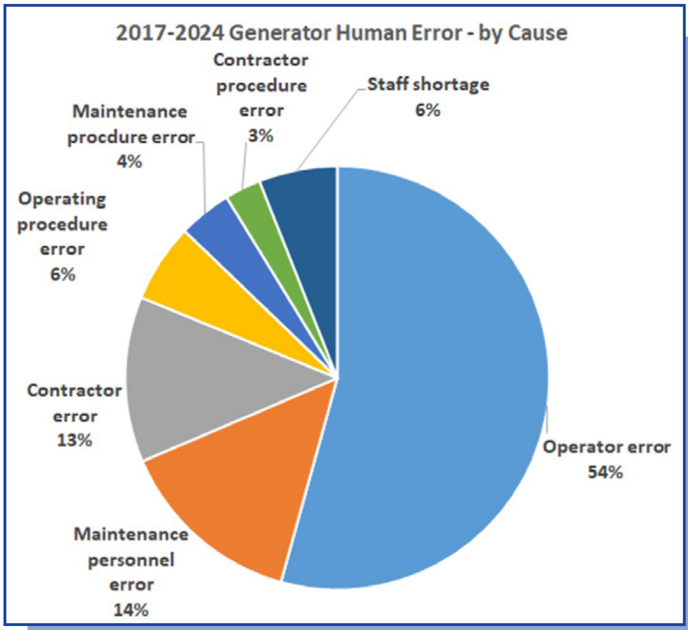
- Outage rates in GADS data caused by human error increased in 2024.
- Human error outage rates for 138 kV circuits continued to decrease in 2024 compared to prior years.
- TADS human error outage rates for 345 kV circuits increased in 2024 compared to 2023.
- Protection System Misoperations from incorrect settings and personnel errors declined in 2024.

AREAS TO MONITOR INCLUDE:

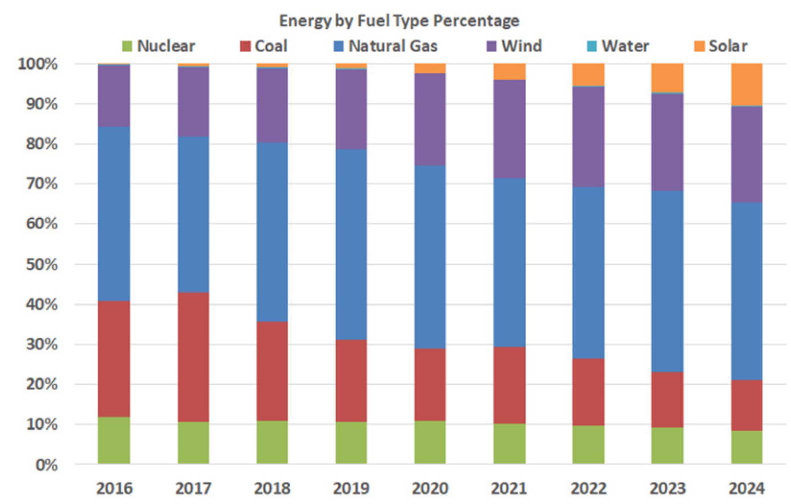
- Causal analysis of human errors in events and Protection System Misoperations continue to show repeated issues due to lack of adequate error checking processes and procedures.
- Overall transmission and generation outage rates due to human error are showing slight improvement in long-term trends. processes and procedures.

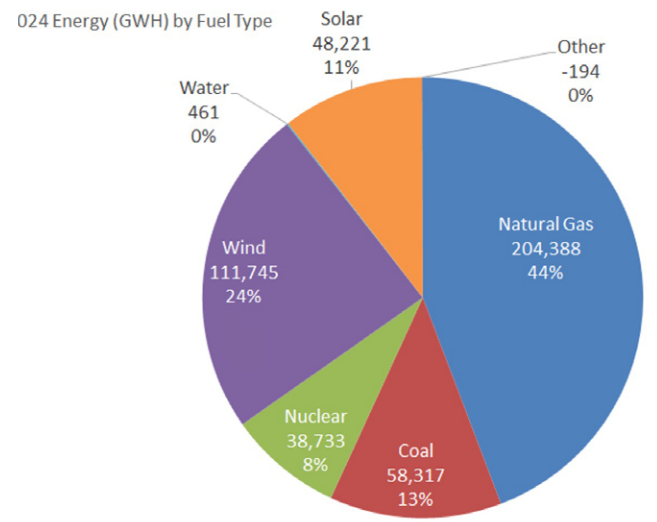


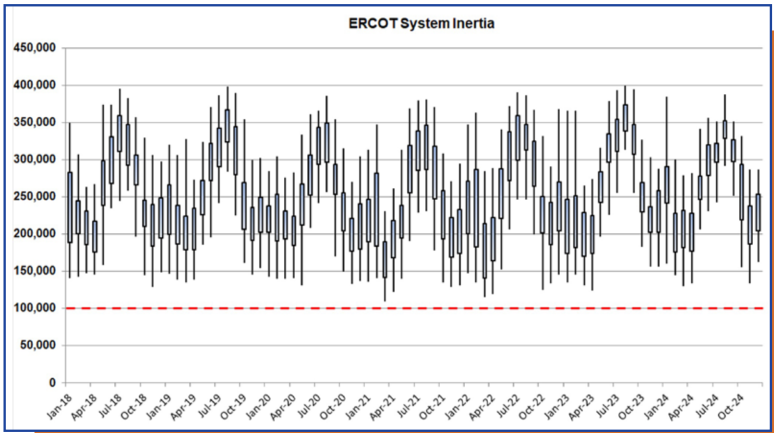




CHANGING RESOURCE MIX



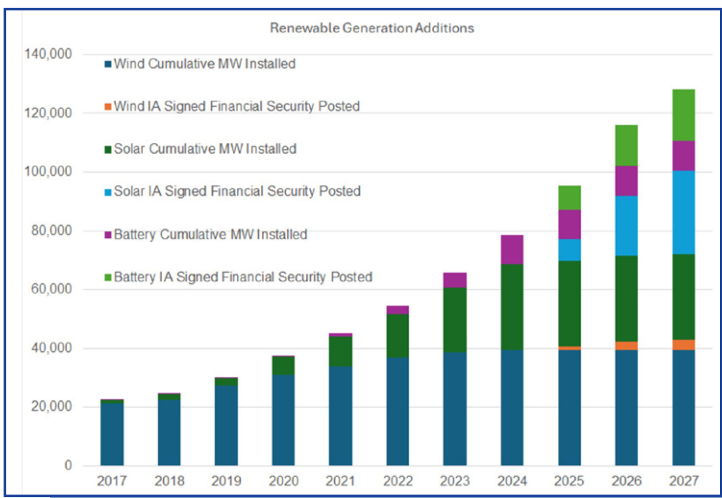




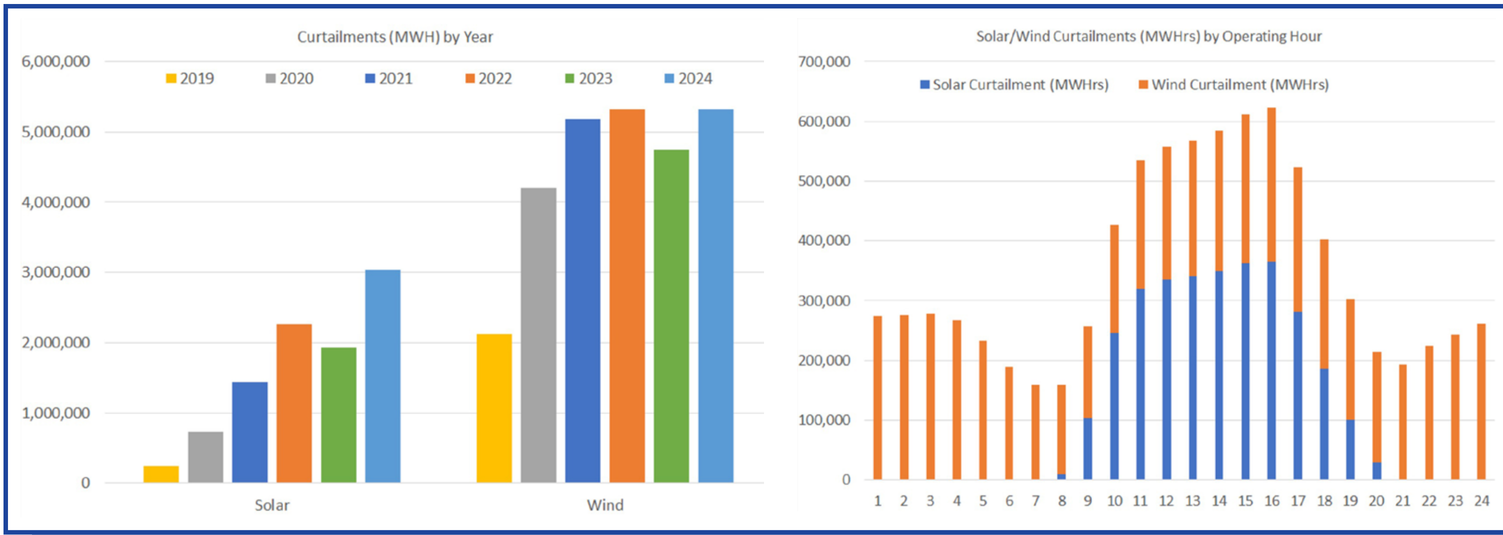
Since 2017, renewable generation has increased from 18% to 35% of energy while coal has decreased from 32% to 13%.

In 2024, almost 12,000 MW of renewable generation was approved for commercial operation. Inertia levels during the highest penetration hours were higher than 2022. The margin between minimum inertia conditions and critical inertia levels remains well within adequate safety margins.

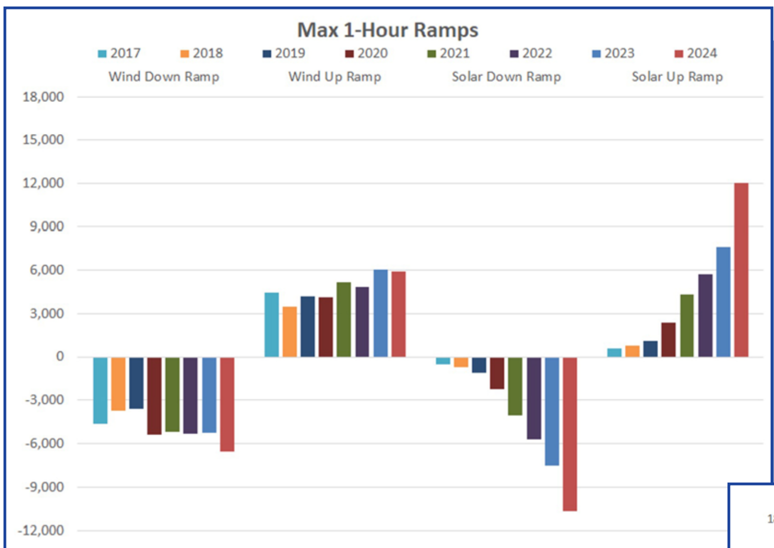
Today's resource mix continues to evolve with the addition of inverter-based generation resources and energy storage. Exponential increases in both solar and storage resources are projected though wind resource growth has slowed. Stability challenges and large solar ramp periods will continue to be significant issues. Voltage and dynamic stability constraints associated with large-scale power transfers from West Texas to the east and from South Texas to the north are expected to continue. Management of stability constraints through generic transmission constraints (GTC) in West and South Texas will continue to result in curtailments of wind and solar energy in order to manage power transfers within stability limits.



CHANGING RESOURCE MIX

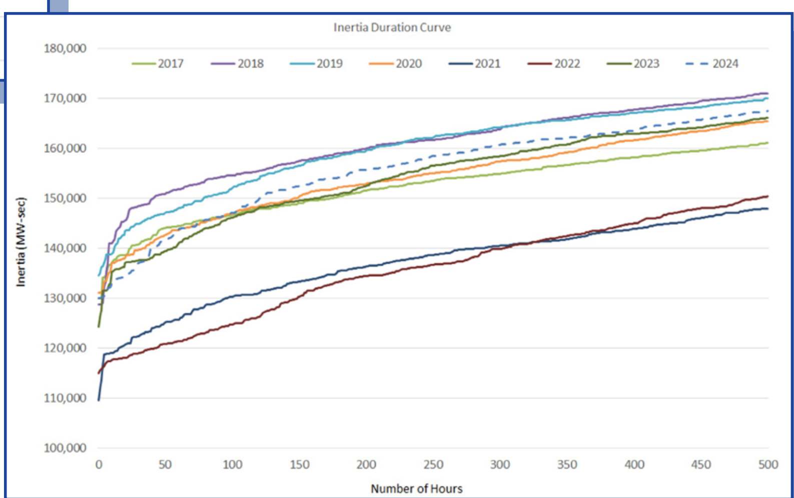


Combined wind and solar generation curtailments increased by 10 percent in 2024, from 6,670 GWh in 2023 to 8,360 GWh in 2024.



Evening solar down ramps continue to increase (especially during the summer months) as shown in the chart below. In 2024, the maximum solar down ramps approached 12,000 MW per hour. Flexible quick start and battery resources were most often used to ensure resource adequacy, control system frequency, and meet ramping needs.

The chart below shows a comparison of inertia levels during the lowest inertia hours. Overall system inertia in 2024 (dashed line) remained near historic norms, at or near the levels from 2023 (dashed line). The minimum

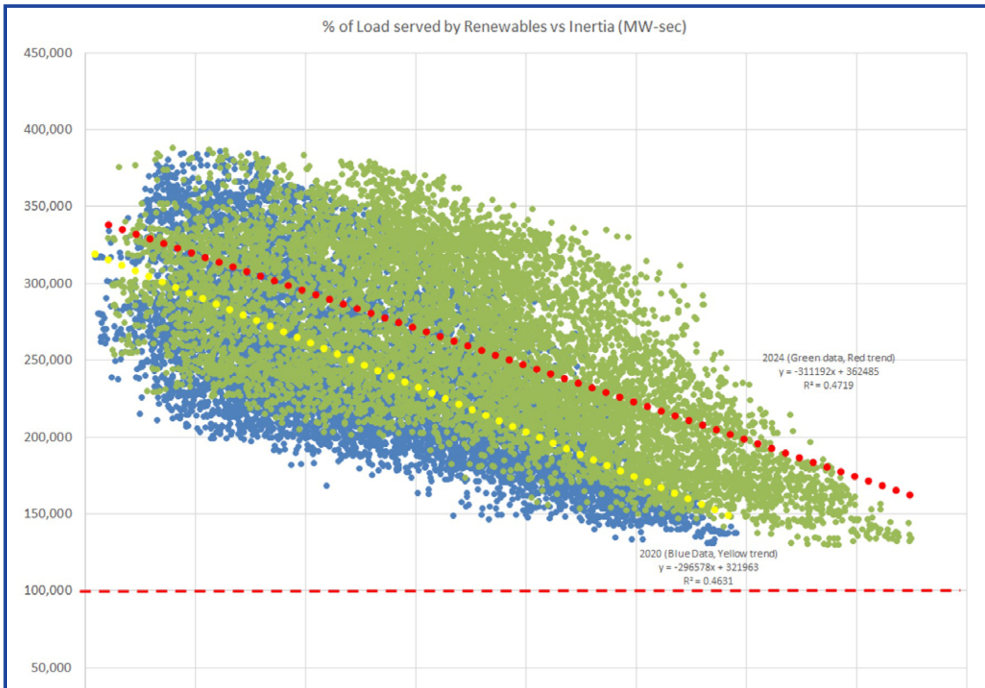


hourly inertia level in 2024 was 129.9 GWs on March 29, 2024, at HE04 when the intermittent renewable resource (IRR—i.e., solar and wind generation) penetration level was 68.1 percent and system load was 37,297 MW (net load of 11,912 MW).

The chart to the right shows the relationship between the percentage of load served by renewables and system inertia levels. The chart compares 2020 versus 2024. It shows how the 2024 slope of the regression trend line has shifted and flattened as renewable penetration levels increased.

CHANGING RESOURCE MIX

2024 HIGHLIGHTS FROM THE ANALYSIS OF CHANGING RESOURCE MIX INCLUDE:



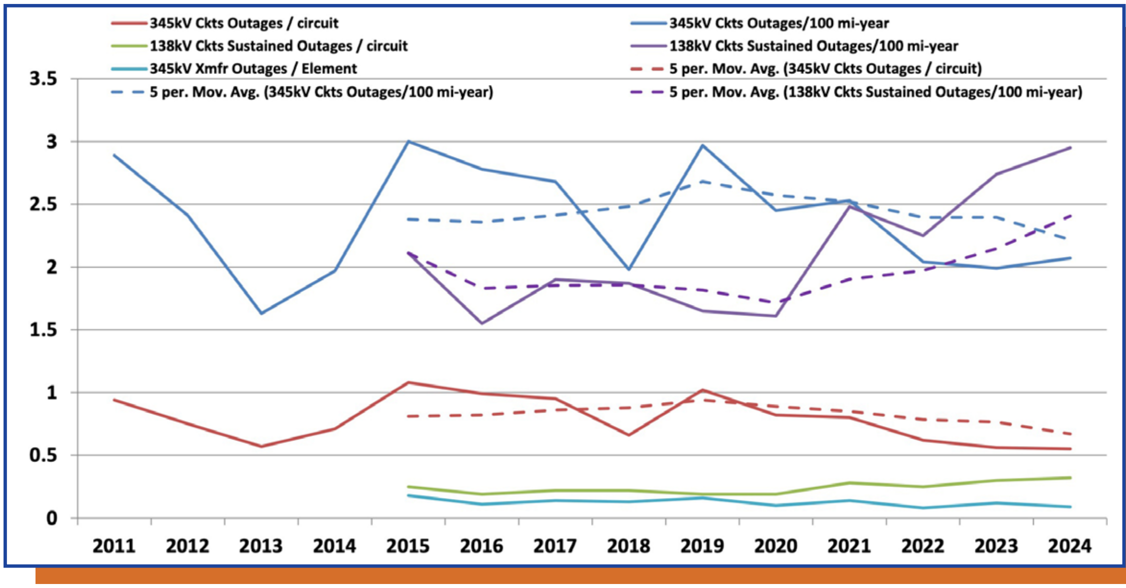
- Overall inertia levels in 2024 showed minor change and remained in line with historical norms from the 2017-2020 period.
- Wind and solar curtailments increased in 2024 with long-term curtailment trends continuing to show an increasing rate, particularly for solar generation.

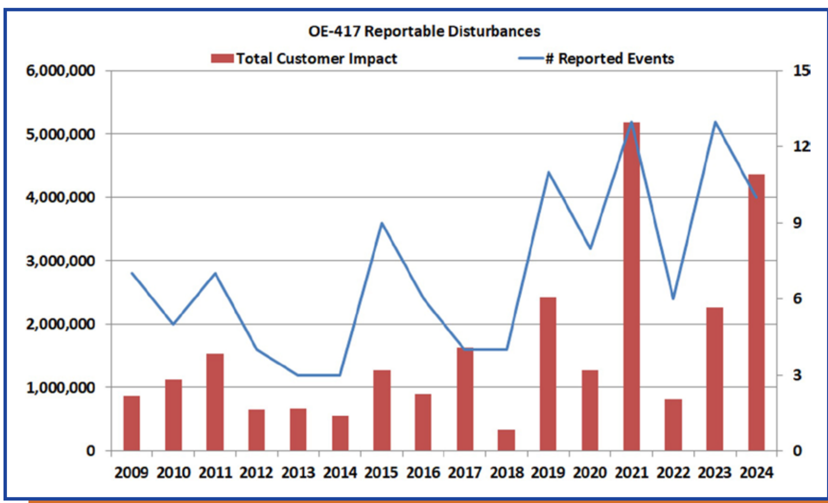
AREAS TO MONITOR INCLUDE:

- The ratio of dispatchable generation to renewable generation is changing rapidly. In 2024, almost 11,400 MW of renewable generation and storage resources were approved for commercial operation.
- Maximum one-hour ramp magnitudes for solar generation are increasing, approaching 12,000 MW per hour. Increased solar penetration will continue to stress the system during solar down-ramp periods and may require more flexible resource capability and ancillary services.
- Low voltage ride-through issues for wind and solar inverters is occurring during transient voltage disturbances on the transmission system. Ongoing implementation of NOGRR245 and NERC PRC standards is expected to reduce the magnitude and impact from these events.

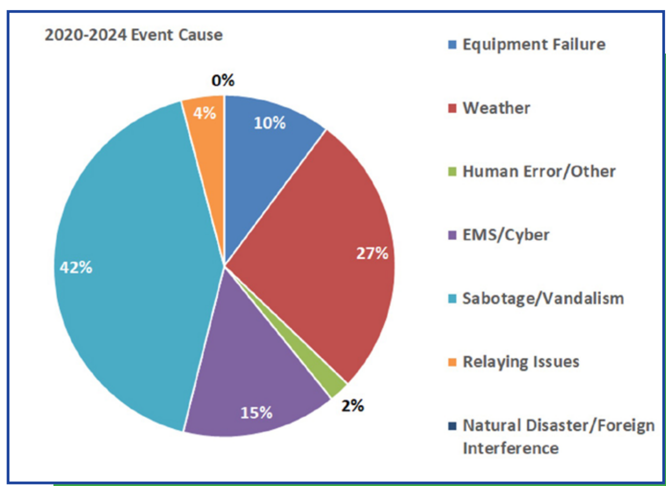
RESILIENCE TO EXTREME EVENTS

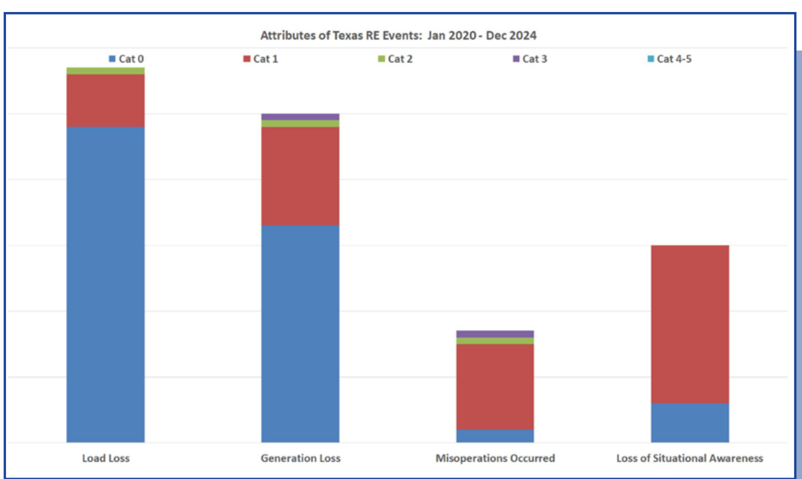
345 kV circuit automatic outage rates remained flat near the five-year moving average. 138 kV circuit outage rates increased in 2024 to its highest level in the last five years. As in prior years, duration of sustained outages was primarily due to failed substation or circuit equipment.





2024 was the second highest level of customer outages in the last fifteen years due to the Hurricane Beryl and Derecho events.





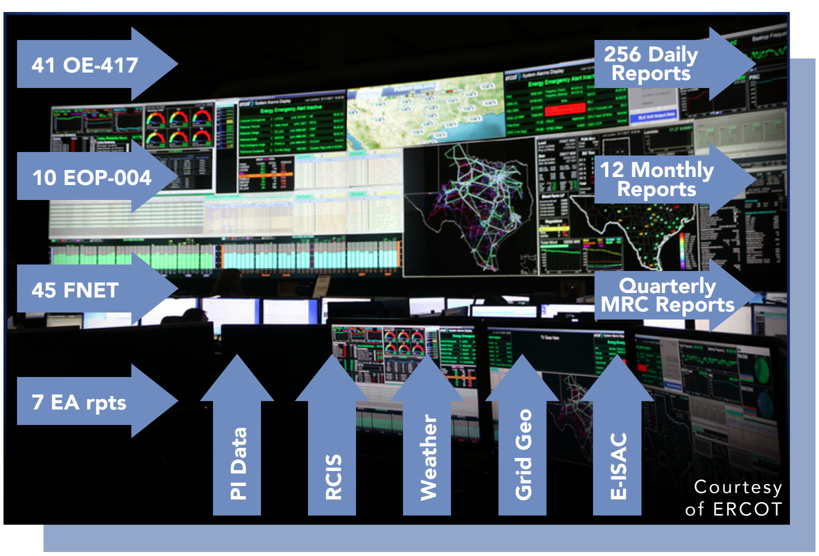
Equipment failure and weather continue to drive major events. Physical intrusions and damage reports have increased significantly.

RESILIENCE TO EXTREME EVENTS

Multiple extreme events in recent years have tested the transmission grid's ability to maintain the reliability levels expected by Texans. These include Hurricane Harvey in August 2017, the cold weather event of January 2018, the Panhandle ice storm of October 2020, Winter Storm Uri in February 2021, Winter Storm Elliott in December 2022, and Winter Storm Heather in January 2024. Generation system outage performance on extreme days in 2018, 2021, 2022, and 2024 have been related to cold weather events.

Date	Number of Generation Outage Events on Extreme Day	Leading Causes for Extreme Day	Cumulative Outage Duration on Extreme Day	Cumulative MW Impact on Extreme Day	Cumulative GWh Impact on Extreme Day
8/27/2017	41	Weather	22,798 Hours	10,107 MW	2,917.5 GWH
1/16/2018	84	Balance of Plant/Fuel	2,891 Hours	11,893 MW	517.8 GWh
5/11/2019	36	Turbine Generator	1,626 Hours	6,449 MW	282.5 GWh
7/1/2020	44	Auxiliary Systems	3,352 Hours	8,251 MW	247.9 GWh
2/15/2021	187	Weather	6,937 Hours	35,241 MW	1,204.1 GWh
12/23/2022	164	Weather	2,180 Hours	23,163 MW	321.8 GWh
1/30/2023	65	Turbine Generator/Fuel	2,745 Hours	9,327 MW	332.4 GWh
1/15/2024	92	Fuel, Weather	916 Hours	10,200 MW	89.6 GWh

Examination of reported transmission outage data over time shows that rates trend in a consistent range and the relative order of causes have not changed significantly for both 345 kV and 138 kV systems. Failed transmission circuit and substation equipment continued to be the dominant causes of sustained outages' duration, accounting for 74 percent of the 345 kV and 61 percent of the 138 kV sustained outages' duration, respectively, from 2020 through 2024.



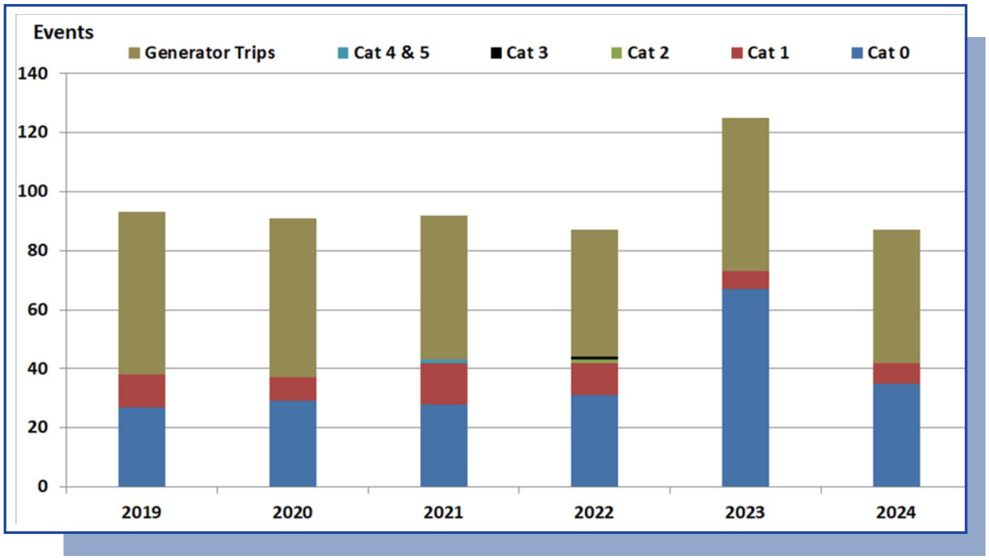
In 2024, Texas RE analyzed 87 BPS events which was on par with historical values. In total, 485 events were reviewed between 2020 and 2024. Of the 418 root and contributing causes identified, the "Equipment/Material" category occurred most frequently with 40 percent of all identified causes. "Design/Engineering" was second with 17 percent, followed closely by "Management/ Organization" with 10 percent. The number of Category 1 events has been stable over the last five years.

RESILIENCE TO EXTREME EVENTS

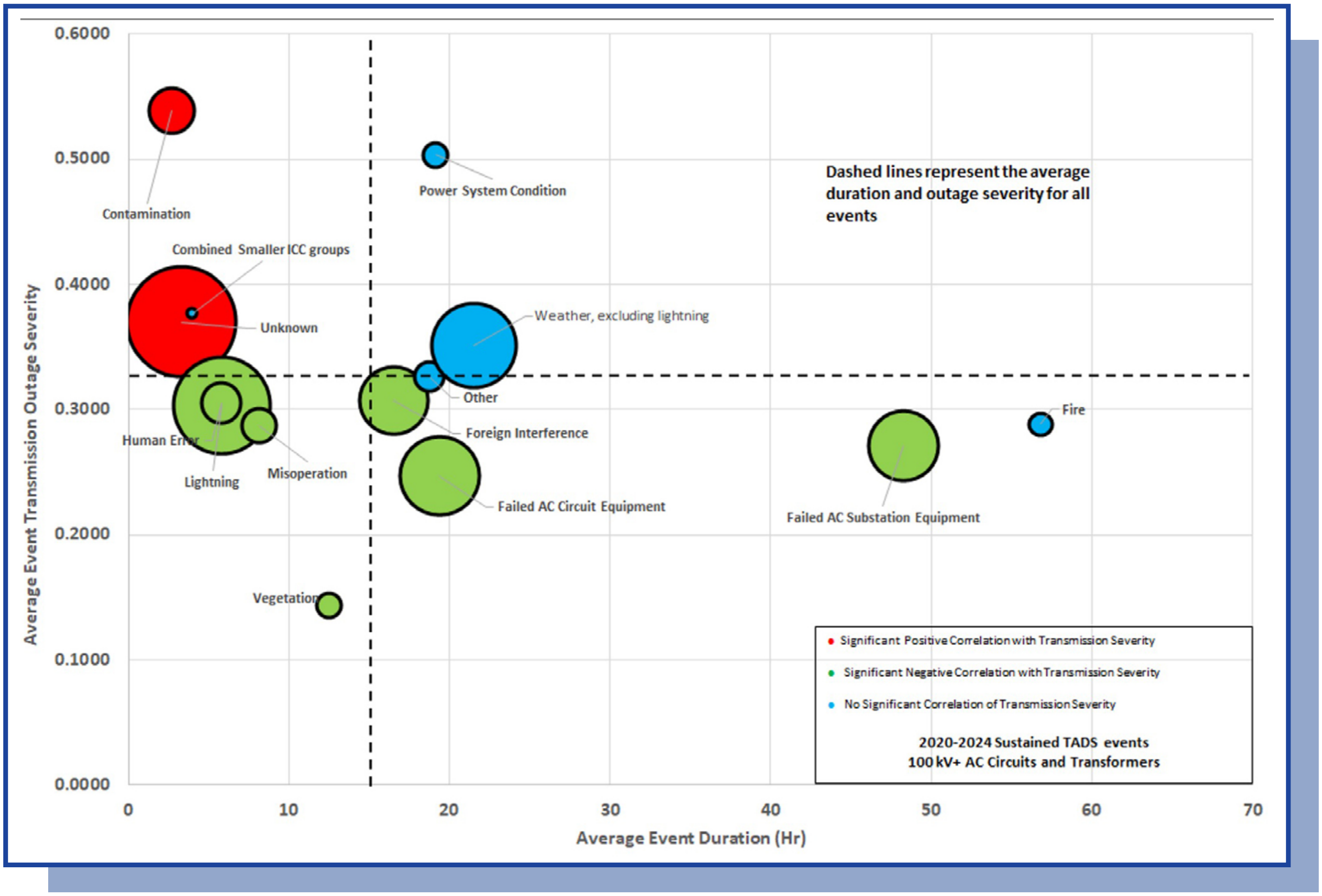
485 Events Analyzed

418 Root and Contributing Causes Identified

Qualified event attributes dominated by:
- Load Loss
- Generation Loss
- Physical Security Events



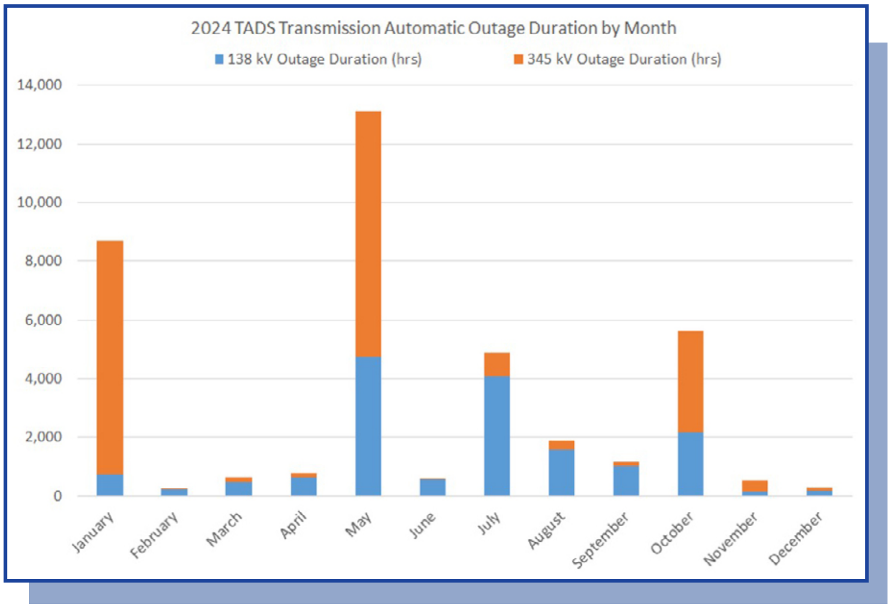
Transmission outage severity, as measured by the cumulative ratings of the circuit(s) unavailable due to outage (expressed in megavolt-amperes (MVA)) and duration of the outage, is one measure of transmission system resilience. Outage severity can be further broken down by the causes of the sustained outages.



RESILIENCE TO EXTREME EVENTS

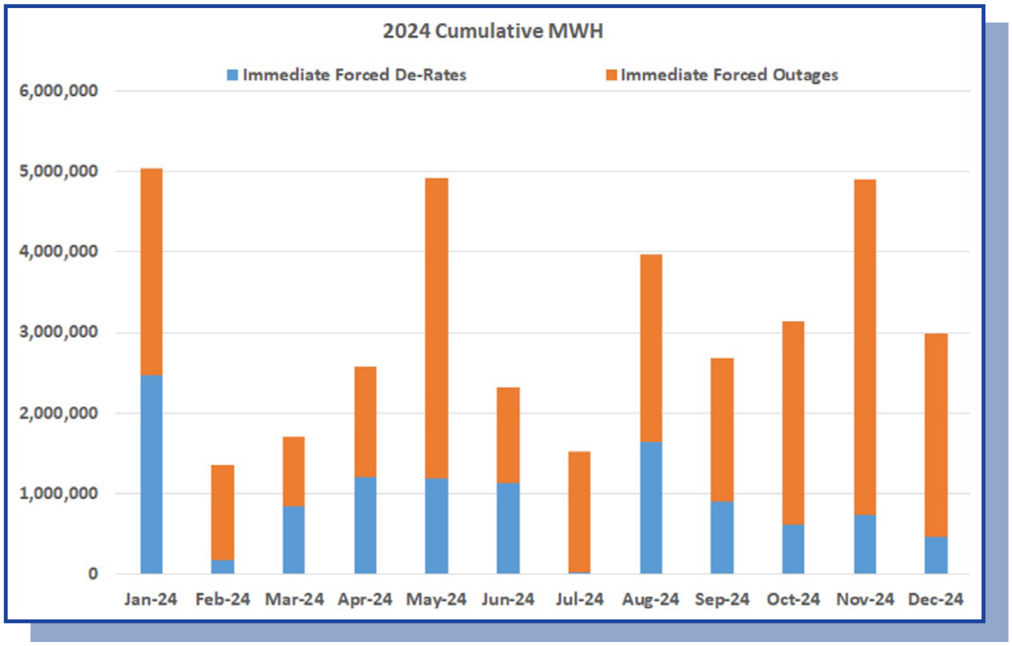
2024 HIGHLIGHTS FROM THE ANALYSIS OF RESILIENCE INCLUDE:

- Long-term trends are indicating stability in outage rates per circuit and per 100 miles of line for the 345 kV and 138 kV systems, although the 138 kV circuit outage rates have increased for two consecutive years in 2024 to its highest level in the last five years.
- For 345 kV transmission circuits, predominant causes for sustained outages in 2024 were weather (excluding lightning), lightning, unknown, and failed substation equipment, representing 61 percent of the total sustained outages. Failed transmission circuit equipment accounted for nine percent of the outage count, but 75 percent of the outage duration.
- For 138 kV transmission circuits, predominant causes for sustained outages in 2024 were weather (excluding lightning), lightning, foreign interference, failed circuit equipment, and unknown, representing 74 percent of the total sustained outages. Failed transmission circuit equipment and failed substation equipment accounted for 60 percent of the outage duration.



AREAS TO MONITOR:

- Weatherization of generation resources will continue to be a primary focus for the foreseeable future.
- Implementation of new NERC Reliability Standard requirement changes to improve voltage ride-through for IBRs will be a primary focus in 2025.
- Significant weather events in 2024 (Hurricane Beryl and the Houston Derecho) led to a significant increase in customer outages compared to prior years. 2024 was the second highest level of customer outages in the last fifteen years.
- Physical security events increased significantly in 2024, led by increases in intrusions and copper theft.



SECURITY RISKS

Critical infrastructure protection demands high vigilance for the reliability and security of the electric grid. In 2024, BPS facilities in the Region experienced minimal impact from cyber and physical security events. Notable risks occurring outside the electric industry and the Region included ransomware, social engineering, cloud security, and AI powered threats. Foreign state-sponsored advanced persistent threats continued to present challenges in 2024.

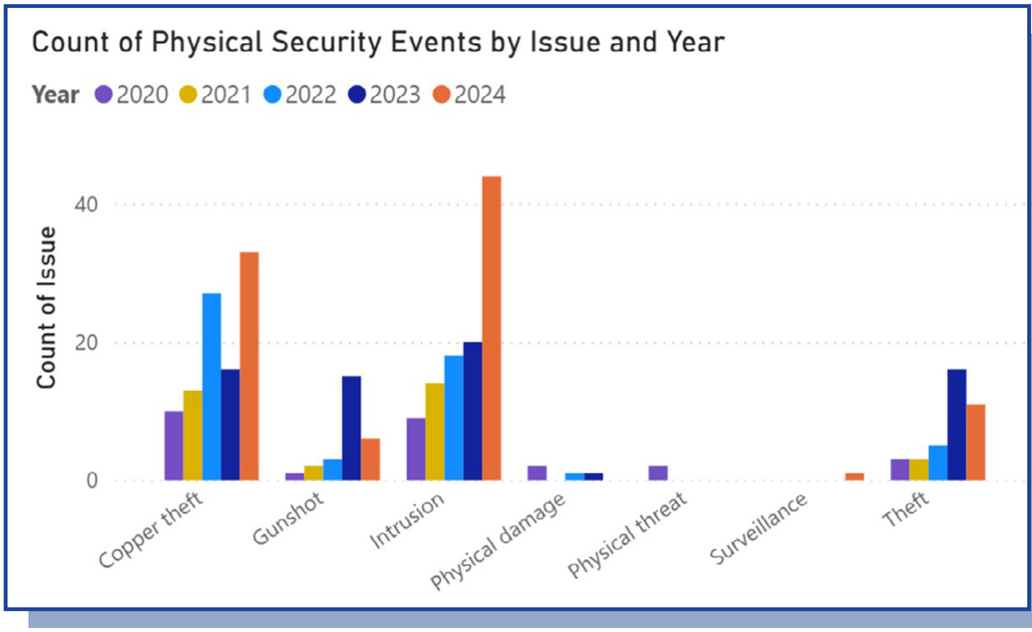
2024 CYBER AND PHYSICAL SECURITY INITIATIVES AND RISKS INCLUDED:

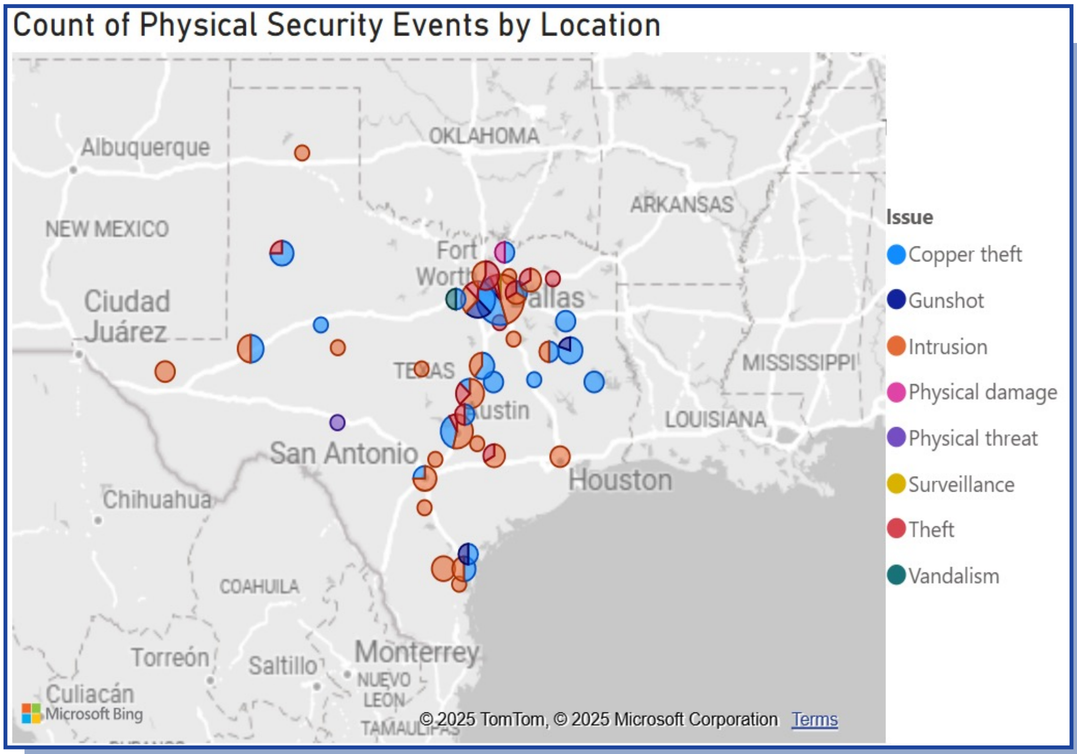
- February 2024 – The Office of the Director of National Intelligence (DNI) released the Annual Threat Assessment of the U.S. Intelligence Community highlighting competitive behaviors and disruptive technology (such as AI) that threaten U.S. national security from state actors Iran, North Korea, Russia, and China.
- April 2024 – The PUCT approved NPRR1199 from ERCOT that introduced new reporting requirements for market participants, mandating that they attest to whether they have acquired equipment or services from companies based in or owned by citizens of China, Russia, North Korea, Iran, or any other country designated by the governor per the Lone Star Infrastructure Protection Act (LSIPA).
- August 2024 – The Office of the Director of National Intelligence National Counterintelligence and Security Center released the National Counterintelligence Strategy that provided strategic direction for the next three years to include protecting critical infrastructure and reducing risks to key U.S. supply chains.
- June 2024 – President Biden issued Executive Order 14123 establishing the White House Council on Supply Chain Resilience.
- February 2024 – The Cybersecurity and Infrastructure Security Agency (CISA) released Malware Analysis Report 10448362.c1.v2 regarding files analyzed by CISA related to the Chinese state-sponsored cyber group known as Volt Typhoon.
- The Department of Energy (DOE), along with CISA, the National Security Agency (NSA), and the Federal Bureau of Investigation (FBI), issued joint cybersecurity advisories including:
  - Joint Cybersecurity Advisory – AA24-038A: PRC State-Sponsored Actors Compromise and Maintain Persistent Access to U.S. Critical Infrastructure
  - Joint Cybersecurity Advisory – AA24-057A: SVR Cyber Actors Adapt Tactics for Initial Cloud Access
  - Joint Cybersecurity Advisory – AA24-207A: North Korea Cyber Group Conducts Global Espionage Campaign to Advance Regime's Military and Nuclear Programs
  - Joint Cybersecurity Advisory – AA24-241A: Iran-based Cyber Actors Enabling Ransomware Attacks on US Organizations
  - Joint Cybersecurity Advisory – AA24-249A: Russian Military Cyber Actors Target US and Global Critical Infrastructure
  - Joint Cybersecurity Advisory – AA24-290A: Iranian Cyber Actors' Brute Force and Credential Access Activity Compromises Critical Infrastructure Organizations
  - Joint Cybersecurity Advisory – AA24-317A: 2023 Top Routinely Exploited Vulnerabilities

SECURITY RISKS

2024 PHYSICAL SECURITY EVENTS AFFECTING BPS FACILITIES:

- Transformer outage when control cables were cut and stolen from a cable tray.
- Multiple transmission lines damaged due to gunfire.
- Transformer radiator damage and oil leak due to gunfire.
- Primary protective relaying and communications affected due to cut fiber optic cable.
- Individuals drove through the gate at a coal power plant after being instructed by security to turn around.
- Multiple wind turbines damaged by gunfire.





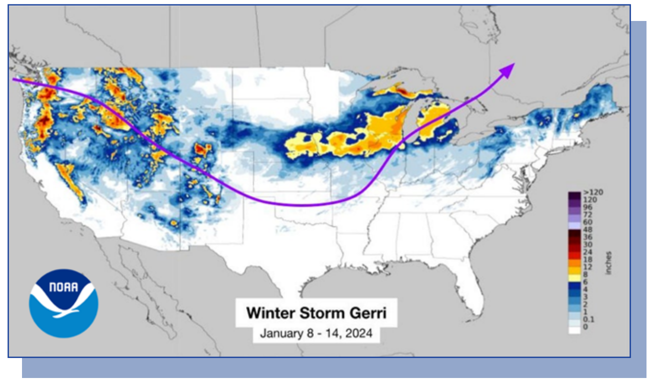
AREAS TO MONITOR INCLUDE:

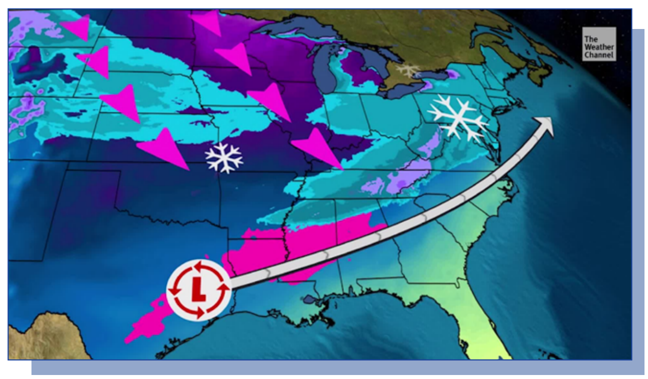
- Physical security events, particularly intrusion and copper theft, increased significantly in 2024.

CRITICAL INFRASTRUCTURE INTERDEPENDENCIES

In April 2024, FERC released a system performance review of the arctic storms that occurred in January 2024, known as Winter Storm Gerri and Heather (System Performance Review of the January 2024 Arctic Storms). Major takeaways from the review included positive steps taken by natural gas entities to improve preparation for extreme cold weather, highlighting improved communication and coordination, as well as improved gas generator stability. Other items noted in the review included:

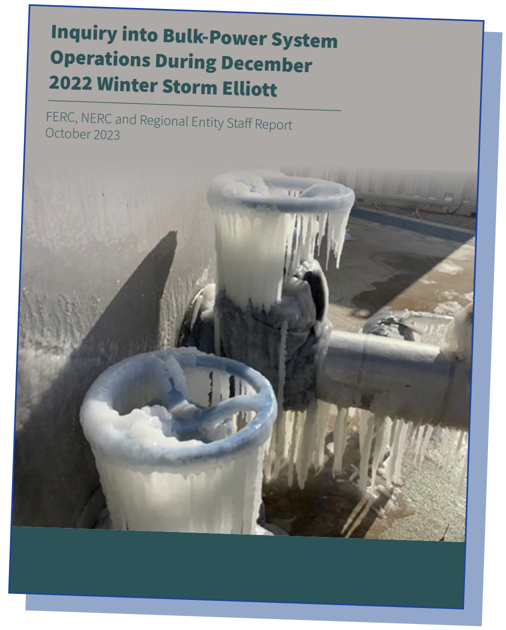
- Natural gas entities communicated system conditions ahead of and during Winter Storms Gerri and Heather throughout their organizations and to shippers.
- Natural gas entities emphasized steps they took to prepare for and operate through Winter Storms Gerri and Heather:
  - Reviewing their entire system to determine needed enhancements and modifications to improve performance during extreme cold weather
  - Communicating with external entities that could be impacted by operations
  - Implementing cold weather protection measures
  - Training staff on emergency response procedures
  - Ensuring adequate staffing levels
  - Testing key compressor stations
- Diversely routed networks could add resiliency to the vulnerabilities seen in communication during Winter Storms Gerri and Heather.
- FERC staff's observations from the natural gas entities are consistent with implementation of recommendations 5 through 8 from the Winter Storm Uri report, recommendations 4 through 7 from the Winter Storm Elliott report, and recommendations 2a and 2b from the recent Blackstart Availability Study.





Winter Storm Heather
January 15, 2024

CRITICAL INFRASTRUCTURE INTERDEPENDENCIES



Of the remaining recommendations from prior cold weather reports, more work needs to be done to improve natural gas cold weather preparedness and gas-electric coordination to reliably support the Bulk Electric System.

Follow-up also continues on two reports from FERC that were issued in 2023 and highlighted the critical interdependency between the natural gas and electric industries. These were the FERC, NERC, and Regional Entity Staff Inquiry into Bulk Power System Operations during December 2022 Winter Storm Elliott, released in October 2023, and FERC, NERC, and Regional Entity Staff Study on Blackstart and Next-Start Resource Availability in the Texas Interconnection, released in December 2023.

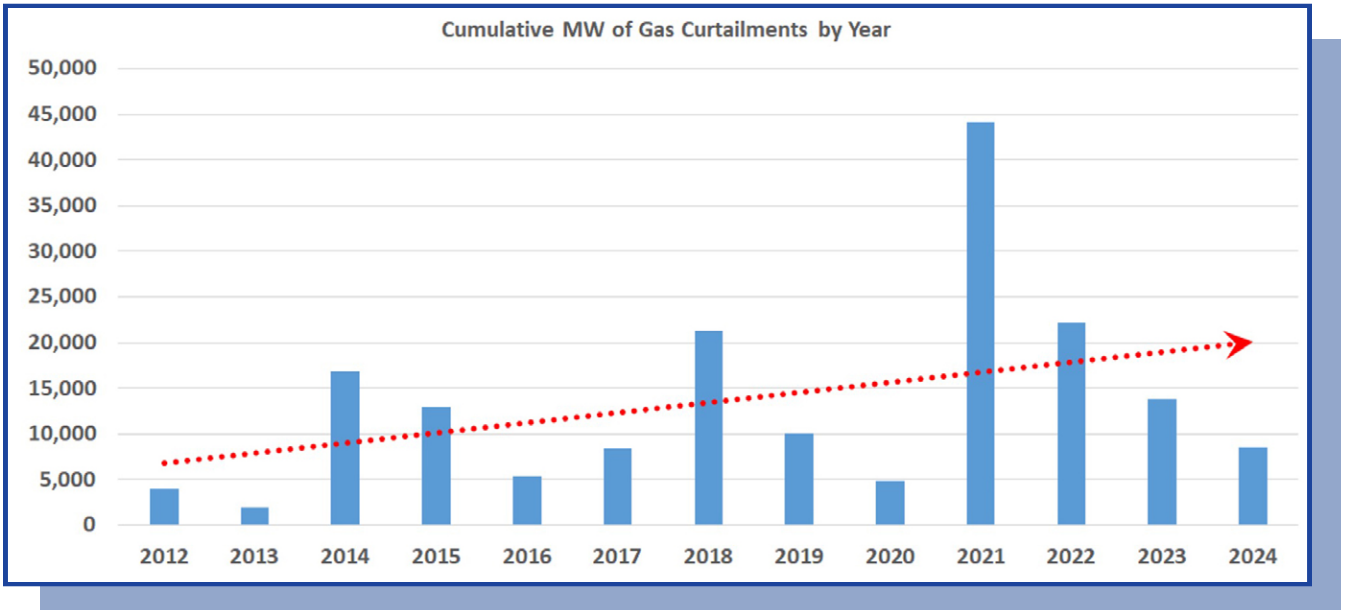
THE KEY RECOMMENDATIONS FROM THESE TWO REPORTS INCLUDE THE FOLLOWING:

1. Because extreme cold weather events have repeatedly impaired the production, gathering, processing, and transportation of natural gas, reliability rules for natural gas infrastructure should (from wellhead through pipeline) require cold weather preparedness plans, freeze protection measures, and operating measures when extreme cold weather periods are forecast, and during the extreme cold weather periods.
2. Reliability rules suggested should address the need for regional natural gas communications coordinators (with situational awareness of the natural gas infrastructure similar to the grid's Reliability Coordinators) that can share timely operational communications throughout the natural gas infrastructure chain and communicate potential issues to, and receive grid reliability information from, grid reliability entities.
3. Reliability rules should address the need to require natural gas infrastructure entities to identify those natural gas infrastructure loads that should be designated as critical for priority treatment during load shed and provide criteria for identifying such critical loads.
4. An independent research group (e.g., selected National Laboratories from the Department of Energy), should perform one or more studies to analyze whether additional natural gas infrastructure, including interstate pipelines and storage, is needed to support the reliability of the electric grid and meet the needs of natural gas Local Distribution Companies. The study should include information about the cost of the infrastructure buildout.
5. Authorities should assess the impact of a blackout on the natural gas supply chain with a focus on natural gas availability to blackstart and next-start resources. This assessment could help the electric and natural gas industries better understand what action is required in a blackout and which electric and natural gas entities are vital for blackstart system restoration.
6. Entities necessary for blackstart system restoration should develop a coordinated blackstart system restoration plan that incorporates the needs of both the electric and natural gas industries. The entities should work collaboratively to develop this plan and should prioritize the natural gas infrastructure required to supply natural gas to the blackstart, next-start, and other essential resources. This plan could help ensure a more coordinated blackstart system restoration between the electric and natural gas industries.

CRITICAL INFRASTRUCTURE INTERDEPENDENCIES

2024 HIGHLIGHTS FROM THE ANALYSIS OF CRITICAL INFRASTRUCTURE INTERDEPENDENCIES INCLUDE:

- Gas curtailments continued to decline in 2024 compared to 2022 and 2023.
- Seven generators at four sites reported immediate de-rates in 2024 due to water conservation during Winter Storm Heather. Total derate capacity was 114 MW for 36 hours.
- A Generator Operator reported loss of monitoring capability due to the CrowdStrike incident.
- A Transmission Operator reported loss of monitoring and control due to loss of external ICCP links.
- A wind generator plant control was lost due to ransomware attack.



KNOWN & EMERGING RISKS FOR 2025

Texas RE continuously evaluates existing and emerging risks to the interconnection. The risk priorities and focus areas for 2025 are summarized by likelihood and impact in the risk matrix and discussion below.

OVERALL RISK IDENTIFICATION

Risk areas were identified based on the North American-wide risks identified in the August 2023 NERC Reliability Issues Steering Committee (RISC) [ERO Reliability Risk Priorities] report. Additional risk areas were identified based on review of geographical, regional, and entity-specific exposure (e.g. severe weather and high concentrations of variable generation).

IMPACT OR CONSEQUENCE

Was assessed by evaluating the potential for widespread or localized effects on the operation of the BPS.

How could a typical event affect BPS reliability?

SEVERE	Widespread effects across North America
MAJOR	Widespread effects across an RC area
MODERATE	Widespread effects across multiple entities or a portion of an RC area
MINOR	Effects on one entity
NEGLIGIBLE	Small or non-existent effects

LIKELIHOOD

Was assessed by evaluating three criteria:

- Are mandatory controls in place to mitigate the risk?
- Are there occurrences, or the likelihood of an occurrence, increasing?
- Are there any documented cases of the risk?

What is the reasonable probability that the event will occur?

	MANDATORY CONTROLS	EMERGING TRENDS	EVENT HISTORY
ALMOST CERTAIN	No NERC Reliability Standards in place for mitigation	Increasing trends have been identified	Widely publicized and documented events have been recorded
LIKELY	No NERC Reliability Standards in place for mitigation	Some trends have been identified	Generally publicized events have been recorded
POSSIBLE	NERC Reliability Standards in place for limited mitigation	Some trends have been identified	Moderate or no documented events have been recorded
UNLIKELY	NERC Reliability Standards in place for mitigation	Some trends have been identified	Minimal or no documented events have been recorded
VERY UNLIKELY	NERC Reliability Standards in place for mitigation	No trends have been identified	No documented events have been recorded

OVERALL SCORE

Based on the likelihood and impact, each risk was assigned an overall score.

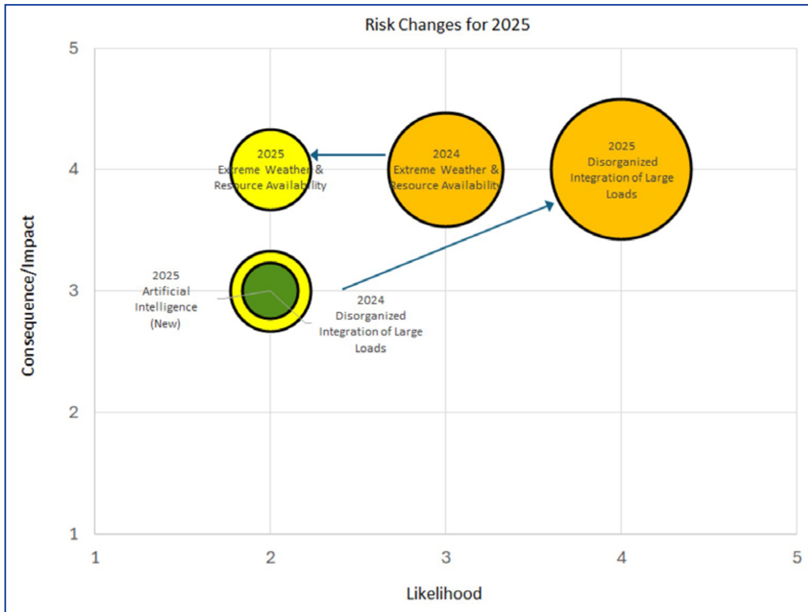
LOW	Low risk area
MEDIUM	Medium or moderate risk area
HIGH	High risk area
SEVERE	Severe risk area

RISK LEVEL			
LOW	MODERATE	HIGH	VERY HIGH

CONSEQUENCE/ IMPACT		LIKELIHOOD (L)				
		L1	L2	L3	L4	L5
		VERY LIKELY	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
C5	SEVERE					
C4	MAJOR			Supply Chain		
				Energy Availability	Disorganized Integration of Large Loads	
			Extreme Weather & Resource Weatherization	Gas Supply Restrictions During Cold Weather	IBR Ride-Through	
C3	MODERATE		Provision of Essential Reliability Services from a Changing Resource Mix	Remote Access		
			Facility Ratings	Inaccurate Resource Modeling		
			Artificial Intelligence		Physical Security	
C2	MINOR					
C1	NEGLIGIBLE					

NEW RISKS FOR 2025

Several changes were identified for the risk focus areas from last year to 2025. These include upgrading the risk category for "Disorganized Integration of Large Loads" from Unlikely/Moderate to Likely/Major and downgrading the risk category for "Extreme Weather & Resource Weatherization" from Possible/Major to Unlikely/Major. A new risk focus area for 2025 is "Artificial Intelligence". All risk focus areas are further described below.



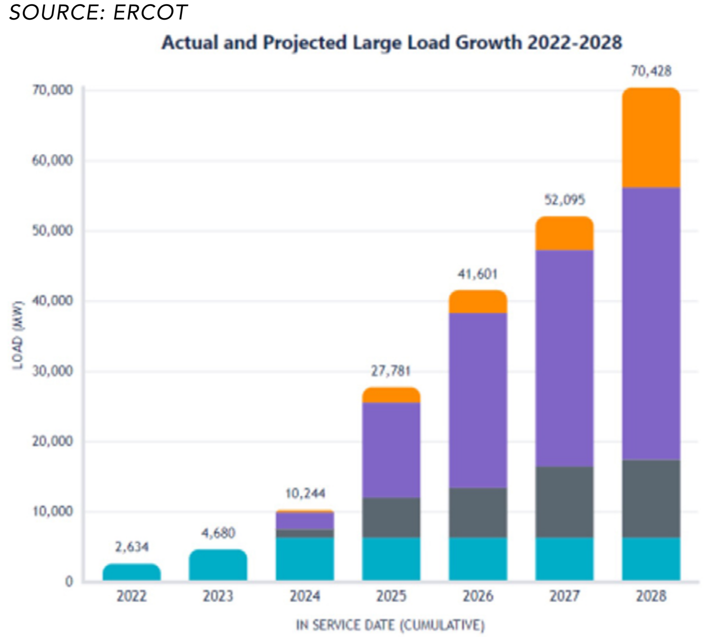
ARTIFICIAL INTELLIGENCE (AI)

Likelihood: ***UNLIKELY*** **// Impact:** ***MODERATE***

AI in the electric utility industry, while promising, carries risks that demand robust mitigation strategies including: cybersecurity vulnerabilities, data privacy, algorithmic errors, and potential for misuse. For example, cybersecurity vulnerabilities can be exploited faster with AI-powered tools and systems enhancing autonomous and adversarial cyberattacks, adaptive malicious code that could bypass security controls, and data poisoning. Effective data privacy controls must be implemented to reduce the risk of data breaches because AI systems use massive amounts of data collection and typically include confidential and/or sensitive information.

AI systems (particularly those relying on complex algorithms) rely on copious amounts of energy in addition to the direct cybersecurity concerns. ERCOT is forecasting significant increases in load over the near-term and medium-term horizons, driven in part by the increased use of AI-based technologies. As state and federal policymakers and grid operators develop new rules for large load interconnection and performance, AI data centers will need to be integrated in a reliable fashion.

SOURCE: ERCOT



Given these dual emerging risks associated with AI, Texas RE created a new Regional risk for "Artificial Intelligence." Texas RE currently assesses that AI integration risks could have a moderate impact on the Region but are currently relatively unlikely to manifest themselves. As AI increases in scale and integration, however, associated risks may increase in both likelihood and impact. Texas RE will be monitoring developments in this area.

GRID TRANSFORMATION

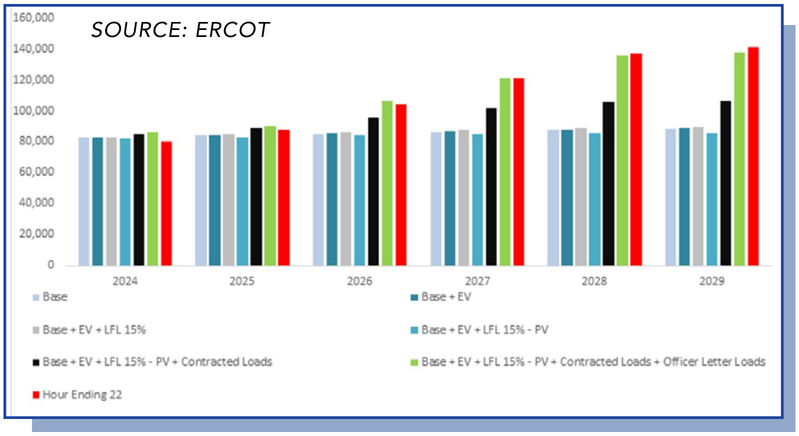
DISORGANIZED INTEGRATION OF LARGE LOADS [INCREASED RISK FOR 2025]

Likelihood: *LIKELY* // **Impact:** *MAJOR*

ERCOT has experienced rapid load growth with data centers, bitcoin mining, and other crypto loads. Current large load interconnection request queues indicate such load totals could reach up to 70,500 MW by the end of 2028. As of December 2024, 6,297 MW have been approved to energize, and 1,256 MW had their planning studies approved by ERCOT. The remaining loads are undergoing ERCOT review or have had no studies submitted. While a number of these resources will likely not materialize, the rapid increase in load on the system presents significant forward-looking challenges.

These load increases reflected in future reserve estimates have been striking. As noted elsewhere in this report, ERCOT's CDR indicates that Planning Reserve Margins for 2025 through 2029 decrease significantly from year to year, and cross over to negative values in 2026 or 2027 (depending on the season). This is largely driven by the incorporation of large loads into these forecasts, reflecting the potential challenges faced by the Region in the short and medium terms.

Integration of these loads has also resulted in modifications to existing methodologies (such as that of the load forecasts) to capture aspects of flexibility and price responsiveness more accurately. This is demonstrated by a new assumption in the long-term load forecast that accredits large flexible loads at 15 percent curtailment assumption during on-peak hours. Efforts are being made to further improve the accuracy of these forecasts and incorporate bitcoin mining economic models to better predict load ramps due to price response.



Texas RE has increased the risk associated with the disorganized (that is, unmitigated) integration of large loads given the pace and scope of load integration in the Region, as well as forecasts of negative reserve margins beginning as soon as 2026. Texas RE is now forecasting that large load integration will likely have a major impact on BPS reliability.

Consistent with this view, state and federal policymakers are responding with a broad range of activities to understand load risks and implement sound approaches to ensure large loads are reliably integrated onto the grid. NERC and the Regions initiated a Large Load Task Force (whose scope is to identify the unique characteristics and risks of large loads) in 2024 to identify gaps and potential risk mitigation. The work plan for the Large Load Task Force in 2025 includes publishing two whitepapers covering characteristics and risks of emerging large loads, and an assessment of gaps in existing practices, requirements, and Reliability Standards for large loads. Texas RE is monitoring these activities and supporting outreach efforts throughout the coming year around large load integration.

INVERTER-BASED RESOURCES RIDE-THROUGH

Likelihood: *LIKELY* // **Impact:** *MAJOR*

Efforts to reduce risks from IBRs continued to evolve and expand in 2024. At the state level, ERCOT has taken great strides to reduce the risk posed by IBR disturbances, particularly through the adoption of more

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stringent voltage and frequency ride-through requirements. As these new ride-through requirements are being implemented, legacy resources are implementing software fixes and other mitigation measures to maximize their ride-through capabilities while mitigating ride-through risks.
At the national level, NERC Reliability Standards directives mandated by FERC Order No. 901 progressed substantially in 2024 and will continue through 2026. In 2024, NERC filed new IBR NERC Reliability Standards for disturbance monitoring (PRC-028-1), IBR frequency and voltage ride-through requirements (PRC-029-1), and unexpected IBR event mitigation (PRC-030-1). At the time of Texas RE's risk analysis, FERC has approved PRC-028 and PRC-030 but is still considering the proposed PRC-029 requirements.

Balanced against these positive developments, Texas RE continues to observe disturbances in the Texas Interconnection related to IBR ride-through issues. Specifically, seven disturbances associated with IBR ride-through issues occurred throughout 2024. Beyond the Region itself, WECC also documented four large IBR disturbances in 2024 that met the NERC Event Analysis criteria, with the largest being a loss of 1,046 MW. These events involved normally cleared transmission faults, similar to the Odessa events. Texas RE also observed an increased number of unit oscillations in real time that were detected by SCADA or phasor measurements.

The Region increasingly relies on IBRs to meet load with wind and solar serving 34.8 percent of total energy in 2024 and a peak hourly penetration of nearly 75 percent in March. Solar in particular now plays a key role in providing energy during the Region's summer peak demand hours—total energy from solar generation has increased 996 percent over the past five years. Moreover, as solar resources ramp down in the evening, batteries now provide critical energy to maintain sufficient generation. IBR resources need to be able to reliably operate as the Region's overall reliance on them grows, and ride-through frequency and voltage events correspondingly increase. Texas RE is emphasizing IBRs in its outreach and compliance.

INACCURATE RESOURCE MODELING

Likelihood: ***POSSIBLE*** **// Impact:** ***MODERATE***

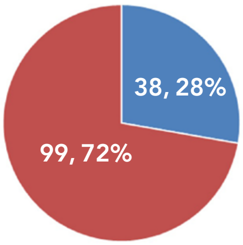
The ERO Enterprise has released multiple detailed disturbance reports related to IBR performance over the last several years. They found that IBR facilities have technical capabilities that require a deeper understanding (such as the lack of sufficient ride-through capability to support the BPS for fault events). In addition, the reports also discussed that system planning assessments need to accurately capture these types of systemic performance issues. Planning Coordinators and Transmission Planners are modifying processes and tools to better model the contribution of IBRs to reliable operations.

In June 2024, NERC issued a Level 2 Alert on Inverter-Based Resource Model Quality Deficiencies. The purpose of the alert was to gather information from BES-connected IBRs to understand the extent of

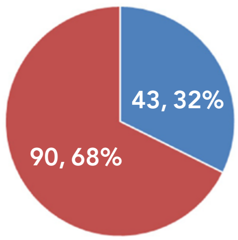
GRID TRANSFORMATION

condition of IBR dynamic modeling to inform mitigations for observed deficiencies. The data collection effort included responses from over 1,600 generation facilities, seventeen different inverter manufacturers, and over 185,000 MW of wind, solar, and battery storage capacity. Within ERCOT, data was collected from over 375 generation facilities and over 53,000 MW of wind, solar, and battery storage capacity. Responses to the alert indicate that approximately 70 percent of ERCOT units have field settings that do not match model parameters for low voltage ride-through, high voltage ride-through, and regulation droop. 90 percent of ERCOT units have field settings that do not match model parameters for frequency deadband settings. Approximately 60 percent of ERCOT units do not set protection settings based on the maximum capability of the inverter.

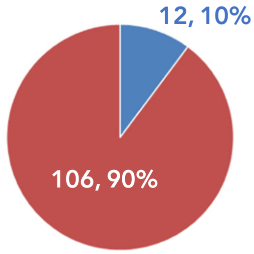
High Voltage Threshold Settings Model vs Reported	# of Facilities	%
As-left control setting matches model parameter	38	28%
As-left control setting does not match model parameter	99	72%
Total	137	100%



Low Voltage Threshold Settings Model vs Reported	# of Facilities	%
As-left control setting matches model parameter	43	32%
As-left control setting does not match model parameter	90	68%
Total	133	100%



Frequency Deadbands Model vs Reported	# of Facilities	%
As-left control setting matches model parameter	12	10%
As-left control setting does not match model parameter	106	90%
Total	118	100%



As-left control setting matches model parameter
As-left control setting does not match model parameter

Recent issuances from FERC also focus on modeling inverter-based resources. FERC Order No. 901 directed NERC to develop new or modified Reliability Standards, including ones that address reliability gaps related to IBRs in model validation and planning. FERC Order 2023 requires asynchronous generating facility interconnection requests to provide the Transmission Provider with the models needed for accurate interconnection studies. In 2023, the Reliability and Security Technical Committee (RSTC) released two Reliability Guidelines: EMT for BPS Connected Inverter-Based Resources—Recommended Model Requirements and Verification Practices and Performance, Modeling, and Simulations of BPS-Connected Battery Energy Storage Systems and Hybrid Power Plants. The ERO Enterprise encourages registered entities to implement the recommendations contained within each Reliability Guideline to support reliable operations.

As with the IBR ride-through requirements discussed elsewhere, efforts to reduce risks from inaccurate IBR modeling continued to evolve and expand in 2024. ERCOT approved changes to its planning guides to establish new requirements for dynamic modeling of IBRs. At the federal level, standards development efforts in 2025 are addressing IBR modeling issues as part of the FERC Order No. 901 Milestone 3 activities.

GRID TRANSFORMATION

ENERGY AVAILIBILITY

Likelihood: ***POSSIBLE*** **// Impact:** ***MAJOR***

Energy availability risks continue to reflect the rapid transformation of the Region from one dominated by large, synchronous generating resources to the fastest growing energy resource in the Region—variable, IBR-based resources. Traditional capacity-focused reliability metrics are no longer sufficient to capture the resource adequacy risks of weather-dependent resources.

State policymakers have undertaken a number of important mitigation measures to understand and address energy availability issues driven by this changing resource mix. The PUCT and ERCOT developed an innovative Region reliability standard that shifts the focus from capacity constructs to one focusing on expected unserved energy. The new reliability standard establishes reliability thresholds around three variables: the likelihood of a reliability issue, the expected duration of the issue, and the magnitude of the impact.

Building upon these Regional initiatives, energy-focused models and standards are an increasing area of focus on the national level. The ERO Enterprise is enhancing reliability assessments to incorporate probabilistic energy assessment analyses into performance assessment products because of the increased penetration of IBRs. Further, flexible resources such as batteries and demand response capabilities are being incorporated into the industry's planning processes to more accurately reflect the needed balance of demand and load. Other factors, such as large loads, data centers, and population growth are being incorporated as load growth increases. Collectively, these efforts will play an important role in understanding energy scarcity conditions and ultimately mitigating energy availability risks. Texas RE will continue to enhance its efforts to incorporate energy assessment models into its reliability products as a key contribution to grid reliability.

PROVISION OF ESSENTIAL RELIABILITY SERVICES FROM A CHANGING RESOURCE MIX

Likelihood: ***UNLIKELY*** **// Impact:** ***MODERATE***

The procurement of sufficient essential reliability services to maintain reliable grid operations continues to evolve as the Region's resource mix moves from dispatchable to variable generation resources. As the penetration of variable resources increases, merely having available generation capacity does not equate to having the necessary reliability services (such as ramping capability) to balance generation and load. Solar generation records are being repeatedly broken, resulting in significant and rapid solar generation down ramps after the peak. Texas RE monitors key indicators such as primary frequency response, ramping capabilities, and system inertia.

Battery resources provide an ever-increasing percentage of the Region's ancillary services, resulting in significant improvements in primary frequency response metrics. The maximum hourly ramp rate for solar resources increased by 43 percent in 2024 compared to 2023 and could approach 15,000 MW per hour in 2025. ERCOT has implemented enhancements to better manage frequency variations during these ramp periods but will continue to be challenged as solar penetration grows.

There is a need for power-based electronic resources to provide reliability functions that more closely mirror the properties inherent in traditional, large spinning mass resources. Grid-forming batteries are needed to ensure grid stability and reliability (as renewable energy like solar and wind becomes more prevalent) by providing a way for these intermittent sources to behave more like traditional power plants.

GRID TRANSFORMATION

Grid-Forming vs. Grid-Following:
- Grid-Following: Traditional battery systems are "grid-following," meaning they rely on the grid to maintain voltage and frequency and follow the grid's signals.
- Grid-Forming: Grid-forming batteries, on the other hand, can "form" the grid by regulating voltage and frequency, even when the grid is down.

Traditional power grids rely on synchronous generators (like those in power plants) to maintain voltage and frequency stability. The intermittent nature of wind and solar can create challenges for grid stability as their share of the resource mix grows. Grid-forming batteries equipped with advanced controls can mimic the behavior of synchronous generators, providing inertia and voltage support to the grid.

There is currently a lack of specifications, standards requirements, and incentives for deployment of the grid-forming battery capability. Without these specifications and the appropriate incentives or requirements, much (or all) of the anticipated battery capacity in the future will lack grid-forming capability. This will result in continued stability challenges, solar and wind curtailment, and the need for supplemental equipment for weak grid areas to support voltage and provide inertia.

All of these issues will continue to be of concern as ERCOT moves forward with the implementation of Real-Time Co-optimization (RTC) in 2025, which will make major changes to the ancillary service market.

CYBER AND PHYSICAL SECURITY

REMOTE ACCESS

Likelihood: ***POSSIBLE*** **// Impact:** ***MODERATE***

The protection of critical infrastructure remains a major focus for the 2025 risk areas. The 2023 RISC report recommends that to mitigate the risk of poor cyber hygiene, the industry must focus on early detection and response to cyber-attacks, and adopt controls that can be executed to protect critical systems. As part of monitoring engagements, Texas RE is addressing this risk by assessing whether registered entities are protecting data used for Real-time Assessment and Real-time monitoring while such data is being transmitted between Control Centers. Texas RE's outreach highlights internal controls around remote connectivity. With remote connectivity and the use of remote workers continuing, it is vitally important that facility staff understand the changes taking place with their technology and have a better understanding of how to protect it. The ERO Enterprise has seen the following poor security practices:

- Remotely unlocking doors for unauthorized individuals
- Neglecting to secure doors and manage keys
- Generally failing to identify a need to create or apply security plans to new sites or sites transitioning from medium/high to low impact

Root causes in these cases often point to ineffective training and lack of direction or guidance, which can result in staff treating low impact sites as functionally out of scope for NERC CIP purposes, which in turn can increase the frequency of less-than-desirable security decisions. As security needs evolve, the ERO Enterprise and industry must remain vigilant, identify any gaps, and mitigate, as necessary. There is a noticeable trend as it relates to low impact BES Cyber Systems. As noted in the 2024 CIP Themes and Lessons Learned Report, a compromise of such assets could create localized issues, and an individual low impact asset could:

- Serve as a channel to attack other assets
- Be used to conduct reconnaissance

The potential risk to the BES multiplies in scenarios where several low impact assets are compromised in a coordinated attack. There is potential for human error (regardless of the sophistication of a security system) across all types of BES facilities.

CYBER AND PHYSICAL SECURITY

SUPPLY CHAIN

Likelihood: ***POSSIBLE*** **// Impact:** ***MAJOR***

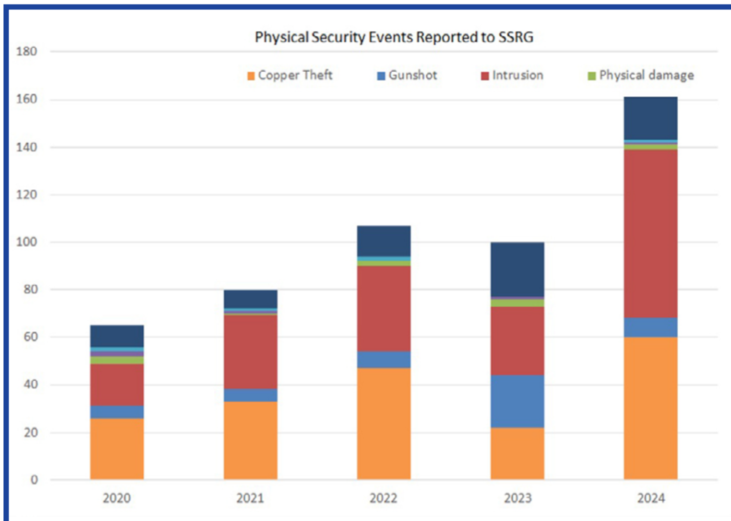
Supply Chain risks continue to be a focal point in various areas for the industry. Lead times for transformers, circuit breakers, transmission cables, switchgears, and insulators have increased significantly since 2020. Additionally, PV panels are more difficult to procure. These issues are delaying new resource and transmission projects. Supply chain bottlenecks have also been a major headache for developers. A lack of supply chain capacity has caused issues with high-voltage electrical equipment, skilled grid connection construction firms, wind installation vessels, data chips, and critical minerals. As a consequence, developers are at risk of not receiving critical deliveries on time, underscoring the importance of awareness as it relates to supply chain risks. The energy market today is both maturing and unstable, characterized by rising demand and fluctuating supply. The renewable energy supply chain is heavily concentrated, dominated by a few suppliers and with a clear concentration in China and a handful of other nations for mineral extraction. This makes renewables more vulnerable to sourcing risks, as there are fewer supplier options and a greater reliance on specific countries or regions.

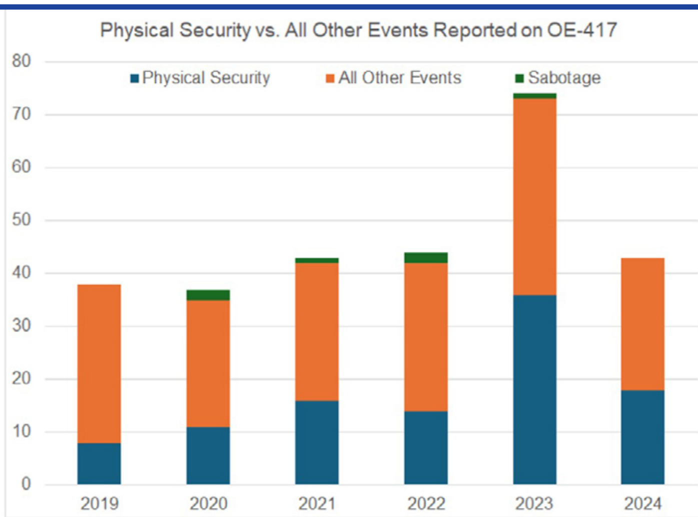
Texas RE assesses the risk associated with supply chain policies and procedures during monitoring engagements. Texas RE also works with the Critical Infrastructure Protection Working Group (CIPWG) to mitigate this risk and CIP risks in general. In addition, Texas RE's outreach highlights internal controls around using vendors.

PHYSICAL SECURITY

Likelihood: ***LIKELY*** **// Impact:** ***MODERATE***

Physical security threats are a top concern in 2025 as threat levels have remained elevated with domestic violent extremists a particular focus. They aim to exploit potential social unrest such as political elections, economic issues, and activistic causes to target infrastructure. There are more registered entities than ever with assets that contain low impact BES Cyber Systems being registered across the ERO. Concerted efforts are needed around these assets as there has been an upward trend in violations regarding physical security plans, electronic security perimeters, and access management and revocation, to name a few. One of the many challenges of executing a physical security program is managing tasks that require repetitive behavior over significant periods of time, as there is increased potential for personnel to lose focus on the performance of an individual act or forget the importance of the act itself.





RESILIENCY

EXTREME WEATHER AND RESOURCE WEATHERIZATION [DECREASED RISK FOR 2025]

Likelihood: ***UNLIKELY*** **// Impact:** ***MAJOR***

The BPS performed well during several notable extreme weather events in 2024 with no significant load loss issues involved in distribution outages. The Region's thermal generation fleet performed particularly well during January 2024's Winter Storm Heather as the approximately 3,000 MW of incremental forced outages and derates were lower than the projected seasonal average for the thermal fleet. The overall level of forced outages for thermal resources was in the range of 7,000 MW, which included approximately 4,000 MW in forced outages prior to Heather. This is in comparison to approximately 14,000 MW of forced outages for the thermal fleet during Winter Storm Elliott (itself an improvement over the fleet performance during Winter Storm Uri).

While it is important to note that Heather was less severe than prior events, continued progress in response to winter storms (including storms in early 2025) demonstrate the benefits of weatherization mitigation measures that have been put in place over the past several years. As noted in NERC's 2023 Long-Term Reliability Assessment, recent extreme winter weather has exposed vulnerabilities to generating units and fuel sources that are not adapted to cold temperatures, raising concerns for blackstart unit readiness. The changing resource mix is cause for additional awareness of blackstart capabilities. Currently, few IBRs on the system are capable of grid forming control, one of the necessary components for blackstart resources. Cold weather events can stress the BPS and expose weaknesses such as poor coordination between neighboring entities in planning or operations.

Review of data collected from the May 2023 NERC Level 3 Alert on Cold Weather Preparations for Extreme Weather Events supports this trend. It shows improvements in the winterization plans and preparations from generation entities. Approximately 88 percent of facilities have calculated the Extreme Cold Weather Temperature (ECWT) based on the proposed NERC standards for their units and approximately 85 percent of the registered entities (95 percent of the MW capacity) reported that their units were capable of operating at the ECWT. Approximately 60 percent of the entities (75 percent of the MW capacity) have identified critical components. Finally, approximately 84 percent of the registered entities (91 percent of the MW capacity) have completed the essential actions recommended by NERC in the Alert.

Over the past two years, numerous federal and state winterization requirements have been put into place. NERC implemented its enhanced cold weather winterization requirements under the EOP-012 Reliability Standard, which became effective on October 1, 2024. Additionally, NERC established planning criteria for extreme system conditions (both heat and cold) under the new TPL-008-1 Standard. Texas RE's compliance program has proactively supported these new requirements by implementing risk-based site visits to review winterization measures under the new Standards, as well as share best practices and lessons learned. These efforts complement the state-level standards and inspections. Texas RE will include monitoring engagements of Generation Owners and Generator Operators that focus on the cold weather Reliability Standards and the controls around implementing cold weather preparedness plan(s).

RESILIENCY

Extreme weather preparedness and winterization require continued planning, preparation, and vigilance. However, Texas RE believes the likelihood of a major impact from the failure to winterize resources has been reduced based on the aggressive implementation of these mitigation measures and the overall positive performance during recent winter events in 2024 and 2025. Accordingly, Texas RE has lowered its risk likelihood assessment for major impacts from "possible" to "unlikely."

GAS SUPPLY CHAIN RESTRICTIONS DURING COLD WEATHER

Likelihood: ***POSSIBLE*** **// Impact:** ***MAJOR***

Natural gas represents the largest fuel source in the Region and serves as an essential fuel to meet demand and balance variable resources on the system. Given this critical role, vulnerabilities associated with natural gas delivery to generators can result in generator outages. This is particularly true during cold weather conditions.

Texas regulators have implemented a range of measures to address gas supply and gas-electric coordination issues, including developing critical infrastructure mapping to prevent reduction in power to critical gas infrastructure during manual load shedding, winterization requirements for certain natural gas facilities, and flexible fuel market products. These efforts appear to be mitigating gas supply issues during cold weather events. Gas curtailments decreased in 2024 compared to 2023 and prior years. Gas curtailments and restrictions in the North Texas Region, however, remain a concern. During Winter Storm Heather, North Texas generators experienced an approximate net loss of 1,700 MW in available generation capacity resulting from gas curtailment issues.

Texas RE is focused on ensuring gas supply issues are identified and supports the implementation of appropriate mitigation measures in the coming years.

FACILITY RATINGS

Likelihood: ***UNLIKELY*** **// Impact:** ***MODERATE***

The accuracy of Facility Ratings is related to other focus areas and remains critically important to reliable operations. Operators depend on Facility Ratings to provide reliable System Operating Limits (SOL) and IROL that inform operating decisions. Engineers rely on Facility Ratings to protect equipment from damage while also enabling equipment to stay online when it is both safe and most needed. Some registered entities have Facility Ratings based on inaccurate equipment inventories, or ratings are not being updated during projects or following severe weather. Texas RE initiated a comprehensive compliance review of Facility Ratings in 2022 and continues that effort in 2025. As part of monitoring engagements, Texas RE assesses whether registered entities are maintaining accurate Facility Ratings as well as the controls that a registered entity has around developing accurate Facility Ratings. Changes under consideration for the FAC-008 Standard will be included in outreach. In addition, Texas RE's online Resource Hub will be updated with relevant materials.

TEXAS RE

Ensuring electric reliability for Texans

8000 Metropolis Drive / Building A, Suite 300
Austin, Texas 78744 / 512.583.4900 / www.texasre.org