Reliability and Resilience in the Balance

2 years later*

Have we made progress?
Have we learned anything?
Are we ready for the next test?

Building Sustainable Infrastructure for a Bright Future

American Society of Civil Engineers (ASCE)

Texas Section

Beyond Storms Infrastructure Network Resilience Task Committee

Preamble

The American Society of Civil Engineers (ASCE) represents more than 150,000 members of the civil engineering profession in 177 countries. Founded in 1852, ASCE is the nation's oldest engineering society. As a public service, ASCE periodically prepares an Infrastructure Report Card (IRC) assessment of critical infrastructure serving essential needs on both a state and national level. The assessment is performed periodically on various critical infrastructure sectors (e.g., water, energy, roads, etc.) and provides a standard assessment approach of the physical condition and performance capacity of the various sectors of infrastructure. It is undertaken to educate the public and those in government who oversee such matters. ASCE released its most current national Infrastructure Report Card (IRC) in February 2021. In addition, when a catastrophic event takes place and infrastructure fails, ASCE deploys skilled engineers from its membership to assess and determine what happened, why it happened, and more importantly, to develop recommendations for future change, as appropriate, to avert such an event. ASCE convened a task committee as Texans experienced Winter Storms Uri and Viola. Now two years later, this same team has been asked to refresh and update the report to determine if the responses to date have addressed the fundamental issues we uncovered in the aftermath.

**Data and reporting as of September 15, 2023*

Reliability and Resilience in the Balance
Refresh Report

Introduction

A reliable and resilient electric system in an increasingly electrified economy is essential to our fellow Texans' safety and economic health. Critical infrastructure, from water systems, transportation, and telecommunications to the broader energy industry, is increasingly dependent on the reliability and resilience of the electric power generation system for its reliable performance in serving the public and businesses. Everyone likes to talk about the weather. We tend to blame the weather as a nefarious villain beyond a myriad of problems. The twin winter storms of 2021, Uri and Viola were blamed as the culprits behind the failures in essential infrastructure that touched the lives of every Texan. However, a detailed analysis of the systemic shortcomings experienced during Winter Storms Uri and Viola confirmed that the problems were ***<u>not</u>*** caused by the weather. It simply served as the catalyst to expose the underlying issues. **Texas has a substantial and growing electric system reliability and interdependence problem.**

In February 2021, the impact of Winter Storms Uri and Viola on Texas was catastrophic. These twin storms served as a catalyst that uncovered latent problems in the Texas energy network and dependent infrastructure. The consequences of these hidden risks for Texans were tragic. These impacts included at least 246[1] Texans who lost their life during the storm and substantial and lingering economic impact to the entire region that is estimated to exceed $200 - $300 billion[2] in addition to disputes and securitizations. The economic impact of Winter Storms Uri and Viola was more significant than the impact from either of the two most costly hurricanes[3] in US history, Harvey ($145B) or Katrina ($161B). In comparison, in 2019, Texans spent around $37 billion on retail power during the *entire year*[4]. Regardless of the metric, from public safety to economic impacts of Winter Storms Uri and Viola and the problems these storms uncovered deserve a comprehensive response to prevent recurrence.

<u>Report fundamentals:</u> The original **Reliability and Resilience in the Balance** report approached the Winter Storms' impact by identifying the "what" to understand the problem and then relentlessly asking "why" this happened. The identified issues ranged from people and processes to regulatory and market structure shortfalls and the impact of industry underinvestment. Based upon an analysis of what happened and why, the Committee then identified specific outcomes or targets needed to address these issues to prevent the types of problems from repeating. There are many ways to solve problems. The scope of the analysis was limited to identifying what and why things happened, and key outcomes needed to provide a performance measure for potential solutions. There was a conscious effort to defer to industry, regulators, legislators, and the public to develop the balanced solutions needed to determine "how" the problems should be solved.

<u>Public outreach:</u> Following the release of the original report in February 2022, members of this Committee and ASCE implemented an extensive state-wide outreach effort to educate the public, industry, legislators, and regulators about the report's findings and recommendations. These efforts ranged from one-on-one meetings with legislators and industry to in-person presentations and webinars open to various participants. During these discussions, informed parties confirmed the Report's findings and identified a few material areas of disagreement. Every Texan had personal experience from the storms that formed opinions on the problems and how to fix them. During the

public outreach, we experienced a wide range of views about the issue and often storm-centric prisms of the problem, frequently incongruous with the facts. We observed that the level of awareness about what and why these events happened was consciously and unconsciously misunderstood. This impacted the efforts by industry, legislators, and regulators to address the issues and frequently resulted in outcomes that solved more straightforward challenges but tended to fall short of more complex problems.

Other performance events: Independent System Operators (ISOs) are independent organizations formed under the Federal Energy Regulatory Commission (FERC) authority to handle electric grid operations, market facilitation for specific electric markets, and bulk electric system planning. ISOs were created to facilitate competitive wholesale electric markets and ensure non-discriminatory access to the transmission system for generators. There are ten (10) ISOs in the lower 48 states. ERCOT was formed in 1970 and became one of the ten ISOs in 1996. Part of the analysis of ERCOT's performance required evaluating how ERCOT compared to other ISO's. ERCOT's lack of reliability is not unique. Its level of intermittent resources and increasing demand continue to confirm ERCOT as the proverbial "canary in the coal mine" of reliability issues. ISOs across the United States face increasing reliability challenges from the early retirement of dispatchable resources and increased intermittent generation resources in their generation mix. This results in these ISO's forecasting an inability to reliably meet demand with the impact of lowering overall system reliability.

Status: During the past two years, a great deal of regulatory, legislative, and industrial activity has occurred. Different constituencies pursued and sometimes implemented myriad solutions to solve the question of "how" Texans can take action to improve the Reliability and Resilience of essential infrastructure in Texas.

Continued weather distraction: In parallel, during the two years following Winter Storms Uri and Viola, Texas, endured several severe winter storms and a series of summer heat waves. These storms tested the energy grid and essential infrastructure, and localized ice events caused extensive local damage. Despite hyperbolic reporting that these recent events were "generational" in nature, these weather events fell materially short of the conditions, impacts, severity, and human costs of Winter Storms Uri and Viola in Texas. Weather serves as a fundamental distraction from addressing the core issues, first as the alleged culprit behind the failures and subsequently as a "test" of the system that appeared to confirm that the system "weathered" the latest stress events. When we fail to recognize this reality, human nature tends to become complacent; we assume the problem has been resolved and turn our attention to other matters.

Report details: This Refresh Report re-examines the factors that contributed to the failures experienced and the conclusions of "why" these events of failure occurred through a Background review. Then, the Report briefly examines the industry, regulatory, legislative, and public solutions. The Report reviews the changes and impacts across the selected infrastructure sectors. It ends with a short summary of the weather and its primary role in uncovering the problems and future risk considerations. Lastly, the report summarizes the original five network-level issues, relative progress in addressing the identified problems, and solution shortfalls.

Texas, we have a problem.

<u>Questions concerning Reliability and Resilience in the Balance.</u>

Since its formation as a competitive energy-only market, ERCOT has lacked a reliability and resilience standard. This failure to adopt a robust and enforceable reliability standard allowed the ERCOT market to ignore a series of early warning signs and indicators for over a decade. These warnings pinpointed the fundamental structural problems in ERCOT's design, creating an increasingly fragile system. The twin Winter Storms of Uri and Viola simply uncovered many of these resource adequacy problems. Lacking a ***reliability compass*** to help navigate its way, ERCOT got lost. ERCOT defaulted to a myopic focus on short-term low cost while obstinately ignoring growing reliability and resilience problems.

The economic consequences and tragic human loss from these failures overwhelmed any accumulated benefit gained from ignoring the warnings and recklessly prioritizing low-cost, short-term solutions with reliability as an afterthought. The lack of a transparent, robust, and enforceable reliability standard facilitated short-term decisions. Without a transparent and enforceable reliability standard there was a lack of clear accountability to respond to warnings, and this created cultural complacency in solving the root cause of structural shortcomings of the energy-only market design. In the aftermath of the storms that uncovered these tragic flaws, Texas remains lost, lacking a reliability and resilience standard.

Undeniable progress has been made on many fronts, but many interim solutions have been costly and temporary Band-Aids. The failure to adopt and embrace a robust, transparent, and enforceable reliability standard has produced the predictable result that the heart of the original problem, revenue insufficiency, has yet to be solved. ASCE Texas now believes that a transparent, robust, and enforceable reliability standard must be established and implemented within ERCOT to serve as a compass for the multitude of efforts required to ensure that ERCOT has a reliable, cost-efficient, and resilient system. Supporting mechanisms must be adopted to reinforce this reliability standard with actions and enforceable changes.

ASCE Texas Section developed a series of questions for the public, industry, and legislators to consider ensuring that reliability and resilience are restored in the ERCOT system.

1. **Have the Public Utility Commission of Texas (PUCT) and ERCOT established a transparent, robust, and enforceable reliability standard or metric to measure performance that will prioritize and ensure cost-efficient and timely reliability investments to ensure resource adequacy?**

2. **Is there a transparent, efficient, and self-correcting mechanism with performance obligations that are neutral or agnostic to the type of resource (generation and/or demand) in place to pro-actively ensure revenue sufficiency for dispatchable resources over an applicable investment time horizon, including confirmatory evidence of incremental market-based investment in such resources?**

3. **Are the standards applied to dispatchable resources (supply and/or demand) technology and resource neutral or agnostic and use consistent and similar financial rewards and penalties for performance that encourage verified and efficient investments?**

4. **Are all dispatchable and non-dispatchable or intermittent resources > 100MW of equivalent installed capacity (or demand response) required to meet similar construction and structural standards (wind loads, etc.) for operating in various weather conditions, and do these resources maintain timely access to minimum critical spares, regardless of technology, to ensure reliable performance and resilient operation in the event that the most impactful or consequential (FMEA - Failure Mode and Effect Analysis or equivalent risk analysis technique) events occur?**

The following section addresses the specific progress made in areas identified in the original report and the remaining gaps.

Background foundation

Winter Storms Uri and Viola exposed major reliability failures in February 2021 and again on a more localized and less severe basis by Elliot and Mara two years later. These failures extend well beyond winter storm events. The weather simply uncovered the problems. **Texas has a substantial and growing electric system reliability and interdependence problem.**

Reliability and resilience of critical and essential infrastructure begins with establishing clear and objective standards for reliability and resilience and the supporting rules and regulations to ensure rigorous adherence to the standard. It is particularly telling that since its inception as a deregulated market, PUCT and ERCOT have failed to establish a clear and transparent reliability standard and implement the various requirements needed to support such a standard.

Advocacy for "electrifying everything" partly addresses the desired result of a sustainable environment for life on Earth. Texas leads the nation in this energy convergence by generating over 40% of electrical power from renewable sources. However, balancing the reliance on intermittent generation with the growth of demand for electrical power requires fine-tuning of the current electrical power procurement and distribution system. We conclude that the failures that caused overwhelming human suffering and economic losses during February 2021 ***will*** increase in frequency and duration due to legacy market design shortcomings, growing infrastructure interdependence, economic and population growth drivers, and aging equipment, even if the frequency and severity of weather events remain unchanged. Increasing reliability and resilience failures will also likely undermine public perception and support for energy transition.

Before we can solve the problems, we need to understand them and why they occur.

<u>Chronic under-investment</u> – *a recipe for a Run to Failure outcome*.

There is a legacy of chronic under-investment in maintaining critical infrastructure of all types across the US, from roads and bridges to water infrastructure, airports, and telecommunications. This problem is called a "missing money" problem and is formally termed revenue insufficiency. It encompasses all phases of an infrastructure's life to ensure sufficient revenue to build, operate, and adequately maintain the infrastructure, including reliability and resilience investments. What frequently happens with essential infrastructure is something different. Even though it costs 3-5 times more, in the long run, to fix an issue when it breaks, routine and preventative maintenance is frequently deferred into the future to become "someone else's problem." The result is that infrastructure from bridges to water and wastewater treatment plants slowly deteriorates until more costly investments become unavoidable.

These problems manifest themselves when the system is stressed. Unfortunately, many of the negative impacts of this under-investment are felt more acutely by lower socio-economic Texans who must rely on critical infrastructure with few viable fallback or alternative solutions when that critical infrastructure fails to perform reliably. Underfunding creates other problems, including worsening public safety and compliance issues. Failure to properly maintain infrastructure results in negative consequences, especially during periods of stress, like was experienced by Winter Storms Uri and Viola. This pattern of deferral and avoidance results in a costly "***run to failure***" outcome followed by surprise that reliability and resilience were compromised. This pattern of persistent underfunding must change. In the Committee's view, this was a material contributor to the impact of Winter Storms Uri and Viola across all essential infrastructure sectors.

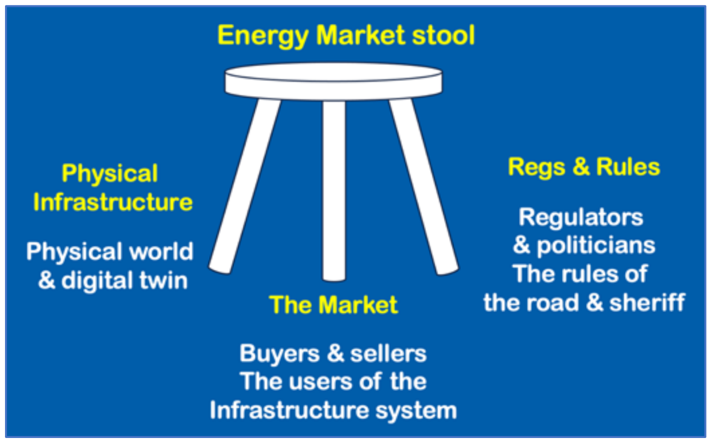
Critical infrastructure delivers services essential for our daily lives at home and work. It includes electricity, water, telecommunications, transportation, and energy services. Critical infrastructure requires large, routine capital expenditures to support expansion, maintenance, and operations to meet demand. The energy industry is one of the world's most complex and capital-intensive industries. Policies, regulations, and market actions can distort, constrain, or negatively impact the flow of capital to needed investment. The inevitable outcome is that the critical network needs to be made aware of the investments required for reliable and resilient performance through deferred expansions, delayed maintenance, and reduced reliability investment.

The reliability of critical infrastructure, from transportation and energy to water, wastewater, and telecoms, is heavily impacted positively or negatively by ***revenue sufficiency*** - the sufficiency and predictability of ongoing investments supporting maintenance and reliability upgrades.

<u>Energy transition:</u> Not an excuse for Reliability and Resilience failures

Since its formation, the Texas electric grid has been evolving to accommodate new, modern technologies, expand grids, and satisfy growing demand. During the current transition, substantial federal and state incentives supporting fresh intermittent wind and solar resources and, more recently, utility-scale storage have led to the dramatic growth of renewable energy resources in Texas. ASCE recognizes that the grid will continue to evolve and that the future grid will not look like today's grid. ASCE does not subscribe to the view that reliability deterioration is an inevitable part of the "cost of transition" in the energy sector. Due to the extreme costs of reliability failure, it is ***reckless to believe*** that the energy market transition should somehow be used as justification or an excuse for reliability declines and extended load-shedding events. For energy transition to work effectively and be accepted, it must occur without any sacrifice of reliability and resilience.

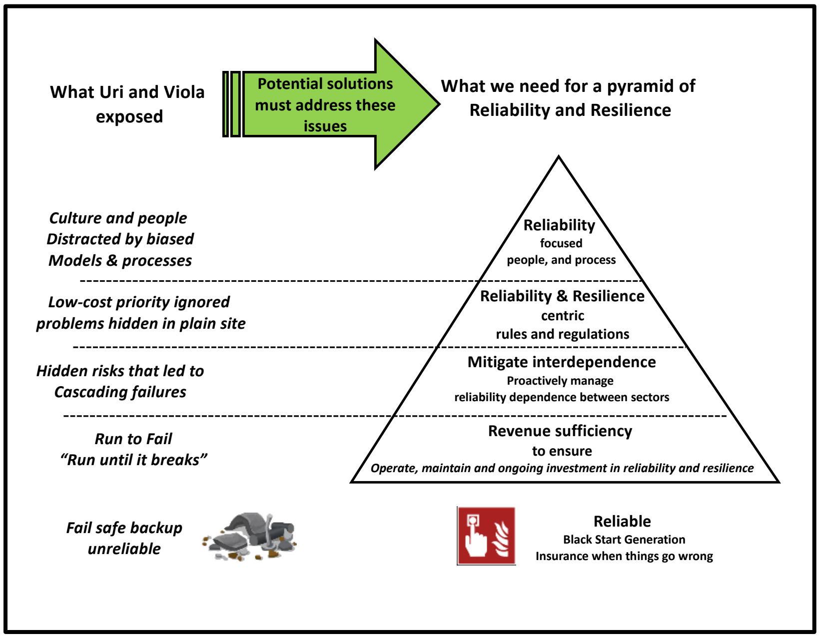
To understand the root cause of the Winter Storm Uri and Viola and Viola problems, it was necessary to look beyond (1) the physical infrastructure and to include (2) the impact of regulations that apply to the use of the infrastructure and (3) the markets themselves. The energy infrastructure system works or fails depending on how well these three legs of the energy market work together. ASCE identified two primary related problems: (1) a failure to economically support reliable dispatchable power generation (ensure revenue sufficiency) and (2) the negative impacts of increased dependence on intermittent electric power generation. This assessment concludes that (1) revenue insufficiency from ERCOT's energy-only market model, influenced by federal and state subsidization of intermittent resources (mainly solar and wind), fails to adequately pay for reliable dispatchable generation and (2) these market model deficiencies because they fail to prioritize reliability and resilience, are the leading contributor to making the ERCOT system less reliable.



This market design and supporting rules and regulations rely on the forecasted expectation that potential periodic scarcity premiums would sufficiently incentivize long-term reliability investments. There is ample evidence that this hope is unfounded. According to Wood Mackenzie[5], "…During the ten years prior to 2021, ERCOT's Energy-only market did not provide a meaningful signal for natural gas or wind generators to winterize." A dispatchable generator confronting this reality rationally is unlikely to invest in winterization, firm fuel supply, dual fuel flexibility, or make other reliability and availability investments. The hope that these investments will still be made despite _neither_ market revenues nor forward markets supporting this outcome is a failed strategy.

Demand Side Management (DSM) provides a potential for the equivalent of "dispatchable demand" as a complementary solution to Dispatchable generation to meet the challenge of intermittent supply resources. There are industrial and commercial loads that can adjust their demand levels in response to system needs, and these demand resources should be considered in the mix of solutions. Failure to perform from dispatchable demand resources should carry similar consequences to failure by dispatchable supply. Residential demand can likewise adjust their load profiles in response to system needs with comparable incentives, performance obligations, and consequences for failing to perform. Residential demand can also be enhanced through increased weatherization and higher efficiency appliances to reduce needle spikes in demand. This type of solution is often overlooked as a viable solution due to administrative complexity and other factors, including poorly designed programs that are inefficient in their design and implementation. PUCT and ERCOT rules should be agnostic regarding the dispatchable demand or supply source. A best-cost approach to reliability investments and costs in ERCOT would develop incentives and structure for equivalent value for equivalent contributions that benefit grid reliability.

Interdependence The next most consequential contributor to reliability degradation is the relentless creep of interdependence between infrastructure sectors, which contributes to increasing the fragility of each system(s) and sets the stage for cascading failures across industries. Interdependence occurs when one sector's reliability depends on the reliable performance of another. The water industry provides a unilateral or one-way interdependence example. The loss of electricity led to the loss or interruption of water supply to customers, which led to the issuance of boil water notices to those customers. The industry simultaneously lost real-time situational awareness and control of their water networks as SCADA (Supervisory Control And Data Acquisition) controls lost power and/or communications with operational controls and field sensors. The natural gas and electric sectors exemplify a bilateral reliance and interdependence problem where the two infrastructure sectors were mutually dependent. The field-level power failures experienced by the gas industry curtailed the fuel supply needed to fuel dispatchable power generators.



Like market-based pricing and the transition to renewable generation, interdependence between infrastructure sectors is not going away. The impacts of interdependence will continue to deteriorate reliability without action – but proactive steps can be taken. It can be mitigated, fragility improved, and reliability enhanced by implementing a series of actions that are (1) relatively modest in scale, (2) focus on enhancing the reliability of ERCOT, and (3) mitigate interdependence risk between critical infrastructure sectors.

The two remaining key contributors to reliability degradation work in more subtle ways. These two contributors include rules, policies, and regulations that negatively impact reliability and a legacy ERCOT philosophy prioritizing low cost to the detriment of reliability.

Overview of Key Failure Themes

The Winter Storms Uri and Viola exposed many problems in essential infrastructure. Texans witnessed many effects through shortfalls in the electric and energy infrastructure. However, many of these underinvestment issues in routine maintenance and a lack of investment in reliability and resilience efforts are present in the water, telecommunications, and transportation industries, impacting all essential infrastructure. Revenue insufficiency, where infrastructure is starved of capital and cannot be adequately maintained for reliable and resilient service, is a chronic problem that touches every corner of critical infrastructure. It results in a **Run to Fail model,** where the asset or infrastructure starved of capital operates until it fails or breaks. This problem is exacerbated when rules and regulations compound the problem. Interdependence, where one sector of infrastructure depends on a different infrastructure for its reliability, must be examined, and steps must be taken to avoid cascading failure between sectors, especially in revenue sufficiency and interdependence. The rules and regulations must be designed to support and prioritize reliability, resilience, and change when they fall short. People, processes, and cultures must train and practice for emergencies, validate their models in the real world under stress, and constantly seek to improve.

<u>Highlight of legislative and regulatory response</u>

The complexity of the regulatory and legislative response was as complex as the original problems themselves. The initial regulatory and legislative response is summarized in the following table[6].

Legislation Passed by the 87th Texas Legislature to Address the Problems Exposed by Winter Storm Uri

Category	Legislation	Description
Agency leadership	SB 2	Reform of ERCOT leadership structure
	SB 3 Secs. 34, 35	Annual review of the statutes, rules, protocols, and bylaws for PUC and ERCOT leadership
	SB 2154	Reform of PUC leadership structure
Emergency management	SB 3 Secs. 4, 17, 37	Designation of critical natural gas facilities and creation of the Texas Electricity Supply Chain Security and Mapping Committee
	SB 3 Sec. 24	Requires the PUC to submit biannual emergency preparedness reports
	SB 3 Sec. 25	Requires the RRC to submit biannual emergency preparedness reports for critical natural gas infrastructure
	SB 3 Secs. 26, 36	Requires water utilities to ensure minimum pressure levels during power outages
	SB 3 Sec. 33	Establishes the State Energy Plan Advisory Committee
	SB 3 Sec. 3	Establishes the Texas Energy Reliability Council
Consumer protection	SB 3 Secs. 1, 2	Mandates the creation of a statewide power outage alert system
	SB 3 Sec. 18	Mandates the creation of a new wholesale market emergency pricing program
	HB 16	Prohibits wholesale-indexed electric plans for residential or small commercial customers
	SB 3 Secs. 8, 9, 10, 11	Reform of load shedding procedures for critical residential and industrial consumers
	SB 3 Sec. 16	Designation of critical natural gas facilities and new procedures for load shedding
Securitization	HB 4492	Securitization of debts for retail electric providers and financing of uplift charges
	SB 1580	Securitization of debts for electric cooperatives
	HB 1520	Securitization of weatherization costs for non-ERCOT electric utilities
	HB 1510	Securitization of debts for gas utilities
Weatherization	SB 3 Secs. 5, 6, 21, 22, 38	Weatherization of natural gas facilities
	SB 3 Secs. 7, 13, 16, 39	Weatherization of electrical generation
	SB 3 Secs. 28, 29, 31, 32	Weatherization of certain water utility systems
Market reform	SB 3 Sec. 18	Wholesale market reform, reliability standards, and weather resiliency requirements
	SB 3 Sec. 14, 35	Ancillary services market reform
	SB 1281	Transmission planning and approval reform

Table 6 1:88th Texas Legislative Session (2023)

This table provides a sense of the initial scale and scope of the response. However, the volume does not necessarily translate into efficacy or provide an assurance that the underlying issues highlighted by the storm are being fundamentally resolved.

After the 88th Regular Session of the Texas Legislature, eleven bills addressing the production and distribution of electrical power successfully navigated the legislative process. Of those, two are significant in enhancing the Reliability and Resilience of the ERCOT Grid Operations. SB 2627, which will appear on the November Ballot as Proposition 7, would authorize the creation of a fund that would offer low-interest loans for capital expenditures to build or upgrade dispatchable power generation in Texas.

Unfortunately, the bill focuses solely on funding natural gas-fired thermal generation, which limits the options for enhancing grid operations while addressing sustainable resource implementation. However, SB 1866 creates alternatives for the participation of aggregated distributed energy resources (customer site generators, residential solar, battery storage, small-scale dispatchable generators) in the ERCOT power market. At the time of publication of this report, Dallas and Houston initiated programs to allow TESLA Battery Storge owners to sell power into the ERCOT Grid during periods of high demand and restricted supply.

Both bills would enhance the existing and evolving electrical generation and distribution grid in Texas but fall short of addressing the principal issue restricting investment in dispatchable generation, the lack of a sufficiently attractive revenue generation stream in the existing market currently applied by PUCT and ERCOT.

88th Texas Legislature Energy Bills Enrolled

Origin	No.	Title
SB	2627	Texas Energy Backup Finance Program – Proposition 7
HB	5066	Electric Service Transmission Project Mgt
SB	1929	Virtual Currency Mining Facilities Registration
HB	4553	Information Services impacting PUCT / ERCOT
SB	1002	Electric Vehicle Charging Regulations
SB	2013	Electric Grid Infrastructure Security
SB	2010	Energy Market Monitor Requirements
SB	1093	Facilities included in Electricity Supply Chain
SB	1404	Study Coal to Nuclear Conversion
SB	1866	Customer Site Distributed Energy Generation
SB	1500	PUCT: Office of Public Utility Counsel

This next section will highlight specific infrastructure sectors.

Energy Infrastructure update

The energy infrastructure includes oil and natural gas production, processing and refining, storage, and delivery. This Refresh update focused more narrowly on natural gas production, processing, storage, and transportation to the customers. In the aftermath of the twin storms, the natural gas industry's performance received a great deal of negative attention due to the perception of a lack of reliability, shut-in production, and a lower level of transparency in responding to the outcry. Several vital issues impacted the natural gas industry production sector performance:

- **Insufficient winter weatherization**: The industry had under-invested in production facility-related weatherization of wellhead and field facilities. Due to pressure drops and related factors, wellhead facilities can begin freezing off at temperatures starting at 40^0F. Increased production of associated water in specific oil and natural gas fields compounds this problem.

- **Interdependence problem:** The natural gas industry has become increasingly dependent on the electric sector's reliability to serve increased field electrification (e.g., production equipment, SCADA, heat tracing) for its reliability.

- **Intrastate market transparency:** The lack of transparency in the intrastate natural gas market complicated and frustrated reactions to curtailments to generators.

- **Curtailment:** Natural gas facilities failed to identify themselves as critical facilities and were curtailed by electric distribution companies. Several other facilities had elected to be curtailed in exchange for lower rates. This created a cascading failure as electricity was interrupted to field facilities, accelerating freeze-offs and natural gas supply curtailments. This led to further electric curtailments from a lack of natural gas supply.

- **Operational awareness:** It became clear during the Energy Emergency Alert (EEA) issued by ERCOT, that many electric industry participants, including ERCOT team members, did not fully understand how the natural gas industry functioned and vice versa.

In other areas, the natural gas industry was blamed for incorrect outcomes during the storm. Some aspects of the analysis uncovered a fundamentally different conclusion than commonly held in the storms' aftermath.

- The analysis confirmed that ~75% of the generators in ERCOT experiencing natural gas outages and derated during the storm relied on less expensive *interruptible* transportation and/or *interruptible* gas supply to fuel their operations. In contrast, those generators with more costly firm supply and firm transportation received delivered fuel that closely matched their nominations during the storm. Based on the lack of revenue sufficiency from ERCOT's energy-only market design, generators made rational decisions to defer various investments, from winterization to firm fuel supply and reliability investments.

Has Energy infrastructure Reliability and Resiliency improved since the winter Storms?
The following summarizes highlights of changes:

- **Summer impacts**: On a general basis, Texas natural gas producers experienced no production interruption issues during excessive summer temperatures above 100^{0}F during the summers of 2022 or 2023.

- **Weatherization**: The Texas Oil and Gas Association acknowledged the implementation of heat tracing and insulation, and compressor stations changed cooling louver blade angles based on cold temperatures. The Association reported in November 2022 that field operations have been enhanced to facilitate working in winter weather events (see inset[7]). Winter weather-oriented gear and pre-positioning of field gangs and transportation are now part of the standard response for anticipated extreme winter weather events. Texas-based natural gas producers are incorporating the "playbooks" of their northern cousins (Colorado, North Dakota, Wyoming) to sustain winter operations. Continuing efforts to collaborate with PUCT and TXDOT will facilitate additional improvements in the resilience of gas field operations during events. Windbreaks were observed to have been installed to mitigate north wind impacts during the December 2022 winter storm event (Elliot).

    - However, 10-30% of natural gas production remains expected to go offline regardless of weatherization due to other factors, including produced water content, uneconomic weatherization for marginal productions, etc.
    - During mid-December Winter Storm Elliot, ~25% of natural gas production went offline due to a "freeze-off" in field production, likely associated with the least productive wells. Supply interruption did not measurably impact thermal power generation or result in interruption of "firm supply / firm transport" contracts.

- **Interdependence problem:** The Texas Oil and Gas Association has recognized the implications of service interruption and is actively working to increase the reliability of the gas supply. PUCT / ERCOT have established "Firm Fuel / Firm Transport" agreements to be applied to thermal power generation suppliers on an "as requested" basis. The Texas Railroad Commission bears the brunt of the requirements for addressing the remaining challenges in this component of resilience. During highly stressful events, no action has been taken to pre-plan for potential compensated curtailments with large natural gas consumers, like LNG terminals. There is limited evidence of fundamental changes and material investments to address field-level interdependence on electricity through alternative solutions.

- **Intrastate market transparency:** There has been no significant action from the Texas Railroad Commission or Texas Oil and Gas Association regarding greater transparency for Intrastate natural gas production in real-time. The lack of transparency by the natural gas industry, especially in relation to the transparency of ERCOT, remains a challenge.

- **Curtailment:** Exemptions filed with the PUCT rose from 100 before Winter Storms Uri and Viola to 3,000+ by December 2022. An automated approach is required to apply for exemptions in an orderly and timely fashion by PUCT / ERCOT when an event threatening the power grid arises. There is limited evidence that the distribution system can remotely manage curtailments to avoid curtailing essential loads.

- **Operational awareness:** Texas Railroad Commission and Public Utilities Commission of Texas continue to employ a "Supply Chain Integrated Map" to increase reliability.

Energy infrastructure Conclusions

In some areas, the energy industry has responded and made necessary investments and procedural changes for prepositioning equipment for weather extremes, and some steps have been taken to mitigate interdependence. Critical supply chain mapping has helped identify potential risk areas in delivering natural gas to the electric industry during weather-related stress.

There has been a focus on reducing interdependence by the electric on the natural gas sector. However, the natural gas industry's reverse dependence on the electric sector appears to have been cosmetically addressed. A lack of a transparent intrastate Texas natural gas market remains an unfulfilled requirement.

Water infrastructure updates.

The ASCE Texas Section's report, *Reliability and Resilience in the Balance*, outlined several critical recommendations intended to focus improvements on the reliability and resilience of service delivery by Texas Water Utilities. The report was prepared in response to the significant power issues experienced during the Twin Winter Storms in February 2021. Ice accumulation caused by the precipitation and frigid temperatures in Texas, rolling blackouts, and extended duration power outages at critical facilities caused widespread disruptions to water and wastewater infrastructure across the State, affecting many components of these systems in multiple categories.

According to the Texas Commission on Environmental Quality (TCEQ), nearly 40% of Texas Water Utilities had to issue boil water notices during the storm. To prevent future water outage events, the report suggested the following critical recommendations for water utilities:

- Consider increasing the amount of treatment capacity available during the winter months.
- Consider increasing the number of backup generators, including portable backup generators on trailers and portable diesel pumps. Install auto transfer switches on generators.
- Consider implementing backup power for Supervisory Control and Data Acquisition (SCADA) communications.
- Consider increasing bulk chemical storage.
- Educate the public on the need for 72 hours of supplies for emergencies.
- Educate customers on locating and operating their premise water shutoff valves.
- Replace cast iron pipes with a history of poor performance.

- Ensure access to all-weather vehicles. Utilize fuel additives for diesel during winter months. Acquire and store tire chains, then distribute them to appropriate vehicles prior to winter weather.
- Top off water supply storage prior to a winter storm event.
- Conduct winter weather preparation at facilities, such as pipe insulation, draining non-critical piping, storing strap-on boot spikes, bedding, and Meals Ready to Eat (MREs). Ensure manual access to critical facilities, such as walk-through gates.
- Include emergency response to the list of benefits when justifying Automated Metering Infrastructure implementation.

Current regulatory and legislative activity

A Statewide response was requested when the Texas Legislature crafted and passed Senate Bill 3 of the 87th Legislature in 2021. Senate Bill 3 requires all drinking water and raw water utilities to submit an emergency preparedness plan to TCEQ with options to demonstrate that the utility can maintain 20 psi water pressure during a power outage lasting 24 hours or more, as soon as safe, and practicable following the occurrence of a natural disaster. The capital infrastructure required to satisfy these requirements has placed a financial burden on Texas Water Utilities.

The Emergency Preparedness Plan was required to be submitted to the TCEQ by March 1, 2022. Senate Bill 3 also added special billing provisions for water outages due to extreme cold weather events (10°F for 24 hours), requiring water utilities to waive late fees, including payment plans and prohibiting suspension of service disconnections due to nonpayment, and allowing Texas Water Development Board (TWDB) to provide grants to weatherize water and wastewater systems.

As of March 15, 2023, the Water Supply Division of the Texas Commission on Environmental Quality is reviewing the Environmental Preparedness Plans (EPPs) submitted by Texas water utilities. Of the 3,865 utilities that TCEQ has determined to be affected utilities, 3,516 systems have submitted an EPP, and 143 have requested a financial waiver. Of the systems that have offered an EPP, 1,964 have listed an implementation date on or before 7/1/22.

Water Utilities were also required to submit information to the PUCT identifying each electric utility that provides transmission and distribution service to the affected utility, each retail electric provider that sells electric power to the affected utility, and contact information for the office of emergency management of each county in which the utility has water and wastewater facilities that qualify for critical load status under rules adopted by the PUC and the division of emergency management of the governor by November 1, 2021.

The TWDB offers a variety of financial assistance programs for the planning, acquisition, design, and construction of water, wastewater, and flood infrastructure projects. In the two years since Winter Storm Uri, there has been a 37% increase in TWDB funding commitments compared to the two years-prior to Winter Storm Uri. This committee requested information on funding commitments to Texas Water Utilities for projects that include weatherization of water and wastewater systems and for emergency preparedness since February 2021 from the TWDB. The TWDB provided a funding commitment list for projects containing 47 utilities totaling almost $432 Million. Twenty-eight percent of the funding commitments were related to emergency preparedness. A review of the project descriptions on this list shows eight projects that include emergency or backup generators, three projects that include developing emergency preparedness plans and two projects that have funding emergency preparedness implementation.

Has the Water Industry Reliability and Resiliency been improved since the Winter Storms?

Texas has experienced several extreme weather events since Winter Storms Uri and Viola in February 2021. None of these extreme events have caused widespread water service outages. Some notable weather events include:

- Between the summer months of June and September of 2022 and 2023, Texas consistently had temperatures exceeding 100 degrees.

- In December 2022, temperatures dropped well below freezing across much of the state, but there was no significant precipitation, which avoided ice and snow buildup.

- In February 2023, Significant ice accumulations in Central Texas caused extended power outages to 400,000 customers. This resulted in some isolated water outages in Central Texas.

Major water outages and/or boil water notices have occurred but have not been tied explicitly to weather events. Two notable city-wide boil water incidents occurred in 2022 but were unrelated to the weather.

- On February 5, 2022, the City of Austin issued a city-wide boil water notice due to an operational error at the Ullrich Treatment Plant.
- On November 27, 2022, the City of Houston issued a city-wide boil water notice because of a power outage at its East Water Purification Plant due to two transformers going offline at Houston's East Water Purification Plant.

To gather more information about water utilities' reliability and resilience preparedness activities, this subcommittee recently sent a survey to 46 Texas Water Utilities. The survey included the following questions and highlights and summary of their responses:

1. Have you submitted your Emergency Preparedness Plan to TCEQ?
   a. *Response:* All had submitted their EPPs to TCEQ

2. What percent of your plan has been implemented?
   a. *Response:* EPP implementation ranged from 12-100%

3. Have you conducted any Tabletop exercises to practice for emergency water events?
   a. *Response*: 80% had conducted Tabletop exercises

4. Have you had water service interruption since Winter Storm Uri? If so, will the steps included in your EPP prevent this interruption in the future?
   a. *Response:* Two reported water service interruptions. In one case, their EPP prevented a more widespread outage. In the other case, the EPP actions will prevent this outage once the plan-specified generator is installed.

5. Has your Utility's communication with the Electric Utility in your area improved since Winter Storm Uri? Please tell us how you went about improving this communication?
    a. *Response:* 80% reported good communication with electric utility in their service area.

The committee also found evidence that organizations are providing more public education regarding public preparedness. For example, the Central Texas Emergency Preparedness Team has been holding Pop-Up seminars on emergency preparedness. These began in September 2022.

Water Industry and Infrastructure Conclusions

The Winter Storms Uri and Viola significantly impacted water utility operations. The State reacted by requiring water utilities to submit EPPs to demonstrate that the utility can maintain 20 psi water pressure during a power outage lasting 24 hours or more, as soon as safe and practicable following a natural disaster. Ninety-one percent (91%) of the affected utilities have submitted their EPPs to TCEQ. The next step will be for water utilities to complete the implementation of their EPPs, including funding and constructing any required equipment and projects, and to exercise preparedness through ongoing activities such as Tabletop exercises where they engage their staff and partners at their local electric utilities. Water Utilities will need to finance the required improvements and infrastructure to meet the requirements in Senate Bill 3 of the 87th Texas Legislature. The TWDB offers a variety of financial assistance programs for the planning, acquisition, design, and construction of water, wastewater, and flood infrastructure projects. A review of project descriptions for projects with TWDB committed funding since February 2021 shows eight projects that include emergency or backup generators, three that have emergency preparedness plans, and two that involve funding emergency preparedness implementation.

<u>Electric Industry Updates</u>

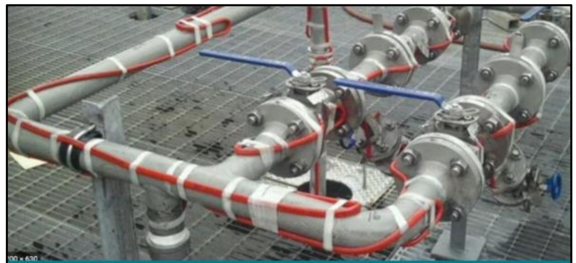
This section will begin with an overview of the legislative and regulatory changes. Some have been implemented, while others remain works in progress. This will, in turn, be followed by an assessment of how the system has performed since Winter Storms Uri and Viola and ID critical open issues.

Regulatory and legislative <u>aftermath of the 2021 storms</u>

HB 4492 and related legislative and regulatory actions were enacted in 2021. Then, in October 2021, the PUCT authorized ERCOT to finance a "default balance" of $800 million that included specific unpaid amounts owed to ERCOT by competitive market participants, congestion revenue rights (CRR) auction funds used to reduce short payments related to Winter Storm Uri and costs associated with implementing the debt obligation order. The securitization of subchapter M default (up to $800M) charges and subchapter N Securitization Uplift Balance (up to $2.1B) in funds. While this securitization resolved a legacy situation, it resulted in an increase in costs to the ERCOT system with limited benefits to improved reliability and resilience. In essence it resolved a legacy issue, not the future issues or issues going forward in time.

SB2 and SB3 reformed ERCOT and enabled weatherization and improved the grid's reliability, among a host of other issues.


Temporary Wind Break Structures


Heat tracing applied to Water Lines (prior to applying insulation and cladding)

The Texas PUC has implemented several changes in response to the Winter Storm Uri events. These changes included:

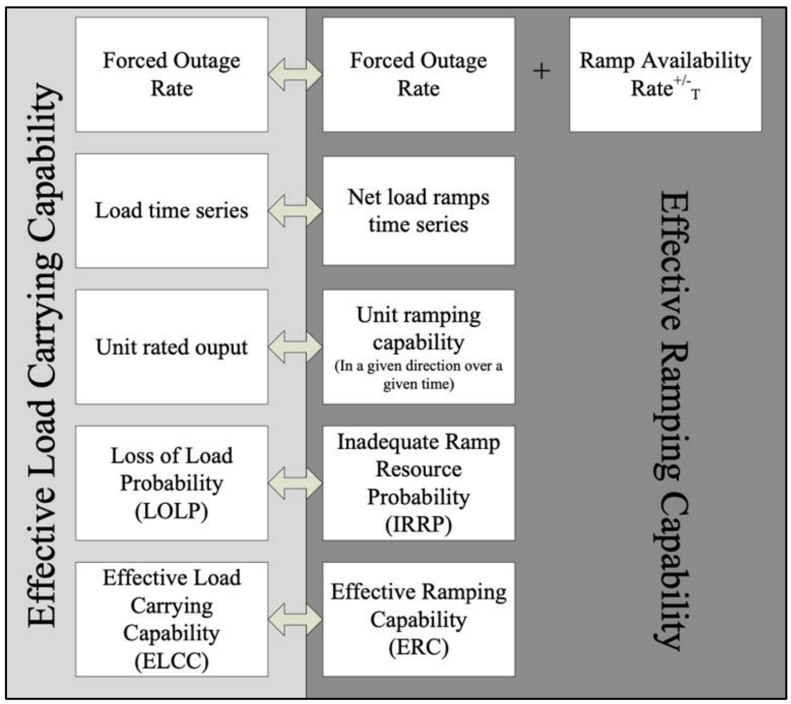
- Increased oversight of ERCOT: The Texas PUC increased its oversight of ERCOT by requiring more frequent reporting and audits of ERCOT's operations.
- Financial penalties: The Texas PUC imposed significant financial penalties on power generators that failed to comply with weatherization standards (pictures – ERCOT).
- Improved regulatory framework: The Texas PUC revised its regulatory framework to ensure that it is better equipped to handle extreme weather events. ERCOT performed 774 inspections (generation and transmission) completed from December 2022 through March 2023, resulting in 69 cure periods (timeframe to complete deficiency or be reported to PUCT).
- Public participation: The Texas PUC introduced measures to increase public participation in the regulatory process, including public hearings and feedback mechanisms.
- Establishing transparent reliability standards within ERCOT (such as a LOLE 1 in 10) remains a heavily debated issue and has delayed implementing solutions supporting such standards. There are several ways to evaluate reliability:

LOLP (Loss-of-load probability)	Probability that there will be insufficient generation to meet the load at a given point in time.
LOLE (LOLP x given unit of time)	LOLP multiplied by a given unit of time. Represents only the number of shortfalls and not the size of the shortfall (e.g., one day in 10 years)
LOLH (Loss-of-load hours)	Form of LOLE, usually expressed in hours per year in which there may be insufficient generation supply
EUE (unexpected unserved energy)	Captures the energy components of inadequacy but does not count the number of occurrences
ELCC (Effective load-carrying capability)	Measures how much more peak load can be added with the introduction of new capacity for a fixed reliability level

There are also a number of reliability metrics that have been used by industry:

Method	Metric	Target value examples
Probabilistic Method	LOLH	2.4 hours/year
	LOLE	One day/10 years – most common in the US and Canada
	LOLP	5% = significant power shortage no more than once in 20 years
PRM Method for Resource Adequacy (Planning Reserve Margin = administratively determined based on capacity w/o Forced Outage Rate (unplanned outages)	PRM	15%
	PRM	12-18%
	PRM	13%

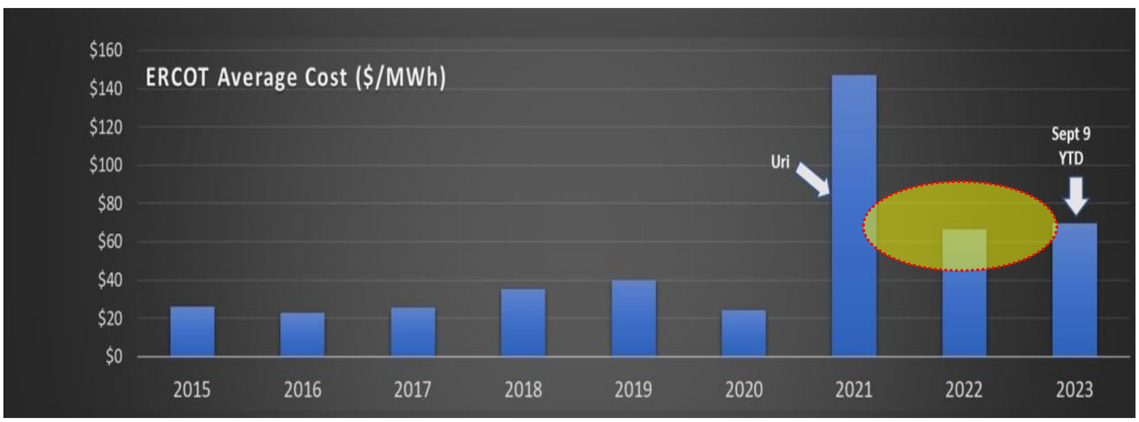
These are further complicated when there is the challenge of trying to flexibly match the different supply sources of variable generation (intermittent) and dispatchable generation to meet the needs of the load.



Astrape Consulting (used by ERCOT) breaks down the LOLE metric into components due to capacity inadequacy and flexibility inadequacy to understand the capability of resources to meet expected flexibility needs (Lannoye et al. 2010). This insight helps understand the impact of increased penetration of variable or intermittent generation on the network needs by requiring increased flexibility from dispatchable generation to meet reliability and resilience standards. This, in turn, also further impacts the challenge of creating further strain on revenue insufficiency.

- Efforts to resolve the problem of revenue insufficiency for a dispatchable generation have been uneven at best, with potentially costly interim solutions that address the symptom in the short term but fail to resolve the more fundamental problem of revenue insufficiency. The regulatory changes implemented manage some aspects of revenue sufficiency and attempt to institute more command-and-control actions to address reliability due to the inability of the retaining energy-only model to address reliability in its structure. The downside of this approach is that it tends to reduce the certainty of revenue-sufficiency streams for potential investors in a dispatchable generation. It may not attract incremental dispatchable generation investments, yet drive up prices in the short term:

- The PUCT reduced the system-wide max cap from $9,000 to $5,000/Mwh, which reduced risks to all market participants.
- The ERCOT market now allows earlier responses to potential emergencies that incentivize more generations to come online. In a market dependent on the volatility of prices to contribute to trying to satisfy a portion of the revenue insufficiency problem, this tends to reduce marginal prices further.
- Compensation for voltage support services rather than the former reliance on out-of-market deployments.
- ERCOT introduced a firm fuel product that pays for on-site fuel storage (dual fuel) – this also addresses interdependence risk.
- Forced weatherization standards on generators but did not address funding of the investments.



While many factors, including fuel costs and inflation, can influence the average power price in ERCOT since 2015, it appears that the reliance on the interim solutions implemented to date may be a factor in a step change in higher average system costs in ERCOT. These levels are more than the reliability and resilience investments that ASCE determined would be needed.

- The passage of SB 2627 during the 88th Legislative Session highlighted ongoing legislative distrust in the PUCT market solution of the Performance Credit Mechanism. It expanded the use of "Ancillary Services" to be effective and, therefore, contemplates Texas subsidizing dispatchable generation. The original problem was created by revenue insufficiency for a dispatchable generation because of subsidized intermittent market competitors negatively impacting prices in the energy-only ERCOT market structure while increasing the operational demands on these same dispatchable resources critical for system reliability. ERCOT's market structure failed to value reliability and the investments required to achieve reliability.

SB 2627 (Proposition 7 on November Ballot) proposes to offer low-interest loans to build or upgrade natural gas-fired thermal generation in Texas. The intent is to increase the amount of dispatchable generation available to the ERCOT market. Regrettably, the narrow focus on fossil fuel-powered generation restricts the options for other power sources (utility-scale battery storage operations in particular) to expand operations. Additionally, the emphasis on subsidizing the capital cost (fixed cost) side of the power generation equation does nothing to address the variable cost associated with reliable power generation (fluctuating fuel prices, firm supply, and firm transport). Consequently, it remains to be seen whether this approach incentivizes investors to build new generations or enhance the capabilities of existing generation operations under the same market structure (Energy Only) that has taxed the capability of the ERCOT-managed grid to date.

- There is an active push to formalize and establish a Reliability Standard and an updated Value of Lost Load (VOLL) in ERCOT. There are several factors in a reliability standard, including the determining reserve margins required to achieve specific frequency (how often the events occur), duration (how long the events last), and magnitude (how many people or how much of the system is impacted). The preliminary modeling results of the ERCOT effort as of 6/23/23 on developing the reliability standard effort confirm that this remains a work in progress. If a transparent and actionable reliability standard is adopted, ERCOT must demonstrate to PUCT and the market that the standard can or cannot be met. If, as anticipated, the reliability standard cannot be met, a yet-to-be-defined process may force a final resolution of the revenue insufficiency problem. However, this is a highly uncertain outcome, and the problem has the potential to be kicked down the road to be solved sometime in the future if tangible results are not satisfied.

Preliminary Modeling Results for the Reliability Standard Study

- **Purpose**
  - Provide preliminary modeling results from the Reliability Standard Study
- **Voting Items / Requests**
  - No action is requested of the R&M Committee or Board; for discussion only

Key Takeaways:

1. Varying Reserve Margin levels in the analysis provide insight into Frequency, Duration, and Magnitude of events.
2. A single metric for Frequency of events will result in a set of events that have a wide range of Duration and Magnitude.
3. Even at 1 in 10 years Frequency (traditionally used LOLE standard) some events will be extreme, illustrating the short coming of just having a Frequency measurement for reliability.
4. Avoiding all extreme Magnitude and/or Duration events may require inordinately high resource investment.
5. Recommend incorporating a risk tolerance metric, like exceedance probability, to appropriately calibrate the reliability standard.

Item 7.1.1 ercot

The failure to address the fundamental problem of revenue insufficiency transparently has the potential for severe negative consequences to the markets and ERCOT's ability to attract private investment in new incremental, reliable, dispatchable generation capacity.

<u>ERCOT efforts to address specific extreme weather preparedness efforts have been:</u>

- ERCOT has conducted 774 weather preparedness inspections since December 2022, covering both generation sites and Transmission Service Providers. These inspections focused on whether each reporting entity performed the weatherization activities described in their Winter Weather Readiness Reports required by the Texas PUC. Cure periods to resolve deficiencies were offered in 69 cases. ERCOT also imposed financial penalties on generators that failed to comply with weatherization standards.

- ERCOT has been working with the Texas PUC on developing phase II of the preparedness standards, which address both winter and summer preparedness compliance, including new communication protocols to enhance collaboration between power generators, transmission companies, and retail electricity providers. An aspect of preparation is understanding winter temperature risks and the percentile of minimum temperatures.

- ERCOT has enhanced its real-time monitoring capabilities to detect potential issues and prevent cascading failures.

- ERCOT procured 2,940.5 MW from 19 generators to provide backup fuel storage to ensure natural gas generators can operate for 48 hours, even during gas supply curtailments or other fuel supply interruptions. This service was developed consistent with directives from the Texas Legislature requiring ancillary or reliability services to address reliability during extreme cold weather conditions and the Texas PUC order for ERCOT to develop a firm-fuel product that provides additional grid reliability and resiliency during severe cold weather and compensates generation resources that meet a higher resiliency standard.

- ERCOT also hosted Winter Weather Preparedness Workshops for generation resources and transmission providers. However, preparedness between infrastructure sectors, including scenario stress testing, remains inadequate.

- ERCOT forecasting of load continues to underestimate demand or generate viable scenarios that are confirmed in the market. However, ERCOT has taken steps to become timelier in its analysis, such as creating monthly SARA reports (now MORA – Monthly Outlook Resource Adequacy).

Has the electric industry's Reliability and Resiliency been improved since the winter Storms?
We'll focus the response on three primary areas of concern.

1. **Actual performance of ERCOT** during seasonal demand indicates that the reliability and resilience problem remains.

2. **Black start generators** – the system failsafe has been addressed, but the extent of the changes and investments are unconfirmed due to confidentiality.

3. **Revenue sufficiency** – Actions to date have failed to resolve how the system ensures sufficient revenue for reliability and resilience investments.

ERCOT performance during seasonal demand periods

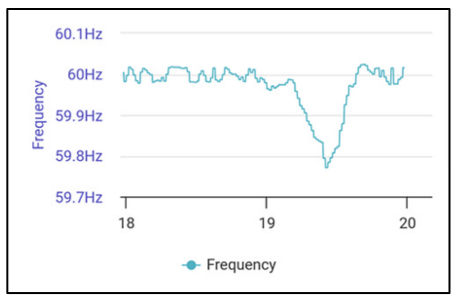
To assist in understanding system reliability, it is essential to understand the emergency energy alert system of ERCOT and what it means as an emergency indicator of reliability. When system reliability is threatened, or at risk of failing, ERCOT issues one of three levels of Energy Emergency Alerts (EEA) intended to help protect the system's reliability and avoid uncontrolled system collapse and significant equipment damage when operating reserve margins drop.

EEA level 1	When operating reserves drop below 2,300 MW and are not expected to recover within 30 minutes, grid operators can call on all available power supplies, including power from other grids, if available.
EEA level 2	When operating reserves are less than 1,750 MW and are not expected to recover within 30 minutes, ERCOT can reduce demand on the system by interrupting power from large industrial customers who have contractually agreed to have their electricity turned off during an emergency. ERCOT can also use demand response resources that have been procured to address tight operating conditions
EEA level 3	An EEA3 is declared if operating reserves cannot be maintained above 1,375 MW. If conditions continue to deteriorate or operating reserves drop below 1,000 MW and are not expected to recover within 30 minutes, ERCOT will order transmission companies to reduce demand on the system.

Including the Winter Storms Uri and Viola, ERCOT has initiated only 4 EEA level 3 controlled load-shedding events (outages) since the grid operator was formed.

Date	Size of load curtailment	Nature of Event
December 22, 1989:	500 MW	winter storm
April 17, 2006:	1,000MW	Unseasonable loads & maintenance period
February 2, 2011:	4,000 MW	severe winter ice storm
February 15-18, 2021:	20,000 MW	severe Winter Storms Uri and Viola

However, on September 6, 2023, ERCOT issued its first EEA Level 2 alert since winter storms Uri and Viola in 2021. At about 7:30 PM, the system frequency dropped below 59.8Hz, a frequency level ***below*** when some load shedding was initiated during Uri and Viola before recovering. This is also ERCOT's first level 2 EEA issued during the summer since its formation.



Seasonal weather has an evident impact on system demand. Texas has experienced various weather conditions on a seasonal basis since the Twin Winter Storms. These are described below:

Summer 2021

During the summer of 2021, weather was generally mild across the state, with temperatures near or below average and more than normal rainfall. ERCOT operated the grid conservatively to lower the risk of insufficient generation online due to forecast errors or unplanned thermal generation outages by purchasing more ancillary services and Reliability Unit Commitments to achieve a 6,500 MW reserve. New monthly peak demands were set in June and September, but no new annual peak was set. The 2021 Annual peak demand occurred on 8/31/21 and was 73,475MW vs.

a forecasted peak demand of 77,244 MW. The electric grid met the demand of the summer events of 2021.

Winter 2021/2022

In the aftermath of Winter Storms Uri and Viola, ERCOT accelerated winterization efforts where possible and conservatively operated the grid with ample reserves. There was a combination of regulatory, legislative, and industry will that manifested itself to ensure that all necessary steps to avoid a repeat of Winter Storms Uri and Viola were taken. No significant storms broadly impacted Texas from December 2021 through March 2022.

Summer 2022

June through August 2022 was the second hottest period on record for the state of Texas (1895 to date). Following a series of 11 new peak demand periods starting at the low end of 74,900 MWs, an all-time peak demand of the system was set at 80,148 MW on 7/20/22, and the highest weekend peak demand was set at 77,359 MW on 7/9/22. While no Energy Emergency Alerts (EEA) were issued in 2022, there were two watch periods when supply was tight. Forced outages of dispatchable generation during the summer of 2022 were higher than in 2021. The system responded with increased ancillary Service quantities in July 2021 and extended this practice into the summer of 2022, and ancillary service prices were higher in 2022 than in the prior two summer periods. The increase in demand is reflective of both increased electrification and customer growth. The electrical grid met the demand of the summer events of 2022.

Winter 2022/2023

On December 22nd through 25th, 2022, temperatures dropped below freezing across much of the state from Winter Storm Elliott. There was no significant precipitation, mitigating accumulations of ice and snow. Due to the extended cold weather from Elliott, ERCOT surpassed its previous peak demand record. A peak demand record of 74,100 MW was set on 12/23/2022. Since the instantaneous Physical Response Capability (PRC) never fell below 4,052, no EEA events were declared. In February 2023, significant ice accumulations in Central Texas caused extended power outages to 400,000 customers. Burnet, Hayes, Travis, and Williamson Counties declared Disaster Areas, due to the ice damage on the lower voltage overhead electrical distribution system, are the power grids least "hardened" aspect. None of the above extreme winter weather events matched the Winter Storm Uri and Viola events in either duration or extent, and the electrical grid in Texas could make it through both. No EEA was issued during this winter period. Part of the success may have been attributable to better public awareness, resulting in better preparedness and more conservative operational parameters of the grid.

Summer 2023

Through early September 2023, ERCOT set another ten new all-time demand records, including an all-time peak demand of 85,464 MW on August 10, 2023. On August 17th, the power reserve dropped from 6,000 MW to 600 MW, and the system requested conservation steps by the public and industry. On September 6, 2023, ERCOT issued a level 2 EEA event notice, indicating operating reserves had dropped below 1,750 MWs and are not expected to recover within 30 minutes. Various factors contributed to these grid performance episodes, including unplanned power plant trips (due partly to deferred maintenance), transmission line congestion, and evening ramp-down of solar power. While the electric grid met the demand of the summer of 2023, it was forced to issue a level 2 EEA.

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Peak Demand Search
2023 Records
September 2023
August 2023
July 2023
June 2023
2023 All-Time Weekend Peak Records
2023 All-Time Records
2022 Records
ERCOT Yearly Peak Demand Records
Yearly Peak Demand

2023 All-Time Peak Demand Records

Previous Peak: 83,961 MW set 08/09/2023

Month	Demand (MW)
June 27	80,787
July 12	81,351
July 13	81,406
July 17	81,911
July 18	82,592
July 31	82,939
August 1	83,593
August 7	83,854
August 9	83,961
August 10	85,464

<u>ERCOT performance since Winter Storms Uri and Viola has mainly remained untested by similar storms during the subsequent two winter periods.</u> No one should take solace in the fact that the Texas electric system withstood the most recent modest stresses from winter storms Mara and Elliot, relatively weak storms, regionalized in their impact. In simple terms, the system has not experienced a material stress test. ERCOT's level 2 EEA event on September 6, 2023, confirms that system reliability remains seriously at risk. It is also an indirect indicator that the initial mitigation steps taken since Winter Storms Uri and Viola to address reliability and resilience issues remain insufficient.

ERCOT's yearly system demand records indicate a strong pattern of load growth and are consistent with the historical pattern of summer load growth, setting new demand records within ERCOT.

Home | ERCOT Yearly Peak Demand Records

ERCOT Yearly Peak Demand Records

Last updated: Aug 11, 2023

*All records are unofficial until final settlements occur.

Year	Month	Demand (MW)
2023	**August 10 (current record)**	**85,464**
2022	July 20	80,148
2019	August	74,820
2018	July	73,473
2016	August	71,110
2015	August	69,877
2011	August	68,379
2010	August	65,776
2009	July	63,400
2005	August	60,274

<u>Black Start Generation</u>

Investments in winterization have been made, and regular seasonal inspection schedules have been implemented on behalf of ERCOT and the PUCT. Black Start training simulation utilizes black start capable units (that may not be contracted as black start resources). These units are capable of isochronous control. This training helps to better prepare operators for various situations and

Low Temperature

Weather Zone	95th Percentile Minimum Temperature	99th Percentile Minimum Temperature	February 2021 Minimum Temperature Percentile Rank
North	-4°	-12°	95th
North Central	1°	-7°	98th
West	-4°	-9°	95th
Far West	-1°	-11°	96th
East	1°	-6°	99th
Coast	11°	5°	93rd
South Central	7°	-2°	95th
Southern	17°	11°	95th
Valley	21°	13°	94th
Panhandle	-11°	-16°	95th

Table 1: Historical Minimum Temperature Data

challenges to try and meet short time frame critical load restorations and prepare for uncertain situations, including protocol solutions for breakers and switches to accomplish desired outcomes. Dual fuel capability has been underwritten with a minimum 72-hour fuel reserve at full load. The dual fuel capability of Black start units during Winter Storms Uri and Viola was limited to only 10 out of 28 units.

ASCE understands that investments have been made/proposed to improve the reliability and resilience of these resources, but supporting confirmation is kept confidential by new rules and regulations. This dual fuel capability for simple cycle gas turbines potentially allows non-black start designated generators to serve in a black start role, subject to appropriate equipment and control modifications. There is a rigorous set of standards for various required tests to confirm the availability and reliability of Black Start generation units. Due to confidentiality, it is unclear if any units have been replaced for failing to meet these standards. It is unknown if sufficient capital has been made available to ensure that appropriate investments have been made to ensure that the performance of these units can sustainably satisfy the reliability and resilience needs of the network.

Revenue Sufficiency.

The PUCT and ERCOT implemented several market changes (Performance Credit Mechanism (PCM), Reliable Unit Commitment (RUCs), and other tools) that addressed short-term transitional issues, including increased incentives for additional dispatchable generation during on-peak periods. Requirements to confirm firm transportation and supply portfolios for winter peak service have been established. Still, whether these levels are sufficient to meet seasonal reliability and resilience requirements remains unknown.

The fundamental problem of revenue insufficiency for dispatchable generation remains to be fully resolved. Central to the ongoing debate is the inability to balance the desire to continue the legacy energy-only market structure (a structure that created the revenue insufficiency problem) and a capacity market. This has fundamental negative consequences in various areas, including a) Reliability investments, b) Firm fuel transportation and supply, and c) Ongoing O&M maintenance.

ERCOT did not previously have a formal reliability standard following the deregulation of the market. The legislature directed the PUCT to develop a formal reliability standard in the aftermath of Winter Storms Uri and Viola. Most ISOs in North America establish a planning reserve margin using some variation of a 1-in-10 standard (meaning loss of load for one day in 10 years). The PUCT indicated that this standard needs to be improved upon and has an active process (project #54584) underway with extensive debate on the nature and scope of an appropriate reliability standard from industry participants, with some participants indicating concerns that such a standard would create a capacity market. The resolution is uncertain at the time of this document. In comments, the PUCT staff supports considering a reliability standard to measure multiple metrics. It also believes that such a standard must be a mandated requirement and that PUCT should mandate that ERCOT include the anticipated cost of various reliability standards with a sensitivity analysis.

There are a variety of potential resources with different operational, capital, and environmental considerations that can contribute to solving the need for additional dispatchable generation. The lack of active investment in the new dispatchable generation indicates continued market uncertainty over the changes proposed by PUCT and ERCOT to attract investment in the new dispatchable generation. During the 15 years from 2008 through 2022, dispatchable generation supply grew by only 1.5% while power demand increased by over 20% in ERCOT. Simultaneous with this lack of incremental investment is increased operational demands to cycle and dispatch on short notice to meet shortfalls in intermittent generation that, in turn, compound capital demand for increased O&M and reliability investments in existing dispatchable generation. Short notice and system duration requirements limit the range of dispatchable solutions to meet these needs. There has been limited tangible investment in incremental dispatchable generation or related financing announcements since 2021, providing clear market feedback on the lack of confidence in the changes being implemented to date.

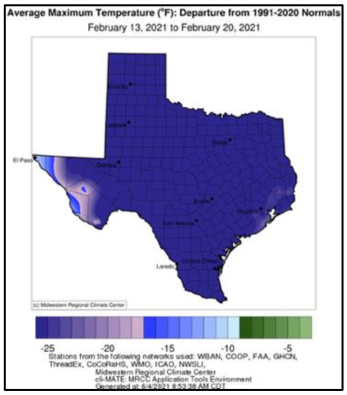
Electricity Infrastructure Conclusions

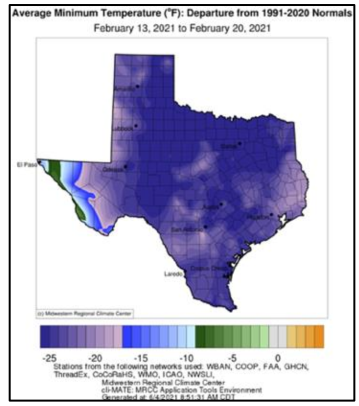
The Winter Storm Uri events highlighted significant shortcomings in the Texas power grid and regulatory framework. ERCOT and PUC appear to have taken steps to address some or parts of these issues, including weatherization of infrastructure, increased reserve margins, enhanced communication protocols, and improved oversight and regulatory framework. However, several critical areas, including a clear resolution for revenue sufficiency, remain unresolved and will create further risks to reliability and resilience in the future. New confidentiality requirements prevent ASCE from confirming that investments have been made/proposed to improve the reliability and resilience of these resources.

		Operational considerations						Environmental considerations			
Resource type	Generation Type	Dispatchable or Intermittent	Typical availability	Other Constraints	Estimated Installed Capital cost per Kw	Effective Capacity Utilization		construction	Operation	greenhouse gas emissions	Other
low carbon resources	**Hydro**	Dispatchable	95%	Seasonal	$$$	95%		Varies	Limited	During construction	Fish
low carbon resources	**Geothermal**	Dispatchable	95%		$$	95%		Mining	Mining	Construction	Drilling waste
low carbon resources	**Wind**	Intermittent	90%	only when wind available	$	30-40%		Varies	None	During construction	Mining
low carbon resources	**Solar**	Intermittent	85%	only during daylight hours	$	25-35%		Varies	None	During construction	End of life disposal
low carbon resources	**Nuclear**	Dispatchable (usually base loaded)	90%	permitting	$$$	90%		Varies	None	During construction	Waste storage
low carbon resources	**Biomass** (wood chip, biogas, plant material)	Dispatchable usually base loaded	85%	Fuel (sometimes seasonal)	$$	90%		Depends on technology	Depends	During construction depends on tech	Ash
storage resources	**CAES** (Compressed Air Energy Storage)	Dispatchable 4 to 10 hour	90%	Depends on design	$	95%		Varies	None	During construction None (indirect)	
storage resources	**Battery** (includes EV)	Dispatchable 4 hour & extending	95%	4-hour storage	$$	20%		Mining	None	During construction None (indirect)	Mining
storage resources	**Pumped storage**	Dispatchable 4-8 hour	95%	Limited sites in TX	$$$	20%		Varies	None	None (indirect)	Depends
Fossil thermal resources	**Coal**	Dispatchable	88%	RR access	$$	90%		Yes	Yes	Yes	Mining
Fossil thermal resources	**Natural gas CCGT**	Dispatchable	95%	Gas supply & transport	$	95%		Yes	Yes	Yes	Production
Fossil thermal resources	**Natural gas & oil CT**	Dispatchable	95%	Fuel supply and storage	$	95%		Yes	Yes	Yes	Production
Demand response	**Industrial and Residential**	Dispatchable or intermittent	NA	Duration question	varies	NA		depends	unless back-up	depends (self generation)	noise if self generating
Other	**Microgrids**	Dispatchable - depending on rules	depends on resource	NA	varies	NA		Depends	Depends	Depends	Depends

<u>Level setting about the weather – *it's NOT about the weather*</u>

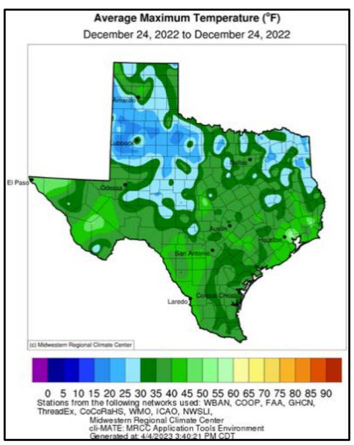
The weather system event of February 2021 was historically severe and was one of just a handful of winter storms of similar strength and expansive statewide reach since 1940. It was the first time in history that all 254 Texas counties were placed on winter storm warning. Fortunately, the physically damaging ice storms during Winter Storms Uri and Viola were localized in impact, and the wind was relatively moderate. Temperatures were not. Some experts have indicated that Winter Storms Uri and Viola were 1 in 100 or 1 in 130-year system events. The severity of a winter storm's impact on infrastructure has four primary dimensions: 1) The number of days when the temperature is below 32^0F for an entire 24-hour period (TMax). 2) The number of days on both sides of TMax when minimum temperatures for at least 1 hour during the 24-hour period was below 32^0F (TMin). 3) Precipitation – especially freezing precipitation that can lead to physical damage and 4) Wind damage impacts from wind chill accelerating cooling or physical damage – especially when combined with freezing precipitation.

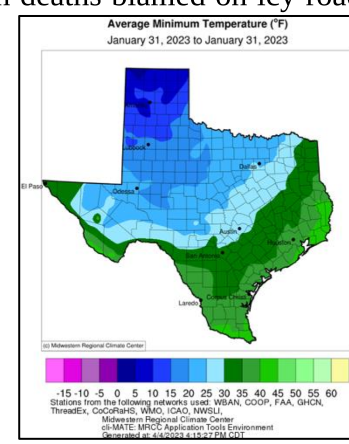




<u>Interim winter storms.</u>

For comparative discussion, Texas was recently subjected to two named Winter Storms, Elliot, December 22-25, 2022, and Mara, January 29 – February 3, 2023. Elliot caused the first-ever wind chill warning for the Austin area and reportedly caused up to 72 deaths nationwide and in Canada. Still, this committee identified no reports of deaths in Texas. Winter Storm Mara was more geographically localized to Texas and its neighboring states. By some accounts, Mara caused at least ten deaths blamed on icy road conditions, seven in Texas, two in Oklahoma, and one in Arkansas. The precipitation in Central Texas during Mara occurred during a narrow time frame of freezing temperatures, which caused extreme ice conditions, putting weight and stress on trees, electrical grid transmission and distribution system, and road hazards. Icing conditions like this tend to occur in relatively narrow temperature bands coincident with precipitation and are more likely to be local and regional in impact. If temperatures rise above freezing conditions, precipitation is rain, while if temperatures fall below this band, it results in snow. As evidenced by the wind chill warnings caused by Mara in Central Texas, wind stresses were also a factor. Despite their relatively mild characteristics, the late 2022 and early 2023 winter events still spawned reports of electric grid risks, weaknesses, and issues.





<u>Weather Conclusions – It's not the weather.</u>

The problems are not about the weather. Weather simply uncovered and exposed the real problem for everyone to see. No one should take solace in the fact that the Texas electric system withstood the most recent stresses from winter storms Mara and Elliot, relatively weak storms, regionalized in their impact.

As this committee initially reported, ASCE continues to maintain that too much focus on storm characteristics distracts attention from the most critical issue. **Winter Storms Uri and Viola exposed major reliability failures in February 2021 and again on a more localized and less severe basis by Elliot and Mara two years later. These failures extend well beyond winter storm events.** As Texas moves beyond the pandemic and the aftermath of the storms, and population growth continues rapidly, the electrical system persists in having substantial and growing reliability and interdependence problems that are slowly addressed but not yet resolved.

The Texas electrical system is not yet ready to face another series of storms like Winter Storms Uri and Viola. As bad as the Twin winter storms were, it could have been much worse. A future storm with the core temperature patterns of Uri and Viola and the same statewide coverage, occurring with excessive precipitation and wind during the coldest periods, would still almost certainly result in similar or worse catastrophic and tragic results than those experienced in February 2021.

In stark contrast, the twin impact of Winter Storms Uri and Viola on Texas and its energy system was far-reaching and catastrophic. However, there is no effective tool to allocate specific responsibility for what impacts were direct from the weather itself, what was directly impacted by the failure of the electric system, and what were indirect impacts. However, ASCE believes that the failure of the electricity grid was directly and indirectly a material contributor to the economic harm and human tragedy experienced during and after Winter Storms Uri and Viola.

The weather served as a catalyst that revealed the fundamental problems to those who looked deeply. It causes point stresses to the system that expose shortfalls in reliability and resilience that could originate from other sources, such as cyber-attacks, terroristic EMP attacks, physical network intrusion, etc. So, as the title of our original committee says, let's go "Beyond the Storms" and stop talking about the weather, clearing the air to address the problem head-on. As this committee initially reported, ASCE maintains that too much focus on storms distracts attention from the most critical issue – namely, a lack of prioritization and under-investment in reliability and resilience. The following recaps and punctuates the Committee's position on the progress made and the long road to achieving true reliability and resilience so future tragic catastrophes will be avoided.

The process and further considerations

Complex problems are seldom solved overnight and often require multiple solution iterations to solve the problem in stages. This is especially evident in high-consequence political situations. Avoiding complex issues, like failing to invest in black start generation by hiding behind a claim that "we're focused on fixing things, so we never get to that stage," is akin to not fixing the sprinkler system and fire alarms because we're going to prevent fires from happening the next time.

Reliability and Resilience of essential infrastructure impacts everyone. As engineers and as a society, we must ensure that critical infrastructure is designed and built on a foundation of reliability and resilience and that this infrastructure is operated and maintained against the touchstone of reliability and resilience. This refresh report provides an updated snapshot of actions taken to date and answers whether the specific problems identified from Winter Storms Uri and Viola have been resolved. This report identifies the gaps and what further actions are needed.

Future issues to consider.

No refresh report on Reliability and Resilience would be complete if it failed to identify three growing concerns impacting essential infrastructure. On the horizon, several emerging issues threaten crucial infrastructure that will heavily impact reliability and resilience.

1. **Accelerated retirements** of dispatchable generation without solutions addressing reliability and resilience impacts. The impact of this ongoing trend can be seen in recent reports confirming growing concerns from state-level regulators to the North American Electric Reliability Corporation (NERC), regional Independent System Operators (ISO) identifying the "high risk of energy emergencies during peak summer conditions" and "regularly available generation might not be able to meet electricity demand this summer….". In simple terms, there is an expected increase in the number of events and operational demands that lead to blackouts.

2. **Increasing electrification** of energy is increasing the strain on grids and generation throughout the United States. In addition to routine demand growth, there are two key drivers of incremental demand growth impacting the speed of demand change and impacts. Electric Vehicles and home heating electrification are_having a growing effect on reliability and resilience.

3. **Situational Awareness and malevolent threats**. Essential infrastructure providers have traditionally focused on solving situational awareness about their networks to support operational needs. A range of SCADA and Operational Technology systems provide this insight and are essential to infrastructure reliability. They are also at increasing risk due to cyber security breaches, which could risk allowing third parties to control critical infrastructure operationally for nefarious purposes. There is a further concerning trend of malicious (local or state sponsors) actors that have the potential to severely impact reliability and resilience in the future through actions against physical network infrastructure. Situational awareness of these events requires a fundamentally different solution concerning network awareness than meeting operational needs.

The following section highlights accomplishments and shortfalls in needed changes

The following tables highlight the five major network themes that contributed to the most impactful adverse outcomes and the current status relative to the identified outcomes:

Issue #1 Invest in Black Start capacity to ensure reliable, failsafe back-up	**What:** Black start generation provides the final fail-safe back-up to the electric network. 21 of 28 (75%) black start generators experienced operational problems. 18 of these 28 units relied on natural gas as their only fuel resource. Revenue insufficiency led to underinvestment in reliability, including winterization, lack of dual fuel capability, and low availability.	
	Outcome: 3 specific outcomes identified	

The status of addressing this issue has been complicated by increased network security concerns limiting access to the supporting information and details.

<u>Changes implemented relative to identified outcomes:</u>

1. Investments in winterization have been made, and regular seasonal inspection schedules against rigorous availability and reliability metrics have been implemented on behalf of ERCOT and the PUCT

2. Dual fuel capability has been underwritten. New confidentiality standards prevent independent confirmation of these details. This dual fuel capability for simple cycle gas turbines potentially creates the opportunity for non-black start designated generators to serve in a black start role, subject to appropriate equipment and control modifications.

3. Operator training on black start scenarios and switching challenges enhances capabilities under stress. Additional non-designated black start generators that may provide black start capabilities have been identified and could serve as additional backup units if required.

<u>Shortfalls and Gaps - changes still required</u>:

1. It is unknown if sufficient capital has been made available to ensure that appropriate investments have been made to ensure that the performance of these units satisfies the reliability and resilience needs of the network.

Issue #2 Restructure regulatory flaws negatively impacting dispatchable generation	**What:** The ERCOT energy-only market structure prioritized low cost over reliability. This led to chronic under-investment (revenue insufficiency) in dispatchable generation and ongoing erosion of reliability and resilience at a time when the system is increasingly stressed from subsidized intermittent wind and solar resources. The lack of revenue sufficiency results in a "Run to Fail" model.	
	Outcome: Predictable and reliable revenue sufficiency is required to support the long-term capital investment and operation and maintenance expenses to achieve the desired system reliability. Five specific outcomes were identified.	

<u>Changes implemented relative to identified outcomes:</u>

The PUCT and ERCOT implemented several market changes (Performance Credit Mechanism (PCM), ERCOT Contingency Reserve Service (ECRS - new), Reliability Unit Commitment (RUCs), and other tools) that addressed short-term transitional issues, including increased incentives for additional dispatchable generation during on-peak periods. Preliminary analysis of

ECRS performance indicates that there may be unintended consequences and incentives to game the system for economic benefit, resulting from increasing prices in ERCOT. Requirements to confirm firm transportation and supply portfolios for winter peak service have been established. Still, whether these levels are sufficient to meet seasonal reliability and resilience requirements remains unknown.

<u>Shortfalls and Gaps - changes still required</u>:

1. The fundamental problem of revenue insufficiency for dispatchable generation remains to be fully resolved. Central to the ongoing debate is the inability to balance the desire to continue the legacy energy-only market structure (a structure that created the revenue insufficiency problem) and a capacity market. This has fundamental negative consequences in a variety of areas, including:
    a. Reliability investments
    b. Firm fuel transportation and supply
    c. Ongoing O&M maintenance

2. ERCOT did not previously have a formal reliability standard following market deregulation. The legislature directed the PUCT to develop a formal reliability standard in the aftermath of Winter Storms Uri and Viola. Most ISOs in North America establish a planning reserve margin using some variation of a 1-in-10 standard (meaning loss of load for one day in 10 years). The PUCT indicated that this standard needs to be improved and has an active process (project #54584) underway with extensive debate on the nature and scope of an appropriate reliability standard from industry participants, with some participants indicating concerns that such a standard would create a capacity market. The resolution is uncertain at the time of this document.
    a. In comments, the PUCT staff supports considering a reliability standard to measure multiple metrics. It also believes that such a standard must be a mandated requirement and that PUCT should mandate that ERCOT include the anticipated cost of various reliability standards with a sensitivity analysis.

1. Lack of active investment in the new dispatchable generation indicates continued market uncertainty over the changes proposed by PUCT and ERCOT to attract investment in the new dispatchable generation. During the 15 years from 2008 through 2022, dispatchable generation supply grew by only 1.5% while power demand increased by over 20% in ERCOT. Simultaneous with this lack of incremental investment is increased operational demands to cycle and dispatch on short notice to meet shortfalls in intermittent generation that, in turn, compound capital demand for increased O&M and reliability investments in existing dispatchable generation. There has been limited tangible investment in incremental dispatchable generation or related financing announcements since 2021, providing clear market feedback on the lack of confidence in the changes being implemented to date.

Issue #3 Mitigate growing inter-dependency between infrastructure sectors.	**What:** Interdependency risk occurs when an infrastructure sector's reliability is dependent upon another infrastructure sector's reliability (e.g., the natural gas industry is reliant on the electric network and vice versa). Issues arising from interdependence were material contributing factors to cascading failures across infrastructure sectors.	
	Outcome: 4 specific outcomes were identified, plus four supplemental actions.	

Interdependency risk is an incredibly challenging issue to address. Explicit forms of interdependency, where interdependence is known to exist and is an integral part of the design and operational decisions, are easier to quantify and address. However, interdependence creep, which typically arises from a series of small discrete choices that, when aggregated together, create systemic risk, is much harder to address and often falls below the radar in assessing risk because individual decisions are discrete and often unknown at a systemic level.

Changes implemented relative to identified outcomes: Clarity on natural gas industry supply chain issues has been implemented, and a greater understanding of the fundamentally different market parameters of natural gas and electricity is underway between both industries. Upstream investments to mitigate weather-related field equipment risk and the confirmation as essential loads prevented us from participating. Changing market incentives to allow compensation for dual fuel capability with storage of fuel to support generators having an alternative to natural gas dependence. Confirmation of increased levels of firm transportation and firm natural gas supply commitments by electric generators reducing interdependence risk from interruptible supply and transportation. This problem created > 70% of the fuel-related issues experienced during Winter. Storms Uri and Viola. There is evidence of individual and company actions being taken, e.g., installing backup generators and similar actions, to reduce interdependency across various sectors (water, telecom, upstream O&G).

Shortfalls and Gaps - changes still required:

1. There was limited action on addressing the growing interdependency driven by increased electrification or any explicit analysis effort around this issue.

2. The analysis could not confirm any clear systemic focus on this problem outside individual sectors.

Issue #4 Establish a foundation of regulations and incentives	**What:** Regulations and market designs can negatively impact reliability or enhance systemic reliability on the grid system. There are regulatory structures that burden the grid and reduce reliability during periods of extreme demand. Subsidizing activities that result in negative impacts on reliability must be eliminated.	
	Outcome: Prioritize reliability-focused regulations and incentives and eliminate regulations that include the unintended consequences of negatively impacting reliability. Five specific ERCOT outcomes and Four general outcomes applicable to all essential infrastructure were identified.	

Changes implemented relative to identified outcomes:

Solutions that address natural gas industry supply chain issues have been implemented, and a greater understanding of the fundamentally different market parameters of natural gas and electricity between both industries is underway. Upstream investments to mitigate weather-related field equipment risk and the confirmation as essential loads prevented us from participating. See the PUCT reliability standard above.

Shortfalls and Gaps - changes still required:

1. The core problem of revenue insufficiency has yet to be fully addressed through regulatory change. Left unresolved, this is a large enough challenge to be considered an existential threat risk to a reliable and resilient grid. Despite extensive debate and discussions, there is a lack of consensus and political will to resolve the problem entirely.

2. The problem of revenue insufficiency extends to all essential infrastructure. Few solutions have been implemented in the aftermath that address the need for a robust systemic solution to ensure essential infrastructure can satisfy revenue-sufficiency requirements and avoid operating in the run-to-fail mode.

3. It remains unclear how the generators responsible for contributing reliability stress to the system are held accountable for the systemic cost of backstop reliability shortfalls through other means.

4. Clarity on battery storage utilization (discharge and recharge) during energy Emergency Alerts remains a partially resolved issue.

<table>
<tr><td rowspan="2">Issue #5
Replace process and model biases and short-term cost priority with a reliability and resilience prioritized culture and best cost approach.</td><td>What: The over-reliance and failure of a model-driven culture were displayed before, during, and after Winter Storms Uri and Viola. Forecasts, models, and expectations were materially inconsistent with reality and were biased to underestimate load and stress events. Reliability and resilience are not performance outcomes that can be inspected or audited in the system.</td><td rowspan="2"></td></tr>
<tr><td>Outcome: clear ownership and accountability for performance. Prioritize reliability relative to legacy bias of low cost. Practice stress events across sectors</td></tr>
</table>

Changes implemented relative to identified outcomes:

In a series of meetings with the executive level within ERCOT and with industry participants, we believe that the message of reliability has finally been identified as a critical performance item. There is a positive sign in debates around issues such as reliability standards to try and ensure that they are transparent, cost-effective, and complex enough to address the issues required while being balanced, usable, and practical.

Shortfalls and Gaps - changes still required:

1. Model under-performance relative to the real continues to impair confidence in ERCOT forecasts.

2. Integrating the importance of reliability and resilience into ERCOT and PUCT decisions will fail in the long term if it results in an inspection mentality instead of an integral part of how things are done.

3. Implementation of a reliability standard and supporting actions in support of meeting such a standard. Comments by several market participants on reliability issues, such as establishing a reliability standard, tend to raise concerns about introducing a capacity market without offering a viable market structure that addresses revenue insufficiency.

Refresh Report Conclusion

Complex problems are seldom solved overnight and often require multiple solution iterations to solve the problem in stages. This is especially evident in high-consequence political situations. Avoiding complex issues, like failing to invest in black start generation by hiding behind a claim that "we're focused on fixing things, so we never get to that stage," is akin to not fixing the sprinkler system and fire alarms because we're going to prevent fires from happening the next time. Reliability and Resilience of essential infrastructure impacts everyone. As engineers and as a society, we must ensure that essential infrastructure is designed and built on a foundation of reliability and resilience and that this infrastructure is operated and maintained against the touchstone of reliability and resilience.

While progress has been made on several fronts, there remain significant solution gaps to solve the identified problems and ensure that Texas has a reliable and resilient electric grid. The forecast of the potential for brownouts during the summer of 2023 and a lack of dispatchable investment in ERCOT are indicators that the problems have not been solved.

Texas is ***not*** out of the woods concerning having a reliable and resilient electric network, as the multiple days requiring "demand response" and the issuance of a level 2 EEA in the summer of 2023 illustrate. Changes have been made, but Texas remains lost without a guiding compass pointing to Reliability and Resilience. The path forward begins with establishing a transparent, robust, enforceable Reliability Standard for ERCOT. Reliability and resilience in Texas will become a reality when this standard is adopted and consistently supported with solutions that address the questions and the gaps identified above. It will take courage and a renewed sense of purpose to solve the remaining issues fully. The clock is ticking, and the subsequent major failure will be in our future if we fall short of answering these questions and implementing comprehensive solutions.

Appendix

Examples of Utility Activities Related to Report Recommendations

Central Texas Emergency Preparedness Pop-Up seminars, which began in September 2022 in Austin, are conducted every month on the third Wednesday. Typically, there will be the following agencies present:

- Member of Austin City Council and their staff
- Homeland Security (event sponsor)
- Federal Emergency Management Administration
- Austin Fire Department
- Austin Police Department
- Austin Water
- Austin Energy

Each organization provides information to citizens recommending preparation for environmental risks (weather, wildfires, power interruptions, etc.), and Homeland Security hands out backpacks with two flashlights, one lantern, face masks, a poncho, a glow stick, a metal knife, spoon and fork, umbrella, and small first aid kit.

<u>Cost estimate from the original report</u>

What does the potential solution cost? This is an overly complex issue that requires resources far beyond the scope of this report. However, a simplified approach[8] considered an existing capacity-based power market, which compensates for reliability, for an ***indicative*** answer. PJM is a capacity market Regional Transmission Organization (RTO) that has what they term a Reliability Pricing Model (RPM) operating in the eastern interconnect. PJM is a larger market than ERCOT. This simplified analysis considered the average capacity cost over ten years from 2011 to 2021 in PJM and adjusted this to the equivalent size of ERCOT. Over these ten years, the amount would have translated to a total cost of $14 billion. This equates to ~$1.4 billion per year. This adjusted amount equates to a < 5% price increase in ERCOT (a $37B annual energy market in 2019). It is a relatively modest level of notional investment for improved reliability and resilience. This provides an indicative level of the relative reliability and resilience investments expected. The value of reliability is overwhelming. And the actual reliability costs are likely to be lower when implemented and the market-force brought to bear.

End Notes

[1] Texas Health and Human Services, Texas Department of State Health Services (2021), *Winter Storm Mortality Report* reported 246 people died from the storm. There are a wide range of estimates for the total number of deaths attributable to Winter Storms Uri and Viola. Other sources, including Buzzfeed which used a different approach (including excess deaths) in analyzing data estimated between 426 and 978 people died in the storm.

[2] The Perryman Group (2021), *Preliminary Estimate of Economic Costs of the February 2021 Texas Winter Storm*, February 2021. (low case = $197.2B, High case= $295.8B)

[3] The Perryman Group (2017), *Preliminary Estimate of Economic Costs of Hurricane Harvey*, August 31, 2017 ($145B). and NOAA.gov Office of Coastal Management, *Fast Facts - Hurricane Costs*

[4] US Department of Energy, Energy Information Administration: https://www.eia.gov/electricity/state/

[5] Wood McKenzie (Woodmac.com) 2021) *Texas Grid Failure and Implications for the energy transition* March 4, 2021)

[6] Texas Public Policy Foundation, August 2022, *Pushed to the Brink – the 2021 electric grid crisis and how Texas is responding.*

[7] Energy State Wide News, Brad Johnson, December 5, 2022, *Texas oil and Gas producers provide a look at weatherization techniques.*

[8] T Popik and R Humphrys (2021). *The 2021 Texas Blackouts: Causes, Consequences, and Cures.* Paper and presentation The Journal of Critical Infrastructure Policy, spring/summer 2021