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The Power Sector's Tough Lessons Learned This Winter

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Key Points:

- The February 2021 winter storm and widespread power outages have raised new concerns about the future of grid resilience. With climate change now causing major shifts in historic weather patterns and producing more frequent and severe extremes, electric cooperatives need to reconsider their approach to resource planning.
- The polar outbreak set dozens of new low-temperature records, challenging regional power systems in a wide swath of the country, but Texas was disproportionately affected. Why? A number of factors played a role, including the lack of climate resiliency planning (winterization) and market design.
- It may be instructive to think about these disruptions as a kind of a dress rehearsal for a greater, more disruptive event. The tough lesson learned is that while the U.S. is growing more and more dependent on electricity, growing high-cost disasters jeopardize our energy resilience. We need to get to work fortifying our power system, physically and economically.
- We envision that the hard-won insights gained over the past season will lead to better climate resilience planning. Those plans will include continuing to build out localized infrastructure. But to enable that local resiliency, we need additional investment to shore up our "macrogrid."

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Introduction

The polar vortex of February 2021 ushered in the coldest air across the central U.S. in more than 30 years, with the nation recording the 19th coldest February in the 127-year period of record keeping. More than 100 million people resided in areas covered by the winter weather warnings and roughly 5 million of those people lost electricity in a handful of southern states battered by the storm. From February 7 to 21, large areas of the country experienced temperatures more than 25 degrees Fahrenheit below average – only nine states in the lower 48 were not under a winter storm advisory for the Valentine's Day weekend.

Utilities from Minnesota to Texas and Mississippi implemented rolling blackouts to ease the burden on power grids. Yet, the situation in Texas deteriorated quickly and proved much more dire, with millions of the state's customers without power for more than 24 hours during the crisis. The results were catastrophic, exacting a human and financial toll on the state. All told, these latest Texas blackouts were the largest forced power outages in U.S. history and may prove the costliest natural disaster that the state has ever witnessed.

White House Homeland Security Advisor Liz Sherwood-Randall summed it up best, reinforcing the urgency for the nation to address the resiliency of our infrastructure, which she characterized as ill-equipped to handle the long-term effects of climate change. "Climate change is real and it's happening now, and we're not adequately prepared for it," Sherwood-Randall said. "And in particular, power grids across our country, particularly in Texas, are overloaded by the demands that are placed on them under these circumstances. And the infrastructure is not built to withstand these extreme conditions."[1]

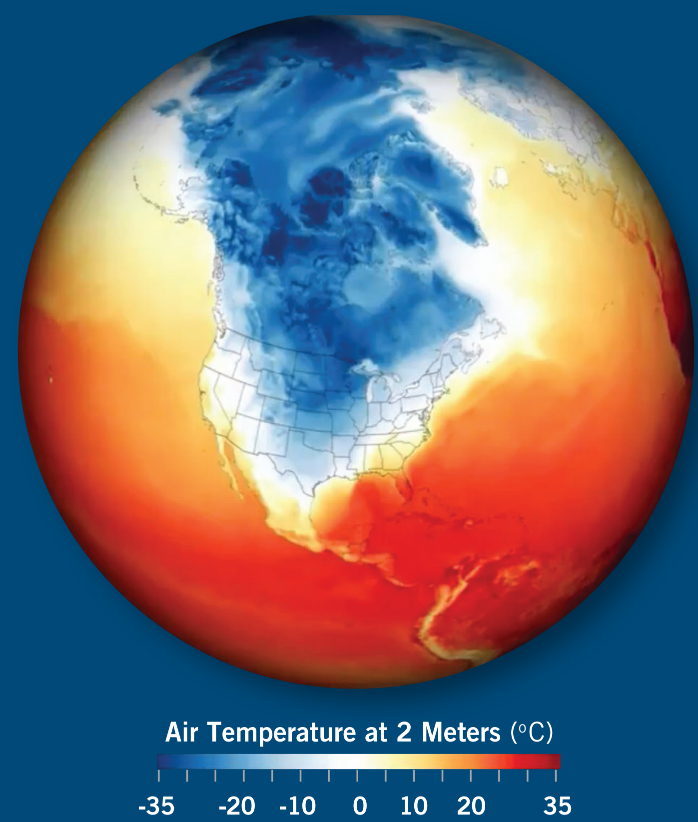
If we think about the disruptions that occurred this winter as a kind of dress rehearsal for a greater, more disruptive event ahead, it is clear that there is work needed to physically and economically reinforce our power system.

Bouts of Extreme Cold May be a Function of a Warming Planet

Mid-February's polar vortex ushered in the coldest temperatures in more than three decades, with 2021 ranking as the 19th-coldest February in 127 years, according to the National Centers for Environmental Information.[2]

NASA's image shows the deep plunge of cold arctic air into the U.S. with areas in Texas colder than Maine or even Alaska. Given changing climate conditions, these events will likely become more frequent. In particular, warmer temperatures in the Arctic and high pressure in northern regions can push the polar vortex further south, driving extremely cold air unusually far into the south. Climate scientist Judah Cohen suggests that there is a strong statistical correlation between warm spells in the Arctic and extreme winter weather in the U.S. Extreme weather, such as February's arctic outbreak, is increasingly likely to test electric grids and energy supply systems.[3]

FEBRUARY'S ARCTIC OUTBREAK SHATTERS LOW-TEMPERATURE RECORDS

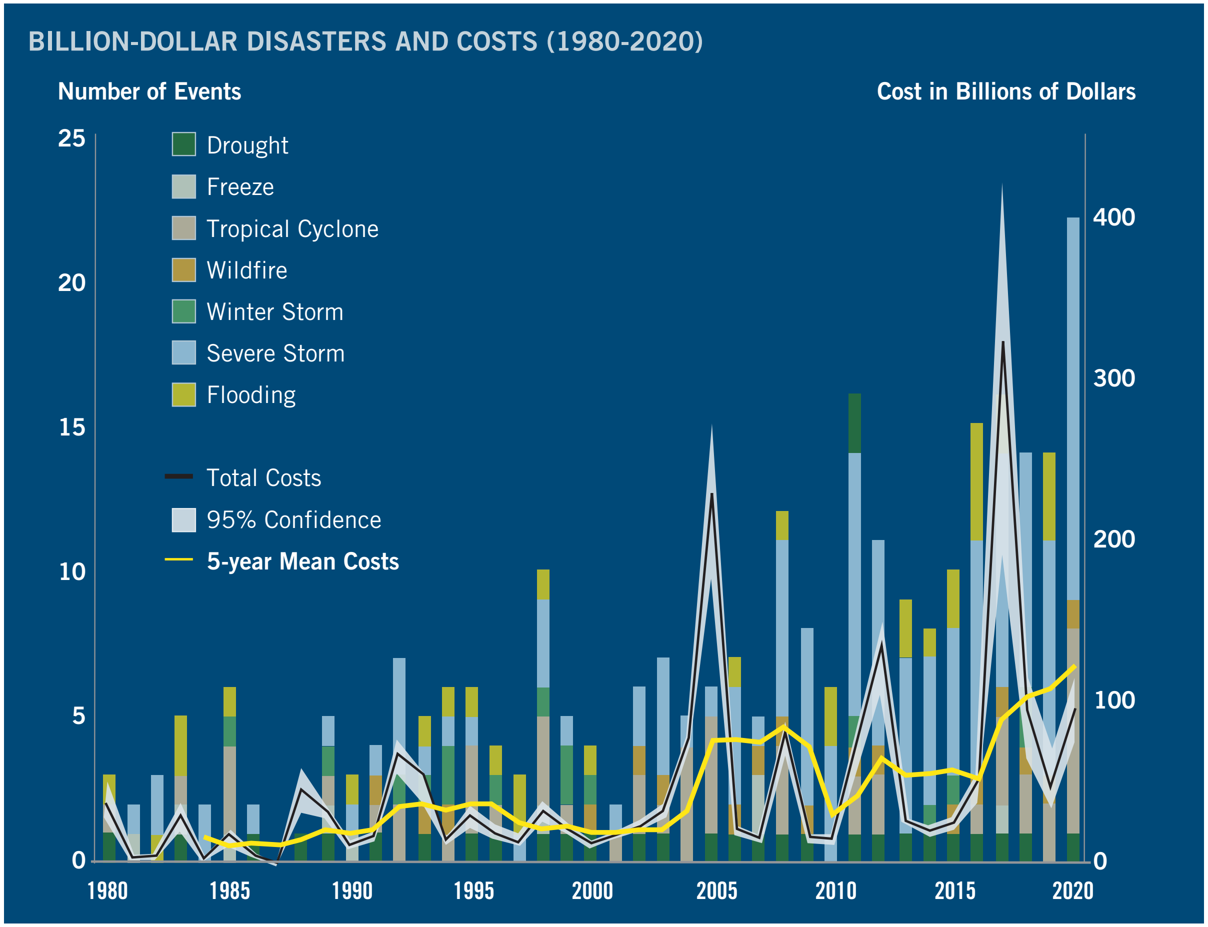


Source: NASA. Data for the map derived from GEOS model; representing air temperatures at 2 meters or ~ 6.5 feet above the ground on February 15, 2021.

Growing High-Cost Disasters Jeopardize Energy Resilience

As the electric power industry has watched high-cost climate disasters become more frequent and more costly, February's storm has renewed urgency to confront the impacts of climate change. The National Oceanic and Atmospheric Administration (NOAA) recently released its billion-dollar disaster report, confirming what communities across the nation experienced first-hand – 2020 was a historic year of extreme weather with 22 separate billion-dollar weather and climate disasters. More to the point, the total cost of these disasters over the past five years now exceeds $600 billion at an average cost of $121.3 billion a year, both of which are new records.

NOAA points out that climate change is increasing the frequency of some types of extremes that lead to these costly disasters. Restoring the grid to its previous state is an inadequate response in the face of increased stress on infrastructure. It is mission critical for rural electric cooperatives to plan for climate resilience.



Source: Smith A. 2020 U.S. billion-dollar weather and climate disasters in historical context. Climate.gov NOAA, (Jan 2021)

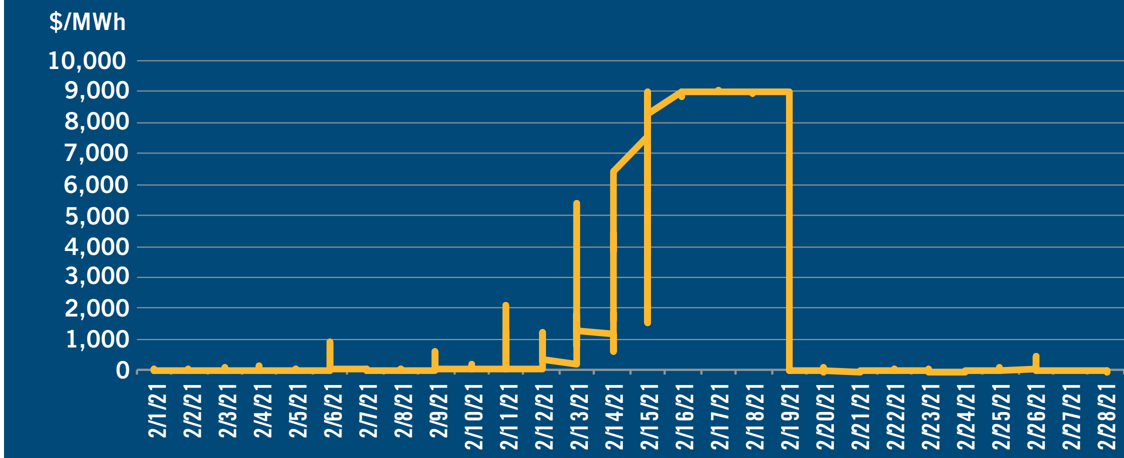
ERCOT Sheds Load as Extreme Cold Forces Generators Offline

Three culprits combined are to blame for the electricity price spike in Texas: soaring weather-related demand, off-line generation, and sky-high natural gas prices. Until February, the Electric Reliability Council of Texas (ERCOT)'s previous highest day-ahead on-peak price for any given month was $974.57/MWh, recorded during Texas' September 2019 heat wave.

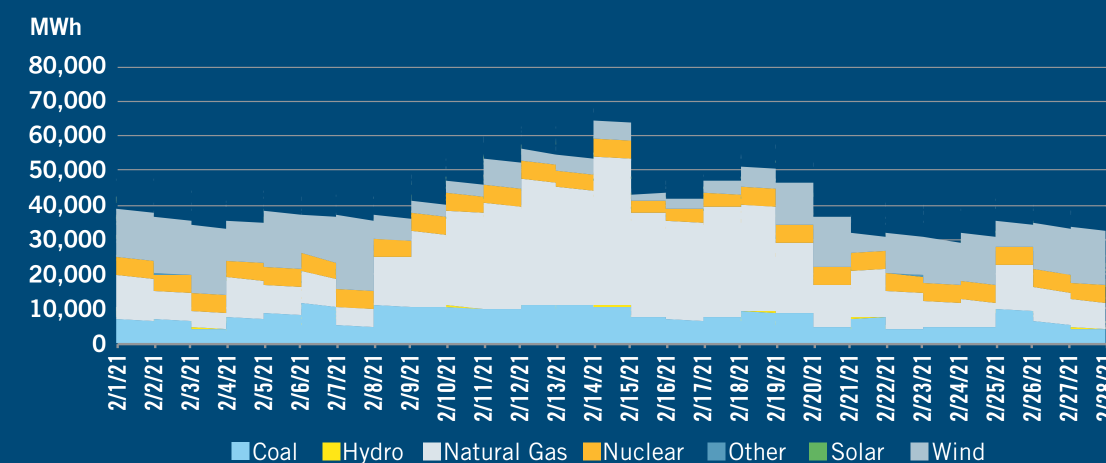
In February, the monthly average exceeded $1,500/MWh as a result of sustained real-time prices elevated to the $9,000/MWh system-wide cap for a four-day period. For just the abbreviated period of the crisis (Feb. 14-19), the average price increased to a staggering $6,612/MWh.

The dispatch data appears to contradict the prices recorded during the crisis – supply was only marginally elevated and low-cost fossil fuel generation appeared to play a critical role in serving load. However, natural gas generators actually recorded the highest level of outages. Moreover, problems with gas production and delivery across nearly all producing basins figured prominently in the elevated prices in Texas, as well as other major markets.

ERCOT REAL-TIME AVERAGE HOURLY ELECTRICITY PRICES



ERCOT HOURLY ELECTRICITY PRODUCTION BY FUEL

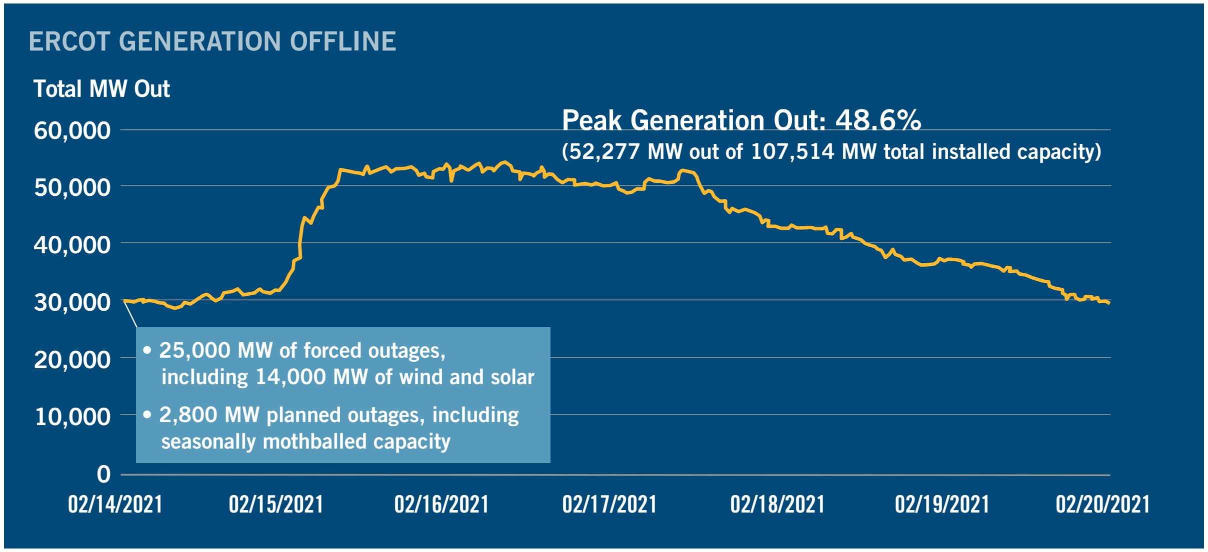


Source: ERCOT

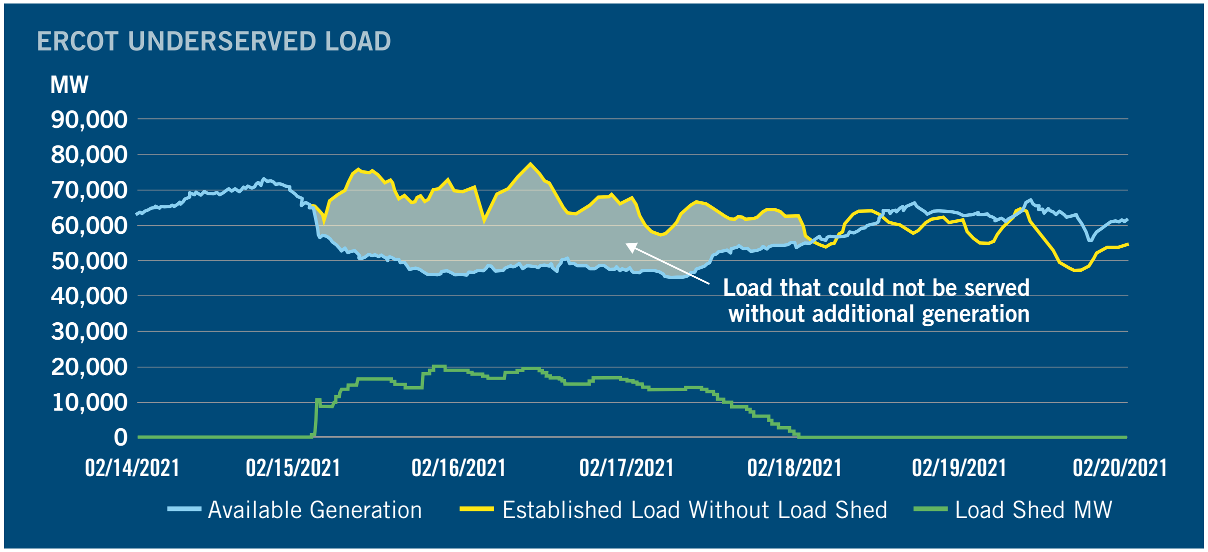
Extreme Weather, Extreme Outages Pushed Texas into Blackouts

Focusing more narrowly on the supply dispatch that didn't occur, the sheer size of the capacity taken off line during the crisis is staggering. At the height of February's winter storm, 52.3 out of a possible 107.5 GWs of operating capacity – almost half – of Texas' generation was off line. That means about 4.5 million homes went without power during one of the state's coldest three-day periods on record.

Preliminary data released by the system operator March 4 reveals the Texas grid suffered 1,796 generating outages, or derates, mid-month during the storm, totaling 169 GWs.[4] Natural gas generators led the outages, with 84 GWs offline, followed by wind at 65 GWs, and coal at 15 GWs. Summing up the problem, ERCOT highlighted that 40% of the state's generation was lost in the storm because facilities were not winterized, which led to frozen wind turbines and well heads.



Source: Review of February 2021 Extreme Cold Weather Event – ERCOT Presentation, February 25, 2021.

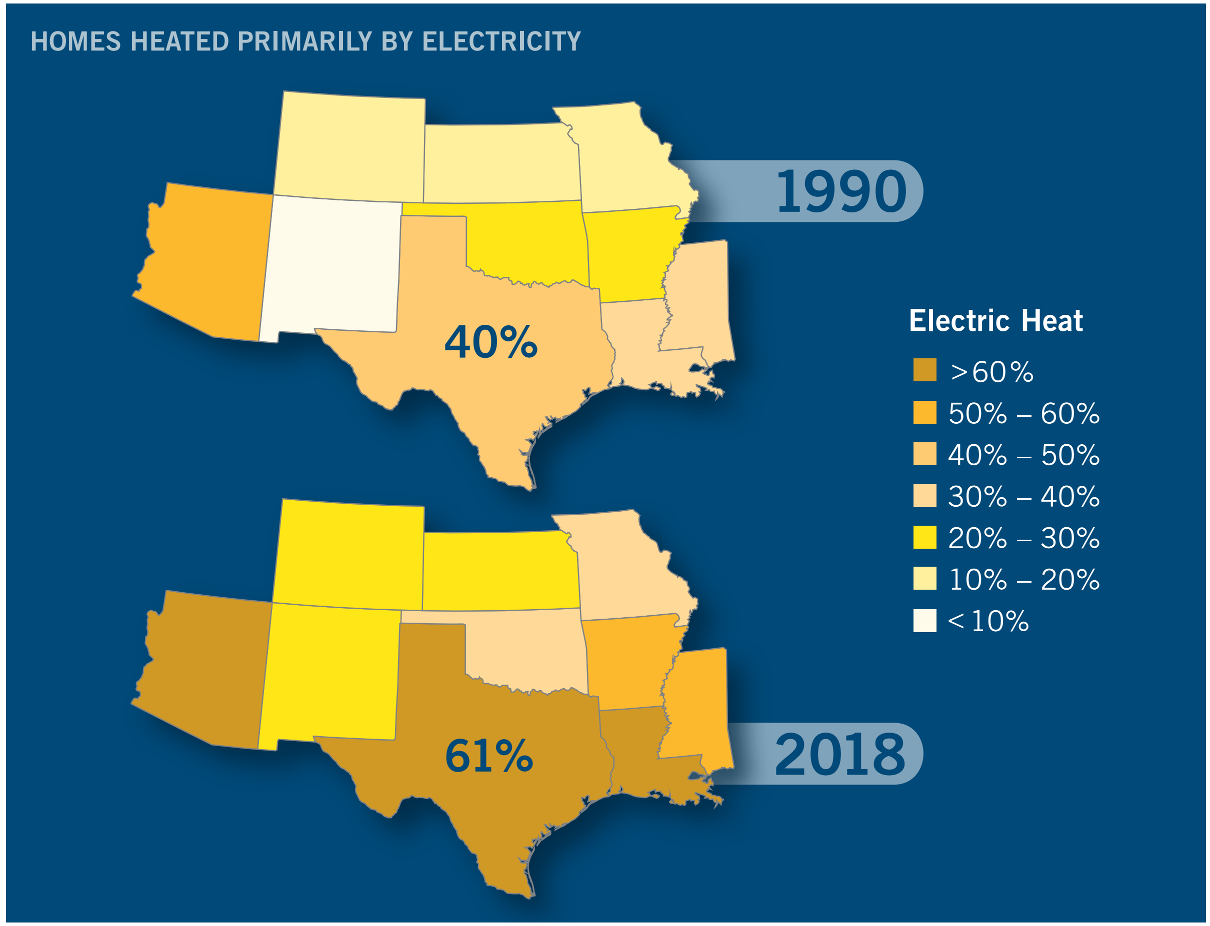


Source: Review of February 2021 Extreme Cold Weather Event – ERCOT Presentation, February 25, 2021.

Why Texas' Electricity Demand for Winter Home Heating Rivals Summer Peak

ERCOT estimates that its February system peak from the winter storm would have been 76,819 MWs without the load shed. This figure not only exceeds the operator's winter-peak estimate of 62,001 MWs (published on Dec. 20, 2020) but also rivals its estimate of the system's summer peak of 77,244 MWs. These numbers suggest that the Lone Star State, predominantly known for its brutally hot summers, might be experiencing winter heating demand that actually rivals the state's summer cooling load.

University of California economist Lucas Davis noted two factors contributed to the state's high winter electricity demand. First, the state's population has exploded, with Texas leading the nation in new home construction. Second, most new homes are now constructed with electricity as the primary source of heating. Davis notes that about 62% of homes built in Texas over the past decade use electric heating.[5]

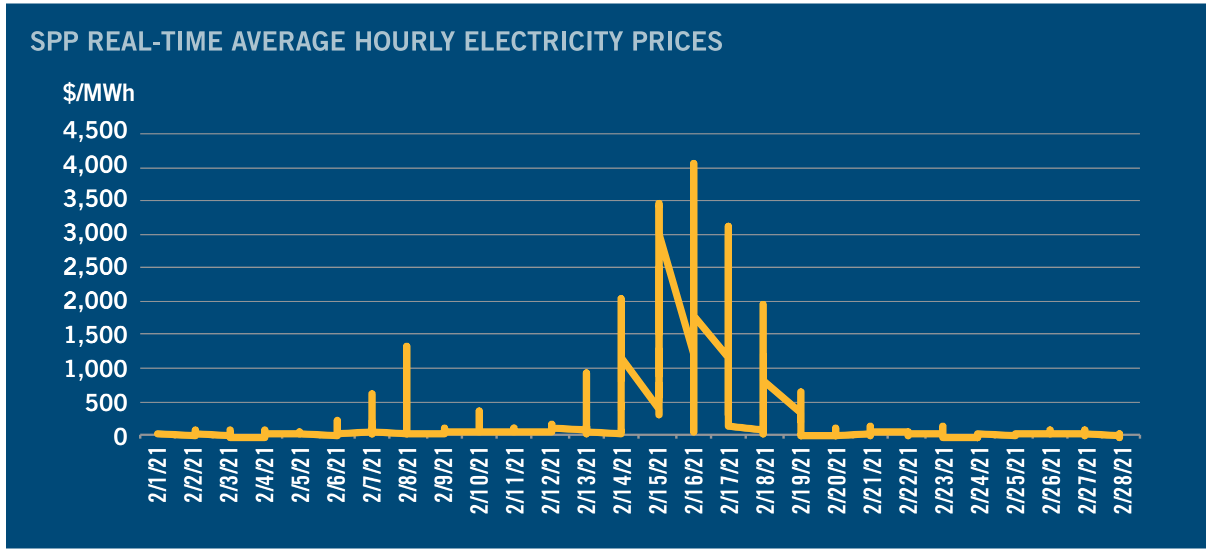


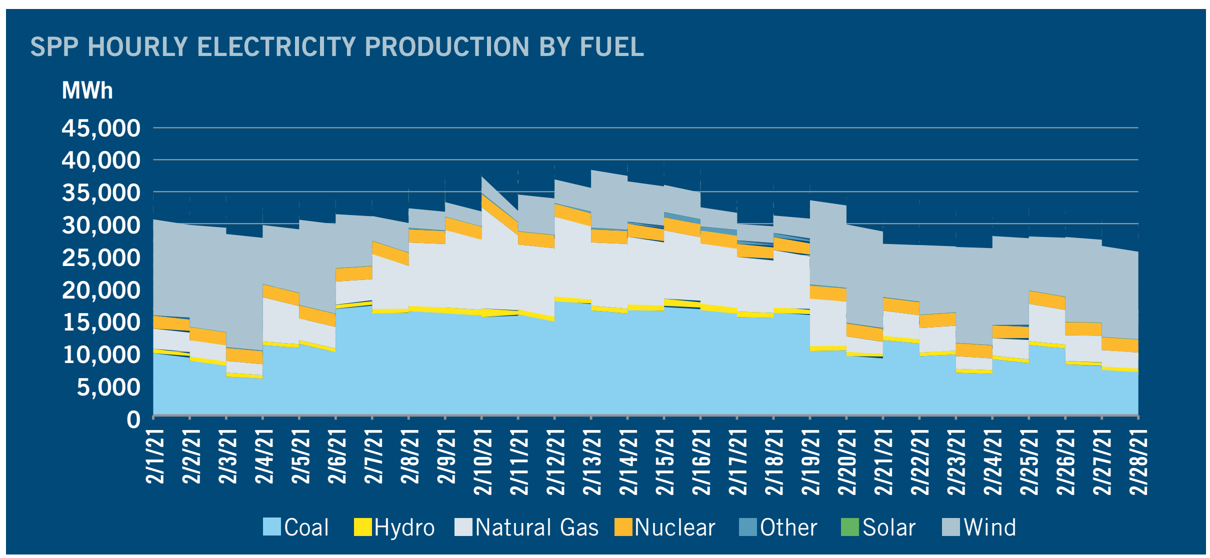
Source: Davis, Lucas. "The Texas Power Crisis, New Home Construction, and Electric Heating" Energy Institute Blog, UC Berkeley, February 22, 2021.

SPP Relied on Redundancy to Manage Grid Stress and Price Spikes

Southwest Power Pool (SPP), another operator north of Texas, also endured extremely cold temperatures and related grid stress. It set a winter peak load record of ~44 GWs on Feb. 15 as well as price records – on-peak day-ahead locational marginal prices hit $3,360.72/MWh. The month-to-date average leading up the crisis, was in the $50s/MWh range. The SPP drivers that caused the price spike were the same as ERCOT: increased electricity use coinciding with a high volume of generation outages and transmission congestion. Yet, SPP's two forced outages proved relatively short and less disruptive by comparison, one on Feb. 15 for 50 minutes and one on Feb. 16 for three hours and 21 minutes.

While the February storms marked the first time SPP ever instituted direct controlled interruptions of service, greater redundancy options averted a more catastrophic outcome.[6]





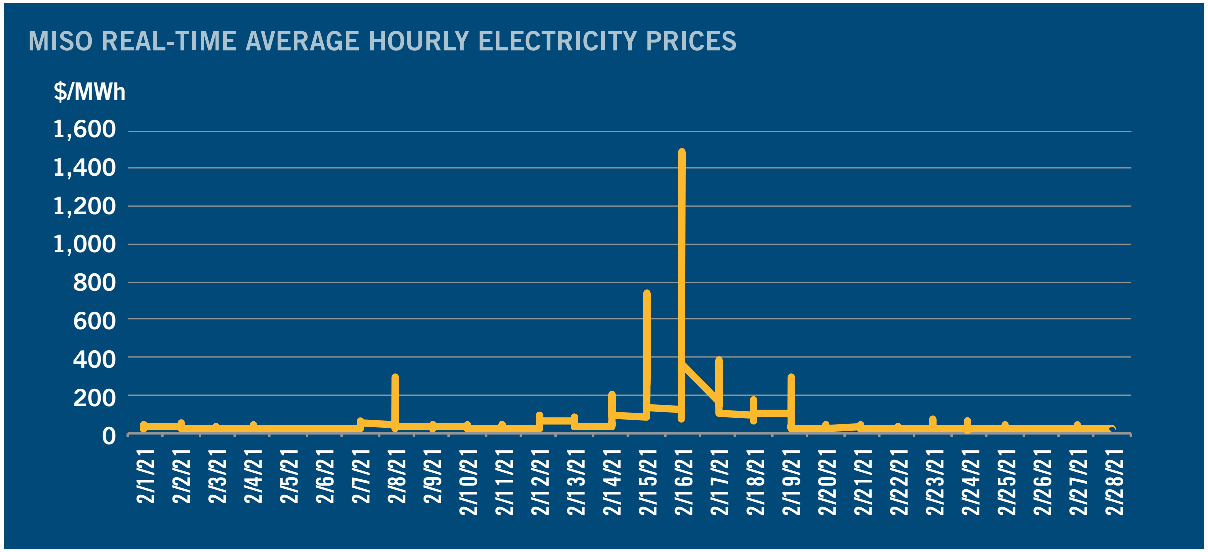
Source: SPP

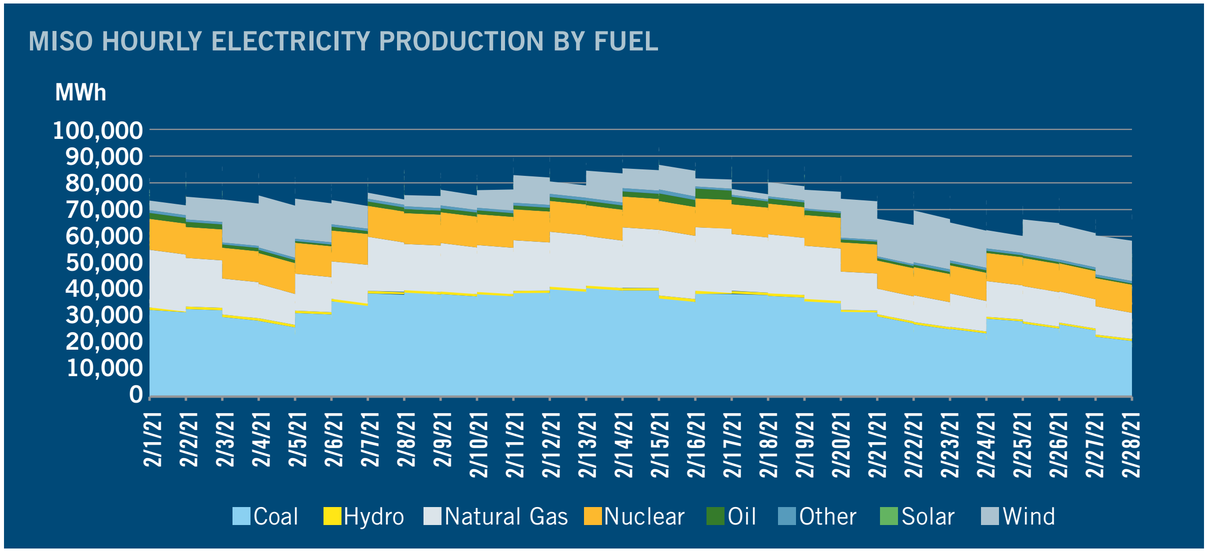
Extensive Grid Connections Eased MISO's System Strain

The Midcontinent Independent Transmission System Operator (MISO), the largest of the system operators to face critical challenges in February, also carried out controlled outages to prevent a larger system-wide shut down. On Feb. 16, MISO directed load-balancing authorities in its affected areas to implement periodic power outages, taking about 25% of the region's electricity-generation fleet off line.

Yet, unlike ERCOT or SPP, MISO was able to restore power within a few hours following the rolling blackouts. MISO's price spikes were much more benign than ERCOT or SPP and its generation varied only slightly.

MISO appears to have handled the strain better than the two other systems because its operating footprint is part of a larger, more connected grid. Nevertheless, similar to SPP, transmission congestion between MISO North and MISO South played a role in the rolling blackouts that began in Texas and ultimately extended into Louisiana, Mississippi, and Arkansas.



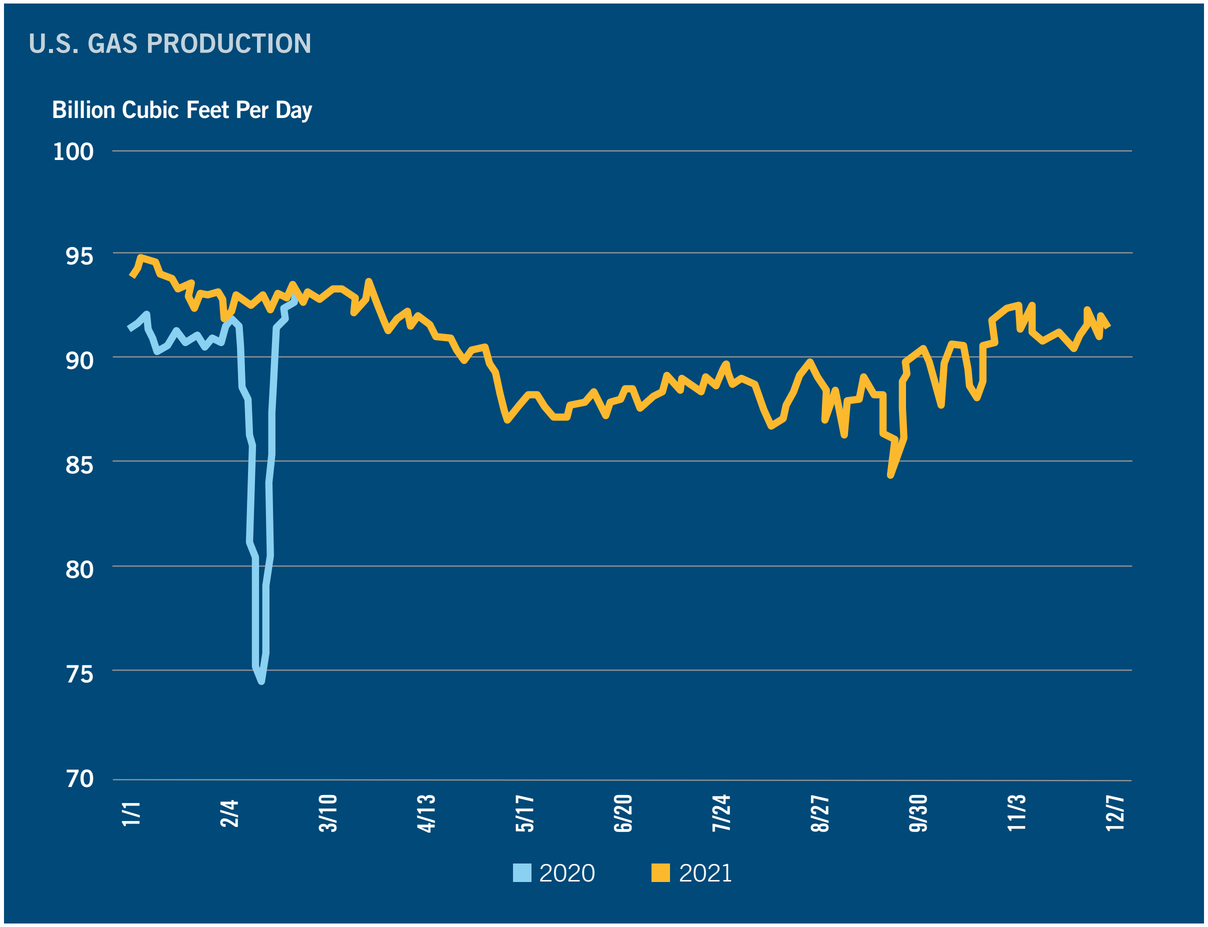


Source: MISO

Natural Gas Dependency Created Vulnerabilities

As we now know, much of the Texas generation fleet (of all different types) was simply not winterized for freezing conditions, but parts of the system proved more vulnerable. The bulk of the outages came from natural gas generation, according to the data ERCOT sent to Texas lawmakers in early March. Of the 1,796 outages, 783 were from natural gas units – 84,000 MWs of capacity or about half of the 169,407 MWs sidelined total. To be clear, Texas' wide-spread power shortage was a direct result of a gas shortage.

Given gas-fired generation's key role in the U.S., resilient power systems depend on resilient natural gas systems. Well freeze-offs severed 20% of the natural gas supply during the crisis, with nearly half of that capacity in Texas and adjacent midcontinent region. These cascading fuel issues played a critical role in February's regional outages and sky-rocketing power prices.



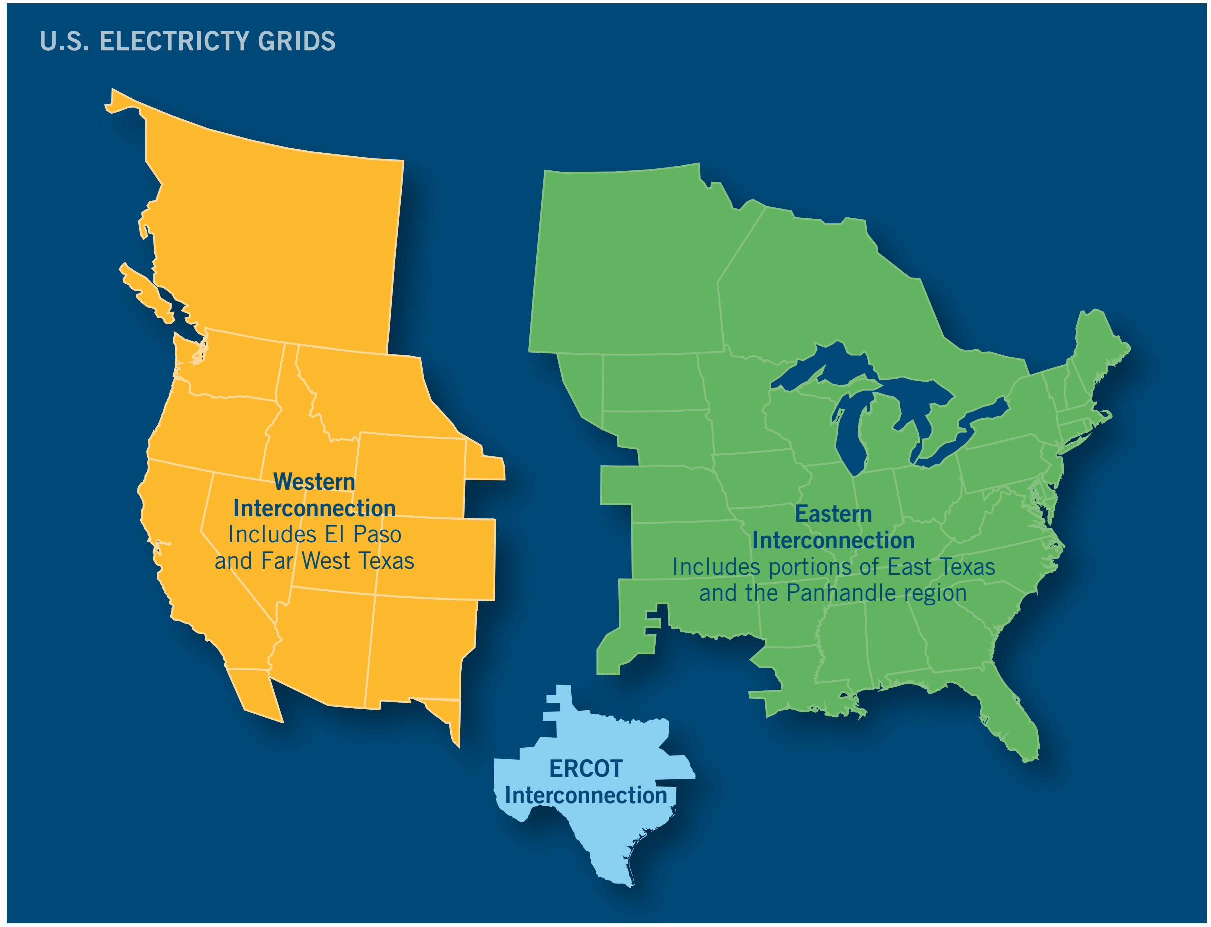
Source: S&P Global Platts Analytics

Lack of Interconnection Hurt Texas Reliability

Among the many explanations of why Texas alone experienced outsized, prolonged system disruptions, the lack of greater interconnection was commonly mentioned. The Lone Star state does have a slim interconnection capacity of 1,200 MWs – three ties to Mexico and two ties to the eastern U.S. grid – but this back-up redundancy is wholly inadequate.

Why has the state decided to go it alone? By keeping the generated electricity within the state's borders, Texas avoids federal regulation. When the federal government set up the two other grids in the 1960s that serve the rest of the country, Texas chose to create its own grid operator, ERCOT.[7]

Increasing the number of high-voltage power lines between jurisdictions could improve reliability, but this idea is probably a non-starter. An alternative to expanding existing grid infrastructure that might prove more palatable and cost effective is to shift towards smart microgrids at the community level.



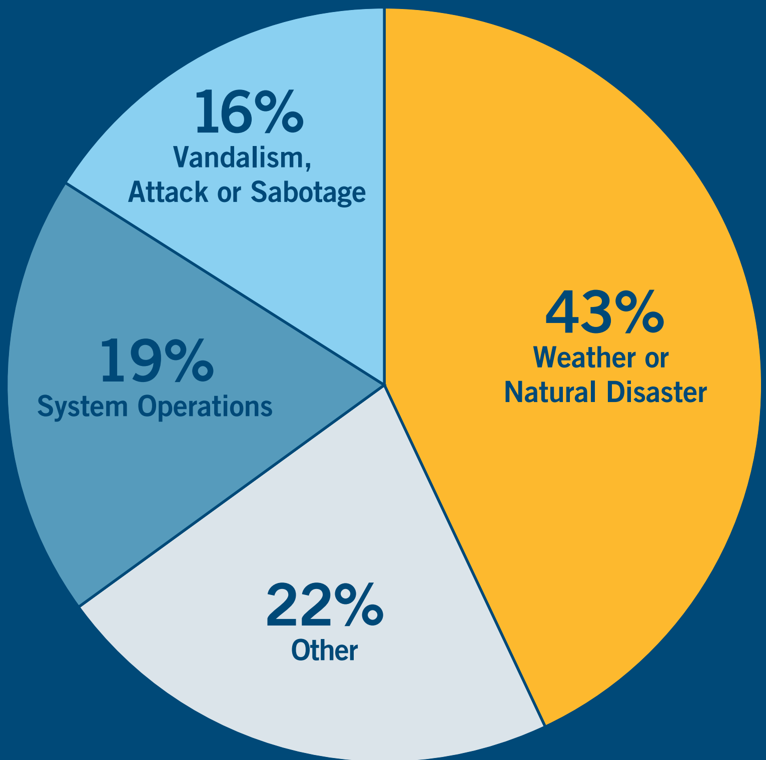
Source: ERCOT

Boosting Grid Resilience Through Microgrids

Power outages like the one in Texas are becoming more common. According to the Department of Energy, the U.S. witnessed 383 "electric disturbance events" in 2020, up from 150 in 2017. Over the past decade, 99% of actual customer outage minutes came from failures related to transmission and distribution – mostly affected by severe weather events – rather than insufficient generation. And the investment required to reinforce or harden wires against such events will amplify consumer costs.[8] These trends suggest that other approaches besides continuing to rebuild the existing grid should be on the table.

Toward that end, controllable and islandable microgrids are time-tested solutions for increasing resiliency (especially after extreme weather events).[9] According to the American Society of Civil Engineers, "Local solutions, such as distributed generation and resilient microgrids, may offer lower-cost alternatives to major system investments particularly in areas at elevated risk from severe weather or other natural disasters."[10]

CAUSES OF U.S. REPORTED ELECTRIC DISTURBANCES IN 2020

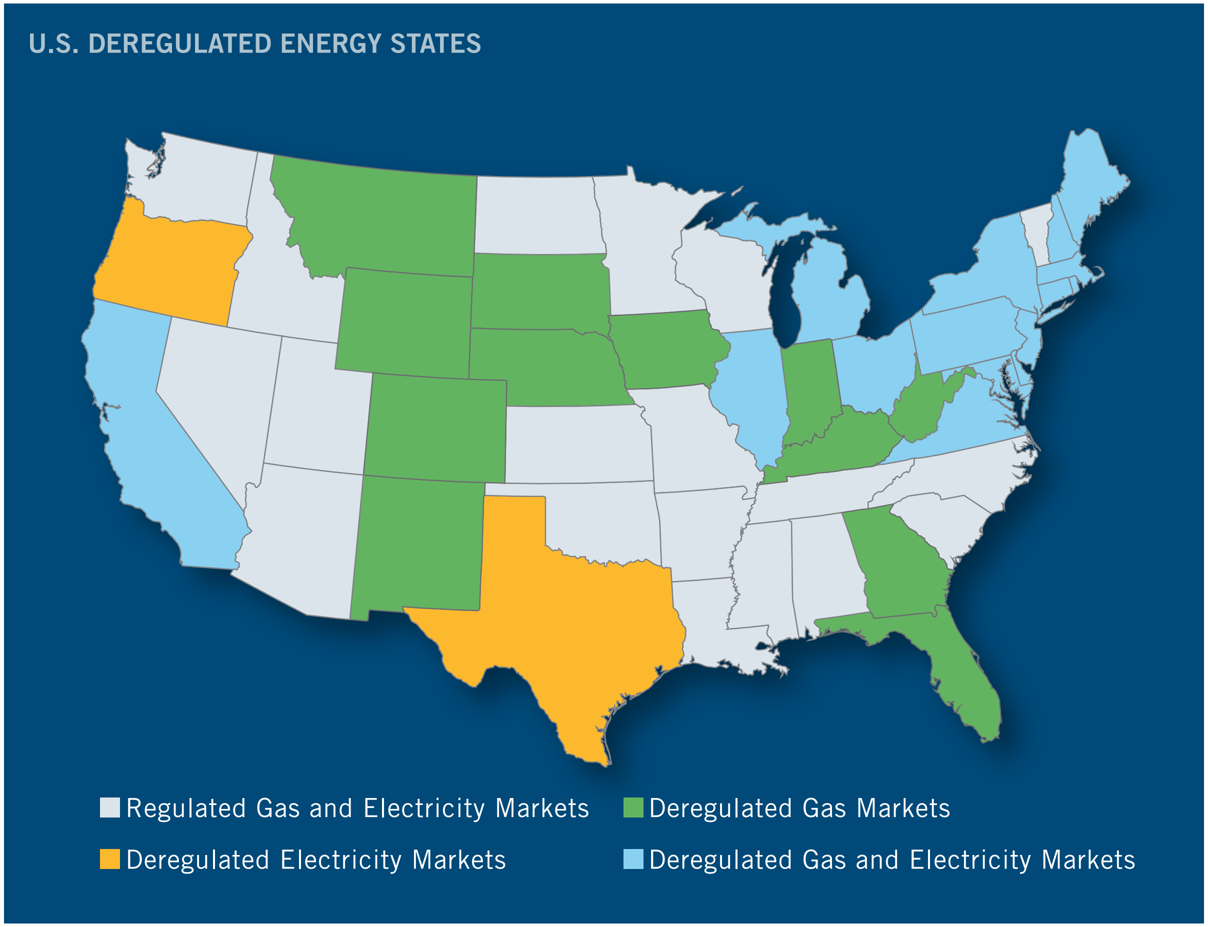


Source: U.S. Department of Energy

(Re)Considering Market Design and Resiliency

Beyond physical configuration, the state's market structure is also under scrutiny. To be clear, Texas experienced prolonged winter outages in 1989 and 2011. Indeed the 2021 event appears to be a more robust recurrence of the problems and requirements identified by regulatory authorities just a decade earlier.

Within the regulatory toolkit, mandatory standards specify what generators and grid operators can do to avert these crises. Former FERC Chair Cheryl LaFleur points out that policy makers can set the amount of power that must be available to restart a system and the required level of winterization. She emphasizes that by having an energy market, not a capacity market, the state's unique structure might actually make it more vulnerable to disruption.[11] An energy market (which pays in real time for the energy currently required) might not have the same built-in insurance protection of a capacity market (which pays for power needed in the future).



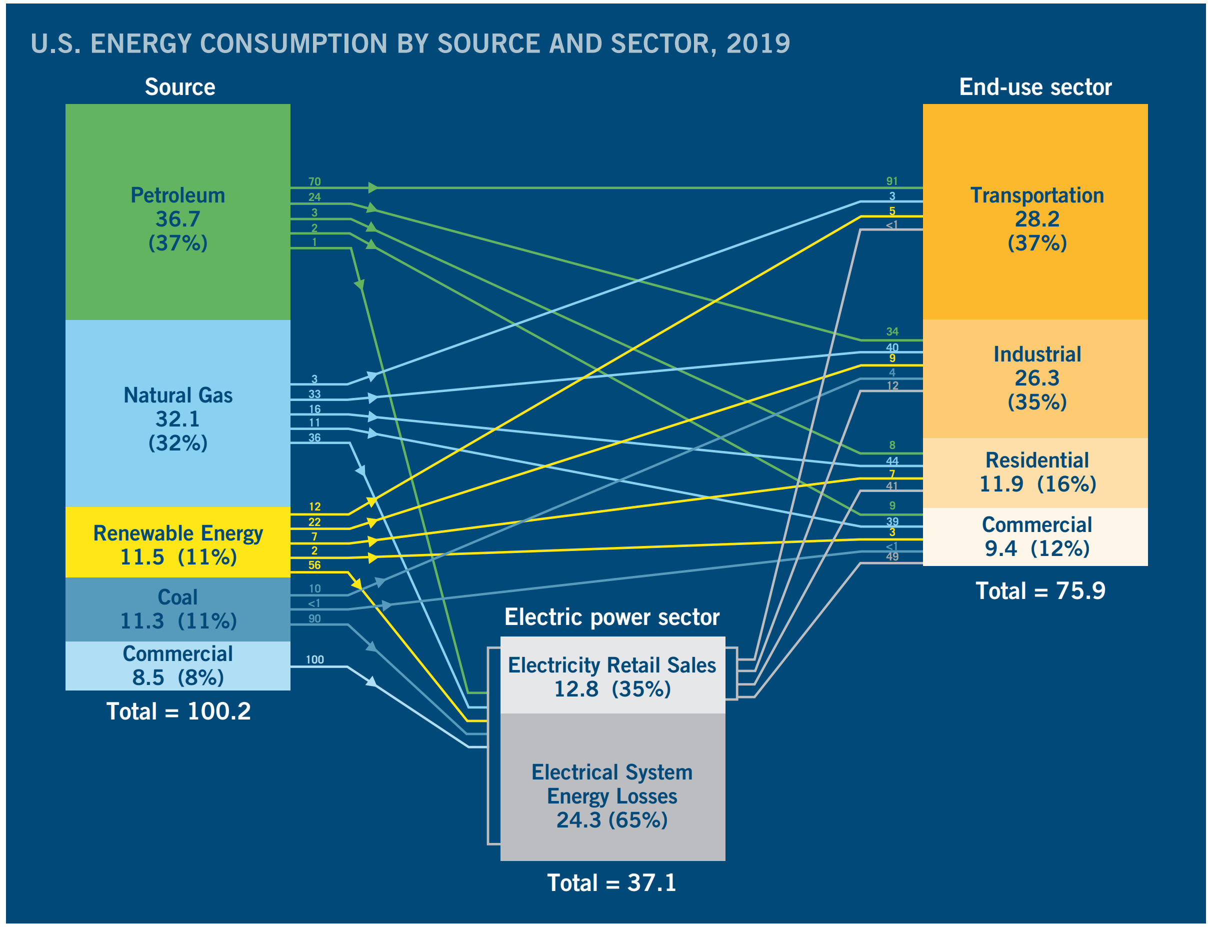
Source: Electric Choice

Electricity is the Largest Source of Energy in U.S., Now Outpacing Oil

To understand why the crisis in Texas has implications for the rest of the nation, it is necessary to realize that the state's growing dependency on electricity foretells what's ahead on the path toward deep decarbonziation.

Electricity is already the dominant source of energy used by homes and businesses. Economics, new policies, and a shift in sentiment around climate change will further increase dependencies for all consuming sectors, in every state.

As the role of electricity grows, so too will the societal intolerance for outages. Climate change will affect every aspect of the electricity grid, from generation, transmission, and distribution to end-user demand – emphasizing the need for immediate action to insulate against future systemic shocks.[12] As we saw in February, electricity powers essential services in our homes and communities, thus much weighs on the climate resiliency planning we do today.



Source: EIA

Summary

The tough lesson learned by the U.S. electricity sector during the past winter is that we must quickly redefine "resource adequacy" to account for the increase in the frequency of extreme weather. Load loss events, historically occurring at a pace of one day in 10 years, now occur more often. The industry's risk methodology that originated more than 70 years ago (and is widely practiced today) appears to be out of step with an economy that will become increasingly dependent on electricity as a primary energy source.

A recent comment by Mark Finley, former U.S. economist for BP and now research fellow at Baker Institute, suggests that power is the "new oil" for energy security. Electricity is the leading source of energy for essential services in our homes and communities, and the impact of a power outage is felt immediately. As Finley highlights, "the immediacy of power outages and the ubiquity of critical elements of modern life powered by electricity mean the impact of oil supply disruptions are a walk in the park compared with our power vulnerabilities."

With more than half the buildings in Texas already dependent on electricity for heating, the Lone Star State surprisingly might be the standard bearer for the trend toward deep de-carbonization. If we think about the disruptions that occurred this winter as a kind of dress rehearsal for greater, more disruptive events ahead, it is clear that there is work needed to physically and economically reinforce our power system. The economy's ever-increasing reliance on carbon-free sources of electricity requires modifications so that sources of supply are available when we need them. Consequently, market and regulatory oversight must compensate for and ensure this reliability.

Toward that end, we envision that better climate resilience planning will occur as a direct result of the hard-won insights gained over the past season. In our view, those plans will include the continued build out of localized infrastructure – more on-site generation (solar and storage) and more microgrids, which can help play a role in emergencies. Further, additional investment will be needed to shore up our "macrogrid," or the country's high-voltage grid, to enable this localized infrastructure.

References

[1] Comments by Deputy National Security Advisor Dr. Elizabeth Sherwood-Randall, The White House Briefing Room, 26 February 2021.

[2] NOAA, "Assessing the U.S. Climate in February 2021", 8 March 2021.

[3] Cohen Judah, Coumou Dim, Hwang Jessica, Mackey Lester, Orenstein Paulo, Totz Sonja, Tziperman Eli. S2S reboot: An argument for greater inclusion of machine learning in subseasonal to seasonal forecasts. WIREs Clim Change 2019, 10: null. doi: 10.1002/wcc.567

[4] ERCOT Letter to Members of the Texas Senate and the Texas House of Representatives, 4 March 2021.

[5] Davis, Lucas. "The Texas Power Crisis, New Home Construction, and Electric Heating" Energy Institute Blog, UC Berkeley, February 22, 2021.

[6] See statement from Barbara Sugg, Southwest Power Pool president and chief executive officer, 24 February 2021.

[7] The Texas Tribune, "Texplainer: Why does Texas have its own power grid?", 8 February 2011.

[8] According to a 2015 U.S. Department of Energy (DOE) technology assessment, electricity infrastructure is aging and a sizeable share of existing facilities are nearing the end of their useful life – 70% of power transformers are 25 years of age or older, 60% of circuit breakers are 30 years or older, and 70% of transmission lines are 25 years or older.

[9] For rural, isolated communities, microgrids are oftentimes the only solution. A microgrid is a small energy system capable of balancing captive supply and demand resources to maintain stable service within a defined boundary. Islandable microgrids are fully interconnected to a local utility grid and are capable of both consuming power from, and supplying power to, the utility grid. They can maintain some level of service during a utility outage. Operators remain tethered to the utility grid and switch seamlessly back and forth, drawing energy when they need it, and selling it back to the utility when they have surplus. (www.microgridinstitute.org)

[10] American Society of Civil Engineers, "2017 Infrastructure Report Card".

[11] Columbia Energy Exchange, "Making Sense of the Texas Energy Crisis", 22 February 2021.

[12] According to the U.S. Government Accountability Office, climate change will continue to have far-reaching effects on the electricity grid that cost billions of dollars.

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