TEXAS POWER FAILURES: WHAT HAPPENED IN FEBRUARY 2021 AND WHAT CAN BE DONE

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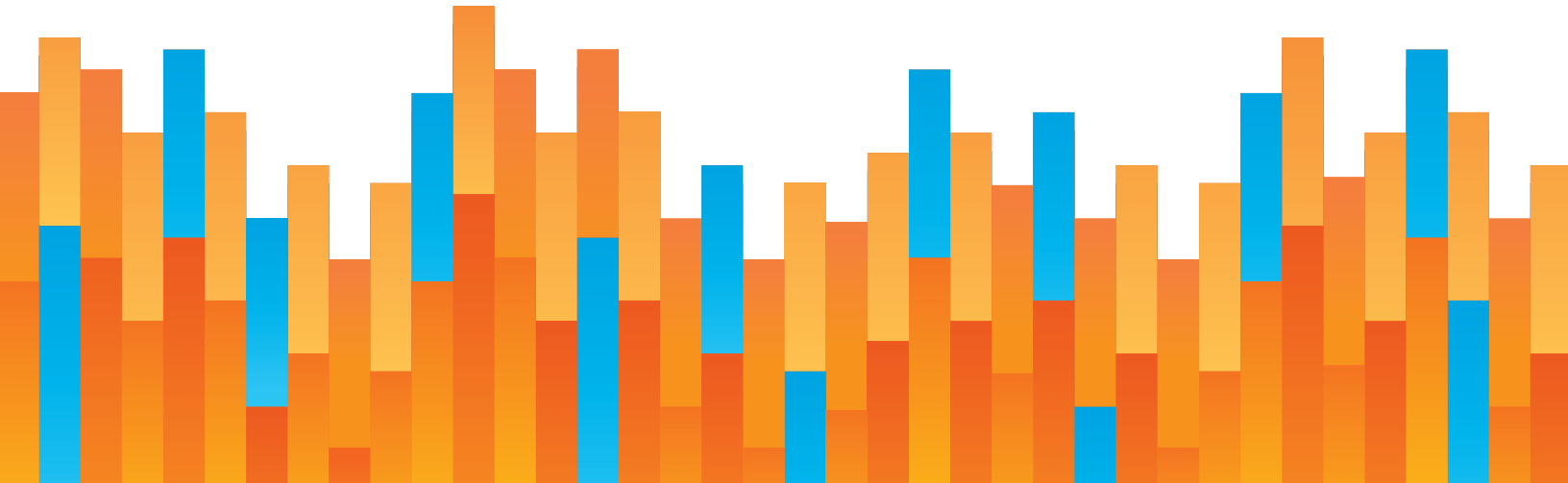

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PART 1

INTRODUCTION

The electric power system in Texas failed to meet customer needs during the extreme cold that descended upon the state in mid-February, 2021. The failures generated a lot of finger-pointing: too much wind power, not enough reliable natural gas, too little regulation, failed long-run planning, and too few connections to neighboring grids, among other targets. Most early complaints were wrong.

> *The electric power system failures were severe, but any diagnosis of the failure or proposed remedy focusing solely on ERCOT will miss the mark.*

Extreme cold overwhelmed winter preparations in Texas: this is the main story. High power bills and other financial repercussions also have created challenges. The electric power system failures were severe, but any diagnosis of the failure or proposed remedy focusing solely on Electric Reliability Council of Texas (ERCOT) will miss the mark. Electric power was not the only industry to see failures, and power systems did not only fail in the ERCOT.

Natural gas wells and pipelines began freezing up. Municipal water systems broke down in several southern states. Roads were closed due to snow and ice. Ranchers and farmers saw severe losses from the cold.

This report focuses on ERCOT and the electric power system because the power outages were the proximate cause of many hardships suffered during the failures. No single cause was responsible and no simple fix will prepare the state to survive the next extreme cold weather event. Many details will only emerge with time, but this paper aims to provide a clear analysis of what is now known, along with a bit of background on how the system works, to help the public and policymakers understand what happened and what should be done next.

PART 2

WHAT HAPPENED?

At about 1:25 AM on Monday morning, February 15, 2021, ERCOT initiated rolling outages across much of the state of Texas. Extreme cold that had arrived in the state days before had pushed demand for power to record levels for winter. At the same time, temperatures well below freezing caused power plants to shut down as generating equipment froze or fuel ran out. The cold similarly interrupted gas production and pipeline services and boosted gas heating demand. All types of power plants failed: wind, natural gas, coal, and nuclear. As a result there was not enough power available to meet consumer demand. Consumers were cut off to keep the grid itself operating and avoid a catastrophic failure that would have taken weeks to recover from.

“Extreme cold that had arrived in the state days before had pushed demand for power to record levels for winter. At the same time, temperatures well below freezing caused power plants to shut down as generating equipment froze or fuel ran out.”

Millions of consumers were affected. Rolling outages are supposed to last just 45 minutes to an hour in any one neighborhood. Distribution circuits serving hospitals and other critical services are exempted, focusing outages on fewer consumers. Conditions were so severe that some consumers lacked power for days. Many Texas households rely on electricity for heating, so long periods without power during extreme cold temperatures resulted in further damage, including burst pipes and household flooding. Efforts to stay warm resulted in deadly fires and exposure to carbon monoxide poisoning. Outages affecting municipal water systems led officials in cities covering as much as 40% of the state's population to issue boil water advisories.[1] Energy system failures in Texas contributed to a very human disaster.

Many Texas households rely on electricity for heating, so long periods without power during extreme cold temperatures resulted in further damage, including burst pipes and household flooding. Efforts to stay warm resulted in deadly fires and exposure to carbon monoxide poisoning.

At its worst, as many as 4.5 million Texans were without power, most but not all served by the ERCOT system. Outages peaked Tuesday night and began improving as power generators were able to return to service. At 12 AM Thursday morning, ERCOT ended calls for rolling outages. By Friday morning, February 19th, just after 10:30 AM, ERCOT declared system conditions had returned to normal. The emergency conditions had lasted over 100 hours.[2]

1 Catherine Marfin, Krista M. Torralva, and Tom Steele, "Texas power grid was 'seconds or minutes' from a total blackout that could have lasted months, ERCOT says," *Dallas Morning News*, February 18, 2021. https://www.dallasnews.com/news/weather/2021/02/18/oncor-ends-controlled-outages-thousands-of-north-texans-still-without-power-due-to-equipment-damage/

2 Bill Magness, "Review of February 2021 Extreme Cold Weather Event – ERCOT Presentation," Presentation to the ERCOT Board of Directors, February 24, 2021. Henceforth "ERCOT Board Presentation by Bill Magness." Magness was President and CEO of ERCOT at the time of the energy emergency, though he subsequently resigned. URL: http://www.ercot.com/content/wcm/key_documents_lists/225373/2.2_REVISED_ERCOT_Presentation.pdf

The widespread damages caused by a lack of access to electricity, including loss of life as Texans struggled to cope with the extreme cold, make it hard to accept that ERCOT might have done its job well during the emergency, and the major failings happened before the bad weather hit. Understanding how ERCOT could have done its job even as the power system failed miserably requires understanding just what ERCOT does, the limits of ERCOT authority, and the reasons for the limits. This paper analyzes these challenges, but first sets the stage by examining conditions leading up to rolling outages.

2.1 HOW COLD WAS IT?

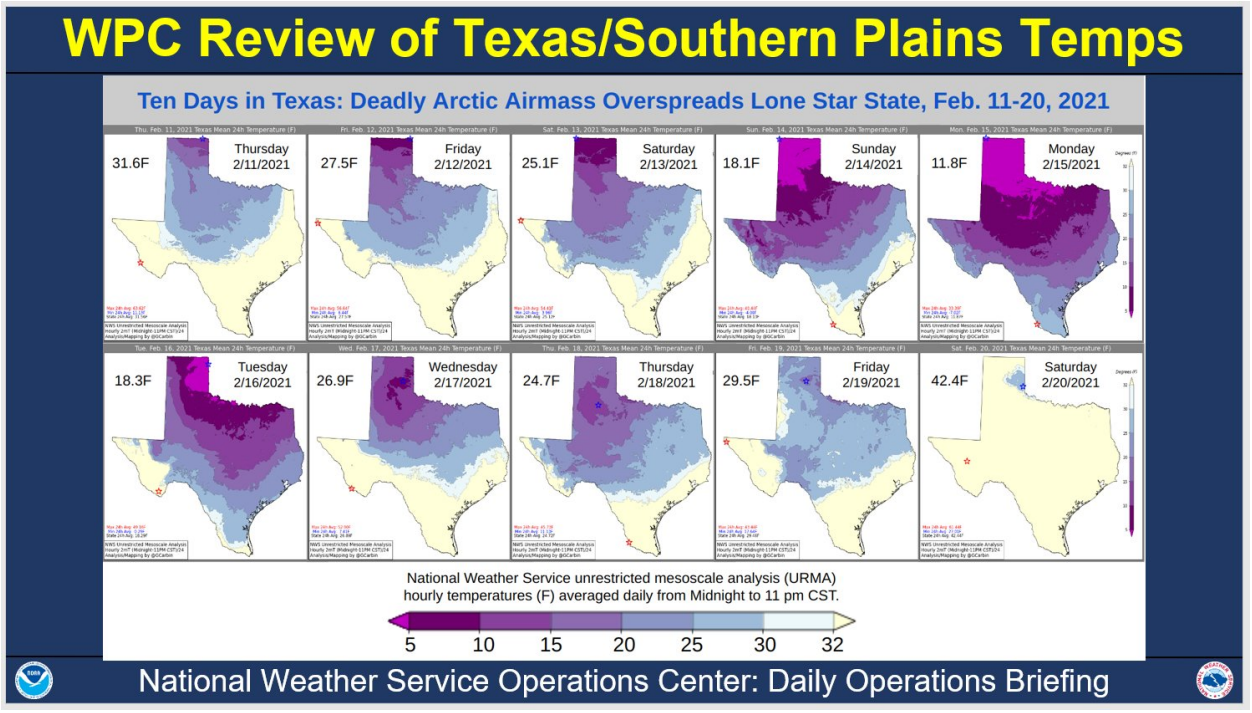
The temperature in Dallas dipped to -2° F, the coldest it had been in Dallas for 70 years. Snow fell on the beaches on the Gulf Coast at Galveston, south of Houston. Temperatures in Austin remained below freezing for six days at a time of when temperatures usually average in the mid-50s. At Brownsville, near the most southern tip of Texas, February weather typically averages 65° F. High temperatures in Brownsville were in the mid-80s just days before the cold. The temperature in the city did not rise above freezing for nearly 48 hours once the cold settled in. For the first time in history all 254 counties in Texas were under a winter storm warning at the same time. The cold was not unprecedented at any particular location, but it was extreme, widespread, and long lasting in February 2021. The National Weather Service provided a visual overview of the cold. As Figure 1 shows, the Arctic cold covered nearly half of the state beginning on Thursday, February 11th, four days before the rolling outages were to begin.

The cold affected more than the ERCOT power system. Some power systems in Texas not within the ERCOT system also resorted to rolling outages. Natural gas production and distribution froze up. Municipal water mains froze in cities across the South. Ranchers in the Panhandle lost cattle to the cold.[3] Citrus growers in South Texas saw damage to trees that may last for years.[4] Roads were closed due to ice and storms. Failures were not solely an electric power industry concern or a natural gas failure. The cold was simply worse than almost anyone in Texas was prepared for.

[3] Tom Polansek, "Texas ranchers scramble to keep animals alive in unusual cold," *Reuters*, February 18, 2021, https://www.reuters.com/article/us-usa-weather-cattle/texas-ranchers-scramble-to-keep-animals-alive-in-unusual-cold-idUSKBN2AI1K3

[4] Ashley Robinson, "Texas Freeze Leaves Citrus Crop in Trouble," *Citrus Industry*, February 17, 2021, https://citrusindustry.net/2021/02/17/texas-freeze-leaves-citrus-crop-in-trouble/

FIGURE 1: 10 DAYS IN TEXAS: ARCTIC AIRMASS AND FREEZING TEMPERATURES

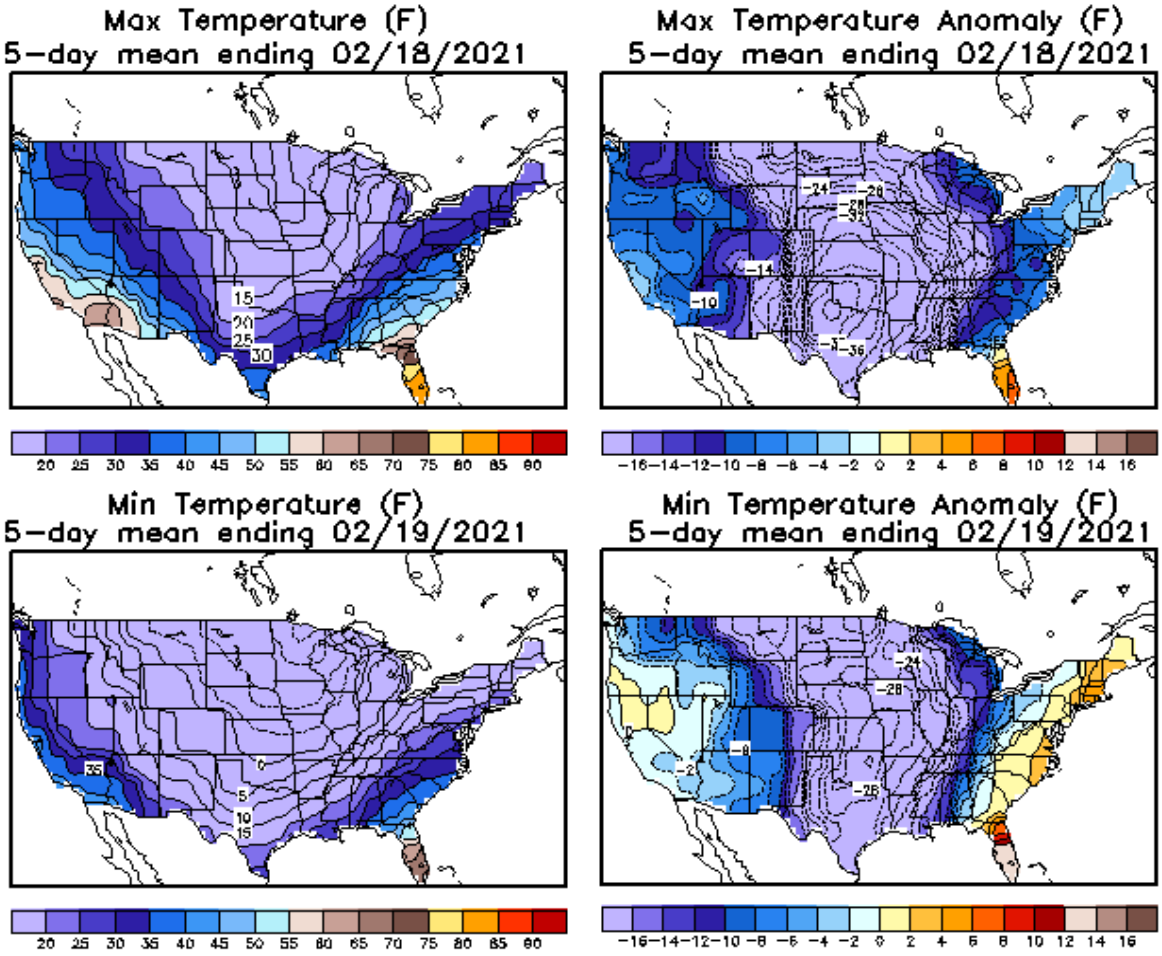


Source: National Weather Service Weather Prediction Center, https://twitter.com/NWSWPC/status/1363859233335349250.

> *Failures were not solely an electric power industry concern or a natural gas failure. The cold was simply worse than almost anyone in Texas had prepared for.*

Figure 2 from the National Weather Service describes average high and low temperatures across the nation over the five days from the beginning of rolling outages to the day ERCOT declared an end to emergency conditions. Daytime highs during the period were more than 30 degrees below average highs, while low temperatures were 20 to 30 degrees below average lows. The figure both documents the extreme cold in Texas and raises questions about the failures. Nebraska, South Dakota, North Dakota, and Minnesota saw similar deviations below normal, but even more extreme cold than Texas. Why were many Texas power plants offline while similar power plants to the north exposed to even colder temperatures were still functioning?

FIGURE 2: NOAA FIVE-DAY MEAN TEMPERATURES IN TEXAS OUTAGES



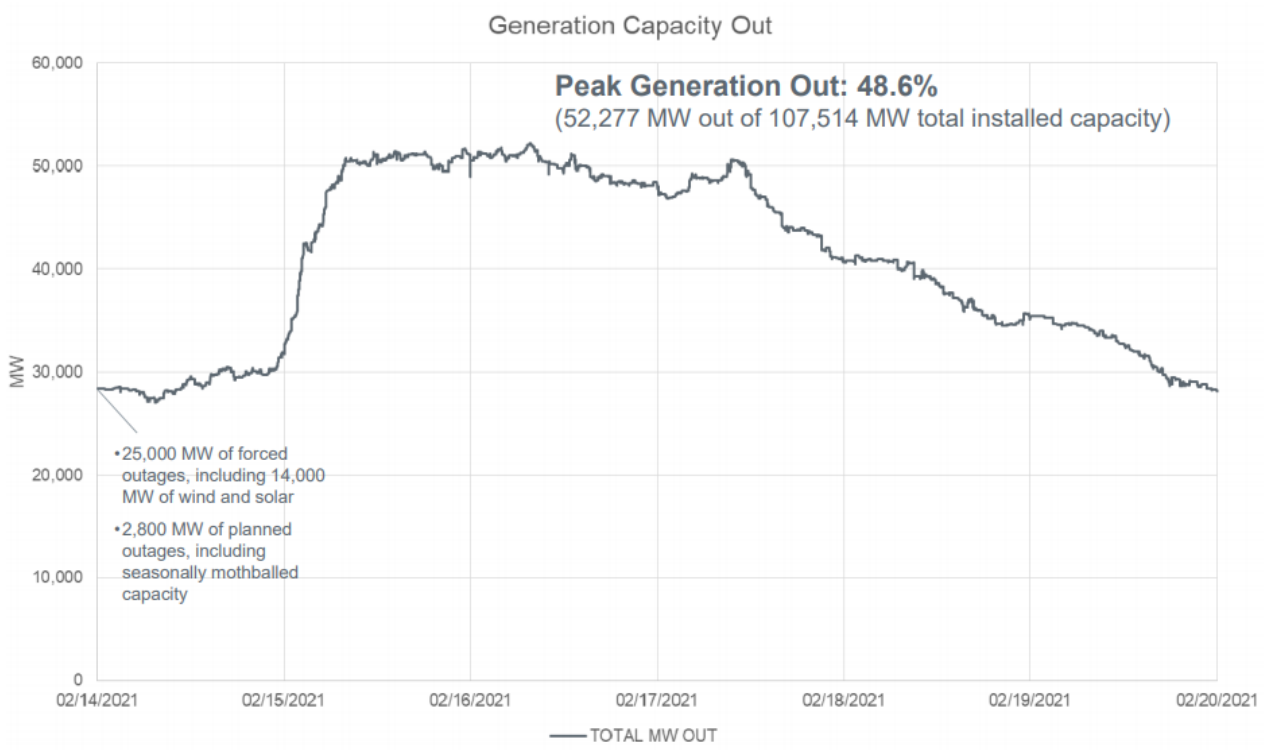
Source: National Weather Service, Climate Prediction Center, https://www.cpc.ncep.noaa.gov/products/tanal/temp_analyses.php; 5-day ending 2-19-2021 Maximum and Minimum Temperatures.

ERCOT had concluded that the Texas power system was prepared for winter. Its regularly scheduled seasonal reliability check published in November, based on extensive historical data, projected a worst-case scenario of customer demand just over 67,000 MW at a time with as much as 14,000 MW of generating capacity offline. With 82,513 MW of generating capacity in total available, the loss of 14,000 MW of supply would leave the system perilously close to being unable to meet demand. Still, worst case, the system was expected to continue serving all customers.[5]

[5] Values from ERCOT Winter 2020 Seasonal Assessment of Resource Adequacy report November 2020, http://www.ercot.com/content/wcm/lists/197378/SARA-FinalWinter2020-2021.pdf. Historical data showed peaks tend to be in January, including the earlier winter peak of 65,915 MW set in January 2018.

Reality was worse than ERCOT's worst-case plan. Much worse. At its peak on Sunday, February 14th, ERCOT oversaw delivery of 69,150 MW of power.[6] Had the system been capable of delivering it, ERCOT's forecast had predicted demand would reach 76,819 MW on Tuesday, higher than the all-time summer peak demand of 74,531 MW. The demand-side forecast was short, but the supply-side forecast more seriously missed the mark. As shown in Figure 3, ERCOT reported that 356 generation units had gone offline during at least a portion of the event, representing 52,277 MW—nearly half—of possible production.[7]

FIGURE 3: TEXAS OUTAGES GENERATION CAPACITY SHORTAGES, FEBRUARY 14-19, 2021



Source: ERCOT Board Presentation by Bill Magness

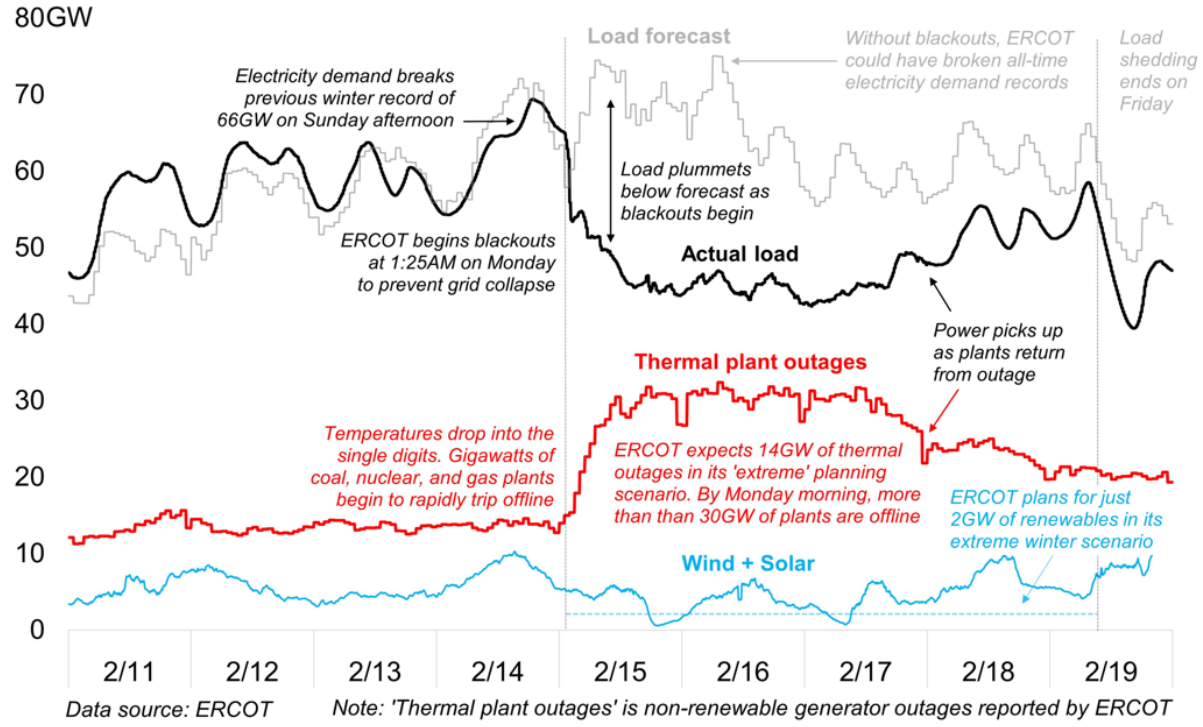
A look at the outages in the context of forecasted and actual power produced, shown in Figure 4 and produced by energy analyst Brian Bartholomew, reveals how production failures combined with higher demands to create the emergency. Warming temperatures on Thursday, February 18th and Friday, February 19th helped supply and demand come back into balance.

6 ERCOT Board Presentation by Bill Magness at slide 19.

7 Ibid.

FIGURE 4: EXTREME WEATHER, EXTREME OUTAGES IN TEXAS

ERCOT electric load, load forecasts, thermal plant outages, and renewables



Source: Brian Bartholomew, energy analyst, https://twitter.com/BPBartholomew/status/1364446059028750337

Weather forecasters saw the cold coming beginning on February 5th, almost 10 days before outages began, but forecasts that far out come with significant uncertainty. On February 10th, ERCOT instructed generators to prepare for the extreme cold. By Friday, February 12th, ERCOT's meteorological division and many others were strongly sounding the alarm. ERCOT's senior meteorologist said, "This period will go down in Texas weather history as one of the most extreme events to ever impact the state. Temperatures early next week will set widespread daily records that are likely to be the coldest experienced since the 1980s."[8]

Even 10 days' notice would not have been enough to avoid an energy emergency. About 27,800 MW of generation was offline the morning of Sunday, February 14th. Some had been taken offline for annual maintenance and nearly half of wind capacity had been iced up by

[8] Andrew Freedman, "Meteorologist for Texas grid operator warned of the winter storm's severity," *Washington Post*, Feb. 19, 2021, https://www.washingtonpost.com/weather/2021/02/19/texas-cold-early-warning/ and for example, ERCOT Weather Analysis on February 12, https://web.archive.org/web/20210216030125/http:/www.ercot.com/about/weather

the arrival of the winter storm. ERCOT oversees scheduling of maintenance to ensure that not too much is offline at the same time, but they were working under assumptions used in the seasonal reliability study. In the days before the cold reached Texas, ERCOT encouraged generators offline for maintenance to return to operating status if possible, but little could be done.

2.2 NATURAL GAS AND ELECTRIC POWER ENTANGLEMENTS

Prominent natural-gas-producing fields in the Permian Basin and North Texas saw some of the earliest and longest-lasting freezing temperatures. Road conditions throughout the northern two-thirds of the state hampered efforts to remedy the failures. On Friday industrial gas consumers were notified their service would be curtailed for several days. The weekend saw the beginning of natural gas pipelines curtailments of power generators. At its low point, natural gas production in Texas was as much as 45% below week-earlier levels according to the Energy Information Administration, even as demand for gas was soaring.[9]

The mutual reliance of the natural gas industry and electric power industry on each other contributed to the breakdown. Rolling outages ordered by ERCOT frequently cut off power supplies to natural gas pipelines, which further cut fuel supplies available to natural-gas-fueled generators. While natural gas pipelines can obtain critical load designation, protecting them from rolling outages, many pipelines had failed to submit the information needed to their local power delivery company.[10] At its worst, as much as 9,000 MW of generation was sidelined by the lack of gas supplies, in part due to power cut offs at gas pipelines. The 9,000 MW of generation capacity could have served an estimated 1.8 million households.[11]

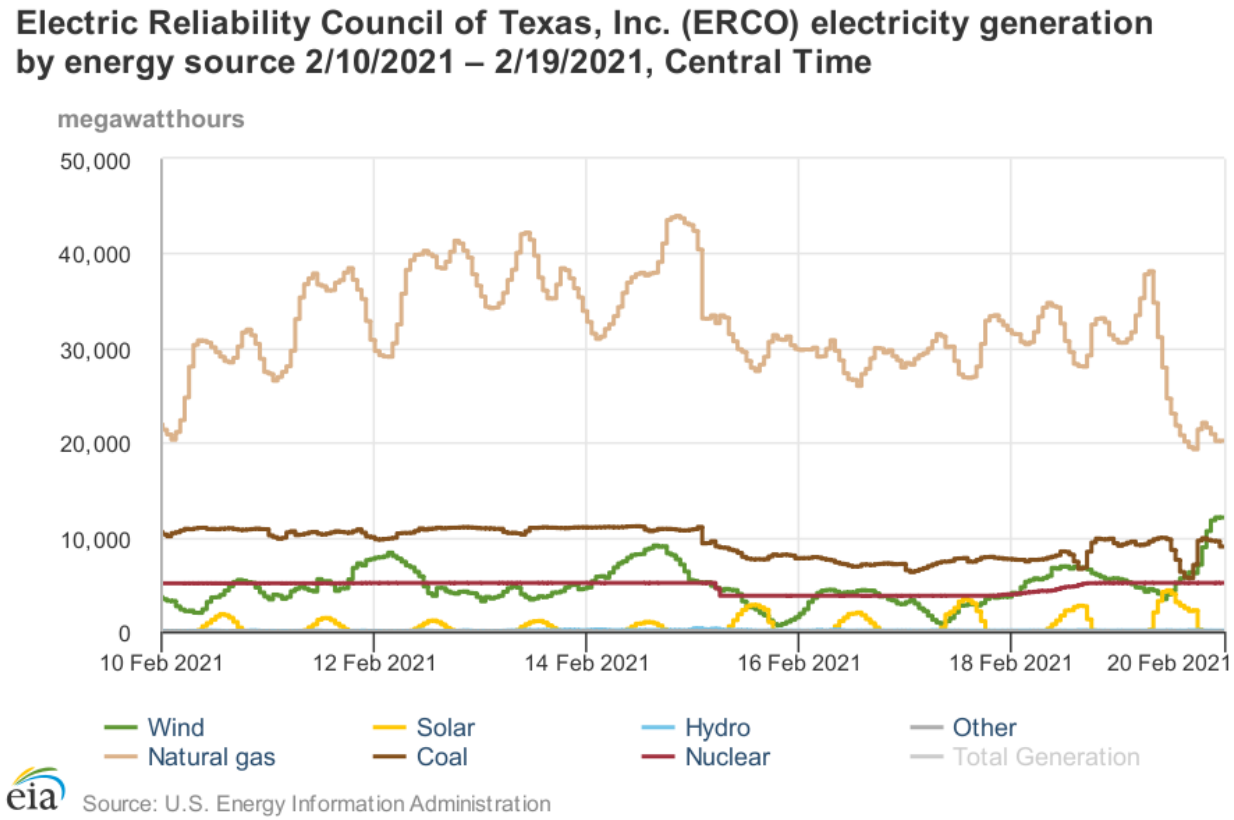
9 Energy Information Administration, “Texas natural gas production fell by almost half during recent cold snap,” *Today In Energy*, February 25, 2021. https://www.eia.gov/todayinenergy/detail.php?id=46896.

10 Erin Douglas, "Paperwork failures worsened Texas blackouts, sparking mid-storm scramble to restore critical fuel supply, *The Texas Tribune*, March 18, 2021, https://www.texastribune.org/2021/03/18/texas-winter-storm-blackouts-paperwork/

11 Calculation by author.

Texas' power industry relies heavily on natural gas, particularly during high-demand periods. As Figure 5 shows, natural-gas-fueled power plants ultimately provided the most electric power during the energy emergency. At the same time, the loss of natural gas generation capacity was the biggest error in ERCOT's winter season resource adequacy analysis. Had natural gas capacity performed as assumed, the scale and duration of outages would have been dramatically smaller.

FIGURE 5: TEXAS ELECTRICITY GENERATION BY SOURCE DURING TEXAS OUTAGES



> *…the loss of natural gas generation capacity was the biggest error in ERCOT's winter season resource adequacy analysis. Had natural gas capacity performed as assumed, the scale and duration of outages would have been dramatically smaller.*

The questions now being asked in Texas and in Washington, D.C. address both operational and financial problems. On the financial side, questions concern the vast sums of money involved with the market price unexpectedly stuck at the cap of $9,000 MWh for several days. The Public Utility Commission issued an emergency order to require prices to stay at the cap as long as rolling outages were required. That order has been disputed, as has the length of time ERCOT kept prices at the cap. Debates continue as to whether or not some or all of those hours should be repriced, and who has the authority to reprice, should it be the right thing to do.

The operational questions asked of ERCOT and the Texas power industry more generally do not focus on the days of rolling outages or the prior 10 days, but rather telescope backwards. Should ERCOT have done better with their seasonal reliability study in fall of 2020? Should power generators and natural gas companies have invested more in weatherization in the years since the rolling outages of February 2011? Should ERCOT introduce capacity markets to encourage more investment in generation? What should regulators have done differently, including the Public Utility Commission of Texas, the Texas Railroad Commission, and the Federal Energy Regulatory Commission? What should the Texas Legislature have done differently?

2.3 NOT THE FIRST TIME

> *February 2021 was not the first time ERCOT resorted to outages to protect the grid as generating resources failed to keep up with customer demand. Severe cold in early February 2011 led to rolling outages that lasted 18 hours.*

February 2021 was not the first time ERCOT resorted to rolling outages to protect the grid as generating resources failed to keep up with customer demand. Severe cold in early February 2011 led to rolling outages that lasted 18 hours.[12] Rolling outages had first been

[12] *Report on Outages and Curtailments During the Southwest Cold Weather Event of February 1-5, 2011* ("2011 Report")

used by ERCOT in winter during a cold spell in December 1989, well before Texans restructured the electric power industry to boost competition and before any utility-scale wind power had connected to the ERCOT grid. The 1989 event suggests that simple explanations blaming the failures on either "too little regulation" or "too much wind energy" are too simple.

The 1989 failures led to an investigation and report by the Texas PUC, *Electric Utility Response to the Winter Freeze of December 21 to December 23, 1989*. The report summarized the event in words that seem to describe the February 2021 failures as well but for the dates:

> *The winter freeze of December 21 through December 23, 1989, greatly strained the ability of the Texas electric utilities to provide reliable power to their customers. Record and new record low temperatures were felt through the state resulting in a significantly increased demand for electrical power. At the same time demand was increasing, weather related equipment malfunctions were causing generating units to trip off the line. The combination of heavy demand and loss of generating units caused near loss of the entire ERCOT electric grid.*[13]

The report observed, "A complete system blackout was prevented by timely implementation of the ERCOT emergency operating procedures and dedicated utility plant personnel working under adverse conditions to keep power plants generating."[14] The report also said, "The near complete loss of the ERCOT grid brings an awareness that, even in Texas, plant operators must prepare for cold weather emergencies. This awareness of and attention to cold weather problems must be continued."[15]

The report detailed a number of recommendations for annual reviews of winter readiness, investment in weatherization of existing plants, and incorporation of lessons from December 1989 into the design of new plants. Utilities reported having access to natural gas curtailed, but none reported lack of fuel as the cause of unit outages. No recommendation addressed gas-electric coordination issues. It was 21 years before the next winter emergency resorting to rolling outages, perhaps suggesting attention to cold weather challenges continued for a while.

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13 *Electric Utility Response to the Winter Freeze of December 21 to December 23, 1989*, 3.

14 Ibid. 7.

15 Ibid.

In February 2011, however, ERCOT resorted to rolling outages after extreme cold caused outages among 210 power plants, and again increasing demand could not be met fully by dwindling power supplies. A subsequent assessment by the Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC)—*Report on Outages and Curtailments During the Southwest Cold Weather Event of February 1-5, 2011* (2011 report)—offered a detailed survey of weather conditions and grid operations in the period surrounding the power system failures.

> *Going into the February 2011 storm, neither ERCOT nor the other electric entities that initiated rolling blackouts during the event expected to have a problem meeting customer demand. They all had adequate reserve margins, based on anticipated generator availability. But those reserves proved insufficient for the extraordinary amount of capacity that was lost during the event from trips, derates* [operating at less than full capacity]*, and failures to start.*
>
> *… Combining forced outages with scheduled outages, approximately one-third of the total ERCOT fleet was unavailable at the lowest point of the event. These extensive generator failures overwhelmed ERCOT's reserves, which eventually dropped below the level of safe operation. Had ERCOT not acted promptly to shed load, it would very likely have suffered widespread, uncontrolled blackouts throughout the entire ERCOT Interconnection.*
>
> *… The majority of the problems experienced by the many generators that tripped, suffered derates, or failed to start during the event were attributable, either directly or indirectly, to the cold weather itself. … At least another 12 percent were indirectly attributable to the weather (occasioned by natural gas curtailments to gas-fired generators and difficulties in fuel switching).*

The February 2011 cold spread across New Mexico and Arizona as well as Texas, and rolling outages and other weather-related outages affected electric power service in all three states. Included in the 2011 report were 26 specific recommendations on power system reliability and another six recommendations addressing natural gas supply. These recommendations are already prominently discussed in the early reactions to the power system failures. Regulators, legislators, and industry observers want to know which recommendations were followed and which were ignored. The recommendations are listed in Table 1 for reference.

TABLE 1: RECOMMENDATIONS - FERC/NERC STAFF REPORT ON THE 2011 SOUTHWEST COLD WEATHER EVENT

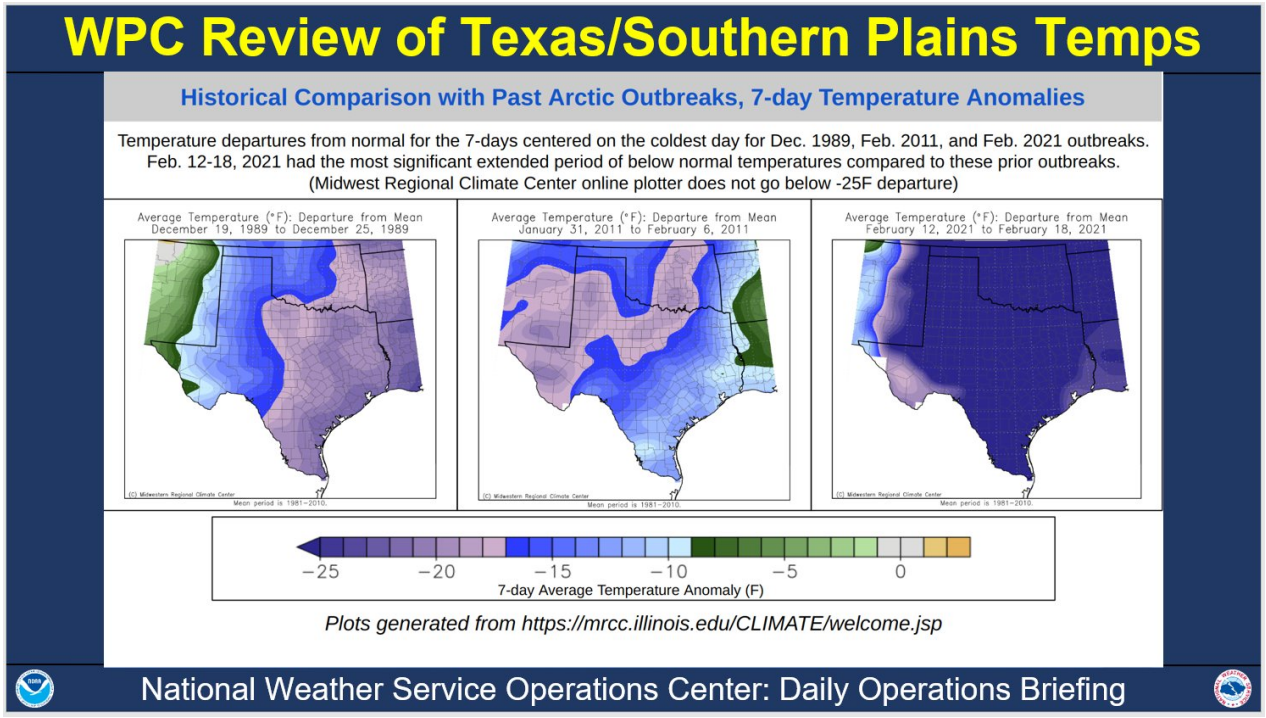
Electric	
1	Balancing Authorities, Reliability Coordinators, Transmission Operators and Generation Owner/Operators in ERCOT and in the southwest regions of WECC should consider preparation for the winter season as critical as preparation for the summer peak season.
2	Planning authorities should augment their winter assessments with sensitivity studies incorporating the 2011 event to ensure there are sufficient generation and reserves in the operational time horizon.
3	Balancing Authorities and Reserve Sharing Groups should review the distribution of reserves to ensure that they are useable and deliverable during contingencies.
4	ERCOT should reconsider its protocol that requires it to approve outages if requested more than eight days before the outage, consider giving itself the authority to cancel outages previously scheduled, and expand its outage evaluation criteria.
5	ERCOT should consider modifying its procedures to (i) allow it to significantly raise the 2300 MW responsive reserve requirement in extreme low temperatures, (ii) allow it to direct generating units to utilize preoperational warming prior to anticipated severe cold weather, and (iii) allow it to verify with each generating unit its preparedness for severe cold weather, including operating limits, potential fuel needs and fuel switching abilities.
6	Transmission Operators, Balancing Authorities, and Generation Owner/Operators should consider developing mechanisms to verify that units that have fuel switching capabilities can periodically demonstrate those capabilities.
7	Balancing Authorities, Transmission Operators and Generator Owners/Operators should take the steps necessary to ensure that black start units can be utilized during adverse weather and emergency conditions.
8	Balancing Authorities, Reliability Coordinators and Transmission Operators should require Generator Owner/Operators to provide accurate ambient temperature design specifications. Balancing Authorities, Reliability Coordinators and Transmission Operators should verify that temperature design limit information is kept current and should use this information to determine whether individual generating units will be available during extreme weather events.
9	Transmission Operators and Balancing Authorities should obtain from Generator Owner/Operators their forecasts of real output capability in advance of an anticipated severe weather event; the forecasts should take into account both the temperature beyond which the availability of the generating unit cannot be assumed, and the potential for natural gas curtailments.
10	Balancing Authorities should plan ahead so that emergency enforcement discretion regarding emission limitations can be quickly implemented in the event of severe capacity shortages.
11	States in the Southwest should examine whether Generator/Operators ought to be required to submit winterization plans, and should consider enacting legislation where necessary and appropriate.
12	Consideration should be given to designing all new generating plants and designing modifications to existing plants (unless committed solely for summer peaking purposes) to be able to perform at the lowest recorded ambient temperature for the nearest city for which historical weather data is available, factoring in accelerated heat loss due to wind speed.
13	The temperature design parameters of existing generating units should be assessed.
14	Generator Owner/Operators should ensure that adequate maintenance and inspection of its freeze protection elements be conducted on a timely and repetitive basis.
15	Each Generator Owner/Operator should inspect and maintain its generating units' heat tracing equipment.
16	Each Generator Owner/Operator should inspect and maintain its units' thermal insulation.
17	Each Generator Owner/Operator should plan on the erection of adequate wind breaks and enclosures, where needed.

18	Each Generator Owner/Operator should develop and annually conduct winter-specific and plant-specific operator awareness and maintenance training.
19	Each Generator Owner/Operator should take steps to ensure that winterization supplies and equipment are in place before the winter season, that adequate staffing is in place for cold weather events, and that preventative action in anticipation of such events is taken in a timely manner.
20	Transmission Operators should ensure that transmission facilities are capable of performing during cold weather conditions.
21	Balancing Authorities should improve communications during extreme cold weather events with Transmission Owner/Operators, Distribution Providers, and other market participants.
22	ERCOT should review and modify its Protocols as needed to give Transmission Service Providers and Distribution Service Providers in Texas access to information about loads on their systems that could be curtailed by ERCOT as Load Resources or as Emergency Interruptible Load Service.
23	WECC should review its Reliability Coordinator procedures for providing notice to Transmission Operators and Balancing Authorities when another Transmission Operator or Balancing Authority within WECC is experiencing a system emergency (or likely will experience a system emergency), and consider whether modification of those procedures is needed to expedite the notice process.
24	All Transmission Operators and Balancing Authorities should examine their emergency communications protocols or procedures to ensure that not too much responsibility is placed on a single system operator or on other key personnel during an emergency, and should consider developing single points of contact (persons who are not otherwise responsible for emergency operations) for communications during an emergency or likely emergency.
25	Transmission Operators and Distribution Providers should conduct critical load review for gas production and transmission facilities, and determine the level of protection such facilities should be accorded in the event of system stress or load shedding.
26	Transmission Operators should train operators in proper load shedding procedures and conduct periodic drills to maintain their load shedding skills.
Natural Gas	
1	Lawmakers in Texas and New Mexico, working with their state regulators and all sectors of the natural gas industry, should determine whether production shortages during extreme cold weather events can be effectively and economically mitigated through the adoption of minimum, uniform standards for the winterization of natural gas production and processing facilities.
2	The gas and electric sectors should work with state regulatory authorities to determine whether critical natural gas facilities can be exempted from rolling blackouts.
3	State utility commissions should work with LDCs to ensure that voluntary curtailment plans can reduce demand on the system as quickly and efficiently as possible when gas supplies are disrupted.
4	State utility commissions should work with balancing authorities, electrical generators, and LDCs to determine whether and under what circumstances residential gas customers should receive priority over electrical generating plants during a gas supply emergency.
5	State utility commissions and LDCs should review the events of early February 2011 and determine whether distribution systems can be improved to increase flows during periods of high demand.
6	State utility commissions should work with LDCs to determine whether the LDC distribution systems can be improved so that curtailments can be implemented, when necessary, in a way that improves the speed and efficiency of the restoration process.

While comparisons to earlier periods of winter weather emergencies will be instructive, the cold in Texas was deeper for longer over a larger portion of the state in 2021 than during either of the two earlier blackout events. In other words, had the gas and power industries

winterized sufficiently to survive a weather event as cold as February 2011, it would have been no guarantee that the industries would have been prepared for the conditions of February 2021. Figure 6, another assessment by the National Weather Service, illustrates the point. It shows "7-day temperature anomalies," that is to say, how much lower than typical for the dates, temperatures were during the three Texas energy emergencies. In February 2021, temperatures were 20 to 25 degrees below typical everywhere but for El Paso at the western-most tip of the state.

FIGURE 6: HISTORICAL COMPARISON OF PAST ARCTIC OUTBREAKS IN TEXAS



Source: National Weather Service Weather Prediction Center, https://twitter.com/NWSWPC/status/1363896522291707907

Clearly, it was not negligent on ERCOT's part—and maybe anyone's part—to fail to anticipate such anomalous temperatures.

PART 3

HOW DID ERCOT PERFORM DURING THE EMERGENCY?

When it comes to operation of the grid, think of ERCOT as a kind of "traffic cop." Traffic cops do not own the cars and trucks on the roads, nor do they own the roads. The cop enforces the rules that are intended to help drivers of cars and trucks share the roads successfully so that everyone gets where they want to go, safely and efficiently.

Electricity flows on the grid at speeds approaching the speed of light, so the rules for "sharing the road" are more demanding than traffic rules. ERCOT is necessarily more involved in coordinating operations on a moment-to-moment basis than a traffic cop. Still, the analogy helps explain the division of responsibilities and how ERCOT could work as planned even as the power system failed disastrously. If your truck does not start on a cold winter morning, your car runs out of gas, or your car gets stuck in the snow because you were incautious, it is not the traffic cop's fault.

One critical reason for ERCOT's rules for "sharing the road" is that small problems can lead to disastrous consequences. By calling for rolling outages when it did, ERCOT helped avoid serious damage to the electronic and other components of the power grid as well as the generation equipment still online. As the cold and ice knocked electric generation

resources offline, system frequency dipped down toward levels that could have caused additional and widespread harm. The result would have been power outages that lasted for weeks, possibly months, rather than outages affecting a third of consumers for a few days. The power system failed to serve all customers for several days, but ERCOT's action allowed those generators still available to keep serving customers and protected the grid so it remained ready to serve additional customers as generators came back online.

> *By calling for rolling outages when it did, ERCOT helped avoid serious damage to the electronic and other components of the power grid as well as the generation equipment still online.*

But reliability requires ERCOT to do more than just be "traffic cop." Specifically because 10 days' notice is not enough to prepare for extreme weather, ERCOT must look further ahead. Another job ERCOT performs is to provide resource adequacy assessments, studies aimed at detecting in advance when power supplies and consumer demand might become seriously out of balance.

3.1 THE FINANCIAL FALLOUT CONTINUES

The weather has warmed up, consumer demand has waned, and generators have returned to service. The financial consequences of the power system failures are still being worked out. Prices in ERCOT's real-time market reached the $9,000 MWh cap when rolling outages were called. Hours later, in what was still early in the event, real-time market prices began falling even as rolling outages continued. The Texas PUC issued an emergency order to force the price back to the $9,000 MWh cap.[16] The ERCOT system had only reached the $9,000 MWh cap once before, for three hours during the summer of 2019. In February 2021, under the order from the PUC, ERCOT's price stayed at the cap for about 90 hours.

[16] Katherine Blunt, "Texas Utility Commission Chief Resigns After Blackouts," *The Wall Street Journal*, March 1, 2021, https://www.wsj.com/articles/texas-utility-commission-chair-resigns-after-blackouts-11614640494

The Independent Market Monitor concluded ERCOT kept prices at the $9,000 cap over 32 hours too long and recommended revising the prices for those hours.

That order and the resulting economic burdens have already been challenged in court, creating some uncertainty about ultimate financial obligations. The Independent Market Monitor concluded ERCOT kept prices at the $9,000 cap over 32 hours too long and recommended revising the prices for those hours.[17] The PUC declined, so far, to do so. So bills are coming due and some retailers and utilities find they are unable to come up with the cash. The Brazos Electric Co-op, a generation and transmission co-op that serves several retail co-op systems, declared bankruptcy on March 1st, stating it could not pay its $2.1 billion bill from ERCOT. Some retailers are reluctant to pay their bills, concerned that if regulators, legislators, or courts ultimately reduce financial obligations, ERCOT will not refund the excess.

Headlines about high power bills began even before the emergency had ended. A customer in Odessa, Texas reported owing $12,000, and a customer in Houston is suing her retail supplier over a $9,300 MWh bill. In both cases the retailer is Griddy, a company offering retail consumers direct exposure to wholesale prices for a flat fee of about $10 per month plus regulated distribution charges. Consumers saved a few dollars most months by taking price risk, but now tell reporters they did not understand just how high prices could go. Overall, though, Griddy served a very small fraction of the competitive retail market, fewer than 30,000 customers out of more than 10 million.[18] The headlines do not represent the typical consumer impact, which will be very modest. Almost every customer in the competitive retail market had picked contracts that shift price risks onto the retailer. Some consumers were on products offering free energy on nights and weekends, and such consumers likely kept warm very cheaply during the emergency.

17 Haley Samsel, "Texas regulators will not correct $16 billion in electricity 'overcharges.' Why?" *Fort Worth Star Telegram*, March 08, 2021, https://www.star-telegram.com/news/state/texas/article249723448.html

18 Griddy Energy filed for bankruptcy on March 15th, an action that may lead to relief for consumers on the wholesale price pass-through plan. See Reese Oxner, "Griddy Energy customers may be off the hook for exorbitant energy bills after company files bankruptcy," *The Texas Tribune*, March 16, 2021. https://www.texastribune.org/2021/03/16/griddy-bankruptcy-electricity-bills/

PART 4

WHAT CAN BE DONE?

What can be done to avoid winter power emergencies in Texas? The early finger-pointing was too simplistic to be helpful. News of the Texas power system failures spread rapidly. Blame spread almost as quickly. “Too much wind power” and “too little regulation” were popular early conclusions, but the opposite views of “too much fossil fuel” and “too much of the wrong regulation” also made appearances.

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More than one critic tagged Enron, an energy trading company absent from the scene for nearly two decades, as somehow connected to the failures. It was not Enron. Neither were the failures due to the Green New Deal, a legislative proposal that has been circulated in Congress, but not enacted and not particularly popular in Texas, and not at all relevant to the winter readiness of the Texas power system. Some people were quick to blame the “free market” energy system in Texas, apparently unaware of the continued role of the Public Utility Commission and its extensive set of regulations. A critic of ERCOT made the

baffling claim that the system somehow resembled the last days of the Soviet Union, and then urged Texans to create a much more powerful regulatory bureaucracy in Austin to better give consumers what they want.[19] These early judgments didn't connect well with the facts.

More-sophisticated and directly relevant discussions centered on winterization requirements, ERCOT's market design, and ERCOT's isolation from neighboring systems. The twice annual report on Seasonable Assessment of Resource Adequacy, issued just before the summer season and again just before winter, lays out the assumptions and decisions made by ERCOT; much analysis must focus on whether flaws in these assumptions and decisions left ERCOT and market participants blind to foreseeable hazards. It was clear that ERCOT resource adequacy assessments did not identify the potential for failures this large, and many argued they should not have missed so badly. Finally, technology enthusiasts pitched their favorites: maybe microgrids or battery storage could save us. This report addresses these suggestions briefly.

4.1 WINTERIZATION REQUIREMENTS

When equipment fails due to cold weather, failure to prepare for the cold is the obvious diagnosis. While over 50,000 MW of generating equipment in Texas froze up, many observed that power plants to the north endured even colder temperatures and continued working. The difference? Farther north, power plants are designed to survive the cold.

Winterizing Texas power plants comes with an additional challenge: Texas power plants must also survive hot Texas summers. Some winterization techniques employed farther north would reduce summer power plant reliability in Texas. For example, enclosing portions of Texas power plants now exposed to the weather would have protected them against freezing, but would make summer operations more challenging. System components are often exposed by design because the ventilation helps the power plant manage excess heat. Fortunately, not all winterization methods see such tradeoffs. Both the report on the December 1989 failure and that on the February 2011 failure

[19] Marcy de Luna and Amanda Drane, "What went wrong with the Texas power grid?" *Houston Chronicle*, Februrary 15, 2021. https://www.houstonchronicle.com/business/energy/article/Wholesale-power-prices-spiking-across-Texas-15951684.php. See also Ed Hirs, "How to fix Texas' Soviet-style electricity market [Opinion]," *Houston Chronicle*, August 20, 2019. https://www.houstonchronicle.com/opinion/outlook/article/How-to-fix-Texas-Soviet-style-electricity-14363388.php

recommended investment and operational practices to promote winter reliability, but compliance was mostly voluntary.

> *Winterizing Texas power plants comes with an additional challenge: Texas power plants must also survive hot Texas summers.*

The Texas Legislature followed up the FERC/NERC report on the February 2011 event by passing SB 1133, a state law requiring the PUC to analyze utility readiness for extreme weather and prepare a report by September 2012. The law required the PUC to submit a follow-up report as often as twice a year anytime it found that "significant changes to weatherization techniques have occurred or are necessary to protect consumers or vital services." In February 25, 2021 hearings before the Senate, the now-former chairman of the PUC acknowledged that after the first such report was issued the commission never considered whether a subsequent report was needed.

Part of power system winterization requires either dual fuel capability at gas power plants or investments in natural gas system reliability. In Texas, the electric power industry is primarily regulated by the PUC, but the natural gas industry is regulated by the Railroad Commission of Texas. The division of responsibilities spurred attempts by both regulators to pass at least some of the blame to the other.[20] Proposals have been advanced to combine the two entities into a single energy regulator.[21]

It is possible that the extent of the extreme cold, both geographically and temporally, would have produced this scale of generator outages even had the recommendations been implemented faithfully. As stated above, the cold weather was more extreme in February 2021. It seems implausible, though, that the outages would have been as severe.

[20] Erin Douglas, "Oil and gas interests left to "self-regulate" in aftermath of winter storm as Texas politicians pile on to ERCOT," *The Texas Tribune*, March 5, 2021.

[21] Michael McCardel and Jason Whitely, "Texas lawmakers considering placing Railroad Commission under Public Utility Commission," WFAA, March 7, 2021.

4.2 RESOURCE ADEQUACY ASSESSMENTS

There is no question that ERCOT's seasonal resource adequacy assessment failed to identify the threat to reliability from both the demand and supply side. The question is whether it was reasonable to expect it to do so, given the extreme winter cold. ERCOT's resource adequacy assessment employs deterministic models that rely on historical weather data, economic activity forecasts, and assessments of generator capacity. The issue now is whether anticipating a repeat of the worst winter weather on record is sufficient, or whether some further margin of protection should be incorporated into the modeling.

> *At least some climate modelers expect both that winter temperatures will be higher on average and that extreme cold events such as February 2011 and February 2021 will become more common.*

Climate change has added uncertainty to the question. At least some climate modelers expect both that winter temperatures will be higher on average and that extreme cold events such as February 2011 and February 2021 will become more common.[22] The apparent contradiction arises due to the effect of higher average temperatures on the stability of the jet stream. The jet stream usually operates to keep the Arctic cold in the north and more moderate temperatures to the south. Instability, however, occasionally allows Arctic cold to travel far south in some areas while pushing warmer temperatures northward elsewhere.

Whether climate change is directly connected to instability of the jet stream is uncertain, but the instability of the jet stream and its consequences are clear. Current uncertainties make it difficult to incorporate the effects into formal resource adequacy plans. However, power generators regularly subscribe to sophisticated weather and climate analysis services and can incorporate these possible effects into their corporate plans as they see

[22] Bob Berwyn, "Polar Vortex: How the jet stream and climate change bring on cold snaps," *Inside Climate News*, February 2, 2018.

reasonable. Unlike some reliability measures that require incurring private costs to promote system-wide benefits, any company working with a better-than-average weather forecast can expect to be rewarded in ERCOT's market.

Another way that resource adequacy assessments play a role in power systems operations comes through scheduling maintenance in late winter and early spring. ERCOT coordinates maintenance outages to prevent too much generation from going offline at the same time, with "too much" defined in part by resource adequacy concerns. A more stringent resource adequacy study might have resulted in ERCOT delaying some requests to go out for maintenance in February. The challenge is to ensure enough generators start maintenance soon enough such that as many as possible are available for hot summer months.

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The Energy Policy Act of 2005 gave the FERC responsibility for electric reliability standards for the entire United States—including the power system in ERCOT. The NERC, overseen by FERC, develops and enforces compliance with the NERC Reliability Standards through regional reliability organizations, in Texas through the Texas Reliability Entity (TRE). Ultimately, changes to requirements governing resource adequacy assessments should be developed through NERC and applied consistently across the United States. Nonetheless, Texas legislators and regulators could insist ERCOT implement more stringent practices.

4.3 DOES ERCOT NEED A CAPACITY MARKET?

Owners of generating plants have long criticized ERCOT's lack of a capacity mechanism. An energy-only market design relies on expectations of high prices to reward power plant investment over time, while a capacity market provides generators (and other qualifying programs) an additional payment in exchange for commitments to be available in high-demand periods. Had ERCOT had a capacity market, advocates of this approach say, then more generation would have been built and the system would have been better able to weather the winter storm.

> *"If, as in ERCOT, the resource adequacy assessment is badly off target, then the capacity market would have secured far too little "extra capacity" to have made a difference."*

The diagnosis appears questionable on a few grounds. First, a capacity market relies on resource adequacy analysis to determine how much capacity the system should buy on behalf of customers. That reliance should suggest an immediate concern. If, as in ERCOT, the resource adequacy assessment is badly off target, then the capacity market would have secured far too little "extra capacity" to have made a difference. The MISO and SPP power systems adjacent to ERCOT both have capacity mechanisms driven by state resource adequacy policies, and both also experienced rolling outages (though at a much smaller scale).[23] Lack of a capacity market cannot be the primary factor.

In addition, many natural gas generators were ready to deliver but lacked natural gas supplies. The EIA reports that natural gas production fell by 45% during the week of the cold snap.[24] Formal capacity markets have rules intended to encourage reliable fuel

[23] Benjamin Storrow, "Why the deep freeze caused Texas to lose power," *Scientific American*, February 18, 2021. See also SPP, "Resource Adequacy," online at https://spp.org/engineering/resource-adequacy/; MISO, "Resource Adequacy," online at https://www.misoenergy.org/planning/resource-adequacy/.

[24] U.S. Energy Information Administration, "Texas natural gas production fell by almost half during recent cold snap," February 25, 2021, https://www.eia.gov/todayinenergy/detail.php?id=46896.

supplies, but it is unlikely they would have made much difference given the scale of the natural gas supply shortfall.

4.4 INTERCONNECTING WITH NEIGHBORING GRIDS

Better transmission links into neighboring grids offer access to relatively low-cost reserves and promise economic and reliability benefits both under normal and emergency conditions. One reason portions of Texas outside of ERCOT saw a more limited need for rolling outages was that they were able to draw on an integrated transmission system that stretched far to the north and east. That meant the Texas panhandle region could bring in power from states that normally experience extreme cold and therefore have power systems that are well prepared to keep working.

One reason portions of Texas outside of ERCOT saw a more limited need for rolling outages was that they were able to draw on an integrated transmission system that stretched far to the north and east.

The PUC has prioritized development of ERCOT rules to accommodate the Southern Cross transmission project linking the northeastern portion of ERCOT to as far away as northern Mississippi.[25] The Tres Amigas project once proposed to connect the western side of ERCOT to the Southwest Power Pool and the Western Interconnection. That proposal appears to have been abandoned, but project sponsors suggested it would bring economic savings and added reliability by enabling trade to the north and west of the ERCOT system.[26]

[25] Public Utility Commission of Texas, "Revised Order Creating and Scoping Project," PUC Project No. 46304, May 23, 2017.

[26] Kevin Robinson-Avila, "Tres Amigas Full of Promise, Challenges," *Albuquerque Journal*, August 5, 2012. Jeff St. John, "Tres Amigas Loses Key Partner for Project That Would Connect Regional US Grids," *GreenTechMedia*, July 30, 2015.

While these transmissions links offer potentially significant reliability benefits, a too-large link brings reliability risks as well. The larger the capability of imports across a single line, the larger the amount of reserves needed inside the system to protect against line failure. For this reason, among others, both the Southern Cross and Tres Amigas projects were proposed to handle delivery of about 2,000 MW of power. Obviously two or three projects of this size would not alone have prevented the 2021 failures, but they would have significantly limited the depth and duration of outages with attendant humanitarian benefits.

Jurisdictional concerns raise significant regulatory and political barriers each time a link is proposed. Each proposed link must secure FERC's assurance that the project would not threaten the PUC's existing jurisdiction. Absent that assurance, the project would be unlikely to obtain PUC permission to connect to the ERCOT grid. The Tres Amigas project continued for years before it stalled, and the Southern Cross project originated a decade ago, suggesting that current regulatory processes are onerous.

The general economic benefits of linking separate power systems have been well known for a century. In everyday conditions retailers can access a wider range of suppliers for both energy and reserves. Reserves can be shared among retailers located in different areas and so reduce risks from large-scale weather events. Links enabling trade between regions produce power prices that are less volatile even as supply conditions become tight. The typical direct current links used also can provide transmission-support services including frequency control service. Such services would have been extremely valuable over the first few hours of emergency conditions the morning of February 15th.

> *In emergency conditions, links to neighboring systems can provide what is quite literally a lifeline.*

In emergency conditions, links to neighboring systems can provide what is quite literally a lifeline. The extreme cold of February 2021 resulted in emergency conditions in areas just outside of ERCOT, too, limiting the value of the small number of existing small links. However, the Southern Cross proposal would link to power systems beyond immediate neighbors, which are likely capable of supporting imports throughout rolling outages. The

Tres Amigas project would have connected ERCOT into New Mexico, which experienced severe cold but had generating capacity available that could have helped.

Interconnecting links are not a complete solution, yet if two long-promoted links had been built, the emergency in ERCOT would have been shorter and much less severe. The best approach may be for FERC and the PUC to develop a standardized process for links between ERCOT and neighboring systems. The rules being developed in ERCOT to address integration of the Southern Cross system should be completed as quickly as feasibly possible, but then refined and extended into a generalized set of rules that any link to neighboring systems can use.

4.5 MICROGRIDS, BATTERY STORAGE, AND OTHER NEW AND IMPROVING TECHNOLOGIES

Various new or improving technologies have been offered not as fixes, but rather as approaches that would have substantially reduced hazards for at least some consumers. Batteries are obvious technologies for storing excess power when it is available and returning the power to the grid when needed. However, battery storage remains too expensive to be of much use for power system challenges of the scope seen in February 2021. Costs are falling but current battery technology will relegate the technology to a bit part in energy emergencies for at least a decade.

Microgrids are small networks connecting both power generators and load, connected to the regional power grid but capable of operating independently. When the regional power grid runs into trouble, the microgrid can safely disconnect from the regional grid, allowing local service to continue and protecting equipment from voltage or other threats from the outside grid. As the regional grid stabilizes, the microgrid can reconnect and contribute to regional grid recovery. Microgrids can be particularly useful for business or industrial parks requiring very high degrees of electrical reliability. In addition, microgrids can provide public service through support of critical infrastructure technologies should the regional grid fail.

4.6 ANALYZING THE FINANCIAL CHALLENGES

Other than the headlines created by high power bills and a bankruptcy or two, information on the financial fallout has been slower to emerge. The PUC delayed ERCOT settlements by several days, but the unexpectedly high energy costs during the energy emergency have left several market participants unable to pay in full even on the delayed schedule. Lawsuits, legislative actions, and regulatory changes add to uncertainty.

> *Much attention has surrounded proposed repricing of the last 32 hours of the energy emergency.*

Much attention has surrounded proposed repricing of the last 32 hours of the energy emergency. When ERCOT requires rolling outages, prices are by rule intended to reach the $9,000 MWh cap. The $9,000 figure intends to reflect the "Value of Lost Load" (VOLL), the estimate of added value created for consumers on forced outages should they be able to again obtain power. Prices did reach the $9,000 MWh cap on Monday when outages were ordered, but unexpectedly dropped Monday afternoon even as outages remained necessary. The PUC issued an emergency order on Monday pinning prices to the price cap for as long as ERCOT required outages to keep the system operating.

The dispute is over when prices should have been unpinned from the cap. The PUC's independent market monitor issued an opinion stating that prices should have been allowed to fall just after midnight on Thursday morning, when rolling outages were no longer required by ERCOT to maintain the system. ERCOT retained the price at the $9,000 cap until just after 9 AM on Friday. While outages were no longer required as of early Thursday, ERCOT anticipated that outages might be needed again later in the day. In addition, restoring services from such extensive outages takes time. It was Friday morning before ERCOT fully emerged from emergency conditions and chose to let prices be again determined by supply and demand.

The market monitor characterizes the disputed 32 hours as a mistake inconsistent with market design principles. ERCOT characterizes its choice to retain prices at the cap as made to ensure the highest degree of vigilance among generators to keep them operating and to discourage industrial consumers from prematurely ramping up energy use.

The market monitor characterizes the disputed 32 hours as a mistake inconsistent with market design principles. ERCOT characterizes its choice to retain prices at the cap as made to ensure the highest degree of vigilance among generators to keep them operating and to discourage industrial consumers from prematurely ramping up energy use. The Texas Legislature has considered bills addressing the repricing issue, but appears to be unwilling to order the action.[27]

On March 3rd, ERCOT reported that 12 market participants had not yet paid their bills for power and services.[28] The largest obligation, at $1.8 billion, is due from Brazos Electric Cooperative. Brazos has entered bankruptcy proceedings in an effort to protect its customers from the bill. The second largest obligation, owed by retail supplier Entrust Energy, is about $200 million. The remaining 10 obligations add an additional $200 million to the unpaid amount. Any obligation ultimately not paid is recovered through an uplift charge on all consumers that is capped in ERCOT rules at $2.5 million per month. If the entire $2.21 billion reported owed were to remain uncollected, it would take over 70 years to recover the sum via monthly uplift charges.

27 Shawn Mulcahy, Cassandra Pollock, and Patrick Svitek, "Electricity repricing bill hits wall in House, marking first major schism with Senate this session," *The Texas Tribune*, March 17, 2021.

28 Gary McWilliams, "Texas power grid names firms with unpaid bills, cuts off second," *Reuters*, March 3, 2021. https://www.reuters.com/article/us-usa-texas-grid-finances-idUSKBN2AW027

PART 5

RECOMMENDATIONS

What now? While the power grid is back in business, the financial fallout is likely to continue for months, maybe years. Resolving financial problems as soon as reasonable will reduce uncertainty and likely help facilitate the investment needed to improve integrated energy systems in Texas. Much analysis has already identified specific problems in the Texas energy system contributing to the outages, but investigations should be continued. As the Texas Legislature was already in session at the time of the outages, hearings already have been held and bills already have been introduced in response.

The FERC/NERC *2011 Report* will be one place to look for recommendations, updated to reflect the more extreme cold conditions experienced in 2021. FERC and NERC are collaborating on an analysis and recommendations addressing the 2021 experience. Presumably the degree of compliance with recommendations from the *2011 Report* will be among the topics investigated.

Likely better to let investigations continue before imposing significant reforms. The high stakes of failure demand a well-informed and well-considered response. What changes are called for to help the system improve reliability?

Winterization: More-stringent winterization requirements seem politically unavoidable, though again the degree to which winterization is needed depends on the critical assessment of the cold. The severity of failures in 2021 may lead the incautious to say *any* cost of winterization is justifiable, but that is not true. It is the potential severity of failures

in the future that demand that resources be devoted to where they will be most effective. Benefit-cost analysis is the standard approach for answering the question, "Where should resources be devoted to secure the best overall protection?"

Winterization standards should allow power plant operators significant flexibility to adapt plants to colder weather. It may be reasonable to prioritize implementation for plants that failed in February 2021 or February 2011, and possibly appropriate to excuse plants that performed well through both events from any new rules. It may be reasonable to set standards differently in the northern and southern parts of the state. Whatever winterization requirements ought to apply to Panhandle wind turbines, they are likely more stringent than those applied to Coastal wind turbines. Rules will likely be tailored to generating technologies, with some rules targeting wind energy, others targeting natural gas generation, and so on. Care should be taken to ensure requirements do not unreasonably burden any one type of generation or region of the state.

Lack of fuel supply is a concern. The loss of natural gas generation came both from plant outages and from a lack of natural gas supply. Winterization standards should not neglect the natural gas production and distribution system. Natural gas plants can be adapted to allow the plants to run on fuel oil when gas is not available, and regulators should consider whether some minimum amount of dual-fuel capability is desirable. In addition, gas pipelines should take the opportunity to have their facilities listed as critical services during rolling outages in order to avoid unintentional cuts to otherwise available gas supplies. While gas generation contributed the largest share of outages, coal-fueled plants and nuclear plants also deserve attention.

In assessing winterization requirements, the public and policymakers should be aware that owners of power plants have strong financial incentives to avoid failures and will take steps to improve their plants with or without added regulations. Each additional MWh of power a generator could supply during the grid emergency could have earned $9,000, an amount almost 300 times higher than typical market prices. Any power plant already contracted to supply power, but unable to do so because of the cold, was likely paying that $9,000 MWh price to replace the power they could not provide. The prospects of earning that revenue or avoiding that cost provide a strong market signal. The good news, then, is that regulations can be focused on systemic challenges beyond investments that will already happen.

A related issue arises with calls for "bailing out" companies hard hit financially by the failures. If bailouts provide cover directly or indirectly for losses suffered by generators, it will reduce generator willingness to spend their own money to prevent failures. If bailouts

cover losses incurred by retail electric suppliers, then it undermines incentives for retail providers to engage in long-term firm contracts that can encourage investment in new power plants. Bailouts for residential customers struck by $1,000 power bills raise more complex issues, but having seen the risks residential consumers will likely be much more cautious about supply offers that expose retail consumers directly to wholesale prices.

As part of ERCOT's winterization response, it should fully reassess its resource adequacy analysis and the manner in which that analysis figures into its operational decisions.[29] Scheduling of maintenance outages and reliability commitment policies for winter weather should be among operational practices updated. The PUC of Texas failed to produce annual reports on electric power winter readiness, as required in a law passed after the February 2011 rolling outages. Had it done so, potential failures may have been foreseen and avoided. As should go without saying, regulators should comply with the law.

Capacity Market: Installing a capacity market would achieve little without a better resource adequacy assessment, but how the resource adequacy assessment should be improved depends upon how and why the assessment was wrong. While the errors of the assessment are clear in hindsight, the relevant question concerns how it can be improved using information available as much as three to six months before the season arrives. Improvements in resource adequacy assessments are critical.

However, a better resource adequacy assessment combined with reasonable winterization of electric power and natural gas systems in Texas are likely adequate to the task. Fundamental changes to the ERCOT market design could impose additional costs without predictable benefits.

Transmission links: More-substantial connections to neighboring grids would have reduced the depth and duration of the crisis. Proposals have been made, but appear to be mired in regulatory processes. The PUC had directed ERCOT to prioritize rule developments needed for the Southern Cross proposal, but rules will mean little if the project cannot obtain regulatory permission from other states involved. FERC does not currently have authority to mandate transmission siting, but does bear significant responsibility for interstate transmission and wholesale power transactions crossing state borders. FERC's authority

[29] The preliminary seasonal assessment for summer 2021, released by ERCOT on March 25th, shows that the organization has already broadened its analysis to consider more-extreme conditions. ERCOT, "Seasonal Assessment of Resource Adequacy for the ERCOT Region (SARA), Summer 2021," March 25, 2021. http://www.ercot.com/content/wcm/lists/219840/SARA-PreliminarySummer2021.pdf

over power flows in interstate commerce suggests it examine ways in which it can promote interstate transmission more effectively.

Many state legislatures, including in Texas, have granted existing transmission owners a right of first refusal (ROFR) over construction of new transmission projects in their states. Supporters of ROFR provisions point to the benefits of working with experienced transmission owners. Critics of ROFR provisions say the provisions unnecessarily add costs and tend to discourage transmission expansion. If transmission expansion is part of the state's response to the February energy emergency, the legislature may want to reconsider its ROFR law.

ERCOT and the PUC should ensure rules can accommodate Southern Cross and then are generalized for any subsequent link. The PUC and FERC should adopt standardized procedures for such links to add predictability to regulations. FERC should guard against the use of state regulatory processes to impede interstate commerce in power.

New technologies: The ERCOT market design has demonstrated an ability to accommodate new and improving technologies from wind and solar to batteries to distributed energy resources. Retail market rules have allowed REPs to offer the most diverse selection of retail supply contracts available, including market-based net metering proposals and offers providing home energy management capabilities. Risks associated with retail offers passing through wholesale costs have demonstrated such contracts are not wise for most consumers, but they have not undermined the value of allowing experimentation by retailers. Rather, competition in the market should be protected to foster continued innovation as technology and communications improve and open up new ways of creating customer value.

These changes are not likely to provide more than modest improvements to winter reliability in the short run, but are nonetheless desirable and will continue. Resource adequacy assessments should reflect whatever reliability benefits new technologies offer.

Financial reforms: Resolving financial problems surrounding the energy emergency will be a particular challenge. A quick resolution reduces uncertainty, which allows market participants to move forward more confidently. Few investors will be willing to put millions of dollars into a system in which billion-dollar obligations remain unresolved. But resolving problems quickly can raise the cost or force the liquidation of market participants that may otherwise have been capable of reestablishing their financial position.

Legislators and regulators also have to be concerned about imposing unnecessary costs on outside investors and financial market participants. The presence of purely financial market

participants helps the market run more smoothly by making it easier for physical market participants to enter into both short-term and long-term contracts. Costs that do not reflect the costs associated with market participation will unnecessarily raise the cost of capital for market participants, slowing investment and ultimately resulting in somewhat higher prices for consumers.

Retail competition: Some critics of retail competition in electric power took the opportunity of the Texas power outages to again state their case. One such article stated the point in its headline, "The real problem in Texas: Deregulation."[30] Reporters at *The Wall Street Journal* claimed that residential consumers in Texas had paid billions of dollars too much because of retail competition, although their calculations are inadequate to justify their conclusion.[31] Adjusted for inflation, retail power rates in the competitive retail parts of Texas are lower than the rates charged in those areas when they were last regulated by the state PUC, which makes the overcharge claim hard to accept. The best economic analysis of Texas retail power prices, a peer-reviewed academic study published in the journal *Energy Economics*, found that retail competition brought cost savings to end consumers.[32] Also, it is not the case that savings have come by cutting corners on reliability. Industry veterans Devin Hartman and Beth Garza report competitive markets have a superior reliability record overall.[33]

30 Paul Griffin, "The real problem in Texas: Deregulation," *Utility Dive*, February 24, 2021.

31 Scott Patterson and Tom McGinty, "Deregulation Aimed to Lower Home-Power Bills. For Many, It Didn't," *The Wall Street Journal*, March 8, 2021. See criticism by Josiah Neeley, "Bad electricity math at the Wall Street Journal," R Street blog, March 11, 2021. https://www.rstreet.org/2021/03/11/bad-electricity-math-at-the-wall-street-journal/.

32 Peter Hartley, Kenneth Medlock III, and Olivera Jankovska, "Electricity reform and retail pricing in Texas," *Energy Economics* 80 (2019): 1-11. The article and supporting data are publicly accessible here: http://www.bakerinstitute.org/research/electricity-reform-and-retail-pricing-texas/. For more on electric competition in Texas see Lynne Kiesling and Michael Giberson, *Electric Competition in Texas: A Successful Model to Guide the Future*, Report prepared for Conservative Texans for Energy Innovation, July 2020. https://www.conservativetexansfor energyinnovation.org/2020/07/22/new-report-calls-for-greater-competition-in-the-texas-electricity-market/

33 Devin Hartman and Beth Garza, "Five truths about grid reliability and deregulation," *Real Clear Energy*, March 15, 2021. https://www.realclearenergy.org/articles/2021/03/15/five_truths_about_grid_reliability_and_deregulation_768172.html.

PART 6

CONCLUSION: LOOKING FORWARD

In responding to the power system failures, the identification of the root causes of failures will be critical. Many critics and analysts were quick to offer their long-favored prescriptions—limit renewables, add a capacity market, return to vertical integration—but the very rapidity of the prescriptions ensured they were not based on a deep understanding of what happened. The days following the emergency have allowed a tentative picture of circumstances to be assembled, but more investigation remains.

The weather was colder for longer across a larger portion of the state than ever recorded before. The widespread damages caused by a lack of access to electricity, including loss of life as Texans struggled to cope with the extreme cold, were disastrous, but examining ERCOT's response shows that ERCOT did its job during the emergency. The major failings happened before the bad weather hit. It may not prove to be cost effective to fully weatherize every system component against the possible extremes of cold and heat experienced in Texas. Yet the severity of the failures, the lives lost to the cold, and the significant costs imposed on the state demand a careful look at the range of possible alternatives.

We should not overlook the point that the ERCOT power system has performed well under a wide variety of weather conditions. The regulations established promoting competition in ERCOT's wholesale and retail market have served the state well. While these regulations must change in response to the failures of February 2021, this fundamental commitment to competition should be maintained.

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