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News & Highlights

Texas Crisis Highlights Grid Vulnerabilities

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In February 2021, during a massive blackout in Texas, USA, a man made the news for using his hybrid Ford F-150 pickup truck, a model equipped with a generator, to power his house for three days [1]. Other hybrid F-150 owners followed suit, and Ford requested that its Texas dealerships lend out the trucks on their lots so that more people could access these mini-power stations during the week-long disaster [2].

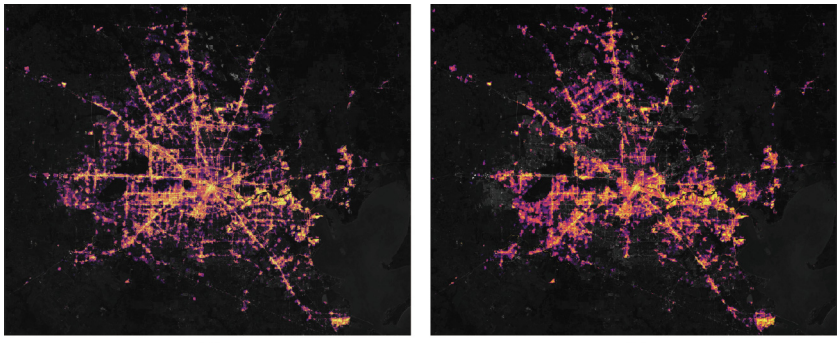
That some residents had to rely on their pickup trucks to provide electricity for their homes illustrates the severity of the grid crisis that paralyzed Texas. For an average of 42 h, 69% of Texans had no electricity (Fig. 1) [3], leaving many homes without heat as temperatures fell to record lows. About half of the population also lacked running water because water plants lost power [3]. According to the state's figures, hypothermia, carbon monoxide poisoning, and other storm-related causes exacerbated by the power outage killed at least 210 people [4], but one analysis put the death toll at 700 [5]. The economic price tag, including damage to homes and businesses from burst pipes, may be as high as 200 billion USD [6].

Experts are still analyzing what went wrong, but they have a pretty good understanding of the cascade of failures that led to the blackout. The extreme cold that swept through the state put severe pressure on the grid, which had not been adequately prepared for such an intense storm. "Given the circumstances, I am not surprised that it went down," said Joshua Rhodes, a research associate in the Webber Energy Group at the University of Texas at Austin (UT Austin), USA.

The disaster spotlights an important issue for the rest of the country, said Robert Hebner, director of the Center for Electromechanics at UT Austin and former acting director of the US National Institute of Standards and Technology. Every state must strike a balance between protecting its grid from extreme weather and keeping electricity affordable, he said. "The real outstanding question nationally is, given climate change, how much more extreme weather should we be protecting against."

Texas' power system differs from those serving the rest of the United States in several ways. Most of the state depends on a grid, managed by an organization called the Electric Reliability Council of Texas (ERCOT), that is almost completely separate from the other two US grids, the Eastern and Western interconnections, that provide electricity to the rest of the country [7]. Large amounts of electricity move among the states within the other grids, but the Texas grid has only a few, low-capacity links to the Eastern Interconnection and Mexico, and it can import less than 2% of its needs [8]. Texas' deregulated power market also sets it apart [9]. Unlike in other states, producers are compensated only for generating electricity, not for maintaining reserve capacity [10].

Previous winter storms in 1989, 2003, and 2011 strained the grid's ability to supply electricity. During a four-day deep freeze in February 2011, for instance, multiple gas-fired generating plants



(a) (b)

Fig. 1. Satellite images of Houston, TX, USA, from (a) before and (b) during the February 2021 blackout show that large areas of the city were without power. More than one million people in the city and surrounding area had no electricity at some point during the crisis, and at least 43 died from storm-related causes. Credit: National Aeronautics and Space Administration Earth Observatory (public domain).

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went offline, either because of equipment failures or because wellheads and other components of the gas production and delivery system froze, leaving the plants short of fuel [6]. Electricity generation fell by 4 GW [10], forcing ERCOT to begin rolling blackouts [11].

The 2021 storm was not the coldest to ever hit Texas, but it affected more of the state, lasted longer, and brought lower temperatures than the 2011 freeze (Fig. 2), spurring unprecedented winter demand for electricity [12]. But as Texans were turning up their heaters, more and more power sources were shutting down. About 50% of wind turbines iced up [13]. One of Texas' four nuclear reactors stopped generating electricity because a water pump quit working in the cold [14]. Piles of coal at some coal-fired plants froze and could not be used [15]. Like in 2011, the natural gas-fueled plants that provide about 50% of the state's electricity faltered [10]. The freezing weather again disrupted gas production and delivery [10] and caused malfunctions at some plants [16]. "Our grid was demanding a record amount of electricity, and we had lost about half of our generating capacity," said Rhodes.

The crucial moment for the Texas grid arrived early on 15 February 2021, when ERCOT's projections showed that electricity demand would soon outstrip supply by almost 8 GW [17]. In response, the organization attempted to instigate rolling blackouts. These temporary service interruptions "are inconvenient, but they generally do not kill people," said Hebner. However, shifting the outages proved difficult because of the reduced levels of power generation and the need to provide electricity to critical circuits that serve facilities such as hospitals, Rhodes said. As a result, the blackouts failed to roll—some people never lost power, whereas millions lacked electricity for days. Still, ERCOT's action came when the grid was less than 5 min from shutting down entirely [18]. "If ERCOT had not stepped in, everyone would have lost power for an extended period of time," possibly months, said Hebner.

The Texas grid reached the verge of collapse for many reasons. One of the most important factors, experts agree, was that facilities had not been sufficiently winterized to withstand the bitter cold. Rhodes and colleagues found that of the roughly 585 power plants that were down during the storm, 167 went offline because of weather-related problems—removing 30 GW of generating capacity from the grid [19]. Another 131 plants capable of generating 6.7 GW stopped producing electricity because of insufficient fuel, another consequence of the weather [20].

After the 2011 storm, the US Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation recommended that Texas power plants weatherize so that they could operate at the lowest temperature ever recorded in the nearest city [20]. Following these recommendations would have made a difference in 2021, Rhodes said. "If we had taken those lessons to heart, this event probably would not have been so severe."

Fig. 2. During the storm, temperatures dropped to −14 °C in normally balmy Austin, TX, USA, and more than 16 cm of snow fell. Ice shrouds these palm trees in downtown Austin on 17 February 2021. Credit: Jno.skinner (CC BY-SA 4.0).

However, after the 2011 freeze the state did not mandate measures to protect power plants or the natural gas infrastructure [10]. Although some facilities took steps to protect themselves, others were not ready for the 2021 conditions. About 75% of plants that were down for weather-related reasons in 2011 also went offline or reduced output in 2021, according to one analysis [21]. Many commentators have blasted Texas' lack of preparation, including Ed Hirs, an energy fellow at the University of Houston, TX, USA, and long-time critic of the Texas electricity market. He blames the rules under which producers are paid only for electricity furnished to the grid, which he said discouraged the owners of many power plants from voluntarily undertaking expensive winterization. "They had no incentive to weatherize. As a result, they did not."

Since the most recent crisis, the Texas Legislature passed a bill intended to improve winterization of power plants, although some experts question how effective it will be [22]. In any case, the state needs to take stronger steps to shield the system for producing gas and delivering it to the plants, said Alison Silverstein, an energy analyst in Austin, TX, USA and former adviser for the Public Utility Commission of Texas and FERC. A report she co-authored offers more than a dozen other measures [23], such as requiring essential facilities to have backup generation and revamping the critical circuits that prevented blackouts from rolling. "We need to redesign and sectionalize these circuits more efficiently," she said, "so that we can do effective, fair rotations of outages."

Texas also needs to address demand, analysts say. Construction standards of homes and businesses helped drive February's surge in use, said Mark Dyson, an energy analyst at the Rocky Mountain Institute, a think tank in Boulder, CO, USA that focuses on sustainability. Texas did not enact statewide energy efficiency requirements for buildings until 2001, he said, and many residents live in poorly insulated houses with inefficient resistance electrical heating. The Texas grid has come close to a power shortfall at other times, including in April and June 2021. On 14 June 2021, ERCOT asked consumers to conserve electricity after the state's reserve generation capacity neared the 15.7% safety margin [24]. Improving the energy efficiency of buildings would be doubly beneficial by helping to stabilize the grid in the winter and the summer, said Emily Grubert, assistant professor of civil and environmental engineering at the Georgia Institute of Technology in Atlanta, GA, USA. Stricter building codes "would go a long way," she said.

Several factors blamed by some for the crisis had little impact. Contrary to some claims, iced wind turbines did not precipitate the blackout [25]. Wind generation declined, but ERCOT was expecting little wind power at the time, Rhodes said. On average, between 15 February and 19 February 2021 wind facilities provided about 4 GW of the 7 GW that ERCOT anticipated. However, natural gas supplied only 30 GW of the 48 GW expected, and coal delivered 8 GW of the 14 GW expected [10]. The independence of the Texas grid also was not a culprit. Even if Texas could import large amounts of power from neighboring states, those states were affected by the same storm and had little electricity to spare, said Hebner.

Strengthening the Texas grid to avoid another crisis will be expensive, with winterizing power plants alone estimated to cost as much as 20 billion USD [26]. Climate change is making severe weather events more damaging and more frequent, putting added stress on existing grids and other infrastructure [27–29]. Another recent example is the searing, early summer 2021 heat wave in

the US Pacific Northwest, likely driven by climate change, during which high temperatures soared to more than 20 °C above average in some areas [30]. In the face of such extreme events, the challenge for everyone, not just Texas, may be—as Hebner says—finding the level of protection that strikes an acceptable balance between keeping grids operating and providing affordable power.

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