2022

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Zakeri, Golbon; HMaria Hernandez, Maria; Lackner, Matthew; and Manwell, James, "Weatherization and Energy Security: a Review of Recent Events in ERCOT" (2022). *Current Sustainable/Renewable Energy Reports*. 9.
https://doi.org/10.1007/s40518-022-00203-0

Weatherization and Energy Security: A Review of Recent Events in ERCOT

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August 2021

Key words
Energy security, Texas blackout, weatherization, winterization, just in time fuel, market failure.

Abstract
Purpose of review: This review addresses the question of energy security. With the transition of energy generation fleet to cleaner, more sustainable electricity production, energy security is a topic of increasing importance.
Recent findings: Recent events in Texas brought the concept of energy security to the fore. In this review we examine the makeup of electricity generation and the causes of the February 2021 blackout of Texas. We will investigate the cost/benefit of winterization in Texas and ask why this was not undertaken subsequent to a similar event in 2011.
Summary: We investigate the case of Texas blackout of February 2021 and estimate the cost of prevention of this undesirable outcome. We suggest that market mechanisms need to be in place to incentivize electricity producers to ensure energy security going forward.

Introduction
One of the main outstanding challenges of today's electricity markets is energy security. To alleviate emissions and remedy climate change, there is an increasing burden of heating and transport electrification on the electricity grid, and simultaneously, penetration of volatile renewable energy sources into the generation mix. It is clear that now, more than ever, electric grids are exposed to the risk of supply shortage and its highly negative consequences.

In this article, we review the February 2021 events of the Electric Reliability Council of Texas (ERCOT) market and explore remedies through weatherization of generation sources. We will start by summarizing the basic structure of ERCOT as laid out in [1] and [2]. We will then present the events of February 2021 and explore the causes. We will provide an analysis of weatherization of the so called "just in time" generation equipment. We will briefly discuss possible market structure improvements to incentivize participants for taking such measures and conclude the article with a summary. (We note that market mechanisms are not the only way to get obtain a resilient system. Regulations and/or a set of standards/certification process are also options.)

Market Description for ERCOT

The Electric Reliability Council of Texas was established in 1970. Since 1996, ERCOT has brokered the wholesale electricity market in Texas. ERCOT is governed by a board of directors and subject to oversight by the Public Utility Commission of Texas (PUC) and the Texas Legislature. ERCOT facilitates a competitive wholesale market in Texas to maintain a reliable electric power system consisting of generation, transmission and ultimately consumption, meeting the needs of nearly 28 million Texas homes. The generation mix of ERCOT is provided in Table [1], which indicates that three quarters of the generation is "just in time," supplied by natural gas flowing in pipelines that run across the state from areas like the Permian Basin in West Texas to major demand centers like Houston and Dallas, or supplied by wind.

GENERATION TYPE	INSTALLED CAPACITY	MARKET CAPACITY? PERCENTAGE
NATURAL GAS	51,667 MW	47.45
WIND	31,390 MW	28.83
COAL	13,630 MW	12.52

SOLAR	6,177 MW	5.57
NUCLEAR	5,153 MW	4.73

Table 1 ERCOT generation mix

ERCOT manages the power flow across the Texas Interconnection, which is not connected to either the Eastern or the Western Interconnections in the US. Soon after the February extreme cold event in Texas, it was suggested (see [3]) that the event may cause Texas to join the rest of the US grid – something Texans have been reluctant to do for the past many decades.

Extreme Cold Event of Feb 2021

In advance of each season – fall, winter, spring and summer – ERCOT develops a Seasonal Assessment of Resource Adequacy known as SARA reports. The report focuses on the availability of sufficient operating reserves that would be able to avoid emergency actions such as implementing voluntary load reduction resources. For the 2021 Winter season, the SARA report predicted that the "Forecasted Season Peak Load" scenario expected about 74,000 MW of net resource capacity would be available to meet a winter peak of 57,699 MW (see [4]). Nevertheless, on February 8th the weather models began to show worrisome weather for their service regions, though there was uncertainty of timing and severity of the extreme cold weather fronts. On February 10th, "the total amount of offline power plant capacity increased from 14,400 MW to 25,850 MW, or about 12% to 21% of the total 123,050 MW of installed nameplate capacity in ERCOT" (see [4]). Similarly, on this day, ERCOT began to see wind turbine outages as the fog was resulting in ice accumulation on the blades and later on the gearboxes and nacelles. The generators fueled with natural gas were also facing issues due to a lack of fuel supplies, which resulted in the generators going offline or derating. We discuss icing issues and mitigation strategies as well as effects of the cold weather on generation from natural gas in the next section. The winter storm progressed to a Winter Weather Advisory (WWA) and subsequently a Winter Storm Watch (WSW) on the 10th and 11th of February.

Throughout the nights of February 13th and 14th, the weather dropped to "extreme low" temperatures (Dallas for instance reached a low of 3 degrees Fahrenheit), whereupon the state officially went into a Hard Freeze Warning. ERCOT deployed responsive reserves and issued an emergency notice. On the night of the 13th generators began to go offline and by noon on February 14th approximately 8,400 MW of capacity was offline due to existing outages. The majority of this capacity (7,700 MW) was from coal and natural gas power plants. On the morning of February 15th, ERCOT declared a Level 3 Energy Emergency Alert that had caused blackouts. The resource status on the morning of February 16th indicated a shortage of 28,345 MW in capacity. The shortage might have been prevented or at least mitigated to some extent had measures been taken to protect electricity generation sources against extreme weather. We discuss weatherization below. Further details of the Texas blackout, on a finer timeline, can be reviewed from [1].

Risk and Mitigation; Weatherization

The lack of weatherization was the most significant factor in the 2021 blackouts. It is worth noting that two different types of weather conditions combined to make the situation worse than it otherwise might have been. High humidity together with moderately cold temperatures caused ice formation on wind turbine blades and extreme cold temperatures resulted in reduced natural gas availability. The Texas Tribune reported that "production of natural gas in the state has plunged, making it difficult for power plants to get the fuel necessary to run the plants.

Natural gas power plants usually don't have very much fuel storage on site, experts said. Instead, the plants rely on the constant flow of natural gas from pipelines that run across the state." see [5]. In early February, Texas operators were producing about 24 billion cubic feet per day, according to an estimate by S&P Global Platts. However, during the extreme weather event, Texas production plummeted to a fraction of that; operators in the state produced somewhere between 12 billion and 17 billion cubic feet per day.

A similar though less severe version of the February 2021 events occurred in 2011. A report published by the North American Electric Reliability Corporation following the February 2011 cold weather event contained several recommendations applicable to ERCOT (see [6]). Over the past 10 years, ERCOT has made changes that support those recommendations. Significant modifications include:

• Implemented the Seasonal Assessment of Resource Adequacy report that includes an analysis for extreme winter weather.
• Began a resource weatherization process that includes an annual workshop, review of resource weatherization plans and spot checks of facilities.
• Added additional staff (Shift Engineer and Resource Reliability Desk) in the control room.
• Modified the Ancillary Services procurement to allow additional procurement in anticipation of severe weather.
• Established the Gas Electric Working Group and created a notification procedure for Qualified Scheduling Entities to notify ERCOT if there are anticipated fuel restrictions.
• Modified the survey sent to natural gas generators. The survey collects information on fuel switching capability for some resources in preparation for each winter season.
• Changed the rules and processes for withdrawing approval of resource outages in anticipation of severe weather.

Subsequent to the 2011 blackouts, Texas PUC amended its rules to authorize ERCOT to conduct generator site visits to review compliance with weatherization plans. Spot checks include reviewing the weatherization plan, verifying that plant personnel are following the plan and providing recommendations based on PUC requirements, lessons learned or best practices. Nevertheless, generation owners and operators are not required to implement any minimum weatherization standard or perform an exhaustive review of cold weather vulnerability. No entity, including the PUC or ERCOT, has rules to enforce compliance with weatherization plans or enforce minimum weatherization standards.

The question then arises on why the generators had not weatherized their fuel supply? To answer this question, observe that uniform price auctions, such as those operated in the US markets, and in particular ERCOT, signal scarcity through high prices. Therefore, periods of supply shortage coincide with (significantly) higher prices. Therefore, a period of shortage could be quite profitable for some generators which means there is clearly misalignment of incentives on the generators part. While capacity procurement auctions mitigate this to an extent, they do not help with procurement of required shorter term storages that can see generation through an extreme cold spell, lasting hours to days. This problem has been diagnosed in other markets with a similar "just in time" generation mix such as New England and some remedies, such as energy options have been suggested [7].

The approach suggested in [7] consists of allowing generators to offer in reserve energy options that may be called upon in real time (RT). This market is then co-optimized and cleared with the day ahead (DA) energy market. In a set of previous papers [8] to [11], an enhanced version of the energy options has been suggested. In particular the authors introduce "pre-dispatch" products offered by each generator, which would reflect the cost to the seller's adjustment to dispatched generation. The adjustment may be upward or downward (i.e. generate more than indicated in the day ahead, or less), and the cost may be scenario dependent. Such measures are likely to have a positive effect on voluntary procurement of reserves by generators, but further research is required to ensure the market mechanisms will result in sufficient supply side security.

Our discussion above is centered on electricity markets that are fueled by "just in time" fuels and weatherization readily presents itself as a solution. However there are many other considerations and methods in the literature when it comes to grid resilience. In [12] for instance, authors discuss the power system value chain and resilience interdependencies. They outline broad conclusions on existing approaches to resilience and recommend guiding principles for improving the resilience of the evolving grid. Other solutions such as utilization of micro-grids and demand response have also been presented and discussed extensively in the literature (see e.g. [13]) but are beyond the scope of this brief article.

Winterization of Wind Turbines and Gas Fired Generation

In this section we will describe approaches to weatherization, in particular winterization of both wind and natural gas fueled generation. We start with wind turbines. Extreme cold weather can cause ice to form on wind turbine blades. In fact, there are two main types of icing of wind turbine blades: clear (glaze) ice and rime ice. Glaze ice mostly occurs in freezing rain or other precipitation, when the blades may be cold (below 32 degrees F) because of previous low temperatures subsequent to which rain freezes. Rime ice occurs from supercooled water droplets, such as in fog. The formation of ice interferes with the aerodynamic performance of the turbine blades and reduces the efficiency of the turbines, sometimes by 20% (see [14, 15]). Clearly, the solution is to de-ice the blades or to prevent ice formation in the first place. Turbine blades can be prepared for severe freezing temperatures through systems that proactively heat the blades. Passive approaches are also options, such as coatings that prevent the ice from building up. Cold weather packages, used in various jurisdictions such as the Midwest of the US, Canada and Nordic countries can be implemented to protect a turbine's gearbox and other components through heaters in the turbine's nacelle. These operations can help turbines operate in temperatures down to -22 degrees Fahrenheit [16]. An important distinction between Texas and other jurisdictions amenable to accumulation of ice on the turbine blades is the amount of moisture in the air. Most other such US states have lower humidity levels than Texas. During the February extreme cold event, the volume of ice on wind turbines reduced power production from wind to about 50% of what would otherwise be expected.

Siemens was one of the first companies to investigate de-icing techniques and produced the first de-icing system in 1994. Their electrical method uses built-in carbon heating mats to remove ice from blades. This system consists of an ice detection sub-system, a heating and a control sub-system. The price of a wind turbine equipped with gear to handle winter conditions is estimated to be 5%-10% more than a turbine without winterization. It can cost up to $400,000 more to winterize a 2.5 MW utility scale wind turbine (see [16]).

While loss of power from wind turbines was a significant factor in the February blackout of Texas, by far the major factor was the decrease in access to gas supplies. King et al. report that natural gas production in Texas reduced by more than 10 billion cubic feet per day (Bcf/d) in the extreme cold event of February 2021. This decline of production is due to a phenomenon called freeze off, whereby water and other liquids present in natural gas gathering lines or wellheads freeze and obstruct the collection process (see [17]). The same report indicates that natural gas exports (via pipelines) were reduced to 5% of their normal, steady state operational levels.

To investigate the cost of winterization for natural gas pipelines, we return to the 2011 report by FERC and NERC ([6]) that puts the cost of winterization equipment for gas powered plants anywhere from $50,000 to $500,000, in 2011. In terms of today's worth accounting for inflation and assuming cost estimates remain the same, the total cost is estimated to be equivalent to $95M for winterizing all of the 162 gas-powered plants in Texas (see [18]).

There are different approaches to estimating the cost of the outages in Texas during the February 2021 storm. The outages lead to property damage (both residential homes and businesses), contaminated water supplies, loss of economic activity and even loss of life. It is of course very hard to estimate the monetary value of these damages, although estimates between $80 billion to $130 billion dollars have been reported (see [18]). In a much more conservative approach, we can simply estimate a value of lost load (VOLL), which is close to $6,000/MWh, the spot price reached in ERCOT. Using this price and calculating the power loss of the February event (namely 70 hours at an average of 14,000 MW), the figure of $4.3 billion dollars is reached.

Conclusion

On balance, with the available cost estimates, and assuming that the extreme weather events occur with increasing frequency (e.g. one in every ten years or more frequently), it seems that the winterization expenses are well justified. Nevertheless, the justification of winterization is based on costs to all of those affected by the extreme weather and not just producers, yet in a restructured deregulated electricity market, the investment cost must be borne by the producers. Similar events were encountered in 2011 and left to the wholesale electricity market, however producers were not enticed to procure storage, weatherize equipment, or find other measures against energy scarcity encountered due to weather events. Given the nature of scarcity pricing, there is impending need to structure wholesale electricity markets to ensure that producers are incentivized to invest in energy security measures. This can be done in conjunction with regulatory measures for security.

Conflict of interest declaration

This review is funded by the National Science Foundation NSF Research Traineeship (NRT) program (Award Number 2021693) and Growing Convergence Research (GCR) program (Award Number 2020888). The authors have no competing interests to declare that are relevant to the content of this article.

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