Low-cost, High-risk Electricity and the Texas Polar Vortex

BY CONNEMARA DORAN

Abstract

The Texas polar vortex highlights the relationship between electricity cost and societal risk. We analyze six types of risk and possible policy responses, including R&D to improve wind-turbine deicing.

Texas enjoys low electricity costs but suffers high risks of shutdowns. The Texas polar vortex of February 2021 provides a highly instructive case study of the problematic relationship between the cost of electricity and the societal risk of loss of power during an extreme, extended polar freeze and ice-storm.

We first examine the origin of these costs and risks in Texas. Next, we identify six types of societal risk associated with the polar vortex. Finally, after reviewing these risks and the possibility of abatement with respect to each risk, we conclude that technological innovation regarding the deicing of wind turbine blades is a necessity.

Societal risks were actualized in deaths, suffering, and losses. The Texas government officially tallies 151 deaths from the plunging temperatures. These deaths spread unevenly across Houston, for example, disproportionately affecting the poor, homeless, elderly, and already-ill. The U.S. Census Bureau reports that, in 2019, Texas had the twelfth-highest poverty rate (13.6%) in the nation, and the second-highest population.

Economic risks also took their toll in Texas. On March 3, Insurance Journal reported that the oldest and largest power cooperative in Texas had declared bankruptcy.[1] The Insurance Council of Texas, an industry group, faulted the energy companies for insurance losses of at least $20 Billion.[2] On March 5, AccuWeather specialists updated their estimate of damage and economic losses in Texas alone to $130 Billion, three times their earlier estimate.[3] News headlines declared the blackout "the most expensive disaster in Texas history."[4] Whatever the eventual losses, they will be very substantial.

Texas enjoys some of the lowest energy costs in the nation, ranking fourth lowest in terms of its cost of electricity. Average residential electricity costs for the U.S. as of May 2021 were 13.19 cents per kilowatt hour (kWh). Residential electricity costs were as high as 19.90 cents per kWh in California. But in Texas these residential electricity costs were only 11.36 cents per kWh.[5]

Texas features a free-market based energy economy where each energy firm must compete with every other energy firm for a share of the market. Demand and supply determine the price of energy in Texas, not a single utility or regulatory body which, as a monopoly, would set the price of energy for the whole society.

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How much electricity a state uses varies with a number of conditions such as the climate, the productivity of each economy, the nature of industrial output, the quality of residential and commercial construction, the price of electricity, and the size of the population. As of 2018, Texas consumed about 1,177 kilowatts per month, or about 39.2 kilowatts per day. Across states, according to the Energy Information Administration (EIA), Texas is the sixth largest overall consumer of energy at 498 million BTU. California, the largest population state, uses only about 202 million BTU.

But in terms of their electricity rates, Texans benefit from very low energy costs. The average residence in California, benefitting from a relatively mild climate, consumes about half as much electricity per household as the average household nation-wide. Texas, where residential temperature extremes are larger and summers are consistently very hot (ranging from dry heat to extreme humidity), consumes more electricity per household, overall, especially for air-conditioning, than the average state.

Reliability, Societal Risk, and Financial Cost

Figure 1 depicts the dilemma a state faces regarding the reliability of electric energy supply during an extended deep freeze. This four-celled table places the financial cost of energy on the horizontal axis, societal risk on the vertical axis. Texas finds itself in Cell B with low financial energy costs but high societal risks regarding energy reliability. California finds itself in Cell D with high financial costs but low societal risks in

Societal Risk	**Cell B:** Low financial cost High societal risk **Texas**	**Cell C:** High financial cost High societal risk **AVOID**
	Cell A: Low financial cost Low societal risk **GOAL**	**Cell D:** High financial cost Low societal risk **California** (outside wildfire season)
	Financial Cost	

Figure 1. Table depicting financial cost and societal risk regarding electric energy reliability in the winter months: Texas and California.

terms of a polar vortex. (If summer heat waves were to be included, California would move to Cell C while Texas would remain in Cell B).[6] Each actor seeks to avoid Cell C characterized by both high energy costs and high societal risks. Ideally, the goal for Texas and California is to enter Cell A with low costs and risks.

To enter cell A, Texas would need to reduce societal risks during winter weather crises without sacrificing its low energy cost; California would need to reduce its costs of electricity consumption without increasing societal risks. (Regarding summer weather crises, both Texas and California would need to reduce their societal risks). Each of these reductions is a serious strategic challenge.

At least six types of societal risk accompany severe winter freezes in Texas.

- Risk of maladministration
- Risk of insufficient spare capacity
- Risk of inadequate winterization (at wind turbine, natural gas storage unit, pipeline, utility)
- Risk of non-optimal grid expansion and connectivity
- Risk of a lack of citizen preparedness and the challenge of resilience
- Foregone hypothetical worst-case risks

Maladministration

Maladministration lurks in odd places, here in the logic of strategic best-practices. Concerned about summer hurricanes, Texas decision-makers planned equipment maintenance (with the accompanying impediment to electricity transmission) during winter months when down-time would interfere less with energy consumption. Severe winter weather (as in 1989 and 2011) destroyed the logic of this schedule, instigating assessments and recommendations to strengthen the system. The 2021 polar vortex prompted new laws regarding maintenance and enforcement (see below).[7] Maintenance should be programmed for the intervals between hurricanes and winter vortices (in spring and/or autumn) while remaining alert for black-swan events.

Insufficient Spare Capacity

When unanticipated spikes in electricity demand occur, a corresponding spike in electricity output may be needed to meet the increase in demand and/or offset the loss of production elsewhere in the system. But who would be paying for this spare capacity that may lay idle for years before being called upon during an emergency? If no one pays for the spare capacity, it does not exist.

Throughout the electrical grid crisis, natural gas (NG) continued to flow to direct users. The problem was in getting NG from storage unit to utility. No shortage of NG existed, since huge amounts were in storage. The difficulty was in ramping up access to stored NG beyond the peak normal load and transmitting that extra gas to the utilities.

In terms of base load considerations, nuclear was the most reliable in February. Of the four nuclear plants in operation, only one shut down very briefly, for instrument repair. Without the nuclear power supplied by these plants, the number of Texas residences lacking electric power would have been far greater.

Texas possesses a back-up system that is supposed to provide "capacity" during a crisis of any sort – a severe winter cold-spell, a summer hurricane, or hacking of the cyber network. In theory, inputs from some 28 standby generators called "black starts" can replace lost generator capacity. But they have not been fully tested as a unified system, which is complex, sensitive, and hard to coordinate. Vulnerabilities include "freeze damage and problems getting fuel" and unstable system frequency when power production cannot meet system demand.[8] During the polar vortex, 15 of the 28 black starts were periodically out of service, and only 13 have fuel oil as a backup in case NG fails. During the February 2011 freeze-up, 10 of the 21 then-extant black starts went down at the same time as the grid itself.[9]

Hence, spare capacity is very expensive and potentially unreliable, or both, especially when it goes unused for such long periods.

Inadequate Winterization

Winterization may be required at the NG well-head where frozen pipes and pumps can interfere with the flow of fuel to electric utilities or to consumers directly. Weatherization may be associated with underground NG storage units and/or wind turbines. Some users of electricity may require portable generators as backup. All of this energy substitution is expensive. Determining which types of weatherization may be necessary, how much and at what cost, needs to be carefully calculated. This process could be incorporated within larger-scale rationalization and modernization innovations in the engineering of the electric grid.[10]

Wind and solar are intermittent sources of energy. During periods of low wind, after sunset, and when expensive storage batteries are not available, NG is the principal go-to energy source for electric utilities. In Texas, NG is proximate and abundant. But the problem during the polar vortex was that the electricity to operate the wells, pumps, compressors, and pipelines was often unavailable.

Most of the necessary NG came from storage facilities, not from the wells directly. Large volumes of gas in storage had been accumulated for exactly the purpose of emergency supply. But this source of supply needed electric compressors to operate. The spike in energy demand during the polar vortex, accompanied by the downward spike in production, led to a cascading failure to provide electricity to those pumps. Absence of ability to transmit emergency gas in storage to the electric utilities led to a partial shutdown of the overall process of electricity generation and transmission lasting for days.

The associated effects of the grid distribution crisis were even more serious. Cascading effects included a shutdown of water pumping stations and of some sewage facilities.

Winterization at various locations would have solved many problems. That winterization did not exist is primarily the consequence of a single consideration. At present, with current technology, winterization is very expensive, especially when it protects against a threat that is rare.

The Problem of Non-optimal Grid Connectivity

The oldest regulatory commission in Texas, the Railroad Commission of Texas (RRC), was founded in 1891 to prevent price discrimination by railroads, but soon became the chief regulator of the oil and NG industry in the state, with the goal of defending public interests. Under the state constitution, the RRC "exercises its statutory responsibilities under state and federal laws for regulation and enforcement of the state's energy industries."[11] Texas Senate Bill 3, signed into law by Governor Greg Abbott on June 8, 2021, expanded the roles of the RRC to include participation in establishing "a process to designate certain natural gas facilities ... as critical during energy emergencies."[12]

Texas did not establish interconnectivity with either the large eastern or western power grids. Since efficiency of electrical transmission declines with distance, the more proximate 14-state Southwest Power Pool was more feasible for Texas, though the polar vortex severely affected some of these states as well. To make sense for Texas, an interconnecting power grid must be sizeable enough to offer meaningful backup capacity, exclude areas also hit by the polar event, meet Texas concerns about burden-sharing and fairness, exclude additional federal controls, and respect the Texas commitment to free market competition across electrical utilities.

Citizen Preparedness and Resilience

Texans are accustomed to preparedness in the face of catastrophic seasonal hurricanes, but they were not at all prepared for the devastations of an enduring winter deep freeze and ice storm. Going back more than 100 years, temperatures in Texas had plunged to below freezing for about a week at least five times. But Texas had not incorporated experiences from those disasters into advisory planning for citizens at the individual and community levels about how to survive a lengthy deep freeze. Resilience requires, minimally, access to a warm winter coat and knowledge of how to layer clothing, bedding to resist sub-freezing temperatures inside homes, and drinking water contained in bathtubs if necessary. Texas Senate Bill 3 includes a provision on monitoring weather and disaster preparedness education, which directly addresses these issues for "winter storms, hurricanes, floods, drought, fires, and other potential disasters."[13]

Foregone hypothetical worst-case risks

By employing a "rolling blackout" technique of electricity distribution, and a lot of luck, the Texas utilities were able to avoid a far worse fate in terms of human and economic impact. The entire system could have collapsed, and Texans might have been without electricity for as long as three weeks or even months. We identify this risk as a hypothetical worst-case risk.

The RRC had authority regarding transmission of oil and gas inside Texas; it had no direct responsibility regarding the electricity grid. But, since no one else was acting, and without formal authorization from the Governor's Office or the Texas Legislature, the head of the RRC, in a live communication with some 20 of the utilities, made a spur-of-the-moment executive decision to employ the rolling blackout approach to save the entire electrical system. By some estimates, the Texas electricity grid came within five minutes of catastrophic collapse.

The Need for Winterization Innovations

Loss of energy supply to the utilities began with the wind turbines. Wind energy as of January 2021 was providing 25% of the Texas electrical output. By 2 AM on February 15, the second day of the crisis, electricity generation from the wind turbines had already plummeted by more than 37% of its normal level of supply. By 7 PM, wind was providing only 2% of Texas total electricity generation.[14] Despite the effort of NG to fill the gap, when the wind turbines began to freeze up, the electric utilities had to start reducing their output of electricity.

Freeze-ups at the NG well-heads did occur, but these well-head problems affected supply only marginally. The central problem was elsewhere: NG from underground storage units was unable to make up for the loss of wind energy throughout the entire storm interval. Yet NG production never fell below its normal peak level of delivery. The problem was the freeze up of the wind turbines and the resulting loss of 23% of the electricity supply.

The policy implication is to winterize wind turbines effectively even against the impact of an ice storm. One way to pay for this would be to offer tax incentives to wind turbine operators for winterization.

The ice itself, not only freezing temperatures, was the problem. Even a "weatherized" wind turbine has difficulty operating when the turbine blades ice up. Normally, the way to deal with icing of turbine blades is to shut the turbine down. Operation of the turbine under an ice build-up will tear up the rotors and gears. Flying slabs of ice could create safety problems as well. Additionally, a recent study found that up to 80% of wind energy is lost due to icing.[15]

Regarding an ice storm, policy makers must identify exactly what "weatherize" means. The term "weatherization" is used several times in the Texas Senate Bill 3, but what are the requirements for weatherization, and applied to what phase of electrification? The term "winterization" is never used in the bill. Winterization of NG supply is even less easily defined than with wind turbines. Attempts to weatherize every NG well-head would involve a substantial waste of funds since the inability to get emergency increases in energy supply from NG storage was the result of electrical pumps that faltered for a lack of electricity, not frozen well-heads.

Wind power is central to long-term energy supply in Texas and globally. The problem is not that wind energy constitutes too high a proportion of the Texas electrical energy base. The Achilles-heel of energy supply in Texas, and the central lesson to be learned in policy terms elsewhere, is the failure to winterize the wind turbines in a way that could offset the effects of an ice storm.

How can Texas move in Figure 1 from a low-cost but high-risk energy situation (Cell B) to a low-cost and low-risk situation (Cell A)? How can Texas prevent another winter storm blackout? The answer, and challenge, is technological innovation. Current state-of-the-art deicers for wind turbine blades use hot air inside the blades combined with a carbon fiber outer coating that can be heated, requiring energy input into the process. Yet they have limited effectiveness and high cost. Can a more effective lower-cost device, strategy, or process be invented to prevent the icing-up of wind turbine blades?

Footnotes

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[2] Mary Williams Walsh, "Texas Froze and California Burned. To Insurers, They Look Similar," *The New York Times*, April 13, 2021.

[3] Mark Puleo, "Damages from Feb. winter storms could be as high as $155 billion," Accuweather, updated March 5, 2021. www.accuweather.com

[4] Victoria Lara, "Experts say winter blast might become most expensive natural disaster in Texas history," ABC News KLTV East Texas, February 26, 2021. www.kltv.com

[5] Electric Choice, Electric Rates by State. www.electricchoice.com/electricity-prices-by-state

[6] California has suffered from rotating outages due to heat waves, and its electrical system has been the cause of many wildfires. Andrew J. Van Horn, "Causes of California's Rotating Outages and A Resilient Reliable Remedy: Geothermal Power," *IAEE Energy Forum*, Second Quarter 2021, pp 11-14. California Public Utilities Commission, Wildfire Safety Division. www.cpuc.ca.gov/wildfires/

[7] For instance, Texas Senate Bill 3, TX SB3. legiscan.com/TX/text/SB3/2021

[8] Rebecca Smith, "The Texas Grid Came Close to an Even Bigger Disaster During February Freeze," *Wall Street Journal,* May 27, 2021.

[9] Ibid. See also the August 2011 report by the Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC): www.ferc.gov/sites/default/files/2020-04/08-16-11-report.pdf

[10] Janusz Bialek, "What do the recent blackouts tell us about the current state of decarbonized power systems?" presentation at the IAEE webinar "Texas' and Other Power Markets After the Big Freeze: Diagnosis and Prognosis," March 19, 2021. www.iaee.org/en/webinars/webinar_kiesling.aspx

[11] Texas Railroad Commission. www.rrc.state.tx.us/about-us/

[12] TX SB3, Sec. 38.074.

[13] TX SB3, Sec. 418.048.

[14] Department of Energy, Energy Information Administration. www.eia.gov

[15] Hui Hu, et al., "A field study of ice accretion and its effects on the power production of utility-scale wind turbines," *Renewable Energy* 167 (April 2021), pp 917-928.