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King Abdullah Petroleum Studies and Research Center

Commentary

Climate and Power System Reliability in the Aftermath of the Texas Blackouts

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The February 2021 blackout in Texas underscored the importance of reliable and resilient power systems. In this commentary, we discuss the roles of regulators, markets, fuel and generation supply chains, and interdependent infrastructures, and find that they need to be reconsidered and redefined to successfully meet the future challenges of increased electrification and severe weather.

Climate change and severe weather are stressing power grids, while climate change policies are increasing the role of electrification in transportation, heating, and industrial processes. The February 2021 catastrophic blackout in Texas underscored the importance of reliability and climate resilience, and raises questions regarding the roles of markets, the grid and fuel supply weatherization, renewable energy sources, transmission interconnections, and regulatory structure in the electric power industry. This event occurred during a cold snap that brought temperatures in Texas to lows not seen in more than 30 years, with millions of people losing power and tens of people losing their lives.

The policy response to severe weather and the industry's changing generation mix should be based upon the engineering and economics of the grid, integrated across regulatory and market policies, and extended beyond the power sector. This paper provides an overview of how reliability has been addressed in power systems and identifies key challenges for the future.

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We raise the following questions:

- Instruments: Are the instruments that we currently have at hand (feed-in tariffs, capacity markets, fixing value of lost load [VOLL], etc.) sufficient to solve the resource adequacy problem in case of more frequent extreme events?
- Regulation: Given that the impact of extreme events caused multiple parts of the electricity system to fail at the same time, along with natural gas production and delivery, is it time to coordinate the regulation of both sectors to improve reliability?
- Mitigation versus adaptation: Mitigation and adaption are complementary in their responses to climate change. However, since policy instruments that promote the deployment of renewables (emissions mitigation) may increase the impacts of extreme events (adaptation), how should these two issues be reconciled?

Important Preliminaries: Climate change, severe weather, blackouts, and generation markets

Climate change affects weather patterns, including potentially contributing to severe weather events. However, it is not possible to connect any individual weather event to climate change (Chandramowli and Felder 2014). Recent examples of extreme weather in the United States (U.S.) include polar vortexes in the north and mid-Atlantic states, extreme hot and cold weather in Texas, and hurricanes along the Atlantic coast. Common cause failures such as severe weather can result in widespread equipment failure of generation, transmission, and distribution components, resulting in widespread and long-term power outages. For instance, the severe cold weather in Texas in February 2021 prevented large amounts of conventional and renewable generation from producing electricity. On the other hand, hurricanes can result in widespread failures of distribution components.

A reliable electric system delivers electricity to consumers in the desired amounts, and a resilient system quickly recovers from power outages and mitigates the impacts of power losses. The electric sector is intertwined with other critical infrastructures, and they need to be able to collectively adapt to blackouts by providing critical services, such as heating, cooling, communications, public safety, and health care, during power outages.

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Distribution and transmission systems are regulated. That is, regulators determine the levels of investment, the rates, and the quality and reliability of service that a regulated monopoly or government-owned utility provides. Generation is provided through a wholesale market (and possibly a retail service, as in Texas, which consists of electricity procurement services). Whether Texas' wholesale market design played a significant role in the recent blackouts is an issue of contention, but it is only a part of a broader question of what the roles of regulation and markets are in achieving reliability and resiliency in the power sector.

Texas and its 'Energy-Only' Market

Texas' electricity 'energy-only' market design was considered a role model of electricity reform by many until February 2021, and reflective of the state's market orientation. The Electric Reliability Council of Texas (ERCOT) operates the grid, while power generators produce electricity for the nodal-pricing wholesale market, and some 300 retail electricity providers compete for retail consumers.

The ERCOT model is close to the theoretical energy-only model. Its generation shortage pricing mechanism is designed to provide one important component of reliability: adequate generation resources to supply load. In a theoretically ideal energy-only market, the value of loss load (VOLL) and loss of load probability (LOLP) would be set by the market. Instead, the VOLL is prescribed by regulators and the LOLP is calculated by ERCOT. Still, Texas has enjoyed lower average electricity prices than the U.S. since it liberalized its electricity market in the early 2000s (in part due to its wholesale market, but also due to its abundance of natural gas).

Because the cold weather observed in February 2021 in Texas is relatively infrequent, natural gas production and delivery companies have not invested in winterizing their equipment. Adding a further complication, in 1999 the state set targets for renewables, which now constitute roughly 25% of Texas' generation capacity, almost all of it wind. Wind and solar photovoltaics are variable, limiting their ability to balance supply and demand, which power systems must do continuously to avoid blackouts. Furthermore, ERCOT can only import small amounts of electricity from other regions, severely limiting neighboring regions from providing emergency power. However, this ensures that very little of Texas' electricity market is subject to U.S. federal regulation.

Given ERCOT's context, the following are some immediate policy solutions to the widespread blackout:

- Increase the VOLL.
- Incentivize winterizing equipment by creating mechanisms that incentivize (either through penalties or benefits) companies foregoing short-term profits to ensure their equipment withstands extreme weather.

- Assess the relevance of creating a capacity market or establishing a mandatory capacity requirement. This mechanism should consider extreme weather events carefully and incentivize the winterizing of equipment.

- Increase interregional trade by investing in interconnections with other grids.

- Promote grid storage to increase the ability of renewable generation to contribute to balancing supply and demand.

These approaches would essentially act as an insurance policy against the lights going out. The costs of implementing these policies would be borne by retail electricity consumers in exchange for improved reliability in normal times, and mitigating problems caused by relatively rare extreme weather. Taking these actions, however, might also interfere in a market that functions well the rest of the time. This tradeoff might change should extreme weather events become more frequent, more severe, or with longer durations due to climate change. The latter scenario would require a change in the current market-regulatory framework, necessitating policies beyond the immediate solutions given above.

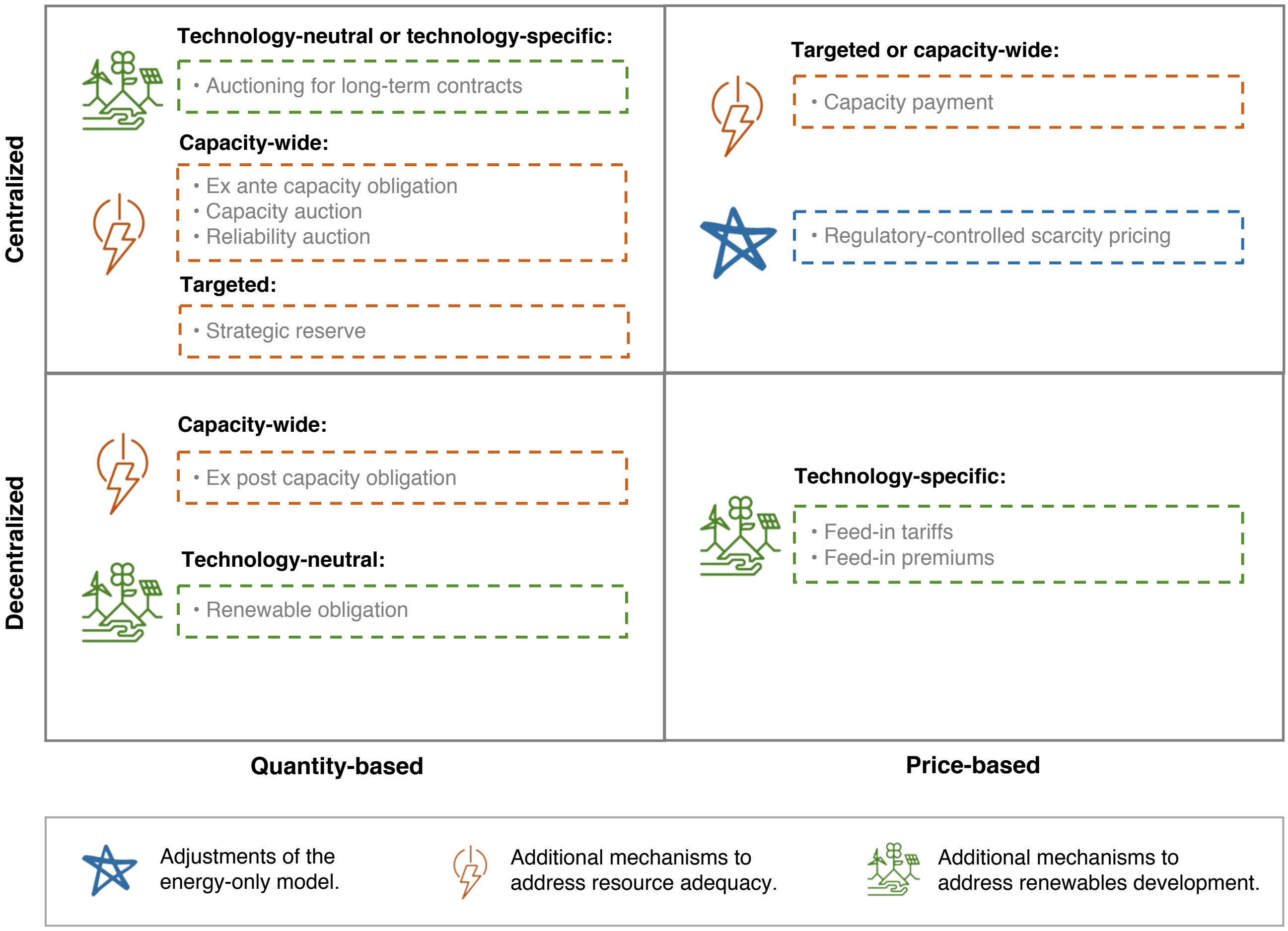
A counterintuitive proposal might be to deepen market approaches. Although reliability is a main goal for system operators, there are multiple degrees of reliability depending on the frequency, magnitude, and duration of outages. For instance, a once-in-a-decade cold snap or heatwave that causes a few hours of rotating blackouts may be something that can be lived with. As the Texas crisis reveals, however, multiple days without power and heat during sub-freezing temperatures cause very high costs in terms of lives lost and economic damage. Between these two scenarios, there are many alternative options that combine technological solutions, prices, costs, and consumer preferences. Given the new nature of extreme weather problems, what combination of planning, technological, and market solutions should be pursued?

Other Market-Based Methods to Address Resource Adequacy and Climate Change

Energy markets are considered the cornerstone in enabling the cost-effective use of existing generation units (short-term dispatch role) and guiding long-term investments due to infra-marginal rents (Caramanis et al. 1982). In practice, many concerns have been raised about (i) the ability of these markets to sufficiently invest in capacity adequacy (Jaffe and Felder 1996; Joskow 2006; Keppler 2017; Petitet et al. 2017) and (ii) their effectiveness to deal with energy transitions (Finon 2013; Peng and Poudineh 2019).

Regulators, whose main objectives are to provide secure, affordable, and environmentally friendly electricity to all residents, want to avoid large blackouts, such as the recent one in Texas, and facilitate the transition to low-carbon energy sources. To this end, many regions have decided to implement additional mechanisms that have been specifically designed to tackle adequacy or mitigate climate-change issues, beyond an energy-only market. Figure 1 provides an overview of implemented and proposed mechanisms with their key characteristics: quantity versus price-based; centralized versus decentralized; targeted versus capacity-wide for capacity mechanisms; and technology-neutral versus technology-specific for support mechanisms.

Figure 1. Overview of adjustments or additional mechanisms in liberalized power systems.



Source: Authors.

Ensuring resource adequacy

Resource adequacy is generally treated as a public good and, thus, is handled by regulators or governments. To ensure adequacy, some advocate that the energy-only market can be enhanced to avoid missing money without the need for any additional mechanism (Hirst and Hadley 1999; Hogan 2005). Others propose introducing capacity mechanisms to complement the long-term coordination that power systems require (Jaffe and Felder 1996; De Vries 2007; Cramton et al. 2013). Many global regions have already implemented capacity mechanisms to deal with resource adequacy, such as in the U.S. (PJM, ISO-NE, and NYISO), the United Kingdom, France, and Poland. However, no country has yet dealt with its grid's resilience to climate change.

Once implemented, resource adequacy should be evaluated based on possible future relevant scenarios, including geographical scope, and weather and climate assumptions. In particular, extreme weather events and climate change effects should be carefully considered. Adequacy studies of the French power system will be carried out, with future scenarios based on Intergovernmental Panel on Climate Change (IPCC) assumptions until 2050 (RTE and IEA 2021; RTE 2021). Following the European Commission's recommendation, the European Network of Transmission System Operators for Electricity (ENTSO-E) is working on enhancing its methodology for adequacy studies in Europe (ENTSO-E 2020).

Tackling climate change and energy transitions

Renewable energy sources of electricity (RES-E) are rarely developed based solely on energy market signals. These technologies have been identified as key solutions to decreasing carbon dioxide (CO_2) emissions from generation, while providing other benefits for governments such as energy independence and job creation. To foster RES-E deployment despite their limitations, many countries have implemented specific support mechanisms, as presented in Figure 1. Renewable obligations prevail in the U.S., and feed-in tariffs prevail in Europe. Both are decentralized, and they incentivize RES-E projects while allowing RES-E to participate in energy and balancing markets as conventional technologies do. In many countries, RES-E support mechanisms have been implemented in addition to pre-existing carbon pricing, which, unlike RES-E, has not necessarily been limited to the power sector. Carbon pricing has not been sufficient to drive investments in RES-E due to, in part, political concerns surrounding high electricity prices. Though renewables were being developed to mitigate climate change, they could paradoxically contribute to magnifying the impacts of extreme events, and thus reinforce the importance of adaptable and resilient power systems.

Early on, many regulators preferred feed-in tariffs because they are relatively simple to implement. However, recent history has shown that dramatic, unexpected effects can arise when RES-E are out of the market, including episodes of negative and highly volatile wholesale prices. Thus, recently more attention has been paid to enhancing the functioning of support mechanisms by increasing the participation of RES-E in energy and balancing markets.

Multiple-layer power systems and interactions between mechanisms

Energy markets are complemented by multiple layers of capacity mechanisms, RES-E support schemes, and other support schemes for specific technologies

Many power systems are far away from the theoretical energy-only model. Energy markets are complemented by multiple layers of capacity mechanisms, RES-E support schemes, and other support schemes for specific technologies (e.g., zero-emission certificates for nuclear power). As initially proposed by economists, energy markets were supposed to provide long-term signals for investors. In practice, investors face a much more difficult forecasting exercise that includes predicting energy prices and the interactions between and outcomes of the additional capacity mechanisms. For instance, introducing a minimum offer price rule[1] (MOPR) in U.S. capacity markets changes the remuneration structure of renewable power by removing its capacity revenue and increasing the REC price to ensure its profitability (Cleary 2020). Another classical interaction is the direct effect of a carbon price on energy prices, because it is transferred to the variable generation costs of CO_2 emitting technologies.

[1] The MOPR has been introduced to prevent subsidized technologies being more competitive than non-subsidized ones. It stipulates that new, subsidized resources offer a minimum required price, which is defined by the regulator based on the energy-only missing money (with no consideration of subsidies).

In hindsight, these mechanisms reintroduce centralized coordination and requirements, as previously implemented by regulators and regulated utilities. These include pushing the development of certain technologies regardless of market signals, and ensuring resource adequacy, which energy markets have not achieved. An alternative could be to switch to a new market design paradigm with two elements: (i) energy markets to deal with short-term coordination, and (ii) long-term contracts for investments issued by a central authority in charge of driving the energy mix through technology-specific and/or technology-neutral tenders. This has been summarized by Roques and Finon (2017) as a competition in two steps: competition *for* the market, and then competition *in* the market. This hybrid model could facilitate investment in line with governments' objectives, but it would rely on a central authority to guide the long-term mix. Introducing a predictable energy mix in future forecasts could also reduce uncertainties around cash flows, and thus reduce the cost of capital for investors by transferring the risk to ratepayers when the central authority's mix trajectory is improperly defined. Finally, the system operator could also handle extreme weather events or climate change issues by considering relevant scenarios and common cause failures when assessing resource adequacy.

Designing Markets Resilient to Climate Change

Looking forward, planning for climate risk and the increasing frequency of extreme weather events will require a fundamental shift in the mindset of regulators. Importantly, without understanding how markets operate, whether energy-only or energy-plus-capacity markets, and what price signals can and cannot do, regulators will fail to cost-effectively implement policies that can secure grids against climate change, and instead blame the markets.

Resolving the quintessential energy economics question of energy-only or energy-plus-capacity markets will not necessarily better prepare us for the threat of climate change. Both types of markets, if properly designed, can ensure resource adequacy during non-extreme events. However, a theoretically 'perfect' market design might not guarantee resource adequacy under the extreme weather events that climate change is likely to bring.

Even with continued market improvements, as suggested above and in Bialek et al. (2021), and eliminating market and regulatory barriers to clean energy resources, whether through incorporating a carbon price or eliminating the MOPR, energy regulation must evolve for markets to be resilient.

First, regulators need to step back to understand the associated market failures, and then implement policies to solve these market failures, not just for the power system but for entire critical infrastructure systems.

Resilience to extreme weather events is a public good distinct from reliability or resource adequacy (Unel and Zevin 2018), and the Texas experience highlights this difference. ERCOT's Seasonal Assessment of Resource Adequacy report shows sufficient installed capacity for both its demand forecast and all-time winter peak demand (ERCOT 2020). Its analysis after the blackout event also showed that, had they been able to generate, the installed capacity would have been sufficient to cover the (estimated) peak load (ERCOT 2021). However, not enough of these generators were sufficiently winterized, despite their potential to earn revenues high enough to cover a significant portion of their entire capital costs in just a few days (Cramton 2021). In other words, while market revenues have incentivized the installation of sufficient capacity to meet peak demand, they were not sufficient to incentivize weatherization without further intervention.

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Second, climate risk brings additional information problems that regulators must address. It is possible that grid actors consider extreme weather risks, but they take little or no action because they underestimate the probability of a significant event affecting them due to insufficient data and analysis, or there are insufficient market incentives to do so. Such underestimation is even more problematic if future analyses are based on historical data, given that climate change is expected to increase the frequency and severity of extreme weather events, or if they do not account for the uncertainty of forecasts of such events (Li, Coit, and Felder 2016). In the case of such information problems, markets would similarly fail to incentivize a socially efficient level of weatherization.

Third, it is important to understand the interconnected nature of the infrastructure and to holistically assess the systemic vulnerability to extreme weather events.

Even if power markets are designed 'perfectly' with proper scarcity pricing, VOLL, or capacity product definition, the power system will not be reliable or resilient if that design, and other policies including coupling regulation, does not consider common cause failures, the vulnerabilities of the gas system, or the interdependencies between the natural gas and electric systems (Felder 2001, 2004).

Finally, regulators and policymakers should understand the markets they are regulating and what market incentives can and cannot achieve. Overriding market algorithms to increase prices to incentivize generators to come back online once they are already frozen, the way the Public Utility Commission of Texas did, will not achieve resilience, just a large transfer of surplus from consumers to generators (Jaffe and Felder 1996). However, coordinated planning and advance action by regulators of different sectors is required, with a combination of market incentives and regulatory requirements. Regulators need to also evaluate how markets can prepare for and respond to future extreme events.

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Overall, preparing for a future with more frequent extreme weather events requires a comprehensive vulnerability assessment that covers the power systems and all the critical infrastructure systems, such as pipelines, water, and communications, and their interdependencies. To be informative, this assessment should consider the increasing risk posed by climate change, and hence be forward looking in its assumptions for the changing risk and the changing demand and supply. This requires better information about threats to be available for market participants and regulators. Importantly, designing a reliable and resilient power system requires regulators who understand the power markets and market failures, how electricity markers are embedded in the reliability and resiliency policies for transmission and distribution, who recognize the systemic risk climate change poses, and are willing to take direct regulatory action when certain market failures require it. Market designs should aim not just for reliability and resource adequacy, but also for resilience, with a combination of market-based incentives and mandates for risk assessments.

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About the Project

This commentary is written as part of the Energy Transitions and Electric Power Program’s project “Innovations in electricity markets, network regulations, low-carbon investments and technologies.” The project aims to provide insights on the transformation of the Saudi electricity sector, characterized by the willingness to increasing the share of renewables, replacing liquids fuels with natural gas, while ensuring fiscal balance, expanding electricity exports, producing green hydrogen, and diversifying the Saudi economy through localization. This project also discusses and learns from electricity markets worldwide. This commentary builds on recent events in Texas to highlight the key conditions for the success of liberalized power systems.

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