ENCHANTED ROCK
The Power is On.

A New Grid Architecture for Optimizing Resiliency

EXECUTIVE SUMMARY

Grid resiliency has never been more topical than it is now. Extreme weather, supply constraints, cyberattacks-attacks on critical infrastructure and broad electrification are creating greater risks for modern society as it increasingly relies on the grid for its energy needs. Forward-thinking policy makers must consider a new grid architecture to achieve greater resiliency against multiple threat vectors. As the list of critical customers and community services relying on electric service expands, policies that support microgrids can work in tandem with the existing regulatory framework for electric utilities to cost effectively deliver high levels of resiliency.

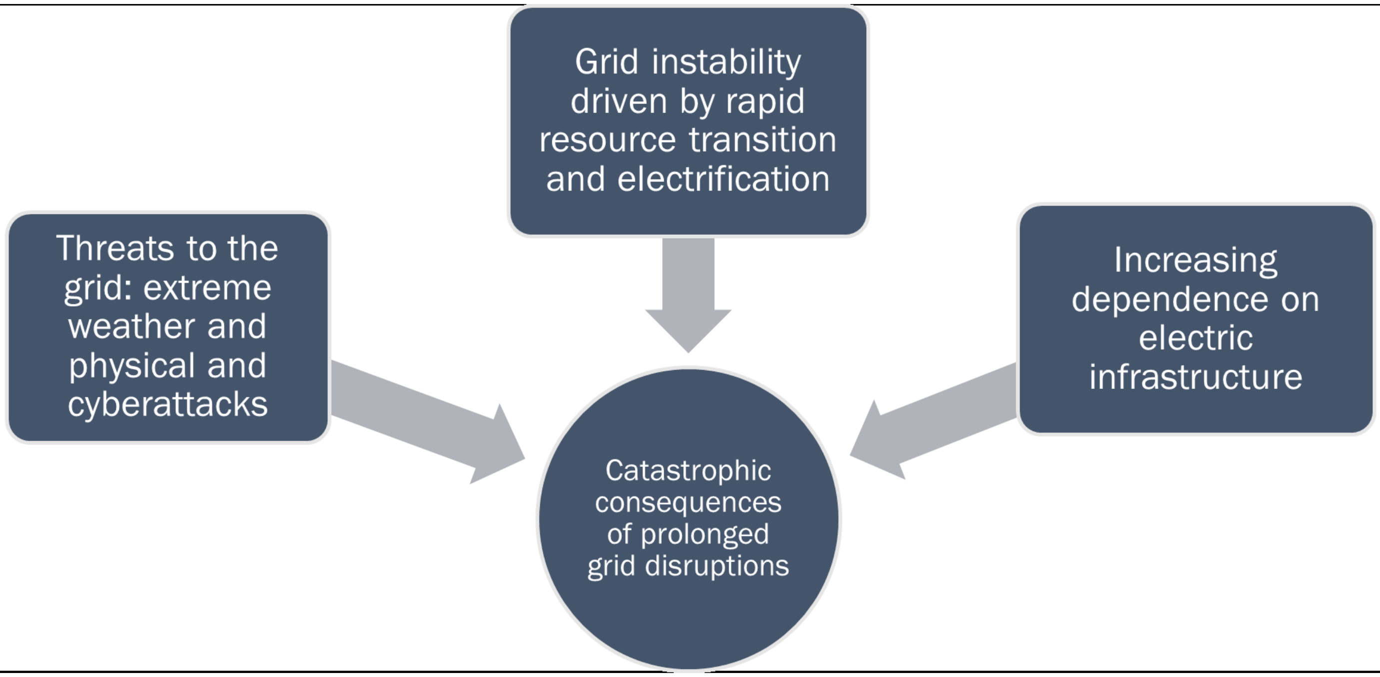
Microgrids are the key to achieving resiliency while optimizing for customer needs, economic value, and expeditious project development. Regulators should promote overall grid modernization and hardening funded by ratepayers to achieve basic standards for resilience. Furthermore, regulators should allow the costs for local, customer-driven "dual purpose" microgrids funded by private capital to be offset by revenues from market-based grid support services.
A holistic regulatory approach to grid design and resource participation will encourage more microgrid development and resiliency enhancements.

The Three-Headed Challenge for Grid Resilience

Threats to grid resilience can have synergistic effects. For example, in February 2021, a record-setting winter storm swept across large portions of the southern United States. The prolonged and extreme cold proved to be a major challenge for the electrical grid, particularly in Texas where 4.5 million homes and businesses lost power for days[1] and 210 people lost their lives because of the storm and its blackouts[2].

Though final root cause analyses have yet to be published, one does not have to look far to see that multiple factors converged to precipitate such a disaster: (i) the realized threat to grid resilience in the form of severe weather; (ii) grid instability driven by electrification and renewable penetration; and (iii) increasing dependence on electrical infrastructure to serve critical facilities. These challenges stand like Cerberus, the mythical three-headed dog, between the current grid infrastructure and the resilient grid of the future, not only in Texas but across the United States.

Figure 1: Converging Threats to Grid Resilience



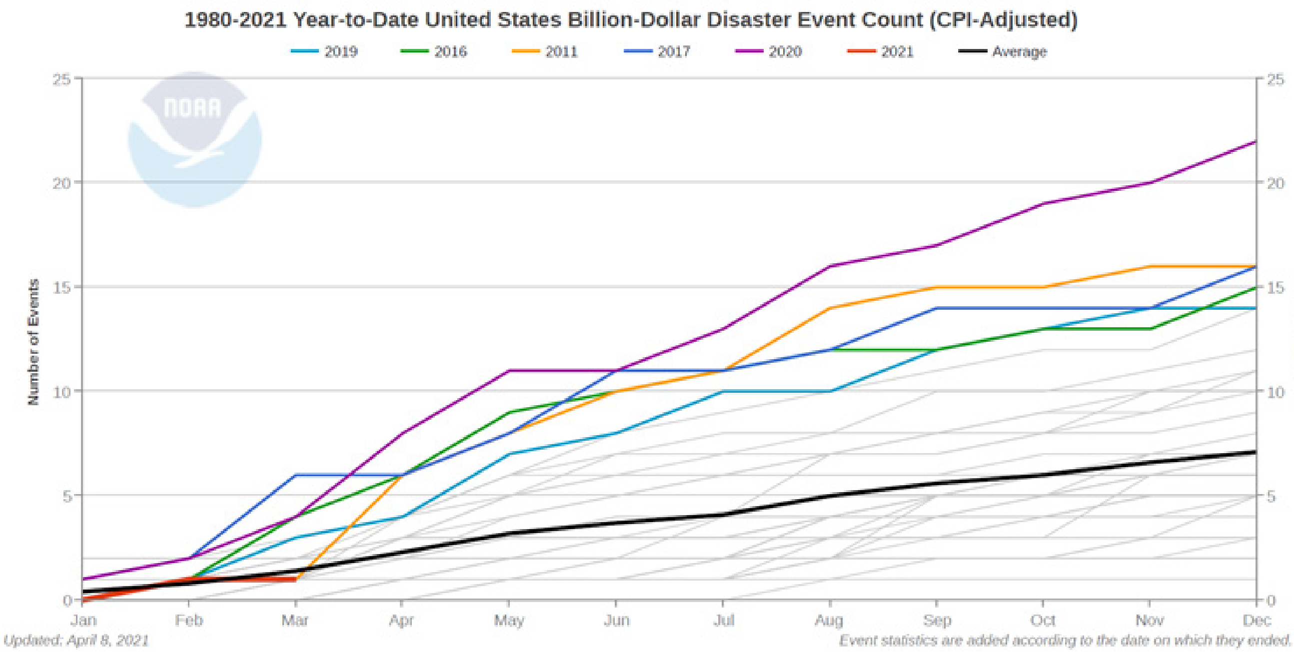
1 Pollock, Cassandra, "Gov. Greg Abbot says power is almost fully restored statewide and grocery stores will soon be restocked," Texas Tribune, 21 February 2021, Texas power almost fully restored and grocery stores willl soon be restocked | The Texas Tribune.

2 Rouege, Ciara and Eline de Brujin, "Death toll from Texas winter storm rises to 210 statewide," KHOU, 14 July 2021, Texas winter storm: Death toll at 210; Harris County at 43 | khou.com.

Threats to Grid Resilience are Real and Imminent

Rare, once-in-a-century events are becoming more common, and the consequences are catastrophic — resulting in massive loss of life and property with disproportionate impacts to disadvantaged communities. Though the recent winter storm was severe, it was not unprecedented. The United States has seen large-scale weather-related disasters increase in frequency over the past four decades (see Figure 2). Hurricanes, winter storms, wildfires, and attacks on infrastructure are increasingly frequent and severe, causing tremendous economic losses not just from direct impacts but also from the consequences of prolonged electric grid outages as business operations are interrupted, goods are spoiled, and homes are damaged.

Figure 2: Billion-Dollar Weather and Climate Disaster Events



Source: National Centers for Environmental Information; National Oceanic and Atmospheric Administration; 1980-2021 Year-to-Date United States Billion-Dollar Disaster Event Count (CPI-Adjusted), April 2021. Billion-Dollar Weather and Climate Disasters: Overview | National Centers for Environmental Information (NCEI) (noaa.gov)

Compounding the severe weather threat to resilience, electric grid infrastructure has been and continues to be under-prepared to maintain critical services. The American Society of Civil Engineers' (ASCE) 2021 Report Card for America's Infrastructure grades the energy infrastructure as a C-, citing the investment gap to update or replace the high percentage of generation, transmission, and distribution facilities that are beyond their 50-year life expectancy[3].

3 American Society of Civil Engineers, "Energy," 2021 Report Card for America's Infrastructure, 2021. Energy-2021.pdf (infrastructurereportcard.org)

Apart from the investment gap in traditional infrastructure, the system is also facing emerging threats to grid resiliency in the form of cyberattacks[4] and electromagnetic or geomagnetic events[5].

Despite these trends, there has been little proactive, strategic policymaking to address the broad issue of grid resilience. Policymakers and utilities have favored an incremental approach, implementing a patchwork of system hardening and operational improvements.

Over the longer term, there are some signs of helpful federal action, as the Department of Energy is developing an energy planning and real-time awareness tool called the North American Energy Resilience Model and as Congress considers various energy-focused bills, such as H.R. 448, the Energy Resilient Communities Act. The Federal Energy Regulatory Commission (FERC) also opened a new rule making docket to consider electric reliability in the face of climate change and extreme weather events (RM21-23). However, state level policymakers must take a lead role to address the full scope of the grid's resilience needs. A DOE report notes that roughly 90% of all outages occur on the distribution infrastructure, which is largely outside of FERC's purview[6].

Customers are not waiting for improvement as they are buying backup generators at a record pace, often using diesel or gasoline with the concomitant health and safety risks.

Trends in Electric Consumption and Generation Mix Present New Grid Stability and Resilience Challenges

Economic and policy drivers are accelerating the electrification of everything and forcing changes to the generation mix around which existing markets and regulations were constructed. Texas may prove to be a helpful preview of the future, with respect to both trends, for regions all around the country.

Texas leads the US in new homes constructed and population growth since 2010[7]. This growth has been accompanied by some of the lowest average electricity prices in the nation, and modest heating needs for residences and businesses contribute to a very high adoption rate of electric heating[8,9]. During the prolonged cold snap in February, the Electric Reliability Council of Texas (ERCOT), the Texas grid operator, saw winter peak demand shatter expectations. Without load shedding, ERCOT estimates that the peak load would have been 76,819 MW, where the system only hit 59,000 MW in 2011 during a similar record-setting winter storm.

4 See the 2021 Colonial Pipeline attack by DarkSide, a ransomware gang, and the 2016 cyberattack of the Ukrainian power grid. A 2019 report issued by the US intelligence community found that "Russia already has the ability to execute cyberattacks in the United States that generate localized temporary disruptive effects on critical infrastructure—such as disrupting an electrical distribution network for at least a few hours—similar to those demonstrated in Ukraine in 2015 and 2016." Coats, Daniel, "Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community," 2019. 2019-ATA-SFR---SSCI.pdf (dni.gov)

5 The US Department of Homeland Security that "Extreme electromagnetic incidents caused by an intentional electromagnetic pulse (EMP) attack or a naturally occurring geomagnetic disturbance (GMC, also referred to as 'space weather') could damage significant portions of the Nation's critical infrastructure, including the electrical grid…" US Department of Homeland Security, "Strategy for Protecting and Preparing the Homeland Against Threats of Electromagnetic Pulse and Geomagnetic Disturbances," 2018. 18_1009_EMP_GMD_Strategy-Non-Embargoed.pdf (dhs.gov)

6 U.S. Department of Energy (DOE), "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages," 2013. Grid Resiliency Report_FINAL.pdf (energy.gov)

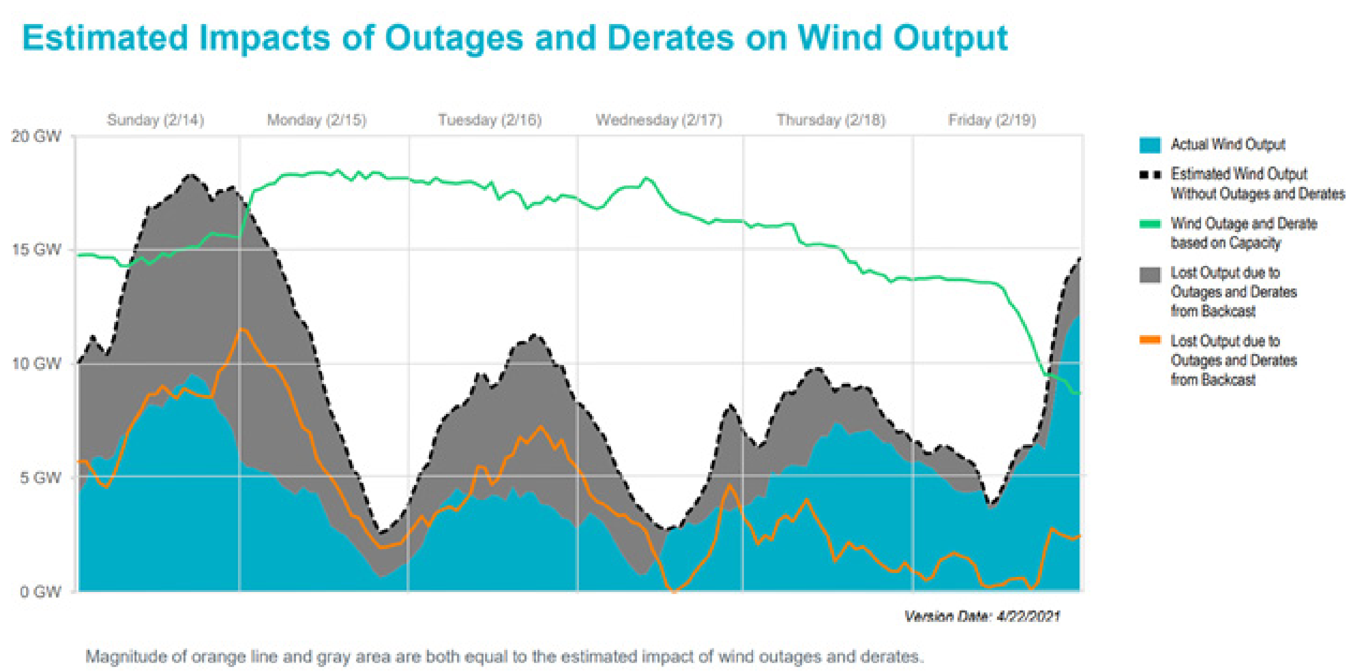
7 "Table 4, Cumulative Estimates of the Components of Residential Population Change for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2019 (NST-EST10194-04)," US Census Bureau, Population Division, December 2019. https://www2.census.gov/programs-surveys/popest/tables/2010-2019/state/totals/nst-est2019-04.xlsx

8 Davis, Lucas, "The Texas Power Crisis, New Home Construction, and Electric Heating," Energy Institute Blog, UC Berkeley, February 22, 2021. The Texas Power Crisis, New Home Construction, and Electric Heating – Energy Institute Blog (wordpress.com)

9 Pecan Street, "Electric Texas: Emission and Grid Impacts of All-Electric Residential Heating," September 2019.

Meanwhile, Texas has seen a tremendous growth in renewable generation installed capacity as a proportion of the roughly 86,000 MW of total resource capacity as of 2021. According to the Energy Information Administration (EIA), Texas was the first state to reach 10,000 MW of wind generating capacity in 2011 and remained the only state to do so through January 2020[10]. By the end of 2020, there was over 30,000 MW of wind capacity in Texas providing 23% of the state's annual energy needs[11]. Solar capacity has also grown significantly to roughly 6,000 MW in 2020. These renewable resources, while providing significant benefits to electric customers from avoided emissions and low energy costs, pose a significant challenge to maintaining the stability of the grid. During the winter storm, a vast majority of the renewable MWs were unavailable to provide energy to the grid to meet the record peak (See Table 2). ERCOT expected only 963MW of the combined wind and solar capacity to be available to meet the forecasted winter peak of 57,699MW in its 2020 Seasonal Assessment of Resource Adequacy report[12]. As a result, the burden of balancing the grid fell to other bulk power resources that were woefully unprepared for the challenging winter conditions, partly due to the difficult investment conditions caused by renewable resource-driven energy market prices and declining fundamentals. California has faced similar challenges as they manage high renewable penetration and compete for regional resources across a growing western US. Wildfire-related Public Safety Power Shutoffs only make reliability concerns worse[13].

Figure 3: ERCOT February Storm Wind Outage Data



Source: "Estimated Impacts of Outages and Derates on Wind Output," ERCOT Winter Storm Generator Outages By Cause Updated Report, ERCOT, April 28, 2021.
http://www.ercot.com/content/wcm/lists/226521/ERCOT_Winter_Storm_Generator_Outages_By_Cause_Updated_Report_4.27.21.pdf

10 "Texas: State Profile and Energy Estimates," US Energy Information Administration, April 15, 2021. Texas - State Energy Profile Analysis - U.S. Energy Information Administration (EIA)

11 "Fuel Mix Report: 2020," ERCOT, March 9, 2021.
http://www.ercot.com/content/wcm/lists/181766/FuelMixReport_PreviousYears.zip

12 "Seasonal assessments show sufficient generation for winter and spring," ERCOT, November 5, 2020.
http://www.ercot.com/news/releases/show/216844

13 "California has found itself strapped for electricity this summer during heat waves in the later hours of the day. To reduce carbon-dioxide emission, the state has almost eliminated coal-fired generation and reduced its reliance on natural-gas power in favor of renewable energy. That has posed a supply challenge when electricity demand spikes. Solar energy production begins to decline in the early evening hours, when power usage peaks, reducing the capacity available during a supply crunch." Blunt, Katherine, "California Faces New Risk of Blackouts This Week," Wall Street Journal, September 7, 2020. California Faces New Risk of Blackouts This Week - WSJ

Society Demands Greater Electric Reliability and Resilience

Traditionally, critical electric loads have been narrowly defined as hospitals or buildings with life-sustaining equipment powered by electricity, and utilities have managed their maintenance plans and load-shedding priorities around these customers. However, as residences, businesses, and industries grow increasingly reliant on electrical service, it is becoming clear that a much broader set of facilities warrant consideration as “critical.”

During the prolonged grid outages of the February winter storm, facilities that are critical to the continuity of community life, like grocery stores, pharmacies, and gas stations, could not provide essential services to their surrounding communities. Potable water also became unavailable to many, mostly due to cold-related pipe and equipment failures, but also due to power outages in some areas[14]. Natural gas facilities that relied on electric power could no longer deliver gas to the electric generators needed to meet peak demand[15]. In the storm’s aftermath, a flurry of legislative activity focused on expanding the scope of critical load designations for protection from load shedding[16] and requiring backup generation to ensure electric reliability and resilience apart from the grid[17]. Meanwhile, residential customers, looking to take electric resilience into their own hands, rushed to find traditional backup generation solutions[18].

Even apart from weather disasters, the current trends in vehicle electrification adoption and demand for connectivity will require greater reliability and resilience for charging infrastructure[19] and for data centers[20], respectively.

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14 Suarez, Miranda, “What Happened to Fort Worth’s Water During the February Freeze,” KERA News, March 11, 2021. What Happened To Fort Worth’s Water During The February Freeze | KERA News

15 “Power Outages Up and Down the Natural Gas Supply Chain Impacted Production and Transportation of Natural Gas During Winter Storm, Analysis Finds,” Texas Oil & Gas Association, April 22, 2021. Power Outages Up and Down the Natural Gas Supply Chain Impacted Production and Transportation of Natural Gas During Winter Storm, Analysis Finds - TXOGA

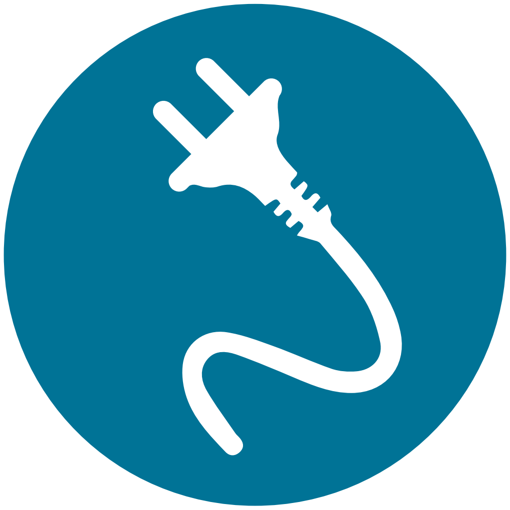
16 For example, Texas House Bills 3915, 3648, 2786, and Senate Bill 3. Across these bills, critical customers would be expanded to include nursing facilities, assisted living facilities, police and fire stations, water and wastewater facilities, natural gas production and transportation, fuel production, nitrogen supply, hydrogen supply, and telecommunications.

17 For example, Texas House Bills 2151 and 2325, which would require emergency backup generators for nursing facilities and assisted living facilities. Florida, which has seen its share of resilience challenges in the form of extreme weather events, has already implemented regulations requiring backup power at these types of facilities (Rules 59A-4.1265, F.A.C. and 58A-5.036, F.A.C.).

18 Clifford, Tyler, “Generac CEO says demand for power generators high: ‘We can’t make them fast enough’,” CNBC, February 17, 2021. Generac CEO on power generator demand: ‘We can’t make them fast enough’ (cnbc.com)

19 Dinh, Paul, “Underscoring the Need for a Robust, Resilient EV Charging Network,” September 24, 2020. Underscoring the Need for a Robust, Resilient EV Charging Network (evgo.com)

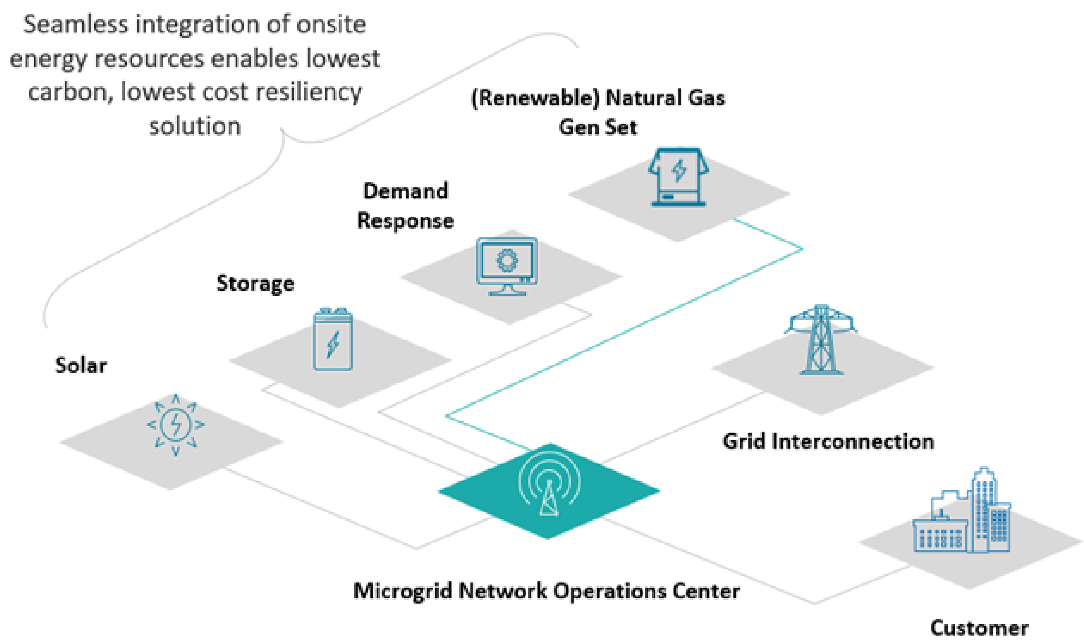
20 “Designing and Managing Data Centers for Resilience: Demand Response and Microgrids,” US Department of Energy, Office of Energy Efficiency & Renewable Energy, Access May 19, 2021. Designing and Managing Data Centers for Resilience - Demand Response and Microgrids_3Dec2019.pdf (lbl.gov)



The Solution: Broad Deployment and Full Integration of Low-Cost, Resilient Microgrids for Backup Power and Grid Services

The challenges for grid resilience seem daunting in magnitude and complexity, demanding a Herculean response. However, the best solution for grid resilience is already commercially ready and operationally proven: the dual-purpose microgrid.

Figure 4: Illustrative Microgrid



During the Texas winter Storm, a fleet of over 200 dual-purpose, natural gas fired microgrids performed extremely reliably, even while conditions drove over 50 GW of bulk power assets offline. The microgrids operated continuously over the eight-day period, providing backup service to 140 customers covering approximately 5,000 outage hours and exporting much-needed energy to the grid when the grid was available. Microgrid-backed water facilities, senior living homes, and grocery stores were able to provide essential services for their communities, even as surrounding neighborhoods faced days-long power outages.

Enchanted Rock's Winter Storm Uri Experience

- **200+ microgrids operating in Texas**
- **8 consecutive days run in support of outages and grid services**
- **97% reliability rate for all run-hours compared to a 54% forced outage rate from ERCOT resources broadly**
- **143 sites protected from grid outages**
- **176 generators with over-the-air software upgrades for cold weather performance while running**

Despite the demonstrated value of microgrids, status quo policy on grid resilience persists

The recent Berkshire Hathaway proposal for 10 GB of large gas generators for the Texas grid serves as one example[21]. The proposed transmission-level assets would not protect customers from most reliability events, which occur due to equipment damage or failure of a distribution system, nor would they run to support grid needs based on economics. Instead, the full cost of the inefficient investment would fall to customers in the state through a non bypassable fixed change on utility bills.

On the other end of the grid, status quo policymaking continues to drive end-use customers to deploy traditional diesel backup generation, even when cost-effective microgrid technologies are commercially available. For example, at a recent workshop at the California Energy Commission, it was reported that there is over 1.5GW of proposed diesel generation to backup the booming data center industry in the Bay Area[22]. California's aversion to natural gas, in particular, sidelines a flexible, dispatchable resource that can cut local emissions of volatile organic compounds, nitrogen oxides, carbon monoxide, sulfur dioxide, and particulate matter to a fraction of even the cleanest diesel technologies[23]. Regulations and market rules do not fully value the resource adequacy, reliability, and resilience benefits of microgrids today.

21 Pollock, Cassandra and Erin Douglas, "Warren Buffet group lobbying Texas lawmakers for deal to build $8 billion worth of power plants for emergency use," Texas Tribune, March 25, 2021. https://www.texastribune.org/2021/03/25/warren-buffett-texas-power-plants/

22 Zielkiewicz, Jakub, "Diesel Backup Generation in the Bay Area," Bay Area Air Quality Management District, CEC Workshop on Research into Clean Energy Alternatives to Diesel Backup Generator Systems, January 21, 2021. https://efiling.energy.ca.gov/getdocument.aspx?tn=236425

23 Hledik, Ryan, et al. "Decarbonized Resilience: Assessing Alternatives to Diesel Backup Power," The Brattle Group, June 2020.

Policy Recommendations

A new resilient grid infrastructure requires policies to support broadly deployed, fully integrated microgrids throughout the transmission and distribution networks to meet the local needs of critical infrastructure customers and to provide needed grid services via dispatchable, distributed resources:

- **Prioritize grid resilience in the face of increasing threats.** Load shed planning is not enough to provide the level of grid resilience required by customers and communities today, and the expanding set of critical facilities will be harder for utilities to manage effectively. Critical loads should be expected to contribute to their own reliability and resilience so that low-income or disadvantaged communities are not unduly burdened when the load shed conditions arise[24]. This can be achieved through mandates for backup generation at critical facilities[25] or through incentives. Resilience metrics above and beyond existing utility reliability metrics may also be helpful to determine the need for investment in microgrids by individual critical facilities.

  From a security perspective, distributed generation resources, like microgrids, make it more difficult for attackers to engage in broad energy system disruptions compared to status quo reliance on large bulk power system assets because the system will rely on a diverse set of technologies and providers with decentralized control systems. Furthermore, microgrids can be designed to operate for local backup power autonomously from a central control center, resulting in greater protection for critical facilities.

- **Eliminate undue interconnection and market access barriers for microgrids.** Community resilience can be rapidly deployed through technology-neutral pathways to market for behind-the-meter and front-of-the-meter microgrid applications. In certain areas, the only standing barrier is local utility reluctance to collaborate with new technologies for fear of competition and liability for reliability issues. However, best practices from existing utility-microgrid partnerships can be replicated easily with support from regulators and policymakers[26].

  Dual purpose microgrids can be deployed through resiliency-as-a-service offerings by third-party solution providers, who can maintain, operate, and optimize the microgrid assets for reliability and market services while taking on the risk of project performance[27]. The private financing paired with open access to wholesale market revenues results in a customer solution that requires little to no upfront costs and produces significant long-term cost savings for the customer and benefits to the grid. Robust wholesale market revenues allow microgrids to be developed without state funding or incentives, though such incentives can be used to accelerate deployment much like long-standing renewable tax credits

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24 Forward-thinking legislators at the state and federal level have proposed various measures, for example, the CLEAN Future Act would require the Secretary of Energy to establish a program to promote microgrid development for isolated communities and for improving resilience of critical infrastructure. At the state level, Texas House Bill 2275 was proposed to create a resilience fund supporting backup generation and microgrids for critical infrastructure like water facilities, hospitals, nursing homes, assisted living facilities, and telecommunications facilities.

25 See Florida legislation requiring nursing homes and assisted living facilities to deploy backup power to maintain facility operations through a 96-hour event. 59A-4 (myflorida.com)

26 See Commonwealth Edison's Bronzeville Microgrid Project that will deploy a hybrid microgrid utilizing a combination of battery storage, solar generation, and long-duration, dispatchable natural gas generation. Entergy's Power-Through program and Xcel's Resiliency Service Pilot can also serve as functional models.

27 Asmus, Peter, "What California and Texas Have in Common: Lack of a Coherent Microgrid Strategy," Public Utilities Fortnightly, May 2021.

- **Adopt programs to encourage utility investments to facilitate microgrids, including grid modernization and increased system granularity.** During the recent winter storm, inability to sectionalized circuits and facilitate exports from microgrid assets left customers out of power, despite nearby resources with the capability to power the community. While host customers pay for resilience services from the microgrids, the entire community benefits from the provided grid services. Interconnection and upgrade costs to facilitate microgrid integration could be shared with the local community for the microgrid's benefits for the grid at large.

- **Enable utilities to directly support customer resiliency investments.** Several utilities have proposed or piloted direct investments in support of customer resilience projects[28]. Customers benefit from the expertise and low cost of capital provided by the utilities when they partner with third-party developer-operators in deploying resilience projects. Regulators should promote the development of utility tariffs to facilitate utility participation and cost-sharing in customer resilience projects.

- **Ensure access to firm natural gas.** Local gas distribution companies should be required to accommodate firm service to distributed generation that is supporting customer resilience and grid services. For example, during the Texas winter storm, the Railroad Commission issued an emergency order modifying curtailment priorities for the utilities in recognition of the fact that gas supply to electric generation serves human needs broadly[29]. Effective coordination between the gas and electric sectors will ensure that customers have adequate energy resilience.

28 See Xcel's Resilience As A Service Pilot (https://www.xcelenergy.com/staticfiles/xe-responsive/Working%20With%20Us/Renewable%20Developers/Resiliency-RFQ.pdf) and Entergy's Power Through Program (https://powerthrough.entergy.com/).

29 "Emergency Order," Railroad Commission of Texas, February 12, 2021. https://rrc.texas.gov/media/cw3ewubr/emergency-order-021221-final-signed.pdf

Conclusion

As threats to the grid evolve and technology advances in support of the clean energy future, policymakers can take a no-regrets approach to securing reliability and resilience by supporting the cost-effective and rapid deployment of dual-purpose microgrids. This paper maps the threat landscape for the electric grid and draws from the recent winter storm experience in Texas to recommend appropriate mitigation measures. Policies in support of grid modernization investments and microgrid enablement will drive improvements in local air quality, continuity of critical businesses and community services, and energy costs to achieve the necessary reliability and resilience to serve an increasingly electricity-dependent society.

Author Information

Joel Yu
Director of Regulatory & Legislative Affairs
Enchanted Rock
jyu@enchantedrock.com

Allan Schurr
Chief Commercial Officer
Enchanted Rock
aschurr@enchantedrock.com

About Enchanted Rock

Enchanted Rock provides resiliency as a service to commercial, industrial, and institutional customers. By utilizing a Dual Purpose Microgrid (DPM), we bring down the cost to the customer by selling power back to the grid.

We pioneered the DPM to solve two problems with one asset. By doing so, we've greatly expanded the market for electrical resiliency while enabling much more rapid renewables integration.

ENCHANTED ROCK™
The Power is On.

Enchanted Rock Dual-Purpose Microgrids

Texas A&M RELLIS Campus
10 MW

H-E-B Grocery
1.3 MW

Raven Chemical Plant
3.6 MW

Entergy Texas Partnership
1.3 MW