Keeping Everyone's Lights On

How to Build an Equitable, Climate-Resilient Power Grid

HIGHLIGHTS

A reliable, resilient power grid is one that can "keep the lights on" through extreme weather events like hurricanes, wildfires, or blizzards. But the grid today is woefully unprepared to meet our current climate reality—and that leaves communities facing perilous, sometimes deadly, outcomes.

Achieving a climate-resilient power grid will take rigorous planning. And because the electric transmission system investments we make today will be in operation for a half century or more, the time to act is now.

Planning that incorporates community voices and integrates science-based climate risk assessments will ensure a power grid that is more resilient, more cost-effective, and does not perpetuate the inequities in climate-burdened communities that the status quo would unjustly ignore.

Sam Gomberg

Rachel Licker

Sital Sathia

Pamela Worth

June 2025

www.ucs.org/resources/keeping-everyones-lights-on

https://doi.org/10.47923/2025.15855

Union of Concerned Scientists

CONTENTS

Introduction

In February 2021, an intense and prolonged winter storm buried the state of Texas in snow and ice. Temperatures plummeted to single digits. As people switched on their heating systems and plugged in space heaters, the increased demand strained the state's main power grid. Power plants ran out of gas, pipelines froze and became unusable, and the electrical grid operator shut off power for millions.

Families shivered in the dark with no heat in their homes. Hundreds of people, including children, froze to death or died from carbon monoxide poisoning as gas grills and cars were turned on indoors in desperate attempts to stay warm. In all, more than 4.5 million people lost power for as long as four days in frigid winter conditions. Almost 250 people died as a result of Winter Storm Uri, 161 from exposure to extreme cold. Another 25 died from carbon monoxide poisoning or smoke inhalation (Goggin and Schneider 2022; Texas Department of State Health Services 2021).

As with so many climate-related disasters, the harms of the winter storm were not evenly felt. Texans with low-incomes or disabilities and Black and Latino Texans bore the brunt of the crisis (Chakraborty, Collins, and Grineski 2023; Nejat et al. 2022). In Harris County, nearly 67 percent of census tracts reported water-related damages such as burst pipes—most of them in neighborhoods with lower median incomes and higher percentages of Black residents (Lee, Maron, and Mostafavi 2022). These nonrandom outcomes reflect how structural inequities leave historically disinvested and marginalized communities least protected when the grid fails.

And until it fails, most of us do not register how much we rely on the power grid to keep us safe during extreme weather, but many observers saw Winter Storm Uri coming. Federal regulators and other experts had warned for more than a decade prior that Texas's power infrastructure could fail in extreme winter weather (Natter and Dlouhy 2021).

Unfortunately, a similar catastrophic grid failure is conceivable anywhere in the United States in the face of any number of extreme weather events because our energy infrastructure is unprepared for climate change (Allen-Dumas, KC, and Cunliff 2019). Again, the communities most vulnerable to its impacts are often those that have received the least resources to prepare for extreme weather and build resilient infrastructure.

Science is clear that burning fossil fuels is the primary cause of climate change and the resulting increase in the frequency and intensity of extreme weather events (IPCC 2023). Avoiding the worst impacts of climate change requires a rapid decarbonization of our electricity supply, which means generating power from non–fossil fuel sources, such as geothermal, solar, and wind energy. The necessary pace and scale of the clean energy transition presents its own challenges, particularly because of expected load growth in the coming years, but we must account for the current impacts of climate change as well as likely future impacts due to historical and ongoing emissions.

A Dual Challenge for Grid Operators

The US electricity grid connects power plants and consumers through a vast network of wires and equipment to deliver a relatively reliable supply of electricity to hundreds of millions of consumers across the country. Historically, building the grid has largely been accomplished piece by piece across individual utilities. But as the risks of extreme weather grow, a piecemeal approach to transforming and expanding the nation's transmission system is no longer sufficient.

The high-voltage wires that carry electricity from power plants to local distribution systems are known as the bulk transmission system. Strengthening this system will be a core element of building an overall resilient power grid. To do so, transmission system planners, including states, utilities, and regional transmission organizations and independent system operators (RTO/ISOs)—here, collectively referred to as "system planners"—must factor in climate change and its impacts on the transmission system in ways they typically have not. (See Box 1 for more about RTO/ISOs and their responsibility in transmission planning.)

It can take 10 or more years to build new transmission infrastructure. Once built, it is intended to last 40 years or more. This means we are currently building our grid for 2050 and beyond. Doing so without considering the risks and impacts of climate change is irresponsible and puts communities in harm's way.

As the impacts of climate change increase in severity and frequency (Marvel et al. 2023), we need a resilient electric grid that can respond to, withstand, and quickly recover from extreme weather events. A climate-resilient power system can save lives, especially in communities with fewer resources to protect themselves from and recover after such events.

In planning and maintaining our nation's power infrastructure, new processes are needed to

- better project future conditions and risks posed by a changing climate;
- identify, collaborate with, and protect those communities and populations most vulnerable to these emerging risks; and
- implement the appropriate processes and investments to mitigate in a cost-effective manner the risks of power failures caused by extreme weather events.

This report describes the current state of these core elements of transmission system planning for climate risks—specifically, risks from extreme weather events related to climate change—so that grid operators, state decisionmakers, and a broad range of interested parties may have more informed and constructive discussions about how to plan for and invest in an equitable and resilient transmission system that can meet the challenges posed by a changing climate.[1]

How Climate Change Stresses the Grid

While weather has long been a dominant driver of power outages, climate change–related outages are growing in both frequency and intensity as extreme weather becomes more frequent and intense (Leung et al. 2023). Between 2000 and 2020, weather-related power outages increased 67 percent, costing tens of billions of dollars each year and endangering people's lives, particularly those in already vulnerable communities (Climate Central 2020).

[1] *While we specifically focus on the bulk transmission system, the issues raised and potential solutions identified are applicable across the power sector.*

Major weather-related outages—those impacting at least 50,000 customers or interrupting service of 300 megawatts (MW) or more—nearly doubled in the period from 2014 to 2023 over those of the 2000 to 2009 period (Climate Central 2024).

More frequent and severe extreme weather events driven by climate change are creating a higher-risk environment for the transmission system we rely on, leading to more frequent and severe power outages. Mitigating the risks posed by climate change necessitates well-planned, forward-looking transmission system investments that protect communities from extensive, long-duration power outages.

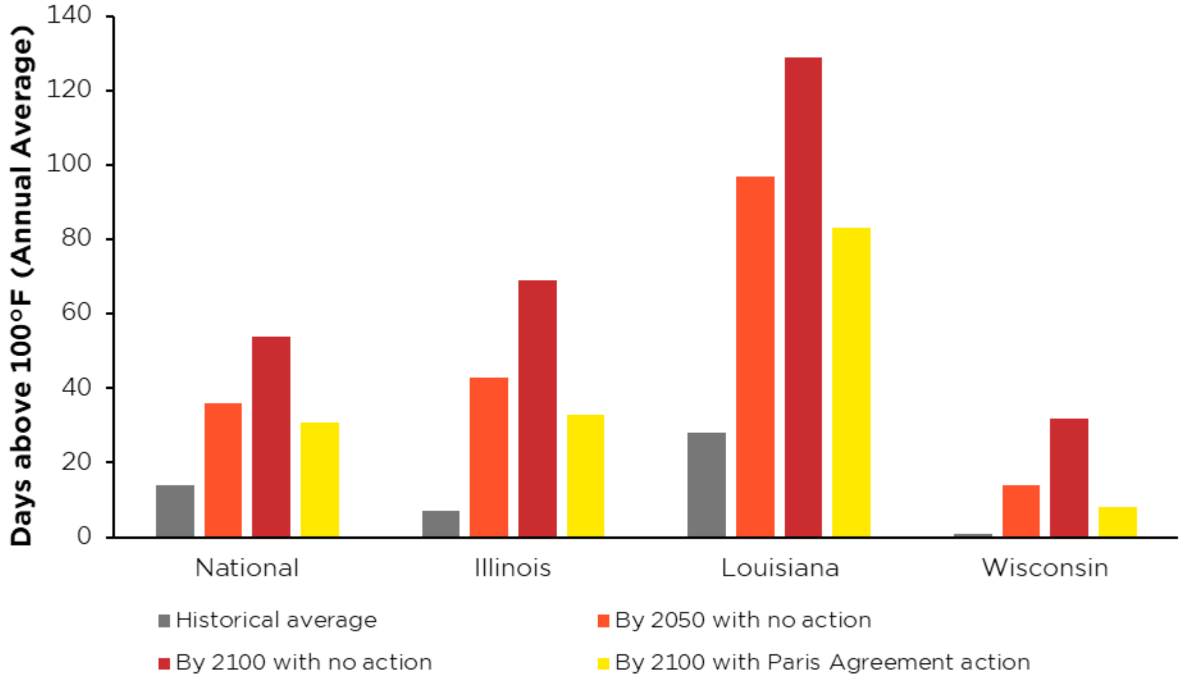
No region of the United States is immune to the effects of climate change, and the most consequential hazards can vary from region to region, state to state, or even community to community. Scientific advances coupled with lived experience can provide a wealth of information on the current electric system's strengths and weaknesses in the face of climate change. Current science can help identify risks and inform decisionmaking on where and how to invest in grid infrastructure to protect communities from extreme weather impacts, including navigating uncertainty over future conditions. Next, we review a selection of climate change–related extreme weather events that are particularly relevant to the power system.

Extreme Heat

In the years ahead, extreme heat is projected to increase across the country to levels that could fundamentally alter daily life and energy demand. When the power goes out during extreme heat, it can be deadly (Stone et al. 2023). In the summer of 2021, for example, a catastrophic heat wave hit the Pacific Northwest, causing temperatures to soar into triple digits across the region and leading to hundreds of deaths (White et al. 2023). Electricity use also soared, with utilities resorting to rolling blackouts as they struggled to cope with demand. In some cases, energy infrastructure melted in the heat (Fischels 2021). Research has found that the event would have been "virtually impossible" without human-caused climate change (Philip et al. 2022).

States across the country face dramatic temperature increases, both those already accustomed to extreme heat and the many that are not. Figure 1 shows how extreme heat is projected to change in three US states (alongside the national average) in scenarios in which the steep rise in heat-trapping emissions since the mid-1900s continues (i.e., "with no action") and in which the Paris Agreement target to limit global warming to 2°C over preindustrial levels is met (Dahl et al. 2019).

Figure 1. Extreme Heat Will Become More Frequent and More Severe Nationwide



The average number of days with a heat index, or "feels-like temperature," above 100°F is projected to increase markedly across the United States, especially without significant action to reduce heat-trapping emissions. States across the jurisdiction of the Midcontinent Independent System Operator (MISO), for example, face steep rises. Meeting the Paris Agreement's target of holding global warming to 2°C above preindustrial levels substantially limits the increase in extreme heat days.

Source: Dahl et al. 2019

Nearly all types of power plants struggle during extreme heat conditions, often having to reduce output even as power demand soars to meet air conditioning needs (EPRI 2022). When this occurs, power prices skyrocket as system operators seek every available resource to avoid a power outage. When power demand outpaces all available supplies, targeted power outages, known as "load shed," occur as system operators try to avoid widespread collapse. As conditions worsen, power outages spread both in terms of duration and the number of communities affected.

Transmission systems also are challenged during extreme heat. Power lines lose efficiency, meaning they cannot carry the same amount of energy as during normal conditions. They also sag, increasing the risks of contacting nearby vegetation or other infrastructure that might force them offline.

Wildfires

In some parts of the country, climate change has generated hotter and drier conditions, and as a result, the risk of wildfire has grown (Ostoja et al. 2023). In the western United States, this is amounting to an increase in the severity of large wildfires as exemplified by the deadly 2025

Los Angeles wildfires, which left more than a million residents without power (Alfonseca 2025; Ostoja et al. 2023). The size of the area burned by wildfires in the West is projected to increase in the coming decades as the world continues to warm (Abatzoglou et al. 2021).

The risks of wildfire are also increasing in some regions of the country where they had been infrequent (Climate Central 2023). In the summer of 2023, Louisiana faced unprecedented wildfires over a three-month period that burned tens of thousands of acres and forced evacuations (Cline 2023). In the summer of 2024, Mid-Atlantic and New England states, too, experienced unprecedented wildfires after an extended period of dry conditions (Metzger 2025).

In the event of wildfire, to be able to carry energy from power plants not directly affected is vital; however, transmission infrastructure must be constructed from nonflammable materials and transmission lines must be undergrounded to avoid further fire risk, since the soot and smoke produced by wildfires ionizes the air, creating an electrical path that can make transmission lines a liability rather than a solution (Ward 2013). Access to additional transmission infrastructure located outside the fire zone can also provide redundancy in the system, creating an alternative path for delivery of electricity, but these measures can be expensive and must be proactively implemented in advance of an event.

Severe Winter Weather

The effects of climate change are evident even in winter. Across much of the northern part of the nation, winters are warming faster than summers (Marvel et al. 2023). The entire contiguous United States is projected to experience significant decreases in the number of days with temperatures below freezing as global warming continues (USGCRP 2023). And since the mid-twentieth century, much of the country east of the Rocky Mountains, particularly the region's northern part, has experienced an increase in severe winter weather events. Research reveals a connection between more severe winters in this part of the country and Arctic warming (Cohen, Francis, and Pfeiffer 2024).

Like extreme heat events, severe winter weather can cause problems throughout the bulk power system, in both power plants and transmission systems. Thermal (fossil fuel and nuclear) generators can fail due to freezing equipment or lack of fuel (Arbaje and Specht 2024). Wind turbines can have a cutoff switch at a certain low temperature to avoid equipment damage, and icing on blades can force them offline. Solar panels perform well during cold events, but snow and ice can reduce output and potentially damage the equipment. Severe cold temperatures and ice build up can also damage transmission infrastructure, threatening power outages.

Hurricanes

Among the most consequential extreme weather events for power outages are hurricanes. In 2024, an above-average hurricane season left millions of US customers without power (NOAA 2024a). The back-to-back Hurricanes Helene and Milton left 1.3 and 3.4 million Florida customers, respectively, without power as a result of wind and flood damage to electricity infrastructure (Simonton 2024). Over the last four decades, the rate at which hurricanes intensify has increased, resulting in higher storm surge and heavier rainfall (Marvel et al. 2023).

In a high global warming emissions scenario, the Electric Power Research Institute (EPRI) in collaboration with the Pacific Northwest National Laboratory (PNNL) projects significant increases in hurricanes—and severe power outages—along the entire Eastern seaboard and for all the Gulf states, with particularly large increases projected in parts of Florida, Louisiana, North Carolina, and Massachusetts (EPRI 2024a).

Coastal storm surge, inland flooding from extreme precipitation, high wind, flying debris, and falling trees all have the potential to take power plants and transmission infrastructure out of operation. When Hurricane Harvey struck the Gulf Coast of Texas in 2017, for example, it brought to the southeastern part of the state 130-mile-per-hour winds coupled with more than 50 inches of rainfall. As a result, several high-voltage transmission lines were forced offline by either high winds or flooding (EIA 2017). More than 15 electrical substations were out of service across the local utility's territory (Mercado 2017), and outages from the storm lasted more than 10 days in some areas (Entergy 2018).

Compound Events

Extreme weather events often do not occur in isolation. When multiple events interact either in space or time, they can become compound events with worse consequences than if they had occurred alone. The Fifth US National Climate Assessment found that compound events are likely to become more common in a warming world since extreme weather events in general are becoming more frequent and severe across the country (Singh et al. 2023), meaning a greater chance they will collide.

Compound hazards can have significant implications for all aspects of the power system, from energy demand to power generation to transmission and distribution. For instance, compound wind storms and ice storms could create far greater problems for and damages to energy infrastructure than one type of storm occurring alone (EPRI 2024b). Similarly, a heat wave–drought combination can place enormous stress on the energy grid (Zeighami et al. 2023). Rising temperatures drive up electricity demand for cooling while drought conditions reduce output from hydropower and thermal generators, increasing the risk of blackouts. When wildfires are followed by heavy rain—which is more likely to occur in the western United States in a warming world (Touma et al. 2022)—flooding, debris flows, and erosion (EPRI 2024b) further compromise already weakened energy infrastructure, delaying repairs and prolonging outages.

The growing risk of compound events—and isolated extreme weather events of various types—elevates the need for focused efforts on electrical system planning that capture all these risks and enable smart investment decisions to boost resilience. We must plan, invest in, and build our bulk transmission system in ways that are responsive to the myriad risks climate change presents.

What Does Resilience Look Like?

Reliability vs. Resilience

The increased frequency and severity of extreme weather events fueled by climate change are forcing us to change how we plan for and ultimately invest in the bulk electric system. No longer is it sufficient to plan a system that is simply reliable under typical conditions. The system must also be resilient to “high-impact, low-frequency” (HILF) events that have an outsize impact on the system and create the risk of large-scale or extended power outages that bring significant economic and societal costs (NERC 2024b). While definitions of resilience vary, most include the core elements of the system’s ability to (1) anticipate, (2) prepare for, (3) withstand, and (4) recover from a HILF event (see Table 1).

Table 1. Reliability and Resilience Are Each Important but Not the Same

Reliability		Resilience
The ability to meet the electricity needs of end-use customers during typical day-to-day conditions and routine uncertainty	**Definition**	The ability to anticipate, prepare for, withstand, and recover from high-impact, low-frequency events and disruptions
Uncertainty associated with fluctuating load and generation, fuel availability, and failure of assets under typical operating conditions	**Event Characteristics**	High-impact, low-frequency events that represent extreme operating conditions and apply significant stress to a system over a large scale
Seconds to hours	**Outage Duration**	Days to months
Localized over a relatively small geographic area (e.g., a facility, campus, or neighborhood)	**Spatial Extent**	Covering a large geographic region (e.g., states, regions, or islands)
Losses largely limited to those resulting directly from unserved load	**Economic Losses**	Losses arising from both lost load and cascading impacts on the economy and public health

Reliability and resilience represent two different challenges that require different approaches for transmission system planners and operators to address in a cost-effective manner.

Source: Adapted from Hotchkiss, Grue, and Petty 2023

Today’s system planning processes largely fail to account for the full range of potential HILF events that can cause long-duration, widespread power outages. The entities responsible for planning and building out transmission systems have typically designed the bulk power system considering only the so-called credible (or “average”) outages that represent the routine, shorter-term events expected during day-to-day operations.

In contrast, a resilience approach typically focuses on HILF events that can cause multiple instantaneous or cascading component failures and affect a significant number of customers, often spanning a wide geographic area. Three core elements to resilience planning are understanding (1) the hazards the system might be exposed to, (2) the vulnerabilities the current system shows regarding those hazards, and (3) the likelihood of those events occurring, and perhaps simultaneously occurring, over time. System planners who grasp these three elements can make smarter investment decisions to bolster the resilience of the system.

Regional and Interregional Transmission: Key Elements of Resilience

Regional and interregional transmission—the larger, high-voltage bulk transmission lines that connect multiple utility service territories or that strengthen the system across large geographic regions—is critical to building a more resilient system alongside local or community-level investments. Regional and interregional transmission systems enable access to a broader, more diverse set of resources located further from areas affected by extreme weather and provide redundancy within the system so that no community is overly dependent on a single transmission line for electricity delivery. If properly planned and built, regional and interregional transmission investments can help limit the potential for extended or widespread power outages and assist in the timely restoration of the critical infrastructure supplying the power communities rely on (Goggin 2021).

When the transmission system performs well during extreme weather events, it saves money as well as lives. As the system becomes stressed because of power plant and transmission outages, often in tandem with rising demand, electricity prices rise quickly as system operators seek out every available resource that can deliver energy to the affected areas. Because of this dynamic, electricity prices during extreme weather events can be a good indicator of whether the system is at risk of not meeting demand and if it may need to limit or shut down power to communities. During Winter Storm Uri in 2021, for example, additional high-voltage transmission capacity into Texas could have saved consumers billions of dollars while helping to maintain power to communities, keeping them safe (Goggin 2021; Texas Department of State Health Services 2021).

Over the last five years, analyses by federal agencies tasked with ensuring a reliable power supply have come to similar findings on the importance of regional and interregional transmission during extreme weather events. A Federal Energy Regulatory Commission staff report to Congress emphasizes that high-voltage transmission improves the resilience of the bulk power system by allowing utilities to share generating resources, enhances the stability of the existing transmission system, and aids with restoration and recovery after an event (FERC 2020). In 2024, the Department of Energy's National Transmission Planning Study determined that the build-out of additional interregional transmission supports the power system during extreme weather events, decreasing the potential for power shortages (DOE 2024). The North American Electric Reliability Corporation (NERC) arrived at the same conclusion in its 2024 Interregional Transfer Capability Study, in which it determined that interregional transmission mitigates extreme conditions and reduces the likelihood of energy deficits during extreme weather (NERC 2024b).

Despite these recognized benefits in improving power system resilience, the construction of higher-voltage regional and interregional transmission has declined significantly over the past decade, even as overall spending on the transmission system has increased (Shreve, Zimmerman, and Gramlich 2024). In some regions of the country, no regional or interregional investments have been approved at all over the past decade, as investments have largely focused on local projects that tend to be easier to build and more profitable for local utilities. This trend must be reversed to enable more resilient outcomes for all.

Tools for Guide Smart Investments in Resilience

Science-informed planning is key to maximize the well-documented potential resilience benefits of regional and interregional transmission and achieve the prepare-withstand-recover criteria that define resilience. System planners must understand

- the risks facing the system from future extreme weather events,
- the likelihood of those risks materializing over time, and
- how various system investments could mitigate risks to an acceptable level for the communities being served by the system (and that typically pay for those investments).

Fortunately, recent advancements in science and analytics can inform smart decisionmaking to improve the resilience of the bulk power system. Advances in climate science over the last decade have brought more certainty about the future in a warming world (Gillett 2024). Readily available datasets now provide detailed, local information about how the climate—both average and extreme weather—is expected to change in the coming decades and in the longer term under different global warming scenarios. Climate science has also evolved to tell us in real time how climate change is contributing to the weather we experience on any given day by using tools like Climate Central's (n.d.) Climate Shift Index, as well as how it is contributing to destructive events by applying research from initiatives such as World Weather Attribution (n.d.).

As a result of climate science advancements, a plethora of resources are available to support the industry in better planning for climate change. Table 2 summarizes several of these resources and datasets. Many other resources and datasets that concern different climate variables or that are specific to locations, communities, or industries are available to help system planners understand the risks climate change poses to the system.

Table 2. Existing Resources Can Support Power Sector Climate Planning

Source	Product	Content	Link
Electric Power Research Institute (EPRI)	Climate READi	Tools for applying climate information in the electricity sector; detailed datasets on evaluating local climate change impacts as well as an analysis of how hurricane-induced power outages are expected to change in a warming world	www.epri.com/research/sectors/readi
US Global Change Research Program (USGCRP)	Fifth National Climate Assessment	County-level datasets for various climate variables (e.g., temperature, precipitation, coastal inundation) under different global warming scenarios; reports, including one specifically about the US energy system	nca2023.globalchange.gov
US Forest Service	Understanding the Wildland-Urban Interface (WUI)	Data on where infrastructure and wildland vegetation intermingle; relevant to wildfire planning	research.fs.usda.gov/nrs/fire/wui
Union of Concerned Scientists (UCS)	Killer Heat in the United States	County, state, and regional data on how the heat index, or "feels-like" temperature, is projected to change	www.ucs.org/resources/killer-heat-united-states-0
Union of Concerned Scientists (UCS)	Looming Deadlines for Coastal Resilience	County, state, and national data on infrastructure at risk from sea level rise	www.ucs.org/resources/looming-deadlines-coastal-resilience

Advances in climate science and analytic methodologies in the last decade, and resources such as these, can support transmission system planners in understanding the risks posed by climate change and identifying cost-effective solutions to adapt to that risk.

Even with a better understanding of extreme weather risks, system planners need to be able to incorporate these risks along with climate change projections into the models they use to understand system performance and identify preferred investment strategies. These models typically focus on minimizing costs while maintaining reliability under various assumptions about the future, such as load growth projections, changes in the resource mix, or state and federal policies being implemented over the coming years. Historically, system planners largely have not incorporated climate change into their modeling of future conditions.

This is beginning to change, but not quickly or robustly enough to meet the challenge. In some cases, system planners are now including one or more "extreme weather" scenarios as a system "stress test," but these are typically limited to a single extreme weather event, the details of which are usually based on historic events rather than future projections. This approach is woefully insufficient to capture the full range of risks that extreme weather poses over the coming decades.

Fortunately, improvements to computing power and analytic processes can help system planners better incorporate extreme weather risks into their modeling efforts. For example, EPRI (2024c) developed a framework for incorporating climate data into current power system modeling practices. And the Department of Energy created the Extreme Stress Analysis Framework while conducting its National Transmission Needs Study, providing a tool for better representing extreme weather risks in transmission system planning (DOE 2023).

Another emerging field in transmission system planning is probabilistic modeling that incorporates probability distributions for extreme weather events and indicates the likelihood of different outcomes, including compounding events (Webb, Panfil, and Ladin 2020). This probability-based approach is crucial for system planners. The decision to invest in resilience measures for an event likely to happen every one or two years is fundamentally different from trying to protect against an event that may happen every 25 or 50 years. These probabilistic projections better inform the understanding of where, when, and how infrastructure will be affected by extreme weather events and therefore lead to a better understanding of what investments will provide the most benefits or avoid the most harms to communities.

Recommendations

Climate change presents real risks to the US energy system and the communities it serves, but many science-based tools are available to system planners to help them prepare for these risks. System planning processes must evolve to integrate scientific advances to account for these risks. To that end, we offer transmission system planners and operators the following recommendations:

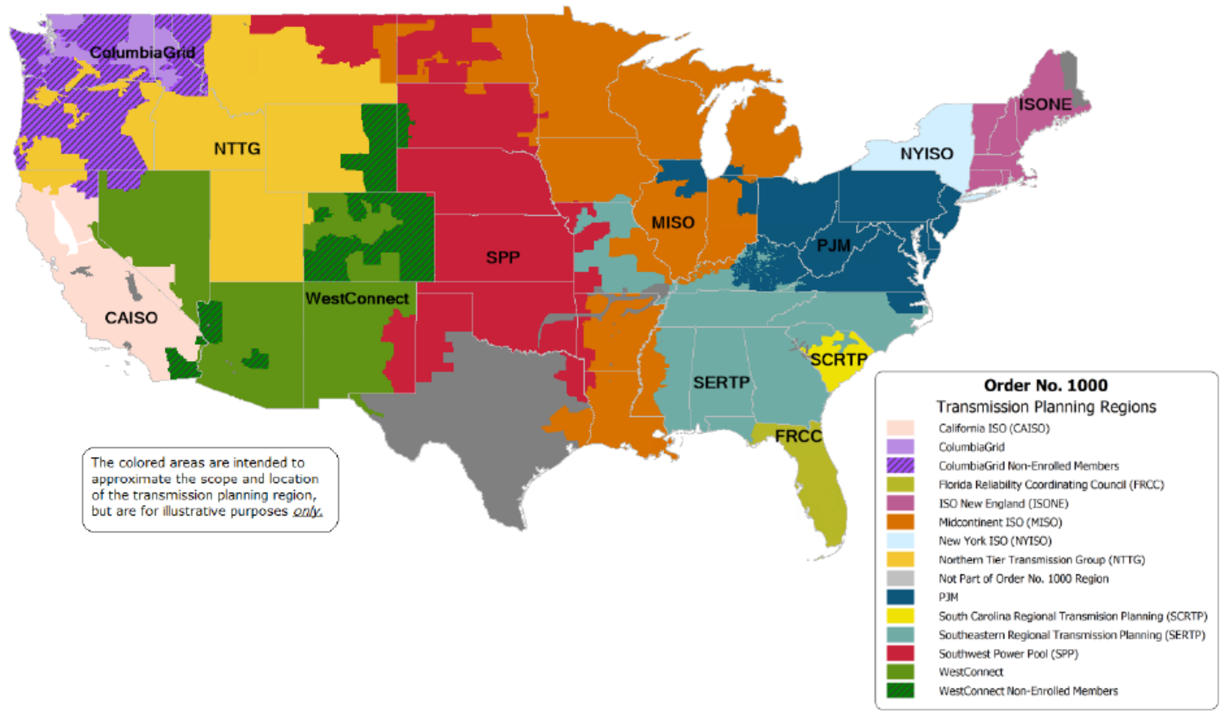
- **Assess climate risks.** Conduct forward-looking, science-informed climate risk assessments using the best available, properly scaled climate data that project impacts at least 30 years into the future and across multiple emissions pathways to capture a reasonable range of extreme weather risks.

- **Acknowledge the role of fossil fuel reliance in exacerbating grid vulnerabilities to extreme weather.** Maximize the value and impact of resilience investments by integrating transmission planning with actions that accelerate the transition away from fossil fuels.

- **Reform planning processes.** Establish transmission planning processes that analyze a broad range of potential future conditions, including extreme weather risks and other key drivers of change, such as demand growth, electrification, and the transition to clean energy. Planning processes should be the foundation for cost-effective investment in the transmissions system to build resilience to climate change and extreme weather.

- **Collaborate with researchers.** Greater collaboration between climate science researchers, electricity systems researchers, system planners, and decisionmakers can help develop the tools required for robust planning, ensure their workability from day one, and facilitate rapid adoption by the planning community.

Box 1. Whose Responsibility Is Regional and Interregional Transmission Planning?



The responsibility to conduct regional transmission planning and coordinate planning across regions is held by FERC-recognized transmission planning regions. In much of the country, these are represented by RTOs and ISOs. In other regions, such as the Southeast, very little planning is done at the regional level.

Source: FERC 2024

Across much of the country, FERC-approved regional transmission organizations and independent system operators (RTO/ISOs), such as MISO and PJM, are responsible for conducting regional transmission planning and for coordinating this planning across regions. These entities also operate their respective regional transmission systems and the wholesale energy markets that allow resources to be shared to more efficiently meet power demands. In non-RTO/ISO regions, such as the Southeast Regional Transmission Planning (SERTP) region, the regional transmission planning entity plays a much more limited role, committing only nominal efforts to coordinated system planning (Mahan 2023).

In the RTO/ISO regions, local utilities are typically responsible for proposing projects that address near-term and local needs, such as connecting new loads or new power plants to the system or meeting local reliability needs. But it is the RTO/ISOs that have the authority, technical capability, and region-wide perspective necessary to do forward-looking, region-wide planning of the bulk transmission system. RTO/ISOs are also well suited to coordinate with their neighbors on interregional planning.

Once transmission plans are approved by the responsible entity in the transmission planning region, the states within that region have the ultimate authority to site and permit approved projects through their jurisdiction over local utilities and hold the responsibility to ensure investments are in the best interest of ratepayers. These overlapping roles means that RTO/ISOs, states, and utilities must work together on regional and interregional transmission system planning to ensure that their efforts lead to the construction of the cost-effective investments identified through that planning process.

Communities Experience Outages Differently

System planners identify emerging climate risks to the energy system and evaluate risk mitigation options, but they must also focus on the communities and populations most vulnerable to extended power outages. Without this focus, solutions designed at the system level risk perpetuating inequities and undermining efforts to provide equitable access to a reliable and resilient energy system.

Extreme weather has caused 80 percent of the major US outages—those affecting at least 50,000 customers—from 2000 to 2023, with the frequency of weather-related outages nearly doubling in the 10-year period of 2014–2023 compared to 2000–2009 (Climate Central 2024). The data show that most resulted from high winds, rain, and thunderstorms (58 percent), winter storms (23 percent), and tropical cyclones, including hurricanes (14 percent). While extreme weather poses significant risks on its own, the loss of electricity can transform these events into prolonged crises. In a power outage, communities experience cascading disruptions that permeate every aspect of daily life, which is further evidenced to disproportionately affect low-income households, medically vulnerable individuals, and marginalized populations (Ganz, Duan, and Ji 2023). As power outages grow more frequent and longer, they not only expose inequities in energy access and resilience—they deepen them.

To effectively mitigate the risks of extreme weather and prolonged power outages, it is necessary to recognize that these challenges are driven by both climate change and structural inequities within our energy system. Like many other US systems, the energy sector reflects a history of racialized policymaking that has shaped how risk and investment are distributed. This unequal landscape has resulted in decades of discriminatory policies, including redlining, exclusionary zoning, and unequal infrastructure investments (Solomon, Maxwell, and Castro 2019), that have concentrated environmental burdens in low-income communities and communities of color (Cushing et al. 2023).

The 1930s practice of marking certain borrowers as high-risk for loans led to “redlining” borrowers of color out of White neighborhoods and underinvesting in areas where they were permitted to live (Rothstein 2017; Winling and Michney 2021). Even after redlining was outlawed through the 1968 Fair Housing Act, many Black and Brown communities continued to experience systemic disinvestment, resulting in aging housing and infrastructure—a legacy that persists today (Clapper et al. 2024; Milletich et al. 2025).

Redlining fundamentally shaped the built environment, structuring where and how neighborhoods were planned, developed, and invested in, in ways the country is still reconciling. Many residents of historically redlined or low-income neighborhoods live in rental housing, often in older, poorly maintained buildings or public housing, and have little control over outdated electrical systems, poor insulation, and inefficient HVAC infrastructure. These conditions all contribute to higher energy burdens, meaning a disproportionate share of household income goes toward heating, cooling, and electricity (UCS 2024). These same neighborhoods also tend to experience more extreme urban heat island effects due to the lack of tree cover and green space, compounding both health risks and cooling needs (Bird 2022). This heightened exposure reflects a broader pattern of housing insecurity and disinvestment that particularly affects Black and Brown renters (DeLuca and Rosen 2022; Milletich et al. 2025).

When extreme weather occurs, such homes heat up or cool down faster and their systems fail more often, leaving residents less protected. These risks are not just the result of aging buildings, but they are reinforced by policy. Exclusionary zoning laws, such as those that prohibit more affordable and diverse housing options, compound the problem by segregating low-income families and families of color into specific districts and excluding them from newer, well-resourced suburbs (Airgood-Obrycki, Maaoui, and Wedeen 2025). Over time, these policies have shaped energy infrastructure investments, resulting in stark disparities: wealthier and predominantly White areas have received modernized energy systems, like modern distribution lines and backup resources, whereas redlined and economically disenfranchised neighborhoods have seen their systems stagnate and deteriorate (Emiel 2024).

The influence of these policies extends beyond infrastructure; they continue to contribute to socioeconomic conditions that weaken community resilience during prolonged outages. (Andresen et al. 2023; Dugan, Byles, and Mohagheghi 2023). Consequently, numerous communities facing the greatest risks from outages are affected by systemic barriers that hinder their ability to withstand and recover. These barriers include:

- limited financial resources that restrict access to backup power and relocation options during crises;
- aging and poorly insulated housing, which can lead to increased exposure to extreme temperatures when heating and cooling systems fail;
- greater reliance on public transportation, which can become inoperable during power outages, thus limiting mobility;
- higher rates of chronic illness and disability, often necessitating electricity-dependent medical devices;
- limited access to grocery stores and pharmacies, directly exacerbating food insecurity when refrigeration or supply chains are disrupted;
- reduced political and economic influence, which can result in longer delays in power restoration and fewer investments in resilience; and
- cumulative environmental and health burdens, such as exposure to pollution, toxic substances, and legacy contamination, which, when combined with social stressors like housing insecurity and poor health care access, amplify a community’s overall vulnerability during outages.

When Power Outages Hit Vulnerable Communities

In the first hours of a power outage, impacts can be immediate and life-threatening, especially for those reliant on electrically powered medical devices, such as ventilators, oxygen concentrators, and dialysis machines (EPA 2022; Lathan 2024). Even a brownout, which is a temporary drop in voltage rather than a full loss of power, can cause medical equipment to malfunction, lights to flicker, and refrigeration systems to weaken. When refrigeration is lost, temperature-sensitive medications like insulin begin to degrade, increasing risks for people with chronic conditions. Unlike blackouts, which involve total loss of power, brownouts often occur when utilities intentionally reduce voltage to prevent a total grid failure, typically during heat waves or other high-demand periods. Our aging infrastructure makes these disruptions more frequent and unpredictable (NERC 2023).

These risks are not experienced equally across communities. Research shows the use of electricity-dependent medical devices to be more prevalent among individuals with lower socioeconomic status, who often face additional barriers to backup power or medical support during outages (Casey et al. 2020; Casey et al. 2021). A 2020 national study of over 12,000 census tracts found that areas with higher historic redlining scores had significantly higher rates of chronic illness, poverty, and social vulnerability, highlighting how structural racism continues to shape community health outcomes (Richardson et al. 2020).

Lower-income patients are also more likely to rely on public health care facilities (e.g., community clinics, public hospitals) that may lack reliable backup power, compounding the challenge of managing medical needs during outages. For example, after Hurricane Maria made landfall in Puerto Rico, over one-third of hospitals on the island had no electricity for months, severely limiting care for those who could not afford to seek it elsewhere (Rodríguez-Madera et al. 2021; Seervai 2017).

As an outage extends from hours into days, an already difficult situation can turn into a public health emergency. Many low-income households are less likely to have basic emergency supplies (e.g., food, water, medications) for even a three-day outage (Casey et al. 2020). Food insecurity rises as perishable goods spoil, leaving families who cannot afford to replace groceries without options. In areas where there is already limited access to healthy and affordable food, blackouts can further limit access to fresh food, especially when local grocery stores, supermarkets, and distribution centers shut down. Water access becomes another serious concern. If the power fails at water treatment facilities, communities may go for days without access to safe drinking water and struggle to afford bottled water to replace it (Ganz, Duan, and Ji 2023). After Hurricanes Irma and Maria in 2017, some communities in Puerto Rico endured water service disruptions for more than nine months (Roque et al. 2021).

Those without transportation or the financial resources to relocate remain in worsening conditions. When Hurricane Beryl made landfall 100 miles south of Houston, Texas, in July 2024, its strong winds and heavy rainfall caused widespread devastation, leaving over 2.7 million households and businesses without power in the Houston metro area (NOAA 2024b). The extended outage, intensified by the summer's extreme heat and humidity, aggravated food insecurity for groups most vulnerable to these conditions, including older adults, individuals confined to the home, immigrants, and families with children.

Emergency planning research shows that socially vulnerable populations are less likely to evacuate during disasters and prolonged outages, often because they lack access to vehicles, have other mobility challenges, or encounter language barriers (Franklin 2023; SAMHSA 2017). When emergency updates and alerts are not issued in multiple languages, non-English speakers lack critical information on evacuation orders, shelter locations, and safety measures (Uekusa and Matthewman 2023).

When power outages extend for weeks or longer, such as after a major hurricane, winter storm, or wildfire, the long-term consequences erode community resilience. Multiweek blackouts create multifaceted, cascading crises. In lower-income neighborhoods, children face amplified challenges, including emotional trauma tied to housing instability, food insecurity, parental job loss, and social disconnection, all factors that widen learning gaps (GAO 2022; Wakeman 2024). Housing also becomes more precarious as public housing units and rental properties often face delayed power restoration, leading to temporary displacement and added financial pressure on tenants (Do et al. 2023; Ganz, Duan, and Ji 2023). In some cases, repeated long-term outages accelerate patterns of disinvestment and displacement, pushing residents out of their communities altogether (Coleman et al. 2023; Foster 2024; Yabe and Ukkusuri 2020). Meanwhile, public transit service shutdowns prevent residents from accessing work, health care, and emergency shelters, further compounding hardship for those with the fewest resources (Yabe and Ukkusuri 2020).

Economic, Physical, Emotional, and Societal Costs of Outages

The economic consequences of prolonged power loss can heighten existing inequalities. Local economies stall, small businesses shutter, and workers lose wages, leading to lasting financial downturns (Andresen et al. 2023; Sanstad et al. 2020). Workers in industries such as food service, retail, and manufacturing, sectors that disproportionately employ people of color and low-income individuals, often lack paid leave and face immediate financial strain when outages persist (Bruess 2024).

In addition, extreme weather can trigger unpredictable energy price spikes and higher utility bills, particularly in regions with fragile infrastructure or deregulated markets.[2] These sudden costs increase the energy burden on low-income households, many of whom face difficulty between paying energy bills and covering basic needs. Research shows that low-income households are far less able to increase their energy spending during periods of extreme heat or cold, often cutting back on food or forgoing cooling altogether (Doremus, Jacqz, and Johnston 2022; Lei and Xu 2025). This financial precarity makes prolonged outages even more dangerous and recovery more difficult because transmission system failures are often preceded by severe energy price spikes.

In another clear disparity, power restoration is often prioritized based on economic activity rather than human vulnerability, leaving lower-income communities waiting longer for essential services to be restored (Ganz, Duan, and Ji 2023). In 2021, after Hurricane Ida caused catastrophic damage to Louisiana's grid, over a million residents were left without electricity for weeks (EIA 2021; Morris 2021). With temperatures exceeding 100°F, many residents, especially in low-income areas, endured extreme heat without air conditioning. Entergy, the local power company, failed to restore power to more than 80 percent of residents within the

[2] *Deregulated markets are those where the state has privatized power generation and relinquished authority to set wholesale electricity prices. Texas as well as many Mid-Atlantic and Northeast states have deregulated markets. In these states, when power shortages occur and energy prices spike, there are no regulatory protections to ensure energy prices remain affordable for consumers.*

first week after the storm, and in some areas, thousands remained without electricity a month later (Bisaha 2021; National Low Income Housing Coalition 2021). Public housing and rental properties were often the last to be repaired, leaving families displaced and relying on shelters or temporary housing (Kutz 2023).

Beyond financial harm, prolonged power outages take a serious toll on people's physical and mental health. Homes can quickly become uninhabitable in extreme temperatures. In colder months and during winter storm events, losing power means losing heating. This can sometimes force residents to rely on unsafe alternatives, such as gas stoves or improvised fires, increasing the risk of carbon monoxide poisoning and house fires (CDC 2024; Louzon and Lysouvakon 2023). In summer, especially during heat waves, access to cooling can mean life or death. During the 2021 Pacific Northwest heat wave, an estimated 500 excess deaths above normal occurred across the region—many of people in their homes without air conditioning (Mass et al. 2024; White et al. 2023). Risks to human health during heat waves are particularly pronounced in older buildings with poor insulation or no cooling, where indoor temperatures can reach fatal levels (Hampo, Schinasi, and Hoque 2024).

For individuals with disabilities or mobility challenges, outages can mean being trapped in their homes without access to elevators, life-sustaining medical equipment, or other essential assistive devices (S. Collins 2019). Those living in communities already burdened by environmental pollution and substandard housing face even greater health risks, further compounding existing vulnerabilities. In addition to these physical dangers, the mental health impact can be profound (Andresen et al. 2023). The longer essential services like electricity remain unavailable, the greater the risk of heightened stress, anxiety, depression, and, in some cases, post-traumatic stress disorder (Rubin and Rogers 2019).

Compounding and Cascading Events

Compounding and cascading events challenge the capacity of energy systems and deepen existing inequalities in how communities experience and recover from disaster. While isolated weather events are devastating on their own, compounding weather events can create even more complex and long-lasting challenges (Moddemeyer, Sobhani, and Oztekin-Gunaydin 2022). When extreme weather events occur back-to-back or simultaneously, they strain power generation, destabilize infrastructure, and weaken emergency response systems, making recovery much harder (Gonçalves et al. 2024).

Florida's 2024 hurricane season is a clear example. Multiple storms hit the state in just over two months—Debby (Category 1) in early August, Helene (Category 4) in late September, and Milton (Category 3) in early October. The rapid series of storms left communities with little time to rebound between disasters and kept Florida in a near-constant state of response and recovery (Landis 2024; Office of Resilience and Coastal Protection 2025). For residents already living paycheck to paycheck, the repeated trauma of storms led to a surge in anxiety, nightmares, and signs of post-traumatic stress (Garfin et al. 2022; Meyers 2024).

By contrast, cascading events are primary events like heavy rainfall, seismic activity, or rapid snowmelt that cause a sequence of secondary impacts, often amplifying the overall damage (Moddemeyer, Sobhani, and Oztekin-Gunaydin 2022). The 2023 Maui wildfires are an example of both compounding and cascading events. Although strong winds from Hurricane Dora may have contributed by bringing down power lines, the long drought and hot, dry summer—

worsened by climate change—created the conditions for fires to ignite and spread rapidly, damaging infrastructure and overwhelming emergency response (County of Maui Department of Fire and Public Safety 2024; Dance 2023). A University of Hawaiʻi survey reveals that the share of fire-affected households living below the poverty line more than doubled after the fires, rising from 14 percent to 29 percent, over three times the county average in 2023, underscoring the deep economic toll on residents already vulnerable to the droughts' effects. More than a year after the disaster, poverty, unemployment, rent costs, and housing instability remained widespread. The survey notes that 80 percent of residents were displaced, nearly half left West Maui entirely, and many still lacked basic support (Bond-Smith et al. 2024).

Challenges to Incorporating Equity in Resilience

Despite growing recognition of disparities in vulnerability to power outages, current resilience planning often falls short in addressing this issue. This is due to not only data limitations but also deeper structural issues in how risk and recovery are prioritized. Research shows that limited access to granular, real-time power outage data, which are often withheld by utilities on the grounds of confidentiality, creates significant information asymmetries between utilities and local governments. These gaps in data availability and transparency continue to hinder efforts to design resilience strategies responsive to community-level needs (Dugan, Byles, and Mohagheghi 2023).

Even when data are available, they are often too coarse to reflect neighborhood-level disparities. Census tract or zip code data (~4,000 people) are often too broad to reveal block-by-block differences in grid vulnerability. Without more granular, validated data at the level of the distribution grid, system planners risk misallocating resources, thus overlooking those most at risk and unintentionally worsening existing inequities (Dunn et al. 2019; Maes et al. 2023).

The challenge is not just technical. Standard grid restoration procedures prioritize critical infrastructure, then commercial and industrial customers, and finally, residential areas—regardless of those communities' social and economic vulnerabilities. While designed for efficiency and public safety, these routines can overlook the compounding risks faced by communities that are more physically isolated or have weaker infrastructure (Ganz, Duan, and Ji 2023). And their residents do not have much recourse, as most grid planning processes remain top-down with limited transparency and few opportunities for meaningful community participation, particularly from frontline and environmental justice communities (Byers et al. 2023).

A persistent disconnect exists between large-scale grid planning and local resilience efforts. Community-driven solutions, such as microgrids, resilience hubs, and mutual aid networks, are often overlooked or underfunded in regional planning processes. And even when equity is referenced in planning documents, few accountability tools exist to track whether those commitments translate into meaningful, measurable outcomes.

Ultimately, resilience that fails to account for who is vulnerable, and where and when they are vulnerable, is likely to be maladaptive. Without a clear commitment to data transparency, community-driven decisionmaking, and equity-focused metrics, resilience strategies may end up reinforcing the very disparities they aim to address.

How to Work toward Equity in Resilience-Based Grid Planning

Equity in resilience planning starts with recognizing and addressing the unique vulnerabilities and capacities that put some populations at greater risk of harm when grids fail. Many existing frameworks prioritize system-wide efficiency and reliability but fail to account for the disparities in resources, infrastructure, support, and lived experience that leave some communities far less protected from the outcomes of grid failure than others (Twitchell et al. 2022; Kazimierczuk et al. 2023).

Resilience planning requires a shift away from traditional system-wide efficiency frameworks toward an approach grounded in the broader concept of energy equity. Energy equity calls for the fair distribution of risks and benefits across the energy system while addressing systemic disparities in how energy systems are developed, maintained, and accessed across different communities (Gastelum 2023). Advancing energy equity in resilience planning means building systems, technologies, procedures, and policies that not only withstand disruption but also reduce harm for those most affected historically. It also requires defining clear equity objectives, creating metrics that reflect real-world community impacts, and giving regulators the tools to ensure those goals shape utility decisions (Kazimierczuk et al. 2023).

For equitable and just resilience, system planners must consider both the capacity of energy infrastructure—such as the electric grid—to withstand and recover from extreme weather events and the capacity of communities to prepare for, adapt to, and recover from these disruptions. As planning frameworks evolve to address resilience and adaptation, system planners should take note of how equity is—and is not—embedded in their existing resilience planning. Without meaningful metrics that capture both dimensions, system planners risk overlooking critical vulnerabilities, and the subsequent resilience strategies may fail to serve those most at risk (Byers et al. 2023).

Resilience planning will require moving beyond the traditional metrics that utilities typically use to guide restoration and infrastructure investments, like overall load or the number of customers served. While these metrics maximize system efficiency, they often neglect the most vulnerable when the grid fails. Consequently, densely populated or high-demand areas may be prioritized over communities with greater health, economic, or housing-related risks.

Including in resilience planning indicators such as household income, access to essential services, housing quality, and exposure to environmental risks is essential. These indicators align with broader climate resilience principles, which emphasize reducing systemic risk through systems thinking, planning for future climate conditions, and centering in decisionmaking those who are affected most. Resilience strategies should be shaped with communities, not for them. They must also account for the long-term costs of inaction (Spanger-Siegfried et al. 2016). These dimensions better reflect which communities are least equipped to endure prolonged outages. System planners can take this notion further by applying equity across four dimensions (Twitchell et al. 2022):

- Recognizing the historical harms of past infrastructure decisions
- Analyzing how costs and service disruptions are distributed
- Ensuring procedural inclusion through meaningful engagement, representation, and capacity building

- Prioritizing restorative action, such as retiring polluting infrastructure in overburdened communities and evaluating alternatives that bring restorative outcomes

In short, community well-being must be treated as central—not secondary—to system performance.

To build truly resilient energy systems, system planners must engage meaningfully with the communities most affected by disruptions. This means not only gathering input but also following energy democracy principles so that communities have real power, ownership, and voice in shaping the systems that affect them. Energy justice frameworks remind us that equity is about both the outcomes and the process: who decides, who benefits, and who is accountable. While this report focuses on grid resilience through an energy justice lens, it is important to recognize that energy justice, environmental justice, and climate justice are interconnected pillars of the broader just transition framework (See Box 2).

Box 2. Energy Equity Is a Key Component of the Just Transition Framework
The just transition framework encompasses environmental justice, climate justice, and energy justice to ensure that the shift to a sustainable energy future actively addresses historic inequities rather than reinforces them (UCS 2025a). Environmental justice focuses on the fair treatment and meaningful involvement of all people in environmental decisionmaking, especially communities historically burdened by pollution and environmental hazards. Climate justice emphasizes that those least responsible for climate change—often marginalized communities—are also the most vulnerable to its effects. It calls for policies that prioritize these communities in climate adaptation and mitigation efforts. Energy justice, as this report emphasizes, centers on who has power, who bears the costs, and who benefits in our energy systems. This means fair access to clean energy, affordable rates, and community participation in decisionmaking, particularly in building resilience against grid disruptions. Together, these principles deepen our understanding of the systems and processes that shape energy access, distribution, and resilience, highlighting both the structural barriers that have produced disparities and the opportunities to create more just and sustainable solutions (UCS 2025b).

Centering Community Wisdom in Resilience-Based Grid Planning

Frontline and fenceline environmental communities have long borne the brunt of environmental burdens and power outages—impacts that are worsening as the climate crisis accelerates (Sultana 2021; Tuck 2009). For these communities, resilience is not an abstract concept; it is a lived necessity. Yet, too often, grid planning processes are developed from the top down, relying on limited engagement mechanisms that fail to reflect the knowledge, priorities, or lived experiences of the people most negatively affected by the decisions made (Byers et al. 2023).

A truly equitable approach to grid resilience must be rooted in the wisdom and self-determination of communities themselves. This means

- honoring Indigenous sovereignty and place-based knowledge systems that offer generations-deep understandings of land, climate, and resilience (Maldonado et al. 2016);
- recognizing the leadership of community-based organizations that are developing solutions like resilience hubs, local microgrids, and mutual aid networks; and
- understanding and supporting energy democracy so that communities have a meaningful voice, decisionmaking power, and ownership in the systems meant to serve them (Gastelum 2023).

To move toward a more community-centered model, the communities, states, utilities, and RTO/ISOs ultimately responsible for building a resilient electricity system must reimagine engagement not as a formality but as a relationship. Proactive, iterative, and trust-based collaboration should be the standard. System planners must partner with trusted institutions, respect local expertise, and support community readiness with resources, capacity building, and transparency, taking particular care to do the following:

- **Develop shared governance structures that** create and compensate community advisory boards with explicit decisionmaking power (Kazimierczuk et al. 2023).
- **Engage early,** including reaching out before plans are drafted to build trust and ensure that community priorities guide project design (Ellickson 2024).
- **Align with local resilience efforts** so that bulk system investments support rather than override community projects, such as resilience hubs and electrification goals (Ross and Day 2022).
- **Support community capacity** by including funding for technical assistance, providing translated and simplified planning tools, and compensating communities for their time and expertise (EPA 2023; UCS 2024).
- **Embed accountability tools** by using equity impact statements, resilience benefit-cost ratios, and dashboards so that outcomes are community informed and track progress transparently over time (Byers et al. 2023).

Rethinking One-Size-Fits-VOLL

What is the value of not having your power go out for two hours? What would you pay to avoid a two-day outage? System planners, who must strike a balance between the cost of an investment and the benefits it provides, or the costs it avoids, regularly attempt to factor these questions and their answers into transmission build-out plans.

Today, the industry relies on the “value of lost load” (VOLL), a metric meant to capture the societal benefits of reduced power outages as a dollar amount that can be inserted into a cost-benefit evaluation of a potential system investment. It is typically represented as a dollar amount per unit of electricity, such as dollars per megawatt-hour, or $/MWh (Gorman 2022).

The most common way to calculate VOLL is through surveys that ask a statistically representative sample of customers about their willingness to pay for reliable electricity service under various circumstances.

Using VOLL is convenient for system planners, but it has significant shortcomings that must be addressed if the objective is to build a more resilient and equitable power system. Using a single number or a narrow set of numbers, which can, for example, represent residential, business, and industrial customers separately, across a region as large as the FERC planning regions (see Box 1), misses the significant differences in community vulnerabilities to power outages and the variation in consumer willingness (and ability) to pay. This can lead to underinvestment that leaves communities exposed to unacceptable risks. Accounting for where and when outages occur and how long they last will produce different values for VOLL that can better inform how system planners prioritize resilience investments across a region, or even interregionally.

Another pitfall to using VOLL in investment decisions is the inherent biases that are present in how VOLL is calculated. Measuring VOLL based on one customer's willingness to pay to avoid an outage indicates and assumes that the customer has the ability to pay (Gorman 2022). If VOLL instead considers different customers' willingness to pay, lower-income communities may register lower VOLL based on financial constraints rather than on their level of vulnerability to power outages (Gorman 2022). An economic approach such as willingness to pay can also lead to perverse prioritizations, such as focusing restoration efforts on industrial customers, who may face significant economic losses during extended outages, over residential customers, who may face public health or even life-threatening conditions.

Even with refinement of the calculation of VOLL, the metric should be supplemented by assessments of community-level vulnerability to extended power outages. Some of the factors not typically captured in a VOLL methodology are public health impacts, costs of compounding stressors on communities, disruptions caused by temporary relocations, and differential abilities among communities to recover from setbacks (Kalra et al. 2022). Our current methods for assigning a monetary value to the provision (or lack of provision) of electricity are limited, and they cannot be applied accurately and equitably for understanding how widespread or long-lasting power outages may disrupt communities.

The measures used by system planners, including VOLL and other supplementary metrics, need to better account for health impacts, diversity of customer types, electrification and changing technologies, effects on adjacent services (e.g., water, gas, transportation), and who may be especially vulnerable to an outage. These considerations, whether quantitative or qualitative, must be key inputs for valuing and prioritizing system resilience investments (EPRI 2023). This requires inclusive planning processes that enable input from communities and community-specific assessments.

Successful regional and interregional system planning also requires more robust coordination among communities, utilities, and transmission system planners to identify right-sized solutions and risk mitigation measures that meet specific community needs. Community-based investments, distribution system level investments, and bulk transmission system investments must be considered holistically to determine cost-effective solutions that can mitigate extreme weather risk while meeting other needs of the system, such as electrification, decarbonization, and improved reliability.

To achieve more equitable and community-informed outcomes from regional and interregional transmission planning and investment, we offer the following recommendations:

- **Improve the metrics used to make decisions about transmission system investment**, such as the value-of-lost-load (VOLL) metric, to be more reflective of how the costs of power outages vary significantly across time and space as well as among communities.

- **Complement economic-focused metrics with additional metrics** or qualitative assessments—transparently developed in coordination with local government, state decisionmakers, and communities—that consider vulnerable communities and populations in how we invest in a more resilient transmission system.

- **Improve coordination and collaboration** across transmission, distribution, and community efforts so that regional and interregional transmission investments complement resilience-based investments made at the utility and local levels.

- **Make decisionmaking more inclusive and responsive** to the unique needs of communities by establishing and maintaining meaningful community engagement for better-informed consideration of the impacts and trade-offs of different investment options to build system resilience.

Current Planning Efforts Fall Short on Resilience

Current practices for planning and investing in the electric system reveal significant gaps and shortcomings that ultimately put communities at risk of wide-scale, long-duration power outages under extreme event conditions.

Box 3. Resilience Must Be Part of a Multivalued Planning Process
A wide range of benefits should be considered when evaluating transmission investment options. Reduced operating costs, access to low-cost renewable energy resources, positive environmental and public health impacts from a reduced reliance on fossil fuels, and improved system efficiencies, as well as mitigated risks of climate change and extreme weather, are all well recognized and reasonably quantifiable benefits of smart investments in the bulk transmission system (Stenclik and Deyoe 2022). While certain investments might be justified solely for resilience purposes to address system weaknesses and protect vulnerable communities, in many cases, resilience considerations should be included alongside the many other potential benefits of transmission system investments. In doing so, system planners and decisionmakers make sound investment decisions that maximize the benefits flowing to consumers. Some resilience investments should also be viewed as partial redress for the harms caused by fossil fuel–driven climate change. By incorporating this understanding, planning frameworks can more equitably prioritize new system investments.

Federal Efforts Fail to Adequately Advance Resilience

FERC regulates the RTO/ISOs and regional transmission planning entities responsible for regional and interregional transmission (see Box 1). In its role, the agency has recognized the potential benefits to consumers from properly planned regional and interregional transmission projects, including maintaining reliability, reducing electricity prices by enabling lower-cost resources to meet demand, and helping to meet public policy requirements, such as states' clean energy standards (Zimmerman, Gramlich, and Hayes 2023).

FERC has attempted to promote better regional and interregional system planning with several rulemakings over the years. Unfortunately, FERC's efforts have not resulted in the kind of benefits-focused or multivalue transmission planning that would ultimately meet system needs—including improved resilience—in the most beneficial manner for consumers (see Box 3). In 2021, FERC made an effort to drive more meaningful regional transmission planning, recognizing that past efforts had failed to produce planning that

- incorporated a sufficiently long-term assessment of transmission needs;
- adequately accounted for expected changes to the system over time; or
- considered the broad set of benefits that new transmission system investments provide to consumers, including improved resilience (FERC 2021).

Ultimately, FERC determined that much of the current transmission planning was either too narrowly focused on near-term local needs or too reactive in nature and not holistic in planning for future needs. Set in FERC's findings was the recognition of an additional benefit of regional and interregional transmission—that of mitigating the risks of extreme weather events increasing in magnitude, scale, and frequency across the United States (Wayner 2024).

From these deliberations came FERC's much-heralded Order 1920, released in 2024, that requires forward-looking transmission system planning and investment strategies to meet the needs of a rapidly evolving energy sector. Order 1920 requires the use of scenario-based planning processes that analyze system needs under a variety of assumed future conditions (in this case, 20 or more years out) that account for ongoing trends, such as increasing electricity demand, the clean energy transition, and decarbonization commitments. As part of this order, FERC made two explicit efforts to advance transmission system planning with respect to the growing risks of extreme weather. It required transmission system planners to

- include analysis of the system under high-stress conditions due to an extreme weather event as part of their modeling efforts, and
- consider the benefits of mitigating the impacts of future extreme weather events when analyzing the economic benefits of a potential transmission investment.

Both moves, if implemented, would make progress toward consideration of climate risks in transmission system planning while recognizing the benefits of a more resilient system. But Order 1920 does not require anyone to build anything. It requires only the study of future system needs and an exploration of the benefits of potential investments. Further, even with these relatively modest requirements, the rule is currently hampered and delayed by ongoing litigation over various provisions and the authority of FERC to impose such requirements. At the time of this writing, any meaningful impact Order 1920 may have on transmission planning for resilience is uncertain.

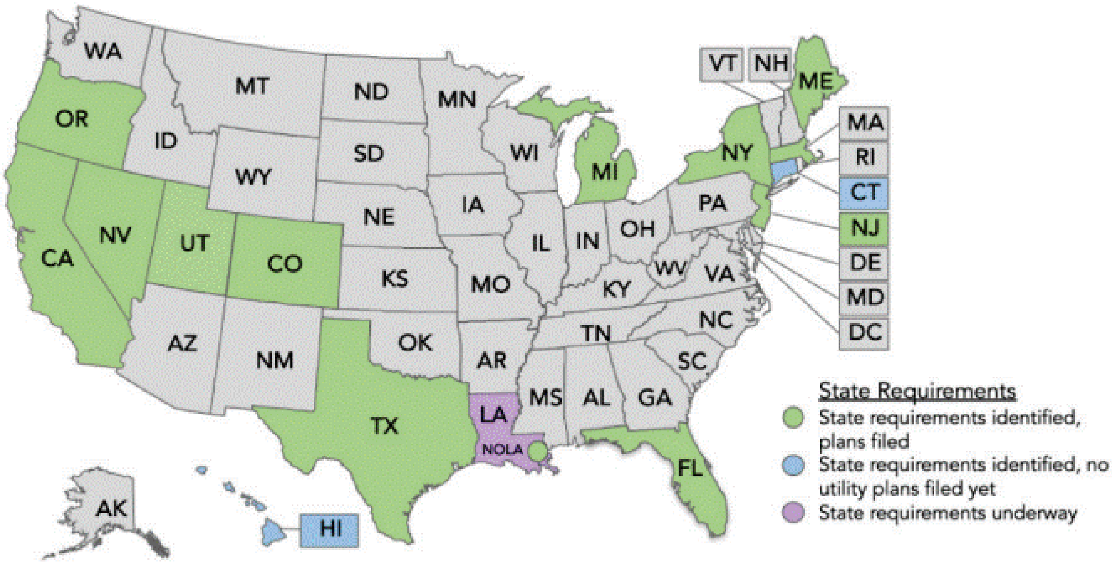
Some progress has been made, however, with respect to new standards that will begin to integrate the potential for extreme heat or cold events into transmission planning processes. In June 2023, FERC issued Order No. 896, which acknowledges the increasing risks to the bulk power system from extreme heat and cold, noting that “extreme weather events have occurred with greater frequency in recent years, leading to load shed events that present an unacceptable risk to life and have an extreme economic impact” (NERC 2024a). Order No. 896 directs transmission system planners and operators to evaluate systems under extreme heat and cold conditions to identify potential weaknesses and establish corrective action plans to help maintain reliability during these events.

While these new requirements are a step forward, key shortcomings will ultimately narrow their effectiveness at building resilience into the system. First, the new standards are generally near-term focused and directed primarily at localized or operational solutions that will not drive the system-wide approach needed to meaningfully confront the challenges of climate change. Also, the new standards address the system risks posed only by extreme heat and cold events—not the full range of risks posed by climate change—and call for an evaluation of only historical events to determine what conditions the system might encounter in the future. This approach can still produce meaningful insights and is certainly better than no evaluation at all, but a proper analysis of potential future extreme conditions must be informed by what climate science is telling us about shifts in future conditions over time.

States Are Inconsistent at Best on Resilience

Despite limited leadership at the federal level, some states and the utilities they regulate are taking action to improve grid resilience. But only a handful of states require their utilities to conduct resilience planning. A mere 14 states and the city of New Orleans require electric utilities to file some sort of resilience plan; these plans vary significantly from state to state (Figure 2) (M. Collins et al. 2025).

Figure 2. Too Few States Require Utility Resilience Planning



Fourteen states and the city of New Orleans require electric utilities to file some sort of resilience plan. Requirements vary from state to state. For example, some require a risk evaluation only for certain events, such as wildfires, and others apply only to a subset of the state's utilities.

Source: M. Collins et al. 2025

Best practices and lessons learned from these leading states can inform planning across the nation. These include what processes to use to measure a system's vulnerability to various threats, how to incorporate unique community-level vulnerabilities and capabilities, and how to prioritize potential cost-effective investment options to maximize resilience benefits.

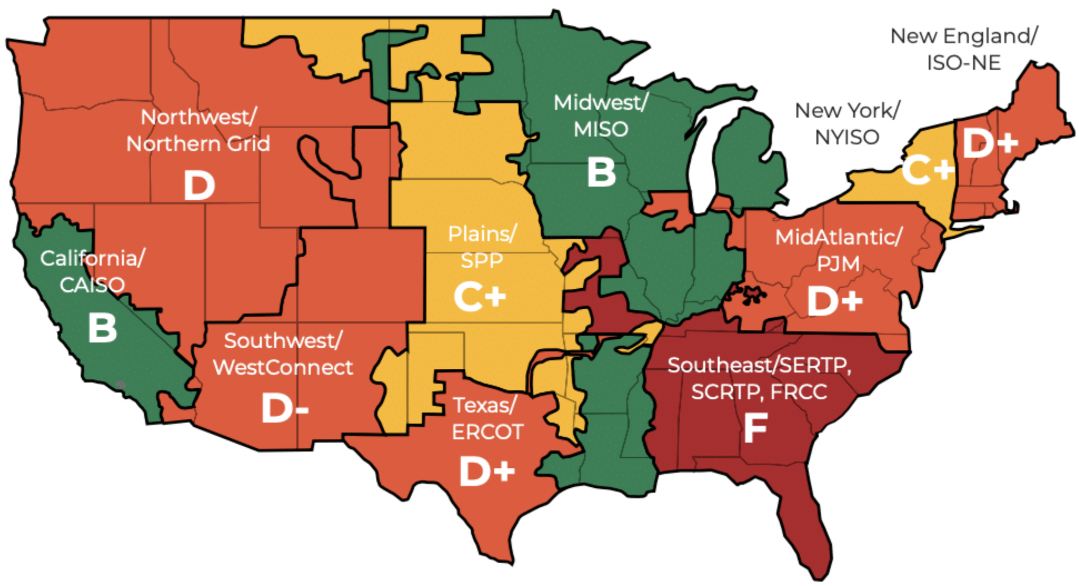
With a few exceptions—notably California and New York, which have single-state RTO/ISOs—lessons learned at the state level have not made their way up to regional and interregional transmission planning processes. The result is a void in transmission system planning that neglects the need for more regional- and interregional-focused resilience planning in the face of climate change and ignores the possible benefits to communities from transmission system investments that improve system resilience.

Time for RTO/ISOs to Do the Planning

Still, none of the hurdles or shortcomings discussed previously prevent the RTO/ISOs and other designated regional planning entities from engaging in the types of forward-looking, data-driven and community-centered planning processes needed to build greater resilience into the system in a cost-effective manner. RTO/ISOs have broad latitude based on their arrangements with member utilities to plan and approve investments to meet anticipated system needs, including those presented by extreme weather risks. They have access to the resources required to do robust system planning, and they have an established convening role that enables them to include the broad range of entities whose input will be critical to success. Currently, a hodgepodge of planning is taking place among these regional entities. Some employ best practices and sound processes. Other laggard regions continue to lean into a more piecemeal, uncoordinated approach to transmission system planning.

In its 2023 Transmission Planning and Development Regional Report Card (Zimmerman, Gramlich, and Hayes 2023), Americans for a Clean Energy Grid used multiple metrics to grade each of the ten regions (merging the multiple Southeastern FERC-designated regions into one). Six of the 10 regions scored a D+ or worse on deploying robust planning methods and best practices sufficient to plan proactively for future uncertainty (see Figure 3). This report and its 2024 update (Zimmerman and Gramlich 2024) detail some progress among planning regions in evaluating extreme weather risks, but their extreme weather scenarios are typically backward-looking rather than forward-looking assessments of potential climate change impacts. Further, none of the progress detailed in these reports suggests the level of engagement from communities and other interested parties necessary to drive optimal solutions for the risks identified.

Figure 3. Few Regions Score Well on Transmission Planning



Of the 10 regions graded by Americans for a Clean Energy Grid, six scored a D+ or worse on how well they deployed robust planning methods and best practices sufficient to address future uncertainty. Even among those regions that performed better, resilience considerations largely failed to implement the recommendations presented in this report.

Source: Zimmerman, Gramlich, and Hayes 2023

Conclusion: Inclusive Planning for Climate Impacts

With limited leadership coming from the federal level, it will take a critical mass of engagement to move states and RTO/ISOs and regional transmission planning entities toward a more holistic, community-centered approach to building the resilience of the bulk power system. Communities, advocacy organizations, consumer advocates, local and state decisionmakers, and other interested parties should be engaging in their regional planning processes—either directly with their system planners or through their local and state leaders, who should be representing them in these processes—to push for improved grid resilience through science-informed climate risk assessments, modernized analytic capabilities, community engagement, and reevaluation of the benefits of avoided power outages.

All these elements are achievable and well within the power of transmission planning entities to implement. All that is needed is the will to invest the time and resources to meet the challenge. A reliable, resilient power grid that keeps all people safe in our changing climate is within reach.

Key Recommendations for a More Equitable and Resilient Bulk Power System

- **Assess climate risks.** Conduct forward-looking, science-informed climate risk assessments using the best available, properly scaled climate data that project impacts at least 30 years into the future and across multiple emissions pathways to capture a reasonable range of extreme weather risks.

- **Acknowledge the role of fossil fuel reliance in exacerbating grid vulnerabilities to extreme weather.** Maximize the value and impact of resilience investments by integrating transmission planning with actions that accelerate the transition away from fossil fuels.

- **Reform planning processes**. Establish transmission planning processes that analyze a broad range of potential future conditions, including extreme weather risks and other key drivers of change, such as demand growth, electrification, and the transition to clean energy. Planning processes should be the foundation for cost-effective investment in the transmissions system to build resilience to climate change and extreme weather.

- **Collaborate with researchers.** Greater collaboration between climate science researchers, electricity systems researchers, system planners, and decisionmakers can help develop the tools required for robust planning, ensure their workability from day one, and facilitate rapid adoption by the planning community.

- **Improve the metrics used to make decisions about transmission system investment,** such as the value-of-lost-load (VOLL) metric, to be more reflective of how the costs of power outages vary significantly across time and space as well as among communities.

- **Complement economic-focused metrics with additional metrics** or qualitative assessments—transparently developed in coordination with local government, state decisionmakers, and communities—that consider vulnerable communities and populations in how we invest in a more resilient transmission system.

- **Improve coordination and collaboration** across transmission, distribution, and community efforts so that regional and interregional transmission investments complement resilience-based investments made at the utility and local levels.

- **Make decisionmaking more inclusive and responsive** to the unique needs of communities by establishing and maintaining meaningful community engagement for better-informed consideration of the impacts and trade-offs of different investment options to build system resilience. To achieve this objective, we offer these further recommendations:
    - **Incorporate energy justice principles** that focus on achieving equity in social and economic participation within the energy system while also addressing the disproportionate burdens faced by marginalized communities. Integrating these principles, including assessing cumulative impacts, shapes resilience planning that actively works to remedy past injustices and prevent future disparities.
    - **Develop shared governance structures** that create and compensate community advisory boards with explicit decisionmaking power.
    - **Engage early,** including reaching out before plans are drafted to build trust and ensure that community priorities guide project design.
    - **Align with local resilience efforts** so that bulk system investments support rather than override community projects, such as resilience hubs and electrification goals.
    - **Support community capacity** by including funding for technical assistance, providing translated and simplified planning tools, and compensating communities for their time and expertise.
    - **Embed accountability tools** by using equity impact statements, resilience benefit-cost ratios, and dashboards so that outcomes are community informed and track progress transparently over time.

Authors

Sam Gomberg is associate director for transmission policy in the Climate and Energy Program at the Union of Concerned Scientists. **Rachel Licker, PhD**, is the principal of Connected Science, LLC. **Sital Sathia** is a research officer for energy justice research and policy in the Climate and Energy Program at UCS. **Pamela Worth** is senior writing manager at UCS.

Acknowledgments

For their feedback, the authors thank Yvonne Cappel-Vickery, Alliance for Affordable Energy; and Claire Wayner, RMI. We are also grateful to our colleagues Colin Byers, Deanna Celi, Jeff Deyette, Amanda Fencl, L. Delta Merner, Kathy Mulvey, Alicia Race, John Rogers, Eric Schulz, Lee Shaver, Daela Taeoalii-Tipton, Heather Tuttle, Shana Udvardy, and Bryan Wadsworth, and to Dana Johnson for her expert editing.

Organizational affiliations are listed for identification purposes only. The opinions expressed herein do not necessarily reflect those of the organizations that funded the work or the individuals who reviewed it. The Union of Concerned Scientists bears sole responsibility for the report’s content.

References

Abatzoglou, John T., David S. Battisti, A. Park Williams, Winslow D. Hansen, Brian J. Harvey, and Crystal A. Kolden. 2021. “Projected Increases in Western US Forest Fire despite Growing Fuel Constraints.” Communications Earth & Environment 2 (1): e227. https://doi.org/10.1038/s43247-021-00299-0

Airgood-Obrycki, Whitney, Magda Maaoui, and Sophia Wedeen. 2025. “Rental Deserts, Segregation, and Zoning.” Journal of Urban Affairs, 1–20. https://doi.org/10.1080/07352166.2025.2455606

Alfonseca, Kiara. 2025. “LA Wildfires Maps Show Evacuations, Power Outages, Air Quality.” ABC News, January 14, 2025. https://abcnews.go.com/US/california-wildfires-maps-show-evacuations-power-outages-air/story?id=117460700

Allen-Dumas, Melissa R., Binita KC, and Colin I. Cunliff. 2019. Extreme Weather and Climate Vulnerabilities of the Electric Grid: A Summary of Environmental Sensitivity Quantification Methods. ORNL/TM-2019/1252. Oak Ridge, TN: Oak Ridge National Lab. https://doi.org/10.2172/1558514

Andresen, Adam X., Liza C. Kurtz, David M. Hondula, Sara Meerow, and Melanie Gall. 2023. “Understanding the Social Impacts of Power Outages in North America: A Systematic Review.” Environmental Research Letters 18 (5): e053004. https://doi.org/10.1088/1748-9326/acc7b9

Arbaje, Paul, and Mark Specht. 2024. Gas Malfunction: Calling into Question the Reliability of Gas Power Plants. Cambridge, MA: Union of Concerned Scientists. https://www.ucs.org/resources/gas-malfunction

Baker, Shalanda, Subin DeVar, and Shiva Prakash. 2019. The Energy Justice Workbook. Boston: Initiative for Energy Justice. https://iejusa.org/wp-content/uploads/2019/12/The-Energy-Justice-Workbook-2019-web.pdf

Bird, Marlee. 2022. “The Temperature of Disinvestment: Examining Urban Heat Islands and Historically Redlined Communities.” National Community Reinvestment Coalition. July 7, 2022. https://ncrc.org/the-temperature-of-disinvestment-examining-urban-heat-islands-and-historically-redlined-communities/

Bisaha, Stephen. 2021. “Thousands In Louisiana Are Still without Power 1 Month after Ida Landfall.” WWNO, September 29, 2021. https://www.wwno.org/news/2021-09-29/thousands-in-louisiana-are-still-without-power-1-month-after-ida-landfall

Bond-Smith, Daniela, Jack Driggers, Trey Gordner, Rachel Inafuku, and Caleb Wood. 2024. One Year after the Wildfires: Rising Poverty and Housing Instability Point to Ongoing Gaps in Assistance. Honolulu: The Economic Research Organization at the University of Hawaiʻi. https://uhero.hawaii.edu/wp-content/uploads/2024/10/OneYearAfterTheWildfires.pdf

Bruess, Elena. 2024. “No Power Means No Work for Many in Houston after Beryl. The Strain Is Starting to Show.” Houston Landing. July 12, 2024. http://houstonlanding.org/no-power-means-no-work-for-many-in-houston-after-beryl-the-strain-is-starting-to-show/

Byers, Colin, Kelly Lynch, Maggie Schuppert, Yvonne Cappel-Vickery, Colette Pichon Battle, Bridget Vial, James Gignac et al. 2023. Equitable Grid Principles: Guidance for Electric Grid Infrastructure Decisionmakers and Stakeholders in the MISO Region. Cambridge, MA: Union of Concerned Scientists. https://www.ucs.org/resources/equitable-grid-principles

Casey, Joan A., Mihoka Fukurai, Diana Hernández, Satchit Balsari, and Mathew V. Kiang. 2020. “Power Outages and Community Health: A Narrative Review.” Current Environmental Health Reports 7:371–83. https://doi.org/10.1007/s40572-020-00295-0

Casey, Joan A., Marriele Mango, Seth Mullendore, Mathew V. Kiang, Diana Hernández, Bonnie H. Li, Kris Li, Theresa M. Im, and Sara Y. Tartof. 2021. “Trends from 2008 to 2018 in Electricity-Dependent Durable Medical Equipment Rentals and Sociodemographic Disparities.” Epidemiology 32 (3): 327–35. https://doi.org/10.1097/EDE.0000000000001333

CDC (US Centers for Disease Control and Prevention). 2024. “What to Do to Protect Yourself during a Power Outage.” Natural Disasters and Severe Weather. February 14, 2024. https://www.cdc.gov/natural-disasters/response/what-to-do-protect-yourself-during-a-power-outage.html

Chakraborty, Jayajit, Timothy W. Collins, and Sara E. Grineski. 2023. “Disability and Subsidized Housing Residency: The Adverse Impacts of Winter Storm Uri in Metropolitan Texas.” Disability and Health Journal 16 (2): e101403. https://doi.org/10.1016/j.dhjo.2022.101403

Clapper, Haley, Eliza Hotchkiss, Dana-Marie Thomas, Philip White, Jordan Burns, Jordan Cox, and Brian McAdoo. 2024. “The Effects of Redlining on Residential Energy Efficiency and Resilience in Extreme Temperature Events” (working paper, American Council for an Energy-Efficient Economy, Washington, DC). https://www.aceee.org/sites/default/files/proceedings/ssb24/assets/attachments/20240722163126187_5c425eb7-5505-4642-afb4-30a548e9f16d.pdf

Climate Central. 2020. “Power OFF: Extreme Weather and Power Outages.” September 30, 2020. https://www.climatecentral.org/climate-matters/power-outages

———. 2023. Wildfire Weather: Analyzing the 50-Year Shift across America. Princeton, NJ. https://www.climatecentral.org/report/wildfire-weather

———. 2024. “Weather-Related Power Outages Rising.” April 24, 2024. https://www.climatecentral.org/climate-matters/weather-related-power-outages-rising

———. n.d. “Climate Shift Index.” Accessed March 22, 2025. https://www.climatecentral.org/climate-shift-index

Cline, Sara. 2023. “In a state used to hurricanes and flooding, Louisiana is battling an unprecedented wildfire season.” AP News, September 18, 2023. https://apnews.com/article/louisiana-wildfire-b9d8968c1ce98b009c3ce95fa08a8f40

Cohen, Judah, Jennifer A. Francis, and Karl Pfeiffer. 2024. “Anomalous Arctic Warming Linked with Severe Winter Weather in Northern Hemisphere Continents.” Communications Earth & Environment 5:e557. https://doi.org/10.1038/s43247-024-01720-0

Coleman, Natalie, Amir Esmalian, Cheng-Chun Lee, Eulises Gonzales, Pranik Koirala, and Ali Mostafavi. 2023. “Energy Inequality in Climate Hazards: Empirical Evidence of Social and Spatial Disparities in Managed and Hazard-Induced Power Outages.” Sustainable Cities and Society 92 (May): e104491. https://doi.org/10.1016/j.scs.2023.104491

Collins, Myles, Matia Whiting, Josh Schellenberg, and Lisa Schwartz. 2025. Bridging the Gap on Data, Metrics, and Analyses for Grid Resilience to Weather Events: Information That Utilities Can Provide Regulators, State Energy Offices, and Other Stakeholders. Berkeley, CA: Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/2025-01/bridging_the_gap_resilience_data_metrics_and_analysis_final.pdf

Collins, Stephanie. 2019. “US Power Outages Endanger People with Disabilities.” Human Rights Watch, October 23, 2019. https://www.hrw.org/news/2019/10/23/us-power-outages-endanger-people-disabilities

County of Maui Department of Fire and Public Safety. 2024. Origin and Cause Report. FI 23-0012446 – Wildfire – Lahaina. Wailuku, HI. https://www.mauicounty.gov/DocumentCenter/View/149693/FI23-0012446-Lahaina-Origin-and-Cause-Report_Plus-Appendix-A-B-C-Redacted

Cushing, Lara J., Shiwen Li, Benjamin B. Steiger, and Joan A. Casey. 2023. “Historical Red-Lining Is Associated with Fossil Fuel Power Plant Siting and Present-Day Inequalities in Air Pollutant Emissions.” Nature Energy 8:52–61. https://doi.org/10.1038/s41560-022-01162-y

Dahl, Kristina, Rachel Licker, John T. Abatzoglou, and Juan Declet-Barreto. 2019. “Increased Frequency of and Population Exposure to Extreme Heat Index Days in the United States during the 21st Century.” Environmental Research Communications 1(7): e075002. https://doi.org/10.1088/2515-7620/ab27cf

Dance, Scott. 2023. “Maui Fires Not Just Due to Climate Change but a ‘Compound Disaster.’” Washington Post, August 12, 2023. https://www.washingtonpost.com/weather/2023/08/12/hawaii-fires-climate-change-maui/

DeLuca, Stefanie, and Eva Rosen. 2022. “Housing Insecurity among the Poor Today.” Annual Review of Sociology 48:343–71. https://doi.org/10.1146/annurev-soc-090921-040646

Do, Vivian, Heather McBrien, Nina M. Flores, Alexander J. Northrop, Jeffrey Schlegelmilch, Mathew V. Kiang, and Joan A. Casey. 2023. “Spatiotemporal Distribution of Power Outages with Climate Events and Social Vulnerability in the USA.” Nature Communications 14:e2470. https://doi.org/10.1038/s41467-023-38084-6

DOE (US Department of Energy). 2023. National Transmission Needs Study. Washington, DC. https://www.energy.gov/sites/default/files/2023-12/National%20Transmission%20Needs%20Study%20-%20Final_2023.12.1.pdf

———. 2024. National Transmission Planning Study. Washington, DC. https://www.energy.gov/gdo/national-transmission-planning-study

Doremus, Jacqueline M., Irene Jacqz, and Sarah Johnston. 2022. "Sweating the Energy Bill: Extreme Weather, Poor Households, and the Energy Spending Gap." Journal of Environmental Economics and Management 112 (March): e102609. https://doi.org/10.1016/j.jeem.2022.102609

Dugan, Jesse, Dahlia Byles, and Salman Mohagheghi. 2023. "Social Vulnerability to Long-Duration Power Outages." International Journal of Disaster Risk Reduction 85 (February): e103501. https://doi.org/10.1016/j.ijdrr.2022.103501

Dunn, Laurel N., Michael D. Sohn, Kristina Hamachi LaCommare, and Joseph H. Eto. 2019. "Exploratory Analysis of High-Resolution Power Interruption Data Reveals Spatial and Temporal Heterogeneity in Electric Grid Reliability." Energy Policy 129 (June): 206–14. https://doi.org/10.1016/j.enpol.2019.01.042

EIA (Energy Information Administration). 2017. "Hurricane Harvey Caused Electric System Outages and Affected Wind Generation in Texas." September 13, 2017. https://www.eia.gov/todayinenergy/detail.php?id=32892

———. 2021. "Hurricane Ida Caused at Least 1.2 Million Electricity Customers to Lose Power." September 15, 2021. https://www.eia.gov/todayinenergy/detail.php?id=49556

Ellickson, Kristie. 2024. "Robust Public Participation Makes for Better Regulations." The Equation (blog). September 9. https://blog.ucs.org/kellickson/robust-public-participation-makes-for-better-regulations/

Ellickson, Kristie, and Kathleen A. Curtis. 2024. The Community Guide to Cumulative Impacts: Using Science and Organizing to Advance Public Health Policy. Cambridge, MA: Union of Concerned Scientists. https://doi.org/10.47923/2024.15622

Emiel, Farudh. 2024. Wiring the Divide: The Impact of Redlining on Electric Infrastructure. San Francisco: Vote Solar. https://votesolar.org/wp-content/uploads/2023/10/Wiring-the-Divide_Issue-Brief-2024-AEAC.pdf

Entergy. 2018. "Hardening the System after Historic Harvey." Press release, August 21. https://www.entergynewsroom.com/news/hardening-system-after-historic-harvey/

EPA (Environmental Protection Agency). 2022. "Climate Change and the Health of Socially Vulnerable People." Overviews and Factsheets. March 21, 2022. https://www.epa.gov/climateimpacts/climate-change-and-health-socially-vulnerable-people

———. 2023. Capacity Building through Effective Meaningful Engagement: A Tool for Local and State Governments. EPA 440B23001. Washington, DC. https://www.epa.gov/system/files/documents/2023-09/epa-capacity-building-through-effective-meaningful-engagement-booklet_0.pdf

EPRI (Electric Power Research Institution). 2022. A Starting Point for Physical Climate Risk Assessment and Mitigation: Future Resilience and Adaptation Planning. Palo Alto, CA. https://www.epri.com/research/sectors/readi/research-results/3002024895

———. 2023. Climate-Informed Planning and Adaptation for Power Sector Resilience. Palo Alto, CA. https://www.epri.com/research/products/000000003002026317

———. 2024a. "Projected Changes in Hurricane-Induced Power Outages in a Future Climate." July 2024. http://view.ceros.com/epri/readi-storymap

———. 2024b. Compound Hazards and the Power Sector in a Changing Climate. Palo Alto, CA. https://www.epri.com/research/sectors/readi/research-results/3002030518

———. 2024c. "Practices for Representing Climate Impacts in Bulk Electric System Models." Palo Alto, CA. https://www.epri.com/research/sectors/readi/research-results/3002030855

FERC (Federal Energy Regulatory Commission). 2020. Report on Barriers and Opportunities for High Voltage Transmission: A Report to the Committees on Appropriations of Both Houses of Congress pursuant to the 2020 Further Consolidated Appropriations Act. Washington, DC. https://www.congress.gov/116/meeting/house/111020/documents/HHRG-116-II06-20200922-SD003.pdf

———. 2021. “Advance Notice of Proposed Rulemaking: Building for the Future through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection.” Press release, July 15. https://www.ferc.gov/news-events/news/advance-notice-proposed-rulemaking-building-future-through-electric-regional

———. 2024. “RTOs and ISOs.” January 17, 2024. https://www.ferc.gov/power-sales-and-markets/rtos-and-isos

Fischels, Josie. 2021. “Photos: The Record-Breaking Heat Wave That’s Scorching the Pacific Northwest.” NPR, June 29, 2021. https://www.npr.org/2021/06/29/1011269025/photos-the-pacific-northwest-heatwave-is-melting-power-cables-and-buckling-roads

Foster, Joanna. 2024. “Too Many Blackouts: How Underserved Communities Are Making Utilities Listen.” Last updated February 16, 2024. Vital Signs, Environmental Defense Fund. https://vitalsigns.edf.org/story/too-many-blackouts-how-underserved-communities-are-making-utilities-listen

Franklin, Jonathan. 2023. “Some Don’t Evacuate, despite Repeated Hurricane Warnings, Because They Can’t.” NPR, August 31, 2023, Weather. https://www.npr.org/2022/09/28/1125448849/why-people-dont-evacuate-hurricane-ian-florida

Ganz, Scott C., Chenghao Duan, and Chuanyi Ji. 2023. “Socioeconomic Vulnerability and Differential Impact of Severe Weather-Induced Power Outages.” PNAS Nexus 2 (10): epgad295. https://doi.org/10.1093/pnasnexus/pgad295

GAO (Government Accountability Office). 2022. Disaster Recovery: School Districts in Socially Vulnerable Communities Faced Heightened Challenges after Recent Natural Disasters. GAO-22-104606. Washington, DC. https://www.gao.gov/assets/gao-22-104606.pdf

Garfin, Dana Rose, Rebecca R. Thompson, E. Alison Holman, Gabrielle Wong-Parodi, and Roxane Cohen Silver. 2022. “Association between Repeated Exposure to Hurricanes and Mental Health in a Representative Sample of Florida Residents.” JAMA Network Open 5 (6): e2217251. https://doi.org/10.1001/jamanetworkopen.2022.17251

Gastelum, Bryana. 2023. “Energy Equity: How Can Power Utilities Get It Right?” The Equation (blog). September 21. https://blog.ucs.org/guest-commentary/energy-equity-how-can-power-utilities-get-it-right/

Gillett, Nathan P. 2024. “Halving of the Uncertainty in Projected Warming over the Past Decade.” NPJ Climate and Atmospheric Science 7:146. https://doi.org/10.1038/s41612-024-00693-3

Goggin, Michael. 2021. Transmission Makes the Power System Resilient to Extreme Weather. Washington, DC: Grid Strategies LLC; American Council on Renewable Energy. https://acore.org/wp-content/uploads/2021/07/GS_Resilient-Transmission_proof.pdf

Goggin, Michael, and Jesse Schneider. 2022. The One-Year Anniversary of Winter Storm Uri: Lessons Learned and the Continued Need for Large-Scale Transmission. Washington, DC: Grid Strategies LLC. https://gridstrategiesllc.com/wp-content/uploads/2024/05/the-one-year-anniversary-of-winter-storm-uri-lessons-learned-and-the-continued-need-for-large-scale-transmission.pdf

Gonçalves, Ana C. R., Xurxo Costoya, Raquel Nieto, and Margarida L. R. Liberato. 2024. “Extreme Weather Events on Energy Systems: A Comprehensive Review on Impacts, Mitigation, and Adaptation Measures.” Sustainable Energy Research 11: e4. https://doi.org/10.1186/s40807-023-00097-6

Gorman, Will. 2022. “The Quest to Quantify the Value of Lost Load: A Critical Review of the Economics of Power Outages.” Electricity Journal 35 (8): e107187. https://doi.org/10.1016/j.tej.2022.107187

Hampo, Chima Cyril, Leah H. Schinasi, and Simi Hoque. 2024. “Surviving Indoor Heat Stress in United States: A Comprehensive Review Exploring the Impact of Overheating on the Thermal Comfort, Health, and Social Economic Factors of Occupants.” Heliyon 10 (3): e25801. https://doi.org/10.1016/j.heliyon.2024.e25801

Hotchkiss, Eliza, Nick Grue, and Moriah Petty. 2023. Understanding Resilience Valuation for Energy Systems: An Overview of the NYSERDA-NREL Research Collaboration. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy23osti/86923.pdf

IPCC (Intergovernmental Panel on Climate Change). 2023. AR6 Synthesis Report: Climate Change 2023. Geneva, Switzerland. https://dx.doi.org/10.59327/IPCC/AR6-9789291691647

Kalra, Nidhi, Swaptik Chowdhury, Kelly Klima, and Liam Regan. 2022. Equity Metrics for Climate Adaptation in the Electricity Sector. Santa Monica, CA: RAND. https://www.rand.org/pubs/research_reports/RRA1721-1.html

Kazimierczuk, Kamila, Mercy Berman DeMenno, Rebecca S. O'Neil, and Brian J. Pierre. 2023. Equitable Electric Grid: Defining, Measuring, and Integrating Equity into Electricity Sector Policy and Planning. PNNL-34933/SAND2023-10695R. Richland, WA: Pacific Northwest National Laboratories; Livermore, CA: Sandia National Laboratories. https://www.pnnl.gov/sites/default/files/media/file/MOD-Plan%20Equity%20Paper%20Final.pdf

Kutz, Jessica. 2023. "Climate Change Is Destroying Public Housing and Displacing Women of Color." The 19th, September 26, 2023. https://19thnews.org/2023/09/climate-change-public-housing-hurricane-women/

Landis, Meg. 2024. "Hurricanes Helene & Milton: A Visual Timeline." Project HOPE. November 4, 2024. https://www.projecthope.org/news-stories/story/hurricane-visual-timeline/

Lathan, Nadia. 2024. "People on Breathing Machines Struggle without Power after Weather Disasters." AP News, November 23, 2024. https://apnews.com/article/power-outages-medically-vulnerable-texas-electricity-grid-60154dbd83ad162f3bb57d757b96e464

Lee, Cheng-Chun, Mikel Maron, and Ali Mostafavi. 2022. "Community-Scale Big Data Reveals Disparate Impacts of the Texas Winter Storm of 2021 and Its Managed Power Outage." Humanities and Social Sciences Communications 9: e335. https://doi.org/10.1057/s41599-022-01353-8

Lei, Xue, and Xueguo Xu. 2025. "Climate Crisis on Energy Bills: Who Bears the Greater Burden of Extreme Weather Events?" Economics Letters 247 (February): e112103. https://doi.org/10.1016/j.econlet.2024.112103

Leung, L. Ruby, Adam Terando, Renu Joseph, George Tselioudis, Lori M. Bruhwiler, Benjamin Cook, Clara Deser et al. 2023. "Ch. 3. Earth Systems Processes." In Fifth National Climate Assessment. Edited by A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, and T. K. Maycock. Washington, DC: US Global Change Research Program. https://doi.org/10.7930/NCA5.2023.CH3

Louzon, Matt, and Poj Lysouvakon. 2023. "Wintertime Dangers of Carbon Monoxide Poisoning: 'The Silent Killer.'" UChicago Medicine. November 1, 2023. https://www.uchicagomedicine.org/forefront/health-and-wellness-articles/2023/november/wintertime-dangers-carbon-monoxide-silent-killer

Maes, Mikaël J. A., Alexandre Bizeul, Arnau Risquez Martin, Ivan Haščič, and Roberta Quadrelli. 2023. "Data Tool Gives Fine-Grained View of Climate Vulnerabilities in the Energy System and Beyond." International Energy Agency. November 21, 2023. https://www.iea.org/commentaries/data-tool-gives-fine-grained-view-of-climate-vulnerabilities-in-the-energy-system-and-beyond

Mahan, Simon. 2023. "Gridlocked: Planning Failure with the Southeastern Regional Transmission Planning Process." Southern Renewable Energy Association. December 20, 2023. https://www.southernrenewable.org/2/post/2023/12/gridlocked-planning-failure-with-the-southeastern-regional-transmission-planning-process.html

Maldonado, Julie, T. M. Bull Bennett, Karletta Chief, Patricia Cochran, Karen Cozzetto, Bob Gough, Margaret Hiza Redsteer, Kathy Lynn, Nancy Maynard, and Garrit Voggesser. 2016. "Engagement with Indigenous Peoples and Honoring Traditional Knowledge Systems." Climatic Change 135:111–26. https://doi.org/10.1007/s10584-015-1535-7

Marvel, Kate, Wenying Su, Roberto Delgado, Sarah Aarons, Abhishek Chatterjee, Margaret E. Garcia, Zeke Hausfather et al. 2023. "Chapter 2. Climate Trends." In Fifth National Climate Assessment. Edited by A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, and T. K. Maycock. Washington, DC: US Global Change Research Program. https://doi.org/10.7930/NCA5.2023.CH2

Mass, Clifford, David Ovens, John Christy, and Robert Conrick. 2024. "The Pacific Northwest Heat Wave of 25–30 June 2021: Synoptic/Mesoscale Conditions and Climate Perspective." Weather and Forecasting 39 (2): 275–91. https://doi.org/10.1175/WAF-D-23-0154.1

Mercado, Kenny. 2017. "ERCOT Board of Directors - CenterPoint Energy's Response to Hurricane Harvey." PowerPoint presentation to Electric Reliability Council of Texas Board of Directors, October 17, 2017. https://perma.cc/5KCJ-V2VK

Metzger, Christian. 2025. "CT Had Five Times More Wildfires Than Usual in 2024. Officials Warn This Could Be the New Normal." Stamford Advocate, January 27, 2025. https://www.stamfordadvocate.com/recordjournal/article/connecticut-wildfires-climate-change-floods-20024877.php

Meyers, Talya. 2024. "At Florida Health Centers, 'A Rush of Folks' Seek Mental Health Care in Hurricane Aftermath." Direct Relief (blog). November 4, 2024. https://www.directrelief.org/2024/11/at-florida-health-centers-a-rush-of-folks-seek-mental-health-care-in-hurricane-aftermath/

Milletich, Salvatore, Andres Manrique, Sonia Karsan, Tamara Spikes, Anuj Nanavanti, Jared Bailey, Eric Coker, and Christine C. Ekenga. 2025. "Historical Redlining and Community-Reported Housing Quality: A Spatial Analysis." Journal of Urban Health 102 (1): 49–60. https://doi.org/10.1007/s11524-024-00935-y

Moddemeyer, Steve, Negin Sobhani, and Berna Oztekin-Gunaydin, eds. 2022. Resilience for Compounding and Cascading Events. Washington, DC: National Academies Press. https://doi.org/10.17226/26659

Morris, Frank. 2021. "Two Weeks after Hurricane Ida, Tens of Thousands in Louisiana Are Still without Power." NPR, September 13, 2021, Weather. https://www.npr.org/2021/09/13/1036665971/two-weeks-after-hurricane-ida-tens-of-thousands-in-louisiana-are-still-without-p

National Low Income Housing Coalition. 2021. "Louisiana Housing Advocates Aim to Hold Energy Company Accountable." October 4, 2021. https://nlihc.org/resource/louisiana-housing-advocates-aim-hold-energy-company-accountable

Natter, Ari, and Jennifer A. Dlouhy. 2021. "Texas Was Warned a Decade Ago Its Grid Was Unready for Cold." Bloomberg, February 17, 2021. https://www.bloomberg.com/news/articles/2021-02-17/texas-was-warned-a-decade-ago-its-grid-was-unprepared-for-cold

Nejat, Ali, Laura Solitare, Edward Pettitt, and Hamed Mohsenian-Rad. 2022. "Equitable Community Resilience: The Case of Winter Storm Uri in Texas." International Journal of Disaster Risk Reduction 77 (July): e103070. https://doi.org/10.1016/j.ijdrr.2022.103070

NERC (North American Electric Reliability Corporation). 2023. 2023 Long-Term Reliability Assessment. Atlanta, GA. https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2023.pdf

———. 2024a. Consideration of FERC Order 896 Directives: Project 2023–07 Transmission System Planning Performance Requirements for Extreme Weather. Atlanta, GA. https://www.nerc.com/pa/Stand/Project202307ModtoTPL00151TransSystPlanPerfReqExWe/2023-07_Consideration%20of%20FERC%20Order%20896%20Directives%20Final_032024.pdf

———. 2024b. Interregional Transfer Capability Study (ITCS): Strengthening Reliability through the Energy Transformation: Recommendations for Prudent Additions to Transfer Capability (Part 2) and Recommendations to Meet and Maintain Transfer Capability (Part 3). Atlanta, GA. https://www.nerc.com/pa/RAPA/Documents/ITCS_Part2_Part3.pdf

NOAA. 2024a. "Atlantic Hurricane Season Races to Finish within Range of Predicted Number of Named Storms." Press release, November 25. https://www.noaa.gov/news-release/atlantic-hurricane-season-races-to-finish-within-range-of-predicted-number-of-named-storms

———. 2024b. "Hurricane Beryl - July 2024." December 30, 2024. https://storymaps.arcgis.com/stories/a027387bfa714243a16285c4fb143035

Office of Resilience and Coastal Protection. 2025. Hurricanes Debby, Helene and Milton Recovery Plan for Florida's Beach and Dune System. Tallahassee: Florida Department of Environmental Protection. https://floridadep.gov/sites/default/files/2024%20Hurricanes%20Debby_Helene_Milton_Recovery%20Plan_Final_0_0.pdf

Ostoja, Steven M., Allison R. Crimmins, Robert G. Byron, Amy E. East, Michael Méndez, Susan M. O'Neill, David L. Peterson et al. 2023. "Focus on Western Wildfires." In Fifth National Climate Assessment. Edited by A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, and T. K. Maycock. Washington, DC: US Global Change Research Program. https://doi.org/10.7930/NCA5.2023.F2

Philip, Sjoukje Y., Sarah F. Kew, Geert Jan van Oldenborgh, Faron S. Anslow, Sonia I. Seneviratne, Robert Vautard, Dim Coumou et al. 2022. "Rapid Attribution Analysis of the Extraordinary Heat Wave on the Pacific Coast of the US and Canada in June 2021." Earth System Dynamics 13 (4): 1689–1713. https://doi.org/10.5194/esd-13-1689-2022

Richardson, Jason, Bruce C. Mitchell, Helen C. S. Meier, Emily Lynch, and Jad Edlebi. 2020. Redlining and Neighborhood Health. Washington, DC: National Community Reinvestment Coalition. https://ncrc.org/holc-health/#Results

Rodríguez-Madera, Sheilla L., Nelson Varas-Díaz, Mark Padilla, Kevin Grove, Kariela Rivera-Bustelo, Jeffrey Ramos, Violeta Contreras-Ramirez, Sergio Rivera-Rodríguez, Ricardo Vargas-Molina, and Jose Santini. 2021. "The Impact of Hurricane Maria on Puerto Rico's Health System: Post-disaster Perceptions and Experiences of Health Care Providers and Administrators." Global Health Research and Policy 6 (November): e44. https://doi.org/10.1186/s41256-021-00228-w

Roque, Anais, Amber Wutich, Alexandra Brewis, Melissa Beresford, Carlos García-Quijano, Hilda Lloréns, and Wendy Jepson. 2021. "Autogestión and Water Sharing Networks in Puerto Rico after Hurricane María." Water International 46 (6): 938–55. https://doi.org/10.1080/02508060.2021.1960103

Ross, Liz, and Megan Day. 2022. "Community Energy Planning: Best Practices and Lessons Learned for NREL's Work with Communities." NREL/TP-6A50-82937. Golden, CO: Joint Institute for Strategic Energy Analysis. https://www.nrel.gov/docs/fy22osti/82937.pdf

Rothstein, Richard. 2017. The Color of Law: A Forgotten History of How Our Government Segregated America. New York: Liveright, a division of W.W. Norton.

Rubin, G. James, and M. Brooke Rogers. 2019. "Behavioural and Psychological Responses of the Public during a Major Power Outage: A Literature Review." International Journal of Disaster Risk Reduction 38 (August): e101226. https://doi.org/10.1016/j.ijdrr.2019.101226

SAMHSA (Substance Abuse and Mental Health Services Administration). 2017. Greater Impact: How Disasters Affect People of Low Socioeconomic Status. Washington, DC: US Department of Health and Human Services. https://www.samhsa.gov/sites/default/files/dtac/srb-low-ses_2.pdf

Sanstad, Alan H., Qianru Zhu, Benjamin D. Leibowicz, Peter H. Larsen, and Joseph H. Eto. 2020. Case Studies of the Economic Impact of Power Interruptions and Damage to Electric System Infrastructure from Extreme Events. Berkeley, CA: Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/impacts_case_studies_final_30nov2020.pdf

Seervai, Shanoor. 2017. "How Hurricane Maria Worsened Puerto Rico's Health Care Crisis." The Commonwealth Fund. December 18, 2017. https://www.commonwealthfund.org/publications/other-publication/2017/dec/how-hurricane-maria-worsened-puerto-ricos-health-care

Shreve, Nathan, Zachary Zimmerman, and Rob Gramlich. 2024. Fewer New Miles: The US Transmission Grid in the 2020s. Washington, DC: Americans for a Clean Energy Grid; Grid Strategies. https://cleanenergygrid.org/wp-content/uploads/2024/07/GS_ACEG-Fewer-New-Miles-Report-July-2024.pdf

Simonton, Teghan. 2024. "Hurricane Milton Caused Nearly Triple the Power Outages of Helene." Tampa Bay Times, October 11, 2024. https://www.tampabay.com/hurricane/2024/10/11/hurricane-milton-caused-nearly-triple-power-outages-helene/

Singh, Deepti, Allison R. Crimmins, Justin M. Pflug, Patrick L. Barnard, Jennifer F. Helgeson, Andrew Hoell, Fayola H. Jacobs, Michael G. Jacox, Alessandra Jerolleman, and Michael F. Wehner. 2023. "Focus on Compound Events." In Fifth National Climate Assessment. Edited by A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, and T. K. Maycock. Washington, DC: US Global Change Research Program. https://doi.org/10.7930/NCA5.2023.F1

Solomon, Danyelle, Connor Maxwell, and Abril Castro. 2019. Systemic Inequality: Displacement, Exclusion, and Segregation: How America's Housing System Undermines Wealth Building in Communities of Color. Washington, DC: Center for American Progress. https://www.americanprogress.org/article/systemic-inequality-displacement-exclusion-segregation/

Spanger-Siegfried, Erika, Jason Funk, Rachel Cleetus, Melissa Deas, and Juliet Christian-Smith. 2016. Toward Climate Resilience: A Framework and Principles for Science-Based Adaptation. Cambridge, MA: Union of Concerned Scientists. https://www.ucs.org/sites/default/files/attach/2016/06/climate-resilience-framework-and-principles.pdf

Stenclik, Derek, and Ryan Deyoe. 2022. Multi-Value Transmission Planning for a Clean Energy Future: A Report of the Transmission Benefits Valuation Task Force. Reston, VA: Energy Systems Integration Group. https://www.esig.energy/ multi-value-transmission-planning-report

Stone, Brian, Jr., Carina J. Gronlund, Evan Mallen, David Hondula, Marie S. O'Neill, Mayuri Rajput, Santiago Grijalva et al. 2023. "How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk." Environmental Science & Technology 57 (22): 8245–55. https://doi.org/10.1021/acs.est.2c09588

Sultana, Farhana. 2021. "Critical Climate Justice." Geographical Journal 188 (1): 118–24. https://doi.org/10.1111/geoj.12417

Texas Department of State Health Services. 2021. February 2021 Winter Storm-Related Deaths – Texas. Austin. https://www.dshs.texas.gov/sites/default/files/news/updates/SMOC_FebWinterStorm_MortalitySurvReport_12-30-21.pdf

Touma, Danielle, Samantha Stevenson, Daniel L. Swain, Deepti Singh, Dmitri A. Kalashnikov, and Xingying Huang. 2022. "Climate Change Increases Risk of Extreme Rainfall following Wildfire in the Western United States." Science Advances 8 (13): eabm0320. https://doi.org/10.1126/sciadv.abm0320

Tuck, Eve. 2009. "Suspending Damage: A Letter to Communities." Harvard Educational Review 79 (3): 409–27. https://pages.ucsd.edu/~rfrank/class_web/ES-114A/Week%204/TuckHEdR79-3.pdf

Twitchell, Jeremy, Jennifer Yoshimura, Kamila Kazimierczuk, Kaveri Mahapatra, and Rebecca O'Neil. 2022. "Incorporating Equity Objectives into Transmission Planning." Paper presented at IEEE PES General Meeting, Denver, CO, July 2022. https://www.pnnl.gov/sites/default/files/media/file/2022%20IEEE%20PES%20Slide%20Deck%20Incorporating%20Equity%20Objectives%20in%20Transmission%20Planning.pdf

UCS (Union of Concerned Scientists). 2024. "The Electric Utility Toolkit: An Activist's Guide to Changing the Power Grid." May 30, 2024. https://www.ucs.org/resources/electric-utility-toolkit

———. 2025a. "Environmental Justice, Climate Justice, and Energy Justice—What Do They Mean?" January 28, 2025. https://www.ucs.org/resources/environmental-climate-and-energy-justice-what-do-they-mean

———. 2025b. "Understanding Different Applications of Climate Justice, Energy Justice, and Environmental Justice." January 28, 2025. https://www.ucs.org/resources/applications-climate-energy-and-environmental-justice

Uekusa, Shinya, and Steve Matthewman. 2023. "Preparing Multilingual Disaster Communication for the Crises of Tomorrow: A Conceptual Discussion." International Journal of Disaster Risk Reduction 87 (March): e103589. https://doi.org/10.1016/j.ijdrr.2023.103589

USGCRP (US Global Change Research Program). 2023. Change in the Number of Days under 32 Deg F. National Climate Resilience. Last updated November 14, 2023. https://atlas.globalchange.gov/maps/nationalclimate::change-in-the-number-of-days-under-32-deg-f/about

Wakeman, Jessica. 2024. "'They Regress': Kids Struggle without School and Structure after Helene." Guardian (US edition), October 25, 2024, US News. https://www.theguardian.com/us-news/2024/oct/25/north-carolina-schools-helene

Ward, David M. 2013. "The Effect of Weather on Grid Systems and the Reliability of Electricity Supply." Climatic Change 121 (November): 103–13. https://doi.org/10.1007/s10584-013-0916-z

Wayner, Claire. 2024. Understanding FERC's Order 1920. Basalt, CO: RMI. https://rmi.org/wp-content/uploads/dlm_uploads/2024/12/Order-1920A-Reference-Sheet.pdf

Webb, Romany M., Michael Panfil, and Sarah Ladin. 2020. Climate Risk in the Electricity Sector: Legal Obligations to Advance Climate Resilience Planning by Electric Utilities. New York: Columbia Law School; Washington, DC: Environmental Defense Fund. https://climate.law.columbia.edu/sites/climate.law.columbia.edu/files/content/Full%20Report%20-%20Climate%20Risk%20in%20the%20Electricity%20Sector%20-%20Webb%20et%20al_0.pdf

White, Rachel H., Sam Anderson, James F. Booth, Ginni Braich, Christina Draeger, Cuiyi Fei, Christopher D. G. Harley et al. 2023. "The Unprecedented Pacific Northwest Heatwave of June 2021." Nature Communications 14:e727. https://doi.org/10.1038/s41467-023-36289-3

Winling, LaDale C., and Tom M. Michney. 2021. "The Roots of Redlining: Academic, Governmental, and Professional Networks in the Making of the New Deal Lending Regime." Journal of American History 108, no. 1 (June): 42–69. https://doi.org/10.1093/jahist/jaab066

World Weather Attribution. n.d. "World Weather Attribution" (website). Accessed March 22, 2025. https://www.worldweatherattribution.org/

Yabe, Takahiro, and Satish V. Ukkusuri. 2020. "Effects of Income Inequality on Evacuation, Reentry and Segregation after Disasters." Transportation Research Part D: Transport and Environment 82 (May): e102260. https://doi.org/10.1016/j.trd.2020.102260

Zeighami, Amir, Jordan Kern, Andrew J. Yates, Paige Weber, and August A. Bruno. 2023. "U.S. West Coast Droughts and Heat Waves Exacerbate Pollution Inequality and Can Evade Emission Control Policies." Nature Communications 14 (March): e1415. https://doi.org/10.1038/s41467-023-37080-0

Zimmerman, Zach, and Rob Gramlich. 2024. 2024 State of Regional Transmission Planning. Washington, DC: Americans for a Clean Energy Grid and Grid Strategies. https://cleanenergygrid.org/wp-content/uploads/2024/10/ACEG_2024-State-of-Regional-Transmission-Planning.pdf

Zimmerman, Zach, Rob Gramlich, and Christina Hayes. 2023. Transmission Planning and Development Regional Report Card. Washington, DC: Americans for a Clean Energy Grid. https://gridstrategiesllc.com/wp-content/uploads/2023/06/ACEG_Transmission-Planning-and-Development-Report-Card.pdf

https://doi.org/10.47923/2025.15855