How Renewable Energy Can Make the Power Grid More Reliable and Address Risks to Electricity Infrastructure

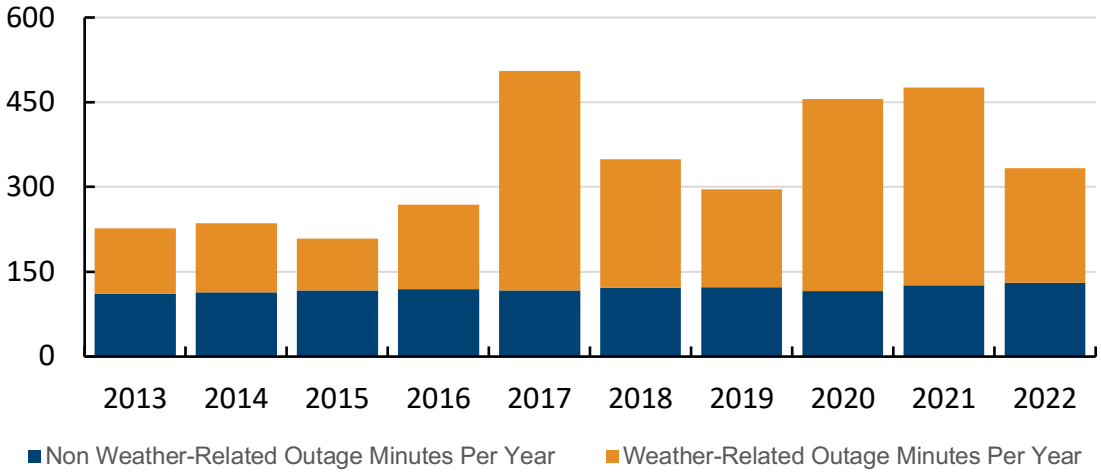
The electrical grid in the United States is a complex network that provides energy to millions of homes and businesses, putting it at the center of the nation's economy. Nearly all aspects of commerce and industry depend on affordable and available sources of energy. However, the grid is vulnerable to climate change-related and national security risks, including cyber-attacks, with outages costing the U.S. economy approximately $150 billion each year. Renewable energy sources, such as wind and solar, have already bolstered parts of the grid and have demonstrated flexibility and reliability in extreme weather. Congress and the Biden administration have made unprecedented investments to deploy renewable energy, strengthen transmission, and address security and privacy concerns related to the grid.

The electrical grid faces both climate and security risks.

The aging U.S. electrical grid was not designed to deal with the severity or frequency of extreme weather events exacerbated by climate change and is vulnerable to outages and damage that may be caused by it. Over 70% of the grid is more than 25 years old and will need replacing in the coming decades. Currently, the leading cause of electric power outage events is extreme weather events and climate-related threats, including coastal flooding, heat waves, ice storms, droughts, wildfires, and winds from severe storms.

Weather-Related Outages Contribute Significantly to Power Disruptions

Average non weather-related and weather-related outage minutes by year



Source: Energy Information Administration

From 2000 to 2021, weather-related events were responsible for 80% of all outages, and the average customer has now experienced an increase in weather-related outage duration over the last decade. The average weather-related outage minutes per year was 109 minutes between 2013 and 2015, but more than doubled to reach 297 minutes between 2020-2022. Though storms and other extreme events are an obvious threat to grid integrity, intense heat can also sap the efficiency of transmission lines. Transmission lines can swell and sag—potentially damaging grid infrastructure—when heat from high temperatures and increased demand physically expand transmission wires beyond their usual range. Grid enhancing technologies such as advanced conductor cables and dynamic line ratings can reduce these risks.

In addition to climate risks, cyberattacks from state and non-state actors threaten the energy grid, including through the exploitation of vulnerabilities from the increased use of smart technology for grid management. Because of its potential to better manage distribution and end-user consumption, AI is likely to play a large role in grid infrastructure. While AI and smart grid technologies can help electricity producers, distributors, and consumers alike adapt to higher demand, deploying the technology carefully and monitoring risks to it will be important. The risks to grid security and consumer privacy loom larger now that the grid must grow and be optimized to meet greater demands for electricity. To address vulnerabilities, President Biden issued an Executive Order directing the Department of Homeland Security (DHS) to apply rigorous standards set by the National Institute of Standards and Technology to critical infrastructure sectors, such as the electrical grid. DHS and the Department of Energy (DOE) will assess AI systems' threats to critical infrastructure from physical attacks and cyberattacks. Additionally, the Government Accountability Office recommends that the Federal Energy Regulatory Commission (FERC) enhance and enforce standards to mitigate cyber threats.

Grid outages are costly to families and the broader economy.

As the frequency and severity of power outages increase over time, so too does the cost to the economy. The DOE estimates that outages cost American businesses $150 billion per year. In 2022, the United States experienced 18 extreme weather events that cost over one billion dollars each. Much of that cost comes from outages, as businesses, schools, and emergency services are shut down for hours or days. Businesses face increased price volatility, higher capacity charges to ensure electricity supply during peak periods, and replacement costs for failing energy infrastructure that they often pass on to consumers. Additionally, a lack of transmission capacity to deliver the lowest-cost generation, known as grid congestion, cost consumers an estimated $20.8 billion in 2022.

Upgrading existing transmission capacity, replacing traditional steel power lines with advanced conductors—reconductoring—and developing and building large-scale high-voltage transmission lines are necessary steps to ease congestion. Reconductoring transmission lines with high-temperature low-sag lines is a primary option, as the process has only moderate cost but a moderate-to-high increase in energy transfer capacity. To that end, the Biden administration has invested more than $30 billion in catalyzing the development of thousands of miles of transmission lines to increase delivery capacity and overall resilience, and to decrease costs of power outages caused by extreme weather-related events exacerbated by climate

change. This announcement comes at the heels of a recent $3.46 billion investment by DOE in grid resilience and reliability across the country.

Renewables are making vital contributions to the resilience of the grid.

As extreme weather strains the grid and demand grows, renewable sources of energy are already playing a significant role in building grid resilience. The Energy Information Administration projects that renewable generation will supply nearly half of all electricity by 2050. Already, over 1,300 gigawatts (GW) of clean electricity generation and storage capacity are seeking interconnection to the grid—enough to supply 80% of the United States' electricity. Thankfully, the evidence to date shows that the growing clean power sector is also well-positioned to deal with extreme weather events.

Around the country, wind turbines, solar energy, and batteries often buttress the grid when extreme heat or other weather events tax it the most. During summer heat waves, when energy demand is generally at its peak, renewable energy sources can stay online and keep energy costs down for families. High solar generation is often correlated with peak summer loads when air conditioning units are in heavy use. In May of 2023, solar and energy storage stepped in while 10 gigawatts of power from coal and nuclear plants were offline in Texas because of heat-related failures. Grid operators from North Dakota to Oklahoma to California set records for solar and other renewable energy generation this summer, helping the grid power through hot summer days. With regard to extreme cold-weather events, a Stanford study showed that higher wind generation was correlated to the coldest weather events, which provided additional electrical capacity for heating needs. In general, wind and solar energy generation were found to be complementary to each other—wind generation was generally higher when solar generation was lower and vice versa.

A report by Energy Innovation, a non-partisan energy and climate policy think tank, found that "fossil-intensive grids cannot provide consistent resilience against climate risks they are simultaneously exacerbating." Texas' Big Freeze in February 2021 is a clear example of how fossil fuel electricity grids cannot withstand climate risks. When unseasonably cold weather knocked out power infrastructure and led energy demand to exceed available fossil fuel energy supply, the resulting mass power outages led to nearly 250 deaths. As Texas' energy grid is isolated as a matter of policy, surrounding energy providers were unable to transfer energy to the strained grid. Greater interconnection between regional grids allows for more flexibility, especially in the face of extreme weather events. This tragic example of how extreme weather can disproportionately target fossil-fuel energy production highlights the risks to Americans' health and well-being from an insecure power grid.

Solar and wind energy have proven to work well in tandem, even during extreme weather events, as solar provides energy during the day and wind provides energy in the evening and at night, reducing intermittency issues. Increasing battery storage capacity further mitigates intermittency issues and increases overall flexibility and resilience. Energy storage is already playing an important role in smoothing out energy supply in states that have invested in large-scale batteries.

Congress has taken great steps to undergird the grid, but more work needs to be done.

Congress and the Biden administration have taken important steps to ensure that appropriate regulation and ample funding exist to boost renewable electricity production. The Inflation Reduction Act (IRA) supercharged investments in utility-scale solar projects, wind power, and energy storage. For individuals and families, IRA's Residential Clean Energy Credit provides a credit for local investment in solar, wind, geothermal, and energy storage that can complement broader grid modernization. The DOE has also announced $1.3 billion in funding from the Bipartisan Infrastructure Law to further develop interstate transmission lines. A portion of this funding will go to the Southline Transmission Project, which connects New Mexico and Arizona grids, enabling substantial renewable energy development opportunities and creating new jobs in New Mexico and Arizona. In June 2023, the Department of the Interior proposed a rule making it easier for the development of wind and solar energy projects on public lands. Further investments in research and development of emerging long duration energy storage technologies, such as iron-air and thermal batteries, could help decarbonize the industrial sector, which consumes a third of the energy produced in the United States.

Though federal agencies have taken steps to facilitate permitting, significant barriers still exist. Chairman Heinrich has introduced the FASTER Act to improve upon existing transmission siting and permitting practices without compromising environmental standards. Legislation introduced by Senator Hickenlooper is designed to provide flexibility and capacity sharing between grid operators across the country. And various firms are deciding to nearshore supply chains—bringing manufacturing processes closer to home—to avoid snarls from extreme weather events and geopolitical crises.

Extreme weather events, which have increased in severity and frequency, pose a significant challenge to the electrical grid and the U.S. economy. Advanced technologies like AI promise to play an important role in managing increased energy demands, but they also create vulnerabilities. Investments by Congress and the Biden administration in renewables, grid enhancing technologies, and security protocols help strengthen the electricity grid, secure energy infrastructure, and protect Americans from the costs associated with extreme weather events.