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ELECTRICITY GRID RESILIENCE

Climate Change Is Expected to Have Far-reaching Effects and DOE and FERC Should Take Actions

Statement of Frank Rusco, Director,
Natural Resources and Environment

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Highlights

Highlights of GAO-21-423T, a testimony before the Committee on Environment and Public Works, U.S. Senate

March 2021

ELECTRICITY GRID RESILIENCE

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Why GAO Did This Study

According to the U.S. Global Change Research Program, changes in the earth's climate are under way and expected to increase, posing risks to the electricity grid that may affect the nation's economic and national security. Annual costs of weather-related power outages total billions of dollars and may increase with climate change, although resilience investments could help address potential effects, according to the research program. Private companies own most of the electricity grid, but the federal government plays a significant role in promoting grid resilience—the ability to adapt to changing conditions; withstand potentially disruptive events; and, if disrupted, to rapidly recover. DOE, the lead agency for grid resilience efforts, conducts research and provides information and technical assistance to industry. FERC reviews mandatory grid reliability standards.

This testimony summarizes GAO's report on grid resilience to climate change. Specifically, the testimony discusses (1) potential climate change effects on the electricity grid; and (2) actions DOE and FERC have taken since 2014 to enhance electricity grid resilience to climate change effects, and additional actions these agencies could take. GAO reviewed reports and interviewed agency officials and 55 relevant stakeholders.

What GAO Recommends

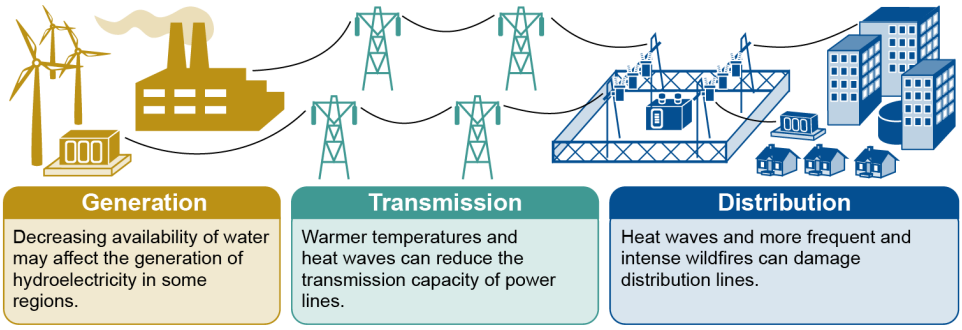
In its report, GAO made two recommendations (1) that DOE develop a department-wide strategy to enhance grid resilience to climate change, and (2) that FERC identify and assess climate change risks to the grid. The agencies neither agreed nor disagreed.

View GAO-21-423T. For more information, contact Frank Rusco at (202) 512-3841 or RuscoF@gao.gov.

What GAO Found

Climate change is expected to have far-reaching effects on the electricity grid that could cost billions and could affect every aspect of the grid from generation, transmission, and distribution to demand for electricity, according to several reports GAO reviewed. The type and extent of these effects on the grid will vary by geographic location and other factors. For example, reports GAO reviewed stated that more frequent droughts and changing rainfall patterns may adversely affect hydroelectricity generation in Alaska and the Northwest and Southwest regions of the United States. Further, transmission capacity may be reduced or distribution lines damaged during increasing wildfire activity in some regions due to warmer temperatures and drier conditions. Moreover, climate change effects on the grid could cost utilities and customers billions, including the costs of power outages and infrastructure damage.

Examples of Climate Change Effects on the Electricity Grid



Source: GAO analysis of reports. | GAO-21-423T

Since 2014, the Department of Energy (DOE) and the Federal Energy Regulatory Commission (FERC) have taken actions to enhance the resilience of the grid. For example, in 2015, DOE established a partnership with 18 utilities to plan for climate change. In 2018, FERC collected information from grid operators on grid resilience and their risks to hazards such as extreme weather. Nevertheless, opportunities exist for DOE and FERC to take additional actions to enhance grid resilience to climate change. For example, DOE identified climate change as a risk to energy infrastructure, including the grid, but it does not have an overall strategy to guide its efforts. GAO's Disaster Resilience Framework states that federal efforts can focus on risk reduction by creating resilience goals and linking those goals to an overarching strategy. Developing and implementing a department-wide strategy that defines goals and measures progress could help prioritize DOE's climate resilience efforts to ensure that resources are targeted effectively. Regarding FERC, it has not taken steps to identify or assess climate change risks to the grid and, therefore, is not well positioned to determine the actions needed to enhance resilience. Risk management involves identifying and assessing risks to understand the likelihood of impacts and their associated consequences. By doing so, FERC could then plan and implement appropriate actions to respond to the risks and achieve its objective of promoting resilience.

March 10, 2021

Chairman Carper, Ranking Member Capito, and Members of the Committee:

Thank you for the opportunity to discuss our report on climate change and the resilience of the electricity grid.[1] Climate change poses risks to the electricity grid—the power generation, transmission, and distribution system—that can potentially affect the nation's economic and national security. In 2013, we identified the federal government's management of climate change risks as a high-risk area due to the fiscal exposure it represents.[2] According to the U.S. Global Change Research Program, changes in the earth's climate are underway, and many extreme weather and climate-related events are expected to become more frequent and intense.[3] Extreme weather events have been the principal contributors to an increase in the frequency and duration of power outages in the United States.[4] Recent weather events—such as extreme heat and associated wildfires in California, extreme cold in Texas, and Hurricane Isaias on the East Coast—have adversely affected millions of electric utility customers.

[1]GAO, *Electricity Grid Resilience: Climate Change Is Expected to Have Far-reaching Effects and DOE and FERC Should Take Actions*, GAO-21-346 (Washington, D.C.: Mar. 5, 2021).

[2]The rising number of natural disasters and increasing reliance on the federal government for assistance is a key source of federal fiscal exposure. The costliness of disasters is projected to increase as extreme weather events become more frequent and intense due to climate change. See GAO, *High-Risk Series: An Update,* GAO-13-283 (Washington, D.C.: Feb. 14, 2013).

[3]Greenhouse gases already in the atmosphere are expected to continue to alter the climate in the future, regardless of efforts to control emissions, according to the U.S. Global Change Research Program (USGCRP) and the National Academies of Sciences, Engineering, and Medicine (National Academies). Nevertheless, according to the Fourth National Climate Assessment, more immediate and substantial global greenhouse gas emissions reductions, as well as regional adaptation efforts are needed to avoid the most severe consequences of climate change in the long term. USGCRP, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. II (Washington, D.C.: 2018).

[4]According to the Quadrennial Energy Review and the USGCRP's Fourth National Climate Assessment, the leading cause of power outages in the United States is extreme weather. Quadrennial Energy Review (QER) Task Force, *Transforming the Nation's Electricity System: The Second Installment of the QER* (January 2017). Extreme weather includes high winds, thunderstorms, hurricanes, heat waves, intense cold periods, intense snow events and ice storms, and extreme rainfall. Such events can interrupt energy generation, damage energy resources and infrastructure, and interfere with fuel production and distribution systems, causing fuel and electricity shortages or price spikes.

Moreover, power disruptions during extreme weather events illustrate the need to plan for climate change risks and invest in climate resilience.[5]

Private companies own most of the electricity grid in the United States, but the federal government plays a significant role in promoting grid resilience—the ability to adapt to changing conditions; withstand potentially disruptive events, such as the loss of power lines; and, if disrupted, to rapidly recover.[6] According to the National Academies of Sciences, Engineering, and Medicine (National Academies), no single entity is responsible for, or has the authority to implement, a comprehensive approach to grid resilience.[7] However, the U.S. Department of Energy (DOE) and the Federal Energy Regulatory Commission (FERC) play an important role in shaping electric industry decisions to adopt grid resilience measures. DOE is the lead agency for federal grid resilience efforts, conducts research and development on relevant technologies, and provides industry and other stakeholders with information and technical assistance. FERC regulates wholesale electricity markets and the transmission of electric energy in interstate commerce; reviews and approves mandatory grid reliability standards; and issues licenses for the construction of new hydropower projects, among other things.

My testimony today summarizes the findings in our report on grid resilience to climate change. Accordingly, this testimony discusses (1) the potential effects of climate change on the electricity grid; and (2) actions DOE and FERC have taken since 2014 to enhance the resilience of the electricity grid to climate change effects, and additional actions the agencies could take to further enhance resilience. For the report, we reviewed relevant laws, documents, and reports; and interviewed agency officials and stakeholders who are knowledgeable about grid operations, climate change, and resilience measures. Additional information on our scope and methodology is available in our report. Our work was

[5]GAO, *Extreme Weather Events: Limiting Federal Fiscal Exposure and Increasing the Nation's Resilience,* GAO-14-364T (Washington, D.C.: Feb. 12, 2014).

[6]For purposes of this testimony, we use the definition of "resilience" in Presidential Policy Directive 21, which establishes national policy for critical infrastructure security and resilience. Specifically, Presidential Policy Directive 21 defines resilience as the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions, including naturally occurring threats or incidents.

[7]National Academies of Sciences, Engineering, and Medicine, *Enhancing the Resilience of the Nation's Electricity System* (July 2017).

performed in accordance with generally accepted government auditing standards.

Climate Change Is Expected to Have Far-reaching Effects on the Electricity Grid That Could Cost Billions

Climate change is expected to have far-reaching effects on the electricity grid that could cost billions and affect every aspect of the electricity grid, from generation, transmission, and distribution to end-user demand, according to several reports we reviewed. The type and extent of the effects of climate change on the grid will vary by geographic location, energy source, condition of grid infrastructure, and other factors, according to several stakeholders we interviewed and reports we reviewed. According to the Fourth National Climate Assessment, many regions will experience more than one climate-related effect. For example, a region may see more extreme rainfall combined with coastal flooding, or extreme heat coupled with drought. However, warmer temperatures and more heat waves could affect all regions in the United States and could decrease the efficiency of electricity generation, transmission, and distribution systems, according to reports we reviewed.

The effects of climate change could cost billions, including the costs of power outages to utility customers and costs from storm damage, among others.[8] Specifically, three reports we reviewed estimated that the average annual costs of severe weather-related outages to utility

[8]As we reported in 2017, information on the economic effects of climate change is developing and imprecise, but it can convey insights into the nation's regions and sectors that could be most affected. Decision makers need more comprehensive information on economic effects to better understand the potential costs of climate change to society and begin to develop an understanding of the benefits and costs of different adaptation options, according to a 2010 National Academies report, literature reviewed, and experts GAO interviewed for that report. GAO, *Climate Change: Information on Potential Economic Effects Could Help Guide Federal Efforts to Reduce Fiscal Exposure,* GAO-17-720 (Washington, D.C.: Sept. 28, 2017).

customers in the United States totaled billions each year.[9] In the absence of measures to enhance resilience, more frequent and severe weather associated with climate change is likely to increase the cost of outages, according to these reports. According to one report, the total annual cost of outages to utility customers is estimated to increase from roughly $55 billion over the 2006-2019 period to over roughly $480 billion during the 2080-2099 period in 2019 dollar values, absent aggressive grid resilience mitigation measures.[10] Power outages affect residential, commercial, industrial, and other customers' ability to use electricity for lighting, heating, cooling, and refrigeration; and for operating appliances, computers, electronics, machinery, and public transportation systems. Moreover, power outages can disproportionately affect vulnerable populations that rely on continued electricity service to address certain health conditions.[11] In addition, low-income groups are more vulnerable to events such as heat waves given their limited ability to meet higher

[9]Three reports we reviewed included estimates of the average annual cost of weather-related outages in the United States which range from about $2 billion to about $77 billion (2019 dollar values). Congressional Research Service, *Weather-Related Power Outages and Electric System Resiliency* (Aug. 28, 2012); Executive Office of the President, *Economic Benefits of Increasing Electric Grid Resilience to Weather Outages* (August 2013); and Peter H. Larsen et al., *Projecting Future Costs to U.S. Electric Utility Customers from Power Interruptions* (2017). These estimates cover periods ranging from the mid-1980s through 2012. The three reports differed with respect to the types of costs that they estimated and the data and methods underlying the report. The estimates are based on surveys of customers' willingness to pay to avoid outages or the estimated losses they would incur as a result of an outage, but the estimates do not account for all costs, including indirect costs on individuals, businesses, and local or regional economies. The large range—from $2 billion to $77 billion—reflects differences in what is counted and in methodologies. For example, the $2 billion estimate accounts for outages that are due to severe weather, while the $77 billion estimate includes outages that lasted over 5 minutes that were attributed to weather.

[10]Larsen et al., *Projecting Future Costs to U.S. Electric Utility Customers.* This report projected the future customer costs of power outages through 2099, using climate change scenarios as one of the cost drivers in its model, and estimated changes in future severe weather metrics under 10 scenarios—including two climate change scenarios. The report did not include Hawaii or Alaska nor did it include any indirect (i.e., spillover) effects to the broader economy from power outages.

[11]For example, after Hurricanes Maria and Irma caused widespread power outages in Puerto Rico and the U.S. Virgin Islands, we reported that the chronically ill often did not have access to electricity to power their medical devices, such as ventilators. GAO, *Disaster Response: HHS Should Address Deficiencies Highlighted by Recent Hurricanes in the U.S. Virgin Islands and Puerto Rico*, GAO-19-592 (Washington, D.C.: Sept. 20, 2019). According to the Fourth National Climate Assessment, poor or marginalized populations often face a higher risk from climate change because they live in areas with higher exposure, are more sensitive to climate impacts, or lack the capacity to respond to climate hazards.

energy costs and invest in measures to minimize the impact of outages, such as backup generators. Power outages can also have significant cascading effects on critical sectors such as health, transportation, and telecommunications.[12] In recent years, power outages resulting from extreme weather events have affected millions of customers. For example,

- In February 2021, extreme cold weather from the Canadian border as far south as Texas resulted in record winter power demand and left about 4.5 million customers in Texas without power, along with about 376,000 customers in Louisiana and Oklahoma.
- In 2019, dry and windy conditions in California that increased the risk of wildfires resulted in public safety power shutoff events that affected more than 1 million customers with an estimated economic cost of $2 billion.[13]
- In September 2017, Hurricanes Irma and Maria damaged Puerto Rico's electricity grid, causing the longest blackout in U.S. history.
- In August 2017, Hurricane Harvey left over 300,000 customers in Texas without power after the storm damaged electricity generation and transmission lines. The power outages affected critical infrastructure, such as hospitals, water and wastewater treatment plants, and refineries, and contributed to an increase in gasoline prices, regionally and nationally.

In addition to the costs of power outages to utility customers, extreme weather associated with climate change can increase the financial risk to utilities by contributing to sharp increases or declines in demand for electricity, according to one report.[14] Specifically, extreme weather

[12]Critical sectors rely on electricity, but the reliable operation of the grid also depends on the performance of multiple supporting infrastructures. Power outages can be caused by disruptions to other sectors such as telecommunications, natural gas, and transportation, among other critical infrastructures.

[13]Rocky Mountain Institute, *Reimagining Grid Resilience* (2020). Three utilities in California are authorized to perform public safety power shutoffs in fire-prone areas to prevent wildfires caused by energized transmission and distribution lines. In October 2019, one California utility announced that it would issue $86 million in credits to its customers for one of these public safety power shutoffs.

[14]Moody's Analytics, *Regulated Electric Utilities in the United States: Intensifying Climate Hazards to Heighten Focus on Infrastructure Investments* (January 2020). Sharp volatility in demand could affect liquidity because utilities will need to buy or sell power or natural gas as demand fluctuates.

conditions require more backup generation, which increases costs and can heighten the risk of system stress and service interruptions, according to this report. In addition, utilities and other entities, such as the federal government, also incur costs from storm damage resulting from severe weather. These costs could increase as the frequency and intensity of weather events increase in the future. According to one report, total annual expenditures for transmission and distribution infrastructure in the contiguous United States were found to increase with climate change by as much as 25 percent (or about $25 billion) in 2090 as compared with annual expenditures in 2015.[15]

Investments in measures to enhance resilience can be expensive and it can be difficult for utilities to calculate the return on such investments because the benefit typically is realized only when a major event threatens the reliability of service. As a result, these investments can be difficult to justify, and utilities must balance the need to enhance resilience with the associated costs, which could result in increases to the rates charged to customers.[16] Further, increases in rates could disproportionately affect low-income populations that spend a greater portion of their income on energy expenses. It is important for utilities and other stakeholders to take vulnerable and disadvantaged populations into account when planning for and investing in resilience because many

[15]Charles Fant et al., *Climate Change Impacts and Costs to U.S. Electricity Transmission and Distribution Infrastructure* (January 2020). According to the report, total annual increase in expenditures on transmission and distribution infrastructure due to climate change could range from $6 billion to about $25 billion with climate change by 2090 as compared with annual expenditures in 2015, but expected costs are estimated to decrease by half if resilience measures are adopted. The report estimates these costs using two emission scenarios and three response cases—(1) no adaptation, (2) reactive adaptation, and (3) proactive adaptation. The $6 billion increase estimate is associated with a proactive adaptation strategy under a climate scenario where greenhouse gas emissions have been "significantly" reduced, while the $25 billion increase estimate is associated with a substantial warming scenario due to high emissions and with no adaptation strategy. It considers temperature, precipitation, lightning, wildfires and vegetation growth but does not consider floods, high winds (including hurricanes), or ice storms. All figures reported here have been converted to 2019 dollar values.

[16]In a March 2021 report, we found that most utilities recover the cost of resilience measures through rates paid by the utilities' customers. Utilities face challenges justifying investments and obtaining regulatory approval, and some utilities have limited resources to pursue resilience enhancements, such as researching grid resilience technologies. GAO, *Electricity Grid: Opportunities Exist for DOE to Better Support Utilities in Improving Resilience to Hurricanes*, GAO-21-274 (Washington, D.C.: Mar. 5, 2021).

customers cannot afford rate increases to pay for resilience investments, according to several stakeholders and reports we reviewed.

DOE and FERC Have Taken Actions to Enhance Grid Resilience and Have Opportunities to Further Address Climate Change

DOE and FERC have taken some actions since 2014 to enhance the resilience of the electricity grid. According to stakeholders we interviewed and reports we reviewed, opportunities exist for DOE and FERC to take additional actions to further enhance the resilience of the grid to climate change.

Regarding DOE, the agency has provided information and technical assistance, supported research through its Grid Modernization Initiative and other efforts, and developed resilience tools. DOE has taken some actions consistent with principles described in our Disaster Resilience Framework.[17] However, DOE does not have a strategy to guide its efforts to enhance the resilience of the grid to climate change. In addition, it has not established goals, objectives, or performance measures for its climate change resilience efforts. Our report recommends that DOE develop and implement a department-wide strategy to coordinate its efforts that defines goals and measures progress to enhance the resilience of the electricity grid to the risks of climate change. Developing and implementing a grid strategy for climate change that defines specific goals and measures progress could help guide DOE's agency-wide grid climate resilience efforts and help the agency prioritize actions to ensure that resources are targeted effectively. For example, such a strategy could describe and prioritize DOE efforts to coordinate with industry and other federal agencies; conduct research and development through the

[17]GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters,* GAO-20-100SP (Washington, D.C.: Oct. 23, 2019).

National Laboratories; and identify incentives, such as existing grant programs.[18] DOE neither agreed nor disagreed with our recommendation.

Regarding FERC, the agency has taken several actions to enhance the resilience of the grid. For example, FERC has collected and shared information, assessed grid vulnerabilities, and approved reliability standards that could affect grid resilience. Moreover, on February 22, 2021, FERC announced that it would open a new proceeding to examine the threat that climate change and extreme weather events pose to electric reliability.[19] However, opportunities exist for FERC to take specific actions to further enhance grid resilience to climate change, according to several stakeholders we interviewed and documents we reviewed. The actions stakeholders identified include developing climate resilience standards and guidance; identifying whether statutory changes are needed to address climate change risks; and examining whether and how the Commission should consider climate change risks when reviewing and approving projects, such as hydropower facilities. While the new proceeding might pose opportunities to take specific actions do so, FERC has not taken steps to identify and assess risks posed to the grid by climate change or plan a response. Our report recommends that FERC take steps to identify and assess climate-related risks to the electricity grid, and plan a response, including identifying actions to address the risks and enhance the resilience of the grid to climate change. By taking steps to identify and assess climate-related risks and plan a response, including identifying the actions needed to enhance the resilience of the grid to climate change, FERC could better manage such risks and achieve its objective of promoting resilience. FERC neither agreed nor disagreed with our recommendation.

[18]DOE oversees 17 National Laboratories, which are charged with conducting research and development on behalf of DOE and can perform such work for other federal agencies and nonfederal or private entities, including utilities. DOE program offices support a range of research and development activities related to climate change. For example, DOE's Office of Science supports several climate change-related projects at the National Laboratories. In addition, DOE can provide financial assistance to further its mission and goals in the form of formula and competitive grants, cooperative agreements, and prizes (i.e., competitions). DOE officials told us that they plan to release a funding opportunity announcement in fiscal year 2021 to support energy resilience initiatives. According to these officials, the funding is intended to enhance resilience of critical energy infrastructure to mitigate against malicious and natural threats, including extreme weather events resulting from climate change.

[19]FERC announced that the new proceeding will examine how grid operators prepare for and respond to extreme weather events, including, but not limited to droughts, extreme cold, wildfires, hurricanes, and prolonged heat waves.

In conclusion, recent weather events—such as extreme heat and associated wildfires, extreme cold, and hurricanes—have adversely affected millions of electric utility customers. Power disruptions during extreme weather events illustrate the need to plan for climate change risks and invest in climate resilience. DOE and FERC have taken actions to enhance the resilience of the electricity grid. Nevertheless, we found opportunities for both agencies to take actions to further enhance grid resilience to climate change. The federal government plays an important role in shaping electric industry decisions to adopt grid resilience measures. As our Disaster Resilience Framework states, federal efforts should improve the availability of authoritative, understandable, and comprehensive information on disaster risks and risk reduction strategies to help entities effectively assess their climate risks, determine what viable alternatives are available to increase resilience to those risks, and better understand and measure the impact of resilience strategies. Moreover, the federal government has an opportunity to act as a trusted clearinghouse and integrator of federal and nonfederal information in a way that enhances its reach and value. Federal efforts can leverage the expertise and resources of other partners across agencies, governments, and industry sectors, bringing together the disparate missions and resources that support disaster risk reduction to help build national resilience to natural hazards.

Chairman Carper, Ranking Member Capito, and Members of the Committee, this concludes my prepared statement. I would be pleased to respond to any questions you may have at this time.

GAO Contact and Staff Acknowledgments

If you or your staff have any questions about this report, please contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report.

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