United States Government Accountability Office

Report to Congressional Committees

June 2022

ELECTRICITY GRID

DOE Should Address Lessons Learned from Previous Disasters to Enhance Resilience

Accessible Version

GAO-22-105093

GAO Highlight

Highlights of GAO-22-105093, a report to congressional committees

Why GAO Did This Study

Natural disasters, such as cyclones, earthquakes, hurricanes, wildfires, and severe storms—and the power outages resulting from these disasters—have affected millions of customers and cost billions of dollars. The growing severity of wildfires and extreme weather events in recent years has been a principal contributor to an increase in the frequency and duration of power outages in the U.S. Federal agencies, such as DOE and the Federal Emergency Management Agency, play a significant role in disaster response, recovery, and resilience.

This report (1) identifies lessons learned from federal, state, and other entities' responses to selected disasters that affected the electricity grid from 2017 to 2021; and (2) examines federal agency actions to address those lessons learned. GAO selected a nongeneralizable sample of 15 of 35 disasters that affected the grid from 2017 to 2021. The 15 selected were among the most severe events across a range of types, locations, and years. GAO also examined agency and industry responses; reviewed relevant reports, policies, and documents; and interviewed federal, state, and local officials, as well as selected industry stakeholders.

What GAO Recommends

GAO is making one recommendation: that DOE establish a comprehensive approach to enhance coordination among its disaster response, grid recovery, and technical assistance efforts, including integrating lessons learned from prior disasters. DOE agreed with GAO's recommendation.

View GAO-22-105093. For more information, contact Frank Rusco at (202) 512-3841 or RuscoF@gao.gov.

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DOE Should Address Lessons Learned from Previous Disasters to Enhance Resilience

What GAO Found

In responding to selected disasters occurring between 2017 and 2021, federal, state, and other stakeholders identified lessons learned in the areas of planning and coordination, workforce and training, tools and technology, and local capacity. In the area of planning and coordination, agency officials and reports highlighted that disaster responses were more effective when strong working relationships existed between federal, industry, and local stakeholders. Regarding workforce and training, a Department of Energy (DOE) report emphasized the importance of having a dedicated pool of responders with expertise in grid reconstruction and recovery, especially when responding to multiple, concurrent or successive disasters.

Power Crews Work on Damaged Lines Following a Hurricane in 2020

Source: Federal Emergency Management Agency. | GAO-22-105093

Federal agencies have taken steps to address lessons learned by improving workforce and training, tools and technology, and local capacity. For example, to address workforce lessons, DOE began deploying a Catastrophic Incident Response Team to quickly bring responders with subject-matter expertise to affected areas. However, DOE does not have a comprehensive approach for coordinating its broader grid support mission that includes disaster response, grid recovery, and technical assistance efforts. Specifically, roles and responsibilities within DOE for transitioning from response to recovery are unclear, as are how lessons learned from previous disasters are used to prioritize recovery and technical assistance efforts. GAO's Disaster Resilience Framework states that bringing together the disparate missions and resources that support disaster risk reduction can help build resilience to natural hazards. By establishing a comprehensive approach that clearly defines roles and responsibilities, and acting on lessons learned across DOE, the department could better target resources and technical assistance. This approach, in turn, can lead to enhanced grid resilience and reduced disaster risk.

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Abbreviations

AAR	after-action review
BRIC	Building Resilient Infrastructure and Communities
CESER	Office of Cybersecurity, Energy Security, and Emergency Response
CIRT	Catastrophic Incident Response Team
DHS	Department of Homeland Security
DOE	Department of Energy
EAGLE-I	Environment for Analysis of Geo-Located Energy Information
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GIS	geographic information systems
IMAT	Incident Management Assistance Team
NERC	North American Electric Reliability Corporation
NOAA	National Oceanic and Atmospheric Agency
OE	Office of Electricity
RTO	regional transmission organization
USACE	U.S. Army Corps of Engineers

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

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Natural disasters, such as earthquakes, hurricanes and typhoons, severe storms and temperatures, and wildfires are the leading cause of power outages in the U.S. that have affected millions of customers and cost billions of dollars.[1] The growing severity of wildfires and extreme weather events in recent years has been a principal contributor to an increase in the frequency and duration of U.S. power outages. For example, in 2018, the U.S. and its territories experienced 13 disasters that impacted the grid, including nine tropical cyclones, three wildfires, one earthquake, and one volcanic eruption. In February 2021, extreme cold weather that stretched from the Canadian to the Mexican border resulted in unplanned generator outages and record winter power demand that left about 4.5 million customers in Texas, along with about 376,000 customers in Louisiana and Oklahoma, without power.

According to the U.S. Global Change Research Program, changes underway in the earth's climate are expected to make extreme weather and other climate-related events more frequent and intense.[2] This anticipated change presents risks that may have far-reaching effects on every aspect of the electricity grid, from generation, transmission, and distribution to demand for electricity. This in turn, may affect our economic and national security.

[1]This report will focus on the types of natural disasters mentioned above, which will hereafter be referred to as "disasters," with a few exceptions. These disasters exclude human-caused hazards, such as cyberattacks. According to the National Oceanic and Atmospheric Administration (NOAA), tropical storms, hurricanes, and typhoons are all the same weather phenomenon: tropical cyclones.

[2]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 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 emission reductions, as well as regional adaptation efforts, are needed to avoid the most severe consequences of climate change in the long term. See U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. II (Washington, D.C.: 2018).

Under the federal government's National Response Framework, which describes how the federal government, states and localities, and other public and private sector institutions are to respond to disasters and emergencies, electric utilities are responsible for repairing infrastructure and restoring service. They often use mutual assistance—voluntary partnerships with other electric utilities—to bring in additional resources to help restore electricity. Under the National Response Framework, when appropriate, federal agencies provide financial assistance for response and recovery activities, help coordinate the response, gather and share information, and communicate with key stakeholders and the public.[3] Also, in severe emergencies, federal agencies can provide some logistical support, such as assisting in damage assessments and locating and transporting repair crews and equipment.

The federal government also plays a significant role in responding to disasters and supporting grid resilience through various funding programs, research and development, and information-sharing initiatives. Supporting grid resilience can include taking actions to help prepare for, withstand, and rapidly recover from significant service disruptions caused by extreme events, such as hurricanes.[4] In particular, the Federal Emergency Management Agency (FEMA), within the Department of Homeland Security (DHS), leads the federal response to disasters. FEMA is to coordinate with the Department of Energy (DOE)—including the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) and the Office of Electricity (OE)—and the U.S. Army Corps of Engineers (USACE) on risks to the electricity grid. DOE is to conduct research and development and provide analytical support for efforts designed to ensure the resilience of the electricity grid. Lastly, the Federal Energy Regulatory Commission (FERC) reviews and approves mandatory grid reliability standards that are intended to ensure reliable planning and operations of the grid and conducts inquiries into major outages.

[3]For the purposes of this report, "response" refers to the immediate emergency restoration work that is generally part of the initial response phase to a disaster, and "recovery" refers to long-term efforts to rebuild.

[4]Presidential Policy Directive 21 states that the term "resilience" means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. See White House, Office of the Press Secretary, *Presidential Policy Directive—Critical Infrastructure Security and Resilience Presidential Policy Directive/PPD-21* (Washington, D.C.: Feb. 12, 2013).

The Additional Supplemental Appropriations for Disaster Relief Act of 2019 included a provision that we conduct audits and investigations related to certain declared natural disasters.[5] This report (1) identifies lessons learned from federal, state, and other entities' responses to disasters that affected the electricity grid from 2017 to 2021; and (2) examines federal agency actions to address those lessons learned.

To address both of these objectives, we selected a nongeneralizable sample of 15 disasters to focus our analysis on lessons learned from the response to disaster-caused grid disruptions. We first identified the 35 disasters occurring between 2017 and 2021 that required an Emergency Support Function #12 (ESF #12) response. ESF #12 events are those that required federal coordination for the reestablishment of damaged energy systems, as discussed below. From these, we selected a nongeneralizable sample of 15 disaster responses that were among the most severe of the 35 across a range of incident types, geographic locations, and response years. To identify the more severe cases, we used the number of ESF #12 responders deployed by DOE as a proxy for the magnitude of the effects of the disasters. Findings from our review of disasters cannot be generalized to those we did not select and include in this report.

To identify lessons learned, we reviewed approximately 50 federal, state, and nongovernmental reports containing lessons learned related to the 15 selected disasters. To identify the reports that were relevant to our selection, we requested after-action review (AAR) reports from federal agencies (i.e., DOE, FEMA, FERC, and USACE), conducted a literature search, reviewed prior GAO work, and asked for recommendations from stakeholders we interviewed. We also identified lessons learned by speaking with 30 federal agency officials from DOE, FEMA, FERC, and USACE that had a role in energy disaster response and grid resilience efforts. In particular, we spoke to eight ESF #12 responders at DOE, who have been deployed to national and regional response centers during multiple active disaster responses in our sample. We also spoke with two CESER officials charged with managing the ESF #12 response to gain a

[5]Additional Supplemental Appropriations for Disaster Relief Act, 2019, Pub. L. No. 116-20, 133 Stat. 871, 892-93.

program perspective and to hear their thoughts on the lessons identified by ESF #12 responders.[6]

We analyzed the findings of those reports and interviews to identify lessons related to grid impacts and grid-related responses. We categorized those lessons by common themes (e.g., planning and coordination, workforce and training, tools and technology) and reported those lessons that were most frequently cited by reports and agency officials and that we determined were relevant to the disasters we reviewed. Of the federal agency AARs and interviews, DOE's were the most relevant to our analysis, because of the department's role as the lead agency for ESF #12 Energy.

To examine federal agency actions to address lessons learned, we reviewed agency AARs that contained action items and examined agency procedures for tracking and addressing lessons learned. In addition, we interviewed agency officials responsible for disaster response and resilience programs, including those responsible for tracking lessons learned. After gathering lessons learned by ESF #12 responders, we interviewed CESER officials to gain their perspectives on lessons identified by responders and to identify and evaluate any actions being taken to address those lessons. Furthermore, we spoke to DOE officials outside of CESER—including OE and the Office of Energy Efficiency and Renewable Energy (EERE)—to identify any relevant policies and to evaluate the extent to which lessons learned are communicated across DOE response, resilience, and technical assistance efforts.

For both objectives, we interviewed 18 officials at state agencies involved in the disaster preparedness and response process from varying geographic locations in the U.S., including Alaska, Florida, Georgia, and Hawaii, as well as officials from the National Association of State Energy Officials (NASEO).[7] We also sought to gain industry perspectives by reviewing utility documents; interviewing industry officials, including

[6]To characterize the views of CESER officials and ESF #12 responders throughout this report, we defined modifiers to quantify the 10 officials we interviewed as follows: "nearly all" represents nine officials; "most" represents six to eight officials; "several" represents four to five officials; and "some" represents two to three officials.

[7]We also contacted the relevant Texas and California State agencies, but they did not respond to our requests for interviews. However, we were able to access and review relevant public documents and submissions to utility commission dockets. We included this information, where appropriate.

representatives from utilities, regional transmission organizations (RTO), and industry groups and associations; and by relying on interviews from recent GAO work where perspectives on grid resilience and disaster lessons learned were discussed.[8] We generally asked the same questions during each interview and identified stakeholders by reviewing documents and obtaining recommendations during our interviews about others knowledgeable about grid response efforts. Views of the stakeholders we interviewed cannot be generalized to those we did not select and interview for our review. A more detailed description of our scope and methodology is included in appendix I.

We conducted this performance audit from March 2021 to June 2022, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The Electricity Grid and Electricity Industry

The electricity grid involves three distinct functions: generation, transmission, and distribution. Electricity is generated at power plants by burning fossil fuels; through nuclear fission; or by harnessing renewable sources such as wind, solar, geothermal, or hydropower. Once electricity is generated, it moves through the electricity grid, which consists of high-voltage, high-capacity transmission lines, to areas where it is transformed to a lower voltage and sent through the local distribution system for use by residential and other customers. Throughout this process, a grid

[8] In much of the central, southeastern, and western U. S., integrated utilities operate the grid and provide generation, transmission, and distribution services to all retail customers in a specified area. In other parts of the U. S., RTOs act as grid operators and manage regional networks of electric transmission lines that would otherwise be operated by individual utilities. In some RTO areas, integrated utilities act as electricity suppliers of generation, transmission, and distribution services to retail customers. In other RTO areas, electricity suppliers purchase electricity produced at independently owned power plants to sell to retail customers. While major sections of the country operate under more traditional market structures, two-thirds of the nation’s electricity is served in RTO regions. Independent operators of the transmission system can be referred to as RTOs or independent system operators.

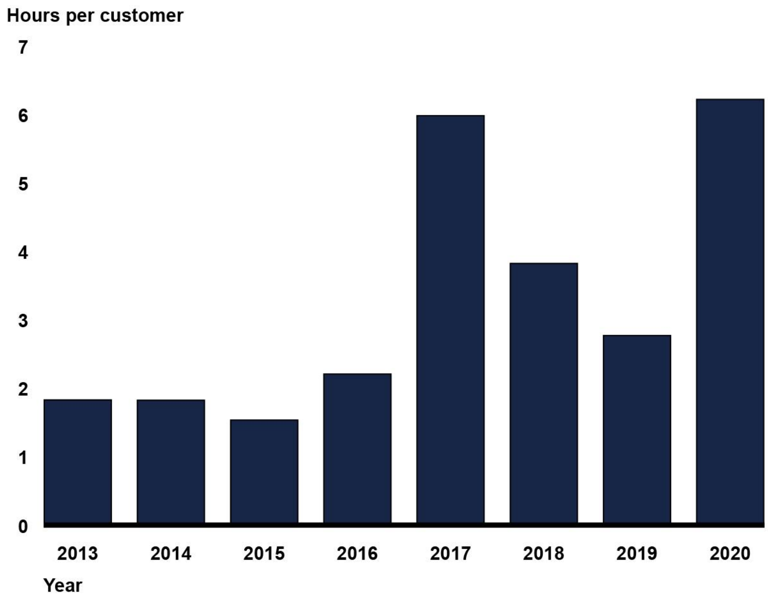
operator or utility must constantly balance the generation and consumption of electricity.

Overall, there are three main types of electric utilities: (1) investor-owned utilities, (2) publicly owned utilities, and (3) electric cooperatives. Investor-owned utilities are large, private, electric utilities that issue stock owned by shareholders. Almost three-quarters of utility customers get their electricity from investor-owned utilities that are most prevalent in heavily populated areas on the East and West Coasts of the U. S. Publicly owned utilities include federal-, state-, and municipal-run utilities. Electric cooperatives are not-for-profit, member-owned utilities that tend to serve customers in rural areas. The responsibility for regulating the electricity industry is divided between the states and the federal government. Most electricity customers are served by electric utilities that are regulated by the states, generally through state public utility commissions or equivalent organizations.

Effects of Disasters on the Electricity Grid

Disasters such as earthquakes, hurricanes and typhoons, severe storms and temperatures, volcanic eruptions, and wildfires can produce dangerous effects and conditions that cause significant damage to the electricity grid infrastructure, including power plants, substations, and transmission or distribution lines. For example, according to the Energy Information Administration (EIA), Hurricane Isaias in 2020 left about 750,000 electricity customers in Connecticut without power, some for over a week. Moreover, power restoration following Hurricanes Irma and Maria in 2017 took roughly 5 months in the U.S. Virgin Islands and roughly 11 months in Puerto Rico. Figure 1 below depicts the impact that major disasters had on the duration of power outages in recent years.

Figure 1: Average Duration of Total Annual Electric Power Outages Associated with Major Events in the Continental U. S. (2013–2020)



Source: GAO analysis of Energy Information Administration (EIA) data. | GAO-22-105093

Accessible Data Table for Figure 1

Year	*SAIDI*	
	without major events	**with major events**
2013	1.768	1.827
2014	1.828	1.822
2015	1.885	1.532
2016	1.948	2.205
2017	1.907	5.978
2018	1.953	3.820
2019	1.977	2.767
2020	1.983	6.215

Note: EIA data on major events include interruptions caused by events that exceed reasonable design or operational limits of the electric power system, such as disasters. Major events in U.S. territories (e.g., the Northern Mariana Island and Puerto Rico) are not depicted here because EIA does not collect data from U.S. territories.

Disasters have varying levels of effects on the grid and its operations, depending on the affected area and the intensity of the event. Hurricanes, flooding, and other severe weather events can result in dangerous debris, while ground shaking, landslides, soil liquefaction, or lateral spreading from earthquakes make electrical infrastructure more seismically vulnerable. For example, the epicenter of the 2020 earthquake in Puerto

Rico was not far from two of Puerto Rico's largest power plants. The physical damage resulting from the earthquake caused widespread power outages, and approximately 900,000 of Puerto Rico's 1.5 million customers temporarily lost power, according to EIA. Similarly, destruction caused by wildfires can threaten portions of the electricity grid and, in some cases, the path of wildfire destruction is difficult to predict, increasing challenges to the response, as illustrated by the 2018 wildfire season in California.[9] Furthermore, volcanic eruptions can cause ash-induced impacts that have the potential to affect grid-related equipment at each phase of electricity delivery.

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, as we reported in March 2021.[10] Power outages can also have significant consequences for critical economic and industrial sectors, such as health care, transportation, and telecommunications. While critical sectors rely on electricity, 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; transportation; and natural gas delivery, among other critical infrastructures. Interdependencies exist between certain sectors that are so closely connected that damage, disruption, or destruction to one infrastructure element in one sector can cause cascading effects, potentially affecting the continued operations of another.[11] See table 1 for examples of the costs and effects of power outages.

[9]The combination of dry conditions and high winds can cause trees and debris to contact energized lines and damage electrical equipment, which can cause a wildfire. As preventative measure in such conditions, utilities employ what is known as a public safety power shutoff, where they deenergize at-risk lines in order to reduce the likelihood that equipment would start a wildfire. One utility official told us that, because of weather conditions and varying topography, certain areas experience these shutoffs more often than others.

[10]See 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.: March 2021).

[11]For example, in 2018, the President's National Infrastructure Advisory Council highlighted the communications sector's reliance on the energy sector and, likewise, disaster restoration and recovery are next to impossible without working communications.

Table 1: Examples of the Costs and Effects of Power Outages

Types of cost or effect	Examples
Residential customer losses	• Spoilage of items dependent on refrigeration • Inability to use elevators, appliances, fans, and lighting • Inability to heat and cool homes (HVAC and boilers), and associated health impacts • Inability to use ATM machines • Inability to refuel at gas stations • Public safety hazards (e.g., disruptions to street and traffic lights)
Commercial and industrial sector losses	• Diminished or halted production of goods and services • Spoilage of inventory dependent on refrigeration
Critical infrastructure disruptions	• Drinking water and wastewater • Telecommunications • Transportation (failure of road and rail traffic signals) • Hospitals/health care (loss of power to medical machinery and instrumentation, such as ventilators and dialysis machines) • Emergency services • Energy sector
Supply chain disruptions	• Impact on businesses that did not lose power but were negatively affected because they rely on businesses that did lose power

Source: GAO analysis of reports and documents that describe the range of effects of power outages. See 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.: March 2021). I GAO-22-105093

Federal Role in Disaster Response

The National Response Framework outlines 15 ESFs, which are the primary response coordinating structures at the federal level. ESFs are a way to group functions that provide federal support to states and federal-to-federal support. The federal government and many state governments organize their response resources and capabilities under the ESF construct. Each ESF is composed of a department or agency that has been designated as the coordinator, along with a number of primary and support agencies.

DOE is the coordinating agency for ESF #12 Energy. Specifically, ESF #12 is to facilitate the reestablishment of damaged energy systems and components and provide technical expertise during an incident involving radiological/nuclear materials. Functions include, but are not limited to, (1) energy infrastructure assessment, repair, and reestablishment; (2) energy industry utilities coordination; and (3) forecasting impacts to electricity delivery. DOE is supported by other agencies, including USACE, which is primarily responsible for emergency generator installation under ESF #12, in addition to its ESF #3 public works and engineering mission.

Additionally, responders are to coordinate across ESF functions. For example, ESF #12 responders may work closely with ESF #3 responders (Public Works and Engineering) on issues related to access to public services. In addition, federal agencies provide support for efforts to enhance grid resilience that may reduce the effects of disasters and improve disaster response.

As we reported in March 2021, grid resilience efforts include funding to rebuild utilities and communities in a way that reduces future disaster losses and developing technologies that can improve disaster response and reduce disaster impacts and response time.[12] For example, DOE and its national laboratories have developed various models that can help in preparing for and responding to major weather-related outages, such as those caused by hurricanes. DOE and FEMA also assist states in developing emergency operations plans to address all-hazards situations and energy assurance plans specific to grid-related impacts.

DOE, FEMA, and USACE formally outline lessons learned in annual AARs. These AARs pertain to specific disasters or years and outline lessons learned based on the agency’s role in responding to the disaster. Specifically, FEMA AARs cover the federal response and issues across energy and other sectors for each declared disaster. USACE also issues disaster-specific AARs, and their energy-related lessons learned address their role of providing emergency generator support. DOE compiles AARs on an annual basis but may also develop event-specific AARs when there is a prominent ESF #12 role, according to agency officials. Furthermore, federal agencies involved in disaster response coordinate via the Emergency Support Function Leadership Group and the Recovery Support Function Leadership Group, federal interagency bodies designed to identify and facilitate resolution of operational and policy challenges related to disaster response and recovery. FEMA, DOE, and USACE officials told us that they share lessons learned and track action items via this group.

In addition, FERC conducts inquiries and investigations of major power outages and other grid-related events to determine the causes of such outages and develop recommendations to mitigate future disruptions under similar circumstances, including whether new or modified reliability

[12]See GAO, *Electricity Grid: Opportunities Exist for DOE to Better Support Utilities in Improving Resilience to Hurricanes,* GAO-21-274 (Washington, D.C.: March 2021).

standards are appropriate. In addition, FERC is to determine whether mandatory reliability standards were violated and may initiate enforcement action, when warranted. It also reviews and approves standards that the North American Electric Reliability Corporation (NERC) develops for the reliable operation of the bulk power system.[13] NERC is the federally designated U.S. electric reliability organization and is responsible for conducting reliability assessments and developing and enforcing standards to provide for the reliable operation of the bulk power system, which become mandatory once approved by FERC.

Disaster Responses Provide Numerous Lessons Learned

Federal, state, and industry stakeholders identified opportunities to enhance resilience and improve the response to grid disruptions in terms of planning and coordination, workforce and training, tools and technology, and local capacity. In addition, certain disasters yielded lessons learned regarding challenges specific to island and remote area responses, grid interdependencies, and the need for revised grid reliability standards.

Lessons Related to Planning and Coordination, Workforce and Training, Tools and Technology, and Local Capacity

Federal, state, and industry documents and stakeholders cited lessons learned from responses to selected disasters that have affected the grid since 2017, identifying opportunities to enhance resilience and improve the response to future grid disruptions in terms of planning and coordination, workforce and training, tools and technology, and local capacity.

Planning and coordination. Federal, state, and industry documents and stakeholders highlighted the need for long-term planning efforts that

[13]The bulk power system includes the facilities and control systems necessary for operating the interconnected electricity transmission network and the electric energy from certain generation facilities needed for reliability. NERC has developed reliability standards for the bulk power system, including standards on cybersecurity and physical security. FERC can approve or disapprove NERC-proposed reliability standards and can remand them back to NERC for further consideration, but it cannot author or unilaterally modify reliability standards.

incorporate entities at all levels, as well as the importance of coordination and relationship-building ahead of a disaster response.

Selected disasters that have affected the grid since 2017 demonstrate the importance of improving long-term planning efforts. Some federal, state, and industry stakeholders we interviewed explained that the disaster response process focused on restoring power but was missing a system-wide planning approach that incorporates steps to enhance resilience to future disasters. They told us that recent disaster responses showed that, in general, state and industry planning efforts did not address the interdependencies among critical infrastructure and that local communities were not included in such planning efforts. One state official told us that interdependencies among critical infrastructure systems can cause cascading disruptions of multiple systems and has slowed disaster response efforts. For example, damage to roads and loss of cellular telephone service during a disaster slows down power restoration crews, limiting utility crews' ability to reach damaged grid infrastructure and coordinate effectively.

Some ESF #12 responders and state officials told us that federal and state planning efforts could more effectively integrate entities at all levels when planning support in areas such as disaster resilience materials or techniques; infrastructure needs across sectors; and implementing response tools, such as mutual aid. As we reported in March 2021, DOE's Office of Electricity has efforts underway to establish a framework for resilience planning that could help address this need for a more holistic approach to planning.[14] The framework aims to enhance grid resilience by helping entities to identify risks to the grid, identify considerations for how utilities should prioritize these risks, and provide tools or analytical approaches that utilities and other stakeholders could use to weigh different resilience alternatives.

In addition, agency AARs—as well as most federal and state officials—noted that responses to the selected disasters in our review highlight the importance of coordination and building relationships across various levels of government and sectors of the economy before the disaster

[14] In March 2021, we recommended that DOE (1) establish a plan, including time frames, as appropriate, to guide the agency's efforts to develop tools for resilience planning, such as performance measures for resilience, a framework for resilience planning, and additional information on the cost of long-term power outages; and (2) take steps to better leverage the national laboratories' emerging grid resilience efforts and technologies by developing a formal mechanism to share this information with utilities. GAO-21-274.

response season. Several ESF #12 responders and state officials we interviewed told us that having strong working relationships and a collaborative environment produced a more streamlined and effective response. Furthermore, in its AAR for the 2018 disaster response season, DOE recommended that regular interactions among federal, regional, local, industry stakeholders, and ESF #12 responders could improve their understanding of ESF #12 roles and responsibilities during a response. State officials and ESF #12 responders told us that response efforts were more effective when such established relationships existed and where the federal responders and local entities had previous experience in coordinating with each other. For example, one ESF #12 responder told us they were able to quickly integrate into state-level emergency operations during the response to the 2018 Camp and Woolsey wildfires in California because of several years of interaction with state personnel on previous responses. However, these relationships and coordination are not always well established, which can hinder coordination, according to some ESF #12 responders. Two responders cited an example where the lack of relationships with the local utility resulted in communication gaps, and they had to determine the location of power restoration crews on their own because the utility was not sharing that information.

Workforce and training. DOE AARs and officials identified lessons pertaining to adequate staffing and disaster response training. DOE's 2017 AAR highlighted the importance of having a dedicated pool of responders with expertise in recovery operations and grid reconstruction. The ESF #12 responders who are activated by DOE are volunteers who typically have primary jobs outside of disaster response. Their availability to support a given ESF #12 response requires approval from their management. Several DOE officials and ESF #12 responders we interviewed also cited challenges in recruiting and retaining specialized personnel. Adequately staffing response efforts can be especially challenging when faced with multiple concurrent or successive disasters, according to some DOE officials. They told us that they prefer to deploy ESF #12 responders as a pair, with one focusing on assessing disaster impacts and the other on coordinating with other response agencies. However, one ESF #12 responder shared that to support three events in September 2018, they were deployed on their own and rotated in and out of the response area too quickly to build valuable relationships or effectively share information.

Agency AARs and officials identified gaps in training for ESF #12 responders. DOE requires ESF #12 responders to participate in an annual training, refresher trainings, and a biennial national exercise.

Some ESF #12 responders told us that they found these training events useful and stated that the refresher training incorporated key lessons learned from the previous response season. However, FEMA's 2018 and DOE's 2020 AARs noted that responders could be better prepared if they had specialized refresher training in a number of areas, including cultural sensitivity, region-specific knowledge, and the differences in mainland versus island disaster responses. Moreover, some ESF #12 responders told us that previous exercises were limited because they only involved DOE personnel. As a result, in 2017, DOE began involving other federal and state agencies in these exercises. However, some ESF #12 responders stated that for inexperienced responders, there was generally no substitute for deploying on a disaster response with an experienced responder.

Tools and technology. DOE's 2017 and 2018 AARs noted the need for improved and centralized access to tools and technology to help inform disaster response decisions, such as outage reporting tools, geographic information systems (GIS) mapping, and predictive modeling analysis. For example, DOE situation reports included prestorm predictive analysis, but there was no capability to request or display predictive analysis products using field-level tools. This meant that ESF #12 responders and other stakeholders did not have centralized access to the model's predicted grid impacts, which may have limited their ability to determine the effect a disruption could have on critical infrastructure. These DOE AARs also stated that ESF #12 responders and stakeholders need to have easy access to products that will help them make decisions on impacts and interdependencies between different energy sectors. Specifically, the 2018 AAR highlighted that the ability to overlay maps and share GIS data would enhance these response capabilities, align with FEMA's vision to support critical community services, and improve responders' ability to provide advice on energy restoration priorities. Furthermore, DOE's 2020 AAR identified the need for a central platform to communicate and share information pertaining to disaster responses. According to ESF #12 responders, this would help the ESF #12 team access and exchange information easily and improve the handoff between responders when they rotate in and out of the disaster response.

Local capacity. Federal, state, and industry stakeholders we interviewed cited lessons learned from the responses to the selected disasters in our review that highlight that smaller utilities and communities may not have the resources to effectively respond to disasters. During interviews with ESF #12 responders, some stated that rural areas, and those serviced by smaller utilities, often have capacity challenges because of the smaller government entities and utilities managing the response. On account of limitations related to resource access and economies of scale, small utilities are unable to manage a robust, on-site inventory that can support disaster response and may have difficulties transporting needed or specialized equipment and supplies to a response site. Moreover, they may have fewer staff and resources when it comes to coordinating with federal partners to provide information for situational awareness, status updates, or paperwork requirements during the response, or afterwards, when navigating federal programs. State officials we interviewed from Florida and Georgia also stated that limited staffing and resources posed challenges to smaller utilities related to the costs of planning and implementing critical resilience strategies, such as vegetation management programs (i.e., preventative strategies to minimize damage by vegetation to power lines during storms or other events).[15]

Specific Events Highlight Lessons Learned from Remote Area Responses and Grid Interdependencies

Certain natural disasters highlighted lessons regarding challenges specific to island and remote area response efforts, interdependencies between the grid and other energy infrastructure, and the need for revised grid reliability standards.

Island and remote area responses. Agency and industry reports and officials highlight that island and remote responses require increased planning and resources. Disaster responses on islands or in remote areas are distinct from those in the contiguous U.S. because of the challenges stemming from geographic limitations and can require a more robust federal role during the response. Specifically, federal and state stakeholders stated that disasters on islands and in remote areas presented larger-scale logistical challenges related to delivering personnel and materials and the increased costs of maintaining a prepositioned equipment inventory to support disaster response efforts. All of the stakeholders we interviewed who were involved in responding to island events told us that logistics and supply chain issues were a primary

[15]Our March 2021 report highlighted that small, rural utilities had limited resources to undertake resilience enhancements or pursue new technologies or tools that could enhance resilience planning. Specifically, industry officials told us that these utilities have limited staff to focus on grid resilience and that applying for federal funding to enhance grid resilience and complying with federal program requirements can be burdensome. GAO-21-274.

factor in what made island and remote response efforts unique and difficult. Some stated that mainland utilities often manage these challenges themselves or through mutual aid agreements with other utilities, whereas island and remote responses often require additional federal resources. Furthermore, island and remote area communities typically face the local capacity challenges associated with limited resources and staff described above.[16]

Grid interdependencies. Power outages in Texas and the south central U.S. in February 2021 highlighted the interdependence of the grid and other energy infrastructure and the need for weatherization of certain infrastructure. Specifically, gas-fired power plants and gas supply infrastructure are interdependent, where electricity is needed to power pipelines or gas processing facilities, and pipelines deliver gas to generators. Under extreme cold weather conditions, both power plants and the natural gas infrastructure supplying those power plants with fuel were susceptible to operating failures because of freezing. Specifically, a November 2021 report by FERC, NERC, and regional entities found that a total of 1,045 individual generating units experienced 4,124 outages, decreases in capacity, or failures to start.[17] Of those, approximately 75 percent were caused by either freezing issues (44 percent) or fuel issues (31 percent). In turn, natural gas fuel supply issues were primarily caused by freezing issues and loss of electricity supply affecting natural gas production and processing facilities. NERC's reliability standards are meant to define requirements for planning and operating the North American bulk power system; however, they currently do not include requirements for utilities to implement cold weather preparedness and operations. According to the 2021 FERC-NERC joint report and one industry stakeholder, the 2021 cold weather power outages in Texas and

[16]We previously reported that the response to Hurricanes Irma and Maria in Puerto Rico involved specific challenges, including an unprecedented scale of federal involvement in grid restoration. For example, in April 2019, we identified various factors that affected federal support for grid restoration, including that it was more difficult and time-consuming to get needed crews and materials to islands. See GAO, *2017 Hurricane Season: Federal Support for Electricity Grid Restoration in the U.S. Virgin Islands and Puerto Rico.* GAO-19-296 (Washington, D.C.: Apr.18, 2019).

[17]According to EIA, generating units are any combination of physically connected generators, reactors, boilers, combustion turbines, and other prime movers operated together to produce electric power. A power plant may have multiple individual generating units. Federal Energy Regulatory Commission, *FERC, NERC, and Regional Entity Staff Report: The February 2021 Cold Weather Outages in Texas and the South Central United States* (Washington, D.C.: November 2021). Hereafter, we refer to this report as the FERC-NERC joint report.

the south central U.S. showed that reliability standards that address the readiness of grid infrastructure to withstand cold weather are needed to enhance grid resilience.[18]

Federal Agencies Have Taken Steps to Address Lessons Learned, but DOE Does Not Have an Approach for Coordinating Its Broader Grid Support Mission

Federal agencies have taken steps to address lessons learned, including those related to planning and coordination, workforce, capacity building, and enhancing resilience. DOE has a broader grid support mission that encompasses the ESF #12 disaster response discussed above, as well as support to postdisaster grid recovery and technical assistance before and after disasters. However, DOE does not have a comprehensive approach for coordinating these efforts, including integrating lessons learned from disaster responses into other related efforts.

Federal Agencies Have Taken Steps to Address Lessons Learned

Planning and coordination. DOE has undertaken efforts to address the need for long-term, cross-sector planning efforts and to augment coordination and relationship building. As of January 2022, DOE's Office of Cybersecurity, Energy Security, and Emergency Response was implementing a Regional Response Strategy to improve planning and coordination before and during disasters. According to agency officials, the strategy is a comprehensive effort to align the ESF #12 response with FEMA's regions and improve the ESF #12 response based on lessons learned. Specifically, the strategy includes several initiatives aimed at

[18]Whereas the temperatures and effects of the 2021 event were more extreme, previous cold weather events in the region in 2011, 2014, and 2018 also demonstrated the need for revised reliability standards to ensure electricity reliability during extreme cold weather. According to the 2021 FERC-NERC joint report, after each of these events, one or more of FERC, NERC, or RTOs issued reports with recommendations to prevent similar events from recurring. In August 2021, FERC approved revisions to the NERC Reliability Standards to address cold weather, including a new requirement for generating units to have a cold weather preparedness plan. However, the effective date for these revisions is April 1, 2023. See 176 FERC ¶ 61,119 (August 2021).

developing relationships between DOE and state and local entities involved in disaster response. For example, the strategy seeks to augment the ESF #12 regional presence by expanding engagement with regional and state partners outside of the disaster response, according to agency documents we reviewed. The effort also includes a plan to educate partnering agencies on how to fully use the available ESF #12 support.[19]

In addition, to improve cross-agency coordination and support the restoration of power during future national response efforts, DOE began deploying ESF #12 responders with FEMA's Incident Management Assistance Teams (IMAT). These teams provide the federal government's initial coordination and response capability prior to, and in the immediate hours following, a serious incident. The IMAT personnel come from a variety of critical services (e.g., DOE, USACE, law enforcement, and public health departments) and often deploy ahead of a predicted disaster (e.g., a hurricane). For example, DOE officials told us that, within the last 5 years, FEMA has typically deployed an ESF #12 responder with the IMAT and may meet with them before the team deploys to the affected area. This change in deployment approach was based on FEMA and DOE's recognition that getting on the ground as soon as possible—for example, a day ahead of a hurricane making landfall—resulted in improved relationship building between ESF #12 responders and local entities (e.g., utilities) and more effective assessments of grid damage. Prior to this change, FEMA would be on the ground before a hurricane making landfall, without the staff needed for an effective response, according to some DOE officials we interviewed.

Workforce and training. To address the need for a dedicated pool of technical experts, in 2020, DOE began deploying the ESF #12 Catastrophic Incident Response Team (CIRT) to quickly bring responders with subject-matter expertise to affected areas. DOE officials we interviewed told us that the CIRT's first mainland deployment during Hurricane Laura in Louisiana in 2020 was particularly effective and stated that CIRT personnel augmented and improved power restoration efforts in areas where smaller cooperative utilities were resource constrained. In

[19]In addition, in Puerto Rico, where longer-term grid recovery efforts following Hurricanes Irma and Maria are ongoing, DOE and FEMA have enhanced existing coordination efforts between their respective agencies and with local entities involved in long-term grid recovery in Puerto Rico by establishing the DOE-led Energy Technical Coordination Team. Since February 2020, this team has demonstrated actions to help coordinate different funding sources and federal permitting requirements as projects eventually move forward.

addition, they told us that CIRT personnel built effective working relationships with utilities that were initially apprehensive about working with federal agency personnel. Furthermore, DOE officials told us in May 2022 that, as part of the agency's Regional Response Strategy, they are evaluating approaches to improve the ESF #12 response, including the addition of full-time, or near full-time, regional coordinators to the existing volunteer structure, particularly in the busiest regions. DOE officials told us that such a permanent presence would allow the agency to more consistently establish working relationships with local entities and to build the ESF #12 responders' understanding of cultural and region-specific knowledge.

To address the need for specialized training, ESF #12 responders we interviewed told us that, since 2017, DOE has adapted its annual training, refresher trainings, and a biennial national exercise to include lessons learned from real-world events and previous disaster responses and to invite other stakeholders to participate in these exercises. In addition, one responder told us that the refresher trainings now typically include a portion that covers specific lessons from the prior year response season, as well as any changes to DOE or FEMA response policies and procedures. Moreover, CESER's Regional Response Strategy aims to design adaptive, multimodal incident response training that includes region-specific information, according to DOE documents we reviewed.

Tools and technology. To address the need for improved and centralized access to tools and technology to help inform disaster response decisions, DOE officials told us that they have completed several updates to the Environment for Analysis of Geo-Located Energy Information (EAGLE-I) system. EAGLE-I is an interactive GIS platform with near real-time informational updates on the electric, petroleum, and natural gas sectors. Specifically, these updates include expanding the coverage of its outage data to cover over 92 percent of customers in the U.S. and transitioning the platform from providing only information on the status of power outages to a situational awareness platform for the whole energy sector. This includes reports and other products produced by DOE during incidents; data from outage prediction models; outage snapshot reports that show outages over time; and utility social media data, which some ESF #12 responders and state officials told us was useful for real-time outage information during a disaster. DOE officials also stated that the overall platform was updated to be more intuitive and that new features were designed with regular input from end-users, through regular discussions between the developers, ESF #12 Regional Coordinators, and other stakeholders. In addition, they told us that future efforts will focus on developing incident-specific dashboards and collaboration, as well as incorporating other tools that CESER is developing. These include predictive power outage estimates, postincident imagery and damage detection, and flood detection developed by national laboratories.

To address the need for a central platform to communicate and share information pertaining to disaster responses, DOE's Regional Response Strategy aims to expand the use of communication platforms, such as Microsoft Teams, to improve ESF #12 personnel's situational awareness and collaboration both within and outside an incident response. DOE officials told us that they are planning to roll out this platform in the spring of 2022 and complete beta testing prior to the hurricane season. They told us that improvements to EAGLE-I and Microsoft Teams could enhance situational awareness before responders are deployed and reduce dependence on face-to-face coordination. Moreover, some ESF #12 responders told us that such platforms are critical for collaboration, especially when maintaining social distancing during the COVID-19 pandemic.

Local capacity. To address limited resources available in smaller communities, DOE has various efforts underway to support state and local capacity to plan for disaster response and resilience. For example, DOE's Energy Transitions Initiative, under the Office of Energy Efficiency and Renewable Energy (EERE), aims to support resilience planning across multiple levels of government, according to agency officials involved in the program. Furthermore, as we reported in March 2021, DOE provides technical assistance to communities as they consider their options for enhancing their capabilities to withstand and respond to disasters. These could include both disaster response and grid resilience efforts.[20]

In addition, FEMA's Building Resilient Infrastructure and Communities (BRIC) program could be used to build capacity at the local level, according to FEMA officials we interviewed. Under BRIC, states, local, tribal, and territorial governments with major disaster declarations in the past 7 years are eligible for grants to fund projects to help reduce risks to critical systems—such as the electricity grid—before a disaster.[21] The

[20]GAO-21-274.

[21]As of April 2022, all states, the District of Columbia, U.S. territories, and federally recognized tribal governments currently meet the 7-year disaster declaration requirement, according to the BRIC program website.

grants can also be used to help quickly stabilize a community after a disaster by preventing cascading impacts. As part of the BRIC program, FEMA has additional capacity-building efforts underway, including providing nonfinancial, direct technical assistance to selected communities that are seeking to evaluate their disaster response and resilience needs and possibly pursue BRIC projects. In addition, FEMA officials told us that they include state, local, and tribal officials on panels that review BRIC applications to expand these entities' understanding of potential resilience approaches and application pitfalls. Moreover, they told us that this effort also helps develop capacity and participation of local entities in wider disaster resilience and response planning.

Enhancing grid resilience. As we reported March 2021, DOE has taken steps to enhance grid resilience through partnerships, technical assistance, and research.[22] Specifically, these efforts include (1) establishing partnerships with industry through the Grid Modernization Laboratory Consortium; (2) developing a resilience roadmap that includes guidance for federal, state, and local entities to plan for resilience at the regional level; and (3) utilizing modelling to help utilities prepare for and respond to major weather-related outages, such as those caused by hurricanes.

In addition, FERC has undertaken a number of efforts to address recent disasters and the threat of more frequent and intense disasters on account of climate change. In November 2021, FERC and NERC jointly released a report that outlined lessons from the 2021 cold weather power outages in Texas and the south central U.S. This report included multiple recommendations to address natural gas infrastructure interdependencies, including recommendations on preserving the reliability of critical natural gas infrastructure during extreme cold temperatures.[23]

[22]GAO-21-274.

[23]In addition to the November 2021 FERC-NERC joint report, FERC hosted a technical conference in June 2021 convening federal, regulatory, and industry officials to discuss climate change, extreme weather, and electric system reliability. The conference included panels on topics such as best practices for long-term planning and assessing and mitigating the risk of climate change and extreme weather events. In addition, the conference included an opportunity for stakeholders to submit comments for the record. Some industry officials told us that the conference served as an effective tool to encourage external and internal conversations to determine where the risks are and any steps that need to be taken to enhance grid resilience.

Specifically, in response to the failures of generating units caused by extreme freezing temperatures, FERC and NERC made several recommendations, including that NERC's mandatory reliability standards be revised to require that generator owners or operators

- identify and protect cold-weather-critical components;
- retrofit existing generating units and, when building new generating units, ensure that the units can operate to specific conditions based on extreme temperature and weather data and also account for the effects of precipitation and cooling winds;
- perform annual training on winterization plans;
- develop corrective action plans in the event they experience freeze-related outages;
- provide bulk power-balancing authorities the percentage of the total generating unit capacity that can be relied upon during forecasted cold weather; and
- account for the effects of precipitation and the accelerated cooling effects of wind when providing temperature data to bulk power-balancing authorities.

DOE Does Not Have a Comprehensive Approach for Coordinating Its Broader Grid Support Mission

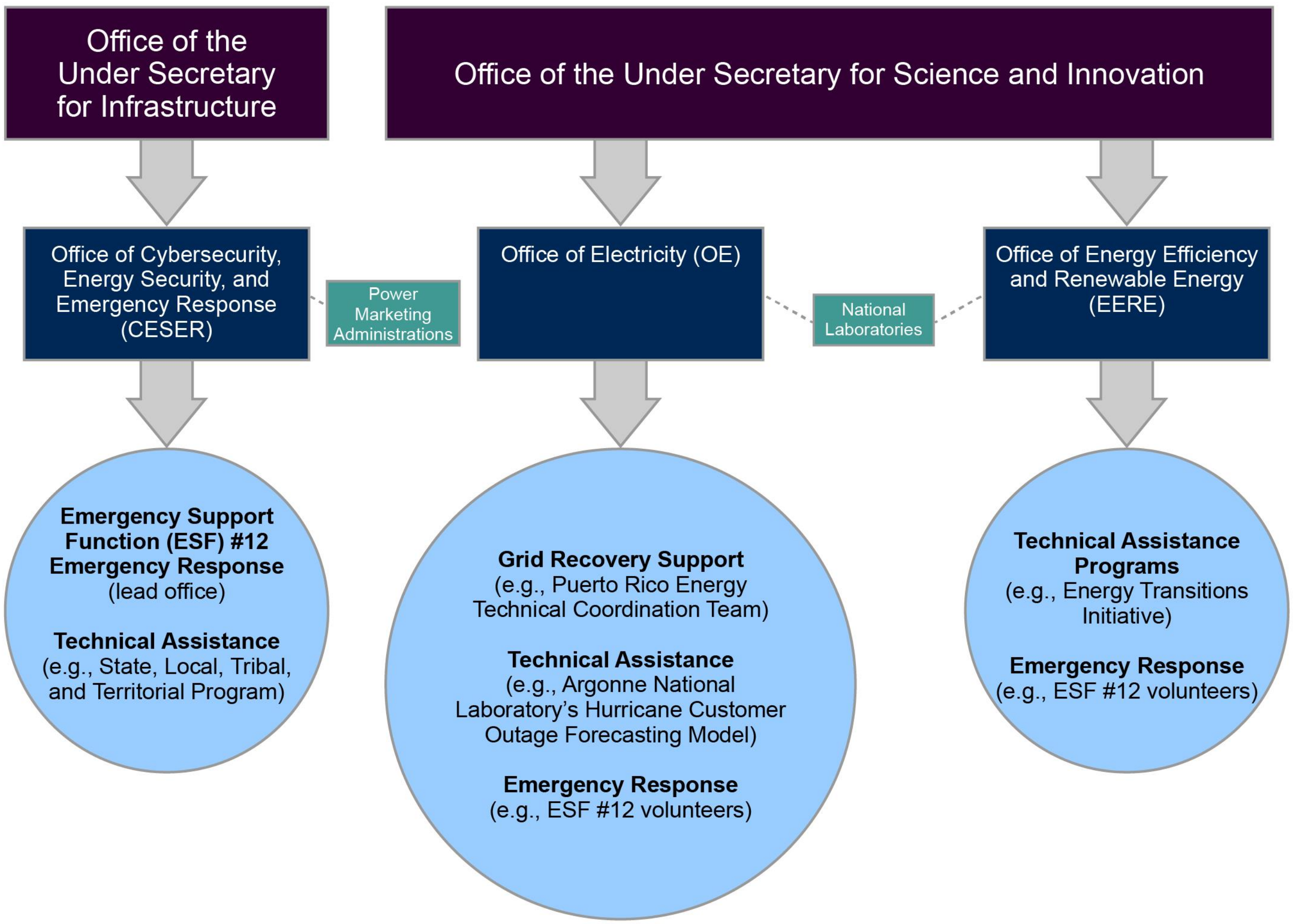
DOE does not have a comprehensive approach for coordinating its broader grid support mission, including integrating lessons learned from previous disaster responses into related efforts across the agency. This broader grid support includes disaster response, grid recovery, and technical assistance efforts. After power is restored following a disaster, DOE transitions from its ESF #12 role supporting disaster response—a role fulfilled by CESER—to longer-term efforts to support grid recovery and provide technical assistance.[24] These grid recovery and technical assistance programs and activities are spread across multiple offices within DOE—including OE and EERE—and its national laboratories. Specifically, OE plays a significant coordination role in grid recovery—for example, by leading the Energy Technical Coordination Team in Puerto

[24]"Long- term grid recovery" refers to long-term efforts to rebuild the electricity grid or enhance resilience, whereas "disaster response" refers to the immediate emergency restoration work that is generally a part of the initial response phase to a disaster.

Rico—as well as providing technical assistance to federal, state, territorial, and industry entities undertaking long-term grid recovery efforts. In addition, OE is responsible for coordinating some of the recovery and technical assistance activities of the national laboratories.[25] EERE provides technical assistance related to grid resilience, especially to island and remote communities. Figure 2 depicts where the program offices are located within DOE and provides examples of these efforts.

[25]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 and the national laboratories have efforts under way that address grid resilience, collaborate with utilities to operationalize technologies, and support grid resilience through basic research and the development of models.

Figure 2: Department of Energy (DOE) Offices Providing Emergency Response, Grid Recovery, and Technical Assistance



Source: : GAO analysis of DOE information. | GAO-22-105093

Note: Personnel from the Power Marketing Administrations (e.g., Bonneville Power Administration, the Western Area Power Administration) support the ESF #12 response by providing volunteers with technical expertise on the electricity grid. The national laboratories support a variety of grid recovery and technical assistance activities.

Agency officials across these offices said that roles and responsibilities during the transition from disaster response to grid recovery are unclear, nor is it clear how lessons learned are communicated among these and other DOE efforts. Moreover, agency officials told us that in some cases there was a disconnect, where one office was not aware of efforts being undertaken by another. DOE officials told us they are working to build partnerships across offices on an ad hoc basis. For example, CESER officials told us they are training two EERE personnel involved in technical assistance in Puerto Rico and the U.S. Virgin Islands as ESF #12 responders. They believe this training could improve coordination among the response and technical assistance efforts in the event of future disasters in those areas. However, DOE does not have a comprehensive approach that (1) clearly establishes roles and responsibilities for disaster response and recovery, (2) ensures that agency offices are aware of the others' actions in these areas, or (3) specifically aligns program goals with lessons learned from disasters.

As a result, DOE may not be leveraging lessons learned from disasters to effectively target its long-term grid recovery and technical assistance efforts or align program goals with those lessons learned. Moreover, such coordination and prioritization to ensure the best use of resources will be important, as DOE receives tens of billions of dollars in appropriations under the Infrastructure Investment and Jobs Act enacted in 2021, including over $10 billion in grid resilience grants for states, tribes, and utilities.[26] GAO's Disaster Resilience Framework states that bringing together disparate federal missions and resources that support disaster risk reduction can help to build national resilience to natural hazards.[27] By establishing a comprehensive approach that clearly establishes the roles and responsibilities for integrating relevant information and lessons learned across DOE's broader grid support mission, the agency could better target resources and technical assistance to where it would more effectively enhance grid resilience and support disaster risk reduction actions.

Conclusions

As communities face more frequent and longer power outages because of the growing severity of wildfires and extreme weather events, the role of federal support for disaster response and grid recovery has grown. In particular, DOE plays a significant role across all phases of a disaster by assisting industry, federal and state entities, and other stakeholders through its various response, long-term grid recovery, and technical assistance efforts. While some steps are underway to coordinate these efforts across its offices, these efforts are ad hoc, and DOE does not

[26]Pub. L. No. 117–58, 135 Stat. 429 (2021).

[27]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).

have a comprehensive approach to clearly establish roles and responsibilities for disaster response and recovery, coordinate the actions of agency offices in these areas, and align program goals with lessons learned from disasters. Effective coordination and leveraging of resources will be critical as DOE plans and implements programs with new funding under the Infrastructure Investment and Jobs Act. By establishing a comprehensive approach, the agency could more effectively target resources to enhance grid resilience.

Recommendations for Executive Action

We are making one recommendation to DOE:

The Secretary of Energy should establish a comprehensive approach to enhance coordination among its disaster response, grid recovery, and technical assistance efforts, including developing a plan to integrate lessons learned from prior disaster response efforts into the resilience goals of its grid recovery and technical assistance efforts. (Recommendation 1)

Agency Comments

We provided a draft of this report to DOE, FERC, the Department of Homeland Security, and the USACE for review and comment. DOE provided written comments, reprinted in appendix II, and concurred with our recommendation. DOE, FERC, and the Department of Homeland Security provided technical comments which we incorporated as appropriate. USACE did not have any comments on the draft report.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, the FERC Chairman, the Secretary of Homeland Security, and the Secretary of Defense.

If you or your staff have any questions about this report, please contact me 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. GAO staff who made key contributions to this report are listed in appendix V.

Frank Rusco
Director, Natural Resources and Environment

List of Addressees

The Honorable Diane Feinstein
Chairman
The Honorable John Kennedy
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Chris Murphy
Chairman
The Honorable Shelley Moore Capito
Ranking Member
Subcommittee on Homeland Security
Committee on Appropriations
United States Senate

The Honorable Marcy Kaptur
Chairwoman
The Honorable Mike Simpson
Ranking Member
Subcommittee on Energy and Water Development, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable Lucille Roybal-Allard
Chairwoman
The Honorable Chuck Fleischmann
Ranking Member
Subcommittee on Homeland Security
Committee on Appropriations
House of Representatives

Appendix I: Objectives, Scope, and Methodology

This report (1) identifies lessons learned from federal, state, and other entities' responses to disasters that affected the electricity grid from 2017 to 2021; and (2) examines federal agency actions to address those lessons learned.

To address both of these objectives, we selected a nongeneralizable sample of 15 disasters to focus our analysis on lessons learned from the response to disaster-caused grid disruptions. We first reviewed major disaster declarations to identify the 35 disasters occurring between 2017 and 2021 that required an Emergency Support Function #12 (ESF #12) response.[1] ESF #12 events are those that required federal coordination for the reestablishment of damaged energy systems. From these, we selected a nongeneralizable sample of 15 disaster responses that were among the most severe of the 35 across a range of incident types, geographic locations, and response years. To identify the more severe cases, we used the number of ESF #12 responders deployed by the Department of Energy (DOE) as a proxy for the magnitude of the effects of the disasters. Findings from our review of disasters cannot be generalized to those we did not select and include in this report. The selected disasters can be found in table 2 below.

Table 2: Selected Disasters, 2017-2021

Disaster name	Incident type	Geographic location	Year
Oroville Dam	Dam breach Potential flooding	California	2017
Hurricane Irma	Tropical cyclone	Alabama, Florida, Georgia, Puerto Rico, U.S. Virgin Islands	2017
Hurricane Maria	Tropical cyclone	Puerto Rico, U.S. Virgin Islands	2017

[1]Under the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the President can declare a major disaster for any natural event that has caused damage of such severity that it is beyond the combined capabilities of state and local governments to respond. A major disaster declaration provides a wide range of federal assistance programs for individuals and public infrastructure, including funds for both emergency and permanent work. 42 U.S.C. §§ 5121-5207.

Disaster name	Incident type	Geographic location	Year
Kilauea Volcano	Volcanic eruption Earthquake	Hawaii	2018
Carr Wildfire	Wildfire	California	2018
Hurricane Olivia	Tropical cyclone	Hawaii	2018
Hurricane Michael	Tropical cyclone	Alabama, Florida, Georgia (Declared states of emergency: Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Virginia)	2018
Camp Wildfire	Wildfire	California	2018
Woolsey Wildfire	Wildfire	California	2018
Alaska earthquake	Earthquake	Alaska	2018
Typhon Yutu	Tropical cyclone	Northern Mariana Islands	2018 & 2019
Puerto Rico earthquake	Earthquake	Puerto Rico	2020
Hurricane Isaias	Tropical cyclone	East Coast of U.S., Puerto Rico, and U.S. Virgin Islands	2020
Midwest derecho	Severe storms	Illinois, Indiana, Iowa, Nebraska, Ohio, South Dakota, Wisconsin	2020
2021 North American winter storm	Severe weather event	Central U.S. (primarily Texas)	2021

Source: GAO analysis of disasters requiring an Emergency Support Function #12 response. I GAO-22-105093

To identify lessons learned, we reviewed approximately 50 federal, state, and nongovernmental reports containing lessons learned related to the 15 selected disasters. To identify the reports that were relevant to our selection, we requested after-action review (AAR) reports from federal agencies (i.e., DOE, the Federal Emergency Management Agency (FEMA), the Federal Energy Regulatory Commission (FERC), and the U.S. Army Corps of Engineers (USACE)); conducted a literature search; reviewed prior GAO work; and asked for recommendations from stakeholders we interviewed. We also identified lessons learned by speaking with 30 federal officials from DOE, FEMA, FERC, and USACE that had a role in energy disaster response and grid resilience efforts. In particular, we spoke to eight ESF #12 responders at DOE, who have been deployed to national and regional response centers during multiple active disaster responses in our sample. We also spoke with two Office of Cybersecurity, Energy Security, and Emergency Response (CESER) officials charged with managing the ESF #12 response to gain a program perspective and to gain their thoughts on the lessons identified by ESF #12 responders.[2]

We analyzed the findings of those reports and interviews to identify lessons related to grid impacts and grid-related response. We categorized those lessons by common themes (e.g., planning and coordination, workforce and training, tools and technology) and reported those lessons that were most frequently cited by reports and agency officials and that we determined were relevant to the disasters we reviewed. Of the federal agency after-action reports (AAR) and interviews, DOE's were the most relevant to our analysis, because of DOE's role as the lead agency for ESF #12 Energy.

To examine federal agency actions to address lessons learned, we reviewed agency AARs that contained action items and examined agency procedures for tracking and addressing lessons learned. In addition, we interviewed agency officials responsible for disaster response and resilience programs, including those responsible for tracking lessons learned. After gathering lessons learned by ESF #12 responders, we interviewed CESER officials to gain their perspectives on lessons identified by responders and to identify and evaluate any actions being taken to address those lessons. Furthermore, we spoke to DOE officials outside of CESER—including the Office of Electricity and the Office of Energy Efficiency and Renewable Energy —to identify any relevant policies and to evaluate the extent to which lessons learned are communicated across DOE response, resilience, and technical assistance efforts.

For both objectives, we interviewed 18 officials at state agencies involved in the disaster preparedness and response process from varying geographic locations in the U.S., including Alaska, Florida, Georgia, and Hawaii, as well as officials from the National Association of State Energy Officials (NASEO).[3] We also sought to gain industry perspectives by

[2]To characterize the views of CESER officials and ESF #12 responders throughout this report, we defined modifiers to quantify the 10 officials we interviewed as follows: "nearly all" represents nine officials; "most" represents six to eight officials; "several" represents four to five officials; and "some" represents two to three officials.

[3]We also contacted the relevant Texas and California State agencies, but they did not respond to our requests for interviews. However, we were able to access and review relevant public documents and submissions to utility commission dockets. We included this information, where appropriate.

reviewing documents submitted by relevant utilities to federal and public utility commission dockets; interviewing industry officials, including representatives from utilities, regional transmission organizations (RTO), and industry groups and associations; and relying on interviews from recent GAO work where perspectives on grid resilience and disaster lessons learned were discussed.[4] We generally asked the same questions during each interview and identified stakeholders by reviewing documents and obtaining recommendations during our interviews about others knowledgeable about grid response efforts. Views of the stakeholders we interviewed cannot be generalized to those we did not select and interview for our review.

We conducted this performance audit from March 2021 to June 2022, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[4]In much of the central, southeastern, and western U.S., integrated utilities operate the grid and provide generation, transmission, and distribution services to all retail customers in a specified area. In other parts of the U. S., RTOs act as grid operators and manage regional networks of electric transmission lines that would otherwise be operated by individual utilities. In some RTO areas, integrated utilities act as electricity suppliers of generation, transmission, and distribution services to retail customers. In other RTO areas, electricity suppliers purchase electricity produced at independently owned power plants to sell to retail customers. While major sections of the country operate under more traditional market structures, two-thirds of the nation’s electricity is served in RTO regions. Independent operators of the transmission system can be referred to as RTOs, or independent system operators .We were only able to schedule interviews with two utilities; however, because we wanted to include their perspectives, we relied on interviews from our most recent GAO work where lessons learned related to disasters were discussed. These interviews took place in spring and summer of 2020.

Appendix II: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

Mr. Frank Rusco
Director
Natural Resources and Environment
U.S. Government Accountability Office 441
G Street, NW
Washington, DC 20548

Dear Mr. Rusco:

The U.S. Department of Energy (DOE or Department) appreciates the opportunity to provide a management response to the Government Accountability Office (GAO) draft report titled, "*Lessons Learned for Responding to Disaster-Caused Grid Disruptions, GAO-22-105093.*"

The draft report contained a total of 1 recommendation for DOE. DOE concurred with GAO's recommendation, and provides the following comments:

In accordance with FEMA's National Response Framework (NRF), the focus of the Emergency Support Function (ESF) #12 mission is the rapid restoration of damaged energy systems. However, beginning early during a disaster response, ESF#12 works closely with the regionally based FEMA Recovery Support Function Field Coordinators to assist with the transition from emergency response to long term recovery efforts. With increasing frequency, DOE/CESER/ESF#12 supports impacted states and utilities with damage assessment and restoration planning to inform public assistance requests, and to provide advice on longer term efforts to build in resilience. This support generally includes engineering analysis, equipment specifics, and the hardening of energy systems. Much of this support exceeds the response timeframe and can go on for years after a disaster. The bulk of the ESF#12 response cadre are trained volunteers who, due to work commitments, are not typically available to support long term recovery.

Most of the DOE ESF#12 technical support and expertise is provided by our Catastrophic Incident Response Team (CIRT), a subset of the response cadre with the technical skill to provide damage assessment support and restoration planning assistance. In the last two years, the primary CIRT product is a comprehensive damage assessment report that can be used to inform public assistance requests and other resilient rebuilding initiatives. The targeted recruiting to build the CIRT has been highly successful and is a capability that not only needs to be sustained but should also be expanded to further assist impacted states and utilities, particularly smaller utilities that may not have the integral resources to conduct rapid energy system restoration or to connect to state and federal programs that can assist with resilient rebuilding.

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GAO should direct any further questions to Kenneth Buell, Response and Restoration, (202) 586-3362, kenneth.buell@hq.doe.gov.

Sincerely,

PUESH KUMAR

Digitally signed by PUESH KUMAR
Date: 2022.05.27 11:59:33 -04'00'

Puesh Kumar
Director
Office of Cybersecurity, Energy Security and Emergency Response

Enclosure

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Text of Appendix II: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

Mr. Frank Rusco
Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Rusco:

The U.S. Department of Energy (DOE or Department) appreciates the opportunity to provide a management response to the Government Accountability Office (GAO) draft report titled, “Lessons Learned for Responding to Disaster-Caused Grid Disruptions, GAO-22-105093.”

The draft report contained a total of 1 recommendation for DOE. DOE concurred with GAO’s recommendation, and provides the following comments:

In accordance with FEMA’s National Response Framework (NRF), the focus of the Emergency Support Function (ESF) #12 mission is the rapid restoration of damaged energy systems.

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GAO should direct any further questions to Kenneth Buell, Response and Restoration, (202) 586-3362, kenneth.buell@hq.doe.gov.

Sincerely,
Puesh Kumar Director
Office of Cybersecurity, Energy Security and
Emergency Response

Enclosure

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, (202) 512-3841 or ruscof@gao.gov.

Staff Acknowledgments

In addition to the contact named above, Janice Ceperich (Assistant Director), Jarrod West (Analyst-in-Charge), Adrian Apodaca, Antoinette Capaccio, John Delicath, Cindy Gilbert, Philip Farah, Krinjal Mathur, and Rachel Pittenger made key contributions to this report.

Related GAO Products

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.: March 5, 2021.

Electricity Grid: Opportunities Exist for DOE to Better Support Utilities in Improving Resilience to Hurricanes. GAO-21-274. Washington, D.C.: March 5, 2021.

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