NIAC The President's National Infrastructure Advisory Council

Surviving a Catastrophic Power Outage

How to Strengthen the Capabilities of the Nation

December 2018

DRAFT

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About the NIAC

The President's National Infrastructure Advisory Council (NIAC) is composed of senior executives from industry and state and local government who own and operate the critical infrastructure essential to modern life. The Council was established by executive order in October 2001 to advise the President on practical strategies for industry and government to reduce complex risks to the designated critical infrastructure sectors.

At the President's request, NIAC members conduct in-depth studies on physical and cyber risks to critical infrastructure and recommend solutions that reduce risks and improve security and resilience. Members draw upon their deep experience, engage national experts, and conduct extensive research to discern the key insights that lead to practical federal solutions to complex problems.

For more information on the NIAC and its work, please visit: https://www.dhs.gov/national-infrastructure-advisory-council.

Executive Summary

The nation has steadily improved its ability to respond to major disasters and the power outages that often result. But increasing threats—whether severe natural disasters, cyber-physical attacks, electromagnetic events, or some combination—present new challenges for protecting the national power grid and recovering quickly from a catastrophic power outage.

The President's National Infrastructure Advisory Council (NIAC) was tasked to examine the nation's ability to respond to and recover from a catastrophic power outage of a magnitude beyond modern experience, exceeding prior events in severity, scale, duration, and consequence. Simply put, how can the nation best prepare for and recover from a catastrophic power outage, regardless of the cause?

After interviews with dozens of senior leaders and experts and an extensive review of studies and statutes, we found that existing national plans, response resources, and coordination strategies would be outmatched by a catastrophic power outage. **This profound risk requires a new national focus**. Significant public and private action is needed to prepare for and recover from a catastrophic outage that could leave the large parts of the nation without power for weeks or months, and cause service failures in other sectors—including water and wastewater, communications, transportation, healthcare, and financial services—that are critical to public health and safety and our national and economic security.

What is a catastrophic power outage?

- *Events beyond modern experience that exhaust or exceed mutual aid capabilities*
- *Likely to be no-notice or limited-notice events that could be complicated by a cyber-physical attack*
- *Long duration, lasting several weeks to months due to physical infrastructure damage*
- *Affects a broad geographic area, covering multiple states or regions and affecting tens of millions of people*
- *Causes severe cascading impacts that force critical sectors—drinking water and wastewater systems, communications, transportation, healthcare, and financial services—to operate in a degraded state*

Recommendations

The United States should respond to this problem in two overarching ways: 1) design a national approach to prepare for, respond to, and recover from catastrophic power outages that provides the federal guidance, resources, and incentives needed to take action across all levels of government and industry and down to communities and individuals; and 2) improve our understanding of how cascading failures across critical infrastructure will affect restoration and survival.

There are a number of ongoing initiatives in both the public and private sector that are in line with our recommendations. We urge the continued advancement of these initiatives in conjunction with our recommendations.

The NIAC was challenged to examine events that are beyond our nation's experience, yet would impact nearly every jurisdiction, industry, and citizen. The solutions we identified will **require strong public-private collaboration**—as the NIAC has recommended previously—to address the scale and significance of catastrophic power outages.

Recommendations Overview

Design a National Approach for Catastrophic Power Outages

Design a national approach for catastrophic power outage planning, response, and recovery to create a cross-sector, cross-government strategy.

Mitigate Cross-Sector Interdependencies and Cascading Failures

Identify cascading failures impacting key sectors, especially natural gas and communications to ensure their availability to aid power restoration, and identify actions to improve resilience to a catastrophic power outage.

RECOMMENDATIONS

1
Examine and clarify the federal authorities that may be exercised during a catastrophic power outage and grid security emergency and clearly identify the cabinet-level leadership and decision-making processes.

2
Develop a federal design basis and the design standards/criteria that identify what infrastructure sectors, cities, communities, and rural areas need to reduce the impacts and recover from a catastrophic power outage.

3
Develop guidance and provide resources for states, territories, cities, and localities to design community enclaves—areas that co-locate critical services and resources to sustain surrounding populaces, maintain health and safety, and allow residents to shelter in place.

4
Design and support a portfolio of incentives that provide financial support or remove financial and regulatory barriers to help companies and state, local, tribal, and territorial governments implement the recommendations included in this report.

5
Conduct a series of regional catastrophic power outage exercises that identify the second- and third-order cascading failures of an outage over time, as backup resources and mutual aid agreements are exhausted, and examine cross-sector supply chain and cyber risks that could delay re-energizing the grid.

6
Ensure that all critical natural gas transmission pipeline infrastructure has the appropriate standards, design, and practices to continue service during a catastrophic power outage and maintain rapid availability to support blackstart generations.

7
Develop or support a flexible, adaptable emergency communications system that all sectors can interoperably use, that is self-powered, and is reasonably protected against all hazards to support critical service restoration and connect infrastructure owners/operators, emergency responders, and government leaders.

Next Steps

Our recommendations provide a path forward for enhancing the nation's capabilities. These actions require a whole-of-nation approach and strong public-private collaboration. Given the importance of this issue and the number of ongoing efforts, **we request the National Security Council (NSC)—working with the lead agencies identified—provide a status update to the NIAC within nine months of the report's approval** on how our recommendations are being implemented, progress being made on the ongoing initiatives, or any significant barriers to implementation.

Introduction: What the Nation Faces

Across the nation, we experience major threats nearly every year: hurricanes, wildfires, flooding, droughts, and other serious disasters. For these events, the nation has well-established response processes where the federal government serves as a backstop for the robust efforts of individuals, businesses, communities, and states. Even as severe weather increases, the nation has steadily improved its ability to respond to growing disasters and resulting outages—improving planning and coordination, hardening infrastructure, and building strong mutual aid agreements.

The risk posed by a catastrophic power outage, however, is not simply a bigger, stronger storm. It is something that could paralyze entire regions, with grave implications for the nation's economic and social well-being. **The NIAC was tasked to examine the nation's ability to withstand a catastrophic power outage of a magnitude beyond modern experience**, exceeding prior events in severity, scale, duration, and consequence.

The NIAC was challenged to think beyond even our most severe power disruptions, imagining an outage that stretches beyond days and weeks to months or years, and affects large swaths of the country. Unlike severe weather disasters, a catastrophic power outage may occur with little or no notice and result from myriad types of scenarios: for example, a sophisticated cyber-physical attack resulting in severe physical infrastructure damage; attacks timed to follow and exacerbate a major natural disaster; a large-scale wildfire, earthquake, or geomagnetic event; or a series of attacks or events over a short period of time that compound to create significant physical damage to our nation's infrastructure. An event of this severity may also be an act of war, requiring a simultaneous military response that further draws upon limited resources.

For the purpose of this study, the NIAC focused not on the cause, but rather on the consequences, which are best categorized as severe, widespread, and long-lasting. The type of event contemplated will include not only an extended loss of power, but also a cascading loss of other critical services—drinking water and wastewater, communications, financial services, transportation, fuel, healthcare, and others—which may slow recovery and impede re-energizing the grid.

Most importantly, the scale of the event—stretching across states and regions, affecting tens of millions of people—would exceed and exhaust mutual aid resources and capabilities. The ability to share public and private resources across businesses and jurisdictions underpins our nation's emergency response plans and strategies today. (See Appendix C for a more detailed definition of a catastrophic outage).

This profound threat requires a new national focus. The NIAC found that our existing plans, response resources, and coordination strategies would be outmatched by an event of this severity. Significant action is needed to prepare for a catastrophic power outage that could last for weeks or months.

Our Task

In May 2018, the NSC tasked the NIAC to build on the insights gathered during a scoping effort to **develop findings and recommendations on how the public and private sectors can work together to further enhance and integrate critical infrastructure resilience with response and recovery actions to mitigate risks posted by catastrophic power outages**. (See Appendix B for more information on the NIAC tasking).

Our Approach

To better understand catastrophic power outages and how they are different from previously experienced disasters, the NIAC conducted a scoping effort—completed in June 2018—to identify the key issues that would need to be further explored. A Working Group of 10 NIAC members led this full study, and formed a Study Group of subject matter experts to vet and validate the results of the scoping effort and provide a crucial input. In total, we interviewed more than 60 senior leaders and subject matter experts from federal, state, and local governments, industry, academia, and nongovernmental organizations (NGOs). We reviewed more than 700 resources, including statutes, regulations, reports, articles, congressional testimony, and prior studies.

Our recommendations seek to address the issues identified in two overarching ways: 1) design a national approach for catastrophic power outages that provides the guidance and incentives needed to take action across all levels of government and industry and down to communities and individuals; and 2) improve our understanding of how cascading failures across critical infrastructure will impact restoration and survival, enabling us to identify further actions needed to mitigate these failures.

The federal government and industry are already leading many initiatives that are consistent with these recommendations. As set forth in subsequent sections, this study relies on and urges continued advancement of these initiatives. The study also encourages the adoption of new initiatives that will complement these ongoing efforts and lead to a better response to a catastrophic power outage.

Recommendations and Supporting Findings

The complexity of the challenge posed by catastrophic power outages will require working across agencies, sectors, and levels of government to involve all stakeholders. For each recommendation we identify a cabinet-level secretary to lead the effort and be responsible for implementation. We have also identified agencies that should provide support, including primary support roles for agencies that will need to provide significant input, expertise, and assistance. We also include supporting findings based on insights from interviews and research, and ongoing federal and industry initiatives that are consistent with our recommendations and should continue to be advanced and supported.

Recommendations Overview

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Mitigate Cross-Sector Interdependencies and Cascading Failures

Identify cascading failures impacting key sectors, especially natural gas and communications to ensure their availability to aid power restoration, and identify actions to improve resilience to a catastrophic power outage.

RECOMMENDATIONS

1. **Examine and clarify the federal authorities that may be exercised** during a catastrophic power outage and grid security emergency and clearly identify the cabinet-level leadership and decision-making processes.

2. **Develop a federal design basis and the design standards/criteria** that identify what infrastructure sectors, cities, communities, and rural areas need to reduce the impacts and recover from a catastrophic power outage.

3. **Develop guidance and provide resources for states, territories, cities, and localities to design community enclaves**—areas that co-locate critical services and resources to sustain surrounding populaces, maintain health and safety, and allow residents to shelter in place.

4. **Design and support a portfolio of incentives** that provide financial support or remove financial and regulatory barriers to help companies and state, local, tribal, and territorial governments implement the recommendations included in this report.

5. **Conduct a series of regional catastrophic power outage exercises** that identify the second- and third-order cascading failures of an outage over time, as backup resources and mutual aid agreements are exhausted, and examine cross-sector supply chain and cyber risks that could delay re-energizing the grid.

6. **Ensure that all critical natural gas transmission pipeline infrastructure has the appropriate standards, design, and practices to continue service** during a catastrophic power outage and maintain rapid availability to support blackstart generations.

7. **Develop or support a flexible, adaptable emergency communications system** that all sectors can interoperably use, that is self-powered, and is reasonably protected against all hazards to support critical service restoration and connect infrastructure owners/operators, emergency responders, and government leaders.

Design a National Approach for Catastrophic Power Outages

Design a national approach for catastrophic power outage planning, response, and recovery. Current planning frameworks focus on sector-by-sector preparedness and response, but in a catastrophic power outage, U.S. infrastructure and services will fail as a system. We need to take a systems approach—from the federal level down to the local level—to plan, design, and respond to these never-before-experienced events. This approach must move beyond existing planning and response frameworks and provide the guidance needed for an integrated cross-sector, cross-government strategy. The recommendations in this section provide a path forward for putting in place a national approach for dealing with catastrophic power outages.

Recommendation 1

Examine and clarify the federal authorities that may be exercised during a catastrophic power outage and grid security emergency and clearly identify the cabinet-level leadership and decision-making processes.

An event of this scale—with severe economic and national security implications—will require an unprecedented level of federal leadership, likely engage the military, and will see the federal government exercise authorities that have rarely or never been used. Infrastructure owners and operators and state leaders recognize this conceptually, yet it is unclear how command authorities will change, who will make decisions, and how resources will be coordinated.

A. **Conduct an examination of federal emergency authorities** and identify how they could be activated, by whom, and what implications they would have for private-sector, state, and local responders and ultimately how they would support Presidential action.

B. **Identify the cabinet-level officials who would take the lead** in a catastrophic power outage and establish how these officials will coordinate and implement response with the public and private sectors, and state, local, tribal, and territorial (SLTT) governments to manage the cascading cross-sector impacts of these events.

C. **Include and authorize catastrophic power outages as a high-priority mission for three key agencies**: the Department of Energy (DOE), namely the Office of Electricity (OE) and Office of Cybersecurity, Energy Security, and Emergency Response (CESER); the Department of Homeland Security (DHS), namely the Federal Emergency Management Agency (FEMA) and the Cybersecurity and Infrastructure Security Agency (CISA); and the Department of Defense (DOD), namely U.S. Northern Command (NORTHCOM), U.S. Indo-Pacific Command (INDOPACOM), and the Defense Threat Reduction Agency (DTRA); and other agencies as appropriate. This authority should be underwritten with specific budget appropriations to provide the supporting resources necessary to achieve this mission, with clear roles and responsibilities identified for each agency. Identify and request that Congress provide any additional authorities and resources needed to execute the recommendations of this study.

D. **Enhance critical infrastructure sector participation at the National Infrastructure Coordinating Center (NICC) and National Cybersecurity and Communications Integration Center (NCCIC)** to provide critical infrastructure sectors with a better

understanding of NICC and NCCIC operations, and position sector representatives to provide industry perspective and insights. Because catastrophic power outages are likely no-notice or limited-notice events, these key infrastructure representatives should be onsite full time to help identify issues and respond more quickly and efficiently.

i. At a minimum, the Electric, Financial Services, and Communications Sectors should have representatives from the Sector Coordinating Councils (SCCs) or Information Sharing and Analysis Centers (ISACs), given the structure and organization of those sectors.

ii. Other critical lifeline sectors, such as the Oil and Natural Gas (ONG) Subsector, Water and Wastewater Systems Sector, and Transportations Systems Sector should work with DHS to determine the appropriate representatives and level of engagement at the NICC and NCCIC to quickly and effectively engage and provide advisory input during a catastrophic power outage.

Lead: Secretary of Homeland Security
Support: Department of Energy (Primary), Department of Defense, and other agencies as appropriate

Supporting Findings

- Existing frameworks do not identify who has ultimate decision-making authority or clearly define the roles to be undertaken by SLTT governments and the private sector during a wide-spread, multi-state catastrophic power outage that will require coordinated cross-sector, cross-government response.
    - While incident command and unified coordination frameworks generally work, if an incident goes beyond a confined geographic area these frameworks start to lose effectiveness due to the increased size of the impact area, the number and diversity of members in unified coordination groups, and the complexity of the response.
    - Owners and operators have limited visibility into how the federal government will manage an event of this size, and how the federal government will be working with the private sector to make critical resource decisions.
    - Although emergency authorities are understood at a high-level, how they are implemented in practice is unclear. There is a better understanding for physical events that are more frequently practiced, but it is less clear for cyber-physical events and larger-scale disasters.
    - The *Power Outage Incident Annex to the Response and Recovery Federal Interagency Operational Plans* (POIA) outlines the responsibilities of federal organizations involved in response and recovery during a long-term power outage (defined as 72-hours or more). However, it is unclear how POIA would be used in practice and what specific federal authorities will actually make priority decisions during a catastrophic power outage.[1]
- The federal government and military organizations have enormous support resources for an event of this scale, but an efficient response requires close coordination of those resources and

[1] FEMA, *Power Outage Incident Annex,* 2017.

capabilities with those in the private sector and who is in charge of the response, and there will/may be competing needs for those resources and capabilities necessitating tough calls on prioritization.

- SLTT leaders and owners and operators have the best understanding of the needs of their community and can provide valuable information on where to most efficiently apply resources and make the most effective allocation decisions with limited available resources.

Ongoing Initiatives

- **National Response Framework (NRF) Update**: FEMA is updating the NRF with a goal to increase the emphasis of the role of the private sector and individuals in response; adding an emergency support function (ESF) to coordinate government and industry response; and focus on outcomes and prioritizing rapid stabilization of lifeline functions. As part of this process, the NIAC recommends:
    - FEMA engage all stakeholders including SLTT governments, NGOs, and private sector owners and operators to ensure the new framework is accessible and understood by all stakeholders.
    - FEMA consider practical and actionable ways to best leverage industry during the response to restore critical lifeline sectors more quickly and efficiently.
    - Exercise the National Cyber Incident Response Plan with the private sector to identify how it will work operationally during a real-life scenario and support the NRF.
- **DOE Emergency Authorities**: Building on 10 C.F.R § 205, DOE is working with Grid Security Emergency (GSE) stakeholders to outline how an emergency order is communicated and building exercises to better understand what conditions the federal government may support during a GSE.[2]
    - Potential emergency orders and provisions should account for regulatory, cost, and liability issues that may speed up the ability to issue and implement orders during a catastrophic power outage when timing will be crucial.
    - Establish a role/structure for private sector owners and operators to provide crucial analysis to inform the declaration of a grid emergency.
        - Monitoring and assessment capability must be in place and survivable against adversary attack and subversion.

Recommendation 2

Develop a federal design basis and the design standards/criteria that identify what infrastructure sectors, cities, communities, and rural areas need to reduce the impacts and recover from a catastrophic power outage.

The design basis should take into account the cross-sector implications and cascading service failures of a catastrophic power outage. The design basis can guide planning and mitigation efforts, serve as a basis to develop appropriate incentives and investments, and provide the framework needed for investments to be made over time.

A. **Develop design criteria and/or standards for critical infrastructure hardening**, backup power, blackstart capabilities, fuel supply requirements, back-up communications requirements (including a standardized mobile command center design), food and water considerations, and other requirements that communities and businesses can build to.

[2] Administrative Procedures and Sanctions, 10 C.F.R. § 205.

B. **Expand the National Institute of Standards and Technology (NIST) Community Resilience Program** to include the catastrophic power outage federal design basis criteria.

C. **Share the DHS National Risk Management Center's (NRMC) national critical function analysis** and analytical capability with SLTT governments and owners and operators to help inform these decision-makers as they identify state and community-level critical functions that must be prioritized for restoration and hardening investments.

D. **Assess the economic and socio-economic impacts of a catastrophic power outage** on critical infrastructure and the ability of the national economy to withstand and recover from such events. The Council of Economic Advisers is well-positioned to conduct this assessment.

   i. The results of this analysis are needed to better understand the financial implications of the catastrophic power outage and how the economic risk should be factored into planning and recovery. It is also necessary to provide the economic justification for meeting enhanced design criteria and preparedness standards.

   ii. The analysis should also examine and identify any barriers to federal financial support services for tribal, territorial, and insular governments to ensure these entities have access to the resources they need to respond and recover from catastrophic events given the economic and geographic limitations some face.

Lead: Secretary of Homeland Security
Support: Department of Energy (Primary), National Risk Management Center, National Institute of Standards and Technology Community Resilience Program, Council of Economic Advisers, and other federal agencies as appropriate

Supporting Findings

- There are no coordinated, consistent standards or design criteria for increasing resilience to a catastrophic power outage that industry and government could work toward over time.
  - Companies and SLTT governments need time and justification to support making investments in more resilient infrastructure. A federal design basis could provide the guidance for a more coordinated and incremental increase in resilience.
- There is no common agreement on the level of redundancy or resilience that should be built into critical utilities—such as energy, water and wastewater, and communications—to lessen the risk and impacts of a long-term catastrophic power outage.
  - Without design basis guidance from the federal government, it is difficult for owners and operators to justify investments, receive regulatory approval, or even know what standards are realistic and sensible to build to because everything cannot be hardened. Sectors will also continue to build based on siloed or individual requirements without taking into account the larger context of national or other critical functions.
- There is a lack of understanding of the cascading, cross-sector interdependencies between infrastructure and what that means for prioritizing backup generation and other limited resources to maintain services and functions during a long-term, widespread outage.
  - Hospitals and other mass care providers are often at the top on priority restoration lists, however, for example, some of the water and wastewater treatment facilities they rely on are not. Without working water or wastewater systems, hospitals are unable to function.

There may even be a lack of understanding of which hospitals are the most critical to prioritize restoration.

- There is no common understanding of how long downstream sectors should be prepared to go without power, and what other services could be affected by the cascading impacts of a catastrophic outage.

Ongoing Initiatives

- **The NIST Community Resilience Program**—part of NIST's broader disaster resilience work—is a program designed to 1) develop the technical basis for tools to assess resilience and support informed decision-making for communities of all sizes; and 2) conduct outreach to community stakeholders to inform the development of NIST community resilience guidance tools for planning and implementing resilience measures.[3]
- **The NRMC** was established to provide a central location for collaborative, sector-specific and cross-sector management efforts to protect critical infrastructure. Within this, the NRMC will identify national critical functions through risk registries and dependency analyses with a focus on lifeline functions, and develop a strategic framework to identify critical cyber supply-chain elements across critical infrastructure sectors.[4]

Recommendation 3

Develop guidance and provide resources for states, territories, cities, and localities to design community enclaves—areas that co-locate critical services and resources to sustain surrounding populaces, maintain health and safety, and allow residents to shelter in place.

Community enclaves are not new mass shelters or camps; rather, they would generally consist of existing facilities and their supporting infrastructure, strategically located across communities to prevent mass migration or support survival when migration is not possible or residents must return as the outage persists.

A. **Identify the critical lifeline functions that communities need** (even in a limited capacity or degraded state)—such as communications, electricity, fuel, limited financial services, food, water and wastewater, and medical facilities—and for how long (e.g., 30-45 days).

   i. Integrate this guidance into the NIST Community Resilience Program. The guidance must include standards such as the number of hospitals, grocery stores, retail providers, gas stations, etc., based on population.

B. **Support demonstrations of community enclaves design approaches**, which may range from traditional hardening of infrastructure to microgrids that combine distributed energy resources, energy storage, and innovative consumer technologies. Deliver peer-reviewed results and lessons learned from demonstrations to provide utilities and communities with effective approaches to design, manage, operate, and fund microgrid and energy resilience capabilities.

[3] NIST, Community Resilience Program.
[4] DHS, DHS National Risk Management Center.

C. **Develop and support voluntary assessments of critical functions at the SLTT level** to help identify the existing infrastructure—electricity corridors, drinking water and wastewater, natural gas and liquid fuel pipelines, gas stations and fuel distribution sources, grocery stores, schools, hospitals, etc.—to create the community enclave.

   i. SLTT governments should use the voluntary assessments to inform emergency preparedness planning efforts to prioritize restoration of the infrastructure supporting the enclave, and to direct investments to harden this infrastructure as they are able.

   ii. The newly formed NRMC's work to identify national critical functions could serve as a starting point and be expanded to conduct these voluntary state and local assessments.

   iii. The voluntary assessments must take into account the different challenges and needs of states and communities, including territories and isolated areas, and at-risk or vulnerable populations.

D. **Develop and conduct outreach and training for businesses and individuals** to build a culture of preparedness at the individual and household level. Community enclaves are predicated on the idea that the majority of U.S. citizens are prepared and able to safely shelter in place for extended time periods.

Lead: Secretary of Homeland Security
Support: Federal Emergency Management Agency (Primary), National Protection and Programs Directorate (Primary), Department of Energy, and the National Institute of Standards and Technology Community Resilience Program

Supporting Findings

- Given the growing frequency and severity of disasters and other risks, there needs to be an increase in individual accountability, enterprise, and community investment in resilient infrastructure.
  - There is a misconception that events occur infrequently.
  - There needs to be more individual accountability for preparedness.
- Resilience at the state and local level will be critical to enable people to shelter in place and facilitate faster recovery. Any event that requires a mass evacuation will use up critical resources, clog transportation pathways, and reduce the workforce necessary for infrastructure recovery.
- Electricity, fuel, clean drinking water, wastewater services, food/refrigeration, emergency medical services, communications capabilities, and some access to financial services have been identified as critical lifeline services that would be needed to sustain local communities and prevent mass migration.
- Any efforts at the community level need to include input from SLTT governments, NGOs, critical services providers, and community leaders.
  - People default to trusted leaders and institutions (e.g., local government officers, faith-based centers, schools, civic organizations) in their community.
- Rather than building new infrastructure, existing community infrastructure (e.g., a school, a mall, or an indoor stadium) could be upgraded using agreed upon resilience standards (i.e., fuel, power, communications, etc.), thus creating local resilience centers quicker and at less cost than building new ones.

    - This level of planning and coordination will require a massive, interconnected analysis of the interdependencies, state processes, and maximum capacities for fuel storage.
- Florida Power and Light has established a model for identifying and hardening "community circuits"—electric distribution lines and substations that feed power to sites where multiple critical lifeline services are provided to communities. This could be expanded beyond electricity to the infrastructure needed for fuel resupply, communications, water and wastewater.
- Reliable fuel supply will be critical for establishing community enclaves and requires a baseline understanding of current storage and distribution capabilities.
    - Emergency fuel supply needs, fuel transportation requirements, the availability of backup generation, and the mutual interdependency of gas and electricity must be clearly understood by all stakeholders.
    - In most cases, in-state fuel resources will not be sufficient to meet the need for a catastrophic power outage.
- NIST community resilience planning guidance and tools are designed to be community driven and incorporated into existing efforts. Counties, cities, and communities need to define what resilience should look like for them, and the program encourages building resilience into all community actions.
    - NIST has also done work identifying building clusters or the buildings that provide crucial services of functions within communities. Those communities are then able to develop performance goals around those clusters.
- A key challenge for community enclaves will be the last mile of distribution and resupply of resources. To address this, enclaves should take advantage of industry efforts and pre-existing capabilities.
    - For example, partnering with companies that have pre-existing robust distribution systems and distribution warehouses.
- People no longer keep enough essentials within their homes, reducing their ability to sustain themselves during an extended, prolonged outage. We need to improve individual preparedness.
    - Most preparedness campaigns call for citizens to be prepared for 72 hours in an emergency, but the new emerging standard is 14 days.
    - For example, Washington, Oregon, and Hawaii have a standard that individuals have enough food and water to support themselves for 14 days. These efforts could serve as a model for federal and state preparedness resources, campaigns, and training.
    - The idea of individual preparedness is not a new concept. Civil defense, an older term used to elevate a level of individual preparedness and activate communities, used to be more widely accepted.
    - FEMA offers a number of tools, resources, and guidance on emergency preparedness, including recent efforts focused on better financial preparedness for disasters, and working with interagency partners on activity books and courses to educate students on emergency preparedness.

Ongoing Initiatives

- **FEMA's 2018-2022 Strategic Plan**: The Strategic Plan is a framework for supporting the United States before, during, and after disasters, and has three Strategic Goals aimed at mobilizing a whole

community approach to disaster response to build a culture of preparedness, readying the nation for catastrophic disasters, and reducing FEMA's complexity.[5]

- **Strategic Goal 1: Build a Culture of Preparedness** includes objectives to incentivize investments that reduce risk, including pre-disaster mitigation; closing the insurance gap; helping people prepare for disasters; and better learn from past disasters, improve continuously, and innovate.

Recommendation 4

Design and support a portfolio of incentives that provide financial support or remove financial and regulatory barriers to help companies, nongovernmental organizations, and state, local, tribal, and territorial governments implement the recommendations included in this report.

Develop incentives at the federal level and provide guidance to help state and local legislators, regulators, and insurers to provide incentives that encourage public and private investment in resilience.

A. **The national design basis provides the criteria needed to justify the actions or necessary funding**. Federal agencies responsible for implementing the recommendations must determine what incentives make sense to drive action, and examine whether they have the authority and funding available to do so.

B. **For the power sector**:

   i. The Secretary of Energy should seek to identify major incentives that could quickly have impact, forming a framework of incentives that can be added to over time, and taking into account the different ownership structures in the power sector (e.g., investor-owned utilities, cooperatives, public power utilities) and that some may need more direct financial support.

   ii. The Federal Energy Regulatory Commission (FERC) should implement cost recovery and return on equity incentives for investments in hardening the bulk power system (BPS).

   iii. The Secretary of Energy should work with Congress to provide incentives and technical assistance for state public utility commissions to evaluate cost recovery for resilience investments or provide cost recovery incentives at the retail or distribution level.

   iv. The Secretary of Energy should work with Congress to provide liability protection and other incentives set forth in the recommendations where the government lacks authority.

C. **Incentives that should be considered by agencies include**:

   i. Regulatory compliance waivers during events

   ii. Matching funds for state grants or other investments

   iii. Mitigation funding (e.g., grant reform for hardening systems)

   iv. Streamlined permitting for investments or actions included in the report

   v. Tax credits for making investments to meet the federal resilience design basis

[5] FEMA, *2018-2022 Strategic Plan*, 2018.

vi. Engaging the insurance industry to discuss insurance rate structures that value investments in resilience

vii. Funding for pilot programs to test implementation of new measures at the state level

Lead: Secretary of Treasury
Support: Secretaries of the relevant Sector-Specific Agencies (Primary), Federal Energy Regulatory Commission, and other federal agencies as appropriate

Supporting Findings

- All levels of government need a more comprehensive understanding of federal and state investments in order to better target funding to help manage the growing costs of catastrophic events. With the increasing severity and frequency of natural disasters, policymakers are looking for ways to control costs by investing in mitigation activities—actions that reduce risk to lives and property—before a disaster happens.
- The federal government and states can support the development of consistent resilience design standards, understanding that regional and state and local circumstances may warrant different levels or kinds of resilience.
    - The NRMC's efforts to prioritize functions that must remain operational during disasters could help identify and prioritize the investments needed to sustain those services/functions during a catastrophic power outage.
- Consistent resilience design standards can make it easier for Public Utility Commissions (PUCs) and regulators to make rates adjusted for owners and operators by providing them with the guidance necessary to understand what the reasonable risk costs and tradeoffs are to support resilience investments.
- The federal government could support additional incentives or tax breaks to the operators, and/or the individual commercial or residential users, to encourage participation in specific resiliency projects. Other incentives include:
    - Regulatory compliance waivers during events
    - Provide federal matching funds to state-run programs
    - Provide funding for mitigation ahead of a disaster (e.g., grant reform and supporting the DOE's strategic transformer reserve)
- As we have recommended in previous studies, outcome-based market incentives—focused on the desired end-state rather than meeting minimum standards—can encourage large-scale infrastructure upgrades, directing company resources toward exceptional resilience improvements rather than demonstrated compliance with minimum standards.
    - Outcome-based requirements give companies the flexibility to best achieve or exceed objectives, while allowing for variations in company structure, size, and resources.
- There should be an emphasis on deliberate planning because the expense of recovery can be mitigated with intentional investment in infrastructure ($1 spend on mitigation, $6 in savings[6]).

[6] National Institute of Building Sciences, *Natural Hazard Mitigation Saves: 2017 Interim Report*, 2017.

- In 2017, DOE and the National Association of Regulatory Utility Commissioners (NARUC) released a cybersecurity primer for regulatory utility commissions with best practices, access to industry and national standards, and other information.[7]
- During a grid emergency or a catastrophic power outage, there needs to be the ability to reduce load or ensure certain areas have power. This will be crucial for national security, but will create haves and have nots. There needs to be liability protections in place for grid owners and operators to do this during an emergency because the Federal Power Act does not provide liability protection.
    - Congress should legislate the expansion of liability protections for grid owners and operators.
- The power grid is a prime target for attack by nation states, and it is not fair for ratepayers to bear the full burden for this national security function.

[7] Karen Evans, *DOE Modernization: The Office of Cyber security, Energy Security, and Emergency Response*, Hearing before the Committee on Energy & Commerce, Subcommittee on Energy, 2018.

Mitigate Cross-Sector Interdependencies and Cascading Failures

Identify cascading failures impacting key sectors, especially natural gas supply and communications, to ensure their availability to aid power restoration, and identify actions to improve resilience to a catastrophic power outage. There is a lack of understanding of the cascading, cross-sector interdependencies between infrastructure and what that means for prioritizing backup generation and other limited resources to maintain services and functions during a long-term, widespread catastrophic power outage. The recommendations in this section are aimed at building a better understanding of how different infrastructure interacts with each other, particularly during a failure, to inform the steps needed to prepare for a catastrophic power outage.

Recommendation 5

Conduct a series of regional catastrophic power outage exercises that identify the second- and third-order cascading failures of an outage over time, as backup resources and mutual aid agreements are exhausted, and examine cross-sector supply chain and cyber risks that could delay re-energizing the grid.

Include all cross-sector partners, including critical infrastructure owners and operators (e.g., natural gas suppliers, water and wastewater, transportation, communications, finance, food and agriculture, public health); SLTT government officials; NGOs; and transmission operators and power utilities. Conduct exercises in the existing bulk power system regions—as coordinated by Regional Transmission Organizations (RTOs), Independent System Operators (ISOs), and North American Electric Reliability Corporation (NERC) Regional Reliability Coordinators—to provide a realistic view of how electricity failures would occur, and the cross-sector and cross-jurisdictional issues that would result. In addition, employ the convening power of the federal government to guide and support planning and exercises for all U.S. geographic areas, particularly islands and territories.

A. **Use results of the exercises to develop guidance** on how RTOs/ISOs and Reliability Coordinators should conduct blackstart exercises and response/recovery planning with their region's generation plant owners, transmission owners, and fuel providers to ensure the sufficiency of blackstart resources and identify risks specific to catastrophic power outages.

B. **Review and build upon lessons learned from GridEx, the National Level Exercise, and other relevant exercises**, including blackstart drills and DOE's Liberty Eclipse, taking into account the need for exercises to simulate the dynamic and compromised circumstances that will be experienced during a catastrophic power outage.

C. **Synthesize the analysis on cross-sector failures over the last 10 years** from after-action reports and other documents to identify and recommend best practices, and to better understand how infrastructure failures cascade.

D. **Employ the convening power of the federal government to guide and support collaborative cross-sector engagement** to improve the shared understanding of cascading interdependencies and mitigation paths and processes. This should involve engaging sectors not previously involved in exercises.

i. Engage cross-sector entities under the Critical Infrastructure Partnership Advisory Council (CIPAC) to encourage more collaboration across government and industry in implementing the recommendations from these exercises.

Lead: Secretary of Energy
Support: Federal Emergency Management Agency (Primary), North American Electric Reliability Corporation (Primary), Department of Homeland Security, and Federal Energy Regulatory Commission

Supporting Findings

- There are a number of existing exercises that consider large-scale power outages, but they have not matured to engage all necessary stakeholders, from local and community leaders and cross-sector representatives; and are unable to answer exactly who will be making decisions and what actions the federal government will take.
    - Centralized tabletop exercises may have challenges with engaging a large number of stakeholders, but distributed play aspects could provide greater opportunities to broaden participation to state and local governments and other sectors. For example, some states, such as Wisconsin and South Carolina, used the distributed play from GridEx as their major state disaster planning exercise.
- RTOs/ISOs and reliability coordinators have existing blackstart plans that are routinely exercised and built upon, but there is a desire for the government to be more involved. There is some inconsistency in how blackstart plans are exercised with key stakeholders including fuel suppliers and state and local government.
- There is no economic backstop to prop up companies that lose a large percentage of their customers during a catastrophic power outage. There is also no nationwide backstop to prop up the national economy if the power is out for so long that financial institutions are unable to operate and companies cannot access capital.
- Emergency managers at the state, county, and local levels have existing relationships with owners and operators of critical infrastructure in their jurisdictions, and should be empowered and supported to take on more responsibility during a catastrophic power outage.

Ongoing Initiatives

- **Cross-sector dependency models**: To understand the impacts of a catastrophic power outage, modeling of the critical U.S. infrastructure—electricity, natural gas, and other dependent sectors—is needed to identify vulnerabilities and define solutions paths. Current efforts include:
    - DOE is working with its partners to develop a North American Resiliency Model.
    - The Electric Infrastructure Security (EIS) Council is working on a Global Infrastructure Network Optimization Model (GINOM).
- **Tri-Sector Executive Working Group**: The NIAC had previously recommended the formation of a strategic infrastructure group—made up of senior executives from the Electricity, Financial Services, and Communications Sectors who can direct priorities and marshal resources. The Tri-Sector Executive Working Group is being chartered under the Critical Infrastructure Partnership Advisory Council (CIPAC). The newly formed NRMC intends to work closely with the group for sustained cross-sector engagement.

Recommendation 6

Ensure that all critical natural gas transmission pipeline infrastructure has the appropriate standards, design, and practices to continue service during a catastrophic power outage and maintain rapid availability to support blackstart generation.

Establish programs—working with the pipeline, electric power, and communications industries—to ensure secure pipeline operations and resilience by examining overall interconnectedness and mutual interdependencies.

A. **These programs may include voluntary, industry-led efforts, mandatory standards, or a combination of these approaches**. It may require using existing legal authorities or, after consultation with industry, developing new legal authorities.

B. **Establish guidance that encourages generation and transmission owners and operators to conduct blackstart exercises with their natural gas providers** to identify and plan for scenarios where fuel supply issues may impede blackstart capabilities and delay re-generation of the grid.

Lead: Secretary of Energy
Support: Department of Transportation (Primary), Transportation Security Administration, North American Electric Reliability Corporation, Federal Energy Regulatory Commission

Supporting Findings

- The electric system has a growing dependence on the natural gas pipeline system to assure operation, resilience, and recovery from outages.
    - The Electricity Subsector is becoming more reliant upon natural gas as a fuel source; from 2002 to 2016, the share of electricity generated by gas-fired units increased from 18 percent to about 34 percent while the share generated by coal fell from about 50 percent to about 30 percent.[8]
- The construction of natural gas pipelines is driven by the market and demand. Pipelines are built to meet firm capacity, when there is a willingness and ability of customers (i.e., shippers) to financially commit to the gas that would be provided.
    - Limited pipeline capacity in a particular region can be attributed to factors such as environmental regulations hindering construction and/or residents who do not want pipelines in their communities. Also, there may be a general lack of incentive(s) among the generator community to contract for firm service.
- There are modest steps being taken to address pipeline security, including recently updated and expanded Transportation Security Administration (TSA) voluntary guidelines, but these steps need to be expanded.

[8] DOE, *Staff Report to the Secretary on Electricity Markets and Reliability,* 2017.

- The NERC has offered a set of recommendations on opportunities for gas-electric coordination, many of which might be supported by data to facilitate broader assessments of fuel resilience and collaborative mitigation measures.

Ongoing Initiatives

- **Pipeline Cybersecurity Initiative**: The CISA Director, TSA Administrator, and CESER Assistant Secretary met in October 2018 to identify ways to collaborate with industry partners to enhance and improve pipeline cyber and physical security.

Recommendation 7

Develop or support a flexible, adaptable emergency communications system that all sectors can interoperably use, that is self-powered, and is reasonably protected against all hazards to support critical service restoration and connect infrastructure owners and operators, emergency responders, and government leaders.

A. **A portfolio of communications capabilities must be put in place to ensure that the private sector**, federal and SLTT governments, and others are able to communicate despite the cause of an outage.
   i. Draw on DOD capabilities and technical expertise on survivable communications during a disaster.

Lead: Secretary of Homeland Security
Support: Department of Defense (Primary), Department of Energy, Federal Communications Commission

Supporting Findings

- Restoration and recovery are next to impossible without working communications systems. Existing plans and exercises rely on the ability to coordinate response via voice or data communications systems, which are likely to be unavailable or degraded during a catastrophic power outage.
  - Most companies have internal emergency communications and/or plans for restoration in a degraded state or blackstart. However, cross-sector coordination and support requires broader telecommunications and hardening.
- Backup power generation is a commonly accepted emergency response standard, but backup (i.e., diverse or redundant) communication capabilities are generally not standard.
- The electric industry has been examining historical methods to enhance resilience. Use of amateur or single-sideband radios for communications and manual management electric grid operations by frequency are being trialed.
- Communications systems, including information technology (IT), need to be robust and capable of operating even in a degraded state to provide situational awareness and allow for coordination and information-sharing among federal government authorities, SLTT government, owners and operators, and communities.
  - Emergency communications must have backup power and be deployable to all infrastructure and critical supply chains.

- Backup communication devices are available—such as satellite phones—but they are typically limited in number and are often not maintained or protected from all hazards. People also may not know how to use them or have the correct numbers for the people they need to reach. The bandwidth capacity and number of devices for these backup communications, like satellite phones, is not adequate to fully support the coordination of recovery and restoration efforts during an event of this scale.
    - All communications systems are vulnerable to damage or attack, necessitating a variety of possible communication methods. To have resilient communications requires being prepared for multiple potential outcomes.
    - There needs to be a prioritized method for communications in a degraded state when communication goes out across multiple sectors.
- The level of network assuredness anticipated to meet these needs can be provided in whole, or in part, by commercial communication providers. A number of federal departments and agencies have already addressed their own need for high-assurance communications to support their essential missions.
- DHS has previously contracted comparable networks for use by critical entities to use under similar circumstances (e.g., the Critical Infrastructure Warning Information Network (CWIN)). The approaches used by these agencies, as well as DHS's past experience, may provide a template to expedite developing the requirements for implementing network capabilities resistant to a wide range of catastrophic scenarios.
- Survivable communications are the lynchpin for responding to this type of event and restoring electricity (e.g., ability for power companies to communicate with each other and the government).
    - The Pentagon has done a tremendous amount of work on survivable communications that can provide the minimum level of functionality needed.
    - Supply chain risk management will also be important to ensuring communications systems are survivable and not able to be compromised.
    - FEMA, DOD, and DOE can all provide technical assistance to meet the minimum level of requirements needed.

Ongoing Initiatives

- **The Electricity Subsector Coordinating Council (ESCC) Resilient Communications Working Group** has identified the need to update, modernize, and move some of the underlying systems out of private networks partially because real-time coordination across multiple sectors makes voice and data telecommunications critical for operation of the grid. The ESCC has also recommended that some form of backup communications capability to restore the grid after a major disaster needs to be created.
    - The ESCC has created a policy principle statement supporting emergency communications to validate and formalize the current work being done with the Communications Sector.
- **The EIS Council** is working on Black Sky Emergency Communications and Coordination System (BSX)—an interoperable, secure system that can incorporate a range of communication technologies to support grid re-start activities.[9]

[9] EIS Council, "Black Sky Emergency Communication & Coordination System: BSX."

Moving Forward: A Call to Action

A catastrophic power outage could paralyze entire regions with grave consequences for national security, economic security, and public health and safety. The magnitude of this threat requires the federal government to lead in every way possible to:

- Establish and execute clearly understood authorities
- Maintain a high-priority mission for catastrophic power outages
- Provide steadfast guidance and incentives for action
- Deliver resources, including dollars, expertise, and decision-making capabilities

To do so requires the federal government serve as convener and lead collaborator for critical infrastructure owners and operators and stakeholders across all levels of government. Strong and effective public-private collaboration will be crucial.

Throughout this study we have learned about ongoing initiatives, such as the work the EIS Council has done developing materials and playbooks on black sky hazards, the current efforts by FEMA to build individual preparedness and incorporate lessons learned into the nation's emergency response plans, and the work of CISA to build cross-sector collaboration, along with many other efforts across government and industry. This work is important and is helping to drive action. It should continue to be supported and advanced.

We believe our recommendations build on this ongoing work and provide a path forward for enhancing the nation's capabilities to respond to and recover from these never-before-experienced events.

Given the importance of this issue and the number of ongoing efforts, we ask the NSC—working with the lead agencies identified—to provide a status update to the NIAC within nine months of the report's approval on how our recommendations are being implemented, progress being made on ongoing initiatives, or any significant barriers to implementation.

Appendix A: Acknowledgements

Working Group Members

Constance H. Lau (Co-Chair), President and CEO, Hawaiian Electric Industries, Inc. (NIAC Chair)

William Fehrman (Co-Chair), President and CEO, Berkshire Hathaway Energy

Jan Allman, President, CEO, and General Manager, Marinette Marine Corporation*

Dr. Georges Benjamin, Executive Director, American Public Health Association

William Terry Boston, Former CEO, PJM Interconnection*

Ben Fowke, Chairman, President, and CEO, Xcel Energy*

George Hawkins, Former CEO and General Manager, District of Columbia Water and Sewer Authority*

Joan McDonald, Director of Operations, Westchester County, NY*

Beverly Scott, Ph.D., CEO, Beverly Scott Associates, LLC; former General Manager, Massachusetts Bay Transportation and Rail, and Transit Administrator for the Commonwealth of Massachusetts (NIAC Vice Chair)*

Mike Wallace, Former Vice Chairman and COO, Constellation Energy

* *Denotes Working Group members who served as part of the scoping effort*

Study Group Members

Scott Seu (Co-Chair), Senior Vice President, Public Affairs, Hawaiian Electric Company

Peter Grandgeorge (Co-Chair), National Security and Resiliency Programs Advisor, MidAmerican Energy – Berkshire Hathaway Energy

Scott Aaronson, Vice President, Security and Preparedness, Edison Electric Institute (EEI)

Ted Basta, Chief Executive, TJB Transit Consultant Services

Kathryn Condello, Director, National Security and Emergency Preparedness, CenturyLink

Randy Crissman, Senior Reliability and Resilience Specialist, Utility Operations, New York Power Authority

Kimberly Denbow, Senior Director of Security, Operations and Engineering Services, American Gas Association

Michele Guido, Business Assurance Principal, Southern Company

Suzanne Lemieux, Manager, Midstream and Industry Operations, American Petroleum Institute

Nathaniel T. Millsap Jr., Director, Industrial Security and Technology, Marinette Marine Corporation

Frank Prager, Vice President, Policy and Federal Affairs, Xcel Energy

Jonathan Reeves, Americas, Resiliency Lead, Facebook; former Chief, Office of Emergency Management, District of Columbia Water and Sewer Authority

Saul Rojas, Vice President, Technical Compliance, New York Power Authority

Working Group Interviewees

Robert Blue, Executive Vice President and President and CEO-Power Delivery Group, Dominion Energy

Jeffrey Byard, Associate Administrator, Office of Response and Recovery (ORR), Federal Emergency Management Agency (FEMA)

Carlos J. Castillo, Associate Administrator, Resilience, FEMA

Stephen A. Cauffman, Research Engineer, Community Resilience Program, National Institute of Standards and Technology (NIST)

Christina Cody, Director of Energy Sector Resilience, National Security Council (NSC)

Jimmie Collins, Senior Advisor, U.S. Indo-Pacific Command (USINDOPACOM), Department of Energy (DOE)

Tom Fanning, Chairman, President, and CEO, Southern Company

Lt. Gen. Reynold Hoover, Deputy Commander, U.S. Northern Command (NORTHCOMM)

Maj. Gen. Donald E. Jackson Jr., Deputy Inspector General, Office of the Inspector General, U.S. Army; former Deputy Commanding General, Civil and Emergency Operations, U.S. Army Corps of Engineers (USACE)

Chris Krebs, Director, Cybersecurity and Infrastructure Security Agency (CISA), U.S. Department of Homeland Security (DHS)

Bob Kolasky, Director, National Risk Management Center (NRMC), DHS

Mark Lauby, Senior Vice President and Chief Reliability Officer, North American Electric Reliability Corporation (NERC)

John McAvoy, Chairman, President, and CEO, Consolidated Edison, Inc.

Arthur Ray, Director, Critical Infrastructure Policy, NSC

Louis Renjel, Vice President, Federal Government Affairs and Strategic Policy, Duke Energy

James Robb, **President and** CEO, NERC

Lt. Col. Brad Smith, Homeland Defense, Defense Support to Civil Authorities, USINDOPACOM

Mark Stephens, City Manager, New Bern, North Carolina

Paul Stockton, Ph.D., Managing Director, Sonecon LLC; former Assistant Secretary of Defense for Homeland Defense and Security Affairs

James P. Torgerson, CEO, Avangrid, Inc.

Bruce Walker, Assistant Secretary, Office of Electricity (OE), DOE

Study Group Interviewees

Keith Adams, Vice Chair, National Voluntary Organizations Active in Disaster (NVOAD); Chair of the New Jersey VOAD

Allen Bintz, Principal Solutions Architect, Strategic Government, CenturyLink

Michael Bryson, Vice President, Operations, PJM Interconnection LLC (PJM)

Janice K. Devers, Director, Tariffs and Regulatory Affairs, Algonquin Gas Transmission, LLC

Antonio L. Fernández, Director, Latinos for Healthcare Equity

Dr. Eric Goralnick, Medical Director, Emergency Preparedness, Brigham and Women's Hospital (BWH)

Brian Harrell, Former Managing Director, Enterprise Protective Services, Duke Energy Corporation

Trevor Hines, Lead of Operations Information and Communications, Midcontinent Independent System Operator (MISO)

Jesse Levin, Founder, Tactivate

Dave McCurdy, President and CEO, American Gas Association (AGA)

James Merlo, Ph.D., Vice President and Director of Reliability Risk Management, NERC

Manuel Miranda, Senior Vice President of Power Delivery, Florida Power & Light Company (FPL)

Jay Montgomery, Vice President, Corporate Security and Business Continuity, Kinder Morgan Energy Partners; Chair, Oil and Natural Gas Sector Coordinating Council (SCC)

Chris Oberg, Principal Engineer, Network, Verizon Wireless; Chair, Communications Information Sharing and Analysis Center (ISAC)

David Owens, Chair, Transformation Advisory Council (TAC), Puerto Rico Electric Power Authority (PREPA)

Jeffrey Pillon, Director, Energy Assurance Programs, National Association of State Energy Officials (NASEO)

Gil Quiniones, President and CEO, New York Power Authority (NYPA); Chair, Puerto Rico Energy Resiliency Working Group

Steve Rourke, Vice President, System Planning, ISO New England (ISO-NE)

Kris Ruud, Principal Advisor of Engineering and Real-Time Operations, MISO

Donald Santa Jr., President and CEO, Interstate Natural Gas Association of America (INGAA)

William Whaley, Vice President of U.S. Pipelines Gas Control, Enbridge Gas Distribution and Union Gas

Dena Wiggins, President and CEO, Natural Gas Supply Association (NGSA)

Le Xie, Ph.D., Associate Professor, Texas A&M University

Wesley Yeomans, Vice President, Operations, New York Independent System Operator (NYISO)

NIAC Scoping Effort Interviewees (Nov. 2017-June 2018)

Scott Aaronson, Vice President, Security and Preparedness, EEI

Nick Akins, Chairman, President and CEO, American Electric Power

Charles R. Alexander, Director, Contingency Operations, USACE

William Ball, Executive Vice President and Chief Transmission Officer, Southern Company

Kathryn Condello, Director of National Security and Emergency Preparedness, CenturyLink

Joshua Dozor, Deputy Assistant Administrator, Response, FEMA

Maj. Gen. Donald Dunbar, Adjutant General of Wisconsin, Wisconsin National Guard

Greg Engle, Director, Bureau of Planning and Preparedness, Wisconsin Emergency Management

Doug Fears, Deputy Assistant to the President, Homeland Security and Counterterrorism Advisor, NSC

Mark Fleming, Director for Homeland Preparedness and Resilience Policy, NSC

Deborah Fulk, Senior Planner, Response Operations Division, FEMA Region V

Sean Griffin, Former Program Manager, Infrastructure Security and Energy Restoration, DOE

Patricia A. Hoffman, Principal Deputy Assistant Secretary Office of Electricity Delivery and Energy Reliability, DOE

Michael Isper, Office of Security Policy and Industry Engagement (OSPIE), TSA

Kenneth Mercado, Senior Vice President, Electric Operations, CenterPoint Energy

Charles Phillips, Surface Transportation Division, TSA

Paul Preusse, Director, Response Operations Division, FEMA Region V

Gil Quiniones, President and CEO, NYPA; Chair, Puerto Rico Energy Resiliency Working Group

Avi Schnurr, CEO and President, Electric Infrastructure Security (EIS) Council

Paul Stockton, Ph.D., Managing Director, Sonecon LLC; former Assistant Secretary of Defense for Homeland Defense and Security Affairs

Gus Wulfkuhle, Operational Planner, Response Operations Division, FEMA Region V

Department of Homeland Security Study Support Resources

Ginger Norris, Designated Federal Officer (DFO), NIAC, IP, DHS

Deirdre Gallop-Anderson, Alternate DFO, NIAC, IP, DHS

Beth Slaninka, Nexight Group, LLC

Lindsay Kishter, Nexight Group, LLC

Kate McClaskey, Nexight Group, LLC

Appendix B: Study Methodology

The United States has experienced long-term power outages (typically defined as 72 hours or more), such as the 2003 Northeast Blackout (more than 50 million customers without power across the Midwest and Northeast for up to four days), Hurricane Katrina in 2005 (2.7 million customers without power across four states for 2-4 weeks), and Superstorm Sandy in 2012 (more than 8.5 million customers lost power in 20 states and the District of Columbia for about two weeks).[10] More recently, the devastation in Puerto Rico following Hurricanes Irma and Maria gave us a glimpse at how a loss of power can cascade into other sectors affecting public health and safety and the economy.

The nation has steadily improved its ability to prepare for and respond to events that are of relatively short duration and extent. Federal and state entities have identified and incorporated lessons learned from each of the events listed above.

This study is not focused on long-term power outages we have experienced. The President's National Infrastructure Advisory Council (NIAC) was challenged to move beyond what we as a nation have experienced and to imagine what would happen if these events stretched beyond days or weeks to months or years, if they affected large swaths of the country, and existing response capabilities were exhausted. This appendix outlines how the NIAC approached this tasking.

Charge to the NIAC

Given the interconnected nature of critical systems and networks, new broad-scale approaches are needed to adequately prepare for, respond to, and recover from catastrophic disasters that can create significant power outages with severe cascading impacts to multiple critical sectors.

On May 21, 2018, the White House through the National Security Council (NSC), tasked the NIAC to build on insights gathered during a scoping effort to develop findings and actionable pragmatic recommendations that address how the public and private sectors can work together to further enhance and integrate critical infrastructure resilience with response and recovery actions to mitigate the risks posed by catastrophic power outages. Specifically, the NSC tasked the NIAC with addressing five questions:

1. What investments, including approaches to increase resilience and reliability, are needed in infrastructure systems and supply chains to minimize the duration, extent, and recovery time for long-duration, large-scale power outages? What are the roles of the private and public sectors in these investments?
2. What critical factors are required to sustain national security; operations within the banking and finance, public health and medical, communications, transportation, and water sectors; and the integrity of the national and regional economies during efforts to restore electric power?
3. What is the Nation's readiness to prioritize and coordinate resource sharing among federal, state, and private entities during catastrophic power outages that will mitigate cascading impacts across the lifeline functions?
4. To what extent are regional and national-level vulnerabilities to catastrophic power outages understood, given the diversity and complexity of North American electric generation, transmission, distribution, and storage configurations and markets?

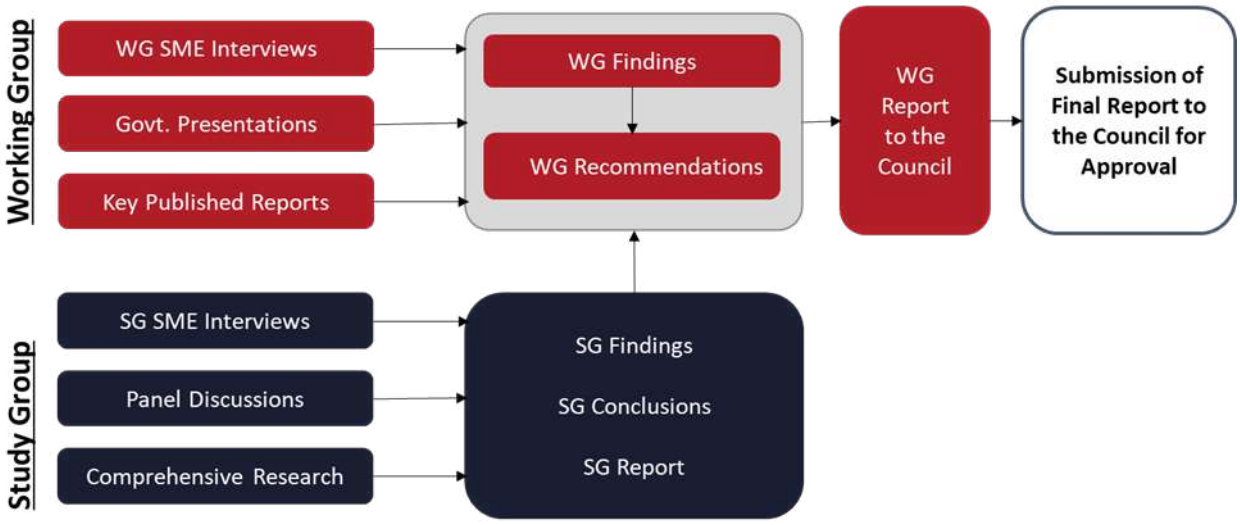
[10] FEMA, *Power Outage Incident Annex,* 2017.

5. Where does the Power Outage Incident Annex to the Response and Recovery Federal Interagency Operational Plans fit within the context of public-private preparedness activities?

Study Approach

To complete this task, the NIAC formed a Working Group of 10 NIAC members that:

- **Built on the *NIAC Catastrophic Power Outage Scoping Study* completed in June 2018**. As part of the scoping effort, the Council was tasked to identify the gaps and challenges the nation's infrastructure would face during a catastrophic outage. A Working Group of six NIAC members:
  - **Interviewed 21 senior leaders and subject matter experts** from federal and state government and industry.
  - **Reviewed over 350 resources**, including laws, reports, articles, and prior studies.
  - **Considered three key pillars to frame the study scope**:
    - The infrastructure investments and system hardening that could minimize outage severity.
    - The critical factors required to sustain public health and safety and the integrity of the national and regional economies during power restoration.
    - The nation's readiness to prioritize and coordinate resource sharing among federal, state, and private entities during an outage of unprecedented scale.
  - **Identified 8 key areas of inquiry** for in-depth examination in the full study.
- **Formed a Study Group of 13 subject matter experts to vet and validate the 8 key areas of inquiry from the scoping effort.** The Study Group:
  - **Conducted interviews of 25 experts** from federal and state government, industry, and academia.
  - **Conducted research and reviewed more than 100 sources** to identify capabilities that aligned with government and industry needs and existing capabilities.



- **Defined catastrophic power outages** to frame interviews, research, and discussions to ensure clarity in how these events are different and that the recommendations would be actionable (See Appendix C for more detail on this definition).

- **Leveraged the wealth of existing information and built on the body of extensive work examining the nation's readiness** to prioritize and coordinate resource sharing among federal, state, and private entities during a catastrophic outage.
- **Conducted interviews with 21 senior leaders and experts** in government and experts in the private sector. (See Appendix A for a list of interviewees and report contributors).
- **Conducted research and reviewed more than 250 different sources,** including statutes, reports, studies, congressional testimony, articles, and prior NIAC studies.

Appendix C: Definitions to Frame the Study

There are a number of terms used by federal agencies and in the emergency management space that describe severe, long-lasting disasters. The Department of Defense (DOD) uses the term "complex catastrophes,"[11] the Electric Infrastructure Security (EIS) Council identifies "black sky events,"[12] the Federal Emergency Management Agency (FEMA) has defined "long-term power outage,"[13] and the National Response Framework (NRF) describes "catastrophic incidents."[14]

The NIAC is not replacing these definitions, but rather it sought to define the focus of this study so it is clear how these events are different; and to provide the framing and context needed to understand and implement its recommendations.

Similarly, the NIAC has defined critical infrastructure resilience in the context of this study based on other uses and definitions. This appendix includes the NIAC's definitions of these two terms and key inputs used to develop them.

I. Catastrophic Power Outage Definition

As part of the scoping effort, the NIAC defined catastrophic power outages as events beyond modern experience that exhaust or exceed mutual aid capabilities. The NIAC built on that definition to provide additional detail and clarity:

1. **These are likely to be no-notice or limited-notice events**, and potentially an act of war that would require a military response. These potential events could include:
    a. Sophisticated cyber-physical attack timed with a major natural disaster
    b. Repeated events in a short period of time with significant physical damage
    c. Electromagnetic events, whether natural or manmade, which could result in severe physical damage
2. **Long-duration**, lasting several weeks to months (at least 2 months, but more likely 6 months or more) due to physical destruction to equipment, such as transformers or transmission lines; or the severity of the event resulting in limited work force to repair damage, or inability to create or transport replacement parts.
3. **Affects a broad area of the nation** covering multiple states or regions, impacting between 50 million and 75 million people,[15] and threatening the viability of state and regional economies and local communities.
4. **Results in severe cascading impacts** that force critical sectors—water and wastewater systems, communications, transportation, healthcare, financial services—to operate in a degraded state, due to back-up generators running out of fuel and fuel resupply hindered by limited transit options or being diverted to higher priorities.
    a. Many generators will also breakdown after they are forced to run beyond design limits during an event that stretches weeks and months.
5. **Exceeds or exhausts capabilities** of existing mutual aid programs and emergency response plans.

[11] DOD, *Memorandum: Definition of the Term Complex Catastrophe*, 2013.
[12] EIS Council, "Black Sky Hazards."
[13] FEMA, *Power Outage Incident Annex,* 2017.
[14] FEMA, *National Response Framework*, 2015.
[15] U.S. Census Bureau. 2017.

a. Current emergency response plans and frameworks rely on aid being provided from unaffected areas and the ability to identify and communicate needs. This is unlikely to be possible during these events.
b. The electricity sector has an effective mutual aid program, but during an event of this scale utilities are unlikely to have surplus supplies or work force, and depending on the severity of the event it may be impractical or impossible to bring help in from unaffected areas of the nation.
c. States are also unlikely to be able to assist others given limited resources and expected barriers both legal and physical for moving materials and work force.

A. Inputs for Definition of Catastrophic Power Outage

The NIAC reviewed how other entities defined similar events and they served as key inputs. It also examined scenarios such as those used in exercises, planning, or actual historical events.

Federal Emergency Management Agency

FEMA sought to address the challenges to the federal government posed by long-term power outages in its 2017 *Power Outage Incident Annex to the Response and Recovery Federal Interagency Operational Plans* (POIA) guidance for federal agencies.[16] FEMA defined a long-term power outage as one that:

- Extends to multiple states and/or FEMA regions and leaves millions of customers without power for an extended period;
- A significant part of the population needs prolonged mass care and emergency assistance;
- A loss of critical lifeline functions (e.g., energy, water, communications, and transportation) creates risk to health, personal safety, national security, and economic viability;
- Results in significant loss of service or functions in other critical infrastructure sectors; and
- State, local, tribal, territorial (SLTT), or insular governments need sustained operational coordination to respond to the effects.[17]

In the POIA, FEMA identified several events in modern experience that fit its definition, including the 2003 Northeast Blackout, Hurricane Katrina, and Superstorm Sandy.

Electric Infrastructure Security Council

The EIS Council defines black sky events as a catastrophic event that severely disrupts the normal functioning of critical infrastructure in multiple regions for long durations.[18]

Department of Defense

DOD uses the term complex catastrophe, as any natural or man-made incident including cyberspace attack, power grid failure, and terrorism, which results in cascading failures of multiple interdependencies, critical, life-sustaining infrastructure population, environment, economy, public health, national morale, response efforts, and/or government functions.[19]

[16] FEMA, *Power Outage Incident Annex,* 2017.
[17] Ibid.
[18] EIS Council, "Black Sky Hazard."
[19] DOD, "Department of Defense Dictionary of Military and Associated Terms," 2010.

National Response Framework

The NRF has defined a catastrophic incident "as any natural or manmade incident, including terrorism, that results in extraordinary levels of mass casualties, damage, or disruption severely affecting the population, infrastructure, environment, economy, national morale, or government functions."[20]

II. Critical Infrastructure Resilience Definition

Resilience is a commonly used term it is important to be clear about it means in this context. The Working Group built on definitions from prior NIAC studies, Presidential Policy Directive-21, and the Executive Office of the President.

For this study, critical infrastructure resilience is defined as the:

- Ability to prepare for and adapt to changing conditions, and reduce the magnitude and/or duration of disruptive events by:
    a. Building robust systems through design, redundancy, and hardening so that the systems are able to operate even in a degraded state; and
    b. Embedding agility and adaptability into infrastructure systems and cyber systems creating the ability to respond and recover through preparedness and contingency planning, training, technology, supply chain management and diversity, and improved information sharing and situational awareness to prioritize critical assets and functions.[21]

A. Inputs for Definition of Critical Infrastructure Resilience

The following sources and definitions were referenced to develop the definition of critical infrastructure resilience for this study.

National Infrastructure Advisory Council

"Infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event."[22]

- **Absorptive capacity**: is the ability of the system to endure a disruption without significant deviation from normal operating performance.
- **Adaptive capacity**: is the ability of the system to adapt to a shock to normal operating conditions. For example, the extra transformers that the U.S. electric power companies keep on store and share increases the ability of the grid to adapt quickly to regional power losses.
- **Recoverability**: is the ability of the system to recover quickly—and at low cost—from potentially disruptive events.

Critical infrastructure resilience is characterized by three key features: robustness, resourcefulness, and rapid recovery.

Executive Office of the President

"The EOP (Executive Office of the President) proposed seven principles as critical success factors by which the task force could examine the resiliency of the network, including:

[20] FEMA, *National Response Framework*, 2015.
[21] NIAC, *Critical Infrastructure Resilience: Final Report and Recommendations*, 2009; NSTAC, *Report to the President on Communications Resiliency*, 2011; and The White House, *Presidential Policy Directive 21*, 2013.
[22] NIAC, *Critical Infrastructure Resilience: Final Report and Recommendations*, 2009.

- Redundancy (multiplicity, spares)
- Diversity (multiple approaches and suppliers)
- Agility (ability to shift)
- Adaptability (ability to adjust)
- Prioritization (dedicated or shared resource)
- Geography (diversity, proximity)
- Hardening (ability to withstand direct force)."[23]

Presidential Policy Directive 21—Critical Infrastructure Security and Resilience

"The term resilience means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[24]

[23] NSTAC, *Report to the President on Communications Resiliency*, 2011.
[24] The White House, *Presidential Policy Directive 21*, 2013.

Appendix D: Government Authorities, Processes, and Roles

In the United States, the role of the federal government in disaster response is to "supplement the efforts and available resources of states and local governments, and disaster relief organizations in alleviating damage, loss, hardship, or suffering."[25] This "bottoms-up" approach is a tried and true mechanism. The federal government is the only level of government with the authority and capability to cope with widespread events, because most catastrophic impacts span multiple states and municipalities.[26]

The Federal Emergency Management Agency (FEMA) noted in its *2017 Hurricane Season After-Action Report* that "no jurisdiction or federal agency has all the staff and resources it will need to respond to a catastrophic incident."[27] And in its *2018-2022 Strategic Plan*, FEMA states that the agency "does not and cannot serve as the sole or primary responder."[28] The Agency's practice is that emergency management strategies are most effective when they are "federally supported, state managed, and locally executed."[29]

However, the concern is that when a catastrophic power outage or other complex disaster occurs, it has the potential to immediately overwhelm state and local capabilities. In this scenario, there is not an equivalent "top-down" approach or process where the federal government acts as the initial and primary source of aid that is understood and accepted by all parties.

This appendix provides an overview of existing federal authorities and processes during a disaster and how these interact with state, local, tribal, and territorial (SLTT) government and community roles. It also includes an overview of the roles of federal agencies, state and local government, and industry during emergencies.

I. Federal Authorities and Processes

Federal response to an event is guided by several frameworks and documents under the National Preparedness System (NPS) building off the National Preparedness Goal to establish "a secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk."[30]

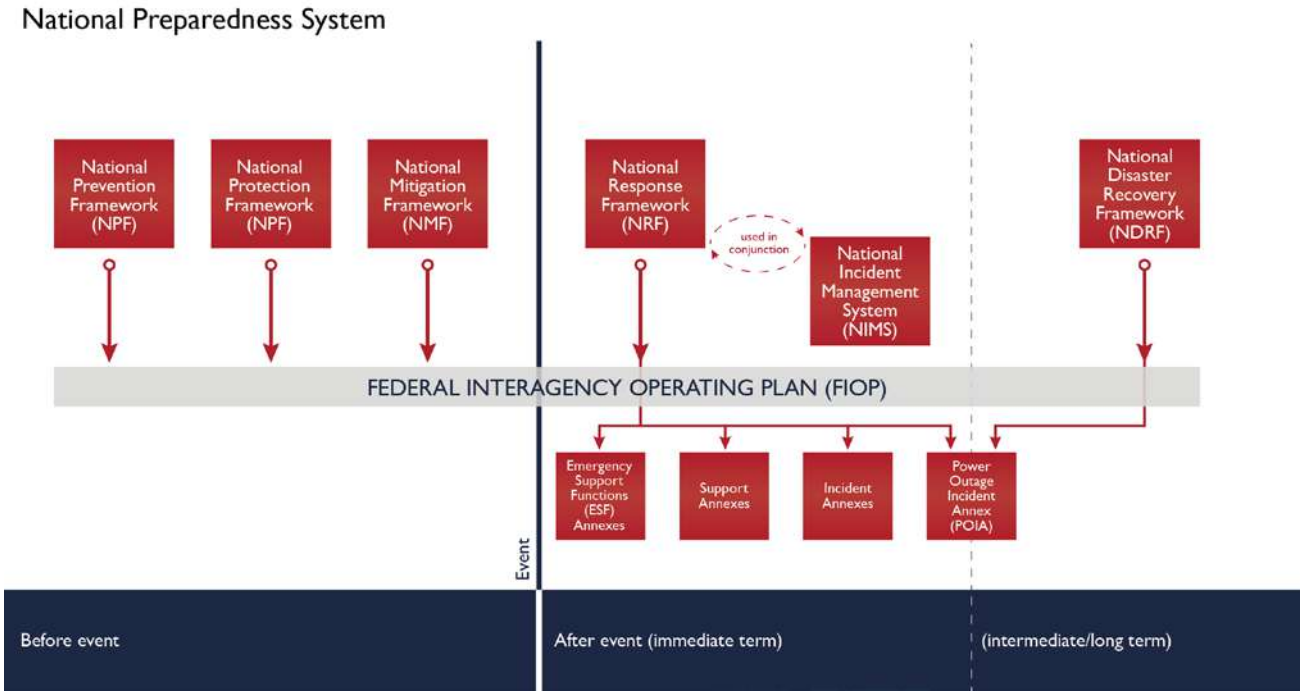
A. National Preparedness System

The NPS was established under Presidential Policy Directive 8: National Preparedness (PPD-8), issued by President Obama in 2011.[31] NPS is designed to help "ensure the Nation's ability to prevent, respond to, recover from, and mitigate against natural disasters, acts of terrorism, and other man-made disasters."[32] NPS includes a National Planning Framework for each of five mission areas—prevention, protection,

[25] *Robert T. Stafford Disaster Relief and Emergency Assistance Act*, Pub. L. 93-288.
[26] Amy Lui, "Feds, States, Cities – The All of the Above Disaster Response," *Brookings,* November 2, 2012.
[27] FEMA, *2017 Hurricane Season FEMA After-Action Report,* 2018.
[28] FEMA, *2018-2022 Strategic Plan*, 2018.
[29] Ibid.
[30] DHS, *National Preparedness Goal*, 2015.
[31] DHS, "Presidential Policy Directive 8: National Preparedness," March 30, 2011.
[32] 6 U.S. Code §§ 743-744.

mitigation, response, and recovery[33]—as well as Federal Interagency Operational Plans (FIOPs) and guidance for SLTT governments for coordinating national preparedness efforts.[34]

The graphic below provides a high-level view of the NPS and its five frameworks and supporting plans.



Under the NPS, the National Response Framework (NRF) is the principal interagency response coordination structure for declared Stafford Act events and non-Stafford Act events[35]—presidentially declared events that initiate federal disaster assistance—providing guidance for immediate response to a disaster.[36] The NRF outlines how the United States responds to disasters and emergencies of all sizes,[37] indicates how federal agencies should interact with SLTT governments and the private sector, and specifies when federal authorities assume control of national response.[38]

The NRF establishes different Emergency Support Functions (ESFs) to organize the response capabilities of the federal government,[39] by grouping federal agencies with relevant authorities, resources, and expertise, with an established coordinator, primary agency or agencies, and support agency relevant to the ESF.[40] ESFs are applied through the National Response Coordination Center (NRCC)—a multiagency center that coordinates the overall federal support for major incidents and emergencies.[41]

[33] Statement of Robert J. Fenton, *Pacific Northwest Seismic Hazards: Planning and Preparing for the Next Disaster,* Hearing before the House Committee on Transportation and Infrastructure, May 19, 2015.
[34] DHS, *Section 2(e): Assessment of Electricity Disruption Incident Response Capabilities,* 2018.
[35] DHS, *National Response Framework*, 2008.
[36] Jared T. Brown, et al., *Congressional Primer on Responding to Major Disasters and Emergencies*, Congressional Research Service, 2017.
[37] DHS, *National Response Framework*, Second Edition, May 2013.
[38] Richard Weitz, "Federalism and Domestic Disasters: Promoting a Balanced Approach," *Hudson Institute*, 2006.
[39] DHS, *National Response Framework,* Third Edition, June 2016.
[40] Jared T. Brown, et al., *Congressional Primer on Responding to Major Disasters and Emergencies*, Congressional Research Service, 2017.
[41] FEMA, "Fact Sheet: National Response Coordination Center," July 2015.

The National Disaster Recovery Framework (NDRF) is a companion to the NRF and outlines the strategy and doctrine for how a whole community builds, sustains, and coordinates recovery. The NDRF provides recovery principles, roles and responsibilities at the respective levels of government, and a structure and process to assist short-and long-term recovery following a disaster event.[42]

The most successful and impactful response following an emergency is local, but local governments and community-level organizations are often not actively engaged in disaster response planning. This creates a disconnect between the federal government and local governments/communities.[43]

The National Cyber Incident Response Plan

The National Cyber Incident Response Plan (NCIRP) is the Cyber Annex to the FIOP that built upon the National Planning Frameworks and the NPS. The NCIRP was developed to articulate the roles and responsibilities, capabilities, and coordinating structures that support how the United States responds to and recovers from significant cyber incidents posing risks to critical infrastructure. It is the primary framework for a national approach to dealing with cyber incidents, addressing the important role that the private sector and state and local governments, and multiple federal agencies play in responding to incidents and how the actions of all fit together for an integrated response.

The last iteration of the NCIRP was in 2016.

Source: NCIRP, 2016

FEMA is in the process of updating the NRF[44] to emphasize stabilization of community lifelines and coordination across critical infrastructure sectors.[45] FEMA has identified seven community lifelines that provide indispensable services to enable the continuous operation of critical business and government functions, and are critical to health, safety or economic security.[46] These lifelines include: safety and security; food, water, and shelter; health and medical; energy; communications; transportation; and hazardous waste.

The intention is that communities would identify what stabilization in each of these lifelines means for their community, and use those stabilization targets in outcome-based planning. The NRF update is expected to put an increased emphasis on the capabilities of the private sector, individuals, and volunteer and nongovernmental organizations (NGOs) with potential public review and comment in early 2019.

The NRF update will also include the creation of a new ESF #14 focused on cross-sector coordination. ESF #14 will serve as a way to bring in industry to help prioritize response. ESF #14 will be used by the federal government for building, sustaining, and delivering response capabilities, including those necessary for sustaining and restoring critical infrastructure.[47] "[This] would cement in doctrine and practice the public-private sector partnership that is essential to stabilization and unity of effort, and bring new capacity to whole community response efforts."[48]

B. National Incident Management System

The 2003 Homeland Security Policy Directive 5 (HSPD-5),[49] called on the Secretary of Homeland Security to develop a national incident management system to provide a consistent nationwide approach for federal

[42] DHS, *National Disaster Recovery Framework, Second Edition*, June 2016.
[43] EIS Council, *Electric Infrastructure Protection (E-PRO) Handbook III Cross-Sector Coordination and Communications in Black Sky Events,* 2018.
[44] DHS, *National Response Framework*, 2008.
[45] FEMA, *2017 Hurricane Season FEMA After-Action Report,* 2018.
[46] FEMA, "National Response Framework Update: Overview Briefing," October 24, 2018.
[47] EIS Council, *Electric Infrastructure Protection (E-PRO) Handbook III Cross-Sector Coordination and Communications in Black Sky Events,* 2018.
[48] FEMA, *2017 Hurricane Season FEMA After-Action Report,* 2018.
[49] DHS, *Homeland Security Presidential Directive 5*, 2003.

and SLTT governments to work together to prepare for, prevent, respond to, and recover from domestic incidents, regardless of cause, size or complexity.[50] In 2004, the Department of Homeland Security (DHS) issued the National Incident Management System (NIMS) as a companion to the NRF, which incorporates the capabilities and resources of various governmental jurisdictions, incident management and emergency response disciplines, non-governmental organizations, and the private-sector into a cohesive, coordinated, and seamless national framework for domestic incident response.[51]

C. Stafford Act

Within the NPS frameworks, the Robert T. Stafford Disaster Relief and Emergency Assistance Act, better known as the Stafford Act, provides the legal and statutory authority governing federal response to events in the United States.[52] The Act provides the system currently used for requesting and obtaining a presidential emergency or major disaster declaration, determining the conditions for obtaining assistance, and defining the type and scope of assistance available from the federal government.[53] An emergency is any occasion or instance in which federal assistance not exceeding $5 million is needed to supplement state and local efforts and capabilities.[54] A major disaster is generally larger, and any natural event causing damage of such severity that it is beyond the combined capabilities of state and local governments to respond.[55]

Federal response under the Stafford Act is generally the same for territories and federally recognized tribal nations, though there may be unique differences. The federal government maintains a moral and legal trust responsibility toward tribal governments, which includes as obligation to protect tribal treaty rights, lands, assets, and resources, as well as a duty to carry out the mandates of tribal law.[56] This means that "any federal agency with a role in emergency preparedness and response, such as [FEMA], is obligated to provide consultation opportunities to tribes in addition to the other services and resources available at the agency."[57] Similar to states, tribal governments are responsible for coordinating resources to address actual or potential incidents.[58] In 2013, the Sandy Recovery Improvement Act amended the Stafford Act to include a provision to provide federally recognized tribal governments the option to request a Presidential emergency or major disaster declaration independent of a state, cutting down on response time.[59]

The same approach and process applies to territories. However, due to their remote locations, territories often face unique challenges in receiving assistance from outside the jurisdiction quickly and often request assistance from neighboring islands, other nearby countries, states, the private sector or NGO resources, or the federal government. Federal assistance is delivered in accordance with pertinent federal authorities." [60]

The graphic below provides a high-level overview of the multi-step process for receiving a federal emergency and major disaster declaration under the Stafford Act.

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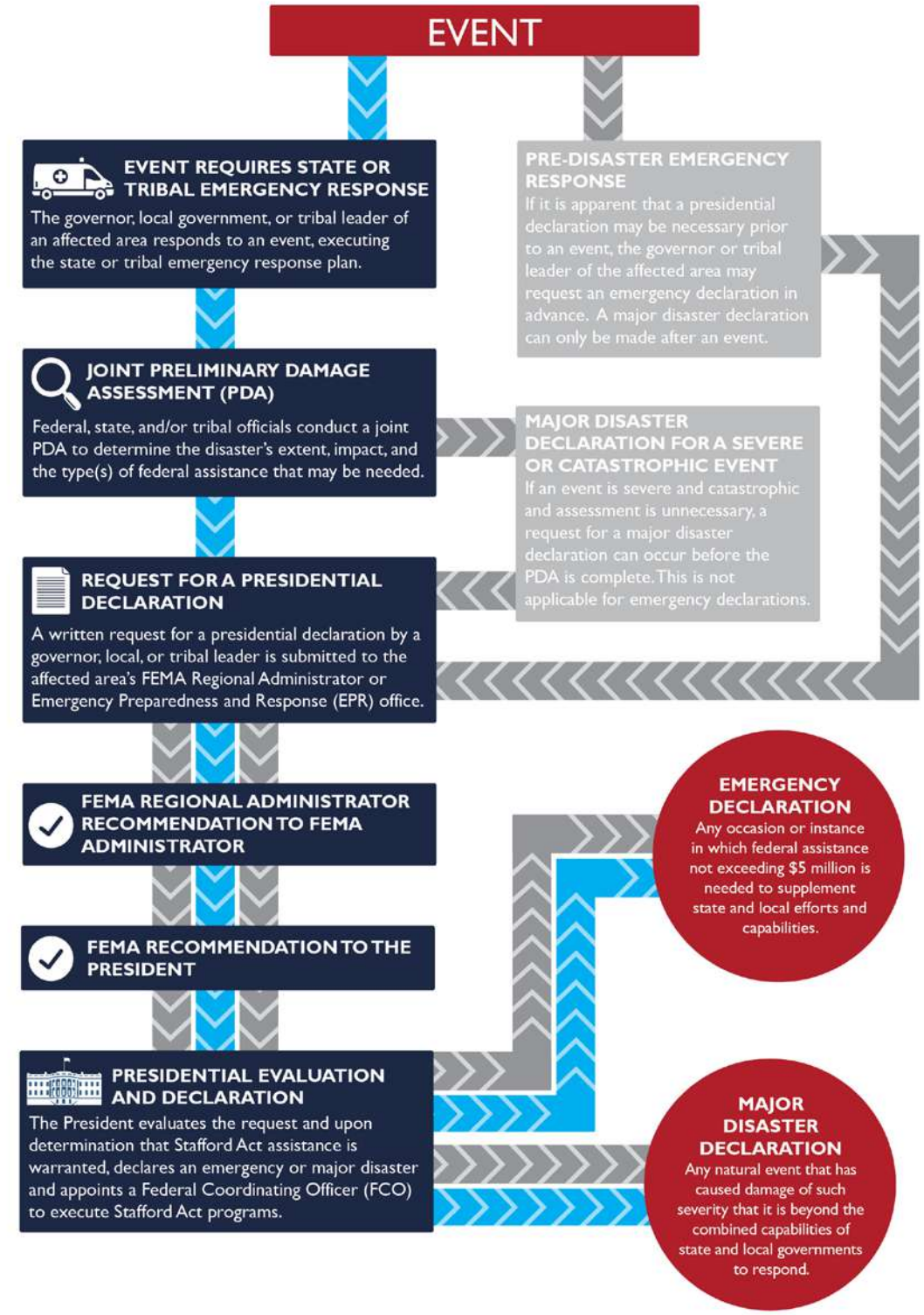
[50] The White House, "Homeland Security Presidential Directive/HSPD-5," 2003 .
[51] FEMA, "NIMS Frequently Asked Questions," 2017.
[52] *Robert T. Stafford Disaster Relief and Emergency Assistance Act*, Public Law 93-288 as Amended. 42 U.S. Code § 5121 et seq.
[53] FEMA, *A guide to the Disaster Declaration Process and Federal Disaster Assistance*.
[54] 42 U.S.C. 5122.
[55] 42 U.S.C. § 5122.
[56] Cohen's Handbook of Federal Indian Law § 5.04[3]; *Seminole Nation v. U.S.*, 316 U.S. 286, 296-97 (1942); *U.S. v. Jicarilla Apache Nation*, 131 S. Ct. 2313, 2324-25 (2011).
[57] The White House, *Memorandum on Government-to-Government Relations With Native American Tribal Governments*, Apr. 29, 1994; Aila Hoss, "Tribal Consultation: Selected Resources," CDC, 2016.
[58] FEMA, "IS-0230.d – Fundamentals of Emergency Management. Lesson 1: Emergency Management Overview."
[59] *Robert T. Stafford Disaster Relief and Emergency Assistance Act*, Public Law 93-288 as Amended. 42 U.S.C. 5121 et seq.; *Disaster Declaration Improvement Act*, Report 115-99.
[60] FEMA, "IS-0230.d – Fundamentals of Emergency Management. Lesson 1: Emergency Management Overview."

Stafford Declaration Process



D. Federal Financial Disaster Relief Assistance, Waivers, and Mitigation Funding

A complex spending relationship underlies federal disaster assistance in the United States.[61] Federal financial assistance is generally only available after a Stafford Act declaration and after an event has occurred. Under the Disaster Relief Fund (DRF)—the primary funding source for Stafford Act declared disaster response and recovery[62]—there are three principal forms of federal financial assistance available through FEMA.[63] Through these forms of assistance, FEMA can fund authorized federal disaster support activities as well as eligible SLTT actions.[64]

No single government source provides comprehensive information about state spending.[65] A Government Accountability Office (GAO) study found that because the federal government and states do not know how much they spend on mitigation in total, they lack the information to accurately compare proactive investments with post-disaster response and recovery expenditures. The larger the natural disaster, the more likely all levels of government participate and spend significant amounts of money.[66] But all levels of government need a more comprehensive understanding of federal and state investments to better target funding to help manage the growing costs of catastrophic events. With the increasing severity and frequency of natural disasters, policymakers are looking for ways to control costs by investing in mitigation activities—actions that reduce risk to lives and property—before a disaster happens.[67]

In April 2018, the U.S. House of Representatives passed components of the Disaster Recovery Reform Act (DRRA) as part of the Federal Aviation Administration (FAA) Reauthorization Act of 2018.[68] The DRRA would provide funding for hazard mitigation programs, as well as introduce new reforms to programs, which include:[69]

- Amend the Stafford Act to establish increased and fixed reimbursement rates to state and local governments for direct and indirect administrative costs associated with disaster recovery efforts. This includes no more than 15 percent for hazard mitigation and 12 percent for essential assistance, repair, restoration, replacement debris removal, and transportation assistance.[70]
- Allow states the option to administer FEMA funding for direct temporary housing and permanent housing construction after a disaster. FEMA must fund 100 percent of the direct temporary housing costs.
- Establish the National Public Infrastructure Pre-Disaster Mitigation Assistance Program, which would commit certain funding from the DRF to pre-disaster mitigation efforts. It would allocate 6 percent of the combined obligations estimated following a major disaster to mitigation assistance.
- Require the FEMA administrator to develop a plan to streamline information collection processes for grant applications and make the process less burdensome and time consuming.

[61] Foundation Center and the Center for Disaster Philanthropy, "Measuring the State of Disaster Philanthropy 2017."
[62] *Robert T. Stafford Disaster Relief and Emergency Assistance Act*, Pub. L. 93-288, as amended, 42 U.S. Code § 5121 et seq.
[63] The Public Assistance program is authorized by Sections 403(a)(3)(A), 406, 407, 428, and 502(a)(5) of the Stafford Act; Jared T. Brown and Daniel J. Richardson, *FEMA's Public Assistance Grant Program: Background and Considerations for Congress*, 2015; Bruce R. Lindsay, *The SBA Disaster Loan Program: Overview and Possible Issues for Congress*, 2015; FEMA, "The Hazard Mitigation Assistance Grant Programs," 2015.
[64] Statement by Craig Fugate, *The Federal Role in Disaster Recovery and Response*, Hearing before the Committee on Appropriations' Subcommittee on Homeland Security, October 12, 2011.
[65] GAO, "Budgeting for Disasters: Approaches to Budgeting for Disasters in Selected States," 2015; National Association of State Budget Officers, "Budget Processes in the States," 2015.
[66] UNISDR, "What Is Disaster Risk Reduction?"
[67] Pew Charitable Trusts, "Natural Disaster Mitigation Spending is not Comprehensively Tracked," September 2018.
[68] *FAA Reauthorization Act of 2018*, H.R. 4, 115th Cong., 2nd Session, May 7, 2018.
[69] FEMA, "Pre-Disaster Mitigation Grant Program."
[70] Lucia Bragg, "House Passes Disaster Recovery Reform Act under FAA Reauthorization," April 27, 2018.

As the number of declared major disasters and emergencies increase,[71] and the amount of money needed for the DRF increases,[72] the federal government bears escalating recovery costs. Insurance reform offers a promising way to encourage infrastructure upgrades that could promote resilience innovations and share disaster costs between the public and private sector. This is becoming more and more important because risk models indicate that the annual likelihood of severe weather causing at least $1 billion in insured losses in the U.S. is 92 percent.[73]

Federal financial assistance can also be in the form of waiver. Waiving statutes and regulations identified as impeding response and recovery efforts can help communities and companies make decisions without the threat of reprisal for noncompliance. For example, after Hurricane Maria hit Puerto Rico in 2017, the Environmental Protection Agency (EPA) granted a blanket waiver from ultra-low sulfur diesel requirements so that the territory could use power generators that use fuel with high sulfur content.[74]

II. Federal Agency Roles

As mentioned in the prior sections, various frameworks, authorities, and supporting documents outline how the federal government responds. Federal agencies also have roles in disaster response and recovery, most notably three agencies with a defined lead role in emergency preparedness and response or critical infrastructure protection. This section will provide an overview of the roles DHS, the Department of Energy (DOE), and DOD each play before, during, and after an event, and the role Federal Energy Regulatory Commission (FERC) the federal agency that regulates the transmission and wholesale sale of electricity and natural gas.

A. Department of Homeland Security

At its core, DHS secures the nation against evolving threats to safety and security through continuous risk assessments and adaptive strategies to effectively address them.[75] Within this, DHS has five missions that include preventing terrorism and enhancing security; managing the country's borders; administering immigration laws; securing cyberspace; and providing the coordinated, comprehensive federal response in the event of a terrorist attack, natural disaster or other large-scale emergency.[76] When events such as natural disasters do occur and the federal government needs to provide assistance, DHS is the primary agency for coordinating federal assistance. This section highlights three key components under DHS: FEMA, the Cybersecurity and Infrastructure Security Agency (CISA), and the newly formed National Risk Management Center (NRMC).

Federal Emergency Management Agency

Within DHS, FEMA is the federal agency that coordinates the federal government's role in preparing for, preventing, mitigating the effects of, responding to, and recovering from all domestic disasters, whether natural or manmade, including acts of terror.[77] FEMA relies on the NRF and NDRF frameworks, which

[71] FEMA, "Incidents by Year."
[72] Bruce R. Lindsay, *FEMA's Disaster Relief Fund: Overview and Selected Issues*. Congressional Research Service, May 7, 2014.
[73] Executive Office of the President of the United States, *Standards and Finance to Support Community Resilience,* 2016; Carolyn Kousky, et al., *Does Federal Disaster Assistance Crowd Out Private Demand for Insurance?* 2013.
[74] Subramanian, R., et al., "Air Quality in Puerto Rico in the Aftermath of Hurricane Maria: A Case Study on the Use of Lower Cost Air Quality Monitors," *ACS Earth and Space Chemistry,* 2018.
[75] DHS, "About DHS."
[76] Ibid.
[77] Statement of Richard Campbell, *Blackout! Are we Prepared to Manage the Aftermath of a Cyber-Attack or Other Failure of the Electrical Grid?* Hearing before the Committee on Transportation and Infrastructure, Subcommittee on Economic Development, Public Buildings, and Emergency Management, House of Representatives, April 11, 2016.

identify the subset of agencies best equipped to respond to a particular challenge, as well as the NIMS for a cohesive, coordinated incident response.

FEMA has stated that the biggest lesson learned after the 2017 disasters is that the most effective strategies for emergency management are those that are federally supported, state managed, and locally executed. FEMA advocates a whole community approach to disaster management that includes individuals, families, communities, the private and nonprofit sectors, faith-based organizations, and local, state, tribal, territorial, insular areas, and other federal agencies.[78] To that end, FEMA emphasizes that it is not the sole or primary responder to an event, therefore its role in emergency management is to coordinate federal resources and assistance to supplement SLTT capabilities.[79] In that capacity, FEMA is responsible for building relationships with emergency management communities to encourage preparedness activities and mitigation investments before an event; manage requests for assistance during one; and coordinate and assign federal grant assistance with response and recovery after an event occurs.[80]

2018-2022 Strategic Plan

FEMA issued the 2018-2022 Strategic Plan as a framework for supporting the United States before, during, and after disasters, with three Strategic Goals aimed at mobilizing a whole community approach to disaster response to build a culture of preparedness, readying the nation for catastrophic disasters, and reducing FEMA's complexity.[81]

- **Strategic Goal 1: Build a Culture of Preparedness** includes objectives to incentivize investments that reduce risk, including pre-disaster mitigation; closing the insurance gap; helping people prepare for disasters; and better learn from past disasters, improve continuously, and innovate.
- **Strategic Goal 2: Ready the Nation for Catastrophic Disasters** focuses on enhancing the nation's collective readiness. This requires a scalable and capable national incident workforce that can adapt and deploy to a changing landscape of events, integrate stakeholders at all levels of the public and private sectors, and communicate and coordinate effectively in every situation.
- **Strategic Goal 3: Reduce the Complexity of FEMA** promotes less complex processes to streamline FEMA and drive decision-making to reduce the administrative burdens that impede impacted individuals and communities from quickly receiving assistance.

Power Outage Incident Annex

In June 2017, FEMA released the *Power Outage Incident Annex (POIA) to the Response and Recovery Federal Interagency Operational Plans: Managing the Cascading Impacts from a Long-Term Power Outage* as guidance for federal agencies responsible for providing energy response and recovery support for a long-term power outage to SLTT, insular areas, NGOs, and the private sector.[82] POIA states that "when a power outage is of such significance and scope that it is beyond the ability of utility companies to restore power in a timely manner, resulting in [SLTT] or insular area capabilities being insufficient to support the population, the federal government provides assistance to jurisdictional response and recovery capabilities."[83]

The POIA is not an electricity restoration plan; it outlines the types of federal support available to critical infrastructure stakeholders when a power outage is of such significance and scope that it is beyond the

[78] FEMA, *2018-2022 Strategic Plan*, 2018.
[79] Ibid.
[80] Ibid.
[81] Ibid.
[82] FEMA, *Power Outage Incident Annex,* 2017.
[83] Ibid.

ability of utility companies to restore power in a timely manner.[84] It is a springboard, providing a framework to address interdependencies. The POIA describes a bifurcated command structure where DOE oversees the restoration of the power system (grid) and FEMA leads the federal consequence management effort. However, actions in the POIA may be to provide support to local, state, tribal, territorial, and insular area governments or other federal agencies to address the ramifications of an incident.

FEMA is funding each FEMA Region to conduct long-duration power outage planning that will be tested, validated, and modified as needed. The goal is to coordinate emergency management and infrastructure protection into response and recovery plans so that each sector and/or region knows what their impacts may be and what support they might need from the federal government during or after an event.

FEMA Region V

FEMA Region V worked with its states (Illinois, Indiana, Michigan, Ohio, and Wisconsin) to review and understand their roles and responsibilities during a long-term power outage in conjunction with FEMA's POIA.

Through the Region's process to develop a POIA to provide supplemental hazard information to their All Hazards Plan, a series of workshops were conducted with local, state, and federal government representatives and private utilities. These workshops reviewed state energy plans, threat hazard identification and threat assessments, and sector interdependencies to understand the current capabilities so FEMA Region V could understand where there were needs from local and state partners and public and private utilities.

Cybersecurity and Infrastructure Security Agency

Legislation was signed in November 2018 that renamed the National Protection and Programs Directorate (NPPD) to the Cybersecurity and Infrastructure Security Agency (CISA) to better reflect the agency's role in both cyber and physical infrastructure security and resilience.[85] DHS Secretary Nielsen stated that the renaming "would… realign [the agency's] structure to reflect the core cybersecurity and infrastructure resilience mission it exercises."[86]

Similar to the former NPPD's mission, CISA will work with public sector, private sector and government partners to share information, build greater trust, and lead the national effort to protect and enhance the resilience of the country's physical and cyber infrastructure.[87] CISA partners with government and the private sector to protect and secure the people, places, spaces, data and networks that make nation

National Cyber Security Strategy

In September 2018, the White House released the National Cyber Strategy, the first of its kind in 15 years.

The strategy highlights the growing threat that malicious cyber actors pose to U.S. national security and identifies cyber priorities structured around the National Security Strategy. The new strategy also calls for the administration to clarify the roles and responsibilities of federal agencies and the expectations of the private sector when it comes to cybersecurity risk management and incident response. DHS Secretary Nielsen stated the Strategy will "guide efforts by DHS to secure federal networks, protect critical infrastructure, and combat cybercrime."

Source: National Cyber Security Strategy, The White House

[84] FEMA, *Power Outage Incident Annex,* 2017.
[85] DHS, "Cybersecurity and Infrastructure Security Agency (CISA)," November 19, 2018.
[86] Tim Starks, "Senate could act on top DHS cybersecurity priority," Politico, September 19, 2018.
[87] DHS, "CISA Cyber + Security."

run,[88] leading the U.S. government's efforts to secure federal networks and critical infrastructure.[89] The agency has also been spearheading the federal government's election security efforts, coordinating with state and local election offices on information sharing and cybersecurity best practices.[90]

CISA's National Cybersecurity and Communications Integration Center (NCCIC) provides constant cyber situational awareness, defense, analysis, and incident response capabilities to the federal government, SLTT governments, and the private sector.[91] CISA also includes the National Infrastructure Coordinating Council (NICC), which is the operations center that maintains situational awareness of the nation's critical infrastructure for the federal government. The NICC serves as the coordination and information sharing hub to support coordination between DHS and owners and operators of critical infrastructure.[92]

National Risk Management Center

In September 2018, DHS stood up a National Risk Management Center (NRMC) to focus on national strategic risks to critical infrastructure and serve as a convener for government and industry to work together, taking an all-hazards approach focused on critical functions.[93] One of the NRMC's goals to be a place to coordinate on long-term cybersecurity and infrastructure security risk management, serving as the operational layer to develop strategic plans and take a unified approach to risks.[94]

Defining national critical functions produced by critical infrastructure that could cause systemic risk will also be a major undertaking by the NRMC. Defining these national critical functions can determine and locate interdependencies and concentrated dependencies that can determine what needs to be prioritized for restoration.

The NRMC is building on prior NIAC recommendations, which called for an operational task force made up of senior executives from government and the Electricity, Financial Services, and Communications Sectors, who can direct priorities and marshal resources.[95] As such, the NRMC is in the process of standing up a Tri-Sector Working Group made up of senior executives from the three sectors, which will be leveraged as a steering group for NRMC.

Through the Critical Infrastructure Partnership Advisory Council (CIPAC), DHS in partnership with the Information Technology Sector Coordinating Council (IT SCC) and Communications Sector Coordinating Council (CSCC), has established the Information and Communications Technology (ICT) Supply Chain Risk Management Task Force within the NRMC. The Task Force is intended to focus on potential near- and long-

[88] Ibid.
[89] Zaid Shoorbajee, "DHS's top cyber office is about to get a name that reflects its office," CyberScoop, October 4, 2018.
[90] Ibid.
[91] DHS, "What does CISA do?"
[92] DHS, "National Infrastructure Coordinating Council," Last updated August 14, 2018.
[93] DHS, "DHS National Risk Management Center," Fact Sheet, 2018.
[94] Ibid.
[95] NIAC, *Securing Cyber Assets: Addressing Urgent Cyber Threats to Critical Infrastructure*, 2017.

term solutions to manage strategic risks through policy initiatives and opportunities for innovative public-private partnership.[96]

Critical Infrastructure Partnership Advisory Council

DHS established CIPAC to facilitate interaction between governmental entities and representatives from the community of critical infrastructure owners and operators. Under CIPAC, members of the Government Coordinating Councils (GCCs) and Sector Coordinating Councils (SCCs) to engage in discussions about joint critical infrastructure planning, coordination, implementation, and operational issues.

CIPAC provides the authority and structure for coordinating among government and critical infrastructure owners and operators; conducting operational activities related to critical infrastructure security and resilience measures, incident response, and recovery; and sharing threat, vulnerability, risk mitigation, business continuity information, and best practices along with lessons learned.

Source: FEMA, CIPAC FAQs

B. Department of Energy

DOE is responsible for coordinating the Energy Sector's emergency preparedness requirements—using processes and structures unique to the energy sector—as the lead for restoration and sector specific lead agency for grid security.

Emergency Authorities

Under the Fixing America's Surface Transportation (FAST) Act,[97] a federal law aimed at providing long-term funding for surface transportation infrastructure, the Secretary of Energy has "broad and nearly unilateral authority over critical electric infrastructure to protect system reliability in emergency situations."[98] Under the FAST Act, the Secretary of Energy has the authority, upon the declaration of a grid security emergency by the President, to issue emergency orders that—in his or her judgement—are necessary to protect or restore the reliability of critical electric infrastructure or defense critical electric infrastructure during the grid security emergency.[99]

Office of Cybersecurity, Energy Security, and Emergency Response

Formally the Office of Electricity (OE), the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) works to ensure that the nation's energy delivery system is secure, resilient, and reliable and develops new technologies to improve the infrastructure and the federal and state electricity policies and programs.[100] Moving forward, CESER will focus on energy infrastructure security, support the expanded national security responsibility.[101] CESER will lead DOE's emergency preparedness and coordinated response to disruptions to the Energy Sector, including physical and cyber-attacks, natural disasters, and man-made events.[102] CESER will also spearhead efforts to secure the U.S. energy infrastructure against all hazards and mitigate the risk of energy disruption from cyber incidents and other emerging threats within the energy environment.[103]

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[96] DHS, "ICT Supply Chain Task Force," Press release, August 31, 2018.
[97] *Fixing America's Surface Transportation (FAST) Act,* Pub. L. 114–94.
[98] Sylvia Bartell, "Transforming the Nation's Electricity System. Part IV: Grid Security," *Husch Blackwell*, January 16, 2017.
[99] DOE, "Grid Security Emergency Orders: Procedures for Issuance," *Federal Register*, January 10, 2018.
[100] Hunton Andrews Kurth, "Department of Energy Announces New Efforts in Energy Sector Cybersecurity," May 30, 2018.
[101] DOE, "Secretary of Energy Rick Perry Forms New Office of Cybersecurity, Energy Security, and Emergency Response," February 14, 2018.
[102] DOE, "CESER Mission."
[103] Ibid.

C. Federal Energy Regulatory Commission

FERC is the federal agency that regulates the transmission and wholesale sale of electricity and natural gas in interstate commerce and regulates the transportation of oil by pipeline in interstate commerce.[104] While FERC does not have jurisdiction over generation facilities, or facilities used for local distribution or transmission in intrastate commerce,[105] more than half of electric energy sales are subject to FERC's rate jurisdiction.

While FERC is responsible for ensuring adherence to mandatory reliability standards in industry, NERC develops those standards with input from the industry, submits them to FERC for approval, and then enforces the approved standards in the Energy Sector.[106]

FERC has also approved new mandatory reliability standards to bolster supply chain risk management protections for the nation's bulk electric system. The new standards will augment current critical infrastructure protection standards to mitigate cybersecurity risks associated with the supply chain for grid-related cyber systems.[107]

North American Electric Reliability Corporation

As required by the Federal Power Act, FERC designated NERC—a nonprofit international regulatory authority responsible for reducing risks and ensuring reliability of the grid—as the Electric Reliability Organization (ERO) for North America. In this role, NERC oversees all interconnected power systems in the United States, Canada, and portions of Mexico and develops mandatory and enforceable reliability grid standards subject to FERC's review and approval. As a designated ERO, NERC issues enforceable guidelines, essentially giving FERC the authority to oversee the reliability and resiliency of the U.S. grid, because FERC through NERC, oversees the bulk power system.

Source: FERC, FAQs

D. Department of Defense

DOD is responsible for providing military forces and certain intelligence capabilities to deter war and to protect the security and national interests of the United States. As such, the Secretary of Defense may assist in the support of domestic infrastructure and essential restoration, or unprecedented events,[108] through the mechanisms of the frameworks.[109]

While FEMA is the federal lead for national disaster response activities, DOD plays a supporting but important role in the national response system.[110] As stated in the National Defense Strategy, while defending the homeland, DOD must also maintain the capacity to support civil authorities in times of national emergency such as in the wake of man-made and natural disasters.[111] In the event of crises within multiple states, or when many military units are deployed on overseas missions, affected regions may require assistance from DOD active-duty troops, the U.S. Coast Guard, and other federal assets.[112]

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[104] *California Independent System Operator Corporation v. FERC*, 372 F.3d 395, 398-99 (D.C. Cir. 2004); Lawrence R. Greenfield, *An Overview of the Federal Energy Regulatory Commission and Federal Regulation of Public Utilities in the United States*, December 2010.
[105] Garry Brown, et al., *The Federal Power Act in the 21st Century: Summary Report of a Discussion Marking the 80th Anniversary of the Enactment of FPA Title II*, Harvard Law School, September 1, 2015.
[106] NERC, *Milestones: NERC Reliability Standards,* May 19, 2014.
[107] Pamela Largue, "FERC announces new supply chain risk management standards," Smart Energy International, October 22, 2018.
[108] Jared T. Brown, et al., *Congressional Primer on Responding to Major Disasters and Emergencies*, Congressional Research Service, 2017.
[109] DHS*, National Response Framework,* 2008.
[110] Statement by Robert G. Salesses and Brigadier General Joseph E. Whitlock, *Defense of Civil Authorities: A Vital Resource in the Nation's Homeland Security Missions*, Hearing before the Subcommittee on Emergency Preparedness, Response, and Communications of the Committee on Homeland Security, House of Representatives, June 10, 2015.
[111] DOD, *National Defense Strategy*, 2008.
[112] Richard Weitz, "Federalism and Domestic Disasters: Promoting a Balanced Approach," *Hudson Institute*, 2006.

The military responds under the authority under Title 32 and Title 10 of the U.S. Code, depending on the purpose and event.[113] The president also has the authority to order the military to help plan for a disaster before it occurs, such as moving airplanes or prepositioning forces. While the president cannot order the military to execute or enforce federal law, that is not a blanket prohibition against deploying troops in a civil emergency.[114]

DOD has taken steps to improve its preparedness to better prepare the department to support civil authorities effectively respond to requests for assistance for power restoration during a catastrophe.[115] The DOD complex catastrophe initiative is aimed at making defense support of civil authorities faster and more effective in delivering life-saving and life-sustaining requirements, which would enable DOD to bring all of its capabilities, from all components, to bear in support of civil authorities.[116] The initiative is also directed improvements in the Defense Security Cooperation Agency (DSCA)—an agency that advances U.S. national security and foreign policy interests by building the capacity of foreign security forces to respond to shared challenges[117]—for regional planning and plans integration, force sourcing, training and exercises, and the role of military installations and Defense Agencies in emergency response operations.[118]

U.S. Northern Command

The U.S. Northern Command (NORTHCOM) was established in 2002 to administer command and control of DOD homeland defense efforts and to coordinate defense support of civil authorities.[119] NORTHCOM's area of responsibility includes air, land, and sea approaches and encompasses the continental United States, Alaska, Canada, Mexico, and the surrounding water out to approximately 500 nautical miles. It also includes the Gulf of Mexico, the Straits of Florida, portions of the Caribbean region that include the Bahamas, Puerto Rico, and the U.S. Virgin Islands.[120]

NORTHCOM plans, organizes, and executes homeland defense and civil support missions, but has few permanently assigned forces. Forces are assigned when necessary to execute missions, as ordered by the President or Secretary of Defense.[121] NORTHCOM also plays an important role in disaster response by providing unique military capabilities to FEMA in support of state requests for emergency aid. NORTHCOM is the DOD synchronizer for all DOD support to FEMA and Defense Support of Civil Authorities (DSCA)—an agency that advances U.S. national security and foreign policy interests by building the capacity of foreign security forces to respond to shared challenges[122]—which gave them a much more proactive role during the 2018 hurricane season.[123]

During the 2017 hurricane season, NORTHCOM sent thousands of troops to hurricane-effected areas in Texas and Florida, and a DOD medical ship to Puerto Rico after Hurricane Maria struck in support of

[113] Federal Research Division, Library of Congress. *Military Support to Civil Authorities: The Role of the Department of Defense in Support of Homeland Defense*, 2007; Title 10. U.S. Code – Armed Forces, as amended 2011, Vol. III §§ 3001 et seq.
[114] Tim Naftali, "Send in the Cavalry: The President's Powers in the Event of Disaster," *Slate*, October 11, 2005.
[115] EIS Council, "Protection Initiatives. Restoration and Response."
[116] Claudette Roulo, "Defense Has Vital Role in Catastrophe Planning, Office Says," American Forces Press Service, DOD, August 14, 2012.
[117] DSCA, "Mission, Vision, and Values."
[118] Statement by Robert G. Salesses and Brigadier General Joseph E. Whitlock, *Defense of Civil Authorities: A Vital Resource in the Nation's Homeland Security Missions*, Hearing before the Subcommittee on Emergency Preparedness, Response, and Communications of the Committee on Homeland Security, House of Representatives, June 10, 2015.
[119] USNORTHCOM, "About USNORTHCOM."
[120] Ibid.
[121] USNORTHCOM, "U.S. Northern Command," May 16, 2013.
[122] DSCA, "Mission, Vision, and Values."
[123] USNORTHCOM, "U.S. Northern Command Prepares for Hurricane Florence," Press release, September 13, 2018.

FEMA.[124] Through its experience, NORTHCOM has stated there a number of lessons learned from the unprecedented season including the need for communication with affected communities and clearly defining the response necessary to provide better assistance.[125] NORTHCOM says that an after action report is currently being drafted that will be translated into how NORTHCOM responds to future hurricanes seasons and disaster response.

U.S. Indo-Pacific Command

The U.S. Indo-Pacific Command (INDOPACOM) is a unified combatant command of the U.S. Armed Forces responsible for the Indo-Asia-Pacific region. Established in 1947, it is the oldest and largest of the unified combatant commands.[126] Its commander, the senior U.S. military officer in the Pacific, is responsible for military operations in an area which encompasses more than 100 million square miles roughly 52 percent of the Earth's surface, stretching from the waters off the west coast of the U.S. to the western border of India, and from Antarctica to the North Pole. The 36 nations comprising the Asia-Pacific region are home to more half of the world's population, 3,000 different languages, several of the world's largest militaries, and five nations allied with the U.S. through mutual defense treaties.[127]

Unlike NORTHCOM, INDOPACOM only has four U.S. jurisdictions within its area: Hawaii, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands (CNMI). When it comes to disaster response, any needed INDOPACOM forces are assigned from lead federal agencies such as FEMA to provide capabilities that do not exist in the civilian sector. Because four U.S. jurisdictions within its area are islands and located at the most almost 6,000 miles away from the U.S. mainland, this creates the potential for additional challenges that are not experienced elsewhere.

In 2018, a memorandum of understanding (MOU) was signed between DOE, DHS, INDOPACOM, and the state of Hawaii "to identify a framework for cooperation and partnership to strengthen coordination of effort to enhance national and state security."[128] The MOU's goal is to create a cohesive and collaborative lens to look at the critical energy infrastructure interdependencies between the civil energy sector and identify vulnerabilities ahead of events and collectively develop mitigation approaches addressing those vulnerabilities.

DOD and INDOPACOM are also supporting a new DHS- and Hawaii-lead Defensive Cyber Industry Consortium (DCIC); an initiative to bring in stakeholders from lifeline sectors across Hawaii to emphasize interconnectedness of critical vulnerabilities and the need for collaboration and sharing information. Still in its nascent stages, DCIC was expected to launch in November 2018.

INDOPACOM, in partnership with Resurgo, LLC (a Honolulu-based DOD contractor), the Hawaiian Electric Companies, and the Naval Facilities Engineering Command (NAVFAC), has also launched a Critical Energy Infrastructure Defense-In-Depth demonstration.[129] It is aimed at exhibiting to the DOD and commercial energy providers a capability to mitigate and recover quickly from online and insider cyber activities directed against Supervisory Control and Data Acquisition (SCADA) infrastructure. The intrusion tolerant

[124] Scott Maucione, "NORTHCOM looking inward after huge hurricane season," Federal News Network, February 15, 2018.
[125] Jim Garamone, "Military Seeks to Learn Lessons of 2017 Hurricane Season," DOD, December 11, 2017.
[126] USINDOPACOM, "History of United States Indo-Pacific Command."
[127] USINDOPACOM, "About USINDOPACOM: Headquarter, Unites States Indo-Pacific Command."
[128] *Memorandum of Understanding between the Department of Energy, the Department of Homeland Security, the U.S. Pacific Command, and the State of Hawaii for Critical Energy Infrastructure Interdependencies*, February 8, 2018.
[129] Ibid.

focus of the demonstration will show how new technologies employed in a defense-in-depth configuration enable a utility grid SCADA system to fight though an attack without disruption of services.[130]

Defense Threat Reduction Agency

The Defense Threat Reduction Agency (DTRA) is an agency in DOD that is responsible for enabling DOD and the federal government to prepare for, prevent, and respond to risks and weapons of mass destruction (WMDs) and improvised threats and to ensure nuclear deterrence.[131] Established in 1998, DTRA supports efforts to prevent the proliferation and use of WMDs, perform research, and develop tools and capabilities in WMD and improvised threat environments.[132]

III. State and Local Government and Industry Roles

Responsibility for responding to disasters begins at the local level. It is only after SLTT government resources have been overwhelmed, and the governor or chief tribal executive of the affected state or a tribal nation has requested federal assistance does the federal government provide supplemental assistance.[133] However, post-disaster recovery is so complex and wide-ranging that solutions do not fit neatly into individual programs.[134]

The current top-down approach to response, including the existing frameworks, is complex and difficult for local communities to navigate. The complexity of federal programs can hinder the speed and nimbleness of local and state response as leaders to spend time trying to figure out which program fits their recovery needs and tailoring their response to federal program rules.[135]

Existing frameworks do not identify who has ultimate decision-making authority or clearly define the roles to be undertaken by state and local governments and the private sector during a catastrophic power outage. Disaster declarations and resource allocations are made at the federal and state level, not the local level, which can lead to a disconnect with the specific area affected. Even under the NPS[136] there is a lack of clarity on the roles and responsibilities in responding to events.[137]

This section will provide an overview of the existing roles outside the federal government for state and local governments and industry during an event.

Mutual Aid

Mutual aid agreements or mutual aid programs are arrangements among agencies, organizations, and jurisdictions that provide a mechanism to quickly obtain emergency assistance in the form of personnel, equipment, materials, and other associated services when a disaster or emergency event has depleted the resources of the affected area.[138] Mutual aid programs produce rapid, short-term distribution of emergency support prior to, during, and after an event.[139]

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[130] Kevin Jordan, "Critical Energy Infrastructure Cyber Defense-in-Depth," SERDP, ESTCP.
[131] DTRA, *Strategic Plan FY 2018-2022*, March 2018.
[132] Statement of Shari Durand, *Countering Weapons of Mass Destruction Posture*, Hearing before the Emerging Threats and Capabilities Subcommittee Committee on Armed Services. House of Representatives, March 23, 2017.
[133] Jared T. Brown, et al., *Congressional Primer on Responding to Major Disasters and Emergencies*, Congressional Research Service, 2017.
[134] Amy Liu, "Federal Post-Disaster Recovery: A Review of Federal Programs," *What Works Collaborative*, May 2010.
[135] Amy Liu, "Feds, States, Cities – The All of the Above Disaster Response," *Brookings*, November 2, 2012.
[136] DHS, *National Preparedness System,* November 2011.
[137] DHS, *Section 2(e): Assessment of Electricity Disruption Incident Response Capabilities,* August 9, 2018.
[138] FEMA, "Mutual Aid Agreements and Assistance Agreements," 2018.
[139] Ibid.

There are different types of mutual aid agreements, ranging from formal ones adopted into statute between states or countries to informal understandings among consortiums outlining how government and private resources will provide aid within a specific community.[140] Participation in mutual aid is also a component of the NIMS.[141]

Emergency Management Assistance Compact

The Emergency Management Assistance Compact (EMAC) is a non-federal national interstate mutual aid agreement, administered by National Emergency Management Association (NEMA), which facilitates the sharing of resources across state lines in times of disaster or emergency.[142] Beginning as a mutual assistance compact established by the Southern Governors Association (SGA) in response to Hurricanes Andrew and Hugo,[143] it later became law when ratified by Congress in 1995. The compact was renamed EMAC and has been adopted by all 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.[144]

EMAC has become the United States' state-to-state, predominantly used mutual aid system.[145] EMAC can be used instead of, or in conjunction with, the federal disaster response system, to provide timely and cost-effective relief to states requesting help from other member states who understand the needs of areas that are struggling to preserve life, the economy, and the environment.[146]

Sector Mutual Aid Agreements

Sector mutual aid agreements and programs were highlighted as effective emergency response tools to provide assistance in the form of personnel, equipment, or other materials following a disaster to improve response.

Mutual aid does have its challenges including the complex logistics of arranging basic necessities of food, water, and shelter for workers during a disaster when there may be limited access and strained infrastructure. And while it is ultimately deemed to be cost-effective, there is a reimbursement requirement. In some instances, challenges may arise if an impacted area is difficult to get to, or potential crews that would respond have other obligations first due to pre-existing contracts or company structure.

Energy Sector

For decades electric utilities and public power authorities have provided assistance to each other following a disaster. There are two major mutual assistance programs led by the Edison Electric Institute (EEI) and the American Public Power Association (APPA), which work in coordination with the National Rural Electric Cooperative Association (NRECA).[147] EEI's mutual aid program enables utilities to increase the size of the workforce following an incident by "borrowing" resources from other member utilities.[148] APPA's mutual aid assures that personnel and resources from other utilities can support national outage events and receive federal reimbursement for expenses incurred during said events.[149]

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[140] FEMA, "Mutual Aid Agreements and Assistance Agreements."
[141] FEMA, *National Incident Management System,* "Frequently Asked Questions."
[142] NEMA, *EMAC: A History and Analysis of the Evolution of National Mutual Aid Policy and Operations,* September 2014.
[143] Ibid.
[144] Ibid.
[145] Ibid.
[146] FEMA, "EMAC Overview for NRF."
[147] EEI, "Understanding the Electric Power Industry's Response and Restoration Process," October 2016; APPA, "Public Power Mutual Aid Playbook," September 2014.
[148] EEI, "Understanding the Electric Power Industry's Response and Restoration Process," October 2016.
[149] APPA, "Public Power Mutual Aid Playbook," September 2014.

Within the Energy Sector, the Electricity Subsector Coordinating Council (ESCC)—building on the industries' culture of mutual assistance—has also formed the Cyber Mutual Assistance (CMA) Program.[150] The program is composed of industry cyber experts who can provide voluntary assistance to other participating entities in advance of, or in the event of, a disruption of electric or natural gas service, systems, and/or IT infrastructure due to a cyber emergency.[151]

Communications Sector

The Communications Sector has pre-established internal and external priorities for end-user restoration before, during, and after an event that are modified in conjunction with Emergency Support Function (ESF) #2 and National Coordinating Center protocols, as needed. In 2016, the Federal Communications Commission (FCC) adopted an order supporting a voluntary industry commitment to promote resilient wireless communications and situational awareness during disasters. The voluntary commitment was through the wireless providers AT&T, Sprint, T-Mobile, U.S. Cellular, and Verizon, together with CTIA, which formed a Wireless Network Resiliency Cooperative Framework which sought to enhance coordination and communication to better ensure wireless continuity during emergency events.[152]

Water and Wastewater Systems Sector

In the Water Sector, the Water and Wastewater Agency Response Network (WARN) serves as a network of utilities prepared to provide assistance through personnel, equipment, materials and other services to help respond and recover from an event.[153]

[150] ESCC, "The ESCC's Cyber Mutual Assistance Program," January 2018.
[151] ESCC, "Frequently Asked Questions About Cyber Mutual Assistance," January 2018.
[152] Marsh et al., *Final Network Resiliency Commitment Letter,* 2016.
[153] EPA, *Mutual Aid/Assistance Agreements,* 2011.

Electric Infrastructure Security (EIS) Council

Since 2010, the Electricity Infrastructure Security (EIS) Council has brought together senior government, utility, and NGO officials from North America, Europe, Israel, and across the world to review the threat of severe disruption of vital national infrastructures. EIS Council projects help utilities and their partners develop and implement cost effective, consensus-based protection measures by hosting frameworks for sustained coordination, planning and best practice development. The Council's Electric Infrastructure Security Summit (EISS) Series has become the primary international framework bringing together senior government, utility and NGO officials from around the world to review the threat of disruption of vital national infrastructure.

In 2017, the EIS Council launched EARTH EX, the first iteration of an annual, international, multi- and cross- sector exercise designed to build off of, and work with existing large-scale exercises, to address complex catastrophes spanning 14 countries, all FEMA regions, 44 states, 500 agencies and corporations, and 16 infrastructure sectors. The lessons learned from the exercise (e.g., there exists a global drive and motivation to work together to tackle resiliency) are being incorporated into upcoming Black Sky Playbooks and update curricula and exercises EIS makes available for government agencies and organizations who want to address black sky event planning. EARTH EX 2018 occurred on August 22, 2018.

The EIS Council has developed a series of handbooks for electric utilities, government, and stakeholders to reduce the scope and duration of black sky event. The playbooks determine internal and external requirements for black sky survival, along with accompanying exercises and training. The EIS Council has also prepared a number of recommendations for improving resilience to black sky events, including recommending the development of performance-based metrics for improving resilience to black sky events. The metrics have the potential to be used in parallel with the EIS sector-by-sector Black Sky Playbooks to determine internal and external requirements for black sky survival and develop compliance lists that each sector would abide by with the potential for incentives and reimbursements.

The Council is in the early stages of creating a working prioritization model with national and international partners of interconnected and interdependent systems would cause cascading effects across sectors beyond human capabilities. EIS has also initiated a simulation effort for a global infrastructure network optimization model (GINOM) to possibly work with relevant interested parties in the private sector and government agencies such DOE to explore the potential for joint development of a mapping effort for explicit interdependencies.

Source: E-PRO Handbook, 2014; EIS Council

Appendix E: Sector Interdependencies

The interconnected nature of the critical infrastructure sectors creates mutual interdependencies that could exacerbate the consequences of a catastrophic power outage. There is a lack of understanding of the cascading, cross-sector interdependencies between infrastructure and what that means for prioritizing backup generation and other limited resources to maintain services and functions during a long-term, widespread outage. Understanding the complex interdependencies between electricity and other critical infrastructure sectors is key to effectively assessing the impact of a long duration power outage.

This appendix provides an overview of the interdependencies between electricity and the natural gas, communications, financial services, water and wastewater systems, and transportation systems sectors that could hinder or prevent power restoration during a catastrophic power outage.

There are a number of ongoing initiatives focused on building cross-sector coordination. For example, exercises in individual sectors are beginning to include additional sectors, and at the state and regional level efforts are being made to better understand the risks posed by these interdependencies. This appendix also highlights a few of these exercises that have addressed cross-sector issues.

I. Electricity Mutual Interdependencies

Electricity is central to the functioning of all other sectors, and a catastrophic power outage would cause cascading failures across all of them.

A. Natural Gas

The electricity sector is becoming more reliant upon natural gas as a fuel source; from 2002 to 2016, the share of electricity generated by gas-fired units increased from 18 percent to about 34 percent while the share generated by coal fell from about 50 percent to about 30 percent.[154] EIA has estimated that natural gas production will account for almost 40 percent of the U.S. energy production by 2040.[155] DOE found that "the electric sector's growing reliance on natural gas raises concerns regarding the ability to maintain bulk power system (BPS) reliability when facing constraints on the natural gas delivery systems."[156]

Similar to other sectors, the natural gas sector relies on electricity to operate industrial control and businesses systems. This section provides an overview of the structure and market of natural gas systems, potential risks, and some ongoing initiatives to build resilience.

Natural Gas Structure and Markets

The construction of natural gas pipelines is driven by the market and demand. Pipelines are built to meet firm capacity, when there is a willingness and ability of customers (i.e., shippers) to financially commit to the gas that would be provided. Limited pipeline capacity in a particular region can be attributed to factors such as environmental regulations hindering construction and/or residents who do not want pipelines in their communities. Also, there may be a general lack of incentive(s) among the generator community to contract for firm service.

[154] DOE, *Staff Report to the Secretary on Electricity Markets and Reliability,* August 2017.
[155] EIA, Annual Energy Outlook 2017 with Projections to 2050, January 5, 2017.
[156] NERC, *Short-Term Special Assessment: Operational Risk Assessment with High Penetration of Natural Gas-Fired Generation,* May 2016.

The pipeline system is designed to be redundant with segmented pipes and looped/parallel pipelines, allowing natural gas to continue to flow despite potential disruptions in one section of the pipeline.[157] According to a report by members of the Oil and Natural Gas Sector, the natural gas system is highly resilient because the production, gathering, processing, transmission, distribution and storage of natural gas is geographically diverse, highly flexible and elastic, characterized by multiple fail-safes, redundancies and backups.[158]

Natural gas is compressible, which allows natural gas to be stored near markets underground in geological formations and as liquefied natural gas (LNG) at aboveground facilities. Most compressor stations are run using natural gas and would not be affected by a loss of commercial electricity. If a compressor were to cease operating, natural gas could continue to flow, though at a somewhat lower capacity. Some natural gas pipeline companies have identified critical locations, including those with electric compressors, and have worked with their electricity service providers to ensure they have prioritized power when electricity is restored following an outage.

If the pipelines and the compressor stations that maintain the pressure within them are compromised, gas could continue to flow to generators at gradually diminishing levels rather than being abruptly halted. The combination of sustained post-event gas flows and rapid restoration could enable generators to face only brief, low-impact interruptions.[159] However, compressors and industrial control systems that keep gas flowing to power generators and other users, are more reliant on electric power. Some compressor stations do have emergency power generators and at least some on-site fuel to sustain operations in a blackout. These growing interdependencies create risks of cascading, mutually-reinforcing failures across both the Electricity Subsector and Oil and Natural Gas Sectors.[160]

Potential Risks

Reliance on a single fuel creates the danger of "common mode failures" where a lack of natural gas incapacitates multiple generators and disrupts fuel supplies for power generation at the same time, which could help create power outages lasting a month or more over multiple regions of the United States.[161] During a catastrophic outage, on-site fuel supplies for emergency generators will quickly be depleted. Massive, multi-sector requirements for fuel resupply would occur and contractors responsible for resupply operations will likely be unable to meet these requirements. For example, New England is especially susceptible to these concerns because it has limited "failsafe" infrastructure with limited trucking capability

[157] NERC, *2017 Long-Term Reliability Assessment*, 2017.
[158] ONG SCC and NGC, *Defense-In-Depth: Cybersecurity in the Natural Gas & Oil Industry,* September 2018.
[159] Statement of Paul Stockton, *Fuel Resilience for the Bulk Power System: Threat-Based Modeling and Analysis.* Response to the Grid Resilience Order, *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, 162 FERC ¶ 61,012. May 8, 2018.
[160] Paul Stockton, *E-PRO Handbook II: Volume 1 Resilient Fuel Resources for Power Generation in Black Sky Events,* EIS Council, 2016.
[161] Paul Stockton*, Resilience for Black Sky Days: Supplementing Reliability Metrics for Extraordinary and Hazardous Events*, NARUC, 2014.

to serve the entire region and it has a high reliance on natural gas supply and LNG imports to meet winter peak loads.[162]

Blackstart Capabilities

Blackstart generation is used to restart the electric system in a blackout. Blackstart generators can start without electricity from the grid and assist in system restoration. This is especially important in the face of a long-term outage when power may be out for an extended period of time. The reliance on a single fuel blackstart without fuel storage capacity or firm fuel arrangements may cause issues during a restoration event. Single fuel blackstart generator owners should develop alternative fuel capability or coordinate with their fuel providers to mitigate this risk. Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) have existing blackstart plans that are routinely exercised and built upon, but there is a desire for the government to be more involved.

RTOs and ISOs build relationships with natural gas suppliers to bolster situational awareness. While RTOs and ISOs are not able to instruct them how to divert resources, they can work with market participants to identify where fuel supplies are running low and assist in that coordination. For example, the energy company ConEd has proposed a number of programs and projects to address the growing demand of natural gas in its service area. This includes building several new compressed natural gas storage sites to reduce the need for conventional pipeline supplies.

Source: NERC, GridEx IV: Lessons Learned; EPRO Handbook II, Vol. I; Utility Drive, Oct. 5

Given the limited number of pipelines and supporting gas infrastructure in New England, the loss of even a single natural gas compressor station or other gas system facility would create recurring energy shortages that would cause frequent and long rolling blackouts.[163] ISO-NE recently implemented two new initiatives to address the risk of winter energy shortages by beginning to publish a 21-day look-ahead energy forecast that describes expected conditions, from normal to conditions requiring declaration of an energy alert or an energy emergency, and a change to ISO-NE energy market. The second initiative, in the daily energy market, will provide each generator with an estimated opportunity cost that can be incorporated into its offer price for the next day. Each morning, the next day's opportunity costs will be calculated for each generator and provided to resource owners.[164]

Natural gas disruptions could also cause ripple effects across supply chains, whose corruption could pose significant challenges.[165] There should be conversations among all stakeholders about emergency energy diversification because as the nation moves away from traditional energy generation (e.g., coal and nuclear) to natural gas, new challenges are created if primary power and backup power are taken out simultaneously (e.g., supply chain issue that disrupt the distribution of natural gas).

[162] NERC, *2017 Long-Term Reliability Assessment*, 2017.
[163] ISO New England, *Operational Fuel-Security Analysis,* January 17, 2018.
[164] ISO Newswire, "ISO-NE is implementing near-term changes in both operations and markets to help address the risk of winter energy shortage," Press release, November 2, 2018.
[165] NERC, *CIP-013-1 – Cyber Security Supply Chain Risk Management Plans*, April 2017.

In the event of significant damage to physical pipeline infrastructure, service restoration for natural gas is time-consuming and expensive. Federal authorities do not have an estimate on the amount of time it would take to recover if natural gas is shut off in a vast portion of the U.S. such as the East Coast.[166] A 2018 report prepared for Southern California Gas examined the resilience of natural gas infrastructure in disasters and recommended utilities sub-divide their gas systems so that when service isolation is necessary it can be done on a more granular level.[167]

Natural Gas and Cybersecurity

The American Petroleum Institute (API), the Natural Gas Council (NGC) and the wider membership the ONG Subsector Coordinating Council (SCC) released a report in October 2018 describing steps the industry has taken to improve its resilience to cyber threats. The report emphasized the industry's preference for voluntary mechanisms including frameworks and public-private collaboration, rather than rigid standards or regulations to provide the necessary flexibility and agility to respond to a constantly-changing cyber threat landscape.

The National Risk Management Center (NRMC) is also working with the Transportation Security Administration (TSA), Department of Energy (DOE), the Federal Energy Regulatory Commission (FERC), and the Electric Subsector Coordinating Council and Oil and Natural Gas Subsector Coordinating Council on cyber and physical risks to natural gas pipeline infrastructure.

Source: ONG SCC and NGC, Defense-in-Depth: Cybersecurity in the National Gas and Oil Industry report

Existing and Proposed Standards and Guidelines

There are existing guidelines and plans that direct the safety and security of the natural gas pipeline system.[168] For example, the Pipeline Security and Incident Recovery Protocol Plan (the Plan), was completed in 2010 as required by the 9/11 Commission Act of 2007[169] by the TSA and the Pipeline and Hazardous Materials Safety Administration (PHMSA). The Plan acted as a framework to support the recovery of pipeline infrastructure and measures to prevent a security incident and enhance pipeline resiliency.[170] Within the federal government, the Plan mainly applies to the TSA and PHMSA, identifying ways they can provide increased security support to the critical interstate and intrastate natural gas and hazardous liquid transmission pipeline infrastructure when threatened and how the government will work to ensure continued transportation of product following an incident.

NERC has offered a set of recommendations on opportunities for gas-electric coordination, many of which might be supported by data to facilitate broader assessments of fuel resilience and collaborative mitigation measures.[171] And while there are NERC standards, NERC reliability standards apply to electric infrastructure, not gas transmission lines and other fuel systems on which the grid depends. Natural gas does not have mandatory reliability standards directly comparable to the bulk electric system. "We need an in-depth understanding of the resilience of our electricity and the related, supporting infrastructure in order to know how best to either modify existing market structures or build new resiliency standards into the system."[172]

[166] Blake Sobczak, et al., "Cyber raises threat against America's energy backbone," *E&E News,* May 23, 2017.
[167] ICF, *Case Studies of Natural Gas Sector Resilience Following Four Climate-Related Disasters in 2017*, Southern California Gas Co, 2018.
[168] DHS, *Pipeline Security Guidelines*, March 2018; Behr, Peter and Blake Sobczak, "TSA to expand gas pipeline cybersecurity oversight," *E&E News*, December 22, 2017.
[169] *9/11 Commission Act of 2007*. Pub. L. 110-53.
[170] A security incident is any event determined by DHS/TSA to be significant enough to begin monitoring the situation for further developments.
[171] Statement of Paul Stockton, *Fuel Resilience for the Bulk Power System: Threat-Based Modeling and Analysis.* Response to the Grid Resilience Order, *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, 162 FERC ¶ 61,012. May 8, 2018.
[172] Bruce Walker, *Testimony Before the United States Senate Committee on Energy and Natural Resources*, January 23, 2018.

The Oil and Natural Gas Sector Coordinating Council (ONG SCC) is working closely with other sectors through Information Sharing and Analysis Centers (ISACs), through DOE and DHS tabletop exercises (e.g., GridEx, National Level Exercise (NLE), ClearPath), through state-led exercises, and through direct coordination with the ESCC.

B. Communications Sector

Restoration and recovery are next to impossible without working communications. Existing plans and exercises across all sectors rely on the ability to coordinate response through voice or data communications. Current emergency communications systems are unlikely to provide the multi-sector connectivity and interoperability that will be essential in catastrophic power outages.[173] Voice and data communications are used for normal business functions (e.g., personnel records, payroll systems) and for supervisory control and data acquisition (SCADA), crew dispatch, and control of electricity generation and delivery.

Communication networks were designed for power outages that are infrequent or of short duration; backup generators and fuel storage are designed to support an outage of a few hours to a few days. Communications systems will require fuel for generators, but pipeline pumping stations, storage depots, and truck distribution could be affected by a catastrophic power outage, preventing the necessary resupply needed for communications networks to continue to operate. Due to its limited lifespan, current battery technology would most likely not have a significant impact in reducing dependencies and/or interdependencies during a long-term outage.[174]

Without communications, crucial sector operations would grow increasingly difficult over extended periods of time since manual operations, when they are possible, depend on timely communications. Most companies have satellite-based phones and radio communications, but these systems need to be properly maintained and tested.

The President's National Security Telecommunications Advisory Council (NSTAC), a presidential advisory council focused on reliable telecommunications, released two reports in 2006 on the interdependency between communications and electric sector and how this could be impacted by a long-term outage in one or both sectors. While the reports were completed more than a decade ago, a number of the conclusions and recommendations are still relevant. For example, the need to identify and prioritize adequate fuel resupply to maintain backup power for communication systems, and the lack of clarity on the transition from local to national management of a long-term outage.[175]

There are a number of ongoing efforts to address emergency communications platforms and processes and prior efforts may provide lessons learned.

Prior Efforts

- **The Critical Infrastructure Warning Information Network (CWIN)** was a DHS program designed to create a hardened communications system as a stand-alone, independent network that connected the government and critical sector owners and operators to coordinate recovery and reconstruction following an event. CWIN was established in 2001 and funded through 2010, with a budget of $30 million in 2003 alone. During its existence, CWIN included 51 state Emergency Operation Center

[173] EIS Council, "Black Sky Emergency Communication & Coordination System: BSX."
[174] CSCC and Communications-ISAC, "Communications Sector Response to DHS Data Call – Executive Order 13800," July 28, 2017.
[175] NSTAC, *NSTAC Report to the President on Telecommunications and Electric Power Interdependencies: The Implications of Long-Term Outages*, December 2006.

(EOCs), 163 federal and state representatives, and had 160 client terminal sites across the United States, and all states and the main ISACs were connected.[176] Though it is unclear why CWIN was discontinued because by all assessments it was well managed and operating effectively, CWIN may have been have had too high a price tag and come before its time because there was no protocol on information sharing liability in the early 2000s.

Ongoing Initiatives

- **The Electricity Subsector Coordinating Council (ESCC) Resilient Communications Working Group** has identified the need to update, modernize, and move some of the underlying systems out of private networks partially because real-time coordination across multiple sectors makes voice and data telecommunications critical for operation of the grid.[177] This Working Group has created a policy principle statement supporting emergency communications to validate and formalize the current work being done with the Communications Sector. The ESCC has also recommended that some form of backup communications capability to restore the grid after a major disaster needs to be created.
- **The Black Sky Emergency Communications and Coordination System (BSX)**—an interoperable, secure system that can incorporate a range of communication technologies to support grid re-start activities—is being developed by the EIS Council as a means to provide secure communications during an event.[178] A BSX system will have the ability to:[179]
    - Survive electromagnetic pulse (EMP) attacks, cyberattacks, catastrophic earthquakes, and other black sky hazards
    - Continue functioning in the absence of grid-provided power for a month or more
    - Withstand adversarial efforts to disrupt communications or corrupt the integrity of data flows
    - Provide critical voice and data connectivity for situational awareness, sustainment, and restoration operations across multiple regions of the United States
    - Provide an engine for decision support, keyed to the unique requirements of the local users' equipment, sector by sector, adequate to help manage the scale of a black sky complex catastrophe
        - There could be reinvestments to FNARS (FEMA's National Radio System)—the Agency's high frequency (HF) radio network that provides a minimum essential emergency communications capability among federal, state, local commonwealth, and territorial governments in times of national, natural and civil emergencies.[180]

C. Water and Wastewater Systems Sector

Water and energy are resources that are reciprocally and mutually linked, because energy needs require water—through mining, fuel production, hydropower, and power plant cooling—and water needs energy—to pump it, treat it, distribute it, and discharge wastewater.[181] There are almost 200,000 drinking water treatment systems in the United States, and roughly 15,000 water treatment facilities.[182] About 85 percent

[176] DHS, "IT Program Assessment: NPPD – Critical Infrastructure Warning Information Network (CWIN);" DHS, "Privacy Impact Assessment for the Critical Infrastructure Warning Information Network," January 7, 2006.
[177] NSTAC, *NSTAC Report to the President on Telecommunications and Electric Power Interdependencies: The Implications of Long-Term Outages*, December 2006.
[178] EIS Council, "Black Sky Emergency Communication & Coordination System: BSX."
[179] Paul Stockton, *E-PRO Handbook III Cross-Sector Coordination and Communications in Black Sky Events,* EIS Council, 2018.
[180] FEMA, "Non-Federal Outreach and Technical Assistance Offerings."
[181] Claudia Copeland and Nicole T. Carter, *Energy-Water Nexus: The Water Sector's Energy Use*, Congressional Research Service, January 24, 2017.
[182] NIAC, *Water Sector Resilience: Final Report and Recommendations*, June 2016.

of the U.S. is supplied by 5 percent of the drinking water system, while the 15,000 water treatment facilities serve over 75 percent.[183]

The Energy Sector's water consumption is projected to rise 50 percent from 2005 to 2030.[184] According to a 2010 Congressional Research Service report, "The more water used by the energy sector, the more vulnerable energy production and reliability is to competition with other water uses and water constraints."[185]

Without water services, factories shut down, hospitals close, communities are disrupted, and most hotels, restaurants, and businesses cease operations.[186] If water and wastewater systems failed in communities across multiple states or U.S. regions, the societal consequences and risk to the lives and safety of affected populations would be difficult to overestimate.[187] As the U.S. Environmental Protection Agency (EPA) put it, "water infrastructure damage can adversely affect the operation of all other critical infrastructure sectors. Conversely, damage to other critical infrastructure sectors could negatively affect drinking water and wastewater services, thereby creating an infrastructure interdependency."[188]

A growing number of electric utilities are installing their own emergency power generators or arranging with partners (including the U.S Army Corps of Engineers (USACE)) to install generators when an emergency strikes. Many utilities are also expanding their capacity to store generator fuel onsite, and are improving their ability to provide mutual assistance when severe events occur.[189]

The EIS Council has been working with American Water, Aqua America, and the American Water Works, developing black sky playbooks and a Water Sector Electric Infrastructure Protection (E-PRO) Handbook for individual water and wastewater systems. A 2016 E-PRO Handbook recommended establishing minimal sustainable service levels with infrastructure investments and developing plans to achieve those service levels to strengthen the resilience and ability of water and wastewater systems to sustain emergency operations.[190]

A 2018 American Water Works Association after-action report on Hurricanes Harvey and Irma, recommended that DHS and FEMA establish a policy that designates water and wastewater services as top priorities for power restoration.[191] The report emphasized that given the critical lifeline functions the Water and Wastewater Systems Sector provide communities for response and recovery such as fire protection and public health and safety, water systems should have top priority status when power supply is at risk.[192] Sustaining drinking water and wastewater services reduces pressure on other emergency management needs, supports shelter in place capabilities and allows for continued economic activity.[193]

[183] NIAC, *Water Sector Resilience: Final Report and Recommendations*, June 2016.
[184] Nicole T. Carter, *Energy's Water Demand: Trends, Vulnerabilities, and Management*, Congressional Research Service, November 24, 2010.
[185] Ibid.
[186] NIAC, *Water Sector Resilience Final Report and Recommendations*, June 2016.
[187] Paul Stockton, *E-PRO Handbook II: Volume 2 Water: Water Sector Resilience for Black Sky Events*, EIS Council, 2016.
[188] EPA, "Understanding Water Sector Interdependencies."
[189] Paul Stockton, *E-PRO Handbook II: Volume 2 Water: Water Sector Resilience for Black Sky Events*, EIS Council, 2016.
[190] Ibid.
[191] American Water Works Association and Water/(WARN), *Hurricanes Harvey and Irma After-Action Report*, 2018.
[192] Ibid.
[193] Ibid.

D. Transportation Systems Sector

In 2017, 29 percent of U.S. energy consumption was for transporting people and goods.[194] As the NIAC noted in its 2015 *Transportation Sector Resilience: Final Report and Recommendations*, "America's transportation system is a very complex 'system of systems,' with seven distinct modes; a diverse ownership across the private sector and federal, state, local, and regional jurisdictions; and a vast array of services to move people and freight. This diversity complicates transportation planning, funding, design, and operations and presents significant challenges for integrating resilience into infrastructure and organizational practices."[195] The seven distinct modes include: aviation, highway and motor carrier, maritime transportation system, mass transit and passenger rail, freight rail, postal and shipping, and pipeline systems.[196]

Limited or degraded transportation systems in an affected area during a catastrophic power outage could hinder response and restoration by delaying supplies or preventing individuals from traveling to their homes or other safe areas.

The Pacific Northwest Cascadia Rising Exercise determined that catastrophic plans were inadequate for a scenario of that magnitude because current response plans are developed assuming that fundamental capabilities, such as communications and transportation, would be functional.[197] The exercise determined that failure to quickly prioritize critical transportation routes for evacuation and clearance delayed the restoration of key routes in and out of impacted areas and that an over reliance on single modes of transportation, such as rotary-wing aircraft, quickly created a bottleneck. Most notably, the exercise illuminated that transportation agencies tend to function in silos, with minimal collaboration with other participating entities to pool information and assets, causing information gaps and a lack of awareness of resources available for assistance.

This was notable after Hurricane Maria struck Puerto Rico. One of the biggest lessons learned and massive limiting factor for response on the island was the time and effort to get supplies and personnel to the island. In the continental United States, supplies can be sent through a variety of methods (e.g., truck, rail, plane), but there were only two ways to get supplies to Puerto Rico—airports and sea ports—both of which were damaged. Given the limited ways to transport supplies, they were only able to send a certain number of planes each day. The result was that supplies for power restoration were competing with public health and safety supplies and priorities.

E. Financial Services Sector

The Financial Services Sector consists of investment institutions, insurance companies, credit and financing organizations, and the infrastructure that enables these businesses to function.[198] Financial Services Sector disruptions can also have cascading impacts on other sectors that require financial data systems for day-to-day operations. For example, in 2012, several financial institutions large and small withstood coordinated distributed denial-of-service (DDoS) attacks.[199]

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[194] EIA, *Monthly Energy Review*, Table 2.1, April 2018.
[195] NIAC, *Transportation Sector Resilience: Final Report and Recommendations*, July 10, 2015.
[196] DHS, "Transportation Systems Sector: Sector Overview."
[197] FEMA, *Emergency Managers Announce Improvements After Cascadia Rising Exercise*, June 7, 2017.
[198] DHS, "Financial Services Sector."
[199] DHS, "Financial Services Sector-Specific Plan 2015."

The Electricity and Financial Services Sectors are not only interconnected, but also underpin all other sectors.[200] The Homeland Security Advisory Council (HSAC) Cybersecurity Subcommittee stated in its 2016 report that these sectors along with the Communications Sector face rapidly growing cyber threats, and because of other sectors' reliance on them, could be attractive targets for a cyber attack.[201]

In 2016, the CEOs of eight banks—Bank of America, BNY Mellon, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, State Street and Wells Fargo—came together to proactively identify ways to enhance the resilience of the critical infrastructure underpinning much of the U.S. financial system. They created a long-term strategic initiative that performs deep analyses of systemic risk across financial products and practices, known as the Financial Systemic Analysis and Resilience Center (FSARC). The FSARC's mission is to proactively identify, analyze, assess and coordinate activities to mitigate systemic risk to the U.S. financial system from current and emerging cyber security threats through focused operations and enhanced collaboration between participating firms, industry partners, and the U.S. Government.[202]

The FSARC leverages the expertise of participating banks' information/cyber-security teams with that of its government partners, including the Department of Treasury, DHS, and the Federal Bureau of Investigation (FBI).[203]

II. Cross-Sector Exercises

There are a number of existing exercises that bring together key stakeholders across industry and government to test plans, identify gaps that need to be addressed, and develop relationships before disaster strikes. This section provides an overview of some recent exercises that could be enhanced or built upon to test preparedness and response to a catastrophic power outage.

A. GridEx IV

NERC conducted its fourth biennial grid security and emergency response exercise, GridEx IV, from November 15–16, 2017.[204] With 6,500 individuals and 450 organizations participating across industry, law enforcement, and government agencies, GridEx IV provided an opportunity for various stakeholders in the electricity sector to respond to simulated cyber and physical attacks that affect the reliable operation of the grid, fulfilling NERC's mission to assure the effective and efficient reduction of risks to the reliability and security of the BPS.[205]

Led by NERC's E-ISAC, GridEx IV was the largest geographically distributed grid security exercise to date. In addition to the distributed play portion of GridEx IV, a six-hour executive tabletop involved industry executives and senior government officials.[206] The tabletop was facilitated as a structured discussion for industry and government to share the actions they would take and issues they would face in responding to the scenario. Participants articulated the severe limitations and barriers that would need to be addressed, both independently and collaboratively, to respond.[207]

[200] NIAC, *Securing Cyber Assets*, August 2017.
[201] HSAC, *Final Report of the Cybersecurity Subcommittee: Part I-Incident Response*, 2016.
[202] "Financial Systemic Analysis & Resilience Center Appoints Scott DePasquale As President," PRNewswire, March 15, 2017.
[203] FS-ISAC, "FS-ISAC Announces the Formation of the Financial Systemic Analysis & Resilience Center (FSARC)," News Release, October 24, 2016.
[204] NERC, *Grid Security Exercise GridEx IV: Lessons Learned*, March 2018.
[205] Ibid.
[206] Ibid.
[207] Ibid.

The exercise identified some action items that need to be addressed. The most relevant for this study include:[208]

- The need for increased shared understanding of the risk environment in different communities from a long duration power outage to ensure there are answers before an event occurs.
    - This would require a coordinated effort starting at the local level then to the state and federal level, with clear roles and responsibilities across all parts of government to divide or align efforts.
- There has been no assessment of the mismatched supply of generators and fuel for backup generators across multiple infrastructure sectors.
- The government needs to provide continual, proactive support through tighter coordination with industry.
    - The government needs to stop providing episodic support and simply reacting to events, and provide continuous support to industry through increased coordination.
- Expand GridEx IV further because the current exercise did not offer an effective opportunity for electric utilities to exercise their external communications response plans with external organizations, such as law enforcement and state emergency managers.

B. Dark Sky Exercise

In May 2018, the State of Wisconsin held Dark Sky, which simulated a long-term, mass power outage across a wide swath of Wisconsin (45 counties—approximately two-thirds of the state—affecting 2.8 million people) to test how Wisconsin Emergency Management (WEM), local emergency management officials, the Wisconsin National Guard, first responders, and private utilities would respond to an outage's second and third order effects.

The purpose of the exercise was to test existing emergency and contingency plans, and to increase the understanding of the coordination, policies, and procedures required to conduct a Joint Inter-Agency response to cyber and physical threats and subsequent attacks on infrastructure.

The exercise was conducted May 15-17, 2018 at 19 different locations in Wisconsin and included more than 1,600 participants from more than 240 agencies and departments across all levels of government and the private sector. It also included a cyber range to simulate a cyber-physical attack on grid infrastructure, which brought together public and private sector participants as part of a Red Team/Blue Team scenario. The exercise was also an opportunity for the state to test its separate secure fiber line that connects the State Emergency Operation Center, Joint Operations Center and key private sector entities.

In March 2015, the Wisconsin Department of Military Affairs (which includes the Wisconsin National Guard and WEM) and the seven private sector electric utilities in the state formally established a public-private partnership. In 2017, the parties established the Wisconsin Utilities Coordination Group to support joint planning and formalize a system to coordinate activities during an emergency.

Source: Wisconsin Department of Military Affairs

Dark Sky was the culmination of a multi-year planning cycle, which built on the state's participation in prior exercises include GridEx IV November 2017 and the 2017 and 2018 annual Statewide Mobile Interoperable Communications exercises. The state was also part of FEMA Region V POIA planning and workshops.

[208] NERC, *Grid Security Exercise GridEx IV: Lessons Learned*, March 2018.

Wisconsin used the exercise to test a draft emergency fuel plan and state-level fuel stakeholder coordination procedure. The state intends to use lessons learned from Dark Sky to inform development of a statewide emergency fuel plan.

C. Cascadia Rising

The Cascadia Rising 2016 Exercise was a two-year effort to test and validate catastrophic plans for a 9.0 magnitude earthquake along the 700-mile Cascadia Subduction Zone (CSZ) fault with subsequent tsunamis and aftershocks, impacting California, Oregon, Washington, and potentially Idaho.[209]

The exercise spanned local, state, tribal, and federal governments, the military, private sector, and non-governmental organizations (NGOs) in a simulated field response to the aftermath of a disastrous CSZ earthquake and tsunami. Specifically, the exercise aimed to test the ability of EOCs in the region to coordinate and communicate priorities and objectives, share situational information, and request, order, and transport life-saving resources to impacted areas in the event of such a scenario.

The exercise highlighted that catastrophic plans should encompass the full planning process; from formation, understanding the scenario, determining goals and objectives, decision making, to development, implementation, and maintenance. Clear and aligned prioritization system should be developed for local areas to work with state and federal entities. Other lessons learned most relevant to this study include:

- Jurisdictions should anticipate widespread communications outages and pre-identify alternate communication strategies before a catastrophic event occurs.
    - The pocket of communication infrastructure that will remain accessible and functional in a heavily degraded state will need to be able share vital information to the public with the correct messaging.
- All jurisdictions should consider extending access to their information management and collaboration systems to external partners as needed, while ensuring the appropriate moderation and maintenance required to sustain any increased access.
- Partnerships with private and military assets would greatly expand the transportation options available. Processes for formalizing new relationships need to be streamlined to an expedited process during disaster response.

D. Liberty Eclipse

DOE's Liberty Eclipse exercise in November 2018, was intended be a "hands-on" test of the grid's ability to bounce back from a blackout caused by simulating the painstaking process of re-energizing the power grid while squaring off against a simultaneous cyberattack on electric, oil and natural gas infrastructure.[210]

The goal of the Liberty Eclipse exercise was to prepare the response to a major incident caused by cyber attacks that could be frequent events in the near future. The exercise emphasized that utilities that have to restore electricity following massive blackouts first need to provide initial jump of electricity before they can start generating it.[211] The 2018 Liberty Eclipse exercise focused on re-energizing the grid and was expected to further examine the electric sector's reliance on natural gas.[212] It featured a two-day tabletop exercise for

[209] FEMA, *Emergency Managers Announce Improvements After Cascadia Rising Exercise*, June 7, 2017.
[210] Blake Sobczak, "DOE to vet grid's ability to reboot after a cyberattack," *E&E News*, August 3, 2018.
[211] Pierluigi Paganini, "Dept. of Energy announced the Liberty Eclipse exercise to test electrical grid against cyber attacks," *Security Affairs*, August 6, 2018.
[212] Blake Sobczak, "DOE to vet grid's ability to reboot after a cyberattack," *E&E News*, August 3, 2018.

grid and oil and natural gas representatives, ahead of an operational drill of the step-by-step process for restoring electricity following massive blackouts.[213]

An after-action report is planned that will contain lessons learned and strategies to protect the grid against emerging cyber threats.[214] DOE aims to make the Liberty Eclipse exercise a recurring, regionally focused supplement to GridEx.

[213] Blake Sobczak, "DOE to vet grid's ability to reboot after a cyberattack," *E&E News*, August 3, 2018.
[214] Ibid.

Appendix F: Individual and Community Preparedness Efforts

Ultimately all events, from small to large disasters, are local.[215] This means that those closest to impacted areas are the true first responders during any emergency or disaster—from individuals to families to neighbors and local communities.[216] However, there remains an ongoing myth that the federal government will be able to provide assistance and resources directly after an event to help with response and that is not always the case.

State and local governments have a better understanding of needs of their communities and have established relationships with owners and operators that will need to be called on following an event. Therefore, a solid capacity at the local and state level to respond to the needs of people is of upmost importance. The more communities can do to focus on preparedness before an event occurs, the more likely they are to have better outcomes following an event.

However, not all communities are at the same level of preparedness. This means that any planning needs to recognize that each community exists in its own context and there is not a one-size-fits-all approach for preparedness.

As the frequency and severity of disasters increases, there are two key ways communities build up their capacity and capabilities:

1. Accountability at the individual level for people and the local community.
2. Investment in infrastructure and community development that can make a big difference in a community's resilience.

State and local efforts are necessary to build community and individual resilience. This includes increased outreach and education for businesses and the general public on steps they can take to survive in place, improved personal preparedness, and support and sustainment of the local workforce that will be critical to infrastructure restoration.

There are a number of ongoing efforts aimed at building individual and community resilience, including state initiatives and the work being done by the National Institute of Standards and Technology (NIST) Community Resilience Program. This appendix provides a high-level overview of those efforts.

National Voluntary Organizations Active in Disaster

The NVOAD is a nationwide coalition of organizations that work together to help communities prepare for and recover from disaster. It is made up of NGOs, faith-based and community-based organizations and promotes cooperation, communication, coordination, and collaboration among members to create a more effective delivery of services to communities affected by disaster.

NVOAD also provides specific liaisons to work at designated DHS/FEMA locations to support ESF #6.

Source: FEMA, ESF #6 Fact Sheet

[215] FEMA, DHS, "Unit Four: Emergency Management in the United States," Training.
[216] FEMA, *2018-2022 Strategic Plan*, 2018.

I. Examples of State Government Initiatives for Community Preparedness

Although federal and state entities provide preparedness resources to individuals through websites, campaigns, and pamphlets, examples observed in the state of Washington, Oregon, and Hawaii reveal additional possible efforts that could better ensure the safety of the public during a catastrophic power outage.

- **Washington:** After the 2016 Cascadia Rising exercise—which tested the Pacific Northwest's ability to not only survive but recover from a Cascadia Subduction Zone earthquake and resulting tsunami[217]—identified issues with transportation, evacuation, sheltering and significant time before regional response agencies and neighboring states send assistance,[218] Washington and representatives from regions, cities, and counties of the entire state, voted to change the disaster preparedness timeline previously at 3 days to 14 days or more. The state has provided information on creating a Disaster Go To Kits and ways to stockpile food within homes.[219]
- **Oregon:** Oregon's Office of Emergency Management encourages people to be prepared to be on their own for a minimum of two weeks, and details guides in time increments, from 2 minutes, 2 hours, 2 days, and 2 weeks after an event.[220] This lessens the strain on emergency responders who need to focus limited resources on injured and other vulnerable populations immediately following a disaster.[221]
- **Hawaii:** Hawaii's Emergency Management Agency (HI-EMA) launched a 2 Weeks Ready Campaign to inform the public of the necessary plans, kits, and procedures for a disaster with wide-spread impacts beyond the standard 72 hours.[222] There is also a Hawaii Hazards Awareness and Resilience Program (HHARP) to help communities prepare to be self-reliant during and after events.[223]

Community Emergency Response Team (CERT) Program

FEMA's Community Emergency Response Team (CERT) program is designed to help communities prepare for effective disaster response through training and preplanning. CERT educates volunteers about disaster preparedness for the hazards that may impact their area and trains them in basic disaster response skills, such as fire safety, light search and rescue, team organization, and disaster medical operations. There are over 2,700 local CERT programs nationwide, with more than 600,000 individuals trained since CERT became a national program.

Source: FEMA, Community Emergency Response

[217] FEMA, *Cascadia Rising 2016 Exercise: Joint Multi-State After Action Report*, September 6, 2016; Emergency Management Division Washington, "Preparedness."
[218] "Disaster Preparedness – 3 Days, (72 Hours) is NOT Sufficient," Website for the City Of Ocean Shores.
[219] "Snohomish County Disaster Preparedness Guide," snohomishcountywa.gov, January 2017.
[220] Oregon Office of Emergency Management, "Communicating during & after emergencies."
[221] "2 Weeks Ready," Oregon.gov.
[222] Eric Holdeman, "Hawaii Opts for 14 Days Preparedness," *Emergency Management*, August 22, 2018; HI-EMA, *2 Weeks Ready Brochure,* August 2018.
[223] HI-EMA, "Hawaii Hazards Awareness and Resilience Program (HHARP)."

II. National Institute of Standards and Technology Community Resilience Program

NIST has been working on developing community resilience planning and related guidance tools designed to be community-driven and incorporated into existing efforts for a number of years. Part of this effort is the NIST Community Resilience Program, which began in 2014 in response to several large-scale disasters.[224]

The program is designed to: [225]

1. Develop science-based tools and metrics to support and measure resilience at the community level and support economic evaluation of alternative solutions to improve resilience.
2. Engage community resilience stakeholders for feedback for products, such as guidance, tools, and metrics, for planning and implementing resilience measures.
3. Learn from events that have impacted the built environment to better understand adverse hazard impacts on communities and develop improved tools and methods for field studies.

The program is meant to be locally led. The community resilience planning and related guidance tools, including economic decisions guides and community resilience planning guides, are designed to be community-driven and incorporated into existing efforts.[226] Through the guidance, communities can establish collaborative planning teams who do the bulk of the work, and engage a larger stakeholder network to inform the process.

To emphasize that the program's solution are not imposed on a community, but rather developed consistent with a community's capacity to build, maintain, and operate over time, NIST is initiating a program call the Community Resilience Panel.[227] Because engagement across the community is key to ensure all stakeholders are bought into the process and its end result, this panel within communities will promote collaboration among stakeholders to strengthen the resilience of buildings, infrastructure, and social systems upon which communities rely.[228] Cities, counties, and communities need to define what resilience should look like for them, such as determining their unique critical functions or locating vulnerable populations. NIST's approach is to develop tools that can be implemented locally to help develop the capacity at the local levels.

The first major deliverable of the Community Resilience Program was the *Community Resilience Planning Guide for Buildings and Infrastructure Systems* report, released in 2015.[229] The Guide offers a six-step process to develop community resilience containing resilience plans that drive or complement ongoing resilience improvement planning across communities. Since the Guide's release, several communities have begun to use it to develop resilience plans. Some examples include:[230]

- **Fort Collins**, **Colorado** used the Guide to address government, education, healthcare, and community service organizations that provide shelter during emergencies.

[224] NIST, "Community Resilience Program."
[225] Ibid.
[226] Ibid.
[227] Ibid.
[228] Ibid.
[229] Stephen A. Cauffman, *Community Resilience Planning Guide for Buildings and Infrastructure Systems: Observations on Initial Implementations*. NISTIR 8229, September 2018.
[230] Ibid.

- **Delaware Department of Transportation (DelDOT)** used the Guide to support two highway corridor assessments and as a reference in the development of Maryland's Strategic Implementation Plan for Climate Change, Sustainability, and Resilience for Transportation.[231]
- **Howard County**, **Maryland** used the Guide as it was in the process of developing a recovery plan for the county that used the NIST Guide as a reference.

NIST has also done work to identify building clusters or the buildings within communities that provide crucial services or functions.[232] Every building and infrastructure system is not needed immediately following a hazard event. The time needed to achieve community recovery depends on the extent of damage, the overall physical and mental health of the community, dependencies between systems, the characteristics of the community's economy, the governance structure, and the availability of financial resources. Therefore, it is important that these factors be known and understood across a community to support recovery.[233] Setting specific performance goals for building clusters communities will shape the sequence of recovery activities for their built environment and identify dependencies between systems. This can help communities identify sheltering capacity, and other needs.[234]

[231] Delaware Department of Transportation, *Strategic Implementation Plan for Climate Change, Sustainability & Resilience for Transportation* July 2017.
[232] NIST, *Guide Brief 11 – Determining Building Cluster Performance Goals*, NIST Special Publication 1190GB-11.
[233] Ibid.
[234] Ibid.

Appendix G: Lessons Learned from 2017 Disasters

The federal government, SLTT governments, and utilities currently have robust systems and processes in place to respond to disasters we have previously experienced (e.g., hurricanes) even if an event is more severe than those previously experienced. These entities continue to learn from each event and incorporate the experiences and knowledge to improve preparedness and response for similar future disasters.

During the course of the study, the nation experienced a number of severe disasters causing loss of life, destruction of communities, and billions of dollars in damage.

This study did not focus on preparedness, response, and recovery from hurricanes, wildfires, and other disasters; rather it focused on events beyond modern experience. However, the lessons learned from prior events, including the disasters that took place in 2017 and 2018 provided the NIAC with a better understanding of current response plans and the challenges that the nation may face in a catastrophic power outage. This appendix provides a high-level overview of the information most relevant to this study, and should not be considered a comprehensive summary of the disasters and their impact, or lessons learned.

I. Overview of the 2017 Disasters

In 2017, four near-sequential disasters—Hurricane Harvey, Hurricane Irma, Hurricane Maria, and the California wildfires—created an unprecedented demand for federal disaster response and recovery resources.[235] It was the most active hurricane season since 2005, and was the seventh most active season in historical record dating back to 1851.[236] The 2017 hurricanes and wildfires collectively affected 47 million people—nearly 15 percent of the nation's population.[237] The cumulative to the U.S. was $306.2 billion, breaking the previous cost record of $214.8 billion from 2005.[238] Specifically, 2017 had 17 named storms, 10 of which became hurricanes including 6 major hurricanes (Category 3, 4, or 5);[239] the strongest Atlantic Ocean hurricane on record with winds peaking at 185 mph (Hurricane Irma); 71,499 wildfires;[240] and greater amount of DOD contracts and mission assignments for the response to the California wildfires than the hurricane response in support of Texas and Florida combined.[241]

A. Puerto Rico

In September 2017, Hurricane Irma caused significant damage to Puerto Rico, leaving over a million residents without power. Before the island could move from response to recovery efforts, Hurricane Maria further destroyed and caused widespread failure to the island's power grid, resulting in the longest power restoration mission in U.S. history.[242] It is also the largest and longest federal response to a domestic disaster, including being the longest air mission for FEMA, the largest medical response ever, and the largest power restoration mission. [243]

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[235] GAO, "2017 Hurricanes and Wildfires," September 2018.
[236] NOAA, "Extremely Active 2017 Atlantic Hurricane Season Finally Ends," November 30, 2017.
[237] FEMA, *2018-2022 Strategic Plan*, 2018.
[238] NOAA, "Hurricane Costs," Last modified October 17, 2018.
[239] NOAA, "Extremely Active 2017 Atlantic Hurricane Season Finally Ends," November 30, 2017.
[240] NIFC, "Total Wildland Fires and Acres (1926-2017).
[241] FEMA, *2018-2022 Strategic Plan*, 2018.
[242] Rhodium Group, "America's Biggest Blackout," 2018.
[243] FEMA, "Puerto Rico One Year after Hurricanes Irma and Maria," Press release, September 6, 2018.

In the immediate aftermath, more than 80 percent of the island's power lines were knocked down in the Category 4 winds—uprooting much of Puerto Rico's infrastructure and leaving all 3.6 million residents without power and 90 percent of cell towers were out of service.[244] Almost full power was restored to the entire island 11 months after Hurricane Maria hit, with only small pockets of outages due to geography constraints or the need for new transmission lines.[245]

There were cascading second-, third-, and fourth-tier effects stemming from the loss of power. Water pumps shut off[246] and water testing labs were affected, causing further delays in accessing safe, potable water.[247] Damage to pharmaceutical manufacturing facilities caused a shortage of saline IV bags across the United States. [248] With no way to keep money flowing, the Treasury Department sent $250,000 in cash to allow commerce to continue on the island.

Puerto Rican officials initially announced that 64 people died as a result of Hurricane Maria.[249] A 2018 study reported that the estimate was much higher at 2,975 people.[250]

2018 Disasters

This year also brought a number of severe storms and disasters:

- *The 2018 hurricane season was the most active recorded for Pacific Ocean storms with Hurricanes Lane, Rosa, Sergio, and Willa.*
- *Hurricane Florence had the second highest rainfall after Hurricane Harvey causing an estimated $13 billion in damages.*
- *Hurricane Michael was the most powerful storm to hit the Florida Panhandle on record.*
- *The 2018 Camp Fire is the deadliest and most destructive fire in California history. As of November 26, 2018, it destroyed 18,000 structures, burned 153,000 acres, and killed 85 people.*
- *The Mendocino Complex fire that began in July 2018, was the largest recorded fire in California burning 459,123 acres. 280 structures were destroyed, including 157 residences, killing a firefighter and injuring four others.*

Source: The Washington Post, Sept. 19; ABC 13 Eyewitness News, November 19; ABC 11 Eyewitness News, Sept. 26; USA Today, Oct. 23

II. Lessons Learned

As discussed throughout the report, the federal government, SLTT governments, and utilities continuously look for ways to improve emergency preparedness and response whether from an exercises or actual events. This section includes insights gathered during interviews and from after-action reports.

A. Utility Lessons Learned

The 2017 hurricanes reinforced that there is no easy or one-size-fits-all solution. The NIAC learned that in most cases, mutual assistance continues to be an effective way for utilities to quickly and efficiently restore service; but this can be dependent on geography and company structures. The pre-positioning of resources and working closely with SLTT and federal partners also helps utilities respond more efficiently. Finally, investments in infrastructure hardening and system modernization ahead of a disaster can make help reduce the impact and/or speed restoration. Other lessons learned, include:

[244] FCC, *Communications Status Report for Areas Impacted by Hurricane Maria*, September 27, 2017.
[245] Jessica Resnick-Ault, "Puerto Rico finally restored power to the entire island – 328 days after Hurricane Maria hit," Business Insider, August 15, 2018.
[246] John Humphrey, "7 Things About Life in Puerto Rico with No Electricity," IEEE Spectrum, December 4, 2017.
[247] Sara Reardon, "Puerto Rico struggles to assess hurricane's health effects," Nature, November 15, 2017.
[248] Sarah Baker, "Are we doing enough to protect the health care supply chain?" The Hill, March 30, 2018.
[249] Puerto Rico Public–Private Partnerships Authority, *An Economic and Disaster Recovery plan for Puerto Rico*, July 9, 2018.
[250] Milken Institute School of Public Health, George Washington University, *Ascertainment of the Estimated Excess Mortality From Hurricane Maria in Puerto Rico*, 2018.

- **Fast and efficient restoration is dependent on prior training, established mutual assistance agreements, and investments in new technology.** For example, before, during and after Hurricane Harvey, CenterPoint—the energy utility covers a 5,000 square-mile service territory in the Houston metropolitan area—mustered resources, created staging sites; and transported, housed, and fed the people needed for response and restoration (approximately 3,500 resources).[251] Over the course of the 5-day event more than 1 million customers lost power, but CenterPoint experienced only 200,000 people without power at any one time.
- **The use of smart meters enabled constant metering and outage tracking during and after the storm.** When crews were unable to go into the field after the storm, meters provided constant power updates enabling power utilities to accurately report to customers, the media, regulators, and legislators about outages and power restoration in real-time, sometimes through social media. This type of response is dependent on working communications.
- **Investments in hardening before a disaster make a difference.** For example, Florida Power and Light (FPL) spent billions to harden its infrastructure following the 2004 hurricane season when it experienced four hurricanes in 44 days (Hurricanes Charley, Frances, Ivan, and Jeanne).[252] FPL was worked with its regulators and conducted outreach with customers as part of the process.
    - Hurricane Irma was a Category 4 storm, which was 1.5 times stronger than a previously devastating storm that caused an average of 8 days until power restoration. After Hurricane Irma, the average FPL customer in Florida had power back after 5 days, the fastest restoration of the largest amount of people by one utility in U.S. history.[253] For the service territory, every day customers are without power results in $1 billion of economic loss. For average customers there were 3 days less outages; those three days saved $3 billion of economic loss.

B. FEMA Lessons Learned

In its *2017 Hurricane Season After-Action Report,* FEMA found that the 2017 hurricanes and wildfires highlighted some longstanding issues and revealed other emerging response and recovery challenges. For example, the concurrent timing and scale of the disaster damages nationwide caused shortages in available debris removal contractors and delays in removing disaster debris—a key first step in recovery. In addition, FEMA's available workforce was overwhelmed by the response needs.[254]

During the 2017 response, a Power Task Force—with representatives from FEMA, DOE, USACE, the private sector, and local government—was stood up to discuss ongoing issues and serve as an operational team during an event as a way to respond more effectively and efficiently. The AAR highlighted the need to continue this collaborative, steady state partnership.

FEMA also incorporated lessons learned from 2017 into its *2018-2022 Strategic Plan*, which outlines the agency's path forward for improving emergency response. FEMA highlighted a key lesson learned is that the most effective strategy for emergency management is when it is federally supported, state managed, and locally executed.[255] As mentioned in Appendix D, FEMA identified 3 strategic goals and 12 supporting objectives to guide efforts in the coming years.

[251] Center Point, "Where we serve."
[252] David Fleshler, "Taken by Storm," *Sun Sentinel*, August 8, 2014.
[253] "FPL completes service restoration to more than 4.4 million customers impacted by historic Hurricane Irma," Press release, September 22, 2017.
[254] GAO, "2017 Hurricanes and Wildfires," September 2018.
[255] FEMA, *2018-2022 Strategic Plan*, 2018.

Other lessons learned that were highlighted in the plan, include:

- **All levels of governments need to be better prepared with their own supplies, have pre-positioned contracts with enforcement mechanisms, and be ready for the economic effects of a disaster.** This includes developing a more comprehensive understanding of local, regional, and national supply chains, as well as stronger relationships with critical private sector partners to support rapid restoration in response to catastrophic incidents. [256]
- **Plans are based on the best information available, but no disaster follows the plan.** Every response requires adaptation, which is why flexible authorities and programs are important. For example, FEMA's plans did not anticipate the massive requirements to directly assist electricity, telecommunications, and fuel sector utilities with air and sea movement for response and recovery efforts in Puerto Rico. FEMA needs to support states to build a greater capacity to respond to small-scale events, without an oversized federal response by providing financial assistance to state-managed disasters. [257]
- **Critical infrastructure owners and operators, and state and local governments, should be encouraged to invest in more resilient infrastructure.** This includes investment in pre-disaster mitigation opportunities, such as up-to-date building codes and hurricane resilient building materials.[258] Investments in hardening infrastructure and ensuring it is well-maintained can help reduce the severity of storm impacts and help areas recover and restore power faster.
- **Private companies working collaboratively can make a huge impact in response and recovery efforts.** A lack of knowledge or awareness about interdependencies and cascading effects can delay response and recovery. The private sector, which has a greater knowledge of day-to-day operational needs, should be engaged from the beginning. For example in Puerto Rico, the power outage caused water pumps to shut off[259] and water testing labs to lose power, which causing further delays in accessing safe, potable water.[260]
- **Mutual aid contracts should be established *prior* to an event, with details such as cost and timing decided ahead of time, so recovery and restoration can begin without delays.** Standardized contracts should be integrated under one umbrella that is applicable across states and the public and private sectors. For example, New York already has this type of contract between states, which is why after Superstorm Sandy resources were organized more efficiently for response and recovery efforts.[261]
- **Federal coordination with other federal, local, and volunteer emergency partners before an event occurs cuts down on response time.** FEMA coordinated closely with Texas, Florida, and California emergency management officials and other federal, local, and volunteer emergency partners to implement emergency preparedness actions prior to the 2017 disasters. This helped overcome a number of challenges such as deploying a sufficient and adequately-trained disaster workforce and removing debris in a timely manner after the 2017 hurricanes and wildfires cutting down on the overall time for response.[262]

[256] FEMA, *2018-2022 Strategic Plan*, 2018.
[257] Ibid.
[258] Ibid.
[259] John Humphrey, "7 Things About Life in Puerto Rico with No Electricity," IEEE Spectrum, December 4, 2017.
[260] Sara Reardon, "Puerto Rico struggles to assess hurricane's health effects," Nature, November 15, 2017.
[261] DOE, *Overview of response to Hurricane Sandy – Nor'easter and recommendations for Improvement*, February 26, 2013.
[262] GAO, "2017 Hurricanes and Wildfires," September 2018.

C. Looking Ahead

While communities continue to recover from these events, FEMA has already started implementing its recommendations from the after-action report and its strategic plan. One such recommendation, is the update to the NRF to focus more on critical lifelines and cross-sector coordination (See Appendix D for more information).

Appendix H: References

The appendix lists all sources for this study, including those for the scoping effort and Study Group.

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