U.S. DEPARTMENT OF ENERGY | Office of Cybersecurity, Energy Security, and Emergency Response

# State Energy Security Plan Optional Drop-In: Energy Sector Risk Mitigation Measures

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This resource was produced by the U.S. Department of Energy's Office of Cybersecurity, Energy Security, and Emergency Response (CESER) to aid states in the development of State Energy Security Plans (SESPs). States may choose to incorporate parts or all of the provided material in their SESPs (optional). States are encouraged to adapt or supplement the provided material to align with existing state roles, authorities, and plans; and to better address state-specific needs and situations. This document is not intended to be prescriptive or suggest non-statutory expansion of State Energy Office responsibilities, which may vary significantly from state to state.

This document presents an inventory of potential risk mitigation measures for energy infrastructure. This inventory is not comprehensive; it is intended to be a starting place for conversations and for developing a risk mitigation approach to enhance energy sector reliability and end-use resilience, including maintaining electric, liquid fuels, and natural gas system reliability, and securing energy infrastructure. Cyber resilience measures, while important, are outside of the intended scope of this document.

**Cyber Resilience** is the ability to anticipate, withstand, recover from, and adapt to adverse conditions, stresses, attacks, or compromises on systems that use or are enabled by cyber resources.

For additional information see:

- IEA: Cyber Resilience, Report Extract
- NIST: "Developing Cyber-Resilient Systems: A Systems Security Engineering Approach"

Energy infrastructure is typically constructed to safety, security, and reliability standards set by the North American Electric Reliability Corporation, Pipeline Hazardous Materials and Safety Administration, and other federal, state, and industry regulating bodies. To mitigate impacts from evolving threats including climate change, states and energy infrastructure operators may consider risk mitigation technologies and operational measures that enhance system resilience *beyond* the standards set by regulators. As defined in Presidential Policy Directive (PPD)-21:

> *"Resilience is 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."*

When evaluating whether to invest in new risk mitigation measures, infrastructure operators evaluate the cost of the measures against the level of risk and the potential benefits of greater system reliability and faster recovery after emergency events. For regulated electric and natural gas utilities, these investments may require approval from state public utility commissions.

The measures summarized on the subsequent pages are categorized into two main groups: "All Hazards" measures can apply to a range of threats; and "Hazard-Specific" measures are designed to mitigate a specific threat or risk, such as cold weather or wildfires. All Hazard measures are divided into categories that align with three of the "infrastructural qualities" outlined in the Department of Homeland Security's Resilience Framework:

1) Robustness – measures that strengthen a system to withstand external hazards without degradation or loss of functionality;

2) Redundancy – measures that allow for alternate options, choices, and substitutions when a system is under stress; and

3) Rapid Detection/Recovery – measures that accelerate the time it takes to overcome a disruption and restore energy services.

The last two sections provide general resources on ways to increase the resilience of energy systems and resources related to specific risk mitigation measures.

LEGEND


## ALL-HAZARDS RISK MITIGATION MEASURES

### Robustness

| Measure | Description | Sector | | |
|---|---|---|---|---|
| Demand response programs | Demand response programs relieve pressure on electric or natural gas delivery systems by reducing or time-shifting customer energy usage. Demand reduction during peak periods reduces the chance of system overload and service failure. In addition to enhancing reliability, demand response can also help reduce generator or supplier market power and lessen price volatility. | ⚡ | | 🔥 |
| System segmentation | Energy systems (power grids, gas pipeline networks, and liquid fuels pipeline networks) can be sub-divided to more efficiently isolate damaged areas, allowing undamaged segments to continue serving customers. By segmenting networks, service isolations can be more targeted and affect fewer customers. | ⚡ | ⛽ | 🔥 |
| Undergrounding power lines | Placing transmission lines underground protects them against external threats, including high winds and falling branches, wildfires, extreme heat or cold, icing, dirt/dust/salt accumulation, and animals. Buried lines may be more vulnerable to flooding if located in low-lying areas and may be more difficult and expensive to maintain and repair. | ⚡ | | |

### Redundancy

| Measure | Description | Sector | | |
|---|---|---|---|---|
| Backup generators | Fixed or portable backup generators can provide backup power to critical facilities when grid-supplied power is interrupted. Backup generators may be designed to power emergency functions, such as emergency lighting, fire suppression, or stormwater removal, or may be designed to power some or all of a facility's operational functions. Mobile generators can power utility or emergency responder base camps (sites where response personnel and equipment are staged). Backup generators require adequate fuel supply to operate. | ⚡ | ⛽ | 🔥 |
| Battery storage | Battery energy storage can be used to provide backup power during electric grid outages. Batteries can be deployed at utility-scale as front-of-the-meter systems, providing services like utility load peak shaving or behind-the-meter by customers. Batteries are often paired with solar photovoltaic systems and included in microgrid designs. | ⚡ | | |
| Microgrids | A microgrid is a group of interconnected loads and distributed energy resources that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to operate in grid-connected or island mode. Microgrids can improve customer reliability and resilience to grid disturbances. | ⚡ | | |

| Measure | Description | Sector | | |
|---|---|---|---|---|
| Ties between gas pipelines | Natural gas system operators can add ties between gas distribution lines or "mains" to diversify the transmission system and allow additional pathways to route natural gas in the event some sections of transmission mains are damaged. | | |  |

## Rapid Detection/Recovery

| Measure | Description | Sector | | |
|---|---|---|---|---|
| Advanced distribution management systems | Advanced distribution management systems integrate numerous utility systems and provide automated outage restoration and optimization of distribution grid performance. These functions improve the resilience of the distribution system and decrease the length of customer outages. |  | | |
| Artificial intelligence analysis | Artificial intelligence analysis can augment the abilities of subject matter experts to prioritize transmission line operations, identify defects, and update asset management systems. |  |  |  |
| Distribution automation | Distribution automation uses digital sensors and switches with advanced control and communication technologies to automate feeder switching; voltage and equipment health monitoring; and outage, voltage, and reactive power management. |  | | |
| Drones for asset inspection | The use of drones to inspect pipelines, transmission lines, or other assets allows for safer and more frequent inspections, enhanced asset information, reduced operational costs and failure rates, and extended asset lifetimes. |  |  |  |
| LiDAR for vegetation management | Vegetation is the primary cause of overhead power line outages. "Light Detection and Ranging" (LiDAR), is remote-sensing technology that can measure how close vegetation is to power lines. LiDAR units can be deployed on the ground, drones or aircraft, to enable more effective vegetation management reducing the impact of storms on electric infrastructure. |  | | |
| Remote-operated valves | Remote-operated valves more efficiently isolate systems during disruptions or peak event load management (e.g., temporarily disconnecting gas customers). | |  |  |
| Advanced Metering Infrastructure | Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables bi-directional communication between utilities and customers. Smart meters can provide near-real-time visibility into customer outages and help utilities allocate resources and restoration activities more efficiently. |  | | |
| Supply chain resilience planning | Assessing current supply chains and working with relevant stakeholders to strategically plan for the continuity and rapid restoration of those supply chains after major disruptions improves supply chain resilience. |  |  |  |

## HAZARD-SPECIFIC RISK MITIGATION MEASURES

### Cold Weather Protection Measures

| Measure | Description | Sector | | |
|---|---|---|---|---|
| **Pipeline insulation & trace heating** | Fiberglass insulation used to enclose piping can protect against freezing. Additionally, an electrical heating element installed along the length of a pipe and covered by thermal insulation can be used to maintain or raise the temperature of the pipe during cold weather. | |  |  |
| **Water line management** | Draining water lines prevents rupturing that would otherwise be caused by the freezing water caught inside. Water lines that cannot be drained can be set to drip. The small amount of flow caused by the steady drip can help prevent the water inside the lines from freezing and rupturing the lines. | |  |  |
| **Heating & pitch adjustment for wind turbines** | Wind turbine blades and lubricant housings can be fitted with heating elements that prevent ice accumulation that would otherwise impair operations. Wind turbines can also be configured to operate in winter ice operation mode, which changes the pitch of the blades to allow continued operation as they accumulate ice. |  | | |
| **Thermal enclosures** | Instrumentation can be enclosed and heated to ensure functionality and operational continuity during extreme cold conditions. |  |  |  |

### Extreme Heat & Drought Resistance Measures

| Measure | Description | Sector |
|---|---|---|
| **Advanced water-cooling technologies** | Power plants require significant volumes of water for thermoelectric cooling. Asset owners can employ approaches to reduce their water use to make them more resilient to drought conditions. Alternative approaches include recirculating cooling, dry cooling (highlighted below), and wet-dry hybrid cooling technologies. Cooling equipment capable of using alternative water sources (e.g., brackish water, wastewater) can reduce the impact of droughts. |  |
| Dry cooling | Nearly all thermal generation, including nuclear and coal-fired power plants, requires large quantities of water for cooling. Extreme heat can lead to water shortages or make the water used for cooling too warm, forcing power plant operators to curtail electricity output. Dry cooling technologies use air-cooled heat exchangers and other technologies to significantly reduce water use. |  |
| **Hydropower reservoir capacity** | Increasing reservoir storage capacity at hydroelectric power plants can offset the effects of precipitation variability. |  |
| **Turbine efficiency** | Higher-efficiency hydroelectric turbines require less water per unit of electricity generated and are more resilient to drought. |  |

## Flood Protection Measures

| Measure | Description | Sector | | |
|---|---|---|---|---|
| Elevate equipment | Elevating equipment located in low-lying areas can protect it from flooding that would otherwise damage or destroy it. |  |  |  |
| Environmental management | Preserving certain kinds of natural habitats (e.g., coastal wetlands) provides a natural barrier to lessen the impact of storm surge. |  | | |
| Flood walls/gates | Installing flood walls, gates, and/or barriers can protect essential equipment in flood prone areas from water intrusion and avoid restoration delays after major storms and floods. |  |  |  |
| Relocate assets | Relocating energy assets away from flood-prone areas can reduce or eliminate their exposure to flooding and inundation threats. |  |  |  |
| Stormwater pumps | Stormwater pumps can remove flood water and help prevent equipment from being submerged. |  |  |  |
| Submersible equipment | Equipment located in flood-prone areas, such as underground power distribution systems in low-lying areas, can be modified or replaced with equipment that is designed to continue functioning when subjected to flooding from water containing typical levels of contaminants such as salt, fertilizer, motor oil, and cleaning solvents. |  |  |  |
| Vent line protectors | A vent line protector (VLP) protects gas regulator vent lines from encroaching water. The VLP is usually open, but if water enters the vent line via the VLP, a float will seal the vent line shut. The float will drop when the water recedes, re-opening the vent to its normal position. | | |  |
| Vented manhole covers | In flooding scenarios, manhole covers can dislodge, and the exposed manhole creates a hazard for pedestrians and vehicles. Proper vent design can allow for the flow of excess water without dislodging the cover. |  | | |

## Seismic Protection Measures

| Measure | Description | Sector | | |
|---|---|---|---|---|
| Base isolation transformer platform | Substation transformers can be placed on platforms designed to absorb the shaking from earthquakes that would otherwise damage the equipment. |  | | |
| Culverts | Placing fuel pipelines within buried concrete trenches, called culverts, significantly reduces the fracturing, buckling, and other damage caused to buried pipelines during an earthquake. | |  |  |
| Flexible joints | Flexible joints between steel pipe segments absorb the deformations caused during an earthquake and lessen the damage caused to pipeline infrastructure. | |  |  |

## Wildfire Protection Measures

| Measure | Description | Sector |
|---|---|---|
| Covered conductors | To mitigate wildfire risk, utilities can replace bare wire overhead conductors on high-voltage transmission lines with conductors that have a plastic covering (also called tree wire). Covered conductors greatly reduce the number of faults, and the risk of ignition. Similar products include spacer cables and aerial cables. |  |
| Fire-resistant poles | Wood poles can be replaced with ones made from fireproof materials, or wrapped in fireproof sheaths (e.g., wool-ceramic fiber). |  |
| Line-break-protection systems | Automated monitoring equipment, called phasor measurement units, installed on transmission lines can detect a voltage change associated with the breakage of a power line. The system can respond in near real-time by de-energizing that segment of the transmission line so that the broken power line does not spark a fire as it falls to the ground. |  |
| Pre-treat assets in path of fire | Pre-treating infrastructure (e.g., by applying flame retardant coatings or wrapping assets such as utility poles in flame retardant sheaths) decreases wildfire damage and expedites restoration of service. |  |
| Reconductoring | Reconductoring is the process of installing new conductor wires on existing towers to increase transmission capacity, thus reducing propensity for high loads and line sag, which can cause ignition. Reconductoring typically involves replacing traditional steel-reinforced lines with composite core lines. |  |

## Wind Protection Measures

| Measure | Description | Sector |
|---|---|---|
| Breakaway service connectors | A breakaway service connector is designed to disconnect when the power line it is attached to is pulled by a falling limb or other debris. This avoids damage caused when a service wire is pulled down in a way that damages the meter receptable. Meter receptables are not owned by the utility, and a private electrician is needed to first make repairs, delaying service restoration. |  |
| Dead-end towers | Dead-end towers (also called anchor towers or anchor pylons) are self-supporting structures made with heavier material than suspension towers. Dead-end towers are used at the end of a transmission line; where the transmission line turns at a large angle; on each side of a major crossing such as a large river or highway, or large valley; and at intervals along straight segments to provide additional support. Suspension towers are typically used when the transmission line continues along a straight path. When weaker suspension towers are compromised or topple, the stronger dead-end structures can stop a domino effect that takes down multiple towers. Reducing the spacing between dead-end structures can limit the impacts of domino effect failures. |  |
| Stronger utility poles | This can involve reinforcing wood poles, replacing wood poles with concrete ones, or replacing wood cross-arms with fiberglass ones. |  |
| Vegetation management | Clearing vegetation away from transmission and distribution lines helps prevent damage (e.g., falling tree branches) to power lines that cause outages. |  |

## GENERAL RESOURCES

Mitigating impacts from hazards to the energy system is a topic that is constantly being reevaluated, and the guidance for best practices is ever-changing. The following reports focus on ways to increase the resilience of energy systems. Note: this is not a comprehensive list of resources.

Institute of Electrical and Electronics Engineers (IEEE). 2020. *Resilience Framework, Methods, and Metrics for the Electricity Sector*.

This report provides an overview of resilience definitions (including its relationship with reliability), the existing frameworks for holistically defining resilience planning and implementation processes, and the metrics to evaluate and benchmark resilience. It also evaluates technologies, tools, and methods to improve electrical system resilience.

National Renewable Energy Laboratory. 2019. *Energy Resilience Assessment Methodology*.

This report presents a replicable energy resilience assessment methodology for sites, military bases, and campuses to assess energy risks and develop prioritized solutions to increase site resilience.

National Renewable Energy Laboratory. 2019. *Power Sector Resilience Planning Guidebook: A Self-Guided Reference for Practitioners*.

This guidebook introduces policymakers, power sector investors, planners, system operators, and other energy-sector stakeholders to the key concepts and steps involved in power sector resilience planning.

U.S. Climate Resilience Toolkit. 2019. *Building Resilience in the Energy Sector*

Examines climate change challenges for the energy sector, possible actions to mitigate risk and links to resources.

U.S. Department of Homeland Security. 2019. *National Mitigation Investment Strategy.*

The National Mitigation Investment Strategy ("NMIS"), developed by the Mitigation Framework Leadership Group is a single national strategy for advancing mitigation investment to reduce risks posed by natural hazards and increasing the nation's resilience to natural hazards. This report outlines the investment strategy and how federal and non-federal partners can coordinate community mitigation investments.

National Academies of Sciences, Engineering, and Medicine. 2017. *Enhancing the Resilience of the Nation's Electricity System*.

This report focuses on identifying, developing, and implementing strategies to increase the electric system's resilience in the face of events that can cause large-area, long-duration outages: blackouts that extend over multiple service areas and last several days or longer.

U.S. Dept. of Energy. 2016. *Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning*.

This report provides basic assistance to electric utilities and other stakeholders in assessing vulnerabilities to climate change and extreme weather, and in identifying an appropriate portfolio of resilience solutions.

Electric Power Research Institute (EPRI). 2016. *Electric Power System Resiliency*.
This report describes innovative technologies, strategies, tools, and systems that the electricity sector is developing and applying to address resiliency. The report explores three elements of resiliency: damage prevention, system recovery, and survivability.

Argonne National Laboratory. 2016. *Front-Line Resilience Perspectives: The Electric Grid*.
This report summarizes how states and local utilities approach all-hazards resilience in planning, construction, operations, and maintenance of the electric system, as well as challenges faced when addressing all-hazards resilience.

U.S. Dept. of Energy. 2014. *United States Fuels Resiliency Volume III: U.S. Fuels Supply Infrastructure Vulnerabilities and Resilience*.
This study evaluates the ability of the nation's oil and natural gas transportation, storage, and distribution infrastructure to respond to and recover from natural disasters and intentional acts, system chokepoints and interdependencies, and other supply interruptions.

U.S. Dept. of Energy. 2010. *Hardening and Resiliency: U.S. Energy Industry Response to Recent Hurricane Seasons*.
This report examines the storm hardening and resilience measures that refiners, petroleum product pipeline operators, and electric utilities in the Gulf Coast area took in response to the 2005 and 2008 hurricane seasons. It focuses on the segments of the energy industry that contribute most to the delivery of gasoline and diesel to the Southeast U.S.

## SPECIFIC MEASURE RESOURCES

### Advanced Distribution Management Systems

- NREL: Advanced Distribution Management Systems
- U.S. DOE: Insights into Advanced Distribution Management Systems

### Battery Storage

- NREL: Valuing the Resilience Provided by Solar and Battery Energy Storage Systems
- NREL: Battery Storage for Resilience
- NREL: Renewable Energy Integration and Optimization Tool (ReOpt)
- SolarResilient: Sizing tool for solar PV and battery storage systems
- DOE: Solar-Plus-Storage 101

### Demand Response Programs

- EIA: Demand-Side Management Programs Save Energy and Reduce Peak Demand
- FERC: Demand Response

### Dry Cooling

- U.S. Energy Information Administration - EIA - Independent Statistics and Analysis
- DOE ARPA-E: Advanced Research in Dry (ARID) cooling program

### Environmental Management

- EPA: What is Green Infrastructure?
- EPA: Green Infrastructure - Manage Flood Risk
- NOAA: Green Infrastructure Options to Reduce Flooding

### Microgrids

- LBNL: Distributed Energy Resources Customer Adoption Model (DER-CAM)
- NREL: Voices of Experience Microgrids for Resiliency
- DOE: Microgrid Portfolio of Activities
- Sandia National Laboratories: Microgrid Design Toolkit

### Advanced Metering Infrastructure

- DOE: Smart Grid Investments Improve Grid reliability, Resilience and Storm Responses
- DOE: Advanced Metering Infrastructure and Customer Systems Report
- NREL: Government Program Briefing: Smart Metering

### Supply Chain Resilience Planning

- DOE: America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition
- DHS: Supply Chain Resilience Guide

### Undergrounding Power Lines

- DOE: Resilient Power Grids: Strategically Undergrounding Powerlines
- FEMA: Reduce Wildfire Risk Case Study

### Use of Drones for Asset Inspections

- Oak Ridge National Laboratory: An Early Survey of Best Practices for the Use of Small Unmanned Aerial Systems by the Electric Utility Industry

### Vegetation Management

- U.S. EPA: Benefits of Integrated Vegetation Management (IVM) on Rights-of-Way
- FERC: Tree Trimming and Vegetation Management