Figure 1. Power infrastructure faces a variety of natural threats that can cause damage and disrupt the power system. Designing and siting power systems to minimize impacts from threats is important. *Photo from iStockphoto, 531920932*

Understanding Power System Threats and Impacts

Background

Understanding potential threats to a power system is an essential first step in supporting power sector resilience. It is important to assess both current and future threats, as well as the likelihood of these threats over time. Threats can be grouped in three categories, as highlighted below.

Natural threats resulting from acts of nature (e.g., severe weather, floods, earthquakes, hurricanes, and solar flares), as well as wildlife interactions with the power system (e.g., squirrels, snakes, or birds causing short circuits on distribution lines).

Technological threats resulting from failures of systems and structures (e.g., defects in materials or water line disruption).

Human-caused threats resulting from accidents (e.g., cutting an underground line) or from intentional actions of an adversary (e.g., cyberattacks or acts of terror).[1]

Identifying Threats

Threats can be identified through stakeholder processes and expert judgement, data sets, literature, and national planning documents and resources. Key experts and stakeholders to engage for threat identification and determination of likelihood of occurrence include:

1 https://training.fema.gov/programs/emischool/el361toolkit/glossary.htm

What is a Power System Threat?

Anything that can damage, destroy, or disrupt the power system is considered a threat. Threats can be natural, technological, or caused by human activity. Threats are not typically within the control of the power system planners and operators and can include wildfires, cyclones or typhoons, droughts, longer-term temperature changes, cyberattacks, and many others.

ministries and offices of energy, environment, and natural resources; meteorological agencies; utilities; power systems operators; risk assessment experts; and emergency managers. Examples of resources that could be reviewed to inform threat identification are outlined below:

- Existing threat and risk assessments
- Historical data related to disasters, extreme temperatures, and grid outages. Figure 1 shows an example of historical data being used to understand risks to the energy sector in the United States related to hurricanes.
- National planning documents across sectors with information and data related to threats to water quality, river systems, floodplain management, and geology, such as landslide areas and earthquakes
- Integrated resource plans
- Emergency plans
- Maps and geographic data
- Utility information.

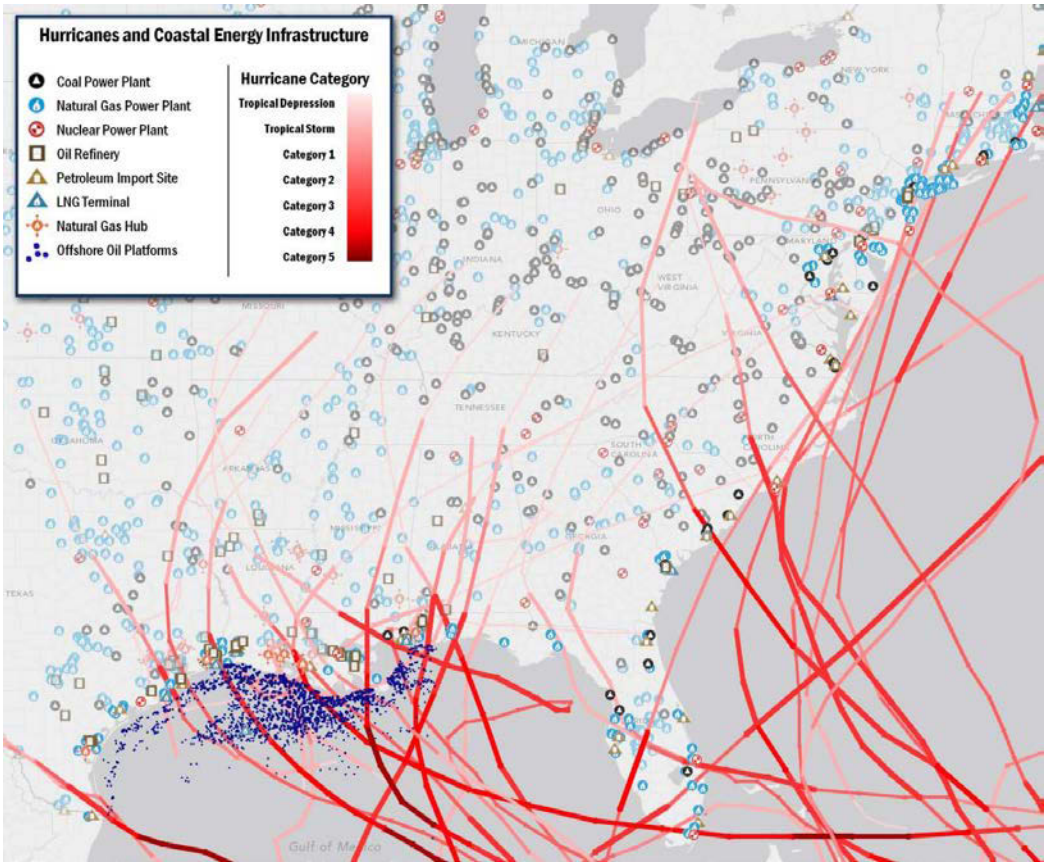

Figure 1. Historical data used to show storm tracks and coastal energy infrastructure in the United States. *https://www.energy.gov/sites/prod/files/2017/01/f34/2016%20DOE%20Climate%20Adaptation%20Plan_0.pdf*

Box 1 presents key questions that stakeholders can consider when working to identify threats to a power system.

Likelihood of Threat Occurrence

The likelihood of threat occurrence is another important step in assessing the vulnerability of power systems. Natural threats can be given a likelihood score based on historical threat data (e.g., disasters) and climate projections. Technological and human threats, which may be more dynamic than natural threats, may be given a score based on a more qualitative stakeholder

Box 1: Key Questions to Support Understanding of Threats to the Power System

1. What natural threats exist for your power sector, and how frequently do they occur?
2. How have power infrastructure systems been impacted by past threats (natural, technological, and human-caused) or system stresses?
3. Has critical power sector infrastructure ever gone offline or experienced reduced operability?
   - What threat caused this?
   - How many hours, days, or weeks was the infrastructure offline or not operational?
4. In the future, which threats and shocks are likely to increase (at the city, national, or multinational scale)?

interview process. Table 1 provides one framework for threat likelihood scoring as presented in the Power Sector Resilience Planning Guidebook.

Connecting Threats to Possible Power System Impacts

Natural, technological, and human-caused threats can have various impacts on electricity infrastructure and systems. Both chronic (e.g., temperature change) and acute events (e.g., storms and cyberattacks) can affect the demand, supply, and delivery of electricity. Impacts are highly localized (in terms of characteristics, severity, and variability), reflecting unique combinations of environmental factors and stressors in a specific location. Table 2 presents types of threats over the near- and long-term and potential impacts on generation, transmission, distribution, and demand.

Table 1. Scoring Framework for Threat Likelihood

Threat Likelihood Scores		Threshold Descriptions
Categorical	**Numerical**	
High	9	Accidents
Medium-High	7	More likely to occur than not.
Medium	5	May occur.
Low-Medium	3	Slightly elevated level of occurrence. Possible, but more likely not to occur.
Low	1	Very low probability of occurrence. An event has the potential to occur but is still very rare.

This fact sheet describes how natural, technological, and human-caused threats might impact the power sector across generation, transmission and distribution, and demand. In addition to direct system and infrastructure impacts, loss of power can affect other sectors (e.g., healthcare, education, and wastewater), as well as society and economic activity more broadly. While these impacts are not described in detail in this fact sheet, they are crucial in considering prioritization of resilience actions.

Power sector threats (including likelihood) and impacts assessed at the local or national level are essential inputs for performing a power-sector vulnerability

Natural, technological, and human-caused threats can have various impacts on electricity infrastructure and systems. A resilience action plan provides key power sector resilience actions designed to address power sector threats identified in a vulnerability assessment. *Photo from iStockphoto, 903206232*

Table 2. Threats and Potential Impacts on the Power Sector

Threats	Technologies/Sectors	Potential Impacts
Temperature Change	**Generation**	
	Biopower	Crop damage and increased irrigation demand
	Hydropower	Reduced generation capacity and operational changes
	Solar PV	Reduced generation capacity (e.g., higher heat can impact panel efficiency)
	Thermal technologies (coal, geothermal, natural gas, nuclear, concentrated solar power)	Reduced generation efficiency and capacity
	Transmission and distribution	Reduced transmission efficiency and capacity
	Demand	Increased demand for cooling
Water Availability and Temperature	**Generation**	
	Biopower	Decreased crop production
	Hydropower	Reduced generation capacity and operational changes
	Thermal technologies	Reduced generation capacity
Wind Speed Changes	**Generation**	
	Wind	Variations in generation capacity, making investments harder to pay back or generation harder to predict long-term
Sea Level Rise	**Generation**	
	Bioenergy	Physical damage to infrastructure and power disruption/loss—all generation technologies
	Hydropower	
	Solar PV	
	Thermal technologies	
	Wind	
Extreme Events (e.g., storms, short-term extreme heat events, floods, fires, and other natural disasters)	**Generation**	
	Bioenergy	Physical damage to infrastructure and fuel sources, and power disruption/loss—all generation technologies
	Hydropower	
	Solar PV	
	Thermal technologies	
	Wind	
	Transmission and distribution	Reduced transmission efficiency and capacity Reduced transmission efficiency and capacity
	Demand	Unpredictable changes to peak electricity demand
Technological	**Generation**	
	Bioenergy	Physical damage and power disruption/loss—all generation technologies
	Hydropower	
	Solar PV	
	Thermal technologies	
	Wind	
	Transmission and distribution	Physical damage and reduced transmission capacity
	Demand	Unpredictable demand
Human-caused (e.g., cyberattacks, accidents, and physical attacks/ malicious events)	**Generation**	
	Bioenergy	Physical damage and power disruption/loss—all generation technologies
	Hydropower	
	Solar PV	
	Thermal technologies	
	Wind	
	Transmission and distribution	Physical damage and reduced transmission capacity
	Demand	Unpredictable demand

Sources: Cox et al. (2017), WBCSD (2014).

Box 2: Identifying Threats to the Power Sector in the Lao PDR, and Planning for Resilience

USAID and NREL partnered with the government of the Lao PDR to perform a vulnerability assessment of the power sector and develop a resilience action plan. Key threats related to potential hydrological changes (and a large dependence on hydropower), wildfires, landslides, and flooding, among others. After undertaking a full vulnerability assessment process, key power sector resilience actions were identified to address these threats and related impacts. Selected actions are highlighted below. As can be seen, actions can relate to operational changes and planning, data collection, analysis, partnership across borders, and technology implementation, as well as other areas.

- Develop standard operating procedures and continuity-of-operation plans for extreme events—including staffing plans, prioritized repowering of networks, and agreements with neighboring countries;
- Develop climate projections and geospatial data for hydropower and other generation planning, and make these maps available publicly;
- Reduce dependence on hydropower through diversification of energy mix;
- Introduce flexibility solutions into power system operation;
- Establish protocol for data collection at all hydropower dams, including data types, collection frequency, and data format for sharing; and
- Develop incentive and enforcement structures to ensure that users and areas that are upstream from hydropower dams protect watersheds located upstream.

Source: Power Sector Resilience Action Plan for Lao PDR (forthcoming)

assessment. Box 2 describes a power-sector vulnerability assessment undertaken in the Lao People's Democratic Republic (PDR), supported by the U.S. Agency for International Development (USAID) and the National Renewable Energy Laboratory (NREL), that fed into a climate resilience action plan. For a full view of how threats and impacts are integrated with broader vulnerability assessment processes and power-sector resilience action plans, see: https://resilient-energy.org/guidebook, and learn more about power sector resilience at www.resilient-energy.org.

Resilient Energy Platform

The Resilient Energy Platform helps countries address power system vulnerabilities by providing strategic resources and direct country support, enabling planning and deployment of resilient energy solutions. This includes expertly curated reference materials, training materials, data, tools, and direct technical assistance in planning resilient, sustainable, and secure power systems. Ultimately, these resources enable decision makers to assess power sector vulnerabilities, identify resilience solutions, and make informed decisions to enhance energy sector resilience at all scales (including local, regional, and national). To learn more about the technical solutions highlighted in this fact sheet, visit the Resilient Energy Platform at https://resilient-energy.org/.

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The Resilient Energy Platform provides expertly curated resources, training, tools, and technical assistance to enhance power sector resilience. The Resilient Energy Platform is supported by the U.S. Agency for International Development.

The USAID-NREL Partnership addresses critical challenges to scaling up advanced energy systems through global tools and technical assistance, including the Renewable Energy Data Explorer, Greening the Grid, the International Jobs and Economic Development Impacts tool, and the Resilient Energy Platform. More information can be found at: **www.nrel.gov/usaid-partnership**.

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