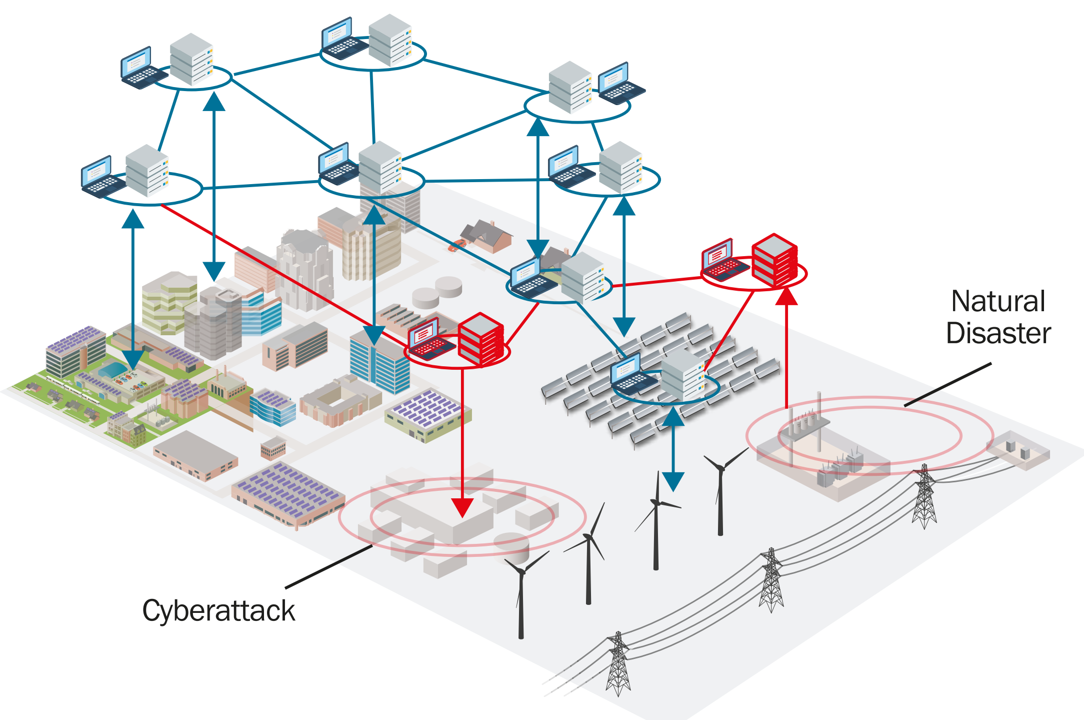
# Increasing the Security and Resilience of the Electric Power System

Power outages can cause major social and economic impacts. Through a Laboratory Directed Research and Development (LDRD) project, NREL researchers are investigating how the resilience of the electric power system can be measured, evaluated, and visualized—ultimately to provide utilities, government agencies, defense installations, and communities with tools that help them prepare for a variety of outage scenarios.

The multidisciplinary LDRD research team is developing a security and resilience methodology and modeling tool set that incorporates value metrics and use-case modeling to optimize the security and resilience of energy systems at various scales. The project, one of many energy security and resilience research efforts at NREL, is focused on systems employing advanced energy technologies, configurations, and business models.




NREL is developing modeling capabilities to analyze and visualize the impacts of cyberattacks and natural hazards on the electric power system. For example, by co-simulating the grid and communications layers, researchers will better understand the interdependencies between infrastructure and find ways to optimize system architectures for resilience.
*Illustration by Anthony Castellano, NREL*

## Research Objectives

- Measure trade-offs among security, resilience, and cost for different power system architectures.
- Develop new capabilities to evaluate and visualize system performance in the event of a cyberattack or physical disruption, using an all-hazards approach.
- Visualize interdependencies between power, critical loads, and communications systems, as well as other interdependencies, in 3-D.

## Research Scope

In developing a security and resilience decision tool, the researchers aim to identify:

- Key attributes of a secure and resilient system
- Energy system architectures that are most resilient for a given scenario
- Communications and control architectures that enhance security in a given scenario
- Benefits and costs of centralized, decentralized, and hybrid energy systems
- The role of digital technology in resilient and secure grid designs
- Cost-optimal investments in security and resilience strategies
- Tools and metrics to quantify the value of security and resilience projects.

## Quantifying Energy Security and Resilience

Part of this project is focused on quantifying resilience, for which there are no commonly accepted metrics. An outage to the energy grid can impact different sectors in different ways, from economic loss to loss of life. A grocery store might experience a loss in revenue due to spoiled food, whereas a fire station's response times could be delayed significantly—impacting homes, businesses, and public safety.

In developing resilience metrics, researchers at NREL recognize the importance in considering the temporal evolution of a disruptive event and how it differs between event types. Combining existing and newly developed metrics with quantitative data from historical outages that shows what individuals in varying regions are willing and able to pay for resilience—or the ability to avoid the consequences of a power outage—NREL analysts are developing a framework to determine lost economic assets over time, following a disruptive event. The ultimate goal is to determine methods for quantifying resilience solutions, including the cost of outage avoidance and how to finance solutions that enhance resilience within various sectors and at different points along the grid system.

## Simulation and Visualization

Using the identified metrics, the team is developing an integrated simulation model to evaluate adaptable and scalable energy system architectures—including power and communications networks. The model will allow researchers to modify test scenarios for various system types and scales, while isolating variables. For example, the team could run a scenario on how a grid outage affects access to clean water on a military campus or within a community, evaluating the economic losses associated with this scenario.

Researchers are visualizing results of the model in 3-D to explore the costs and benefits of different energy systems and control architectures, building upon the metrics and data collected from evaluation scenarios. Leveraging NREL's 3-D visualization capabilities and High-Performance Computing Data Center at its Energy Systems Integration Facility, the research team will demonstrate security and resilience performance and the interdependencies between power systems and communication flows in an immersive 3-D environment. This visualization tool will also allow users to explore the costs and benefits of different energy system architectures to evaluate their performance under cyber or physical attacks.

## Planning for Security and Resilience

Through this LDRD research effort, the team hopes to provide campuses, cities, island communities, and other regions and stakeholders with an effective tool to make informed decisions about security and resilience planning before unexpected events occur. Over the course of the project, the team aims to develop:

- New modeling and visualization methods to understand interdependencies of power and communication systems
- Valuation metrics and analysis tool sets to understand technology and cost trade-offs for more secure and reliable energy systems
- A decision support tool that can be adapted to help utilities, government agencies, and communities make effective security and resilience investments.

For more information about NREL's energy security and resilience activities, visit www.nrel.gov/grid/security-resilience.html.

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## About the LDRD Program

Every year, U.S. Department of Energy (DOE) laboratories, including NREL, are eligible for new funding to launch innovative technical and scientific projects. NREL's LDRD Program serves as a proving ground for new energy system concepts and provides an opportunity for researchers to push the boundaries of existing research.


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