Designing Resilience for Advanced Energy Systems

Advancements in energy technologies are making the grid more powerful, more efficient, and cleaner. As these promising innovations flourish across our communities, it is essential that our nation's infrastructure also becomes more resilient. Natural disasters, cyberattacks, user error, and a changing climate all present risks that could have devastating consequences.

Individual emergencies are unique, but holistic planning and proactive measures can harden the grid and help anticipate and respond to any number of threats. The National Renewable Energy Laboratory (NREL) is at the forefront of this transition, establishing a vision for resilient energy systems today, and in the future.

What is resilience?

The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through adaptable and holistic planning and technical solutions.

Leading-edge Capabilities:

New Research Frontiers

Trends for the next century point to an exponential increase in grid-connected devices, distributed generation, and electricity demand due to a shift in electrification. Harnessing deep technical expertise in energy modeling and systems engineering, NREL visualizes these changes under various scenarios and forecasts the outcomes.

Researchers innovate new approaches to grid resilience using multi-megawatt energy hardware, grid management systems, and high-performance computers in NREL's world-class laboratories. Hardware-in-the-loop evaluations and co-simulation programs emulate power disruptions, either through a generalized model or a digital twin of a real building, campus, community, or microgrid.

Expert Assistance:

Resilience Assessments

NREL developed an effective methodology (above) for providing decision support to federal agencies, states, local and international governments, and other stakeholders. To perform a vulnerability assessment, staff initially gather data about critical loads, threats, energy resources, and energy system infrastructure and interdependencies. After assessing the most likely or most severe threats, analysts identify and prioritize feasible solutions that can be integrated into existing infrastructure or development plans. Solutions may include solar photovoltaic (PV) installations to diversify the sources of electricity, development of microgrids for critical systems, introducing redundancy to the most vulnerable systems, and/or demand side management and efficiency.

Scientific Rigor: **Quantifying the Value of Resilience**

Resilience investments often take the form of a cost-benefit decision in which the cost is weighed against the value, or benefit, it provides. NREL developed metrics to help communities and utilities quantify the benefits of investing in resilient strategies for the grid and interdependent systems. The metrics can include the number of hours that customers are without power, loss of life, the loss of business revenue, and the loss of utility revenue. Because disruption circumstances are unique, the framework provides a methodology to determine the cost of inaction and the value of multiple resilience metrics over time and at multiple scales.

Whole-Community Planning: **Disaster Preparation and Recovery**

NREL has extensive experience and resources to facilitate whole-community energy planning centered on energy efficiency and renewable energy technologies and strategies. Improving grid integration—before or after disaster strikes—reduces long-term vulnerability and realizes significant savings from fewer power outages, fossil fuel independence, reduced waste, and lower electricity costs.

Data-Driven Solutions: **Accelerating Market Transformation**

NREL's proven frameworks help prevent power disruptions from occurring, quickly restore electricity if an outage does occur, and mitigate the damages. Practical tools that optimize for cost, climate, or other conditions remove common barriers to action and pave the way for the adoption of sustainable, low-emission energy resources that provide resilient and reliable power. Policymakers can demonstrate a measurable impact on societal welfare through health, safety, and the economy.

NREL uses robust analysis to answer difficult questions such as,

- What is the likelihood of a disruptive event?
- How quickly could the system recover?
- Are systems automated and self-healing?
- What consequences may result from interdependencies between energy and water, transportation, or communication systems?
- How can investments in resilience be monetized?

Case Studies in Energy Resilience

The Quinault Indian Nation on Washington's Olympic Peninsula has faced repeated coastal flooding and erosion impacting its shoreline, as well as landslides and glacial retreat affecting the tribe's water supply. As the nation prepared to relocate inland, NREL provided a workshop and technical information on energy efficiency and renewable energy options to help enhance economic resilience and ensure continued power and water supply to the remote location during a disruption.

The Tyndall Air Force Base in Florida partnered with NREL to perform an analysis that resulted in an all-hazards assessment and guided their resilience investment decisions. The replicable methodology developed by the joint team gave each threat and vulnerability a score to assess the highest risks and forecast their probabilities. Interdependent systems were modeled to analyze cost-difficulty-impact trade-offs of actionable resilience solutions.

The U.S. Department of Energy's Buildings Technologies Office funded research to quantify how energy efficiency designs enhance building resilience during extreme temperature events. NREL adapted the ResStock™ analysis tool to model various residential buildings and ran simulations on the laboratory's high-performance computer. The result was a standardized methodology to quantify the impact of different extreme heat or cold scenarios and make qualitative assessments of the mitigating design measures.

NREL
Transforming ENERGY

National Renewable Energy Laboratory
15013 Denver West Parkway, Golden, CO 80401
303-275-3000 • www.nrel.gov

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