

Resilience Assessments: A Data-Informed and Stakeholder-Driven Approach

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NREL Resilience Assessment Team



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NREL at-a-Glance



3,343

Team members, including

183 postdoctoral researchers

125 graduate students

68 undergraduate students



World-class

facilities, renowned
technology experts

More
than
1,000

Partnerships

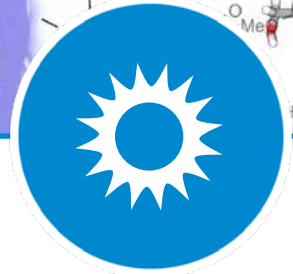
with industry,
academia, and
government



Campus

operates as a
living laboratory

Resilience Is Multidisciplinary



Renewable Power

Solar
Wind
Water
Geothermal



Sustainable Transportation

Bioenergy
Hydrogen and Fuel Cells
Transportation and Mobility



Energy Efficiency

Buildings
Advanced Manufacturing
State, Local, and Tribal Governments



Energy Systems Integration

Energy Security and Resilience
Cyber
Grid Modernization
Integrated Energy Solutions
National Security



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.**”

Hotchkiss, Eliza, and Alex Dane. 2019. *Resilience Roadmap: A Collaborative Approach to Multi-Jurisdictional Resilience Planning*. Golden, CO. National Renewable Energy Laboratory. NREL/TP-6A20-73509. <https://www.nrel.gov/docs/fy19osti/73509.pdf>.

Changing Conditions

“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.”

Anticipate

- Understand what will change either in terms of climate, operational landscape, or other factors

Prepare for

- Evaluate ways to change how things are done now to reduce the impacts of future changes

Adapt

- Improve infrastructure to allow for operations to continue even during adverse events

Disruptions

“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.”

Withstand

- Harden systems and processes to prevent disruptions during an adverse event

Respond to

- Effectively and efficiently identify and remediate disruptions

Recover

- Quickly get operations going again at the same level as before or better

Through...

“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.”

Adaptable and Holistic Planning

- Determine how solutions being suggested can be implemented using existing processes
- Think about the impacts of solutions in the near future and long term
- Consider potential vulnerabilities that might arise within the implementation of new processes or equipment

Technical Solutions

- Power system modeling for component and parameterization
- Applications for microgrid deployment
- Power system fallback and emergency changeover appropriateness
- Evaluate options for on-site generation, including renewable energy resources

Characteristics of Resilience



REFLECTIVE: using past experience to inform future decisions



RESOURCEFUL: recognizing alternative ways to use resources



ROBUST: well-conceived, -constructed, and -managed systems



REDUNDANT: spare capacity purposely created to accommodate disruption



FLEXIBLE: willingness and ability to adopt alternative strategies in response to changing circumstances



INTEGRATED: bringing together a range of distinct systems and institutions



INCLUSIVE: prioritizing broad consultation to create shared ownership in decision-making

Site, State, and Regional Scope

Site-level

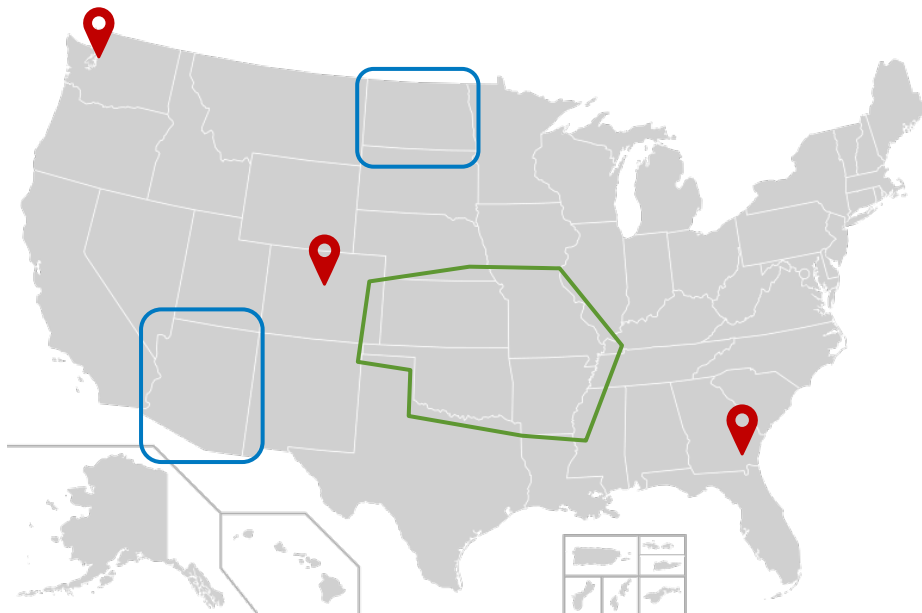
- Resilience assessments
- Vulnerability assessment resilience planning
- Microgrid feasibility studies
- Customer damage functions (CDFs)

State and territory-level

- Energy security plans

Regional and national-level

- North American Energy Resilience Model (NAERM)
- Metrics research
- Puerto Rico 100
- FEMA Critical Facility Analysis



Map from SimpleMaps.com



EXAMPLE

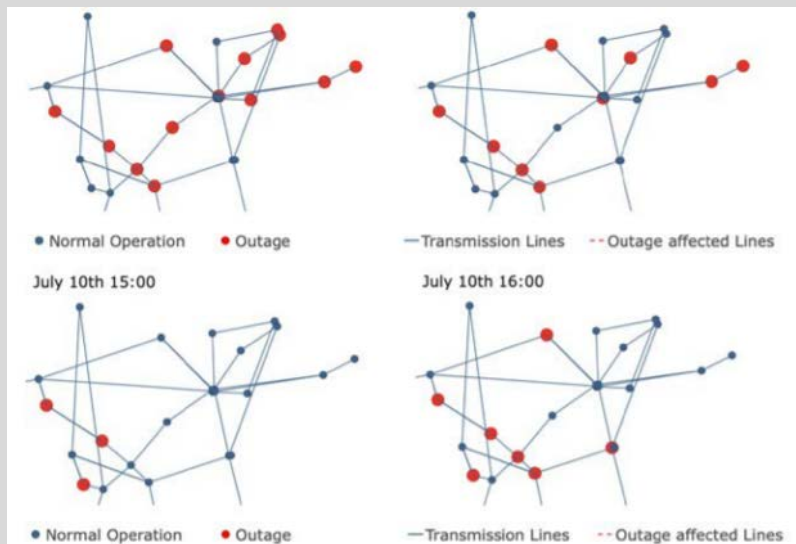
Metrics Research

NEED

Many metrics attempt to measure resilience benefit, but they are not easily calculated or easily factored into energy decisions.

IMPACT

NREL and Sandia National Laboratories (SNL) are researching **performance-based vs. attributes-based metrics** with funding from the Department of Energy's (DOE's) Grid Deployment Office. NREL and SNL are also researching **community resilience metrics** with funding from DOE's Office of Clean Energy Demonstrations. Information will be shared with states, tribes, territories, and communities in support of Infrastructure Investment and Jobs Act implementation.



➔ <https://www.energy.gov/gdo/bipartisan-infrastructure-law>



EXAMPLE

Customer Damage Functions

NEED

The value of resilience and its benefits is unclear, which makes investing in resilient solutions at different scales challenging.

IMPACT

NREL developed a framework for incorporating duration-dependent CDFs into grid- and campus-scale planning and operations models to move beyond *the value of lost load*, which is most used to understand the **cost of inaction**.

Histogram of Customer Minutes Interrupted, Selected Causes



[Customer Damage Function Calculator: https://cdfc.nrel.gov/](https://cdfc.nrel.gov/)



EXAMPLE

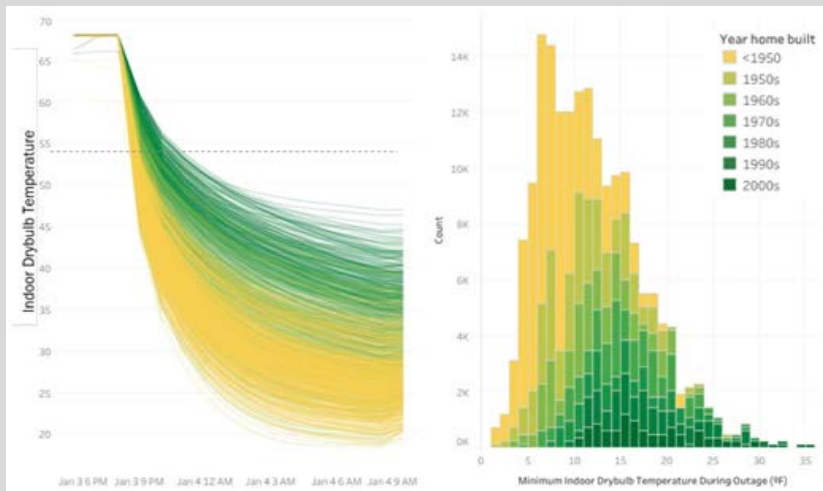
Energy Efficiency + Resilience

NEED

No research study has modeled the synergies of energy efficiency in building design and passive survivability to value the resilience benefit.

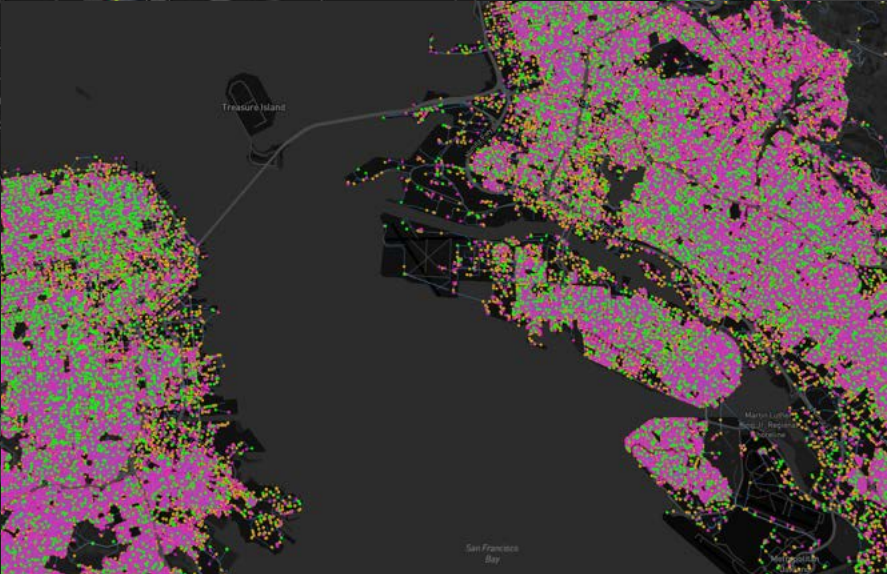
IMPACT

With support from the DOE Building Technologies Office, NREL and two other labs evaluated the impact of **simulated power outages on occupants of different types of buildings**. The results inform what energy-efficiency measures can be taken to increase human survivability under extreme weather conditions, such as a heat wave or a cold snap.



➔ <https://resstock.nrel.gov/factsheets/NY>

https://www.energycodes.gov/sites/default/files/2023-02/Resilience_Buildings_EE_2022.pdf



EXAMPLE

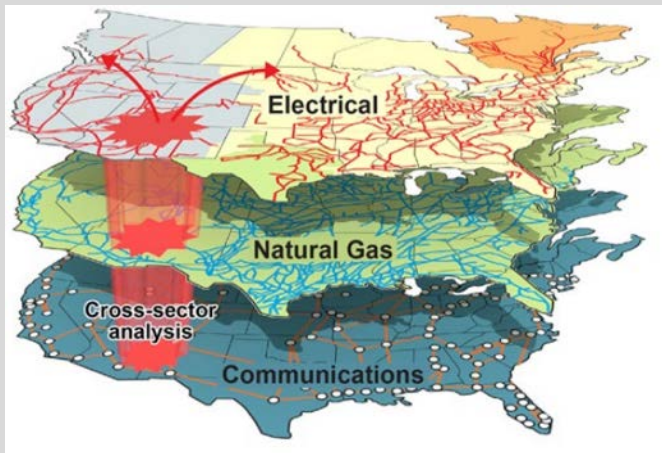
NAERM

NEED

Large-scale infrastructure modeling is needed to understand the consequences related to different threats and hazards.

IMPACT

DOE funded multiple laboratories to create multienergy and interdependent infrastructure models with system data and realistic natural hazard and human threat scenarios to provide actionable information to energy system planners, operators, and government stakeholders.



➔ <https://www.energy.gov/oe/north-american-energy-resilience-model-naerm/>



EXAMPLE

Site Resilience Assessment

NEED

Facilities and campuses need to prepare for current and near-term climate and human threats to determine potential vulnerabilities and invest in mitigations.

IMPACT

Applying resilience concepts to clients on the ground, NREL identifies hazards, threats, and vulnerabilities for sites and determines potential mitigations to reduce the impacts of risks.



<https://www.nrel.gov/resilience-planning-roadmap/>

<https://www.nrel.gov/docs/fy20osti/74983.pdf>

What Is the Purpose of a Resilience Assessment?

- Identify and understand hazards and threats
- Identify vulnerabilities that can be exposed by hazards and threats
- Determine risks to mission-essential functions, assets, the site, and the organization
- Develop mitigation solutions

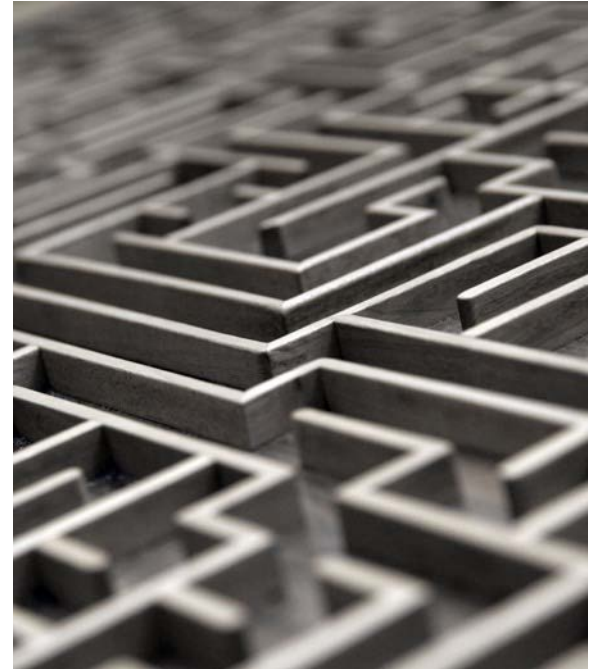


Photo from Microsoft stock images

The Resilience Assessment Process

Evaluating resilience is cyclical, requiring a recurring look at:

- How are things now?
- How can hazards and threats expose existing vulnerabilities?
- How can preparations be made to come back from acute shocks and chronic stressors?
- How did investments from the last assessment improve the resilience posture?

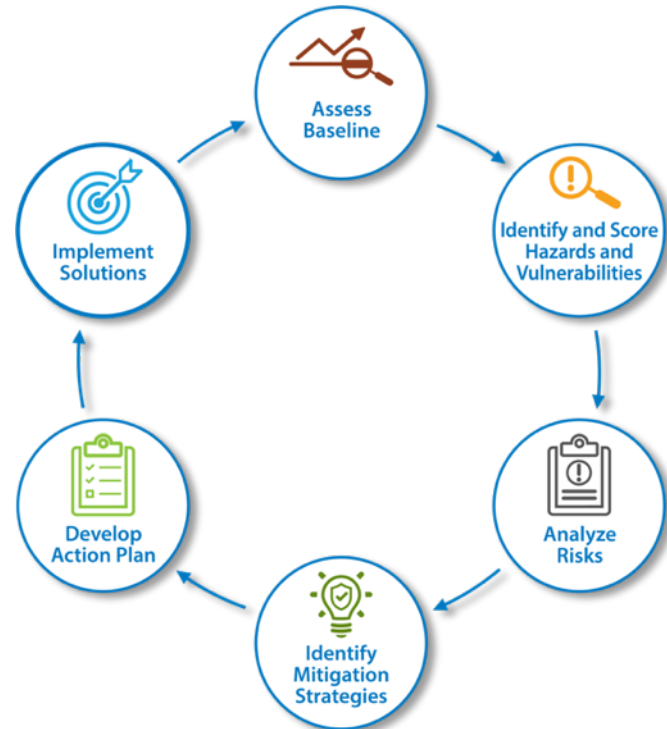




Photo from iStock

A Data- and Stakeholder- Driven Process

Hazards and Threats:

Anything that can damage, destroy, or disrupt an asset or site and is external and **not within control**

- Hurricane
- Cyberattack
- Acts of terror
- Political upheaval

Vulnerabilities:

Weaknesses within infrastructure, systems, or processes that **are within control**

- Lack of redundant power generation
- Ill-trained or overworked staff
- Single points of failure in communications network
- Lack of cybersecurity defenses



Common Vulnerability Findings

IPhoto from NREL

- Aging facilities and infrastructure
- Difficulty recruiting and keeping specialized staff
- Internal restructuring
- Funding uncertainty
- Inflexible working environments
- Changing resource requirements
- Executive orders, presidential directives, regulations and compliance



Photo from FEMA

Common Mitigation Solutions Proposed

- Studies to fill knowledge gaps
- Investment in existing or new equipment
- Metric development and inclusion into existing processes
- Legal and regulatory adjustments
- Process improvement

Challenges and Best Practices for Resilience Assessments

- COVID forcing a remote-only approach
- Getting the right people in the room from the beginning
- Maintaining goodwill capital
- Avoiding rabbit holes
- Learning as much as possible while acknowledging unknowable risks
- Identifying unintended consequences early



Photos from NREL





Unintended Consequences

Photo from Microsoft Images

Outcomes of a purposeful action that are **not intended or foreseen**, such as:

- Higher costs to consumers
- Solutions that create other vulnerabilities (e.g., cyberattack exposure)
- Increased competition for land and resources
- Unequal distribution of resilience benefits

Summary

Resilience research is well established, and lessons are constantly being learned from the research and its application.

- Metrics
- Valuation
- Risk and resilience assessments (data and stakeholder informed)
- Sharing lessons learned



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Questions?

www.nrel.gov

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