Best Practices in Resilience Planning

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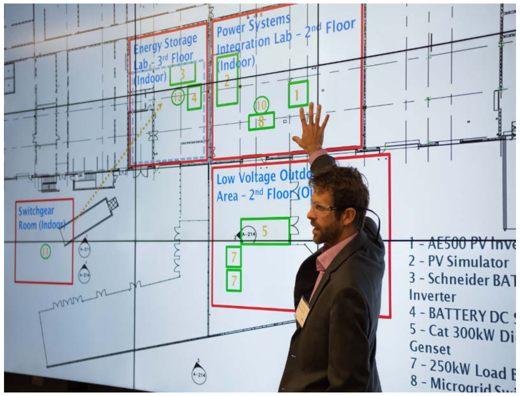
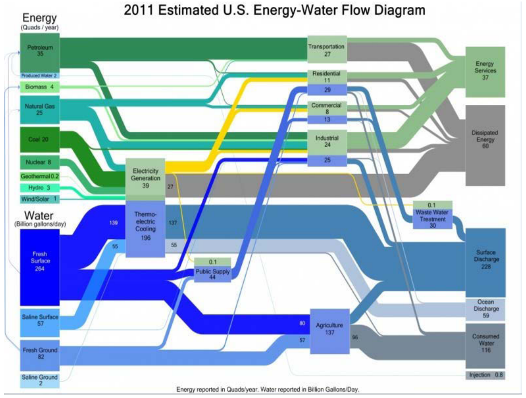


Modeling energy distribution systems is one aspect of energy resilience. NREL experts analyze energy storage options and clean-energy solutions for creating resilient grid systems.

Solar photovoltaics, wind turbines, and other onsite renewable energy technologies enhance resilience through spatial diversification.



A hybrid Sankey diagram from "The Water-Energy Nexus: Challenges and Opportunities" report, issued by the U.S. Department of Energy (DOE) in 2014, how major energy and water flows in the United States are interconnected.

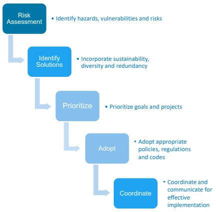
ABSTRACT

At various levels of government across the United States and globally resilience solutions are being adopted and implemented. Solutions vary based on predicted hazards, community context, priorities, complexity, and available resources. Lessons are being learned through the implementation process, which can be replicated, regardless of level or type of government entity carrying out the resilience planning. Through a number of analyses and technical support activities across the world, NREL has learned key lessons related to resilience planning associated with power generation and water distribution. Distributed energy generation is a large factor in building resilience with clean energy technologies and solutions. The technical and policy solutions associated with distributed energy implementation for resilience fall into a few major categories, including:

- Spatial diversification,
- Microgrids,
- Water-energy nexus,
- Policy and financing, *and*
- Redundancy.

METHODOLOGIES

At its most basic level, resilience refers to the ability to recover after the application of stress. Taking an all-hazards approach, NREL has worked with numerous communities to increase resilience to various threats and vulnerabilities. Depending on the stakeholders involved in resilience planning and the end-goal, the methodologies deployed could range from community engagement, resilience planning, policy analysis, microgrid modeling, renewable energy feasibility studies, vulnerability and risk assessments. A best practice approach or methodology would include most of the processes highlighted to the right.



Risk Assessment
- Identify hazards, vulnerabilities and risks

Identify Solutions
- Incorporate sustainability, diversity and redundancy

Prioritize
- Prioritize goals and projects

Adopt
- Adopt appropriate policies, regulations and codes

Coordinate
- Coordinate and communicate for effective implementation

CONCLUSIONS

Reliable, safe and secure electricity is essential for economic and social development and a necessary input for many sectors of the economy. However, electricity generation and associated processes make up a significant portion of global GHG emissions (IPCC, 2014). Electricity systems are aging and are vulnerable to numerous threats and hazards; both short-term events (shocks) and longer term changes (stressors). This vulnerability presents both near-term and chronic challenges in providing reliable, affordable, equitable, and sustainable energy services. Within this context, NREL works to identify challenges and solutions in the energy sector, including the need to reliably meet growing electricity demands in developing countries, lessen dependence on imported fuels, expand energy access, and improve stressed infrastructure for fuel supply and electricity transmission for resilience.

Spatial Diversification

The modular nature of renewable energy technologies, such as wind turbines and solar photovoltaics (PV), allows greater spatial diversification of energy supplies compared to conventional power generation systems, which deliver power from a concentrated point or central location. Increased spatial diversification reduces the vulnerability of the energy supply from a single event or a single critical location, which increases overall energy system resilience.

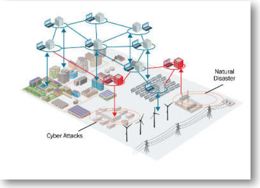


Image Credit: *Anthony Castellano, NREL*

Microgrids

Microgrids capable of islanding based on distributed generation (DG) can disconnect from the central grid during a disruptive event to allow energy to be diverted to critical loads. With microgrids serving critical loads during a blackout utilities have more flexibility in restoring generation stations, responding to critical outages, and shutting down systems before a major event to prevent damage. Islanded renewable energy DG systems ensure consumers have access to power during long-term power outages that severely impact central grid systems, which can occur after major natural disasters.

Water and Energy

The water-energy nexus plays a large role in resilience at many levels. Water is used for energy generation in hydro-electric plants and in cooling systems for nuclear plants. Alternatively, energy is used for treating and pumping water supplies. Technical solutions from making power-generation plants more efficient, using clean-energy technologies, and designing systems to utilize gravity-fed options can enhance resilience of both energy and water systems.

Policies and Financing

New Jersey had more than 1,000 MW of installed solar capacity when Hurricane Sandy hit the Northeast United States. However, only two solar PV systems provided power in the days following the hurricane (Hotchkiss et al., 2013). At the time, a combination of interconnection policies and a lack of dynamic controls or transfer switches or energy storage solutions prevented the islanding of systems. Without appropriate policies and codes, the installed DG capacity in New Jersey did little to aid resilience. Jurisdictions wishing to enhance resilience through islanded renewable energy DG systems should adopt appropriate policy on interconnection and islanding to realize the full benefits of these technical solutions. Identifying and securing financing is an essential part of the process. New Jersey created an Energy Resilience Bank to help fund additional resilience-related technologies.

Redundancy

Redundancy is critical to most operations, but is essential for resilience. The increased stress on infrastructure systems as a result of threats has the potential to increase the likelihood of failure of one or more parts of a system. Increasing supplies, routes, or incorporating redundancy in systems will reduce certain risks. In a community level analysis, NREL determined that pairing renewable energy and energy storage technologies with conventional backup power systems increased the number of days a system could operate without grid connection, illustrated in the image above and to the right.

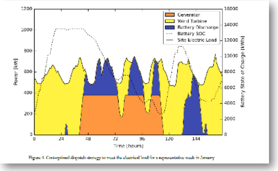


Figure 4. Cost-optimal dispatch strategy to meet the electrical load for a representative week in January

Source: *Cost-Optimal Pathways to 75% Fuel Reduction in Remote Alaskan Villages*, 2015

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