Community Resilience Options: A Menu for Enhancing Local Energy Resilience

Alexandra Kramer, Scott Belding, and Kamyria Coney

National Renewable Energy Laboratory

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Foreword

This report was created as part of the Solar Energy Innovation Network (SEIN). SEIN seeks to overcome barriers to solar adoption by connecting teams of stakeholders that are pioneering new ideas with the resources they need to succeed. Teams that participate in SEIN receive direct funding and analytical support from U.S. Department of Energy national laboratories and participate in peer-to-peer learning with other teams tackling similar challenges.

These teams are developing and documenting their solutions for solar adoption with scale in mind, so that others can adapt those solutions to their own contexts. Ultimately, the true impact of these teams' efforts will be to enable a wide array of communities to adopt solar solutions that meet their needs in their contexts.

SEIN is funded by the U.S. Department of Energy Solar Energy Technologies Office and is led by the National Renewable Energy Laboratory.

SOLAR ENERGY INNOVATION NETWORK

U.S. DEPARTMENT OF ENERGY

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1 Introduction

This document highlights areas of potential community resilience improvements, especially those that relate to clean energy deployment for communities and municipalities. The National Renewable Energy Laboratory (NREL) defines **resilience** as "*a system's ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through sustainable, adaptable, and holistic planning and technical solutions.*"[1] (*see section 3 for additional definitions of resilience*). Under the context of community resilience, a system can be individuals, communities, businesses, institutions, and governments. While there is no single resilience solution that will apply to every community or geographic location, there is a need for resilience solutions as a best practice. This document introduces 10 high-level categories of resilience-enhancing energy-related projects, intended for community members, planners, and decisionmakers new to the topic to build their understanding of which solutions fit their community best. System resilience leads to community resilience by neutralizing threats, minimizing disruptions, and providing enhanced day-to-day security and social cohesion for community members. The categories in this document focus primarily on community-scale measures and different options may be available at larger scales. Community resilience can also mean increasing community equity, capacity, socio-economic health, and social network robustness as a whole. Although those goals might be co-benefits of some of energy resilience strategies highlighted in this document, this document does not specifically cover methods for increasing community resilience through a social lens and is instead centered on resilience to acute disruptions. Full implementation of the measures described here requires in-depth, site-specific considerations that go beyond the scope of this document.

Following this introduction, each category of resilience improvement is described in Section 2's summary table, referred to as the "resilience menu." Section 3 goes into more detail for each category of resilience improvement, and specific resilient options that communities can prioritize for implementation are laid out. A list of useful in-depth resources is also provided for further information. Finally, Section 4 contains technical assistance programs, case studies of resilience projects deployed across the U.S., and additional resources for resilience planning and valuation.

This document was prepared under the Assistance for Early Adopters initiative of the Solar Energy Innovation Network (SEIN) program. SEIN is led by NREL, funded by the U.S. Department of Energy Solar Energy Technologies Office, and provides funding and technical assistance to communities developing transformative approaches to solar energy projects across the nation. Assistance for Early Adopters provides targeted technical assistance for entities seeking to adapt and apply the innovations and insights developed by SEIN project teams.

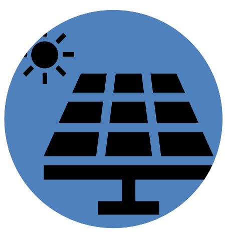
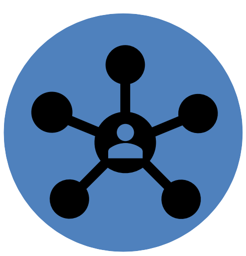
Originating in this programmatic context, this work builds on the SEIN Round 2 Breaking Barriers project and describes resilience initiatives that provide benefits to localities and communities, especially environmental justice communities. This work is not comprehensive, and for those seeking resources on broader-scale resilience enhancements for systems, large networks, and regions, please see Section 4.3: Resilience Planning Resources.

[1] Please refer to Section 3 for additional definitions of resilience

2 Resilience Menu Summary Table

Table 1 provides a summary and description of resilience solutions for ten high-level categories as a menu of options from which community planners can select and adapt. This table is meant to serve as a snapshot of energy-related resilience solutions at different scales.

Table 1. Resilience Menu Summary

	Category	Description
	**Energy Storage**	Energy storage systems, such as battery storage, retain energy in order to supply power at a later time. Properly designed energy storage systems can provide resilience to electric grid disruptions, and they can make power generation technologies like solar and wind power more resilient by storing electricity for times when those resources are not available (e.g., at night when solar generation is unavailable). During normal conditions, energy storage can provide cost savings by supplying power when grid electricity is most expensive.
	**Power Generation**	Resilience can be improved when a community is not entirely dependent on centralized power sources for electricity. Distributed generation resources can help communities avoid and respond to disruptions in the power sector if they are designed to do so, as well as paired with other resilient technologies like energy storage systems.
	**Resilience Hubs**	Resilience hubs are a collection of services and resources that support communities before, during, or after a disaster or disruptive event. They improve resilience by providing critical resources which may include electricity, shelter, fresh water, food, programming, medical services, a hub for emergency responders, and other supplies needed in an emergency and afterward during the recovery process.
	**Network Infrastructure & Security**	Reliable, resilient electricity depends on a network of wires, sensors, communication devices, and other infrastructure. Grid disruptions and cyber-attacks can severely damage electricity networks, but security measures and technology improvements can enhance the resilience of the system. Utilities and government agencies are investing heavily in security measures, but improvements like switch redundancy can also support energy resilience for individual assets.
	**Electric Transportation**	Electric transportation includes electric vehicles (EVs), electric buses, and other forms of transport like electric scooters and bicycles. Electric transportation provides resilience by reducing dependence on fossil fuels, which are often in short supply after disasters. However, electric transportation increases dependence on power networks, which is why a resilient power grid goes hand-in-hand with resilient electric transportation.

	Category	Description
	**Emergency Services Support**	Disasters and disruptions require emergency responders such as firefighters, paramedics, emergency medical technicians (EMTs), and relief organizations to be on-hand to provide life-safety support or restoring damaged systems to support the community. If designed to do so, renewable energy projects like solar and battery storage can ensure that fire stations and municipal buildings remain supplied and powered during certain disruptive events, allowing for the best possible coordination of emergency services and a faster return to normal operations in the community.
	**Community Awareness & Education**	Skill-building and workforce training allow community members to build capacity and qualify for good jobs in emerging clean energy industries, such as solar installation and battery manufacturing. Education can contribute to resilience through improving community knowledge of risks and hazards, strengthening community ties, and building the community's ability to adapt during disruptions and disasters.
	**Efficiency-Resilience Nexus**	Structural resilience is the ability to quickly resume the use of buildings or other structures following a disruption. Energy efficiency upgrades use less energy to achieve the same or better performance and may contribute to the ability to resume operations. Efficiency measures can range from improved appliances that reduce a household's electricity bills to a more tightly sealed building. Energy efficiency and related upgrades can improve public health, decrease energy costs and contribute to structural resilience.
	**Green Infrastructure**	Green infrastructure includes environmentally friendly public works projects, such as bioswales, permeable paving, and rain gardens. Green infrastructure projects can improve community resilience by reducing flood risk, preparing for drought, reducing urban heat island effects and thus reducing energy requirements, and protecting coastlines.
	**Financial Support**	Resilient technologies like renewable energy and energy efficiency often provide benefits over their lifetimes; however, the high upfront cost can limit access for many residents and organizations. Financial support pathways can spread the costs of resilient projects over time so that more people can benefit and save money. Affordable funding options allow marginalized people, businesses, and communities to access resilient technologies and projects.

3 Resilience Definitions, Categories, and Options

NREL defines **resilience** as: *a system's ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through sustainable, adaptable, and holistic planning and technical solutions.* Many definitions of resilience exist, which are shown below. A community should select the definition that applies to their specific culture, location, and needs.

- Resilience is the ability to withstand disasters better, respond effectively, and recover more quickly and to a more improved state (Source: National Governors Association or NGA).

- Resilience is the ability of people and their communities to anticipate, accommodate and positively adapt to or thrive amidst changing climate conditions and hazard events (Source: Urban Sustainability Directors Network or USDN).

- Resilience (sometimes referred to as "resiliency") has been defined broadly as the ability to resist being affected by an event or the ability to return to an acceptable level of performance in an acceptable period of time after being affected by an event closing (Source: Better Buildings Solution Center, U.S. Department of Energy).

- Resilience is the ability of systems to withstand and continue to perform after damage or loss of infrastructure (Source: FEMA).

- Resilience is the ability of a system and its components parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions (Source: IPCC).

In this section, each resilience category listed in Table 1 is described in more detail. Specific options that communities can implement to improve resilience are laid out for each category, and lists of useful resources, both for those newer to the topic ("First Look") and those seeking in-depth publications ("Deep Dive"), are provided for further information.

3.1 Energy Storage

Energy storage systems, such as battery storage, retain energy in order to provide power at a later time. Properly designed energy storage systems can provide resilience by supplying power during outages, and they can make renewable energy technologies like solar and wind power more resilient by storing electricity for times when those resources are not available (e.g., at night when solar generation is not available). During normal conditions, energy storage can provide cost savings by supplying power when grid electricity is most expensive. Systems may be designed for short- or long-term storage, with different technical configurations and available value streams for each depending on the desired duration.

Resilient Options Can Include:

1. **Battery Storage**: Battery energy storage systems (BESS) store energy and then supply that energy when needed, or at the most valuable time for the battery's owner. Battery storage can provide resilient power during electric grid outages, if designed to do so, and be recharged by renewable energy resources like wind or solar. Battery storage can also provide value during times of high electricity demand on the grid, supplying energy during times such as hot summer days when electricity prices are at their peak.
2. **Mobile Storage**: While most battery systems are fixed in place, mobile storage units are portable and can be transported on roads. Mobile storage units may be as large as a shipping container or as small as an electric vehicle battery. During power outages, mobile storage improves resilience by bringing electricity to facilities that need it most.
3. **Uninterruptible Power Supplies (UPS)**: Uninterruptible Power Supplies (UPS) provide emergency power when there is a power disruption, usually at a small scale for specific pieces of equipment. UPS are typically designed to protect and properly shut down hardware such as computers, data centers, servers, and other critical devices. As such, they provide instant backup power but only for a short period of time.

There are other energy storage technologies (pumped hydropower, for example), but the listed options are generally the most common, most affordable, and easiest to implement for community-level projects.

Resources: First Look

- Battery Storage for Resilience (Source: NREL, 2021).
- Valuing the Resilience Provided by Solar and Battery Energy Storage Systems (Source: NREL & Clean Energy Group, 2018).
- SolSmart's Toolkit for Local Governments on Resiliency of Solar + Storage (Source: SolSmart, U.S. Department of Energy [DOE], 2021).

Resources: Deep Dive

- Mobile Energy Storage Study: Emergency Response and Demand Reduction (Source: Massachusetts Department of Energy Resources, 2020).
- Planning Considerations for Energy Storage for Resilience Applications: Outcomes from the NELHA Storage Conference Policy and Regulatory Workshop (Source: Pacific Northwest National Laboratory [PNNL], 2020).
- Understanding the Value of Energy Storage for Power System Reliability and Resilience Applications (Source: *Current Sustainable/Renewable Energy Reports* – Academic Journal, 2021).

3.2 Power Generation

Resilience can be improved when a community is not entirely dependent on centralized power sources for electricity. If they are designed to do so, often combined with other resilient technologies such as energy storage and microgrid equipment, distributed energy resources can help communities avoid and respond to disruptions in the power sector.

Resilient Options Can Include:

1. **Microgrids**: Microgrids can operate and supply power when the electric grid is disrupted, if designed to do so, providing resilient energy during disasters. Power is supplied on-site and the microgrid can "island," or electrically isolate, from the electric grid. Microgrids may involve multiple sources of generation and supply multiple buildings or be confined to a single small area like a resilience hub (see *3.3 Resilience Hubs*).
2. **Dual-Use Solar PV and Agrivoltaics**: For rural communities seeking distributed generation options to pair with resilient technologies such as microgrids, dual-use solar PV sites may be of interest. These involve land being used for both solar panels and a second function. One example is agrivoltaics or installing solar panels on farmland such that agricultural activities (like animal grazing and crop production) can still occur underneath or between the panels.
3. **Biomass and Organic Material**: Farms and rural communities often have abundant access to plant material that can be used to fuel an electricity generator. Animal manures, wastewater biosolids, and food wastes can also be broken down and utilized through anaerobic digestors to make biogas and horticulture products which can be used for various applications from electricity to organic fertilizer.
4. **Redundancy**: Redundant power means having backup systems in case the primary system fails, and can include backup electricity generators, additional fuel storage, or energy storage. Facility resilience plans often require operations to have a certain number of redundant systems in place to avoid or minimize disruptions.

Resources: First Look

- Will Solar Panels Help When the Power Goes Out? (Source: NREL, 2020).
- Microgrid-Ready Solar PV – Planning for Resiliency (Source: NREL, 2017).
- Distributed Energy Planning for Climate Resilience (Source: NREL, 2018).
- Biomass for Electricity Generation (Source: Federal Energy Management Program, 2016).
- How Does Anaerobic Digestion Work? (Source: EPA, 2019).

Resources: Deep Dive

- Renewable Energy Builds a More Reliable and Resilient Electricity Mix (Source: American Wind Energy Association [AWEA], 2017).
- The Five Cs of Agrivoltaic Success Factors in the United States: Lessons from the InSPIRE Research Study (Source: NREL, 2022).
- How Distributed Energy Resources Can Improve Resilience in Public Buildings: Three Case Studies and a Step-by-Step Guide (Better Buildings, U.S. DOE, 2019).

3.3 Resilience Hubs

Resilience hubs are a collection of services and resources that support communities before, during, or after a disaster or disruptive event. They improve resilience by providing critical resources which may include electricity, shelter, fresh water, food, programming, medical services, a hub for emergency responders, and other supplies needed in an emergency and afterward during the recovery process.

Resilient Options Can Include:

1. **Resilient Power**: Resilience hubs can generate their own electricity and “island,” or electrically isolate from the power grid, during an outage if designed to do so. This means they can, at a minimum, keep the lights on and phones charged when the rest of the community may be without power.
2. **Health Services**: Resilience hubs could offer health services similar to a hospital, pharmacy or qualified health center. Refrigeration can also be used to store medical supplies that are sensitive to temperature fluctuations. Resilience hubs can also power the equipment needed to prepare, serve, and store meals and drinkable water.
3. **Air Conditioning & Quality**: Extreme heat, cold, and poor air quality events present the need for locations with air conditioning, heating, or air filtration. With backup power and electrical islanding, resilience hubs can provide these services regardless of a grid outage.
4. **Emergency Management Coordination**: During a disaster, emergency responders may not have a location from which they can organize relief efforts. Resilience hubs can provide resilient power and communications to support these emergency services (see *3.6 Emergency Services Support* for more detail).
5. **Overnight Shelter**: Disruptive events can leave community members without shelter. Properly equipped resilience hubs can provide temporary shelter and hygiene services to displaced community members.

Resources: First Look

- Resilience Hubs: Shifting Power to Communities and Increasing Community Capacity (Source: Urban Sustainability Directors Network [USDN], 2019).
- Clean Energy for Resilient Communities: Expanding Solar Generation in Baltimore’s Low-Income Neighborhoods (Source: Clean Energy Group, 2014).

Resources: Deep Dive

- Guide to Developing Resilience Hubs (Source: USDN, 2019).
- Resilient Solar and Battery Storage for Cooling Centers: Mitigating the Impacts of Extreme Heat on Vulnerable Populations (Source: Clean Energy Group, 2022).

3.4 Network Infrastructure and Security

Reliable, resilient electricity depends on a network of wires, sensors, communication devices, and other infrastructure. Grid disruptions and cyber-attacks can severely damage electricity networks, but security measures and technology improvements can enhance the resilience of the system. Utilities and government agencies are investing heavily in security measures, but community-level improvements can also be made to support energy resilience.

Resilient Options Can Include:

1. **Islanding Capabilities**: Islanding describes the ability for a building or a cluster of buildings to electrically isolate from the overall electric grid (see "Microgrids" in *3.2 Power Generation*). Islanding is often a necessary component for resilient systems so they can operate without grid connection in a safe manner.
2. **Switch Redundancy**: Switches are a core component of communications networks, and direct network traffic. Redundancy of network switches improves the chance that if one switch fails, another already-configured switch can maintain the communication network.
3. **Smart Grid**: Smart Grids provide two-way digital communications between the electric utility and customers. With improved communication and control, wasted energy can be minimized, which saves money for customers and reduces strain on the electric grid. Smart grid technologies include controls, computers, automation, and innovative equipment such as thermostats and water heaters all working together to rapidly meet the electricity needs of communities.

Resources: First Look

- Blog Post Series on System Resilience (Source: Carnegie Mellon University's Software Engineering Institute)
- Electric Grid Resilience and Reliability for Grid Architecture (Source: Pacific Northwest National Laboratory [PNNL], 2018).
- Energy and Cybersecurity Integration (Source: Federal Energy Management Program [FEMP])
- Examining How Smart Homes Interact with the Power Grid (Source: NREL, 2016).

Resources: Deep Dive

- Joint United States-Canada Electric Grid Security and Resilience Strategy (Source: Governments of the United States and Canada, 2016).
- Electric Grid Security and Resilience: Establishing a Baseline for Adversarial Threats (Source: ICF International, 2016).
- Guide to the Distributed Energy Resources Cyber Framework (Source: NREL, 2019).
- Metrics and Analytical Frameworks for Valuing Energy Efficiency and Distributed Energy Resources in the Built Environment (Source: NREL, 2020).

3.5 Electric Transportation

Electric transportation includes electric vehicles (EVs), electric buses, and any mode of transport using electricity as a source of energy. Electric transportation provides resilience by reducing dependence on fossil fuels, which are often in short supply after disasters. However, electric transportation increases dependence on power networks, which is why a resilient power grid goes hand-in-hand with resilient electric transportation.

Resilient Options Can Include:

1. **Electric Vehicle (EV) Charging**: Instead of using gas stations for fuel, EVs have their batteries recharged from electric charging stations, or electric vehicle supply equipment (EVSE). EVSE may be located at public parking lots, along highways, at businesses, or in people's homes. To make EV charging more resilient, charging stations can incorporate energy storage, off-grid capability, renewable energy, or other measures that allow EV charging to occur during disruptions or outages. In addition, community designs need to take into account the location of charging stations and impacts to the grid for optimal resilience as part of the overall electrical demand.
2. **Electric Public Transportation**: Electrified public transportation is a shift from conventional internal combustion engine-based buses and other vehicles to more efficient and cleaner EVs. For equitable solutions, electric public transportation could be designed to serve lower-income communities and be used to provide mobility during disruptive events or emergency evacuations.
3. **Electric Transportation in Emergency Response Planning**: After a disaster, all road-based transportation, regardless of the grid performing, may be inhibited by debris and inaccessible roads. As communities develop and codify emergency response plans, incorporating the use of EVs into these plans can add value to the resilience solution by considering EV charging locations as part of overall vehicle fueling policies.

Resources: First Look

- Fuel Diversification to Improve Transportation Resilience: a Backgrounder (Source: NREL, 2019).
- Connecting Electric Vehicles to the Grid for Greater Infrastructure Resilience (Source: NREL, 2017).

Resources: Deep Dive

- Resilience Enhancement Strategies For and Through Electric Vehicles (Source: *Sustainable Cities and Society* – Academic Journal, 2022).
- Resiliency Impacts of Plug-In Vehicles in a Smart Grid (Source: University of California Institute for Transportation Studies, 2021).
- Federal Fleet Resilience Planning (Source: FEMP, 2021).

3.6 Emergency Services Support

Disasters and disruptions require emergency responders such as firefighters, paramedics, emergency medical technicians (EMTs), and relief organizations to be on-hand to provide life-saving support or restoring damaged systems to support the community. Renewable energy projects like solar and battery storage can ensure that fire stations and municipal buildings remain supplied and powered during certain disruptive events, allowing for the best possible coordination of emergency services and a faster return to normal operations in the community.

Resilient Options Can Include:

1. **Resilient Power for Emergency Responders**: Fire stations, public safety centers, and emergency coordination facilities can all be made more resilient through a reliable and resistant energy supply. With proper design, solar PV and battery energy storage, including mobile storage (see *3.1 Energy Storage*), can ensure that these critical facilities remain operational during disasters. Designing onsite microgrids to support critical loads will help ensure resilient power is provided during grid outages, benefiting the community as a whole.
2. **Resilient Communication Protocols**: Communication between responders, local governments, and relief agencies is crucial for minimizing the impact of disasters. Community resilience can be improved by taking steps to ensure that communications infrastructure will still function after a disruptive event: through resilient power, redundant systems, or clear emergency management planning.
3. **Resilience Shelters for Responders**: In many disasters, responders have their primary center of operations disabled or they may be too far away to be useful. With other damaged buildings in the community, finding space for these responders, like medical personnel or mutual aid workers, can be extremely difficult. Resilient facilities and resilience hubs can be dedicated to shelter and support these responders.
4. **Water-Energy Nexus**: The water-energy nexus describes the interaction between the energy needed to supply treated water to the community and the water required to keep energy systems operational. Emergency personnel and medical providers require clean, potable water to treat patients. Options for improving resilience in the energy-water nexus include resilient energy for treating and pumping water supplies, water storage for community needs, water pumps for flood management, and floodproofing to reduce or eliminate flood damage.

Resources: First Look

- Resilient Power for Emergency Operations: Freeing First Responders from the Burden of Unreliable Backup Power (Source: Clean Energy Group, 2022).

Resources: Deep Dive

- Overview of Response to Hurricane Sandy-Nor'easter and Recommendations for Improvement (Source: U.S. Department of Energy[DOE], Office of Electricity Delivery and Energy Reliability, 2013).
- Resilience Meets the Water-Energy-Food Nexus: Mapping the Research Landscape (Source: *Frontiers in Environmental Science* – Academic Journal, 2021).

3.7 Community Awareness & Education

Skill-building and awareness training allow community members to improve their disaster preparedness as well as qualify for good jobs in emerging clean energy industries such as solar installation and battery manufacturing. Education can contribute to resilience through improving community knowledge of risks and hazards, strengthening community ties, and building the community's ability to adapt during disruptions and disasters.

Resilient Options Can Include:

1. **Clean Energy Job Training:** Job training for community members provides opportunities to learn about and train for jobs in new industries. Training programs for roles such as solar PV installers may be added to existing workforce training opportunities for trades like construction or welding. Clean energy companies and electric utilities may also support these programs and use them as workforce pipelines or sites for job fairs, improving local economic resilience.
2. **Preparedness Training**: Preparedness training provides instruction to community members and volunteers in advance of a disruptive event. These trainings may include programming like individual and family preparedness, introduction to climate change and disruptions, justice and equity in emergency management, Community Emergency Response Team (CERT) training, first aid/CPR, rapid needs assessment, and coordinating volunteers for a disaster scenario. This type of training builds resilience in communities through improved plans during disasters.
3. **Local Solar Education**: Local solar education provides the community with resources, tools, and skills to adopt solar PV for personal and community-scale use. This training may include classes or workshops to educate local residents on clean energy topics, such as costs and benefits, processes for adopting community-scale or residential solar PV, and energy efficiency strategies. Information may be disseminated through traditional classroom methods, hybrid methods, or peer-to-peer networks like solar ambassador programs.

Resources: First Look

- Advancing Inclusion Through Clean Energy Jobs (Source: Brookings Institution, 2019).
- Building Resilient Communities: An Online Training (Source: RAND Corporation, 2013).
- Community Energy Response Team (CERT) (Source: Federal Emergency Management Agency [FEMA], 2022).
- The Importance of Building Resilience into Education Systems (Source: Education in Crisis and Conflict Network, USAID, 2020).

Resources: Deep Dive

- Planning for a Resilient Community: A 4-Hour Workshop for Planners (Source: FEMA).
- Transforming Systems in Times of Adversity: Education and Resilience White Paper (Source: Education in Crisis and Conflict Network, USAID, 2019).
- Rapid Education and Risk Analysis (RERA) Toolkit (Source: Education in Conflict and Crisis Network, USAID, 2018).

3.8 Efficiency-Resilience Nexus

Structural resilience is the ability to quickly resume the use of buildings or other structures following a disruption. Energy efficiency upgrades use less energy to achieve the same or better performance and may contribute to the ability to resume operations. Efficiency measures can range from improved appliances that reduce a household's electricity bills to a more tightly sealed building. Energy efficiency and related upgrades can improve public health, decrease energy costs, and contribute to structural resilience.

Resilient Options Can Include:

1. **Energy Efficiency Initiatives**: Energy efficiency measures require less energy for the same performance. During an energy disruption, an energy efficient community will require less energy to return to normal operations. Examples of efficiency upgrades include heating and cooling equipment, building insulation, or other end-use appliances.
2. **Auditing**: An audit is an assessment of a system to ensure it is suitable for its purpose.
    a. **Resilience Audit**: A resilience audit conducts a baseline review of a facility to identify risks, vulnerabilities, impacts, and solutions to improve resilience. This can be done on any scale including residential, commercial, utility facilities, and at the community level.
    b. **Energy Audits**: Energy audits review a facility's current energy use and identify the most promising efficiency and demand reduction opportunities. Some energy utility companies offer rebates, special programs, or other benefits for efficiency upgrades for customers or non-profit organizations.
3. **Retrofits**: Retrofitting involves making changes or upgrading an existing building to make it more efficient, resilient, or updated. Retrofits can lower energy costs for a facility if energy efficiency upgrades are made and improve a building's ability to withstand natural disasters if structural upgrades are included.
4. **Technology Exposure Considerations**: Improvements can be made to protect equipment from damage during storms and disasters. Examples include liquid-tight conduit to protect cabling systems, weatherproof cells for sensitive electronic equipment, and raised floors to keep technology safe from flooding.
5. **Weatherization**: Weatherization uses energy-efficiency measures to reduce energy costs and improve indoor safety. Examples include upgrades to the building envelope and heating and cooling systems. Weatherization may particularly benefit low-income households by lowering energy costs and other benefits like improved indoor air quality.

Resources: First Look

- How Energy Efficiency Can Boost Resilience (Source: ACEEE, 2018).
- A Resilience Strategy Based on Energy Efficiency Delivers Five Core Values (Source: RMI, 2018).

Resources: Deep Dive

- Enhancing Community Resilience through Energy Efficiency (Source: ACEEE, 2015).
- The Nexus of 'Urban Resilience' and 'Energy Efficiency' in Cities (Source: *Current Research in Environmental Sustainability* – Academic Journal, 2022).
- Energy Efficiency, Resilience to Future Climates and Long-Term Sustainability: The Role of the Built Environment (Source: *Philosophical Transactions of the Royal Society A* – Academic Journal, 2010).

3.9 Green Infrastructure

Green infrastructure includes environmentally friendly public works projects, such as bioswales, permeable paving, and rain gardens. Green infrastructure projects can improve community resilience by reducing flood risk, preparing for drought, reducing urban heat island effects, and thus reducing energy requirements, and protecting coastlines.

Resilient Options Can Include:

1. **Flood Management**: Green infrastructure projects such as planting vegetation in urban areas, bioswales, and detention basins can all divert and retain stormwater from damaging buildings and disrupting the community.
2. **Drought Mitigation**: Green infrastructure such as rain barrels, rain gardens, and other water reclamation strategies can direct additional water into groundwater reserves, reducing the risks and costs of droughts.
3. **Energy Management**: Green infrastructure can retain water, reduce the amount of water going down storm drains, and reduce the burden on sewer pumping systems when it rains. Separating storm piping from wastewater pipes allows wastewater treatment facilities to treat raw sewage, rather than stormwater, thus reducing energy loads.
4. **Heat Reduction**: Green roofs and other shade-producing vegetation can reduce the urban heat island effect and lower both energy usage during heat events (e.g., lower AC needs) and cost required for cooling buildings in the community.
5. **Environmental Protection**: Some areas, like beaches, may be eroded or harmed by storms and disasters. Green infrastructure improvements, such as dune restoration or coastal wetland restoration, can protect these natural features and increase community resilience to environmental disruptions.

Resources: First Look

- Nature as Resilient Infrastructure – An Overview of Nature-Based Solutions (Source: Environmental and Energy Study Institute [EESI], 2019).
- Green Infrastructure for Climate Resiliency (Source: U.S. Environmental Protection Agency [EPA], 2015).
- Green Infrastructure Modeling Toolkit (Source: EPA, 2022).

Resources: Deep Dive

- Building Climate Resilience with Green Infrastructure: (Source: EPA, 2014).
- Building Green Infrastructure to Enhance Urban Resilience in Climate Change and Pandemics (Source: *Landscape Ecology* – Academic Journal, 2021).
- Green Infrastructure for Urban Resilience: A Trait-Based Framework (Source: *Frontiers in Ecology and the Environment* – Academic Journal, 2022).

3.10 Financial Support

Resilient technologies like renewable energy and energy efficiency often provide benefits over their lifetimes; however, the high upfront cost can limit access for many residents and organizations. Financial support pathways can spread the costs of resilient projects over time so that more people can benefit and save money. Affordable funding options allow marginalized people, businesses, and communities to access resilient technologies and projects.

Resilient Options Can Include:

1. **Grants**: Grants are financial awards given to individuals or organizations to facilitate easier or free access to resilient projects like solar or energy efficiency. Grants may be specifically designed to provide financial support to low-income households or non-profit organizations.
2. **Community Clean Energy Fund**: The revenue from energy projects like solar PV arrays may be saved in a fund for the community with a goal to make it easier, or free, for community members to access clean energy. A community fund may be used to reduce the cost of solar PV panels or other resilience improvements for residences, municipal buildings, or other community assets.
3. **Self-Generation Incentive Program (SGIP)**: SGIP programs provide financial incentives for installing electric generators or battery storage. These programs can be customized to support distributed energy resources that improve energy resilience and reduce greenhouse gas emissions. These programs improve the economic resilience if community members can save money to put towards other resilience measures.
4. **Green Banks or Community Development Financial Institutions (CDFI)**: Green banks or CDFIs can provide favorable loan terms and financing options to individuals and organizations who are seeking to invest in energy efficiency, clean energy, or sustainable infrastructure. These institutions improve community resilience by allowing resilient energy projects to proceed when traditional banks would not be willing to finance them. Two examples of green banks are the Energy Resilience Bank in New Jersey and the Connecticut Green Bank.

Resources: First Look

- Environmental Justice Grants, Funding, and Technical Assistance (Source: EPA, 2023).
- Financing Resilient Power Fact Sheet (Source: Clean Energy Group, 2020).
- Green Banks 101 (Source: RMI, 2020).
- Financing Equitable Prosperity (Source: Community Development Financial Institutions Fund)
- Be Prepared for a Financial Emergency (Source: FEMA, 2019).
- Finance for Power Sector Resilience (Source: NREL, 2019).

Resources: Deep Dive

- Finance and Resilience Toolkit (Source: Better Buildings Initiative).
- Financing for Resilience with Commercial PACE (Source: Better Buildings Initiative).
- Evaluating Impacts of the Inflation Reduction Act and Bipartisan Infrastructure Law on the U.S. Power System (Source: NREL).

4 Additional Resources

Other resources may be helpful to community resilience planners when it comes to technical assistance opportunities, specific examples of completed projects, creating comprehensive resilience plans, and methods of valuing the contributions of resilience. Additional resources are provided in the following sections.

4.1 Technical Assistance Opportunities

NREL and other National Laboratories continue to provide direct, customized expertise and analysis to communities in support of their resilience goals and initiatives. While this is not a comprehensive list, both past and present technical assistance efforts from the following programs may be of use to community decisionmakers:

- Solar Energy Innovation Network (SEIN)
- Clean Energy to Communities (C2C)
- Communities Local Energy Action Program (Communities LEAP)
- Decision Support for Island and Remote Communities
- State, Local, & Tribal (SLT) Technical Support Services

4.2 Case Studies

Resilience projects have been deployed all around the U.S. and often provide useful examples for ongoing and future improvements.

Solar Energy Innovation Network (SEIN) Highlights

- City of Largo, FL Clear Sky Assessment Process: Prioritizing Solar + Storage for Resilient Facilities & Communities (Source: Tampa Bay Regional Planning Council)
- Breaking Barriers: Solar HBCU Innovation in Microgrids & Resiliency with Solar + Storage (Source: Groundswell)

Resources: First Look

- The Energy-Resilient City infographic from the Better Building Solutions Center as part of the U.S. Department of Energy (Source: Better Buildings, U.S. DOE, 2019).
- Clean Energy for Resilient Communities: Expanding Solar Generation in Baltimore's Low-Income Neighborhoods (Source: Clean Energy Group, 2014).
- The Solar Energy Technologies Office's Advanced Systems Integration for Solar Technologies (ASSIST): (Source: Solar Technology Office, U.S. DOE, 2019).
- Governor's Office of Storm Recovery Launches Solar Power and Battery Backup Power Program to Protect Flood-Prone New York City Neighborhoods from Power Failures (Source: Governor's Office of Storm Recovery, 2019).
- AC Transit (Oakland) to Participate in Innovative Vehicle-To-Building (V2B) Pilot (Source: California Transit Association, 2022).
- Minneapolis Jobs Program Aims to Grow and Diversify Clean Energy Workforce (Source: Energy News Network, 2022).
- SunSmart Emergency Shelters Program: equipped more than 100 Florida schools with backup solar and storage systems (Source: Clean Energy Group).

Resources: Deep Dive

- Visit Solar Market Pathways for resources, tools, and real-world examples that help local governments, community advocates, solar project developers, emergency management professionals, facilities managers, and others understand all the aspects of implementing resilient solar (Source: Solar Market Pathways, U.S. DOE, 2017).
- Multilab Energy Planning Support for Puerto Rico (Source: NREL).
- LA100: The Los Angeles 100% Renewable Energy Study (Source: NREL).
- Alternative Energy Generation Opportunities in Critical Infrastructure in New Jersey (Source: NREL, 2013).

4.3 Resilience Planning Resources

Communities can lead their own resilience efforts through the use of various publicly available planning tools.

Solar Energy Innovation Network (SEIN) Highlights

- Clear Sky Toolkit: A Resilience-Based Siting Toolkit for Solar+Storage (Source: Tampa Bay Regional Planning Council)

Resources: First Look

- Resilience Roadmap: A Collaborative Approach to Multi-Jurisdictional Planning (Source: NREL) – At the regional level, this roadmap provides holistic planning guidance for local, state, and federal entities.
- Technical Resilience Navigator (Source: PNNL) – Organizations can use the Technical Resilience Navigator to identify their resilience gaps and prioritize solutions that reduce risk from disruptions to energy and water services.
- Guide to Expanding Mitigation: Making the Connection to Electric Power (Source: FEMA, 2020) – Community officials can use the Federal Emergency Management Agency (FEMA)'s electric power mitigation guide to work with public and private actors to mitigate hazards while planning and developing projects.

Resources: Deep Dive

- Power Sector Resilience Planning Guidebook: A Self-Guided Reference for Practitioners (Source: NREL, 2019).
- How Distributed Energy Resources Can Improve Resilience in Public Buildings: Three Case Studies and a Step-by-Step Guide (Source: Better Buildings, U.S. DOE, 2019).
- Resilience in Regulated Utilities (Source: National Association of Regulatory Utility Commissioners [NARUC], 2013).
- Regulating for Resilience Workshop (Source: Sandia National Laboratory, 2019).
- Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico (Source: Sandia National Laboratory, 2018).
- Enhancing the Resilience of the Nation's Electricity System (Source: National Academies Press, 2017).
- Distributed Energy Resource Cybersecurity Framework (Source: NREL).

4.4 Valuing Resilience

Resilience projects may not appear to be economical under traditional cost-benefit calculations; however, placing a value on the benefits or losses during grid disruptions can make resilience projects a fiscally sound investment. Resilience valuation tools include:

Resources: First Look

- Valuing the Resilience Provided by Solar and Battery Energy Storage Systems (Source: NREL, 2018).
- Customer Damage Function Calculator (Source: NREL)

Resources: Deep Dive

- Metrics for Energy Resilience (Source: *Energy Policy* – Academic Journal, 2014).
- Quantifying and Monetizing Renewable Energy Resiliency (Source: *Sustainability* – Academic Journal, 2018).
- Resilience Metrics for the Electric Power System: A Performance-Based Approach (Source: Sandia National Laboratory, 2017).
- Resilience framework and metrics for energy master planning of communities (Source: *Energy* – Academic Journal, 2020).
- Developing a Resilience Model for North America's Energy Sector Infrastructure: North American Energy Resilience Model [NAERM] (Source: Office of Electricity, U.S. DOE, 2019).
- Hetero-Functional Graph Resilience Analysis of the Future American Electric Power System (IEEE – Academic Journal, 2021).

4.5 General Resilient Community Resources

There are many resilience resources that include education material, additional case studies and funding opportunities.

- National Oceanic and Atmospheric Administration (NOAA)-Related Resiliency Resources, Environmental Literacy Program and Case Studies (Source: NOAA).
- COP Resilience Hub Community (Source: UN Climate Change Conference [COP27])
- Communities Responding to Extreme Weather (CREW) Community of Resilience Hubs (Source: Climate Crew).
- National Fish and Wildlife Foundation (NFWF) Resilient Communities Program (Source: NFWF).
- National Institute of Standards and Technology (NIST) Community Resilience (Source: NIST).

4.6 Definitions of Terms Related to Resilience

Table 22. Other Terms Relevant to Resilience

Term	Definition	Source
Reliable Energy Supply	Makes energy available to facilities when it is needed and without interruption.	U.S. Environmental Protection Agency (EPA)
Resilient Facility	A facility that can anticipate, prepare for, respond to, and recover from energy outages caused by storms or other adverse events.	
Resilient Power System	Must be capable of lessening the likelihood of long-duration electrical outages occurring over large service areas, limiting the scope and impact of outages when they do occur, and rapidly restoring power after an outage.	U.S. Department of Energy
Adaptive Capacity	The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.	Urban Sustainability Directors Network (USDN)
Climate Resilience	The ability of communities to anticipate, accommodate and positively adapt to or thrive amidst changing climate conditions or hazard events and to enhance quality of life, reliable systems, economic vitality, and conservation of resources for present and future generations. Resilience differs by setting, facility, and community.	
Resilient Power	The ability not only to provide critical power to essential facilities and services during a power outage, but also to provide economic benefits throughout the year by reducing power bills and generating revenue to utilities and grid operators by generating power onsite and providing services to utilities and grid operators	
Critical Infrastructure	To operate, community serving facilities rely on critical infrastructure that typically includes electricity, water, wastewater, heating fuel (natural gas, propane, or fuel oil), communications (fixed wire or mobile) and Internet service.	
Electricity System Resiliency	Focuses on preventing power disruption and, when an outage does occur, restoring electricity supply as quickly as possible while mitigating the consequences of the outage.	Society of Cable Telecommunications Engineers or SCTE
Community Resilience	A community's ability to use available resources to respond to, withstand, and recover from adverse situations.	Better Buildings Solution Center, U.S. Department of Energy

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