Community Energy Resilience Planning for Extended Power Outages

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About ICF

ICF, one of the world's largest climate consultancies, helps public and private sector clients worldwide develop climate change policy, interpret and comply with regulations, assess and reduce greenhouse gas emissions, evaluate risks and identify opportunities to build resilience to climate change.

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1 Introduction

As more and more communities experience the impacts of a changing climate, leaders at the state and local levels are looking for new solutions to keep their communities safe and make them more resilient over time. Energy services are essential for heating, cooling, and other daily needs, and resilient energy infrastructure is essential to making communities safer and more resilient.

Community energy resilience is defined as the ability of a community to stay healthy and safe even when energy supply is interrupted. This means keeping the energy flowing, it means keeping people safe during energy outages, and it means getting a system (the grid, the community, the local economy) back up and running as quickly as possible once the outages have passed. Communities everywhere are focusing on what it would mean for them to invest in becoming more energy resilient. This means understanding what that would entail, what it might cost, and what the benefits would look like, including:

- A safer community that is better able to protect its populations' health, welfare, and productivity
- A more secure community in terms of energy supply, and potentially the supply of water and other essential services
- A community whose economy is more resilient to the increasing hazards of a changing climate

This guide focuses on community scale resilience, which typically involves a local utility's service area; it does not address national or regional issues, though those can also affect a community's resilience. The guide's purpose is to empower communities to find and use the best solutions *for them* to achieve overall health, safety, and prosperity goals and serve the needs of those with the greatest health and safety risks in **extended power outages (EPOs).**

Communities can meet the increasing need for energy resilience with an evolving set of planning, technology, and operational strategies. This guide is designed to introduce community leaders from government and constituent organizations to the basics of energy resilience, plan for improved energy resilience, and support implementation of selected strategies. It is intended to help non-energy experts with limited resources understand and begin to plan for improved energy resilience in their communities. It is not a comprehensive guide designed to cover all aspects of community energy resilience but does include links to more detailed resources on key topics for those looking for greater depth.

The guide is structured in the following sections:

- **What is energy resilience?** — In addition to basic definitions, this section describes the main types of energy resilience solutions, describes what an energy resilient community looks like, and outlines key issues around building equity into energy resilience.

- **Identifying and prioritizing energy resilience needs in your community** — This section describes some populations likely to have greater health and safety challenges in EPOs, and some climate-related hazards likely to result in EPOs. It ends with a framework of key considerations for understanding and prioritizing your community's resilience needs.

- **Developing energy resilience solutions** — This section provides information relevant for evaluating energy infrastructure resilience risks, understanding technical solutions, defining and selecting government actions to reduce risks, and prioritizing the solutions and actions best suited to improving your community's energy resilience.

- **Developing a community energy resilience strategy** — By bringing together the elements developed in the previous sections, this section provides guidance on how to structure and advance the community processes to move from initial thinking to implementation planning.

2 What is energy resilience?

2.1 Defining energy resilience

Resilience of an energy system can be considered at many levels. At the national level, energy resilience is often predicated on the dependence on foreign fuels and the vulnerability of energy systems to external risks, such as political conflict or trade disputes. Regional energy resilience can address things like the adequacy of fuel stocks and transmission capability to shift energy supply among utilities, as happened in the 2021 Texas winter blackouts. At the utility level, energy resilience focuses more on the ability of a grid to withstand and recover from major events, the way New York utilities worked to do after Hurricane Sandy.

This guide describes a range of energy resilience solutions that communities can deploy (in partnership with their electric utilities) to support their populations. This guide specifically addresses planning and solutions to protect **populations with significant health and safety risks** in extended power outages (EPOs).

In this guide, energy resilience refers to the ability of communities to maintain the health and safety of residents when experiencing interruptions of energy supply including electricity and fuels. EPOs are interruptions of electricity service lasting longer than 24 hours.

Energy resilience solutions include those that help energy providers, communities, and institutions avoid, prepare for, minimize, adapt to, and recover from EPOs.

2.2 Stages of energy resilience strategies

When thinking about an energy resilience event—something that might impact a community because it causes a power outage—there are four stages to consider (Figure 1). When developing a resilience strategy, communities should consider the solutions that can best be put in place to bolster each stage.

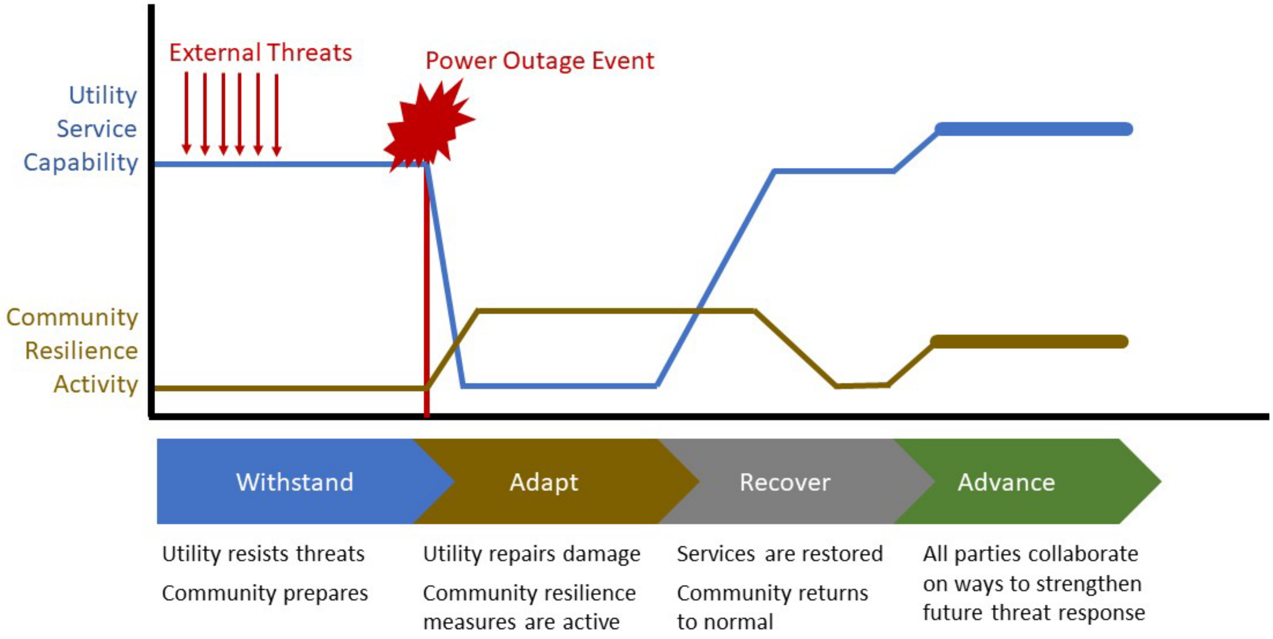

Figure 1: The four stages of energy resilience

Withstanding an event is about keeping the grid up and running when there is an event that threatens its continued operation. It is common to assume that these kinds of solutions are entirely in the utility's purview – such as hardening power lines and gas mains to deal with risks associated with flooding, hurricanes, etc. But communities can also act to support solutions that help the utility grid withstand threats. For example, advanced energy efficiency codes and demand response programs help reduce peak loads on the grid, and also make electricity use more flexible, which in turn can lessen stress on the grid during extreme temperature events. Likewise, local regulations can be used to reduce the risk of equipment flooding through stormwater management and landscaping, and can reduce risks to power lines through vegetation management.

Adapting is about meeting a community's most essential needs when the power goes out. These essential needs begin with physical safety for all, and then include continuation of key elements of social and economic life. Local governments play a lead role in meeting those needs, through first responder emergency management, but there are other complimentary solutions, such as on-site generation for critical facilities, accessible resilience hubs, and pre-planned lines of communication with key populations, both on outage warnings and on resources available during outages.

Recovering grid operations to normal levels is largely a utility responsibility, though in some cases communities help accelerate and support utility efforts (e.g., transportation and emergency response agencies coordinating with utility crews to provide clear routes of passage and added logistical support).

Advancing resilience can be overlooked in the wake of an EPO. But every outage is also a time to better understand community vulnerabilities, effective resilience measures, and opportunities for improved future preparedness. This guide encourages communities to evaluate and update practices and consider new solutions during and after EPOs, which may involve closer collaboration with local utilities; this intentional consideration will accelerate efforts to make communities stronger and more resilient.

2.3 What does an energy resilient community look like?

Resilient communities may experience fewer EPOs, and when they occur, leaders and community members are better prepared to take the steps needed to meet essential needs. If the entire community is aware of plans and resources in place to handle EPOs, those efforts will be more effectively employed.

Planning for and investing in energy resilience can provide benefits including:

- **Safety:** Greater protection of community members' health, welfare, and productivity.
  - For example, well-insulated homes and resilience hubs can increase the likelihood for residents to have their basic need for thermal comfort met during EPOs.
- **Utility reliability:** Increased security of energy supply, and potentially the supply of water and other essential services.
  - For example, adding backup power capacity to water and wastewater systems helps ensure that water supplies are not interrupted, and that streams are not polluted by diverted wastewater.
- **Economic resilience:** Improved ability for local businesses to continue during and recover after EPOs.
  - For example, providing on-site power supply solutions to key facilities and to businesses can keep the local economy moving forward during EPOs.
- **A cleaner environment:** Some energy resilience measures can also reduce emissions by reducing energy usage and incorporating clean energy sources.
  - For example, renewable power with battery storage at key facility sites can reduce or eliminate the need for air-polluting diesel generators, and backup generators to keep water pumps running and avoid flooding can help preserve key land areas.

2.4 Building equity into energy resilience

Each community's energy resilience needs are unique, though there are some common health and safety challenges that many communities face in EPOs.

Many communities also want to design their energy resilience efforts to advance equity given that disadvantaged groups are at greatest risk during EPOs. **Equity in energy resilience** means there is fair and just access to clean, reliable, and affordable energy, and to health and safety measures designed to reduce impacts from EPOs.

Advancing equity in energy resilience is a holistic challenge with multiple dimensions.[1] This guide focuses on distributional equity, recognizing that energy resilience resources often are not available to all people, including those with the greatest need. The goal is to focus on populations in each community that have the most exposure and sensitivity to EPO-related risks.

Key terms

Area: geography; may affect exposure to EPOs (e.g., a rural area with limited energy supply redundancy, or an area near a wildfire risk zone)

Population: Groups of people, defined by socioeconomic, demographic, and other characteristics (e.g., physical ability)

Community: Groups of people, defined by area *and* population (e.g., a hurricane-prone community in Florida where many older adults live)

In Section 3, this guide identifies some of the populations most likely to be predisposed to face the most severe health and safety impacts during EPOs, and describes some ways that each of these populations can be at greater risk. In Sections 4 and 5, it provides energy resilience solutions that leaders can use to build resilience for their communities.

[1] Dimensions of equity such as distributional equity have multiple definitions, and definitions are evolving alongside growing practice. Distributional equity is about ensuring that benefits (e.g., access to energy) and burdens (e.g., health impacts due to loss of energy) are equitably distributed. Resources such as the Energy Equity Project Report (University of Michigan School for Environment and Sustainability, 2022) provide additional discussion on dimensions of energy equity.

3 Identifying and prioritizing energy resilience needs in your community

This section provides resources and tools to help understand and prioritize your community's energy resilience needs. It includes:

- **Key concepts** to assess the energy resilience needs of different populations and communities
- Examples of **populations that may be at greater risk** to health and safety impacts in EPOs, and unique needs they may have in EPOs
- Common **climate hazards** that can cause EPOs, and examples of how communities in areas exposed to those hazards may have greater risks of health and safety impacts
- **Resilience planning considerations** to help identify and prioritize needs in EPOs, and then (see Section 4) identify effective energy resilience solutions to address them

3.1 Key terms and concepts

3.1.1 Exposure and sensitivity

Peoples' exposure and sensitivity to EPO events affect how vulnerable they are to event impacts (Figure 2).

Exposure: The likelihood that your area will experience an EPO.

- Location (i.e., proximity to hazards that can cause EPOs) as well as population and infrastructure distribution affect exposure.
- For example, areas where wildfire- or hurricane-related outages are common may have EPOs more frequently, and rural areas served by power lines with relatively few customers may have longer-duration outages when they occur.

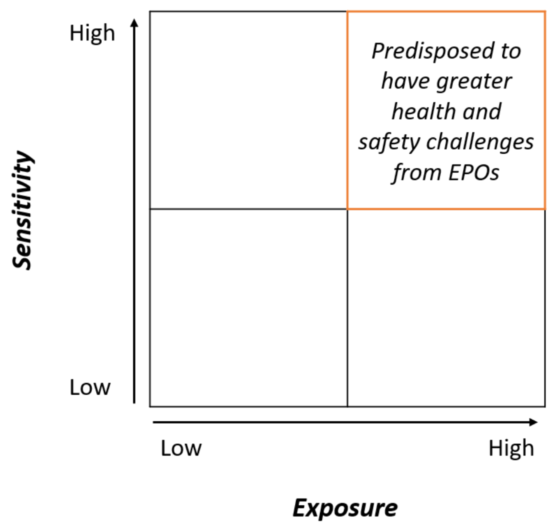

Figure 2: Exposure/sensitivity matrix

Sensitivity: If and how much people will be affected if your community experiences an EPO. Sensitivity is influenced by adaptive capacity.

- For example, older adults may be more sensitive to health impacts from rapid changes in temperature, compared to the average adult.

Adaptive Capacity: The extent to which people can adjust to and respond to an EPO.[2]

- Access to and need for resources to adjust and respond varies due to factors such as wealth, language proficiency, physical or mental abilities, dependence on power-sustained medical support, community support networks, and trust in institutions or networks that provide resources.

[2] The International Panel on Climate Change defines Adaptive Capacity as "The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences." https://www.ipcc.ch/sr15/chapter/glossary/

- For example, older adults with limited physical ability, few social connections, and limited finances that prevent them from affording backup generators for A/C, or people who have historically been discriminated against by local emergency response agencies, may have less adaptive capacity and greater sensitivity to EPO events. By comparison, populations with high wealth, trust in aid institutions, proficiency in language(s) used by aid institutions (often English), few mobility limitations, and strong support networks may be more equipped to access the resources they need to adjust and respond to EPO events.

Communities with high exposure and sensitivity (i.e., high vulnerability) are predisposed to have greater health and safety challenges due to EPOs.

3.1.2 Populations and communities predisposed to have greater risks in EPOs

Improving energy resilience in your community starts with a deep understanding of the specific populations and hazards in the jurisdiction. Who is predisposed to bear the greatest impacts, where do they live, and what are their energy needs? With this understanding, your community can develop more effective and equitable energy resilience plans and implementation methods. Local community leaders, organizations, officials, and community members themselves can speak to different populations' unique needs.

Many populations and communities are predisposed to have greater health and safety challenges in EPOs. This guide describes the needs of several such populations and communities:

- Three populations predisposed to greater health and safety challenges in EPOs:
  - Older adults
  - People with limited disposable income and/or low wealth
  - People with underlying health issues
- Communities in five types of areas predisposed to experience EPOs more regularly:
  - Communities in hurricane-prone areas
  - Communities in wildfire-prone areas
  - Communities in extreme heat-prone areas
  - Communities in extreme cold-prone areas
  - Communities in flood-prone areas

A variety of other factors can affect how people experience EPOs, and community planners should consider these in resilience planning. Some such factors include:

- Access to housing
  - For example, unhoused populations may be exposed to health and safety impacts that housed populations do not typically experience.
- Results of systemic discrimination and inequities, such as
  - Trust in institutions: for example, populations that have historically experienced racial or ethnic discrimination by institutions charged with providing support in outages may be less inclined to turn to them, and thus experience more severe EPO impacts.
  - Wealth and health: for example, due to historically unjust practices making it harder to accumulate wealth and live in healthy environments, Black, Indigenous, and People of Color (BIPOC) populations may be disproportionately exposed to impacts caused by having low wealth or underlying health issues (see Table 1 for examples).
- Citizenship
  - For example, people who are undocumented immigrants may be unable to access or hesitant to ask for support involving legal processes or organizations.
- Geography
  - For example, rural communities served by few power lines, with few customers on each line, may experience particularly long outages if utilities prioritize restoration by number of customers served. Alternatively, urban communities may be more likely to experience

EPOs caused by certain hazards (e.g., in a hot area, urban populations may experience Urban Heat Island effects that rural populations do not).

Recognizing that each person, population, and community has unique and nuanced needs in EPOs, this document includes examples of needs, opportunities, and additional resources from organizations that think about these questions every day.

3.2 Unique needs of populations predisposed to have greater health and safety risks in EPOs

Some populations are predisposed to experience greater health and safety risks in EPOs. The unique needs of several such populations—older adults, people with limited disposable income and/or wealth, and people with underlying health issues—are described below. Resources consulted are in the Appendix.

3.2.1 Older adults

Older adults have a wide range of needs and capabilities; this section highlights trends relevant to prepare for, be safe during, and recover from power outages.

Aging leads to bone and muscle loss, which can limit physical mobility of older adults.[3] Older adults also cannot adjust as quickly to temperature changes as younger people, which is a concern if they are exposed to extreme heat or cold. Extreme temperature exposure in past events has led to frost bite and deaths from hypothermia in cold EPOs, and extreme heat exposure (sometimes fatal) in hot EPOs.[4]

Attaining rescue services and/or accessing resources after EPO-inducing events can also be challenging for the many older adults who do not drive or have limited mobility.[5] Almost 20% of adults over 65 do not drive at all and would need support to evacuate, and those with limited mobility living in multi-story buildings with elevators could have a hard time getting to or transporting food or medicine.[6]

Example energy resilience strategies to support older adults

- Engage older adults in community conversations on EPO planning
- Require group facilities (e.g., assisted living) to have enough backup power to maintain safe temperatures for an extended time (e.g., 4 days)
- Install backup power, and A/C in warm climates
- Identify and make plans to support people living alone (e.g., shelter-in-place, evacuation plans, or buddy systems)
- Target event communications to reach older adults

Many older adults depend on medication that must be refrigerated or administered by another person, and their ability to keep power on or get to a care facility that can appropriately store and/or administer medicine can be critical. One study found older adults are more likely to have chronic conditions (e.g., diabetes) that require medication.[7] Additionally, risks may be greater when outages occur in extreme temperatures. A study by Stone et al. (2021) found that when an outage coincides with a heat wave, 68-100% of the urban population can experience an increased risk of heat exhaustion and/or heat stroke, for example, as air conditioning systems are unusable.[8]

Older people may also be particularly reluctant to evacuate, which may be related to factors such as anxiety around abandoning their home and possessions, being unable to bring a pet that is their main companion,

[3] Climate Change and the Health of Older Adults, *EPA* (2016).
[4] AARP Disaster Resilience Tool Kit, *AARP* (2022).
[5] AARP Disaster Resilience Tool Kit, *AARP* (2022).
[6] AARP Disaster Resilience Tool Kit, *AARP* (2022).
[7] AARP Disaster Resilience Tool Kit, *AARP* (2022).
[8] Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk, *Environmental Science & Technology*, Stone, B., E. Mallen, M. Rajput, C.J. Gronlund, A.M. Broadbent, E.S. Krayenhoff, G. Augenbroe, M.S. O'Neill, and M. Georgescu (2021).

or experiencing disorientation when moving quickly.[9] They also can experience mental and physical health challenges from the disruption that comes with evacuation, sometimes described as "transfer trauma."[10] One study by Willoughby et al. (2017) found higher death rates among nursing home residents evacuated compared to those who sheltered in place, and identified psychological stress of evacuation as a potential factor.[11] But those who do not evacuate may be at risk if they depend on caregivers or support that cannot reach them; and in 2019, nearly 20% of adults 65 and older reported they had significant difficulty or could not independently use at least one of six key modes of function (understanding, self-care, mobility, communication, sight, hearing).[12]

Older adults' communication abilities, and modes of accessing information and connecting with others, may also affect how they are impacted in outage events. 15% of people aged 50 or over do not have internet access, and 60% identified cost of high-speed internet as an issue.[13] The ability to access the internet or send and receive information via text or social media, and cognitive functionality to understand information and/or communicate their needs, all affect peoples' energy resilience needs in an EPO.[13]

A variety of other factors can also come into play for older adults during EPOs. For example, older adults are often the targets of people taking advantage of desperation (e.g., fraudulent repair contractors).[13] Additionally, older adults without formal home ownership or documents to prove ownership may have a harder time receiving assistance; in 2021, FEMA announced people with a broader range of occupancy and home ownership documentation could qualify for disaster relief.[13]

Strategies in action

Shelter-in-place resilience options are often preferable to strategies involving displacement for older adults. Recent efforts by the New York City Housing Authority (NYCHA) provide examples of approaches to protecting older adults' health during EPOs in heat events. In a 2019 study, NYCHA identified a method of at-home A/C supported by backup power as a strong strategy to support older adults. This study informed an effort now underway at the Borinquen Plaza development in Brooklyn: NYCHA is working on a pilot to install solar and storage backup power at senior buildings and the community center at the Plaza, including backup power for critical systems such as elevators and hall lights in senior buildings, and for all systems (including A/C) at the community center. Additionally, NYCHA has installed full-building backup power in over 200 buildings as part of the Hurricane Sandy disaster recovery, which has successfully kept the power on in these buildings when blackouts affected the surrounding neighborhoods.

Additionally, it is critical to build partnerships with those who can effectively reflect older adults' concerns and needs in planning, connect older adults to resources and information, and identify additional relevant partners. The AARP Disaster Resilience Tool Kit notes partners may include representatives from emergency response and disaster recovery organizations, caregiver networks, senior centers, age-friendly coalitions, area agencies on aging (or "triple A's"), and volunteer-led "village networks."

Additional Resources:

- AARP's Disaster Resilience Tool Kit highlights specific disaster risks to older populations and provides guidance on how to reduce these risks and support the resilience of older populations.
- EPA's Climate Change and the Health of Older Adults factsheet provides an overview of the specific health risks of older adults to climate change hazards, including extreme heat, extreme weather events, and poor air quality.
- The CDC webpage Emergency Preparedness for Older Adults, including COVID-19 provides emergency preparedness resources specific to older adults, including for extreme heat events.

[9] AARP Disaster Resilience Tool Kit, *AARP* (2022).
[10] AARP Disaster Resilience Tool Kit, *AARP* (2022).
[11] Mortality in Nursing Homes Following Emergency Evacuation: A Systematic Review, *Journal of the American Medical Directors Association*, Willoughby, M., C. Kipsaina, N. Ferrah, S. Blau, L. Bugejaa, D. Ranson, and J.E. Ibrahim (2017).
[12] 2020 Profile of Older Americans, ACL (2021).
[13] AARP Disaster Resilience Tool Kit, *AARP* (2022).

3.2.2 *Populations with limited disposable income and/or low wealth*

Populations with limited disposable income and/or low wealth have distinct needs; this section highlights trends relevant to prepare for, be safe during, and recover from power outages.

Populations with limited disposable income and/or low wealth tend to fare worse in EPOs. This is due to three main factors: limited time and money to prepare for an EPO, larger barriers to evacuation, and less resources for sheltering in place.[14]

Populations with low wealth may have more difficulty preparing for an EPO because of time and financial constraints. People with low wealth are more likely to work in-person, hourly jobs—so evacuation could mean loss of income—and may not have time to prepare for an outage, or to evacuate.[15]

People with limited income or wealth must evaluate complex questions in preparing for and during an EPO.

First, there is the need to work; those who cannot afford to temporarily lose income may be less likely to leave their areas of employment to flee EPO impact areas. These populations are also less likely to own personal vehicles, which may make it harder to evacuate if they want to. And those with personal vehicles may stay behind to help take of others in their community. They also may not be well situated to shelter in place. Financial constraints can prevent people from buying items that could help them shelter in place during an EPO, like backup generators, fuel, or non-perishable food.

Communities with high concentrations of populations with limited disposable income and/or low wealth generally tend to have older and less efficient infrastructure (e.g., insufficient insulation, no backup generator, aging infrastructure). This is partly because affordable housing tends to be older and less energy efficient.[16] It is also because lower-income households may have trouble accessing the capital to invest in things like new insulation and windows. Many low-income households are renters without direct control over energy efficiency or infrastructure improvements.[17] Some public housing does not have or allow backup generators.[18]

Example energy resilience strategies to support those with limited disposable income

- Ensure community conversations on EPO planning are structured to encourage participation of people of all income levels
- Identify and target funding to support low-income and -wealth households in paying for utility and energy bills
- Identify and make plans to support people in accessing food during an EPO (e.g., community kitchens; systems for food sharing)
- Establish mobile medical clinics to reach low-income and -wealth populations

Strategies in action

Some local governments provide funding support to help populations with limited disposable income and/or low wealth pay for utilities and heating bills. For example, the Low Income Home Energy Assistance Program (LIHEAP) is a federal funding program for assisting with energy costs. The Weatherization Assistance Program (WAP) funds weatherization and energy efficiency upgrades to reduce energy costs and improve the ability to shelter in place longer. Local governments can promote these programs to reach low-income community members.

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[14] Social Vulnerability to Long-Duration Power Outages, Dugan, J., D. Byles, and S. Mohagheghi (2022); Power Outages and Community Health: a Narrative Review, *Current Environmental Health Reports*, Casey, J.A., M. Fukurai, D. Hernandez, S. Balsari, and M.W. Kiang (2020); Power Outages Preparedness and Concern among Vulnerable New York City Residents, *Journal of Ubran Health*, Dominianni, C., M. Ahmed, S. Johnson, M. Blum, K. Ito, and K. Lane (2018).

[15] Social Vulnerability to Long-Duration Power Outages, Dugan, J., D. Byles, and S. Mohagheghi (2022); Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts, *EPA* (2021); Power Outages and Community Health: a Narrative Review, *Current Environmental Health Reports*, Casey, J.A. et al., (2020).

[16] Understanding and Alleviating Energy Cost Burden in New York City, NYC Mayor's Office of Sustainability and the Mayor's Office for Economic Opportunity (2019).

[17] Understanding and Alleviating Energy Cost Burden in New York City, NYC Mayor's Office of Sustainability and the Mayor's Office for Economic Opportunity (2019).

[18] Power Outages and Community Health: a Narrative Review, *Current Environmental Health Reports*, Casey, J.A., M. Fukurai, D. Hernandez, S. Balsari, and M.W. Kiang (2020).

Finally, people with less disposable income often experience more significant and adverse outcomes from EPOs, and as a result may recover more slowly than those with more available funds.[19] Issues include food insecurity and hunger if food spoils, particularly if local food banks and schools that provide free or reduced-price food are hindered by outages.[20] Outages may also cause a significant financial hit as local employment may stop while a community is recovering from the outage. For these reasons, low-income populations may experience both planned and unexpected outages as survival risks.[21]

Populations with limited disposable income and/or low wealth may have a range of communication abilities, and modes of accessing information and connecting with others, relevant to outage events. For example, peoples' ability to access the internet and/or send and receive information via text or social media affect their energy resilience needs in an EPO; low-income households often cannot afford internet access.[22]

Additional Resources

- EPA's Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts discusses the exposure of populations disproportionately impacted by six climate impacts.
- High Energy Burden and Low-income Energy Affordability: Conclusions from a Literature Review revolves around the challenge of high energy burdens for low-income populations. The publication discusses opportunities for addressing this issue.
- U.S. HUD's Community Resilience Toolkit provides guidance on strategies to increase the resilience of a community.
- University of Michigan's Energy Equity Project Report provides a standardized framework for measuring and improving energy equity, which includes significant discussion of low-income populations.

3.2.3 Populations with underlying health issues

Populations with underlying health issues have distinct needs; this section highlights trends relevant to prepare for, be safe during, and recover from power outages.

Many populations with underlying health issues are both at greater risk of experiencing health impacts due to extended power loss and predisposed to have their health issues exacerbated by the hazards that cause power loss. For example, as noted in Section 3.3.2, wildfires can both cause EPOs and increase air pollution, which can intensify symptoms for those with asthma, with potentially severe results.[23]

Some populations with underlying health issues depend on medication that must be refrigerated, must be administered by another person, and/or requires electricity.[24] Their ability to keep power on or get to a care facility that can appropriately store and/or administer medicine can be critical.

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[19] Community-scale big data reveals disparate impacts of the Texas winter storm of 2021 and its managed power outage, *Humanities and Social Sciences Communications*, Lee, C., M. Maron, and A. Mostafavi (2022); Social Vulnerability to Long-Duration Power Outages, Dugan, J., D. Byles, and S. Mohagheghi (2022).

[20] "2022 Detroit energy activists push to hold utilities accountable during power outages," *Energy News Network* and *Planet Detroit*, Catolico E. and N. Ignaczak (2022).

[21] Behavior Analysis of Socially Vulnerable Households Responding to Planned Power Shutoffs, *Natural Hazards Center*, Ham, Y. and S. Lee (2022).

[22] Disaster Resilience Tool Kit, AARP (2022).

[23] Climate Change and the Health of People with Existing Medical Conditions, EPA (2016); Which Populations Experience Greater Risks of Adverse Health Effects Resulting from Wildfire Smoke Exposure?, EPA (2022); Common Asthma Triggers, CDC National Center for Environment Health (2022); 'Breathing Fire': Impact of Prolonged Bushfire Smoke Exposure in People with Severe Asthma, *International Journal of Environmental Resources & Public Health* (2022).

[24] Power Outage Preparedness and Concern among Vulnerable New York City Residents, *Journal of Urban Health*, Dominianni C., M. Agmed, S. Johnson, M. Blum, K. Ito, and K. Lane (2018).

Populations with underlying health issues may have limited mobility during an extended power outage, which can affect their ability to evacuate and access disaster-related resources (e.g., transportation, food, medical care, communication networks). People with diseases or conditions that are physically limiting (e.g., if rely on a wheelchair or a service animal) may have limited mobility during an evacuation.[25]

Communication and support networks that are crucial for populations with underlying health issues may be disrupted during outage events. People's ability to access the internet, make calls, and/or send and receive information via text or social media may affect their resilience needs in an EPO.[26]

Example energy resilience strategies to support those with underlying health issues

- Engage populations with underlying health issues in community conversations on EPO planning
- Inform populations ahead of weather events so that they can prepare (e.g., fill a prescription ahead of time)
- Establish mobile medical clinics to reach populations with barriers to health care access (e.g., cannot visit hospital during open hours; insurance status or cost barriers)
- Install community charging systems with backup power for populations to charge required medical equipment

Strategies in action

Pinellas County, FL offers assistance to residents with specific medical or functional needs during an emergency (e.g., rely on electricity for medical equipment; need oxygen; require extra transportation assistance).

Additional Resources

- EPA's Climate Change and the Health of People with Existing Medical Conditions factsheet outlines the specific climate-related risks of populations with underlying health issues.
- FEMA's Healthcare Cities and Power Outages: Guidance for State, Local, Tribal, Territorial, and Private Sector Partners provides guidance and resources on building climate resilience of health care facilities to power outages.
- The Personal Disaster Preparedness for People with Disabilities Social Media Toolkit provides a list of safety/preparedness messages and resources that local governments can share via social media.
- Example communication methods include checklists, such as FDA's Home Use Devices: How to Prepare for and Handle Power Outages and an Emergency Power Planning for People Who Use Electricity and Battery-Dependent Assistive Technology and Medical Devices.

3.3 Understanding risks from climate-related hazards likely to result in EPOs

A variety of climate hazards can create risks to our energy delivery systems

Every potential climate risk that might impact the energy system is almost certain to coincide with critical needs for energy, be it for heating, cooling, evacuation, or medical care. Beyond knocking out power, these threats can create hazards that put people at greater risk and slow the ability to restore power. Any potential climate hazard should be considered by communities – both in terms of how it will affect the community at large and specific populations at greater risk from that kind of threat.

Climate hazards key to consider include:

- Hurricanes can bring high winds that can carry debris, knock down power lines across wide areas, and cause widespread flooding.

[25] Behavioural and psychological responses of the public during a major power outage: A literature review, *International Journal of Disaster Risk Reduction*, Rubin, G.J. and M.B. Rogers (2019); Planning Considerations for Persons with Access and Functional Needs in a Disaster, ACEP, Mace, S.E., C.J. Doyle, K. Askew, S. Bradin, M. Baker, M.M. Joseph, and A. Sorrentino (2018); The Impact of Hurricanes Katrina and Rita on People with Disabilities: A Look Back and Remaining Challenges, *National Council on Disability*, Frieden, L. (2006).

[26] Disaster Resilience Tool Kit, AARP (2022).

- Wildfires can burn infrastructure and generate smoke, and high fire risk conditions may prompt utilities to intentionally shut off power to reduce fire ignition risk.
- Heat waves can overload the power grid, leading to brownouts and blackouts.
- Cold snaps and storms with snow and ice can cause ice to accumulate on power lines or towers, which can lead to structural failure and outages. They can also increase heating-related load on the grid, or affect generation capacity, which could result in system stress or failures.
- Extreme flooding (e.g., from a severe inland storm, or coastal storm surge) can reach infrastructure that is not flood-resilient, which may cause short- or long-term outages.

For each climate hazard, a community should consider potential frequency and magnitude of impacts that may result. For example, a community may identify that extremely severe hurricanes may not occur often (frequency), but when they do, may knock out power for a long time, leading to severe consequences (impact). The type and extent of preparedness for high-impact and low-frequency EPOs will be different from preparing for relatively lower-impact and higher-frequency EPOs.

Outage-related risks can also be heightened and further complicated when caused by climate-related hazards, and risks may be compounded if there is insufficient recovery time between events.

Each section below discusses how EPOs caused by the hazard (e.g., hurricanes) may affect different populations. They also include examples of resilience strategies to help mitigate risks; examples of strategies in action, which resilience planners may learn from; and links to other resources with additional detail on risks and resilience strategies.

3.3.1 Hurricanes

Climate change projections indicate that communities in hurricane-prone areas may experience more severe and potentially more frequent hurricanes. These storms could cause more frequent and longer EPOs.[27]

In the United States, the Gulf Coast and lower half of the east coast are particularly prone to hurricanes, while hurricane-like 'nor-easters' can strike the northeast states.[28] Hurricanes and other high wind events can knock over and damage energy infrastructure, resulting in EPOs. Figure 3 shows tropical cyclone activity in the North Atlantic since 1950.

In hurricane-prone areas, populations predisposed to have greater health and safety challenges in EPOs may be disproportionately impacted if preparations do not account for their needs. While some people may choose not to evacuate,[29] others who want to but do not have cars or cannot afford temporary housing in safe areas may stay and be exposed to risks from both the hurricane and the outage. In Hurricane Ida in 2021, many unhoused individuals and those with limited disposable income and/or low wealth were unable to evacuate.[30]

Example energy resilience strategies to support communities in hurricane-prone areas

- Ensure local building codes reflect latest standards and practices, such as those provided by the International Code Council
- Create community resilience hubs in appropriately wind-resistant facilities
- Evaluate drainage capabilities and choke points
- Engage community members in EPO planning
- Discuss opportunities for collaboration with the electric utility on vegetation management, undergrounding key power lines, housing out-of-state lines crews, and coordination with first responders

[27] Longer, More Frequent Outages Afflict the U.S. Power Grid as States Fail to Prepare for Climate Change, *The Washington Post*, MacMillan, D. and W. Englund (2021).
[28] National Risk Index, *FEMA* (2022); NCA 4 Chapterhttps://nca2018.globalchange.gov/chapter/18/ 18: Northeast, *USGCRP* (2018).
[29] Health Concerns and Perceptions of Central and Coastal New Jersey Residents in the 100 Days Following Superstorm Sandy, *Science of the Total Environment*, Burger, J. and M. Gochfeld (2014).
[30] "As Ida hit, homeless, other vulnerable people left behind," *AP News*, Willingham, L. and J. Reeves (2021).

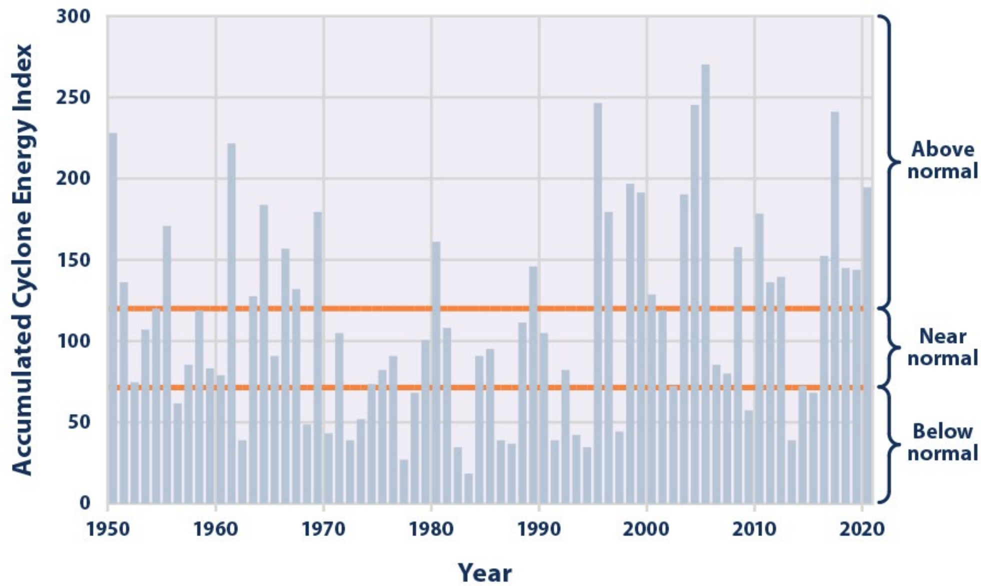

Figure 3: North Atlantic tropical cyclone activity, Accumulated Cyclone Energy Index, 1950–2020[31]

EPO duration and recovery is also complicated by storm impacts, and is affected by resources (staff, funding, training) and existing energy resilience measures in place (e.g., backup generation). Hurricane-related infrastructure damage can be extensive, with long recovery timelines. Emergency responders' and utility staff's ability to restore power and provide critical services can be hindered by hurricane impacts, such as obstructed roads, flooding, and the regional availability of lines crews. These impacts can prolong EPO duration and resulting impacts.

Strategies in action

In New Orleans, LA, several initiatives are underway to build out systems of resilience hubs.

The Community Lighthouse Project is developing a network of renewable (solar and battery) powered hubs at community centers and churches in southern Louisiana, and secured nearly $11M in funding. Nonprofit initiative Get Lit Stay Lit is working to install solar panels and batteries on 300 NOLA restaurants, so they can continue to operate, feed local communities, and serve as phone charging, cooling, and support centers in disasters. And the City and State have also applied for grants to expand on these efforts; for example; the City was recently awarded a BRIC grant to design a solar- and battery-powered resilience hub at a Recreation Center.

Additionally, the length of an outage and the ability to recover from the outage and other hazard-related impacts hinges on how funding is allocated—both during EPOs and in the long term (including after most power has been restored)—which is affected by how different communities' needs are recognized and understood. It is critical to actively build equity priorities into planning and restoration efforts. Federal disaster aid after hurricanes has historically often been focused in wealthier communities.[32] For example, grants were disproportionately distributed in the aftermath of Hurricane Katrina in New Orleans, resulting in wealthier populations generally receiving more funds than poorer populations.[33] This issue stemmed in part from grant allocation programs evaluating needs by considering land value—and land value has historically been affected by systems of discrimination such as redlining.

Communities in hurricane-prone areas should review and update their strategies for energy resilience among other priorities. Many states and counties in such areas, for example, have established building standards for homes, emergency shelters, and other facilities, often using model codes developed by

[31] Climate Change Indicators: Tropical Cyclone Activity, *EPA* (2022).
[32] Equity in Resilience: Planning for hurricanes, *C2ES*, Sedigh, N. (2021).
[33] "The Federal Program to Rebuild After Hurricane Katrina Shortchanged the Poor. New Data Proves It." *ProPublica*, Webster, R., J. Adelson, D. Hammer, and S. Chou (2022); "Katrina battered Black New Orleans. Then the recovery did it again." *The Washington Post*, Williams, N.E. (2020).

groups such as the International Code Council. These storm- and wind-oriented codes tend to focus on structural integrity during extreme events; but including energy codes in your community's code suite can provide additional resilience benefits, by improving thermal performance to support building-focused passive survivability and shelter-in-place strategies.

Additional Resources

- FEMA's National Risk Index is an interactive map that can be used to build a visual understanding of the natural hazard risk at a specific location, including hurricane, strong wind, and tornado data.
- NOAA's National Hurricane Preparedness provides resources to support emergency preparedness of populations in hurricane-prone areas.
- EPA's Incident Action Checklist – Outages provides an example checklist for power outage preparedness. This checklist targets water and wastewater utilities.
- FEMA's Building Resilient Infrastructure and Communities (BRIC) program supports communities aiming to build resilience and reduce risks to disasters and natural hazards.

3.3.2 Wildfires

Communities in wildfire-prone areas may experience more frequent and longer EPOs due to increasingly intense and frequent wildfires.

Power outages may be caused by infrastructure damages or utilities' intentional shut-off of power, such as Public Safety Power Shutoffs (as are now approved in California) to mitigate wildfire risk conditions.[34] Figure 4 shows the increase in the area burned by wildfires in the United States over the past decade.

In the case of infrastructure damage, wildfires can burn a variety of assets, causing failure and resulting in EPOs. The number of planned and sudden outages may increase as wildfires become more frequent and intense, particularly in the western and southwestern United States and the southeast coastal states, which currently have the most significant wildfire risk.[35]

Within wildfire-prone areas, populations predisposed to have greater health and safety challenges in EPOs and planned shutoffs may be disproportionately impacted if preparations do not account for their needs. People with underlying health issues are especially sensitive to wildfire and smoke-related impacts, as air quality worsens with smoke and pollutants.[36] For example, there was an increase in

Example energy resilience strategies to support communities in wildfire-prone areas

- Identify and make plans to manage vegetation and infrastructure maintenance, as well as systems to monitor this maintenance.
- Update building codes and related regulations to improve fire resistance in exterior building components.
- Use a variety of forms of communication to inform communities ahead of intentional power shut-offs.
- Identify and support evacuation routes.
- Establish plans for diverting or avoiding wildlife fleeing nearby fires.

Strategies in action

The Hayman Fire in Hayman, Colorado burned 138,000 acres and cost tens of millions in damage. The community has since increased their training, broadened disaster coordination to include community members, and developed a county-wide community wildfire protection plan. Hayman has also adopted and strengthened their plans, codes, and land development regulations.

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[34] "Wildfire Mitigation Webinar Series," DOE Office of Electricity (2021); Utility Public Safety Power Shutoff Plans (De-Energization), California Public Utilities Commission (2022).
[35] National Risk Index, FEMA (2022).
[36] Climate Change and the Health of People with Chronic Medical Conditions, EPA (2022).

emergency room visits for asthma, respiratory problems, chest pain, and lung disease after wildfires hit San Diego in 2007.[37]

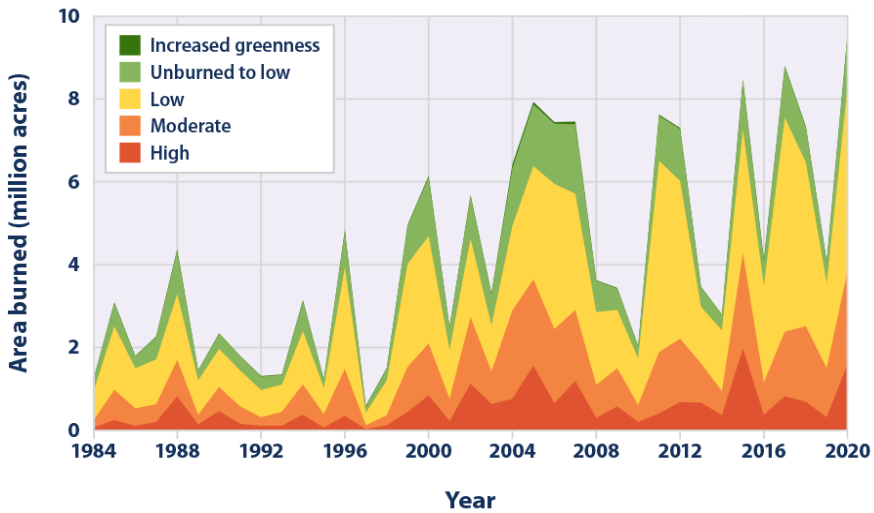

Figure 4: Damage caused by wildfires in the United States, 1984–2020[38]

Wildfire risk impacts certain areas more than others (Figure 5). Remote areas may be more forested and have higher fuel loads that increase wildfire risk. Further, wildfire risk and ability to restore power and access resources may depend on external factors, such as the distance from the nearest fire station. Communities in rural or remote wildfire-prone areas may be predisposed to risks due to their limited access to alternative energy resources and essential supplies like food and water, as well as communication systems.[39]

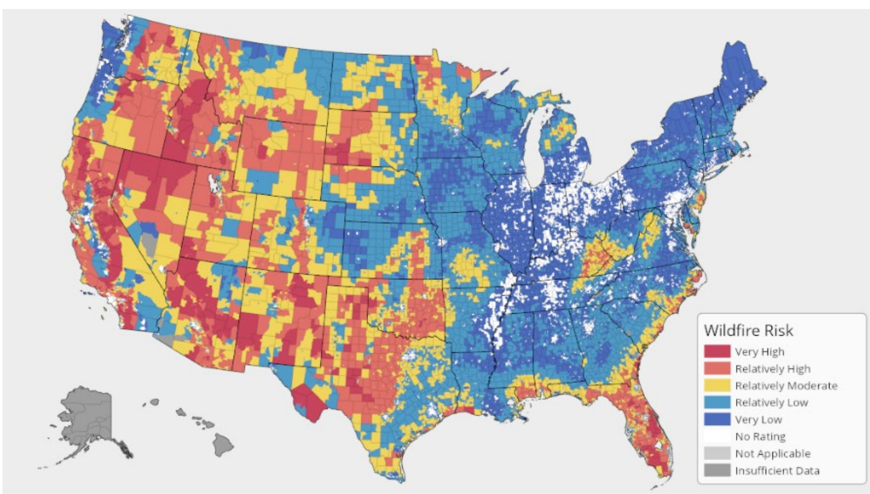

Figure 5: U.S. wildfire risk map[40]

[37] Resilience Strategies for Wildfire, C2ES, Huber, K. (2018).
[38] Climate Change Indicators: Wildfires, EPA (2022).
[39] Evaluating Rural Pacific Northwest Towns for Wildfire Evacuation Vulnerability, *Natural Hazards*, Dye, A.W., J.B. Kim, A. McEnvoy, F. Fang, and K.L. Riley (2021).
[40] National Risk Index: Wildfire, FEMA (2022).

There are also studies demonstrating that different ethnic groups find themselves at different levels of risk from wildfire. In a 2018 study titled "The unequal vulnerability of communities of color to wildfire," the authors found that "wildfire vulnerability is spread unequally across race and ethnicity, with census tracts that were majority Black, Hispanic or Native American experiencing ca. 50% greater vulnerability to wildfire compared to other census tracts."[41]

EPO duration and recovery are significantly complicated by wildfire impacts, and depend on access to resources (staff, funding), services, and existing energy resilience measures in place (e.g., on-site generation). Duration and recovery are also affected by the extent of post-wildfire flooding impacts, such as degraded water supply and debris-damaged infrastructure due to runoff, as flooding risk becomes greater after a wildfire.

Communities in wildfire-prone areas should review and update their strategies for energy resilience among other priorities. Some states and counties have updated or established zoning and building code standards related to wildfires. These codes include fire-resistant construction and retrofits, landscaping regulations, and zoning and development standards.

Additional Resources

- FEMA's National Risk Index is an interactive map that can be used to build a visual understanding of the natural hazard risk at a specific location, including wildfire data.
- The Wildfire Safety Social Media Toolkit provides a list of safety/preparedness messages that local governments can share via social media.
- NACo's Building Wildfire Resilience: A Land Use Toolbox for County Leaders provide guidance, tools, and resources to help local governments improve wildfire preparedness and resilience.
- The Center for Climate and Energy Solutions' Resilience Strategies for Wildfire highlights resilience strategies for wildfire-prone areas, as well as relevant tools and resources. The paper includes strategy implementation examples.
- CAL FIRE's webpage provides comprehensive information for wildfire preparedness, including power outage information – Prepare for a Wildfire: Power Outage Information.

3.3.3 Extreme heat

Energy resilience officers, which are increasingly common in U.S. cities, often say their top concern is extreme heat, because heat has the two-pronged danger of disproportionately impacting certain populations and exacerbating strain on the power grid.

When temperatures are extremely high, increased demand for air conditioning puts a strain on the electrical grid.[42] At the same time, that heat causes high-voltage transmission lines to sag, making them more prone to damage or fault through contact with branches or each other.

Extreme heat is a particularly acute threat to older populations, who make up a disproportionate number of emergency room visits during heat waves.[43] It can also be dangerous in low-income areas where homes may lack air conditioning or may experience service disconnections due to power bill nonpayment.[44]

Extreme heat is expected to become an increasing problem as average temperatures rise due to climate change (Figure 6). A recent study found that approximately 12,000 deaths in the United States each year

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[41] The Unequal Vulnerability of Communities of Color to Wildfire, PLoS ONE, Davies, I.P., R.D. Haugo, J.C. Robertson, and P.S. Levin (2018).

[42] Resilience Strategies for Extreme Heat, *C2ES* (2017).

[43] Excessive Heat Events Guidebook, EPA (2006); The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, USGCRP (2016); Heat Waves, Aging, and Human Cardiovascular Health, ***Medicine & Science in Sports & Exercise***, Kenney, W.L., D.H. Craighead, and L.M. Alexander (2015).

[44] Inequality in the Availability of Residential Air Conditioning across 115 US Metropolitan Areas, ***PNAS Nexus***, Romitti, Y., I.S. Wing, K.R. Spangler, and G.A. Wellenius (2022).

are attributable to extreme heat, with this number expected to increase by nearly 100,000 by 2100 under high climate scenarios.[45]

The deadly nature of extreme heat coupled with this anticipated increase in that hazard will mean greater mortality. Figure 7 below shows the projected increase in deaths due to warming in the summer months (hot season, April–September), the projected decrease in deaths due to warming in the winter months (cold season, October–March), and the projected net change in deaths compared to a 1990 baseline period for the 209 U.S. cities examined.

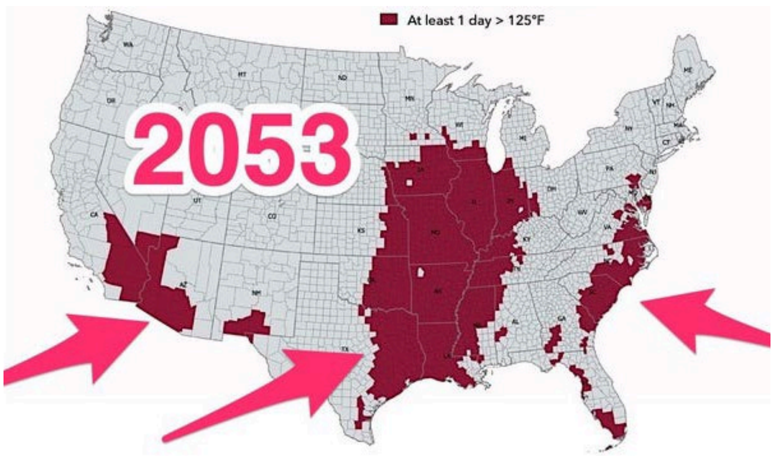

Figure 6: Areas expected to experience heat above 125 degrees F in 2053[46]

Example energy resilience strategies to support communities prone to extreme heat

- Focus on energy efficiency and demand respond capabilities in residential buildings to improve shelter in place capabilities and reduce strain on utility grids
- Establish community resilience hubs to serve as cooling centers
- Prioritize elderly people most at risk from heat stroke
- Work with local pharmacies to develop strategies for medication refrigeration
- Ensure extra water supplies are available
- Engage with the electric utility around
  - Energy efficiency and demand response programs
  - Prioritizing circuits with high numbers of elderly customers

Strategies in action

Chicago, IL has developed resilience actions to improve extreme heat community preparedness, with a focus on neighborhoods and populations particularly at risk. The city conducted outreach to these populations to better tailor strategies to their needs.

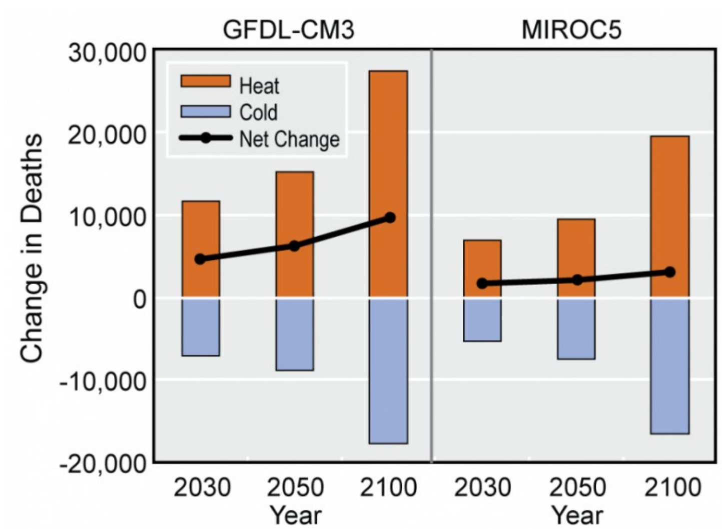

Figure 7: Anticipated deaths due to heat[47]

[45] Planning for Extreme Heat: A national survey of US planners, *Journal of the American Planning Association*, Meerow, S. and L. Keith (2022).
[46] "Highlights from "Hazardous Heat"," *First Street Foundation* (2022).
[47] The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, USGCRP (2016).

Additional Resources:

- The Resilience Strategies for Extreme Heat report from The Center for Climate and Energy Solutions provides an overview of a myriad of community approaches to increasing resilience to extreme heat.
- C40 Knowledge's "How to adapt your city to extreme heat" discusses several threat mitigation measures that can diminish heat threats.
- EPA's Excessive Heat Events Guidebook is a good source for understanding health impacts of extreme heat.
- The Extreme Heat Safety Social Media Toolkit provides a list of safety/preparedness messages that local governments can share via social media.

3.3.4 Extreme cold

Extreme cold can affect the power grid in a variety of ways. Ice buildup can bring down power lines while also increasing the risk of electrocution from contact with downed power lines.[48] Low temperatures can also change the viscosity and pressure of lubricants and insulating gases, leading to malfunctions in electricity switchgear.[49]

Extreme cold can be particularly dangerous in areas that are not prepared for it. Geographies unaccustomed to extreme cold are less likely to have building codes that require strong thermal envelopes; the resulting lower levels of insulation and window efficiency can cause indoor temperatures to drop quickly when the power goes out. Other than self-contained fuel-fired portable heaters or wood stoves, all modern heating systems need electricity to operate, so when the power goes out, the heat goes out. Portable fuel heaters are not generally recommended, because they vent combustion gases in the occupied space, and can also cause fire hazards.[50] In warmer climate zones, many buildings use electric resistance heating, which when cold weather strikes can dramatically raise peak loads on the power grid. These factors create risks for hypothermia, which may disproportionately impact certain populations, as well as the other negative effects of power outages, such as frozen/burst water pipes, food spoilage, and business interruptions.

Example energy resilience strategies to support communities experiencing extreme cold

- Establish community resilience hubs to serve as warming centers
- Focus on buildings codes and standards that improve thermal envelopes and support shelter in place strategies
- Prioritize elderly and unhoused populations most as risk from freezing
- Proactively engage people around the dangers of freezing/burst pipes
- Engage with utilities to understand which roadways should be prioritized for plowing/salting to support repair crews

Strategies in action

In 2021, the Texas power grid suffered catastrophic failures of when extremely cold temperatures caused power generators that had not been weatherized against the cold to fail just as demand was spiking. Since then the Texas Legislature ordered electricity regulators to require power plants to better prepare for extreme weather. In Bosque, Texas, the County Office of Emergency Management is working to establish a network of community shelters in case of cold-related power outages.

Many communities also have significant unhoused populations; in these areas, specific focus should be put on getting the unhoused indoors as extreme temperatures can lead to quickly developing life safety and health hazards. As with extreme heat, elderly communities are also at high risk from extreme cold. Each community should assess its own unique needs for responding to cold weather – whether it will be common but potentially extreme or uncommon and therefore particularly disruptive. As illustrated in Figure

[48] "Why Does the Power Go Out When It's Cold?", *National Geographic*, E. Gunther (2014);
[49] "Why Does the Power Go Out When It's Cold?", *National Geographic*, E. Gunther (2014); Power system resilience to floods: Modeling, impact assessment, and mid-term mitigation strategies, *International Journal of Electrical Power & Energy Systems*, Souto, L., J. Yip, W. Wu, B. Austgen, E. Kutanoglu, J. Hasenbein, Z. Yang, C.W. King, and S. Santoso (2022).
[50] Extreme Cold: Emergency Preparedness and Response, *National Center for Healthy Housing* (2022).

8, the North American Electric Reliability Corporation (NERC) provides updated regional information on how anticipated weather patterns are likely to impact the grid.

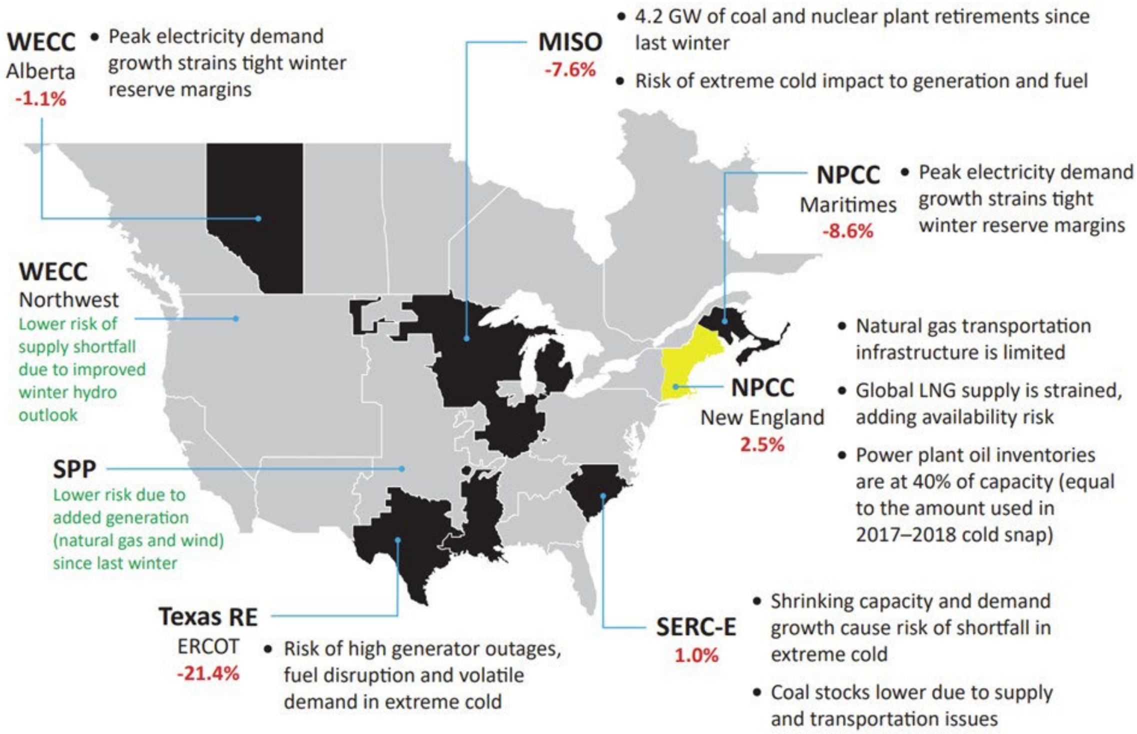

Figure 8: NERC 2022-2023 Winter Reliability Assessment[51]

Additional Resources:

- NERC's 2022-2023 Winter Reliability Assessment provides up-to-date information on anticipated cold-weather threats for the coming year.
- The Center for Disaster Philanthropy's Ice, Snow and Extreme Cold page discusses the impacts of extreme cold on communities and provides links to organizations providing grant funding to address these challenges.

3.3.5 Flooding

Flooding can be caused by a variety of sources – extreme rainfall, coastal storm surge, failures of infrastructure like water mains, or even changes in runoff due to deforestation, urban development, or fires. Flooding is expected to increase, especially in low-lying areas.[52]

As warming air and oceans due to climate change accelerate the water cycle, scientists expect an increase in the number one cause of flooding, heavy precipitation.[53] As urban and suburban development continues, creating less permeable soil and more impermeable concrete, our communities become less able to absorb rain. As sea levels rise as a result of climate change, storm surge in coastal areas will grow increasingly worse.[54]

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[51] 2022-2023 Winter Reliability Assessment, NERC (2022).
[52] The First National Flood Risk Assessment: Define America's Growing Risk, First Street Foundation (2020).
[53] Climate Change Indicators: Heavy Precipitation, EPA (2022).
[54] 2022 Sea Level Rise Technical Report, NOAA (2022).

When flood waters meet electrical equipment, the predictable happens. Transmission and distribution substation equipment is particularly vulnerable as they are typically sited at ground level and need to remain shut down until flood waters recede.[55]

Example energy resilience strategies to support communities experiencing flooding

- Zoning and building codes that require proper drainage and permeable surfaces
- Nature-based solutions creating non-occupied flood plains and drainage paths
- Elevation of critical equipment – particularly backup generation
- Pumping equipment that can relocate water from critical areas
- Fully-submersible switchgear equipment for medium and low-voltage service
- See Figure 9 for flood risk management options

Strategies in action

The longest recorded energy outage in U.S. history was in Puerto Rico as a result of Hurricane Maria in 2017. Thousands died, many because of a lack of power at local hospitals. FEMA is working in partnership with local communities to put mitigation plans in place. Among these is a regional project that will help with river flood control in several municipalities. Another regional project will focus on storm water overflow systems for nine state roads.

Thermoelectric generation stations (like coal, gas, and nuclear plans), by their very design, have to be located near significant sources of water as it is a critical component in the generation of steam to generate electricity. This makes them more acutely susceptible to flooding from rising water levels that can overflow their operations and make transportation to and from the facilities impossible.

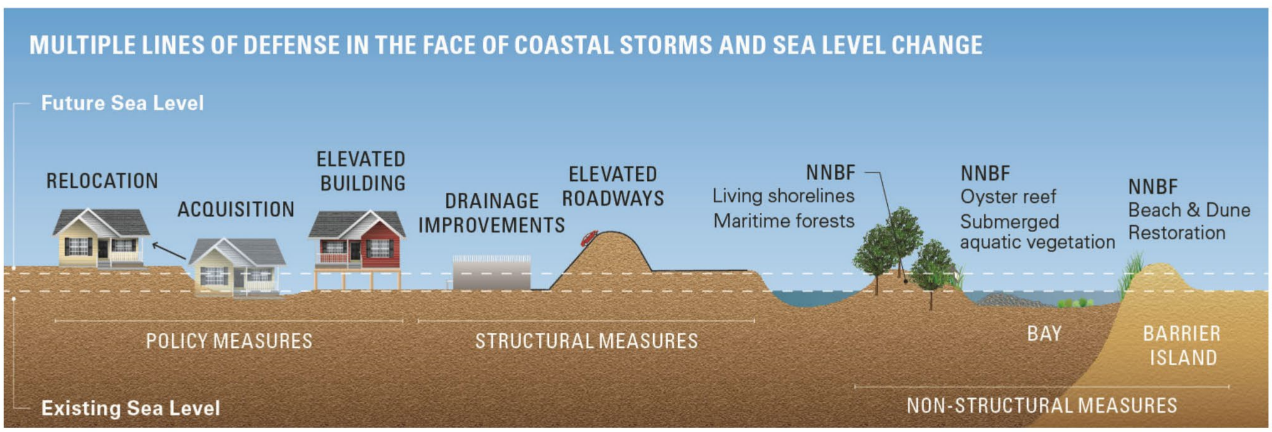

Figure 9: Integrated approach to flood risk management with multiple lines of defense[56]

Much like with other climate hazards discussed in this report, there is a clear connection between higher impacts of energy outages during floods and the higher-risk populations identified earlier in the report. Poorer people are more likely to live in flood-prone areas due to lower housing costs.[57] Their lack of disposable income and lower likelihood of owning a car means that this population is less likely to evacuate well ahead of dangerous flooding. Older populations in the United States are disproportionately

[55] Power system resilience to floods: Modeling, impact assessment, and mid-term mitigation strategies, *International Journal of Electrical Power & Energy Systems*, Souto, L., J. Yip, W. Wu, B. Austgen, E. Kutanoglu, J. Hasenbein, Z. Yang, C.W. King, and S. Santoso (2022).
[56] Nature Based Coast Flood Mitigation Strategies, *City of Virginia Beach*, Moss, A., A. Brazeau, J. Greenspan-Johnston, T. Miesse, X. Liu, B. Batten, and M. Bailey (2019).
[57] "Three things we learned about poverty and flood risk from urban household data," *World Bank Blogs*, Erman, A. (2022).

concentrated in coastal communities with greater likelihood of flooding and their more limited mobility can make relocating to resilience hubs or out of the area slower and more difficult.[58] During a major flood, lack of power may not be the most pressing issue for these communities, but it can considerably complicate first responder efforts to locate and rescue people at risk.

Additional Resources

- The First Street Foundation's National Flood Risk Assessment is an excellent resource to understand where flood risks are greatest.
- The National Oceanic and Atmospheric Administration's 2022 Sea Level Rise Technical Report provides technical insights on future flooding impacts for coastal communities.
- The C40 Knowledge Hub has an excellent resource for understanding nature-based solutions to increase ground permeability and mitigate flooding impacts.
- EPA's Permeable Pavement Factsheet walks through the benefits of using this flood mitigation solution.

3.4 Identifying and prioritizing your community's resilience needs

After identifying the hazards and sensitivities relevant to your community, it is time to prioritize the range of community needs to address first given legal and resource limitations. There is no consistently agreed-upon framework for prioritizing needs. Institutions use a variety of analytical methods for prioritizing capital investments that increase community resiliency (National Academies of Sciences, Engineering, and Medicine, 2019), such as basing them on vulnerability to heat wave-related mortality (Madrigano et al., 2015) or social vulnerability (CDC Social Vulnerability Index).

The basic element of most of these frameworks is to consider where exposure and sensitivity are highest; one limitation is that many frameworks do not take into account other important factors such as resource (e.g., budget, staff) availability. These kinds of frameworks can be more or less complex depending on the resources available.

This section describes how exposure and sensitivity considerations can be used to identify community needs, and factors to consider in prioritizing identified needs using a community stakeholder process.

3.4.1 Identifying community resilience needs

Exposure and sensitivity considerations can be used to outline needs in EPOs. Table 1 provides an example of how to consider hazards expected to cause EPOs locally, and key populations in the community and their sensitivity to EPO impacts. Using this type of matrix can help acknowledge and capture the unevenness of vulnerability in EPOs, and needs of different populations. If this type of method is used in stakeholder workshops, it can help participants visualize needs.

Factors that affect sensitivity and exposure are often interrelated. Some factors that increase sensitivity (e.g., low income, pre-existing health conditions) are often more prevalent in BIPOC populations, for example, due to systemic discrimination and inequities; as such, BIPOC populations are often more sensitive to EPOs and other impacts from these hazards than other populations.

Examples of different sensitivity and exposure to EPOs by race—often intersecting with income and health factors—are provided below Table 1.

[58] Aging in Flood-Prone Coastal Areas: Discerning the Health and Well-Being Risk for Older Residents, *International Journal of Environmental Research and Public Health*, Bukvic, A., J. Gohlke, A. Borate, and J. Suggs (2018).

Table 1. Example matrix to identify community resilience needs

Factor affecting sensitivity to impacts	**Exposed to climate-hazard-related EPOs?**					
	Hurricanes	Wildfires	Extreme Heat	Extreme Cold	Flooding	Other
Race	*Example A**	*Example B**	*Example C**	*Example D**	*Example E**	
Age						
Income						
Pre-existing health conditions						
Other (e.g., gender, ethnicity)						

**Example sensitivity, exposure, and resilience considerations that affect community needs:*

- ***Example A:*** In hurricane-related outages, EPO impacts (e.g., financial, health) can be compounded by other issues in hurricane restoration, which often diverge along racial lines. Studies analyzing the amount of government aid received by communities have found communities with minority status receive significantly less aid overall;[59] this pattern was notable, for example, following Hurricane Katrina.
- ***Example B:*** Communities in majority-Native American, Black, or Hispanic census tracts have a 50% greater vulnerability to wildfires, factoring in exposure and adaptive capacity.[60]
- ***Example C:*** In the United States, Black people are disproportionately likely to develop diabetes, in part due to inequities in access to resources such as food and medical care.[61] Diabetes is known to exacerbate health risks in extreme heat events.[62] Further, historical racist land use policies have contributed to disproportionate exposure of heat impacts on low-income and minority communities; urban areas that were formerly redlined areas are typically about 2.6°C warmer than nearby non-redlined urban areas.[63]
- ***Example D:*** Restoration is often prioritized in areas with hospitals—which also tend to have higher-income populations. In Texas, where Hispanic and Black families are >2x as likely to live below the poverty line compared to White families and many homes lack insulation for severe cold, comparison of restoration times in areas similarly affected by Winter Storm Uri (2017) showed outages were shorter in predominantly non-Hispanic White and high-income areas.[64]
- ***Example E:*** Analysis of federal flood insurance payments has shown they that disproportionately harm predominantly African American neighborhoods.[65] This is because these neighborhoods are more likely to be in floodplains, often have a denser amount of impermeable surfaces, and are less likely to see investment in mitigation measures like levies, pumped drainage, or nature-based solutions.

[59] Environmental Racism and Natural Disasters: Preparing for a Future Defined by Climate Change, *Journal of Student Research*, Mays, P., M. Bischoff, and R. Schmidt (2021).
[60] The unequal vulnerability of communities of color to wildfire, *PLoS ONE*, Davies, I.P., R.D. Haugo, J.C. Robertson, and P.S. Levin (2018).
[61] Diabetes in African Americans: Inequities, genes, prevention, *Medical News Today*, H. Ames (2021).
[62] Extreme Summer Heat & Diabetes, *ADW Diabetes*, Kleinman R. (2022).
[63] The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 US Urban Areas, *Climate*, Hoffman, J.S., V. Shandas, and N. Pendleton (2020).
[64] Texas Winter Storm Uri exposed environmental racism, *North Texas Daily*, Stevens, S. (2021); Equitable community resilience: The case of Winter Storm Uri in Texas, Nejat, A., L. Solitare, E. Pettitt, and H. Mohsenian-Rad (2022).
[65] Flooding Disproportionately Harms Black Neighborhoods, *E&E News*, Frank, T. (2020).

3.4.2 Prioritizing community resilience needs

The description of needs developed in section 3.4.1 can provide the foundation for a community stakeholder process to come to consensus on a community's priorities to plan resilience strategies.

It is also important to physically map your community's needs to specific geographics, where possible. For some populations, especially those that are spread somewhat evenly across the jurisdiction, geography may not affect the mapping of their needs. But some members of a given population may be located in higher-risk areas relative to climate hazards (e.g., elderly populations living along the beach in hurricane-prone regions). Each community's mix of population needs and sensitivities, population distribution, and climate hazards will be different, but it is important to focus energy resilience needs both physically and demographically as much as possible, so that planners can target solutions and investments effectively.

Once your community has identified and mapped its energy resilience needs, the next step is to prioritize these needs. That prioritization can be conducted using principles like shown in Figure 10.

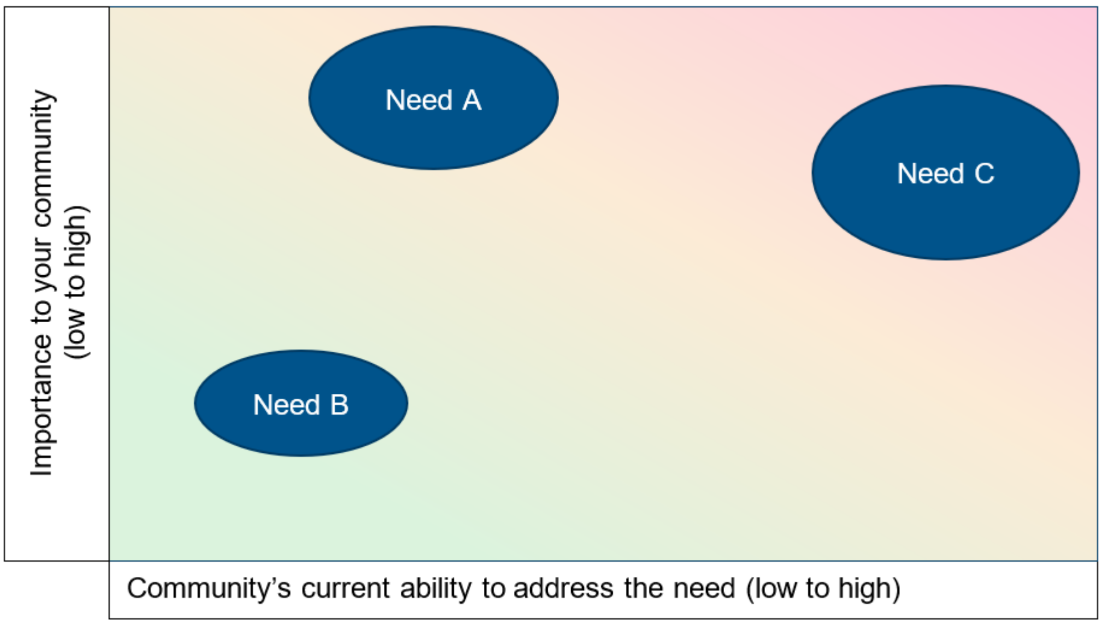

Figure 10: Example framework to prioritize community needs

Figure 10 shows how needs can be evaluated using the axes of importance to community and current ability to meet the need. Ability to address the need is affected by feasibility due to factors such as management bandwidth, finances, geography, political will, and existing understanding of needs to inform systems to meet them. The size of the shapes shown in Figure 10 can also be used to represent the size of the need, such as the number of people in the affected population.

Importance of needs can best be determined through community stakeholder engagement; feasibility can also be determined through community engagement as well as consideration of legal mandates, funding options, and management capacity. Accordingly, the highest priority needs should end up in the upper right-hand corner of a chart like this. And as above, an inclusive stakeholder process should be employed to apply these or other kinds of visualization techniques toward gaining community consensus.

For Example A in Table 1, ensuring EPO restoration and post-disaster funding criteria do not exacerbate inequities may be a high priority for communities in hurricane-prone areas that have seen differential distribution of funds in the past (see Need C placement in Figure 10).

As noted above, a structured process and tools for considering and weighting relevant factors should be used to prioritize needs (i.e., not just broad discussion of the factors described here). Though there is no single widely accepted method, multi-criteria and other forms of decision analysis are often used.

4 Developing energy resilience solutions

Once your community's key populations and their vulnerabilities and needs are better known, you are better prepared to plan for energy resilience. This section provides a toolkit of risk assessment methods, technology solutions, and government actions that your community can pursue to 'up its game' on energy resilience.

4.1 Evaluate energy infrastructure resilience risks

In parallel with the community needs and hazards assessment described in Section 3, it is also important to take a detailed look at existing energy and other infrastructure to assess their energy resilience risks in a community context. Early on in a community's energy resilience planning process, it will be important to engage and collaborate with local electric utilities and other energy and water organizations that own and operate critical infrastructure. Community leaders are familiar with both broad populations and specific individuals and groups with the greatest energy resilience needs. Utilities bring understanding of the design, operations, and risk profile of local (and sometimes regional) power grids. Community leaders and utilities should partner in identifying needs and solutions, with transparency in decision-making and investment prioritization to serve the community.

Understanding the nature of these risks, however, is also critical in crafting policy to address them.

- Understand the hazards and what threats those hazards create – not just to the energy system, but to people who are without power. The loss of energy, in and of itself, is only potentially life threatening to a small group of people – for example, those on ventilators. It is the secondary effects of life without energy (access to heating, cooling, refrigeration, water pumping, etc.) that can create life threatening situations.
- Each threat has both a likelihood of happening and a level of impact once it does. A low-level hurricane is a threat that is likely to occur on a regular basis (high likelihood) but the impact of such an event should be minimal (low impact). On the other hand, a massive earthquake is quite rare but would have devastating effects on energy infrastructure.
- Even after understanding the threat and the impact on the energy system, it must be considered how lack of access to energy will impact people in that instance. Power loss on a 60°F degree, partly sunny day will have massively less impact on human life than energy loss during a blizzard.
- In thinking about risk in these ways, one can identify ways to mitigate the impact on human life and the economy. The likelihood of some threats can be mitigated. The impact on the energy system of most threats can be mitigated. Finally, the impact of energy loss on communities can be mitigated.

One approach commonly used to evaluate potential solutions is called the "bow tie method."[66] This approach, pictured in Figure 11 below, identifies the threats caused by a particular hazard and how they might create an event – in this case an extended power outage. The bow tie then looks at the consequences that stem from that event. When designing solutions (the red octagons in the graphic), communities can evaluate their options to prevent a threat from triggering an EPO (the left side of the bow tie) or mitigate the impacts of an EPO (the right side of the bow tie). There are ways to quantify all of these variables to prioritize resilience investments – looking for the best risk reduction per dollar invested, but that approach requires considerable investment and is typically only used by utilities in consideration of major resilience

[66] Distribution Resilience and Reliability Planning, *PNNL*, De Martini, P. and J. Taft (2022).

investments. For the purposes of state and local resilience planning, it is enough to consider how each measure will impact the bow tie.

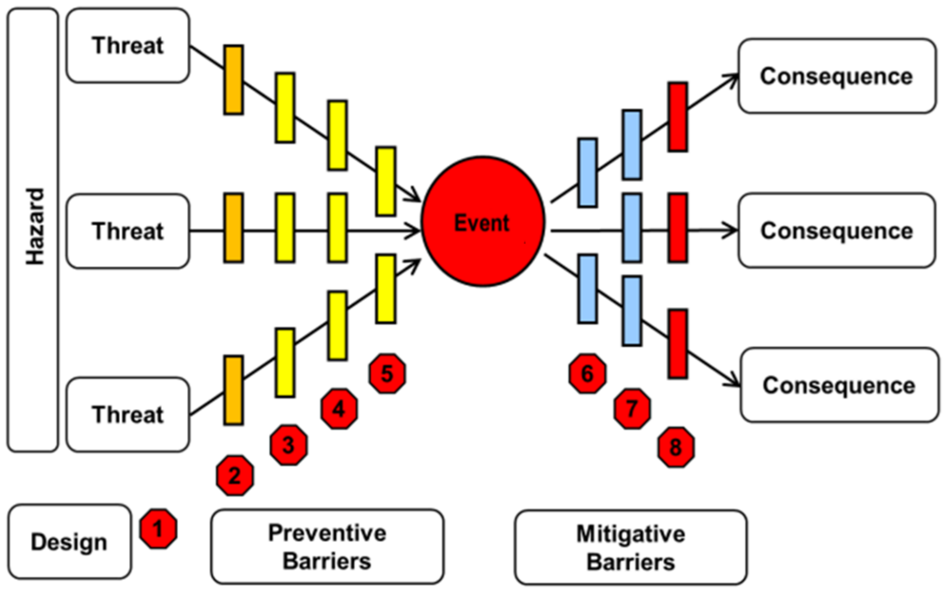

Figure 11: "Bow Tie" resilience solutions visualization method

4.2 Understanding technical solutions

Your community can improve its energy resilience by improving the built environment in several ways; these options fall in three main categories:

- Energy efficiency solutions, such as improved insulation and equipment.
- Energy supply and storage solutions, such as on-site generation and batteries.
- Microgrids that blend the previous two solutions to deliver the highest level of on-site energy resilience.

4.2.1 Energy efficiency solutions

Energy efficiency at the individual building or facility level is an energy resilience resource that:

- Reduces electricity peak demand and energy use overall, which makes energy supply systems more resilient;
- Maintains thermal comfort levels inside buildings, which enables shelter-in-place strategies; and
- Can enable grid-interactivity, which supports electric demand flexibility to further increase electric power system reliability and resilience.

Energy efficiency measures that contribute to these benefits include:

- Thermal insulation, which reduces heat gain and loss, improves comfort, reduces heating and cooling loads, and enables smaller heating and cooling systems; those smaller HVAC systems in turn enable backup systems to be smaller and less expensive to buy and run;
- High-performance windows, which confer the same kinds of benefits as insulation, while also providing the benefits of daylighting;
- High-efficiency heating and cooling equipment, which especially if coupled with insulation and window measures, reduces total energy use and peak power demand; and
- High-efficiency water heating, lighting, appliances, and electronics, which reduce energy bills and can also help manage peak electric demand.

One benefit of energy efficiency that contributes directly to resilience strategies for EPOs is its ability to maintain comfort conditions inside buildings within the ranges needed to support life safety. Well-insulated buildings stay more comfortable by moderating indoor temperatures when energy supplies are interrupted. This means that homes can stay habitable longer when outages occur, giving emergency response teams and other service providers more time to reach and assist the most vulnerable.

It is also important to maintain indoor air quality in well-insulated buildings. That includes controlling indoor conditions such as excess moisture, which can lead to mold growth, and combustion products from sources like cookstoves or unvented fuel-fired space heaters. When such indoor conditions cannot be adequately controlled, ventilation may be needed, using such strategies as operable windows if emergency generation is not available.

Buildings with robust envelopes and grid-interactive efficient energy systems can also help prevent power outages by making demand response programs, such as those that enable the utility to set back thermostats remotely during extreme weather, more effective. They can do this by extending the time period over which indoor temperatures stay within a defined range, which in turn extends the time period during which a utility can keep the HVAC system off.

Thermal insulation

Insulation can be applied to attic floors, roof rafter cavities, exterior wall cavities or continuous surfaces, as well as floors exposed to unconditioned basements or crawlspaces, and to basement walls. Common insulation materials include:

- Fiberglass rolls or “batts”, which are designed to fit in framing cavities in walls, attic floors, and similar spaces; this kind of product is used both by builders for new construction, and in retrofits, which can include do-it-yourself projects;
- Loose-fill fiberglass, which is blown into cavities or open spaces using special contractor equipment; loose-fill is most often used to insulate unconditioned attic floors (the ceilings of topmost conditioned floors), but can also be applied to wall cavities;
- Loose-fill cellulose, blown similarly to fiberglass;
- Foam insulation, installed using special contractor equipment; because it typically has adhesive properties, foam can be applied to almost any space; and
- Rigid-board insulation, most typically applied to the outside of exterior walls to provide a continuous-insulation barrier, typically in addition to insulated wall cavities to yield a very well-insulated wall assembly.

Insulation is technically easiest and most cost-effective to install at the time of construction, when all walls, attics, and other spaces are exposed and contractors can easily access them. When energy codes specify certain levels of insulation, builders can design the framing to accommodate those levels. For retrofits, some spaces can be harder to access; wall cavities must be accessed by making holes in exterior siding or interior wall finish materials, but this can be messy and expensive. Open attics, by contrast, can be easier for contractors to access, and thus attic insulation is the most common retrofit measure for typical smaller wood frame buildings.

Pros: Insulation products are widely available, as are the contractors to install them, for most kinds of building retrofits; and robust insulation levels are typically required in modern building codes.

Cons: Insulation retrofit jobs can be expensive, especially if they involve accessing closed cavities. And if insulation and sealing work reduces air infiltration rates, indoor air quality problems can be exacerbated, and should be mitigated with a combination of source reduction and mechanical ventilation.

Resources

- Energy Star's webpage Why Seal and Insulate? outlines the benefits of insulation and Methodology for Estimated Energy Savings from Cost-Effective Air Sealing and Insulating provides guidance on how to estimate utility cost savings dependent on region of the United States.
- DOE's Insulation discusses how insulation works and types of insulation and insulation materials and provides relevant resources to learn more.
- Urban Green Council's Baby It's Cold Inside 2014 study of indoor temperatures in well-insulated vs. poorly-insulated buildings illustrates the benefits of insulation for preventing hypo- and hyper-thermia.

High-performance windows

Windows have undergone a technical revolution in the last 40 years, based on the development of low-emissivity (low-e) coatings, which are invisible, microscopically thin layers of special materials that selectively block heat gain and/or heat loss while letting most visible light through. High-performance windows, such as those earning the ENERGY STAR label, use low-e coating technology and other features to provide maximum energy efficiency appropriate to the local climate. Low-e coatings have reduced heat loss or gain by more than half; what's more, today's model energy codes such as the International Energy Conservation Code (IECC) have captured the benefits of low-e glass in their window standards, and have also included replacement windows in code requirements, so the vast majority of residential windows sold today have this kind of low-e performance.

Pros: Window replacement is a relatively straightforward process, with contractors available in most markets and high-performance low-e product mostly standard in the residential and small commercial markets.

Cons: Like insulation projects, window replacements can be expensive. But if windows are going to be replaced, the incremental cost of high-performance windows can be very low.

Resources

- DOE EERE's High-Performance (Energy Star) Windows outlines information and resources necessary for understanding and installing high-performance windows.
- ENERGY STAR's Guide to Energy-Efficient Windows factsheet discusses the benefits of Energy Star-qualified windows, selection and installation factors to consider, and relevant resources.

High-efficiency heating and cooling equipment

HVAC systems have also made advances in energy efficiency in the last 40 years, with minimum-standard equipment typically twice or more as efficient as models sold prior to federal efficiency standards. High efficiency in the context of this guide means equipment that exceeds federal minimum efficiency standards, such as models earning the ENERGY STAR label. HVAC equipment lives tend to be 20 years or less, and this creates natural replacement cycles that can help drive efficiency gains as the stock turns over. This replacement cycle contrasts with insulation, which has no natural lifecycle to drive upgrades; and windows can last much longer than HVAC, making those replacements less common.

Buildings' electricity grid interactivity is increasingly important to meeting energy resilience objectives; and technology advancements in this area are increasing enabling cost-effective solutions. Grid-interactivity enables demand flexibility by creating time-sensitive capabilities in HVAC and other building energy equipment and systems. Demand flexibility allows grid operators to draw on building systems for short-term control sequences that reduce a building's peak demand; when aggregated across a large number of buildings, these strategies make grids more resilient by reducing total system peak demand, and thus reducing the risk of outages.

The key with replacement HVAC systems is not only to upgrade their efficiency, but to size them correctly. Sizing practices for some contractors date from the era of poorly-insulated buildings, where large HVAC systems were needed to keep up with the high energy loads that under insulated buildings create. Ideally, insulation and windows upgrades should precede HVAC upgrades, so that the new system is both efficient and rightsized. This improves overall performance and reduces the size of HVAC systems. And when HVAC systems are smaller, they cost less and thus can offset the cost of envelope upgrades.

Pros. Efficient HVAC equipment is widely available, and can be installed cost-effectively when existing equipment needs replacement. Moreover, Inflation Reduction Act tax credits and rebates are available to reduce costs. Many utilities also offer demand flexibility programs with incentives for peak reduction.

Cons. When building envelope conditions are substandard, HVAC systems can be oversized, and their efficiency can be reduced. Such oversizing also increase peak demand, which reduces grid resilience. Ideally, envelope performance should be improved prior to or in concert with HVAC upgrades.

Resources

- DOE EERE's Heating, Ventilation, and Air Conditioning (HVAC) provides an overview of high-efficiency HVAC installation.
- ENERGY STAR labeled products are available across most HVAC system types.
- EPA's Energy Efficiency in Local Government Operations provides guidance to local governments on how to improve energy efficiency of their facilities and operations. The guide includes recommendation that incorporate HVAC systems.
- DOE's Grid-Interactive Efficient Buildings Technical Report series, which documents the research and program experience in this area.

4.2.2 Energy supply solutions

Backup diesel or gas generation

As the most common resilience solution in place today, on-site backup generation allows a facility to maintain at least partial operation in a blackout. The Occupational Health and Safety Administration requires hospitals to have backup generation to serve all lifesaving equipment and emergency lighting for at least two hours – though most hospitals maintain fuel reserves to provide emergency power for as much as 72 hours. Other first responders like police, fire, and utility lines crew facilities also typically have backup generators on hand, but not always. Backup generation is a relatively inexpensive option to install if what is needed is a short period of power on an infrequent basis, however the per hour operational costs can be quite high and these systems need to be maintained and test run regularly.

Pros: Backup generation exist in many facilities today and can operate indefinitely if additional fuel is secured.

Cons: Backup generation emits high pollution levels. It is also an expensive solution if used for extended periods. It typically only picks up emergency operations, meaning it is a sunk cost whenever the grid is up.

Resources

- NREL's A Comparison of Fuel Choice for Backup Generators discusses the costs and benefits of diesel vs natural gas backup systems, including case studies of installed systems.
- Reliability of emergency and standby diesel generators: Impact on energy resiliency solutions assesses the reliability of diesel backup generators during an extended power outage.
- DEPCO's Natural Gas vs Diesel Generators: The Pros and Cons provides a simplified overview of the pros and cons of using diesel vs natural gas generators.
- This solution may have air quality and emissions implications, as discussed in Using backup generators for meeting peak electricity demand: a sensitivity analysis on emission controls, location, and health endpoints.
- Diesel Back-up Generator Population Grows Rapidly in the Bay Area and Southern California discusses a case study on the effects of a rapid increase in diesel backup generation in California.

Energy storage

Energy storage allows facilities to operate when the grid goes down but can do so much more. It can allow the facility to shave peak demand by charging the battery during off-peak times and discharging during peak times. It can facilitate the use of intermittent power sources like solar and wind by shifting usage of that energy to other times of day. Batteries can even provide ancillary services to the electrical grid like frequency regulation.

While batteries are currently the primary form of new energy storage, not all batteries are the same. Lithium-ion batteries have increased in efficiency and reduced in cost to the point that they are the market leader for most applications. However, the industry is developing new battery formats and chemistries each year. There are other energy storage types worth considering as well. Flywheels, pumped hydro and pumped air systems store energy mechanically. Thermal storage includes storing heat or cold in various mediums - in high cooling-degree day climates, ice storage has been highly successful in building applications. Finally, hydrogen storage involves using electricity to separate hydrogen from water and then using fuel cells to run that process in reverse to create electricity.

Pros: Energy storage can handle high amounts of load for short periods of time, and can be used for other use cases (like peak demand shaving or peak shifting).

Cons: Energy storage is expensive – likely too expensive to handle considerable amounts of load. Typically, energy storage is used for a shorter duration, and is not optimal as a long-term solution.

Resources

- DOE's Energy Storage Handbook provides a comprehensive overview of grid-level energy storage, including high-level technical discussions of current technologies, industry standards, best practices and lessons learned, challenges, and other general guidance. The guide is broken down into three sections: Energy Storage Technologies, Engineering Storing Systems, and Applications and Markets.
- USAID's Energy Storage Decision Guide for Policymakers is targeted to support decision makers by providing relevant information to understand grid-connected energy storage and make informed decisions. This guide includes case studies and lessons learned. It does not discuss procurement practices for energy storage.
- The New York State Battery Energy Storage System Guidebook provides an overview of battery energy storage, as well as tools and step-by-step instructions for local governments to manage these systems and their development. The guidebook provides a state-specific example with the purpose of supporting the target audience.
- New Carbon Trust's Energy Storage Guide provides an overview of battery electricity storage, including types of available systems, benefits, and costs. However, this guide is targeted for SMEs.
- The DOE Better Buildings Energy Storage Guide covers the basics of energy storage, potential benefits/incentives, and procurement options for anyone looking to add energy storage to a single/multiple commercial building.
- ACP's Energy Storage Case Studies webpage provides links to case studies of energy storage usage.
- NYSERDA's New York State Energy Storage Study offers a case study, and evaluated the economic viability of energy storage system projects in the State.
- Massachusetts DOER's Mobile Energy Storage Study – Emergency Response and Demand Reduction assesses the ability for energy storage solutions to be mobile and thus able to be physically dispatched to locations, as needed, to expand resilience.

Renewables plus storage

Locally sited solar or wind projects alone do not provide a resilience solution because they are typically not able to operate when the grid is down. In fact, every inverter for distributed energy resources like this must, by design, shut down when not connected to a grid as a safety precaution – ensuring they do not send electrons into downed lines putting people and lines workers at risk. Even if a renewable resource was disconnected from the grid, it would not be a suitable source of electricity for a building or campus unless it had additional equipment (such as energy storage) to smooth out the flow of power. Without this, the ebb and flow of electricity would create inconsistent power at best and, at worst, damage equipment. For this reason, coupling these resources with energy storage creates a system that (with the appropriate switchgear in place) can run independently from the grid. See Figure 12 for a conceptual design of a solar plus storage system.

The most common storage solution for this application today is electric batteries, though ‘green hydrogen’ is advancing as a solution, where excess renewable power can be used to create hydrogen through electrolysis, and the hydrogen can be stored and used as needed to fuel power generation turbines or fuel cells.

Pros: Coupling renewables with storage allows for at least some level of long-term energy during an energy outage. These systems can be leveraged year-round for cost savings from reduced kWh and peak demand charges.

Cons: These systems are more expensive than solar alone and highly expensive if enough energy storage to operate 24-hours per day is installed. They require considerable land/roof space for solar photovoltaic (PV) panels. Wind and solar are intermittent energy sources that may become less effective in cloudy, smokey, or extremely windy conditions.

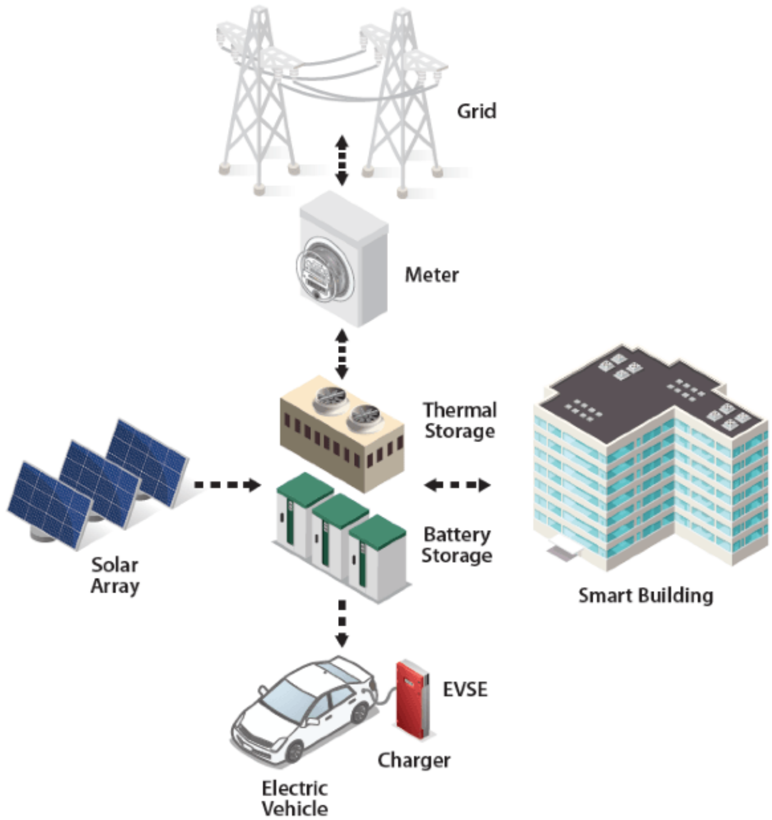

Figure 12: Solar plus storage system's conceptual design[67]

Resources

- American Cities Challenge's Solar and Storage for Cities discusses two application options of behind-the-meter (BTM) solar-plus-storage at city and county facilities: (1) peak load shaving/peak demand shifting and (2) emergency power.
- Evaluating the Capabilities of Behind-the-Meter Solar-plus-Storage for Providing Backup Power during Long-Duration Power Interruptions estimates the ability of BTM solar PV-plus-storage in providing critical-load or whole-building backup during long-term power outages. The study found that in most outage events, homes with a 30kWh storage system would have been able to maintain critical loads.
- Solar-plus-storage economics: What works where, and why? can be used to identify the most economical applications of this solution and understand the key drivers of its viability.
- DOE EERE's Solar-Plus-Storage 101 provides a straightforward and informative overview of this system.
- SolSmart's Solar + Storage: A Guide for Local Governments provides an overview of solar plus storage and its uses/benefits for the target audience, including examples and case studies.
- An Overview of Behind-the-Meter Solar-Plus-Storage Regulatory Design – Approaches and Case Studies to Inform International Applications provides key regulatory considerations for facilitating DPV-plus-storage programs, as well as provides relevant case studies from U.S. States for lessons learned and best practices.
- Where and When Does Solar Plus Storage Make Sense for Commercial Buildings provides an overview of where this solution (solar-plus-storage, specifically) is most viable and why, identifying Alaska, California, Colorado, Hawaii, New Hampshire, New York, and Vermont as the states with the highest potential for solar-plus storage savings.

Thermoelectric generators or turbines

On-site generators differ from backup generators in that these systems are designed to be used year-round and not only in the case of emergency. They typically use natural gas but could also use renewable natural gas or another fuel. These systems tend to work best in times and places where the "spark spread" allows facilities to generate electricity at a lower cost than the equivalent cost from the power grid.[68]

Pros: Generators can provide large amounts of baseload power. They are considered a mature, reliable technology. Gas delivery infrastructure is more resilient than the electrical grid.

Cons: Generators require an external fuel source (gas lines are not invulnerable), reducing the resilience factor. Turbine systems are complex and highly technical, and require trained staff to maintain. These systems are associated with high initial costs and are not ideal for smaller applications. They require a dedicated space to operate and may require constructing a new facility to house them. While efficient, these systems still use non-renewable fossil fuels, produce local air pollution, and contribute to climate change.

Resources

- Thermoelectric generators: A review of applications reviews current applications of thermoelectric generators.
- Cost Estimation of Thermoelectric Generators assesses the cost of thermoelectric generators.
- Thermoelectric generators act as renewable energy sources reviews how TEG can be used as a renewable energy source. The paper includes background information on how a TEG works and its existing applications.

Combined heat and power (CHP)

Improving upon the approach above, CHP uses generators or turbines but captures the waste heat of that process, utilizing it to generate heat (for thermal comfort or industrial processes) or cooling through absorption chilling. This process makes any on-site generation more efficient and more environmentally friendly. See Figure 13 for common CHP figurations.

Pros: CHP provides all the pros of combined-cycle gas turbines or fuel cells but with increased system efficiency. It provides heat as well as power, further contributing to the resilience of institutions using these systems. CHP can be purchased as a pre-packaged system to reduce project complexity.

Cons: CHP has all of the cons of combined-cycle gas turbines or fuel cells with slightly more cost and complexity. It requires infrastructure to transport hot water or steam between buildings to be effective across a portfolio. Creating cooling with these systems requires expensive absorption chiller technology.

[67] "Behind-the-Meter Storage Consortium," *NREL*.
[68] "Spark spread," *Energy KnowledgeBase*.

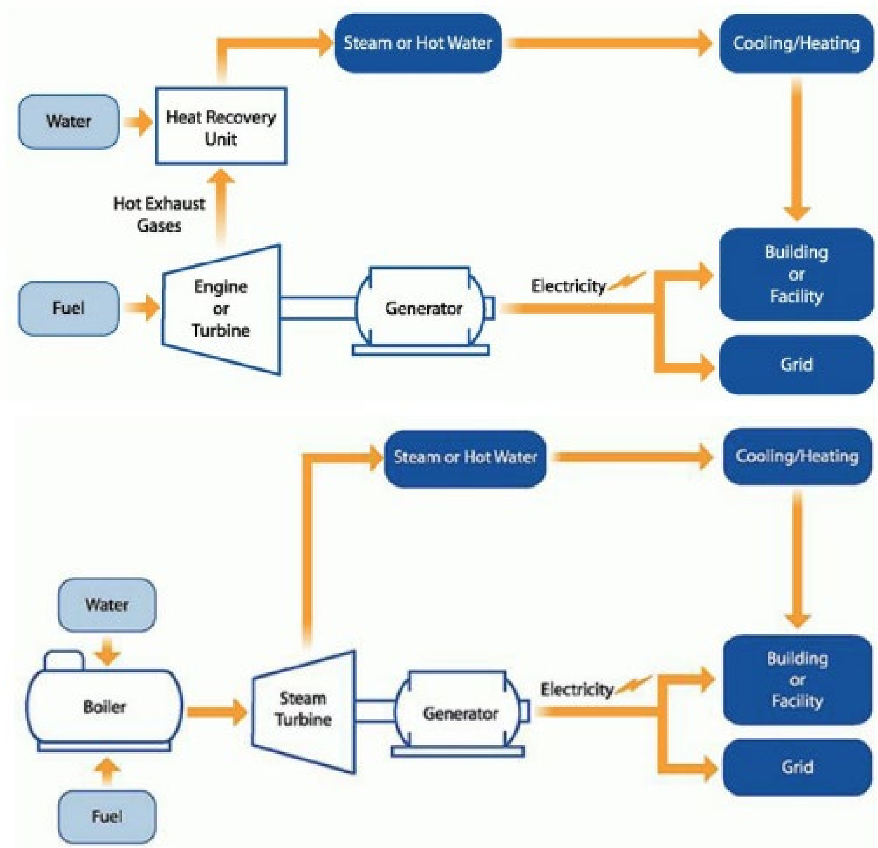

Figure 13: Two common CHP configurations: (1) Reciprocating engine or gas turbine with heat recovery (top), and (2) Boiler with steam turbine (bottom)[69]

Resources

- EPA's Combined Heat and Power: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs is a GHG strategy for local governments, and discusses how local governments can act as leaders in the uptake of CHP. The guide provides an overview of CHP systems, and its benefits, costs and funding sources, and case studies.
- DOE EERE's Combined Heat and Power Basics provides a straightforward and informative overview of CHP, with links to other resources.
- The DOE Better Buildings Combined Heat and Power (CHP) for Resiliency Accelerator webpage links examples from Better Buildings Accelerator partners for CHP solutions for successful resilience planning and implementing.
- EPA's CHP Benefits provides a quick overview of the benefits of CHP systems, including for efficiency, environmental, economic, and resilience/reliability.
- ASHRAE's Combined Heat and Power Design Guide outlines technical information on the application and operation of CHP systems, with the purpose of guiding the assessment of a site's potential for CHP systems. The guide's audience is system designers.
- ESC CHP Case Studies webpage offers linked case studies organized by market segment and prime mover technology type.

[69] Overview of CHP Technologies, *Combined Heat and Power Technology Fact Sheet Series*, DOE (2017).

4.2.3 Microgrids

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or disconnected ("islanded") from the grid. While a solar+storage or a CHP-only microgrid exist, most microgrids today involve combining multiple generation resources, energy storage, and advanced building energy management controls to allow for instant demand response.

These systems, while much more complex than simple efficiency improvements or backup generation, create islands of energy resilience where groups of buildings, campuses, or even entire small communities can continue full operation when the utility grids are down. See Figure 14 for an example microgrid.

Pros: Microgrids can provide a much more robust energy solution. They provide an indefinite energy source during an energy outage. They can be leveraged year-round for cost savings from reduced kWh and peak demand charges. Microgrids are ideal for sites with multiple buildings, and are the best solution for campuses that require energy resilience. Excess heat from CHP used in microgrids can be used for either heating or absorption chilling.

Cons: Microgrids are a highly engineered solution that can be expensive. Connecting facilities of different organizations creates operational and financing complexities.

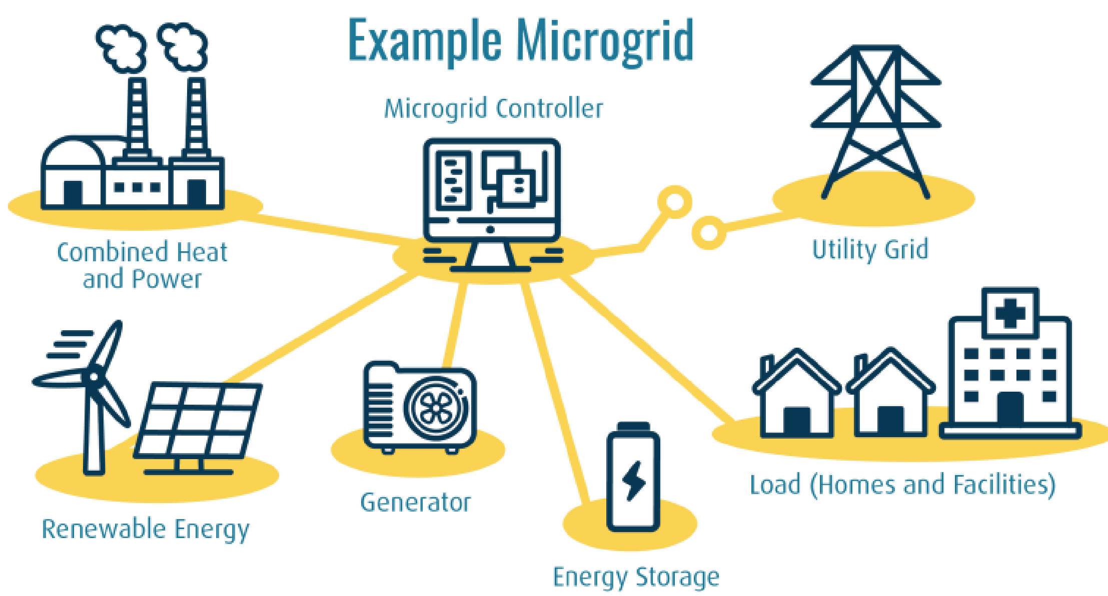

Figure 14: An example microgrid including multiple resource types with a point of common coupling with the utility grid[70]

[70] Microgrids State Working Group, National Association of State Energy Officials (2023).

Resources

- C2ES Microgrids: What Every City Should Know provides an overview of microgrids for cities. The factsheet argues that microgrids can be a solution to local challenges, describe existing legal/financial barriers, and outline the role for local governments. A deeper dive into some of these topics can be found in Microgrids Momentum: Building Efficient, Resilient Power.
- DOE's Better Buildings Microgrids 101 provides a straightforward overview of microgrids, along with case studies and additional relevant links.
- Microgrids: Overview and guidelines for practical implementations and operation provides a review of the main design features of current microgrids, and guidelines for the monitoring, operation, and implementation of microgrids.
- New Jersey Board of Public Utilities' Development of Local Government Resilient Microgrids describes a research project on the NJBPU's approach to procuring/financing "town center microgrids." The report discusses challenges and recommendations.
- The DOE Energy Transitions Initiative Microgrid Conceptual Design Guidebook's purpose is to support communities in the development of a conceptual microgrid design that meets site-specific energy resilience goals.
- California Energy Commission's Microgrid Analysis and Case Studies Report – California, North America, and Global Case Studies dives into numerous microgrid case studies that make innovative business cases, to provide high level takeaways for lessons learned and best practices.

4.3 Defining and selecting government actions to reduce risks

However your community is defined in geographic or legal terms, it will be important for your local government to consider its potential capacity and actions to plan for, implement, and finance energy resilience. This section summarizes options that government officials and other community leaders can take in this area.

4.3.1 Implementing building codes and other regulatory strategies for energy efficiency and resilience

Energy vs. other codes. Much of the resilience focus localities have given to building codes have dwelt on structural and related storm resistance; for example, building codes in Florida and South Carolina were overhauled following the damage wrought by Hurricanes Andrew and Hugo in the 1990-1992 timeframe. This guide's resilience focus places more emphasis on the energy side of the codes world and the benefits that energy codes can bring to local energy resilience strategies.

Building codes cover many technical subjects, from structural to electrical, plumbing, and mechanical systems. Over the past 30 years, energy has become its own code; under federal law, states are required to consider the IECC for residential buildings and ASHRAE Standard 90.1 for commercial buildings. Most states now use the IECC or 90.1 as their official codes, and in most states local governments are required to administer and enforce them. This guide uses these model codes for reference, though as discussed above some states and localities use different documents.

Localities' roles in code adoption and enforcement. Most localities are charged with administering and enforcing a range of building codes under state law. Typically, state law governs the specific codes that must be enforced; some states operate under "home rule" legal frameworks, in which localities can set their own codes. There are many 'flavors' of home rule depending on the state; this guide is written for localities whose state laws limit their options for which codes they enforce.

Building codes primarily address new construction; but they can also be applied to other building activities that require building permits, including building additions, renovations, and alterations. Window replacements, for example, are covered in the IECC by the same thermal performance standards required for new construction.

Other regulatory strategies. Beyond codes, some jurisdictions are pursuing other regulatory measures, including:

- **Mandatory energy performance benchmarking and disclosure.** More and more local governments are requiring building owners to measure and report publicly on their energy performance. While such regulations do not require building upgrades per se, they make energy performance visible in the marketplace, and can motivate building owners to upgrade their performance. In practice, benchmarking regulations have been applied mainly to larger buildings (e.g., 25,000 square feet or larger).[71]
- **Building performance standards (BPS).** Some local governments have gone beyond benchmarking requirements to mandate specific improvements in measured building performance. Using the same data analysis tools that benchmarking involves, BPS typically require buildings to achieve defined levels or percentage of improvement, measured in terms of on-site energy use, or in some cases, carbon dioxide emissions.[72]

4.3.2 Creating resilience hubs in public and private facilities

During an EPO, there are times when sheltering in place without power simply is not an option. This is especially true for extreme temperature events where the lack of heating or air conditioning makes homes unlivable. It is also true in evacuation events like hurricanes, tornadoes, or flood events when staying at home can be dangerous. In these circumstances, the best solution is typically a central community facility where extra resilience measures have been taken. These measures will typically include on-site power generation or a microgrid. Providing some basic electricity to charge space heaters or refrigerators for medicine can be lifesaving. In our highly connected world, power to charge cellular devices goes a long way toward lowering anxiety levels. These hubs are optimal spots for relief supplies, first aid, and community communication and coordination. Creating this central location for services and information makes finding help easy for community members and gives first responders a single point of interaction.

Resilience hubs can be sited at existing facilities like community centers, schools, sporting facilities, or other government buildings. Some key characteristics for a community resilience hub include:

Centrally located to ensure that as many community members can access the facility as possible. Special consideration should be given here to populations at greater risk as their needs for heating, cooling, and evacuation are likely to be greater. Another location consideration might be proximity to local health facilities.

Under local government control so that local planners can invest in resilience measures for this facility and store community resources on-site.

Highly energy efficient with an excellent thermal envelope. This will allow the facility to make the most of any generation placed on-site.

Away from (or protected from) likely hazards. This means that the facility should be away from sources of water that might flood due to topography or storm surge. It should also be sited away from power lines or large trees that might damage it if blown over.

On a priority circuit for utility reconnection by the electric utility. Utilities work with communities to identify which circuits require greater resilience and should be prioritized for reconnection during outage events. Even if on-site generation is installed, full utility connection will ensure maximum energy security at this most critical location.

Hubs work best when people in the community know about them and feel safe using them. They work better still when (if community size warrants it) they are combined into a network of hubs that can support each other. The Urban Sustainability Directors Network has excellent resources to better understand the

[71] Benchmarking and Disclosure: State and Local Policy Design Guide and Sample Policy Language, SEE Action (2012).
[72] "Building Performance Standards," *IMT* (2023).

roles resilience hubs play and a deep dive on technical systems that can be employed at these locations. Several cities have made resilience hubs work for them like Minneapolis, Baltimore, Miami, San Francisco, and Vancouver.

4.3.3 Working with energy and water utilities

A community's energy and water utilities can be their most important partners in developing and implementing energy resilience strategies. Some areas of potential joint activity include:

- Identification of critical facilities and populations at greater risk from EPOs;
- Coordinating and practicing emergency response procedures;
- Technical expertise in designing and implementing energy resilience projects;
- Enabling grid integration for energy resilience facilities that include on-site generation or energy storage;
- Development and deployment of demand response programs in the community;
- Providing community input into long-term utility investments; and
- Supporting building code implementation and compliance, such as energy efficiency programs for new construction that are designed to increase energy code compliance and go beyond code requirements.

Typically, each utility will have a representative to coordinate engagement with local governments around EPO's and disaster response, but that engagement tends to be quite tactical around disaster response. In order to have more community engagement in utility planning for local resilience, consider participating as a stakeholder in the utility's planning efforts. These efforts, which drive the rate plans they will submit to the regulator (or their annual budget in the case of municipal utilities) require collecting and considering stakeholder input. A community in their service territory will have an opportunity to raise concerns and have them addressed in this process. Another option is to communicate directly with utility regulators or legislators to make community needs known. The final avenue for communicating needs is through the permit process – as each utility will need to request permits from the community for their capital improvement projects. Attempting to leverage this avenue to secure utility engagement can be fraught, though, as this happens quite late in the utility investment process – long after meaningful changes should be included in plans.

4.3.4 Pursuing voluntary efforts to fund resilience investments

Regulatory actions such as building energy codes can be an effective strategy for upgrading new and existing buildings; but they also have limitations. Even with active extension of code applicability to existing buildings, the fraction of the total community building stock that codes can reach in a given year is limited by the code's application to projects requiring a permit. In this sense, codes can be viewed as a long-term strategy to transform the building stock over decades. In the nearer term, other approaches are needed if the community wants a more accelerated effort to make over its building stock.

Voluntary approaches to building stock energy improvement typically involve financial incentives in some form. These can come from state-regulated sources such as investor-owned utility ratepayer-funded programs, federal sources such as the multiple clean energy grant programs funded in recent legislation, and a variety of financing mechanisms. Regardless of the source, local governments and community leaders can leverage and promote such options to help drive investments. The subsections below describe these options in more detail.

Federal grant programs

In addition to normal annual appropriations, recent federal legislation including the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA) have created billions of dollars of new federal funds, primarily for existing grant programs. Leading candidates for funds that can support local energy resilience initiatives include:

- The **Weatherization Assistance Program (WAP).** This longstanding federal grant program, administered through state and local community services agencies, can pay for thousands of dollars of home energy upgrades for income-qualified households. The BIL allocated $3.5 Billion for WAP, about ten times its typical annual budget; initial funding began in 2022.
- **Energy Efficiency and Conservation Block Grants (EECBG).** EECBG provides formula (non-competitive) grants to larger units of local government, and directs 28% of total funds to state energy offices for subgrants to smaller units of government. The BIL allocated $550 Million for EECBG; funding is expected to begin flowing by the end of 2022. Grantees have substantial flexibility in applying EECBG funds, for example to complement WAP funds by making non-energy repairs to WAP-eligible homes.
- **Energy codes training and technical assistance.** The BIL and IRA legislation provide over $1 billion for state and local governments to adopt, implement, and train on modern energy codes. More information is available through the Department of Energy (DOE) Building Energy Codes Program..
- **Home energy rebates.** The IRA provides almost $9 billion in funding for states to administer home energy upgrade and electrification rebates; these funds will be administered through state energy offices, with funds expected to become available in 2023.

Utility energy efficiency programs. Many utilities offer customer programs to help improve energy efficiency. Depending on the utility and their state regulatory situation, these programs can include incentives to upgrade various building systems. Utilities often provided dedicated program support to disadvantaged communities through limited-income programs; in some cases, such programs can provide more services and higher incentive levels than for average customers. Check with the local electric, gas, or water utility to find out what kinds of programs they may offer.

State and local housing improvement programs. Most states have housing agencies that provide various forms of financing and other support for affordable housing. They often partner with local government agencies and nonprofit organizations to deliver a range of housing assistance, which can include home repair and renovation for qualifying households.

Financing programs. Finding the money to pay for resilience investments in buildings is a universal challenge. There are numerous options for financing such projects; among the most promising are:

- **Property Assessed Clean Energy (PACE) financing.** PACE is a mechanism that recovers the costs of investments through local property tax billing systems. Many jurisdictions use a similar method to collect funds to cover debt service on municipal services such as waste collection or water and sewer. PACE typically requires state legislation to enable it legally, and then needs to be administered at the local level.
- **Pay As You Save (PAYS).** PAYS is a financing mechanism that allows a project to be completed with little to no upfront investment by the building owner. PAYS programs, most often administered by utilities, typically recover debt payments as a fee on utility bills; the programs are usually designed to combine technical assistance to help define the project, incentives to reduce total project costs, and the PAYS mechanism to recover debt service. In some instances, utilities create a special 'tariff' or rate schedule that applies the PAYS mechanism to the building's 'meter address'; that design allows financing terms to be long duration, e.g. 10-20 years, by keeping the payments in place even if the current customer sells the property. The long duration term helps keep debt payments down, so that energy savings can equal or exceed debt payments, producing positive cash flow and making the investment returns positive from the outset.
- **Revolving Loan Funds.** The BIL provided $250 million to help states set up revolving loan funds for buildings energy audits and upgrade projects. Check with the state energy office on the availability, timing and other details. More information can be found at the Energy Efficiency Revolving Loan Fund Capitalization Grant Program webpage.

- **Green Banks.** Several states and local governments have established green banks as financing programs aimed at clean energy and related projects. The IRA legislation creates a $27 billion Greenhouse Gas Reduction Fund to support such efforts, to be administered through EPA. It is expected that as with many BIL and IRA programs, funds are expected to become available starting in 2023. More information can be found at EPA's Greenhouse Gas Reduction Fund webpage.

4.4 Prioritizing technical solutions and government actions to improve energy resilience

With an understanding of the local energy infrastructure and its energy resilience risks, and of the technical solutions and government actions that can concretely address those risks, the next step is to prepare to prioritize the solutions and associated actions needed to realize the potential benefits. While your community will form its own processes for making such choices, it can follow an analogous process to that used in Section 3 to identify and prioritize community needs.

A matrix like that illustrated in Table 2 could be created to summarize and match the solutions best able to address specific risks.

Table 2. Matrix of risks and solutions

Energy systems resilience risks	Solution Options			
	Energy efficiency solutions	Energy supply solutions	Infrastructure improvements	Government actions
Risk A				
Risk B				
Risk C				
Risk D				

Once risks and solutions are summarized and matched, a prioritization method such as that visualized below in Figure 15 could be used to help prioritize the actions that need to be taken.

Prioritizing solutions and the associated actions to increase energy resilience will in most cases require quantifying benefits and costs. These benefits and costs will vary greatly from community to community for different technical solutions. Common benefit types that communities typically seek to include in such processes include:

- Reduction in the frequency and duration of power outages;
- Reduction in life safety risks for those predisposed to face greater health and safety risks;
- Reduction of disaster recovery costs; and
- Reduction of economic losses from EPO events.

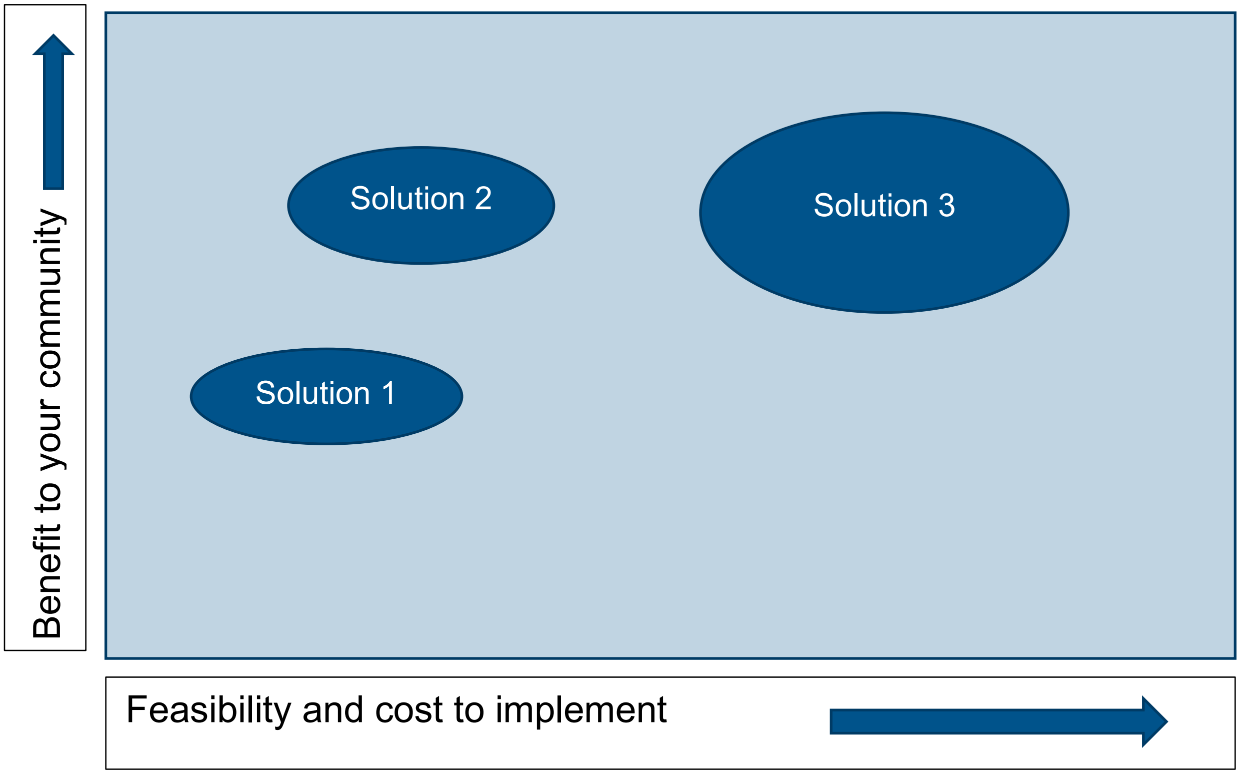

Figure 15: Technical solution priority matrix

Costs are often more straightforward to define, at least in monetary terms. Decision makers typically work hard to identify the least-cost solutions that provide the desired benefits. However, in a changing climate, it is also important to think longer term about emerging risks and their potential to reduce the effectiveness of a given solution. For example, if a community emphasizes diesel generators as its main backup power supply strategy, it can be exposed in the longer term to fuel supply availability and cost risks, as well as future air quality regulations that could restrict the use of such fuels.

5 Developing a community energy resilience strategy

The previous sections of this guide provide the essential elements needed to formulate your community's energy resilience strategy, and its associated plans and investments. Your community will define and pursue its own preferred processes for meeting its energy resilience needs. This guide suggests that an effective process should contain the following elements:

1. A careful assessment of populations in your community particularly at risk to health and safety impacts, and their specific needs related to energy resilience.
2. A specific assessment of the climate-related hazards that most affect energy resilience for your community, such as hurricanes, tornadoes, wildfires, or extreme temperatures.
3. Mapping of the populations' needs to climate hazards.
4. A definition of technical solutions that best meet your community's needs and address key climate-related hazards.
    a. Defining the government actions that are most critical to advancing these solutions.
5. Selecting and prioritizing the solutions that best meet your community's needs at the most acceptable cost.

Local governments play a critical role in ensuring community's energy outage preparedness and practice. There are a host of existing resources to help guide best practices in developing these sorts of plans:

DOE Better Buildings Energy Resilience in the Public Sector: Webpage of resources/tools for states and local governments related to resilience and energy technologies that can help increase resilience.

DOE Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning: Identifies climate resilient planning as falling into three parts: (1) Establish goals, (2) Conduct vulnerability assessment, and (3) identifying and implementing resilience strategies. It discusses each of these steps in more detail, including specific resilience options.

NREL Power Sector Resilience Planning Guidebook: A Self-Guided Reference for Practitioners: Guidance on power sector resilience planning that is relevant for policymakers. The guidance covers five steps of the planning process. It includes exercises, activities, and discussion questions in each section to guide engagement.

DOE EERE Energy Efficiency and Distributed Generation for Resilience: Withstanding Grid Outages for Less: Provides a short overview of case studies and resources related to efficiency and distributed generation resilience. It also provides some examples estimating system costs to compare those costs with and without efficiency measures.

DOE EERE Energy Transitions Playbook: Guidance on community-driven transitions to clean and resilient energy. It includes a framework that overviews seven phases of an energy transition, along with relevant resources outlining recommended actions for each phase and worksheets, templates, and case studies. The Playbook is useful in that community's can create a plan that address their specific energy resilience needs and goals.

DOE Better Buildings Improve Community Resilience: The Energy-Resilient City: Provides a visual that identifies different options for incorporating resilience into a city. The webpage also provides resources and tools for building resilient communities.

ACEEE Community Resilience Planning and Clean Energy Initiatives: A Review of City-Led Efforts for Energy Efficiency and Renewable Energy: Review of 66 city resilience plans to identify trends, gaps, and opportunities. This includes…

NIST Community Resilience Planning Guide for Buildings and Infrastructure Systems: Outlines an approach to support communities in setting priorities and allocating resources to manage risks, in order to improve resilience. The guide is split into (1) a description of the 6-step planning process and example, and (2) a description of how to characterize a community (and its social/economic context) and monitor building/infrastructure performance.

The Resilient Cities Network is a membership-based organization that can act as a significant resource for support for urban resilience. It brings together hundreds of Chief Resilience Officers (CROs), partners, practitioners, and researchers. There are currently 98 member cities and 52 resilience projects supported. Publications relevant to energy resilience include:

- Resilient Cities Network: Co-creating a Resilient Future 2020-2021: Report outlines the network's efforts, barriers, and future, which includes future investment in equitable/resilient energy transition.

C2ES Resilience Strategies for Power Outages: Fact sheet discusses strategies for local governments to implement to reduce frequency/duration of power outages and increase general preparedness. It discusses costs and benefits of each strategy. It also provides a case study of New Orleans, as wells tools for quantifying co-benefits of the strategies.

Urban Institute The Rise of the Chief Resilience Officer: Reflects on the Rockefeller Foundation's 100 Resilient Cities program (launched in 2013) and its support of establishing CRO roles in local governments. The paper is targeted for cities considering adding a CRO within their city structure. It includes typical characteristics of a CRO (e.g., professional background; where the position fits within the government), general lessons learned, and resources needed to support CROs.

PHE Planning for Power Outages: A Guide for Hospitals and Healthcare Facilities: Identifies some power outage impacts to healthcare facilities, provides questions to ask in order to prepare for an outage, and highlights some existing, relevant resources.

Resources include those that outline financing/funding opportunities for energy resilience implementation and/or improvement, such as:

- DOE Better Buildings Financing for Resilience with Commercial PACE: Discusses how commercial property assessed clean energy (CPACE) financing can be used for increasing resilience of buildings to natural disasters and other threats, which includes energy-related resilience improvements. It includes links to other resources and case studies.

6 Appendix: Additional resources

While this guide includes references and embedded links throughout, there are many other sources of information that communities can use to support their energy resilience strategies. For those looking for a deeper dive on the topics presented in this paper, the resources cited below provide additional sources.

3.2.1: Older adults

- Disaster Resilience Tool Kit (AARP, 2022)
- Climate Change and the Health of Older Adults (U.S. EPA, 2016)
- Climate Change and the Health of People with Disabilities (U.S. EPA, 2016)
- Emergency Preparedness for Older Adults, including COVID-19 (U.S. CDC, 2021)
- Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk (Stone et al. 2021)
- Mortality in Nursing Homes Following Emergency Evacuation: A Systematic Review (Willoughby et al. 2017)

3.2.2: Populations with limited disposable income and/or low wealth

- Understanding and Alleviating Energy Cost Burdens in New York City (NYC Mayor's Office of Sustainability and Mayor's Office for Economic Opportunity, 2019)
- Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts (EPA, 2021)
- Power Outages and Community Health: a Narrative Review (Casey et al. 2020)
- Detroit Activists Push to Hold Utilities Accountable during Power Outages (Catolico & Ignaczak 2022)
- Power Outage Preparedness and Concern among Vulnerable New York City Residents (Dominianni et al. 2018)
- Social Vulnerability to Long-Duration Power Outages (Dugan et al. 2022)
- Behavior Analysis of Socially Vulnerable Households Responding to Planned Power Shutoffs (Ham & Lee 2022)
- Community-scale Big Data Reveals Disparate Impacts of the Texas Winter Storm of 2021 and Its Managed Power Outage (Lee et al. 2022)
- High Energy Burden and Low-income Energy Affordability: Conclusions from a Literature Review (Brown et al. 2020)
- Disaster Resilience Tool Kit (AARP, 2022)
- "'Utility Redlining': Detroit power outages disproportionally hit minority and low-income areas" (Perkins 2022)
- "Utility Redlining: Inequitable Electric Distribution in the DTE Service Area"(We the People Michigan 2022)

3.2.3: Populations with underlying health issues

- Climate Change and the Health of People with Existing Medical Conditions (EPA 2016)
- Climate Change, Health, and Equity: Opportunities in Action (PHI 2015)
- Power Outage Preparedness and Concern among Vulnerable New York City Residents (Dominianni et al. 2018)
- Behavioural and psychological responses of the public during a major power outage: A literature review (Rubin and Rogers 2019)
- Behavior Analysis of Socially Vulnerable Households Responding to Planned Power Shutoffs (Ham & Lee 2022)
- The Impact of Hurricanes Katrina and Rita on People with Disabilities: A Look Back and Remaining Challenges (Frieden 2006)
- Hurricane Preparedness for People with Disabilities Takes Time, Thought (FEMA 2018)
- Morbid Obesity in Disasters: Bringing the "Conspicuously Invisible" into Focus (Gray & MacDonald 2016)
- Planning Considerations for Persons with Access and Functional Needs in a Disaster (Mace et al. 2018)
- Power Outages and Community Health: a Narrative Review (Casey et al. 2020)
- Caregiving in U.S. Gulf States During Natural Disasters and COVID-19 (Boucher et al. 2022)
- Danger and Dementia: Caregiver Experiences and Shifting Social Roles During a Highly Active Hurricane Season (Christensen & Castaneda 2014)
- Health Impacts of Citywide and Localized Power Outages in New York City - PMC (nih.gov)

3.3.1: Hurricanes

- Longer, More Frequent Outages Afflict the U.S. Power Grid as States Fail to Prepare for Climate Change (MacMillian and Englund 2021)
- National Risk Index (FEMA 2022)
- Fourth National Climate Assessment – Chapter 18: Northeast (Dupigny-Giroux et al. 2018)
- National Hurricane Preparedness (NOAA 2022)
- Equity in Resilience: Planning for hurricanes (Sedigh 2021)
- Hurricanes and Health (Dresser et al. 2022)
- As Ida Hit, Homeless, Other Vulnerable People Left Behind (Willingham and Reeves 2021)
- Health Concerns and Perceptions of Central and Coastal New Jersey Residents in the 100 Days Following Superstorm *Sandy* (Burger and Gochfield 2014)
- Energy Equity Project Report (University of Michigan – School for Environment and Sustainability 2022)
- "As Ida Hits, Homeless, Other Vulnerable People Left Behind" (Willingham and Reeves 2021)
- Reinforcing Inequalities: The Impact of the CDBG Program on Post-Katrina Rebuilding (Gotham 2014)
- "Katrina battered Black New Orleans. Then the recovery did it again." (Williams 2020)
- In the Eye of the Storm: A People's Guide to Transforming Crisis & Advancing Equity in the Disaster Continuum (NAACP)
- How Climate Change May Be Impacting Storms Over Earth's Tropical Oceans (Buis 2020)
- Figure Source: Climate Change Indicators: Tropical Cyclone Activity (EPA 2022)
- The Federal Program to Rebuild After Hurricane Katrina Shortchanged the Poor. New Data Proves It. (Chou 2022)

3.3.2: Wildfires

- Wildfire Mitigation Webinar Series (DOE Office of Electricity 2021)
- National Risk Index (FEMA 2022)
- Prepare for a Wildfire: Power Outage Information (CAL FIRE)
- "“We need the food that we lost.” Low income families still reeling from blackouts" (Botts 2019)
- Resilience Strategies for Wildfire (Huber 2018)
- Climate Change and the Health of People with Chronic Medical Conditions (EPA 2022)
- Network Resilience: 2022 Collaboration Paper on Network Resilience (NSW/ACT/TAS/NT 2022)
- The Unequal Impacts of Wildfire (Headwaters Economics 2021)
- Evaluating Rural Pacific Northwest Towns for Wildfire Evacuation Vulnerability
- Energy Equity Project Report (University of Michigan – School for Environment and Sustainability 2022)
- In the Eye of the Storm: A People's Guide to Transforming Crisis & Advancing Equity in the Disaster Continuum (NAACP)
- Utility Public Safety Power Shutoff Plans (De-Energization) (California Public Utilities Commission 2022)
- Figure Source: Climate Change Indicators: Wildfires (EPA 2022)
- Figure Source: National Risk Index: Wildfire (FEMA 2022)
- The Unequal Vulnerability of Communities of Color to Wildfire (Davies et al. 2018)

3.3.3: Extreme Heat

- Resilience Strategies for Extreme Heat (Center for Climate and Energy Solutions [C2ES] 2017)
- "How to adapt your city to extreme heat" (C40 Knowledge 2021)
- Excessive Heat Events Guidebook (EPA 2006)
- Extreme Heat Safety Social Media Toolkit (DHS 2022)
- The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (USGCRP 2016)
- Heat Waves, Aging, and Human Cardiovascular Health (Kenney et al. 2015)
- "Heat waves aren't going away. Here's how we can prepare" (Schelenz 2022)
- Assessing Health Vulnerability to Climate Change: A Guide for Health Departments (CDC 2014)
- Morbidity and Mortality Weekly Report (MWWR): Heat-Related Emergency Department Visits During the Northwestern Heat Wave — United States, June 2021 (CDC 2021)
- Inequality in the Availability of Residential Air Conditioning across 115 US Metropolitan Areas (Romitti et al. 2022)
- Highlights from "Hazardous Heat" (First Street Foundation 2022)

3.3.4: Extreme Cold

- 2022-2023 Winter Reliability Assessment (NERC 2022)
- "Why Does the Power Go Out When It's Cold?" (National Geographic 2014)
- "Effects of cold and snowy weather on the design of switchgears and proposed solutions" (Sepehri 2021)
- Extreme Cold: Emergency Preparedness and Response (National Center for Healthy Housing, 2022)

3.3.5: Flooding

- Climate Change Indicators: Heavy Precipitation (EPA 2022)
- 2022 Sea Level Rise Technical Report (NOAA 2022)
- What are the Main Causes and Effects of Floods Around the World? (Earth.org, 2021)
- Long-term trends in storm surge climate derived from an ensemble of global surge reconstructions (Tadesse et. al., 2022)
- Vulnerability of US Energy Infrastructure to Coastal Flooding | National Academies (National Academies of Sciences, Engineering, Medicine, 2018)
- Power system resilience to floods: Modeling, impact assessment, and mid-term mitigation strategies (Souto et. al., Science Direct, 2022)
- The Future We Don't Want (C40 Cities, 2018)
- Water Retention in Nature-Based Solutions—Assessment of Potential Economic Effects for Local Social Groups (Zwozdiak et al, 2020)