Resilient Energy Platform

Mini-Grids and Climate Resilience

Background: Clean Energy for Remote Communities

Reliable and affordable energy can drive economic growth, development, and improved health and security. Yet communities in remote locations often lack access to energy service, hampering their ability to develop. Mini-grid systems can often help solve this problem. Mini-grids provide electric power generation, storage, and distribution, and often harness renewable energy from solar, wind, hydro, biomass, and biogas (IRENA, 2018). Mini-grids are sometimes connected to the main grid, but they are also implemented in communities that are separated from central power grids along the "last mile" (UN, 2018). Ultimately, mini-grids provide low-emission and resilient power systems that promote power reliability, increased income, and improved communications and access to information for the communities they serve (IRENA, 2018).

What Is Power Sector Resilience?

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

Figure 1. Mini-grids can drive socioeconomic development in remote communities by producing and distributing affordable and clean energy (Image: Shutterstock).

Mini-grids are frequently proposed as a low-emission solution for energy resilience in the face of natural hazards and climate change, particularly as a backup source of power that can be islanded if the larger grid fails. However, mini-grids are also frequently implemented in remote communities that do not have reliable connections to the bulk power system. While mini-grids can offer strong climate resilience benefits, it is important for energy system planners to be aware that they also can be vulnerable to many of the same hazards that impact the bulk power system. Considering these risks is particularly important in places where mini-grids serve as the only source of electricity.

Whereas the bulk system may have standards and procedures in place to address at least some hazards, mini-grids are implemented on a local scale by a diverse range of planning actors. This requires stakeholders to take initiative in planning for natural hazards and climate change. Through climate-smart planning, actors can ensure mini-grid climate resilience and safeguard sustainable clean energy for the communities they serve.

How do mini-grids work?

Mini-grids are small-scale electricity generation, storage, and distribution systems. Mini-grids commonly have an installed capacity of 10 kW–10 MW and are generally outfitted with contingency measures to help maintain system reliability (IRENA, 2016). For example, temporary interruptions to or decreases in renewable energy generation can be buffered by energy storage using battery banks and conventional backup diesel generators. Distribution sub-systems then transmit energy to the community for consumer use. Ultimately, optimal mini-grid designs permit eventual integration into the central power grid, which increases longer-term system reliability and energy supply in rural communities.

Climate risks to power systems

Natural hazards pose risks to all power systems. Bulk power systems face increasing risks from climate change through increasing air temperatures, precipitation, and severe weather extremes, potentially causing efficiency and performance losses and direct damage to power systems. Mini-grids are vulnerable to similar natural hazards. Planners should prepare for climate change impacts to ensure that mini-grids operate as intended, whether as stand-alone systems or integrated within the larger grid (USAID, forthcoming). The resilience benefits of mini-grids are only as strong as the resilience of the mini-grids themselves.

Mini-grids in a warming world

Planners should consider the range of underlying climate impacts that pose a risk to the community benefits mini-grids provide. For example, higher temperatures limit energy production and storage by decreasing output capacity from photovoltaic cells and wind turbines, as well as reducing battery efficiency and lifespan. Batteries used for energy storage represent one of the most expensive components of mini-grid installations, and their lifespan can be significantly reduced due to temperature stresses on decadal timescales (see text box on Ghana's experience). Because a warmer atmosphere holds more water vapor, future solar generation could be further reduced by increasing cloud cover and decreasing solar radiation. In addition, higher temperatures can further diminish distribution line capacity. Simultaneously, increasing temperatures and more frequent heat waves increase cooling demand and load, which, combined with efficiency losses, add stress to mini-grid systems operating near full capacity.

Climate-related hazards such as strong storms, flooding, and sea level rise could become more intense in a warming world, amplifying challenges for mini-grids exposed to these events. Strong storms could become more frequent and intense (IPCC, 2013), which increases the possibility of wind- or debris-related damages to solar panels, wind turbines and distribution networks. Mini-grids located in low-lying areas along the coast or in small island communities will experience more frequent flooding from coastal inundation associated with storm surge and rising sea levels.

Logistical challenges

The remote and isolated locations in which mini-grids are frequently implemented as standalone power systems can exacerbate these challenges. Communities may have limited technical support, spare parts, or maintenance capacity to address impacts associated with climate change.

Changes in demand

Finally, installed energy capacity may be insufficient to keep pace with rising demand driven by increasing temperatures and by changing consumer expectations. At the same time, demand may be amplified by increased migration into newly electrified communities, attracting residents seeking power service to improve their living conditions and livelihoods.

Measures to increase mini-grid climate resilience

While all types of power system technologies face climate risks, mini-grid planners can devise strategies and standards to anticipate, prepare for, and adapt to climate change. Actors should consider a broad array of measures to address resilience, reliability, and efficiency losses across mini-grid system components. Once planners and designers understand potential climate risks, they can prioritize responses.

Below are several recommendations that work to address climate resilience and ensure sustainable energy supply to mini-grid communities. These strategies include structural hardening, measures to improve reliability, and demand management techniques.

Mini-grid designs should implement structural measures to mitigate risks from climate change. For example, integrating hardening measures into mini-grid systems, such as protecting distribution lines from flood zones and trees blown down by high winds, will increase system reliability. Other examples of hardening measures include incorporating lightning grounders at power generation sites and ensuring braces and equipment to reduce damage from storms. Mini-grid systems should include low-cost cooling technologies to combat warming temperatures, such as fans or heat pumps designed to streamline airflow. Battery banks designed with cooling technologies will help prolong battery cell lifespans, particularly in locations where ambient temperatures already exceed the optimal battery operating range.

Increasing capacity for reliability, such as including additional battery banks where economically feasible and ensuring backup diesel generator functionality, can help smooth variations in renewable energy sources, such as solar and wind, and reduce the occurrence of power outages. Finally, in order to lower energy demand and reduce system stress, development projects should focus on increasing the use of highly efficient appliances among consumers and end users.

Cooperation and coordination between planning actors and communities are critical to mini-grid climate resilience.

Communities should have the necessary tools and capacity to ensure mini-grid systems are well maintained and operate as intended. For example, communities should regularly engage in tree trimming to mitigate the impact of tree falls during storms and have access to spare parts and technical expertise to fix damage. Finally, increased communications and early warning systems could help alert communities to secure critical mini-grid assets in advance of extreme weather events.

To inform these decisions, mini-grid planning should proactively incorporate assessments of climate change risks. Integration of climate change impact assessments and knowledge about local exposure to climate hazards, such as flooding and extreme heat, will help developers better equip mini-grids for climate resilience in the coming decades. Mini-grids designed with capacity to accommodate both expected increases in cooling demand and efficiency losses due to higher temperatures and more frequent heat waves will help achieve power system resilience. This may take the form of expanded power generation, as well as design features that reduce efficiency losses. Table 1 summarizes climate risks, impacts, and potential resiliency measures for mini-grids.

Ghana Mini-Grids and Climate Resilience

The Government of Ghana implemented five mini-grid systems in remote areas of the Lake Volta Basin as part of its goal to provide sustainable energy for all. To reduce investor risk and ensure sustainable energy, the USAID-funded Integrated Resource and Resilience Planning (IRRP) project supported a 2018 assessment of long-term potential climate change impacts on the mini-grid systems (USAID, forthcoming). The assessment characterized how mini-grid components may degrade or become less efficient in a warmer world. For example, increasing dust concentration on solar panels can reduce solar PV output and cause hot spots that degrade panels. Sea level rise and larger storm surges could flood distribution poles and disrupt energy supply near coastal locations. In addition, reluctance to use backup diesel due to high fuel costs and a lack of spare parts disrupt long-term mini-grid reliability. Measures to reduce these effects, such as increasing battery storage capacity or implementing low-cost cooling systems, could help reduce these risks.

Table 1. Summary of climate risks, potential impacts, and resiliency measures for mini-grids

Climate Risk	Impacts	Resiliency Measures
High Temperatures	• Reduced solar and wind power generation • Reduced battery efficiency and lifespan • Reduced transmission and distribution capacity • Increased power demand for cooling creating system stress	• Implement low-cost cooling technologies, such as fans • Maximize air flow and ventilation in power house • Reinforce battery banks and backup power supplies (e.g., diesel generators) • Anticipate load/demand increases • Increase use of energy-efficient appliances
Extreme Weather and Storms	• Damage to power and distribution components from debris, wind, and lightning • Reduced generation source lifetime (e.g., solar PV and wind turbines) • Power disruptions	• Maintain tree corridors and distribution line fasteners • Implement lightning grounders • Increase technical support, spare parts, and maintenance capacity • Harden equipment and distribution infrastructure
Flooding and Sea Level Rise	• Water damage to low-lying generation sources and distribution infrastructure • Increased saltwater exposure and equipment corrosion • Erosion and scouring of system foundations and components	• Assess flood risks as part of initial design • Harden generation sources and distribution infrastructure • Increase technical support, spare parts, and maintenance capacity

Resilient Energy Platform

The Resilient Energy Platform helps countries to address power system vulnerabilities by providing strategic resources and direct country support to enable planning and deployment of resilient energy solutions. This includes expertly curated reference material, training materials, data, tools, and direct technical assistance in planning resilient, sustainable, and secure power systems. Ultimately, these resources enable decision-makers to assess power sector vulnerabilities, identify resilience solutions, and make informed decisions to enhance energy sector resilience at all scales (including local, regional and national scales). To learn more about the technical solutions highlighted in this fact sheet, please visit the Platform at: resilient-energy.org

Resources to Learn More

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Written by Mason Fried, Molly Hellmuth, and Joanne Potter of ICF

Jennifer Leisch
Clean Energy and Climate Change Specialist
U.S. Agency for International Development
Tel: 303.913.0103
jleisch@usaid.gov

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