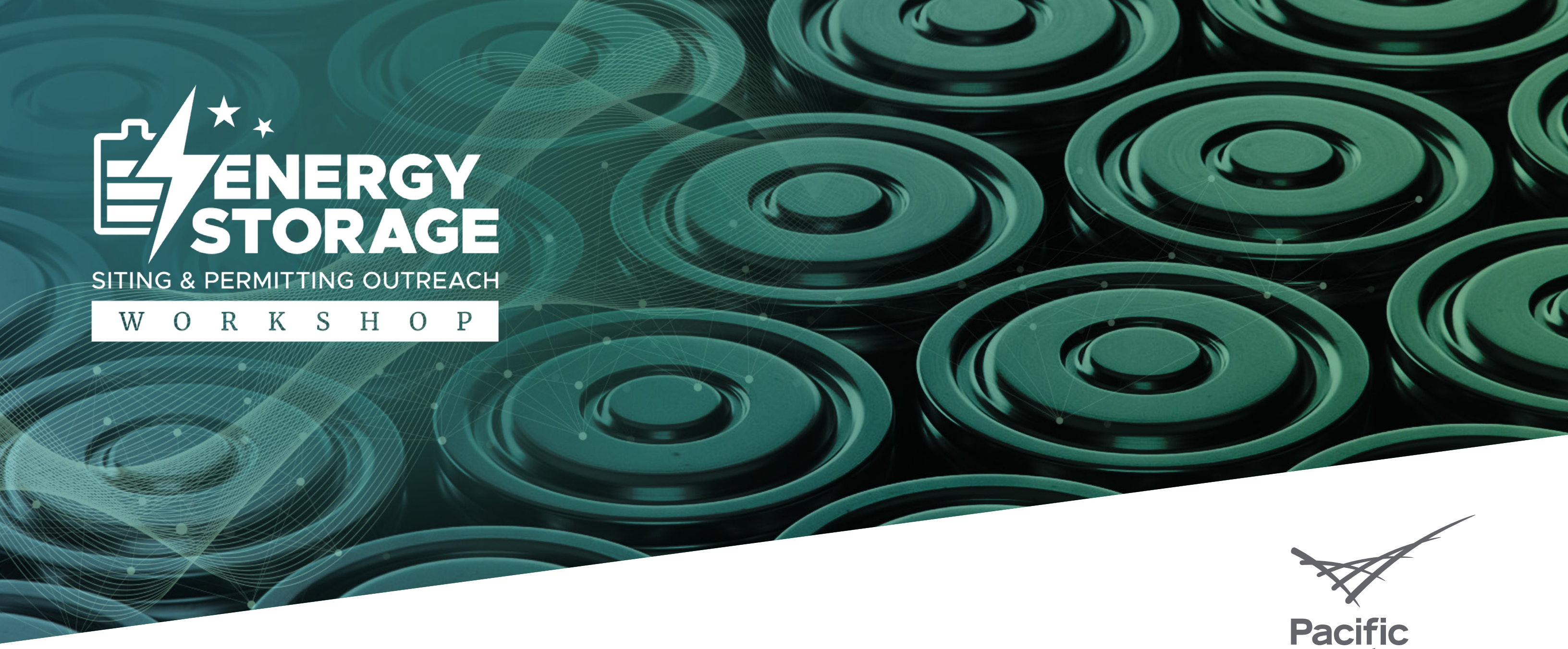


Pacific Northwest
NATIONAL LABORATORY

MICROGRIDS

This factsheet presents an overview of the benefits and use cases of microgrid systems, implementation challenges and potential solutions, planning considerations, and project timelines for their development.

KEY BENEFITS

Access	Microgrids provide access to locally generated energy for remote communities who may not be grid-connected. Microgrids can also provide energy for communities whose utility generation mix comes at a high cost or adversely impacts local air quality.
Affordability	Microgrids can reduce the cost of electricity by using local generators, providing an alternative to utility-purchased electricity and avoiding transmission and distribution costs. Local generators that do not rely on purchased fuel can also provide additional cost savings, especially in remote locations with limited accessibility. These savings can reduce local energy burden and prevent shutoff notices for utility non-payment.
Improved Air Quality	Microgrids that do not rely on purchased fuel can replace the need for backup diesel powered generators or utility-purchased electricity, providing local air quality improvements and health benefits.
Resilience	Microgrids provide resilience to grid outages, whether the result of local grid conditions, extreme weather events, or public safety power shutoffs. By automatically disconnecting from the main grid during these events, a microgrid can provide uninterrupted access to electricity—this is especially important for critical infrastructure, such as hospitals and community gathering spaces.
Social Impact	Microgrids provide an alternative to traditional, utility-purchased electricity. This can allow microgrids to serve as a community asset, not only providing energy independence, but allowing for wealth creation, community ownership, and community building.

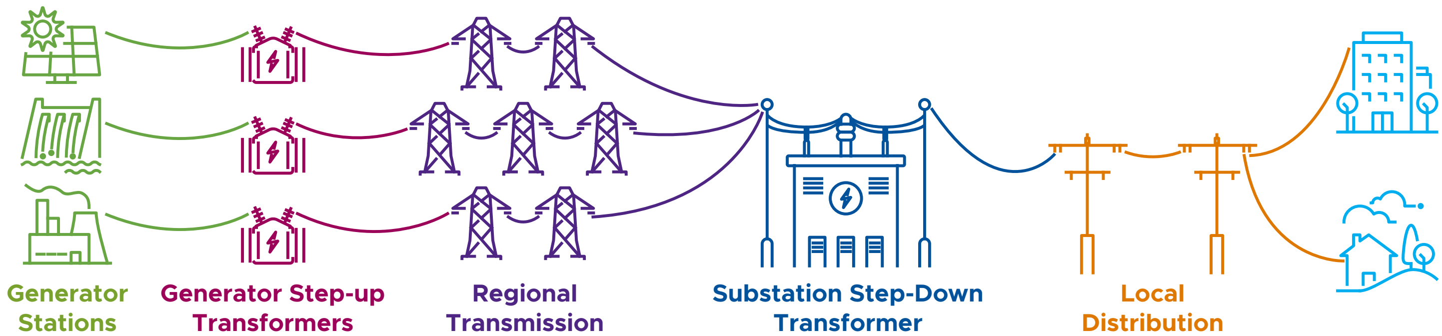


Figure 1. Representation of the electric grid from generation stations (left) through the transmission system to the substation (middle) and then distributed to the local loads (right).

THE ELECTRIC GRID

The traditional **electric grid** was designed to transmit the electricity generated by large resources across long distances to towns and cities and then distribute that electricity to communities, houses, businesses, and other buildings to meet their needs. The electricity generated by these larger generators at the edge of the grid is first stepped up to a higher voltage using transformers so that it can be transmitted great distances without losses. Once the electricity reaches the local distribution substation, it is stepped down to a lower, safer voltage to then be distributed to the end users of electricity. This pathway is described in Figure 1.

OVERVIEW

In this traditional scenario, homes, communities, and businesses consume power that was generated miles away, relying on the safe and uninterrupted operation of every component of the grid connecting them. In contrast, a **microgrid** is a **local electric system connecting smaller, on-site generation sources directly with electricity consumers.** A microgrid can be connected to the main grid to import or export electricity, or it can operate in **islanded mode** by **disconnecting from the grid and operating as an independent system.** Microgrids can switch between these modes using a controller to open or close the switch between the main grid and the microgrid.

When the microgrid is disconnected from the main grid, the local generators and consumers operate as an island, with the controller balancing the demand of the loads (consumers) with electricity from the generators (rooftop, on-site, or nearby) and the energy storage (batteries), as seen in Figure 2. Operating in **islanded mode provides those connected via a microgrid with electricity access even during a power outage on the main grid.** Outages can occur due to unreliable grid conditions, maintenance, extreme weather, or public safety power shutoff events.

MICROGRID USE CASES

Microgrids can be relatively small, containing just one house, rooftop generation, and a battery. Microgrids can also be scaled up to power a community of multiple homes and community centers using a combination of generation sources and energy storage devices, all connected with the required electrical components, such as power converters to convert direct current (DC) to alternating current (AC) and protection relays to sense disturbances in the main grid to signal the controller to disconnect or reconnect the microgrid. The possible components of a microgrid are pictured in Figure 2.

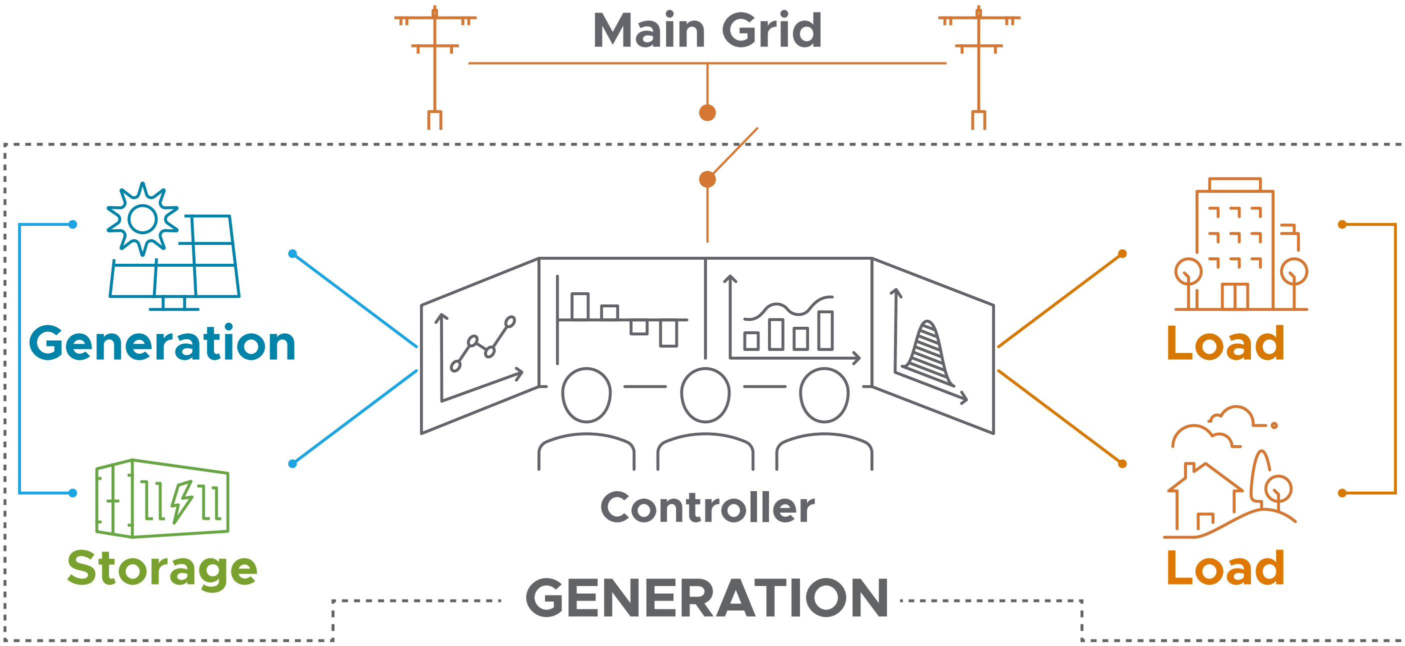


Figure 2. Microgrid components (dashed box) and switch connection to the main grid (top).

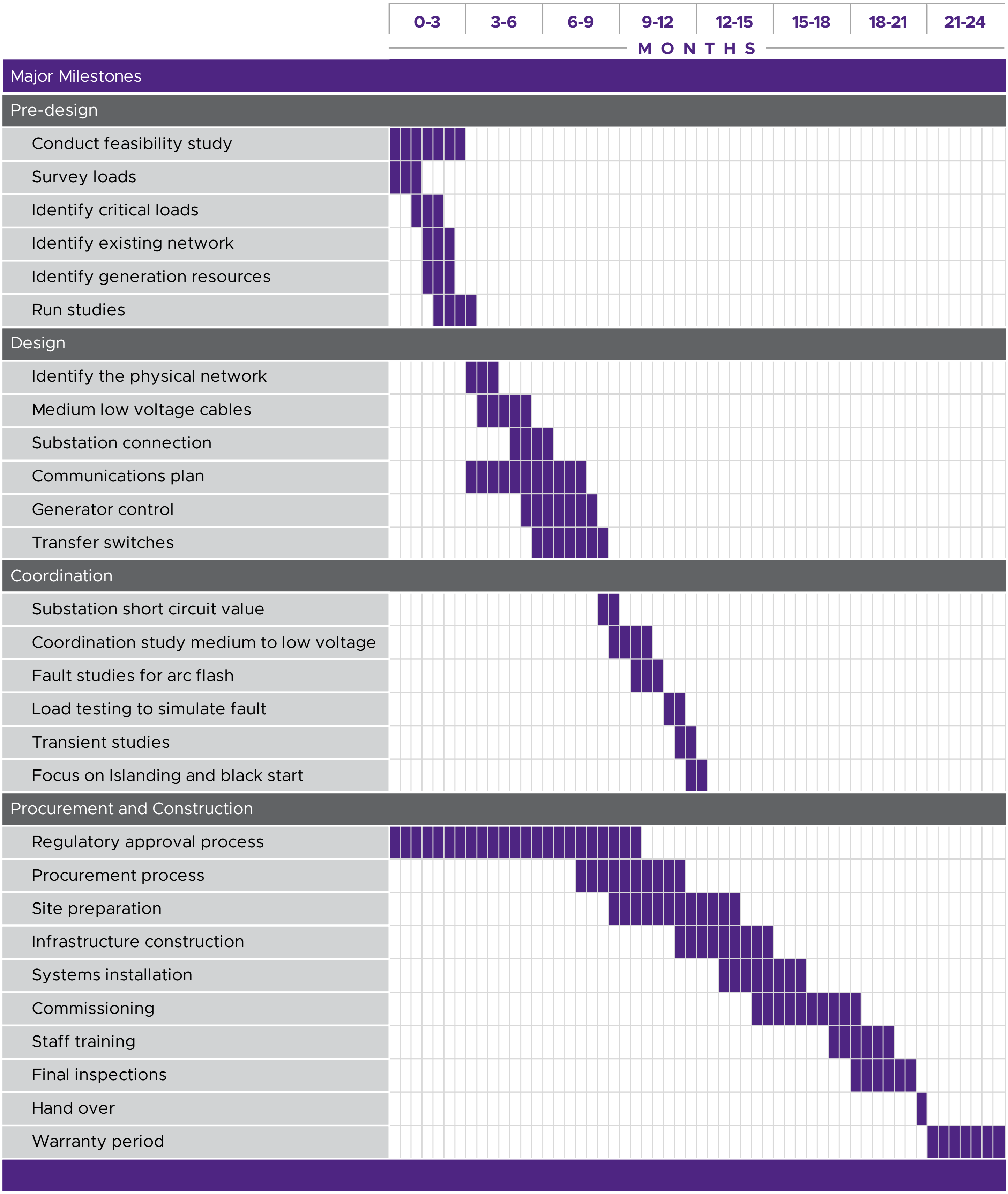
BEFORE PURSUING A MICROGRID

While a microgrid can provide numerous community benefits, it is important to consider simpler, less expensive energy measures as precursors to microgrid development. Improving energy efficiency can reduce electricity demand, lower energy costs, and potentially decrease the size and cost of a future microgrid system. Some example measures are described below.

Weatherization	Weatherization is the process of improving a building's physical condition to more efficiently use electricity. An energy auditor inspects the building to identify the most cost-effective measures to implement. The most common energy-saving measures are usually related to improving insulation and window and door sealing to reduce conditioned air loss. More information can be found at: https://www.energy.gov/energysaver/weatherization.
Energy Efficiency	Energy efficiency measures are any steps that can reduce the energy required to perform the same task; this can be as simple as replacing old, inefficient appliances with newer, high efficiency models. Energy efficiency can also be utilized as a design principle during a building's design and construction by using strategies such as maximizing solar heat gain and applying passive cooling techniques to make the most of solar heat gain and passive cooling techniques. More information can be found at: https://betterbuildingssolutioncenter.energy.gov/efficiency/energy-efficiency/tech.

MICROGRID CHALLENGES AND POTENTIAL SOLUTIONS

Technology Risk	The technology used in microgrids is still evolving, which means that there is a risk of technical problems.	**As of 2026, there were nearly 1,300 microgrid installations across the United States with a combined generation capacity of approximately 5,681 MW and 266 MW of energy storage. Standards organizations work to reduce this risk, as do regulators. Despite this growth, several technical, regulatory and financial challenges continue to affect microgrid deployment[1].**
High Cost	Microgrids can be expensive to install, especially if they are large or require substantial local generation.	**It is important to weigh the upfront and operations and maintenance costs throughout the lifetime of the microgrid against the savings and benefits realized through reduced transmission, distribution, and utility costs, protection from market volatility, and improved resilience.**
Complexity	Microgrids are complex systems that require careful planning and design. They can be difficult to operate and maintain, especially in remote or harsh environments.	**Process checklists aid design, implementation, and training. Lessons learned are also valuable planning and design resources. Third party service providers can also support this task.**
Vulnerability to Cyberattacks	Microgrids are connected to the internet, which makes them vulnerable to cyberattacks.	**Sensors and protection equipment—such as Supervisory Control and Data Acquisition systems—control, collect, and store real-time microgrid operational data to maintain efficient and safe microgrid operation. Modern SCADA can be configured to shield or block cyber-attacks to prevent damage to infrastructure.**
Generator Intermittency	Local generators require either on-site fuel or generation resources, which may not always be available. This can lead to power outages if the demand for power exceeds the supply.	**Long-term battery storage and backup generators can reduce these impacts, and microgrids can shed non-critical loads to lower demand during supply shortages.**
Limited Scalability	Microgrids are limited in their ability to scale up to meet the needs of large populations.	**Microgrids are typically designed for localized areas such as campuses or communities and often operate in the 10–25 MW range. Scaling microgrids to serve larger populations introduces challenges related to system control, protection, communications, and cost. Addressing these challenges remains an active area of research.**
Lack of Standards	There are no universally accepted design or hardware standards for microgrids; this can make it difficult to design, install, and operate them.	**However, organizations such as the Institute of Electrical and Electronics Engineers (IEEE) and the U.S. Department of Energy (DOE) have published guidelines and best practices to help address this gap to assist in developing resilient, efficient, and reliable microgrid systems.**
Resistance from Utilities	Utility companies may resist the development of microgrids, as they could see them as a threat to their business.	**State regulators continue to challenge this paradigm. More states are beginning to adopt legislation facilitating microgrid development (CA, CT, ME, MA, HI, and Puerto Rico have such legislation)[2].**
Regulatory Hurdles	There can be regulatory hurdles to the development of microgrids, such as obtaining permits and licenses.	**While regulators work to reduce these hurdles, some state energy offices provide guidance and resources to navigate the local regulatory landscape.**
Public Acceptance	There may be public opposition to the development of microgrids due to concerns about safety, environmental impact, and cost.	**Microgrids support affordable, reliable, and resilient energy systems and provide energy security. Effective communication and educational resources can also be paramount to gaining public acceptance.**



MICROGRID DESIGN PROCESS

The table below provides an example of the project development stages and timeline for a microgrid project. Note that actual timelines depend on a number of factors such as project size and complexity, supply chains, and interconnection procedures.

[1] "Onsite Energy Installation Database." 2026. U.S. Department of Energy. https://www.onsite-energy-installations.ornl.gov/

[2] Shea, Daniel. 2022. "Microgrids: State Policies to Bolster Energy Resilience." National Conference of State Legislators. https://www.ncsl.org/energy/microgrids-state-policies-to-bolster-energy-resilience (March 20, 2026).

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