



## Microgrids Overview

A microgrid is a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.<sup>1</sup> A microgrid can connect and disconnect from the larger utility grid to operate in either grid-connected or island mode. Microgrids are in the early stages of implementation, with approximately 227 microgrids currently in operation and over 150 planned microgrids expected to come online from 2019–2021—a more than 60% increase.<sup>2</sup> Combined Heat and Power (CHP) can play a central role in microgrid development and wide-scale adoption by providing reliability and resilience, and ensuring continuous operation for host facilities—including buildings, campuses, and communities—in the event of grid outages.

## Applications

Microgrids are designed to improve electricity resilience by enabling facilities to continue operating in the event of a utility grid outage. As highlighted in **Figure 2**, a microgrid's size can vary considerably, depending on its service area: (1) a single customer/facility (single-customer microgrid), (2) a group of facilities within a distribution feeder circuit (partial-feeder microgrid), (3) an entire distribution feeder circuit (full-feeder microgrid), or (4) an entire substation circuit with multiple feeders (full-substation microgrid). This fact sheet focuses on microgrids that consist of multiple technologies and/or multiple customers/facilities.



Figure 1. Montgomery County Public Safety Headquarters microgrid.

A microgrid serves the Montgomery County Public Safety Headquarters in Maryland with 865 kW CHP integrated with 2 MW of solar. Find more information at [https://chptap.lbl.gov/profile/135/MoCoPublicSafetyHQ-Project\\_Profile.pdf](https://chptap.lbl.gov/profile/135/MoCoPublicSafetyHQ-Project_Profile.pdf)

Photo credit: Montgomery County, Maryland

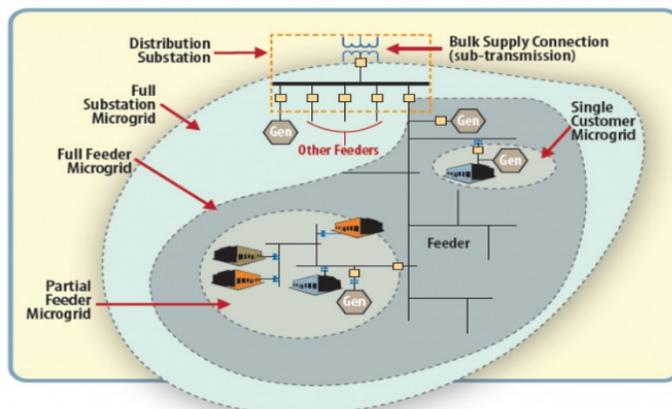


Figure 2. Possible microgrid configurations.

Photo credit: U.S. Department of Energy Microgrid Exchange Group

1 DOE definition developed by the Microgrid Exchange Group: <https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy's%20Microgrid%20Initiative.pdf>

2 ICF Microgrid Database. February 2020. Database includes only microgrids with multiple technologies and/or multiple buildings, serving operational functions beyond emergency/standby power.

Microgrids are currently most often deployed in institutional campus settings, such as military facilities, government buildings, hospitals, and universities, where all buildings are owned and operated by a single entity. Much of the recent interest in microgrids has been for community microgrids that provide energy resilience for multiple critical loads in cities and municipalities (e.g., police stations, emergency responders, hospitals, gas stations, and supermarkets). Applications for current and planned microgrids—including those with and those without CHP—are shown in **Figure 3**.

Community microgrids involve multiple stakeholders, which often presents challenges related to microgrid asset ownership and negotiation of acceptable contract terms and conditions. In one successful development approach, a third-party developer presents the concept of “microgrids as a service.” In this business model, the developer assumes responsibility for engineering, financing, installing, operating, and maintaining the microgrid and typically negotiates a long-term power purchase agreement.

Another approach for developing microgrids involves utilities offering microgrids as a rate-based service. For example, some utilities are exploring utility-owned microgrids with CHP for large customers. In this scenario, the utility benefits by selling both electricity and thermal energy (e.g., steam) to the customers, with an efficient and cost-effective source of electricity for the grid. The customer benefits by securing a local, resilient source of power.

### Technology Description

Microgrids can use any combination of DER technologies. According to ICF’s Microgrid Database, CHP has the most operational capacity of any DER technology for existing U.S. microgrids, but non-CHP natural gas generation, diesel generators, and solar photovoltaics (PV) have the most capacity in planned microgrids (i.e., coming online within the next three to four years).<sup>3</sup> **Figure 4** shows the operational and planned capacity for U.S. microgrids as of February 2020, based on known microgrids incorporating multiple technologies and/or serving multiple buildings. Most CHP microgrids do not incorporate other DER technologies, but for those that do, solar PV is the most common and constitutes the most capacity. CHP is most often used to supply baseload power and thermal energy for microgrids, while other DERs provide supplemental power.

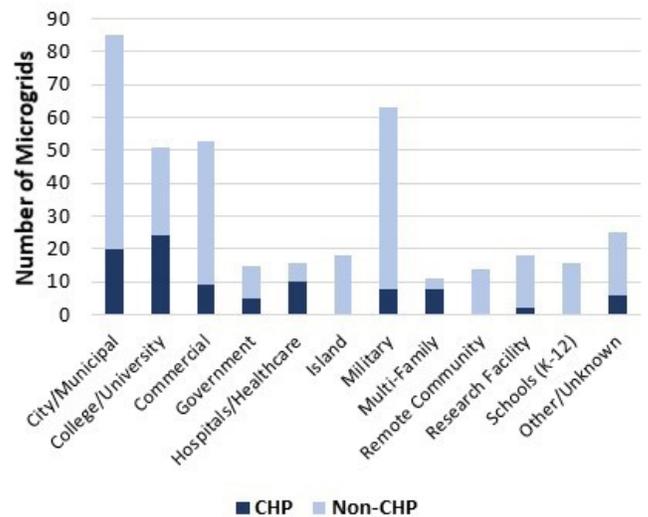


Figure 3. Number of existing and planned microgrids by application. Graphics credit: ICF Microgrid Database, February 2020

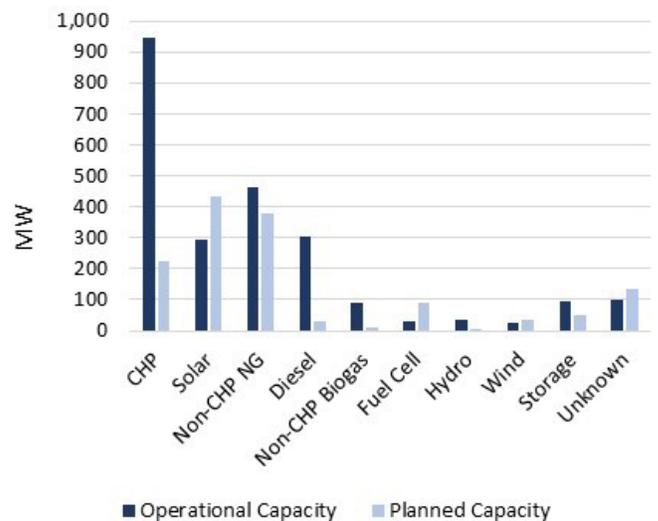


Figure 4. Capacity of DER technologies used in microgrids. Graphics credit: ICF Microgrid Database, February 2020

3 ICF Microgrid Database. February 2020.

## Drivers

End users choose to install microgrids because of a combination of site-specific factors or implementation drivers. There are six primary implementation drivers for microgrids:

- **Clean power:** Achieve emission reductions through efficient and/or zero-carbon microgrid technologies.
- **Economics:** Reduce electricity, heating, cooling, and other costs through various mechanisms, such as self-generation (avoided utility costs), shared operation and maintenance, and lower fuel prices.
- **Reliability and resilience:** Ensure power delivery during grid outages and other major disruptive events (especially important for critical infrastructure facilities).
- **Remote grid:** Provide power to remote locations that cannot rely on the power grid, such as an island community.
- **Renewables integration:** Incorporate renewable technologies into the power generation mix while using other technologies to offset the associated intermittency.
- **Research and development:** Investigate new technologies, microgrid configurations, and financing arrangements.

Figure 5 shows the frequency of primary implementation drivers for microgrids in ICF’s Microgrid Database, based on information available from press releases, interviews, and news articles. Only the primary driver is included for each site.

### Case Study: Parris Island, South Carolina

The Marine Corps Recruit Depot (MCRD) in Parris Island, South Carolina, serves as one of two marine training facilities in the United States, training men from east of the Mississippi and all women who enlist in the U.S. Marine Corps. Approximately 17,000 recruits arrive each year to train at the 8,000-acre facility. MCRD partnered with Ameresco to implement a microgrid to reduce commercial grid demand and bolster base resilience by ensuring the depot can operate during grid outages and extreme weather events.

The microgrid—consisting of a 3.5 MW CHP system, a 5.5 MW solar array, and a 4 MW lithium-ion battery—displaces utility grid purchases and reduces local grid demand by 79%. The system serves the depot’s thermal load and most of its electric load. The microgrid islands itself in the event of a larger grid outage, ensuring reliable energy for the base by using excess energy stored in the battery along with existing energy resources. In addition to the microgrid, the depot also maintains 3.6 MW of backup diesel generation.<sup>4</sup>

4 Southeast CHP Technical Assistance Partnership (CHP TAP). “Marine Corps Recruit Depot Parris Island Project Profile.” [https://chptap.lbl.gov/profile/121/MCRDParrisIsland-Project\\_Profile.pdf](https://chptap.lbl.gov/profile/121/MCRDParrisIsland-Project_Profile.pdf)

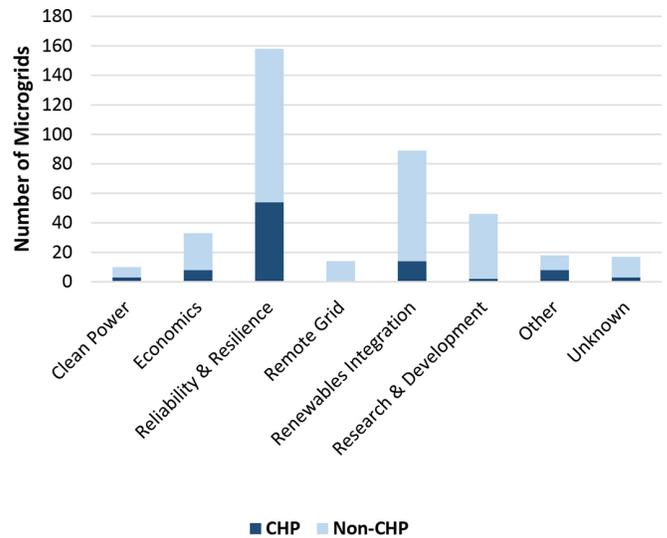


Figure 5. Primary implementation drivers for CHP and non-CHP microgrids (both existing and planned).  
Graphics credit: ICF Microgrid Database, February 2020

The Parris Island microgrid is part of Ameresco’s larger energy services performance contract (ESPC) with the Marine Corps depot. The ESPC involves 121 buildings covering 3.1 million square feet and 20 energy conservation measures that reduce the depot’s energy consumption by 79%.

### Marine Corps Recruit Depot Microgrid

Parris Island, South Carolina

Technologies

- 3.5 MW CHP generation system
- 5.5 MW solar array
- 4 MW lithium ion battery

Benefits from ESPC

- Annual savings: \$6.9 million
- CO2 reduction: 38,000 metric tons
- Total energy consumption reduction: 384,962 million BTUs annually

Photo courtesy of Business Wire



## Hybrid CHP Systems

A new category of microgrid installations is emerging in the form of hybrid CHP systems, which incorporate a combination of CHP and other DERs in a single installation. The defining characteristic of hybrid CHP systems is coordination between developers of different DER technologies (i.e., CHP, PV, and/or energy storage) to engineer combined systems. Compared to standalone DER technologies, hybrid systems are better equipped to serve all of a customer’s site loads and provide grid services to utilities. When configured as a microgrid, a hybrid CHP system can provide maximum resilience with minimal fossil fuel emissions. In a typical hybrid configuration with CHP, solar PV, and energy storage, CHP would be used for baseload power and heat, while PV and storage are used opportunistically to maximize renewable output and participate in utility markets for grid services (see **Figure 6**).

In microgrids with CHP and other technologies, DERs tend to be installed piecemeal over time. For example, a building or campus may already have a CHP system installed, and later management decides to install rooftop PV, additional backup generators, and energy storage in a microgrid configuration. However, this approach can lead to inefficiencies in the design, sizing, and installation of the system and its components. The original CHP system may become larger than is needed when the additional DERs are incorporated, resulting in lower operational efficiencies and more emissions than a hybrid design. When hybrid systems are installed strategically for specific use cases, the components can be designed to work together, with optimal sizing and maximum efficiency.

Hybrid CHP systems can consist of any combination of CHP and other DER technologies, although solar PV and energy storage have been most commonly connected with CHP in multi-technology microgrids (along with backup diesel generators). As more hybrid CHP systems are installed, certain technology combinations, such as CHP+PV or CHP+PV+storage, could lend themselves to standardized equipment options in the U.S. Department of Energy’s (DOE’s) packaged CHP eCatalog.<sup>5</sup> While most hybrid CHP systems are likely to be installed in a microgrid configuration, there are some key differences between hybrid CHP and microgrid installations, as shown in **Table 1**.

Hybrid CHP Systems: CHP + Solar + Storage

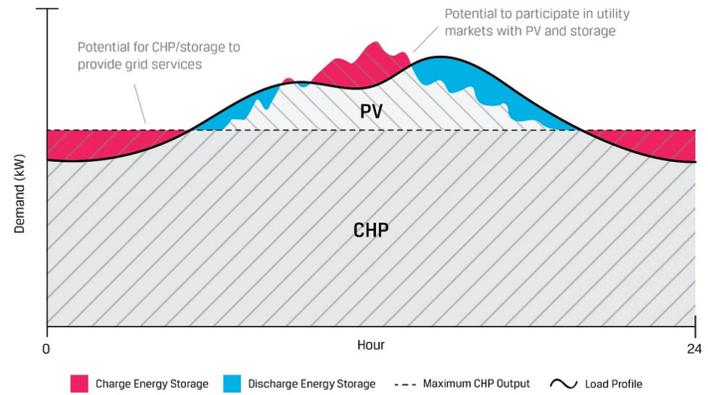


Figure 6. Hybrid CHP operation with CHP, solar PV, and energy storage. Graphics credit: ICF

**Table 1. Characteristics of Hybrid CHP Systems and Microgrids**

Characteristic	Hybrid CHP	Microgrid
Resilience	The system may or may not be configured for islanding during utility outages.	The system must be configured for islanding during utility outages.
Installation	CHP is installed alongside other DERs as an integrated system.	Microgrid components (CHP, PV, etc.) can be installed at different times.
Technologies	Multiple DER technologies (CHP + other technologies) must be used.	The system can consist of a single DER technology.
CHP	CHP must be included.	A microgrid need not include CHP

<sup>5</sup> DOE. Combined Heat & Power eCatalog. <https://chp.ecatalog.lbl.gov/>. Accessed February 2020

A challenge associated with hybrid CHP is establishing teams of DER developers and financiers that can deliver multi-technology solutions to customers. Incentive programs for hybrid systems may help encourage developers to form teams and work together on multi-technology installations. Financing can also be challenging. The product is complex, and simplified power purchase agreements with no capital investment will likely be needed to attract end users. As developers and financiers gain experience with hybrid CHP systems, offerings can become more standardized, reducing these challenges.

## Benefits of CHP Microgrids: Reliability, Resilience, and Power Quality

CHP microgrids provide a variety of reliability, resilience, and power quality benefits to customers located both within and outside the microgrid. Microgrid customers can benefit from immediate continuation of service in the event of a utility system outage. Additionally, by avoiding dependence on utility power, microgrids benefit other utility customers by reducing demands on local grid infrastructure, decreasing the likelihood of utility system equipment failure and removing load from the grid as it recovers from an outage. **Table 2** captures the range of reliability, resilience, and power quality benefits CHP microgrids can provide.<sup>6,7</sup>

**Table 2. Benefits of Microgrids that Incorporate CHP**

<b>Reliability</b>	<ul style="list-style-type: none"> <li>• CHP systems are located closer to loads than central generators, reducing the likelihood of distribution outages.</li> <li>• Fast-ramping capabilities allow quick responses to changes in grid-supplied power, providing flexibility to serve dynamic loads.</li> <li>• CHP systems reduce stress on the local distribution grid, extending the life of grid components and reducing the risk of an outage caused by individual distribution equipment failure.</li> </ul>
<b>Resilience</b>	<ul style="list-style-type: none"> <li>• CHP systems operate near-continuously and can provide firm backup generation during outages.</li> <li>• Island-capable systems can maintain heat and power service to loads within the microgrid network during outages, as well as fulfill load-shedding requests during high-demand periods.</li> </ul>
<b>Power Quality</b>	<ul style="list-style-type: none"> <li>• CHP microgrids serving large, power-quality-sensitive commercial and industrial customers, such as data centers and high-tech manufacturing, can provide high-quality power without service interruptions or voltage dips.</li> <li>• By locating generation closer to loads, CHP and district energy systems prevent voltage fluctuation and other power quality issues that often arise on the utility distribution system.</li> </ul>

CHP plays an important role in many microgrids as a resilient baseload DER anchor. Natural gas pipelines are rarely affected by extreme weather events, and thus gas-fired CHP can be a reliable source of both electricity and thermal energy for host facilities. CHP can be configured with black start capability and the ability to continue operation during utility outages. Other DERs such as PV may require a reference voltage/frequency, which the utility grid normally provides; CHP can be the source of this reference voltage/frequency during utility outages. Based on the cost of power outages and the historical frequency of local outages, microgrid planners can estimate the value that resilient microgrids will provide and incorporate these savings into financial pro formas. Overall, the impact that mitigated outage costs will have on a microgrid project depends on the customer class and sector, frequency and duration of outages, and relative cost of microgrid equipment and installation. ■

6 Chittum and Relf, Valuing Distributed Energy Resources: Combined Heat and Power and the Modern Grid. ACEEE White Paper. April 2018. Available at <https://aceee.org/white-paper/valuing-der>

7 Tim Banach, Bob Chester, Gavin Dillingham. CHP: Enabling Resilient Energy Infrastructure. DOE EERE Webinar. April 3, 2013. Available at [https://www.energy.gov/sites/prod/files/2013/11/f4/chp\\_enabling\\_resilient\\_energy\\_infrastructure.pdf](https://www.energy.gov/sites/prod/files/2013/11/f4/chp_enabling_resilient_energy_infrastructure.pdf)