Power generation

AN INTRODUCTION TO MICROGRIDS; COMBINING MULTIPLE POWER SOURCES FOR MAXIMUM EFFICIENCY AND UPTIME

The energy industry is changing. Demand for decentralized energy sources that don't rely on the traditional power grid, from solar cells to combined heat and power plants, continues to grow. At the same time, advancements in digitalization have already transformed many industries. The combination of these two forces has led to the emergence of small-scale power networks called microgrids. Through the integration of multiple power sources, microgrids can maximize efficiency and ensure uninterrupted power.

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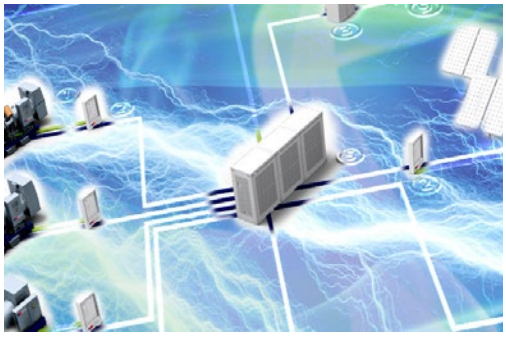
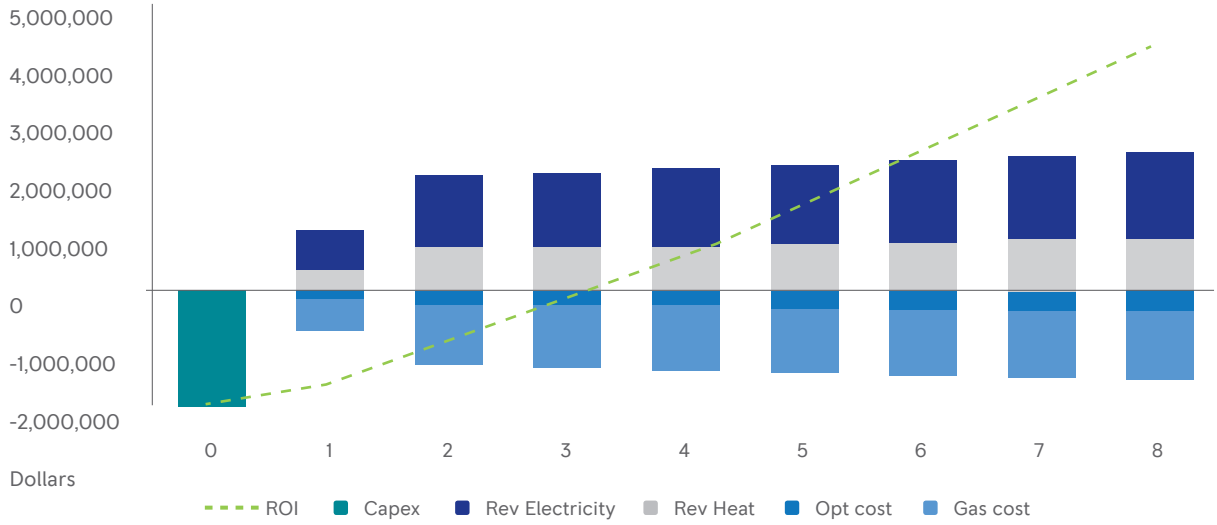


What is a microgrid?

A microgrid is a flexible and localized power generation system that combines multiple assets. While each system is unique, they all share common elements. A microgrid utilizes renewable energy sources such as solar panels, wind turbines, battery storage, diesel gensets and combined heat and power (CHP) modules–operating separately or in parallel. Diesel or gas generator sets may also be included, along with battery banks to store electricity and deliver it when needed. Control systems are a critical component to every microgrid, designed to provide exactly the right energy mix for the customer. Since a microgrid is used primarily for local demand, typical users are local energy consumers (industry, residential, service providers, municipal services). These users may be on the grid with unlimited access or off the grid, running self-sufficient island operations.

A Rolls-Royce solution

Microgrid with chp base load - ROI projection



Why use a microgrid?

Microgrids combine cost-efficient and ecologically friendly regenerative energy sources with the reliability of standby power generator sets.

— **Increased renewable energy**
The world is moving toward a new era of energy generation and consumption. Most corporations and organizations have environmental initiatives in place to reduce their carbon footprint. Governments are moving in the same direction, with green incentives and stringent federal, regional and local regulations. The shift towards renewable energy sources such as solar, wind and biogas—essential components in a microgrid—will only continue to grow.

— **Power diversification**
There are many things that can interrupt the flow of power. No energy source is 100% reliable and foolproof. Whether it's caused by a storm or natural disaster, outages can strike at any time. Smart contingency plans must be in place when a power grid goes down, or when a generator set runs out of fuel. It pays to have options available locally—such as a microgrid—to generate power. Having diverse power options at your command are also advantageous if primary energy costs or peak demand rates rise dramatically. With a mix of energy sources available, you can choose a more cost-effective solution if the price of diesel fuel or natural gas gets too high.

— **Energy efficiency**
Many microgrids use a combined heat and power (CHP) module, which has the ability to produce both electric energy and heat energy from the same fuel, thereby nearly doubling overall efficiency. By lowering fuel consumption, a microgrid can reduce overall operating costs while ensuring the availability of reserve power. However, every site is unique and may have different costs or revenue streams. Determining whether a microgrid will be a cost-effective source of power for your specific needs requires careful data gathering and computer-based analysis. These calculations will reveal whether there is sufficient payback potential. The chart above is an example of a microgrid that features a CHP module. With an initial investment of $2.1 million, the system will pay for itself in only three years. After that period, considerable revenue can be generated.

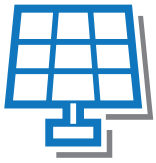
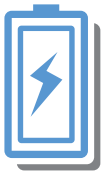
— **Emission reduction**
Different technologies have different impacts on the environment. Large sites may have permitting issues that limit NOx or particulate matter emissions from diesel-powered generator sets. If you reach the run-time limit and need extra capacity, you may need to utilize a gas-powered generator set, renewable energy source and/or battery storage.

Gas-powered generator sets face different challenges. Traditionally, waste gas was flared to reduce emissions. Today, many energy consumers are looking for new ways to use gas more efficiently. CHP modules provide one of the most economical ways for sites such as sewage plants to utilize waste energy to generate electricity and thermal energy, while also controlling methane emissions. It is important to note that these parameters apply more to non-attainment regions where air quality standards are more stringent.

— **Power security**
Concerns about power quality in the grid have led to an increased demand for new solutions. And for good reason. Major regional blackouts can cause billions of dollars in economic losses. Rolling blackouts are becoming more common. Many power grids, such as in North America, are outdated as investments in this infrastructure have been lacking. However, as more variable sources (such as windmills) are added to these grids, the risk of instability grows. As the coal industry slows down, traditional plants that keep electricity flowing are disappearing. With a microgrid on site, an energy user can avoid power interruptions by seamlessly switching over to a diverse mix of alternative energy sources that don't rely on the grid.

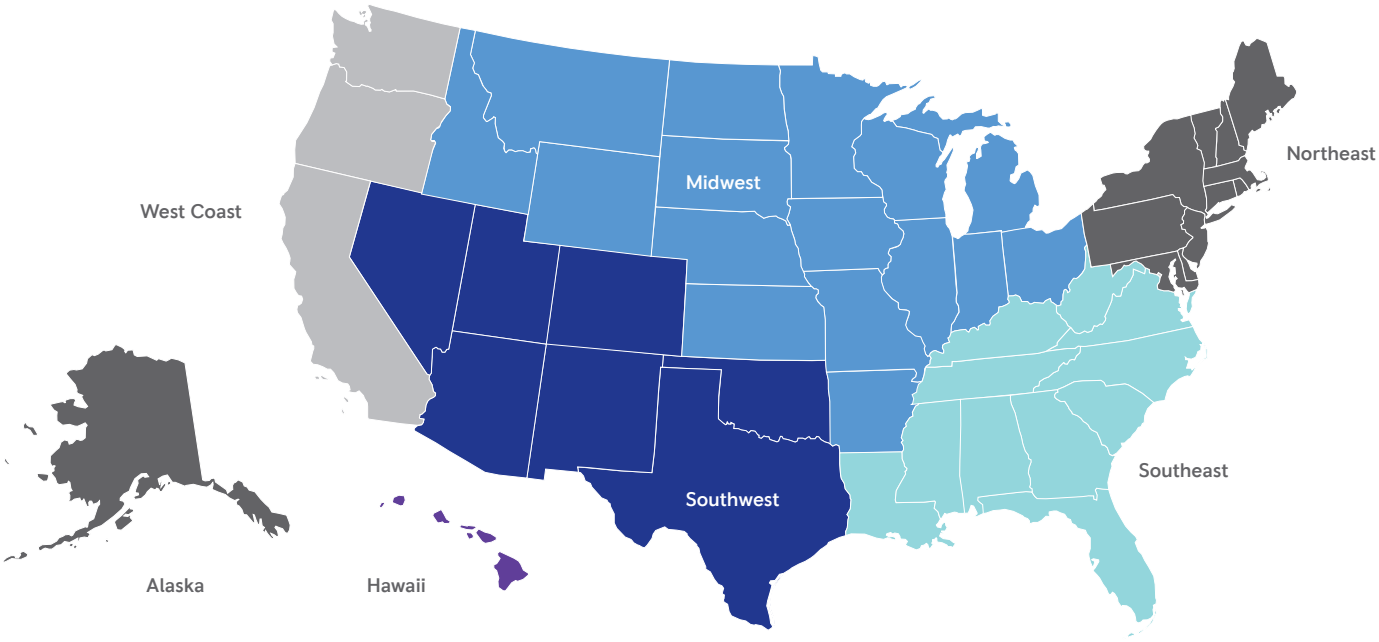
Common technologies

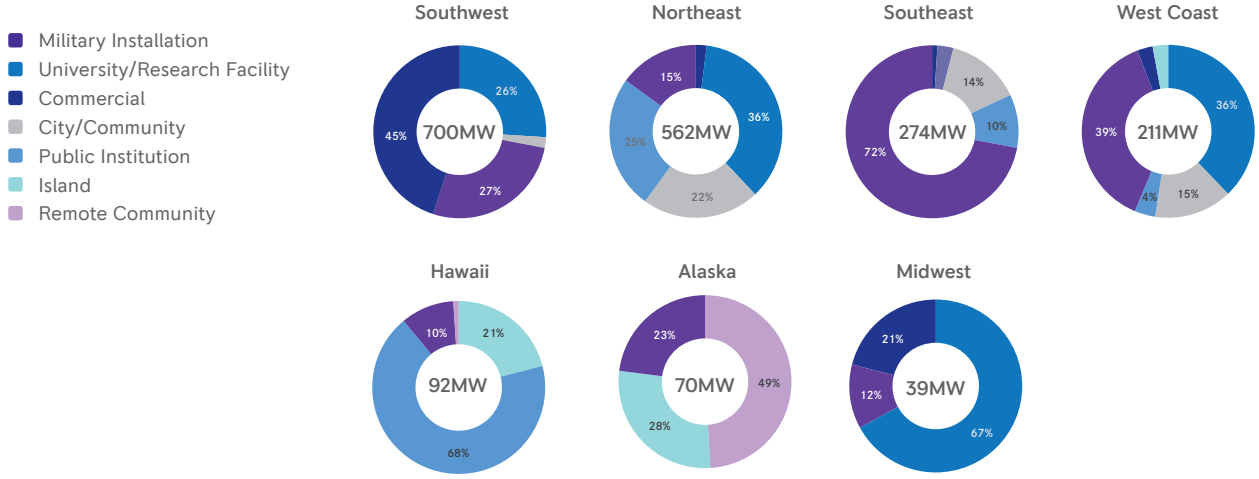
When evaluating a potential microgrid project, it is important to understand its commonly used power generation technologies and applications.

Diesel Generator Set	Pros	Cons
	— Fast start-up — High load acceptance — Very good transient response — Low-load operation of 20% possible — Fuel storage	— Higher emissions, require aftertreatment — Higher fuel cost
Gas Generator Set & CHP	**Pros**	**Cons**
	— High fuel efficiency — Combined heat and power (CHP) option — Low fuel cost — Low emissions — Part load operation of 35% possible	— Slower start-up and limited transient response — Costly fuel storage (if needed)
Solar	**Pros**	**Cons**
	— Low maintenance cost — Diverse applications — Reduces carbon footprint	— Reliance on sun — Requires energy storage — Capital cost — Requires inverter
Wind	**Pros**	**Cons**
	— Location independent — Reduces carbon footprint	— Reliance on wind — Threat to wildlife — Visual/noise pollution
Biogas	**Pros**	**Cons**
	— Free fuel source — Reduces soil/water pollution — Byproduct-fertilizer	— Integration cost — Fuel treatment/filtration — Requires suitable biomass
Battery Storage	**Pros**	**Cons**
	— Carbon savings neutrality — Retrofit-able — Rate optimization/curb — Instantaneous power availability	— Space constraint — Battery life

Current U.S. microgrid market

There's a diverse and growing market for microgrids in the United States. Types of energy user and operation vary by region.





Controls

Microgrids require a wide range of technologies. To ensure safe and reliable operation, every piece of equipment must work seamlessly together. As a critical component to a microgrid, control systems must be smart, predictive and able to deliver exactly the right energy mix for your specific needs. A microgrid controller provides the brains to make all of this possible.

Genset Master Controller

- Complete grid parallel and island mode control logic
- Black start with fast paralleling of multiple gensets

Microgrid Controller

- Dispatches power generation resources according to priority strategy (in order): Renewables, batteries and generator sets (Gas/Diesel)
- Scalable architecture for small, medium and complex solutions
- Trends analysis
- Remote systems
- Efficient power management

Typical applications

While every energy user is different, applications typically share the following solutions in common:

Waste Water Treatment

- Biogas and diesel standby

Hospital

- Diesel STB, battery, CHP

Industrial user

- NG-CHP, solar, battery, diesel

University campus

- NG-CHP, solar, battery, diesel, wind

Data center

- Solar, battery, diesel, CHP

Military & Remote locations

- Diesel, solar, battery

Making things practical

As microgrids become more commonplace, there is great potential for facilities to start a project with a simple installation.

Example #1:
Waste Water Treatment Plant – New Jersey

Technologies

- Biogas CHP
  3x 6R400 GS (200 kWe biogas/ 175 kWe natural gas)
- Diesel Genset
  3x 1500kWe

System overview/layout

- 600 kW biogas / natural gas
- 4.5 MW diesel standby
- Normal Mode Operation: In parallel with utility with 1x 200kWe running on biogas, 1x 175kWe running on natural gas and 1 CHP unit in standby. Available biogas from digester determines how many of the three CHP units are running on biogas. Hot water from CHP used for heating of digester
- Emergency Mode Operation: Diesel standby gensets with option to parallel CHPs running on either biogas or natural gas. Black start of CHP units running on biogas or natural gas to cover critical facility loads in case diesel gensets not available.

Engineering challenges

- Master control system to handle biogas/natural gas operation dependingon available biogas pressure from digester
- Ability to run on biogas in island mode/black start requiring backup power supply to biogas compressors and auxiliaries
- Emissions controls to meet local NOx and formaldehyde limits

Financial consideration

- Incentives from state government for storm mitigation infrastructure

Example #2:
Greenfield Hospital - Maryland

Technologies
- Natural Gas CHP
  1x 20V4000 GS (1932 kWe Continuous)
- Diesel Genset
  2x 16V4000 DS (2000 kWe Standby) with aftertreatment
- Future expansion for additional diesel standby unit planned

System overview/layout
- 2MW continuous CHP
- 4MW diesel standby
- Normal Mode Operation: CHP in parallel with 3 utility feeders. Hot water from CHP used by hospital HVAC
- Emergency Mode Operation: Diesel standby gensets in parallel with CHP
- Storm Preparedness Mode Operation: Planned disconnect from electric utility and switch to island mode. CHP in parallel with diesel standby gensets.

Engineering challenges
- Control system to integrate diesel and CHP for various operational modes
- Integration of CHP into hospital HVAC and maximizing heat recovery to increase profitability. Heat recovery from HT, LT and exhaust.

Financial considerations
- CHP run time 5,000-8,000h per year
- Estimated payback period – 1.8 years
- Incentives from local gas & electric utility and state government

Example #3:
Greenfield Food Industry Plant - Mexico

Technologies
- Natural Gas CHP
  4x20V4000 GS (1.884 kWe Continuous)
- Diesel Genset
  1x16V4000 DS2000 (1.792 kWe Prime)
- Future biogas units planned
- MTU MCS Plant Control - Load step management through diesel unit

System overview/layout
- No electrical utility available at site
- 8000kWe continuous required by plant
- Island mode operation with gas and diesel running in parallel.
- Gas gensets are prioritized to run at maximum capacity to cover plant loads.
- The diesel unit runs at a low load factor and absorbs inrush loading and unloading, as well as a backup function in case a gas genset fails or is under maintenance.
- The MTU MCS master controller is responsible for the control logic.

Engineering challenges
- Large load steps as plant loads cycle. Gas gensets limited in load acceptance, therefore diesel unit running in parallel
- Prevent diesel unit from wet stacking at low load. Will be cycled one hour every 12 hours to +50% load.
- Plans to double plant size. System design to allow for future expansion.
- High altitude operation (>6600 ft). Engine turbocharger modification and special insulation on 13.8kV medium voltage generators

Conclusion

Microgrids are revolutionizing the energy industry by combining renewable energy sources, battery storage and backup generator sets. Every microgrid is unique. Solar panels, wind turbines, battery banks, diesel gensets and CHP modules – whether operating separately or in parallel – can all be included in these sophisticated and flexible systems. A wide range of applications can reap the benefits of a microgrid, such as power diversification, efficiency and security. In addition, it can fulfill a company's green initiatives, reduce emissions and optimize costs. When evaluating a project, make sure to understand the system's technologies and best practices. A microgrid designed to fit your business demands and local requirements can deliver a solid return on investment.

Rolls-Royce provides world-class power solutions and complete lifecycle support under our product and solution brand MTU. Through digitalization and electrification, we strive to develop drive and power generation solutions that are even cleaner and smarter and thus provide answers to the challenges posed by the rapidly growing societal demands for energy and mobility. We deliver and service comprehensive, powerful and reliable systems, based on both gas and diesel engines, as well as electrified hybrid systems. These clean and technologically advanced solutions serve our customers in the marine and infrastructure sectors worldwide.

A Rolls-Royce solution

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