MICROGRID KNOWLEDGE

Fuel Cell Microgrids:

The Path to Lower Cost, Higher Reliability, Cleaner Energy

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Chapter 1

Why Fuel Cell Microgrids Now

Fuel cell microgrids are on the rise, the result of a natural pairing of two technologies—fuel cells and microgrids—that serve a mutual mission. Together, they meet today's demand for energy that is cost-competitive, highly reliable, clean, quiet, contained, modular, scalable and community-friendly.

Once futuristic, both technologies find themselves at the right time and place, as the North American grid becomes increasingly distributed.

America flirted with the idea of microgrids for decades. But microgrids were largely confined to college campuses. Then in 2012 Superstorm Sandy jolted the nation into understanding the fragility of its centralized power grid and the value of distributed energy. Today, a wide range of businesses, institutions and communities are installing microgrids.

Fuel cells have followed a similar trajectory and now operate in more than 40 states, according to the Fuel Cell and Hydrogen Energy Association (FCHEA).

Navigant Research forecasts strong, growing demand for both fuel cells and microgrids over the next several years.

Worldwide, fuel cell installations are expected to increase more than 10-fold, from 262 MW installed in 2016 to over 3,000 MW nine years later. That should put the market for new stationary fuel cells at $16.2 billion in 2025, according to the research firm.

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"Technology breakthroughs are giving way to persistent cost declines, product improvements, and business model innovations, making fuel cells viable in a growing range of markets," said Navigant in releasing its 3rd quarter 2016 report on stationary fuel cells.

At the same time, microgrids grow in separate Navigant forecast from 1.4 GW in 2015 to 7.6 GW in 2024. At that point, the global microgrid market could reach $20 billion in annual revenue.

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The brawn and the brain of fuel cell microgrids

The marriage of these two increasingly popular energy sources brings brawn and brain together. The fuel cell offers reliable generation; the microgrid offers advanced intelligence.

This pairing is crucial to create economic and reliable energy. Here's why: A microgrid may have several sources of generation, some of them intermittent or short-lived, such as solar energy or energy storage. The fuel cell, on the other hand, can run continuously 24 hours a day, seven days a week, 365 days a year (as long it has a fuel supply—often clean, natural gas). When its solar, batteries or other resources are unavailable, the microgrid can always count on the fuel cell to supply continuous power.

Therefore, the fuel cell acts as a kind of backbone that the microgrid can rely on as it configures its various energy resources—including power from the central grid.

What is a fuel cell?

Fuel cells convert chemical energy from hydrogen-rich fuels into electrical power and usable high quality heat in an electrochemical process that is virtually absent of pollutants. Similar to a battery, a fuel cell has many individual cells that form a stack. When a hydrogen-rich fuel, such as clean natural gas or renewable biogas enters the fuel cell stack, it reacts electrochemically with oxygen to produce electric current, heat and water. While a typical battery has a fixed supply of energy, fuel cells continuously generate electricity as long as fuel is supplied. *Source: FuelCell Energy*

What is a microgrid?

A microgrid contains distributed energy resources that directly serve one or more customers. Most U.S. microgrids can operate either connected or islanded from the central grid. Intelligent control software manages the microgrid's resources—and their relationship to the grid—so that the customer receives the most efficient and economic energy at any given time. When a power outage occurs on the grid, the microgrid islands itself for protection and continues serving its customer, sparing them loss of electricity.

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With this backbone intact, the advanced microgrid controller multi-tasks, figuring out which resources to use at any given moment. It makes these decisions based on the goals set by the microgrid controller. The goal may be cost-effectiveness, reliability, environmental performance or another parameter the operator prioritizes.

Microgrids and fuel cells often create further efficiencies by employing combined heat and power (CHP). This technology captures waste heat created in electric production. It then puts the heat to good use warming and cooling buildings (with absorption chillers), or creating valuable steam or hot water.

Fuel cells are also:

- Modular and scalable. More can be added as the microgrid customer's energy demand grows over time.
- Easy to site. Fuel cells can be installed inside or outside. They are community-friendly because they require little space and do not use up large swaths of land, as solar or wind farms may.
- Typically spared regulatory red tape and review due to their clean emissions profile. In fact, in many states no air permit is required for a fuel cell.
- Quiet because they have few moving parts.

Who benefits from fuel cell microgrids?

Not surprisingly, fuel cells and microgrids find themselves popular among similar kinds of customers. These include those who seek highly reliable power, such as data centers, research facilities, hospitals, manufacturers, pharmaceutical companies, and public safety. Utilities also use fuel cells and microgrids as non-wires alternatives to help bolster areas of their grid in lieu of more expensive infrastructure upgrades.

“Fuel cells are a viable and effective technology for microgrids, especially in states where the utility grid is at risk,” said Morry Markowitz, FCHEA president. “Today fuel cells ensure continuous power to essential services, such as hospitals, first responders, data centers, and other critical facilities, while providing economic and environmental benefits to the communities they serve.”

Strong Microgrid Markets

While fuel cells can be found through much of the U.S., three states lead the way—California, Connecticut and New York. Interestingly, these states are also strong markets for microgrids:

California

California has more than 480 fuel cell systems, totaling more than 210 MW of power generation, according to FCHEA. Also an early proponent of microgrids, California is home to several utility, military and commercial microgrids—with more likely to come as the state maps out a new microgrid strategy.

Connecticut

Home of several fuel cell companies, among them FuelCell Energy, Connecticut has at least 35 MW of fuel cells in operation and 20 MW planned, reports FCHEA. A 63.3-MW fuel cell installation, now under development in Connecticut, will be the world’s largest fuel cell when completed. The state was the first in the nation to develop a grant program to spur microgrids.

New York

New York has 14 MW of fuel cells, and more are likely as the state unfolds its Reforming the Energy Vision, a policy designed to create a more distributed grid. To that end, New York is in the process of allotting $40 million in grants to microgrids.

About this guide

Microgrid Knowledge prepared this guide, “Fuel Cell Microgrids: The Path to Lower Cost, Higher Reliability, Cleaner Energy,” in partnership with Connecticut-based FuelCell Energy, a global leader that designs, manufactures, installs, operates and services stationary fuel cell power plants.

We encourage you to read this guide to learn more about stationary fuel cells, particularly those used in microgrids. The information is appropriate for commercial businesses, manufacturers, industrial companies, universities, municipalities, utilities, communities and governments—or any operation in search of clean, efficient and cost effective modern power.

Chapter 2

Three Ways Fuel Cell Microgrids Lower Energy Costs

Businesses and institutions install fuel cell microgrids for many reasons. Driving down energy costs is a big one.

Here we look at three ways fuel cell microgrids create financial advantage.

1. By competing with utility pricing
2. Through favorable financing models that reduce customer risk
3. In achieving efficiencies through use of combined heat and power (CHP) and advanced microgrid controls

Prices fell more quickly for stationary fuel cells than they did for wind energy and at about the same pace as solar energy, a trend Navigant sees continuing. Lower unit costs contribute to quicker payback on the capital investment of installing a fuel cell microgrid.

Fuel cell capital costs have dropped steeply in recent years, with increased production and economies of scale, according to Navigant Research. In fact, prices fell more quickly for stationary fuel cells than they did for wind energy and at about the same pace as solar energy, a trend Navigant sees continuing. Lower unit costs contribute to quicker payback on the capital investment of installing a fuel cell microgrid.

Larger macro-economic trends also are making fuel cells more advantageous, particularly historically low natural gas prices. Natural gas is a commonly used feedstock in the clean electro-chemical process fuel cells use to generate energy.

Not surprisingly, fuel cells offer the greatest cost advantage in parts of the country where utility prices are high. So fuel cell installations are apt to be found in the U.S. Northeast, California and Hawaii, where businesses pay 10 to 20 cents/kWh or more for electricity, double-to-triple the price in lower-cost states. Meanwhile, the fuel cell can produce electricity for the customer for 8 to 14 cents/kWh, according to FuelCell Energy.

FuelCell Energy says a 20 percent cost savings is common for fuel cell customers in these regions. Using a 1.4 MW fuel cell, the customer is likely to save $100,000 for every one penny spread between the fuel cell and grid power costs.

Reducing risk

Risk is often a concern for businesses and institutions that are considering making a large capital outlay on energy equipment. Money spent on energy infrastructure may mean money not spent on core operations or expansion.

The growing use of power purchase agreements (PPA) helps avert this risk. These no-money-down approaches offer monthly electricity prices at or below what the customer would otherwise pay for grid power. At the same time, the customer gains the benefits of reliable power and a cleaner environmental footprint.

Under a PPA model, the fuel cell company guarantees equipment performance, and may serve as operator of the fuel cell, handling all logistics and maintenance. So the customer is spared both financial and operational risk.

Customers considering long-term price differentials should evaluate forecasts for the fuel used by their system because long-term pricing appears favorable for fuel cells that use natural gas.

Evaluating pricing

PPA prices are largely fixed, although fuel costs may vary over the lifetime of the contract (typically 20 years). Customers considering long-term price differentials should evaluate forecasts for the fuel used by their system because long-term pricing appears favorable for fuel cells that use natural gas. The U.S. Energy Information forecasts that natural gas prices will remain “relatively low” through 2040 in its Annual Energy Outlook 2017.

Companies considering a fuel cell PPA also should look at price forecasts for grid power, and see how they compare to their contract. Grid power prices have historically risen in the United States. Governed by state regulatory agencies, utility prices do not necessarily reflect fuel prices alone—as changes in a fuel cell contract might. Instead, utility prices can also be influenced by a utility's need to build new infrastructure, comply with regulatory mandates and other factors.

Additionally, only about a third of the cost of generating electricity using a fuel cell comes from fuel costs; the other two thirds are operations and maintenance costs and plant costs, both of which are fixed for the full term of the PPA. This is why a fuel cell PPA can result in not only much lower utility costs to a business owner than continuing to buy power from the electric grid, but less business cost volatility as well.

In evaluating pricing, fuel cell customers also should take into account heat efficiencies they can achieve if they use a fuel cell in conjunction with combined heat and power (CHP). These units capture waste heat created as a byproduct of electric generation.

EIA forecasts gradual electricity price increases through 2040. In evaluating pricing, fuel cell customers also should take into account heat efficiencies they can achieve if they use a fuel cell in conjunction with combined heat and power (CHP). These units capture waste heat created as a byproduct of electric generation. Ordinarily, this heat would be wasted, dispersed into the air or water. Instead, it is used to heat or cool customer facilities or provide useful steam. So, CHP systems create a kind of two-fer; from one fuel source, they create two forms of energy. Companies using CHP can cut costs of on-site boilers and related fuel contracts.

Advanced microgrid controllers can further leverage CHP, as well as other resources within the microgrid. The controllers can discern which combination of resources should be used at any given time to achieve best pricing. The controllers can leverage not only generators and energy storage within the microgrid, but also power from the central grid.

Incentives to offset costs

Finally, it's important to note that many states offer financial incentives to encourage fuel cell use. These come in many forms, from grants and loans to allowing fuel cells to produce various kinds of renewable energy credits. Utilities and competitive retail suppliers buy the credits to meet state clean energy requirements.

In all, 30 states include fuel cells or hydrogen under their Renewable Portfolio Standards, 25 help fund fuel cells through rebates, grants, loans or other assistance and 16 offer tax incentives, according to the Fuel Cell and Hydrogen Energy Association (FCHEA).

Examples of State Support
reported by FCHEA

Connecticut
Connecticut created the Microgrid Grant and Loan Program to spur fuel cell use. The state also offers fuel cell incentives through its Low-Emission Renewable Energy Credits Program (LREC). Fuel cells can generate Class I renewable energy credits in the state, which can be sold to utilities and Independent Power Producers (IPPs) under long-term contracts.

California
Since 2001, more than 400 fuel cells systems have been installed through California's Self-Generation Incentive Program (SGIP). The total SGIP fuel cell capacity is more than 175 MW, with funding requiring increasingly more efficient, low greenhouse gas emissions installations.

New York
The New York State Energy Research and Development Authority made $150 million in funding available for large-scale renewable energy projects to help the state meets its goal of 50% renewable electricity by 2030. Fuel cells are included with contracts awarded for a term of up to 20 years.

New Jersey
New Jersey's Clean Energy Program offers an incentive for fuel cells with heat recovery with an installed capacity greater than 3 MW.

Chapter 3

The Environmental Advantage of a Fuel Cell Microgrid

A recent study by Argonne National Lab found that fuel cells have lower greenhouse gas emissions than those produced by the U.S. grid mix of technologies.

The same study found that if higher efficiency fuels cells are used, such as those that use solid oxide or molten carbonate technology, the greenhouse gas emissions are comparable to those produced by the California grid mix, which generates 43 percent of its electricity from non-fossil renewable and nuclear sources.

The key to fuel cells' low emissions is that the technology does not involve combustion. Fuel cells produce electricity via a chemical reaction.

A California wastewater treatment plant, operated by the City of Riverside, offers a good example of the superior environmental performance of a fuel cell. The FuelCell Energy project uses renewable biogas, produced from the wastewater treatment process, as a fuel source to generate carbon-neutral power. As compared to other fuel cells which require 'directed' biogas with the same composition as pipeline natural gas, the FCE system operates directly on biogas, thus creating more cost efficiency.

Riverside is located within the South Coast Air Quality Management District, which has the toughest stationary source air emissions requirements in the United States. Because fuel cells do not burn fuel, their emissions are orders of magnitude lower than combustion-based systems. As a result, Riverside's 1.4 MW fuel cell is exempted from air permitting requirements, even in the strict SCAQMD.

It's also important to note that the Riverside fuel cell complies with a strict emission requirement of the California's Self Generation Incentive Program that greenhouse gas emissions be less than 360 kg/MWh.

The key to fuel cells' low emissions is that the technology does not involve combustion. Fuel cells produce electricity via a chemical reaction.

Fuel cells come in a variety of technologies, including the solid oxide and molten carbonate technologies already mentioned, as well as proton exchange membrane technology and phosphoric acid technologies. The common denominator of all those technologies is hydrogen, which provides the fuel for the fuel cell.

Most commercially deployed fuel cells derive their hydrogen from fuels such as natural gas, but renewable fuels such as biogas can also be used—which is the case in Riverside. It's also possible to use more conventional fuels such as propane.

When those same fuels are combusted, either in an internal combustion or gas turbine engine, they produce harmful emissions such as carbon monoxide, nitrogen oxides, sulfur dioxide and particulate matter. But because fuel cells use a chemical reaction and not combustion, they produce virtually zero of those pollutants.

Fuel cells do release carbon dioxide (CO2), but as much as 50 percent less than some conventional technologies, due to their inherently high efficiency. In fact, fuel cells in the 1-10+ MW size range are on-par with the CO2 emissions of the cleanest combined cycle gas turbines of 100+ MW and larger, but without the harmful asthma-inducing pollutants which are commonly associated with fossil fuel plants of this size.

In general, fuel cells exceeding 60 percent efficiency, which is typical of molten carbonate and solid oxide fuel cell installations, offer significant reductions in greenhouse gas emissions compared even to the lowest-carbon electric grids in California and the Northeastern US.

The efficiency of a fuel cell is also a factor in estimating the costs of a system. The higher the efficiency, the less fuel will be required for operation.

All these factors—fuel, cost, emissions—are important considerations in fuel cell microgrid design since a microgrid requires some form of power generation. In the past, diesel generators were often the go-to source, but with heightened concerns about global warming and stricter emissions controls, fuel cells are increasingly at the heart of modern microgrid installations.

Nine states have classified stationary fuel cells as Class I renewable power generation because of their high efficiency and low CO2 emissions. And fuel cells operating on biogas are typically classified as carbon-neutral by regulatory authorities.

In jurisdictions where clean energy is a top priority, such as California and the Northeast where the Regional Greenhouse Gas Initiative operates, the emissions profile and efficiency of fuel cells make them the top pick for microgrid generation.

Chapter 4

How Fuel Cell Microgrids Improve Electric Reliability

The digital world we live in not only makes us more dependent on electric power, but also increases our vulnerability to interruptions in electrical service, even brief interruptions.

Cybersecurity threats heighten those concerns, as do extreme weather, most notoriously Superstorm Sandy, which knocked out power for 8.1 million customers in 17 U.S. states in 2012.

> *A 2014 report from Climate Central found that weather related power outages doubled over the 10-year period studies. And a 2013 White House report found that weather related power outages between 2003 and 2012 were estimated to cost the economy between $18 billion and $33 billion.*

More recently, reliability worries have centered around the 2016 Aliso Canyon methane leaks in California that threatened the fuel supply for about 10 GW of power plants in Southern California.

The frequency and duration of power outages has been on the rise in the United States since 2008, according to Department of Energy and North American Electric Reliability Corp.

A 2014 report from Climate Central found that weather related power outages doubled over the 10-year period studies. And a 2013 White House report found that weather related power outages between 2003 and 2012 were estimated to cost the economy between $18 billion and $33 billion.

In a 2014 report, the Connecticut Public Utilities Regulatory Authority found that cybersecurity posed "serious potential damage" to the state's utilities.

One response to these threats has been an uptick in microgrid installations by utilities. Utilities all across the country, including United Illuminating in Connecticut, Oncor in Texas, Central Hudson Gas & Electric in New York, DTE Energy in Michigan, San Diego Gas & Electric and Southern California Edison, are building microgrids.

Fuel cell microgrids to the rescue

As localized and self-sufficient units, fuel cell microgrids can disconnect from the traditional utility power grid to operate autonomously. That ability to "island" from the larger grid means that microgrids can strengthen grid resilience and help mitigate grid disturbances.

Even stand-alone fuel cells—those not within a microgrid—can offer enhanced resiliency. The fuel cell can be directly wired to critical loads and equipment. When a power outage occurs on the grid, the fuel cell powers the load, in a seamless fashion; the customer is unaware of the switch to fuel cell power.

A fuel cell microgrids' enhanced reliability is even more important with the rise of renewable resources such as wind and solar power, which can only supply power when the wind blows or the sun shines.

Microgrids paired with fuel cells, a continuous power source, can bolster and support the growth of renewable resources by providing a secure, predictable, around-the-clock source of energy that complements intermittent renewable power.

Those in search of reliable energy also are likely to find it easier and quicker to site a fuel cell microgrid than many other energy resources. Compared with fossil fuel-fired plants, wind, or solar farms, fuel cells are relatively easy to site. They do not require specialized orientation to operate, or wide swaths of land. They can be sited either outdoors or indoors.

This means that fuel cell microgrids are more likely to be accepted within communities, especially in densely populated areas where microgrids are often deployed to bolster grid resilience and reliability.

Fuel cells are almost emissions free, compact and quiet. In some air districts, including Los Angeles and California's Central Valley, they are completely exempt from air permitting requirements.

The flexibility and continuous output of fuel cells make them an ideal partner for microgrid installations that seek increase grid reliability while maintaining strict environmental standards.

Chapter 5

A Fuel Cell Microgrid Keeps the Lights on in Woodbridge, Connecticut

Students at the Amity Regional High School in Woodbridge, Connecticut are in for a big letdown, but that's a good thing.

While the school's new 2.2 MW fuel cell microgrid will challenge them as a scientific learning lab, it will also mean an end to forced closures due to storm-related power outages. Like the post office (neither snow nor rain nor heat nor gloom of night), the microgrid will keep running when the main power grid fails due to inclement weather.

This provides multiple benefits not just to students' education, but to the surrounding community as well.

"We view this project as a triple win including clean power for the community, reduced financial impact on the district, and educational opportunities for our students from this innovative fuel cell power generation," said Charles Dumais, superintendent of the Amity Regional School District #5.

A good thing, too. This upscale woodsy community of nearly 9,000 residents is within a seagull's wing of the ocean and gets all the wind, ice and fury of a Nor'easter, albeit buffered lightly by the Long Island Sound. Tropical Storm Irene and Superstorm Sandy unfortunately demonstrated the vulnerabilities millions of people suffer via power failures, flooding, sewer plant failures and water pollution.

During power outages, the fuel cell microgrid will island and serve seven critical buildings in this small town near New Haven. These include, in addition to the local high school, town hall, library, fire station, public works facility and senior center/emergency facility. The remainder of the time the fuel cell will supply the regional grid. And, in addition to supplying power, the fuel cell microgrid will also act as a heat source for the high school.

A utility microgrid, the project uses a new underground distribution circuit which separates from the remainder of the utility system to form the microgrid during islanding. The microgrid supports multiple facilities separated over a half mile expanse.

The fuel cell part of the microgrid project is complete and is providing power. The cell was provided by Connecticut-based FuelCell Energy. The company also is designing the microgrid controller that will run the project's automated operation.

FuelCell Energy will operate the fuel cell under contract with local utility United Illuminating. The unit converts natural gas into electricity and heat through a highly efficient electrochemical process that requires no combustion, so creates no accompanying emissions.

The utility is using the project to help meet its state requirement to develop 10 MW of renewable energy. The fuel cell microgrid has received $3 million from the state's microgrid grant program. A 2.8-MW fuel cell project in Bridgeport by United Illuminating, also powered by FuelCell Energy, will provide additional help to fulfill the utility's commitment to provide cleaner energy.

Chapter 6

Of Smart Financing and Fuel Cell Microgrids

Spiritualist drawing rooms in 19th century Bridgeport were replete with ethereal energies. One stately salon in this seaside Connecticut community ‘saw’ a restless spirit mimic the sound of a hissing steam engine and cause the sense of strong currents of air rushing through the closeted room.

Somewhat more sedate, thankfully, modern Bridgeport is home to complex energies of a different sort.

The University of Bridgeport (UB), with its campus located on Long Island Sound, has more than 5,500 students. Its online degree programs have consistently ranked among the top 15 or so in the country. And the school partnered with the Peace Corps in 2014 to offer New England’s first Peace Corps Preparatory Program.

Now the small private university is set to add another feather to its cap: It is home to a highly innovative—and positively energetic—financing and operational business model for microgrids.

First, Connecticut-based fuel cell manufacturer FuelCell Energy built the university’s 1.4 MW microgrid. Then it sold the project to generation giant NRG Energy. The all-cash deal was structured under a power purchase agreement (PPA) arrangement, the same financing method that aided the dramatic rise of solar photovoltaics over the last decade.

UB is buying the fuel cell’s electricity and heat under a 12-year PPA with a possible seven-year extension. PPAs create tax benefits that draw investors. The tax-exempt university cannot take the federal investment tax credit available for fuel cells. But a private investor can, in this case NRG Energy.

Hence, the deal allows each participant to receive the specific benefits that are important to them. And those that they do not need are turned over to other parties to the deal.

Since the fuel cell is configured for combined heat and power, the waste heat is captured and used at three different locations on campus—to heat an Olympic-sized swimming pool, and for heat and hot water for an apartment complex and dorms.

The university receives clean and reliable on-site power at a known cost. In return, it acts as a creditworthy buyer of the project’s output. As a project investor, NRG receives consistent financial returns that are not dependent on weather or time of day. Meanwhile, FuelCell Energy receives recurring revenue for operating and maintaining the fuel cell for the length of the deal.

The fuel cell now supplies 80 percent of UB’s power needs to critical facilities such as residence halls, campus security, a dining hall, and student center. The savings extend to more than the 7,000 tons of carbon dioxide, 64 tons of sulfur oxides, and 28 tons of nitrogen oxides, but also to cost savings—approximately 20 percent during normal operations.

Since the fuel cell is configured for combined heat and power, the waste heat is captured and used at three different locations on campus—to heat an Olympic-sized swimming pool, and for heat and hot water for an apartment complex and dorms.

The Bridgeport microgrid received almost $2.2 million in state funding for eligible design, engineering and interconnection infrastructure costs. The campus can shelter about 2,700 residents during a crisis, and the dining hall can provide food services. It serves as a logical companion to another Bridgeport project funded in an earlier microgrid solicitation, which will provide power largely for critical city services.

