

RESILIENTPOWER

A project of **CleanEnergy**Group

Hydrogen and Fuel Cells for Resiliency: Microgrids for Grid Power

June 16, 2016



Housekeeping



← All participants are in “Listen-Only” mode. Select “Use Mic & Speakers” to avoid toll charges and use your computer’s VOIP capabilities. Or select “Use Telephone” and enter your PIN onto your phone key pad.

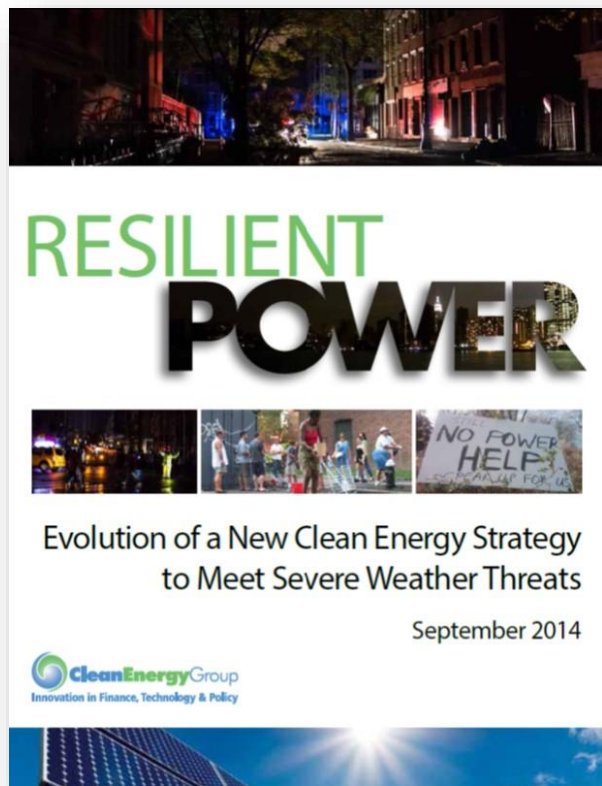
← Submit your questions at any time by typing in the Question Box and hitting Send.

This webinar is being recorded.

You will find a recording of this webinar, as well as previous Resilient Power Project webinars, online at:

www.resilient-power.org

Who We Are



www.cleangroup.org

www.resilient-power.org



SURDNA FOUNDATION

Fostering sustainable communities in the United States

Resilient Power Project

- Increase public/private investment in clean, resilient power systems
- Engage city officials to develop resilient power policies/programs
- Protect low-income and vulnerable communities
- Focus on affordable housing and critical public facilities
- Advocate for state and federal supportive policies and programs
- Technical assistance for pre-development costs to help agencies/project developers get deals done
- See www.resilient-power.org for reports, newsletters, webinars, and more.

CleanEnergyGroup
RESILIENT POWER CASE STUDY SERIES

FUEL CELLS FOR CELL PHONE TOWERS

Fuel Cells Keep Mobile Communications Services Running

OVERVIEW
PROJECT TYPE Cell Phone Towers
TECHNOLOGY Hydrogen, Solid Oxide, Proton Exchange Membrane Fuel Cells
FUEL Hydrogen, Methanol, Natural Gas
CAPACITY 15, 55, 155 KW
YEAR INSTALLED 2011
LOCATION Hartford, Connecticut
PROJECT PARTNERS US Dept. of Energy, Ballard, and Solstice

Technology Overview
 Fuel cell systems at cell phone towers include a range of technology and fuel types. Ballard Power Systems, for example, has installed a MW-class fuel cell at the Mount Saint Joseph site, which is powered by a mixture of methanol and water, at cell towers across the Baltimore. These fuel cells provide reliable power during widespread outages caused

Ballard fuel cells provided seamless backup power at 35 Sprint cell towers, where grid outages averaged 35 hours per site, with one outage lasting 20 hours. Today, more than 6,000 fuel cell systems have been installed at cell phone towers across the United States, including at towers owned by Sprint, T-Mobile, Verizon, and AT&T.

Fuel cells at communication towers provide reliable mobile communications services for emergency, as seen here in Hurricane Irene in 2011.

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RESILIENT POWER CASE STUDY SERIES

FUEL CELLS IN HOSPITALS

Fuel Cells Help Provide Life-Supporting Services

OVERVIEW
PROJECT TYPE Hospital
TECHNOLOGY Hydrogen Fuel Cells
FUEL Natural Gas
CAPACITY 400KW - 1.4MW
YEAR INSTALLED 2003-2013
LOCATION Hartford, Connecticut
PROJECT PARTNERS Hartford Steam Company, Low Intensity Renewable Energy Credits Program, UTC Power/Doosan, Fuel Cell Energy, Inc.

Superstorm Sandy caused power outages at hospitals across the northeastern United States, leading to the evacuations of hundreds of patients. Several hospitals have now installed fuel cells to provide backup power for critical services like operating rooms, labor and delivery rooms, intensive care, and refrigeration for medicine and blood.

Technology Overview
 The fuel cell at St. Francis Hospital's main building, a Power PC2, that was provided by UTC Power of South Windsor, Connecticut, meets 10 percent of the facility's electrical needs. The newer FuelCell Middlesex fuel cell at the Mount Saint Joseph campus meets 40 percent of that building's electrical needs. Importantly, the fuel cells provide backup power to the operating

Hospitals provide critical medical technology and support for their patients, such as life support, operating rooms, and refrigerated blood and medicine. They must be able to deliver those services even when the power goes out. Because of this, hospitals are required to have 24 hours of back-up power on-site. Most accomplish this with diesel-powered on-site generators. But this technology is prone to failure, as was seen at hospitals and nursing homes in Louisiana during Hurricane Katrina in 2005, and throughout the Northeast during Superstorm Sandy in 2012. At Johnson Memorial Center in Stafford, Connecticut, for example, 40 critically ill patients, including those in intensive care, had to be evacuated during Superstorm Sandy when the hospital's back-up diesel generator failed. New York University Langone Medical Center, in New York City, also had to perform a harrowing evacuation of 400 patients during Superstorm Sandy when its backup generators began to fail. Throughout the storm, critical units like the emergency room, labor and delivery rooms, and refrigeration lost power. Baltimore and critically ill patients were evacuated and freed, including 10 babies from neonatal intensive care, some of whom had to be placed on battery-powered respirators. Critically ill patients were carried down as many as 15 flights of stairs because elevators could not function without electricity, and scenes were marred by gaping gaps of capacity to replace respirators that were without power.

As a result of the widespread and catastrophic failure of diesel generators during recent storms, hospital administrators in the Northeast have looked for more reliable ways to provide emergency backup power, and several have turned to fuel cells. St. Francis Hospital in Hartford, Connecticut installed a 400 kW fuel cell at the Mount Saint Joseph site in 2013. This was its second fuel cell; a 1.4 MW unit was installed in its main campus in 2011, which was later upgraded to a 400 kW unit. In 2013, Hartford Hospital installed a 1.4 MW fuel cell.

The fuel cell at St. Francis Hospital's main building, a Power PC2, that was provided by UTC Power of South Windsor, Connecticut, meets 10 percent of the facility's electrical needs. The newer FuelCell Middlesex fuel cell at the Mount Saint Joseph campus meets 40 percent of that building's electrical needs. Importantly, the fuel cells provide backup power to the operating

UTC Power is now operating in Doosan Fuel Cell America.

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FUEL CELLS FOR EMERGENCY RESPONDERS

A New York City Police Precinct Turns to Fuel Cells

OVERVIEW
PROJECT TYPE Police Station
TECHNOLOGY Hydrogen Fuel Cell
FUEL Natural Gas
CAPACITY 200KW
YEAR INSTALLED 2009
LOCATION Central Park, Manhattan, New York
PROJECT PARTNERS New York Power Authority, US Department of Defense and Energy, OMN Corporation/Doosan

The Central Park Station remained fully operational during the blackout. Staff at the facility didn't even know about the blackout until they looked outside and saw all the lights were off.

A fuel cell power plant at New York City's Central Park Precinct kept the building powered during Superstorm Sandy, leaving people in Manhattan safe.

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RESILIENT POWER CASE STUDY SERIES

FUEL CELLS FOR SCHOOLS

A School's Fuel Cell Saves Money and Provides Emergency Shelter

OVERVIEW
PROJECT TYPE Public High School and Emergency Storm Shelter
TECHNOLOGY Hydrogen Fuel Cell
FUEL Natural Gas
CAPACITY 400KW
YEAR INSTALLED 2011
LOCATION Hartford, Connecticut
PROJECT PARTNERS US Dept. of Energy, Connecticut Green Bank, and UTC Power/Doosan

The school provided space for 200 people to sleep each night and served 600 hot meals over the course of a 24-hour day. A nurse's station was kept operational, hot showers were available, and power outlets were available to charge cell phones.

Technology Overview
 The school's fuel cell ran on natural gas, which is delivered through underground pipes and therefore typically much less susceptible to storm damage than electrical lines. Because of this, the school was able to supply itself with electricity and heat during the power outage. The school provided space for 200 people to sleep each night and served 600 hot meals over the course of the 24-hour day. A nurse's station was kept operational, hot showers were available, and power outlets were available to charge cell phones. "It was almost like a hotel," said Town Manager Matt Gagliardi in a Hartford Courant article.

Using a fuel cell to generate electricity and heat has been used at South Windsor High School since 2009.

DOOSAN Fuel Cell America

Resilient Power Project

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RESILIENT POWER PROJECT

To reduce impacts and dangers of power outages in communities now and in the future, the Resilient Power Project works to provide technology and policy solutions to address three challenges: Community Resiliency, Climate Adaptation, and Climate Mitigation.

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With the Resilient Power Project, Clean Energy Group and [Meridian Institute](#) are working to accelerate market development of clean energy technologies for resilient power applications that serve low-income communities and vulnerable populations during disasters and power disruptions, and to address climate adaptation and mitigation goals through expansion of reliable renewable energy deployment. To reduce impacts and dangers of power outages in communities now and in the future, the Resilient Power Project works to provide technology and policy solutions to address three challenges facing the country: Community Resiliency, Climate Adaptation, and Climate Mitigation.

Clean Energy Group's role in this process is to help inform, coordinate, and support federal, state, and local officials, policy makers and developers with the goal of deploying resilient power projects in communities across the country. In addition to providing program guidance to policy makers and limited technical assistance funding for project development, we also prepare reports and analysis on resilient power

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Northeast Electrochemical Energy Storage Cluster (NEESC)

NEESC is a network of industry, academic, government and non-governmental leaders working together to help businesses provide energy storage solutions.



www.neesc.org

Today's Guest Speakers

- **Robert Rose**, Vice President, A-Z Corp
- **Ben Toby**, Vice President of Sales, FuelCell Energy



FuelCell Energy
Ultra-Clean, Efficient, Reliable Power



FuelCell Energy

Ultra-Clean, Efficient, Reliable Power



Hydrogen & Fuel Cells for Resiliency: Microgrids for Grid Power

June 16, 2016



Ben Toby

FuelCell Energy, Inc.

Robert Rose

A/Z Corporation

Ultra-Clean | Efficient | Reliable Power

- Interconnected Loads
- Distributed Generation
 - Fuel Cell
 - Reciprocating Engine
 - Gas Turbine
 - Micro-Turbine
 - Renewables
 - PV
 - Wind
 - Energy Storage
- Defined Electrical Boundaries
- Single Controllable Entity



Define Overall Objective(s)

- Critical Facility
- Existing infrastructure
- Financial Options
- Technical Requirements
 - Electrical Distribution
 - Thermal Distribution
 - Fuel Source



Daegu, South Korea, 11.2 MW

Why Fuel Cells?

- Energy Cost Savings
- Reliable, Grid Independent
- Clean, Quiet & Efficient
- Fuel Flexible
- Permitting and Siting Ease



Central CT State University, 1.4 MW



Hartford Hospital, 1.4 MW

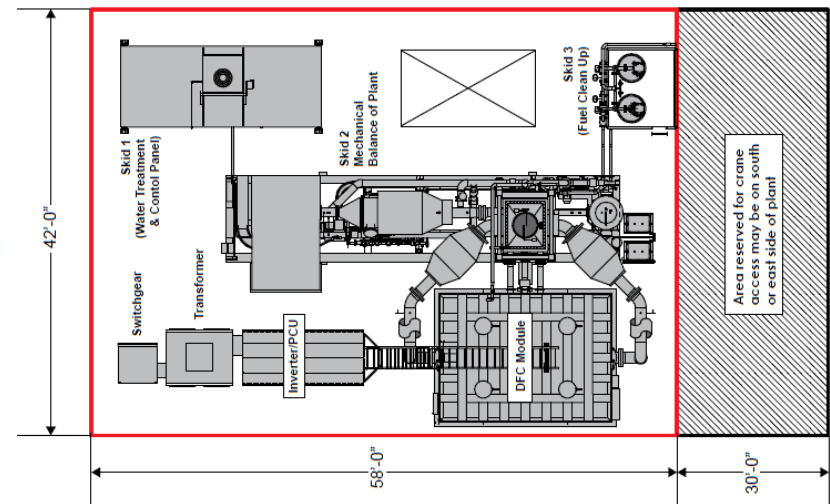
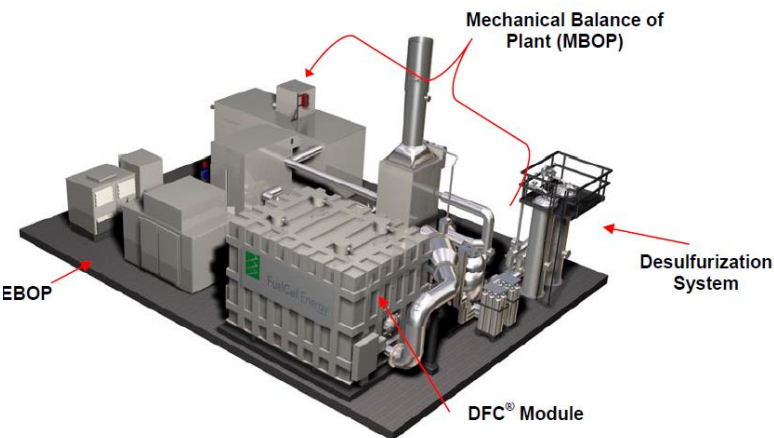
Power Source	Efficiency (%LHV)	NOx (lb/MWh)	SOx (lb/MWh)	PM ¹⁰ (lb/MWh)	CO ₂ (lb/MWh)
Average U.S. Grid	33%	3.43	7.9	0.19	1,408
Average U.S. Fossil Fuel Plant	36%	5.06	11.6	0.27	2,031
DFC® Fuel Cell on Nat Gas	47%	0.01	0.0001	0.00002	940
DFC® Fuel Cell on Nat Gas (CHP)	80%	0.006	0.00006	0.00001	550
DFC® Fuel Cell on Biogas (CHP)	80%	0.006	0.00006	0.00001	0

Source for non-DFC data: "Model Regulations For The Output Of Specified Air Emissions From Smaller scale Electric Generation Resources Model Rule and Supporting Documentation", October 15, 2002; The Regulatory Assistance Project report to NREL

DFC[®]1500 Fuel Cell Power Plant

The DFC[®]1500 stationary fuel cell power plant from FuelCell Energy provides high-quality, Ultra-Clean electrical power with 47% efficiency, and high quality exhaust heat suitable for hot water, steam, or absorption chilling applications, around the clock. Designed for commercial and industrial applications, the system offers easy transport, quiet and reliable operation, and simple site planning and regulatory approval. The DFC1500 is ideal for wastewater treatment plants, manufacturing, food and beverage processing, universities and office campuses.

Gross Power Output		Available Heat		Pollutant Emissions	
Power @ Plant Rating	1,400 kW	Exhaust Temperature	700 +/- 50 °F	NOx	0.01 lb/MWh
Standard Output AC voltage	480 V	Exhaust Flow	18,300 lb/h	SOx	0.0001 lb/MWh
Standard Frequency	60 Hz	Allowable Backpressure	5 iwc	PM10	0.00002 lb/MWh
Optional Output AC Voltages	By Request	Heat Energy Available for Recovery		Greenhouse Gas Emissions	
Optional Output Frequency	50 Hz			CO ₂	980 lb/MWh
Efficiency		(to 250 °F)	2,216,000 Btu/h	CO ₂ (with waste heat recovery)	520-680 lb/MWh
LHV	47 +/- 2 %	(to 120 °F)	3,730,000 Btu/h		



DFC[®] 3000 Fuel Cell Power Plant

FuelCell Energy's DFC3000™ system is the largest of the Direct FuelCell[®] (DFC[®]) power plant fleet, capable of providing high-quality baseload power with 47% electric power generation efficiency around-the-clock. Scalable for Multi-Megawatt Fuel Cell Parks, the system is especially suitable for applications with larger load requirements such as universities, manufacturing facilities, wastewater treatment plants, and utility/grid support.

Gross Power Output

Power @ Plant Rating	2,800 kW
Standard Output AC voltage	13,800 V
Standard Frequency	60 Hz
Optional Output AC Voltages	By Request
Optional Output Frequency	50 Hz

Efficiency

LHV	47 +/- 2 %
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Available Heat

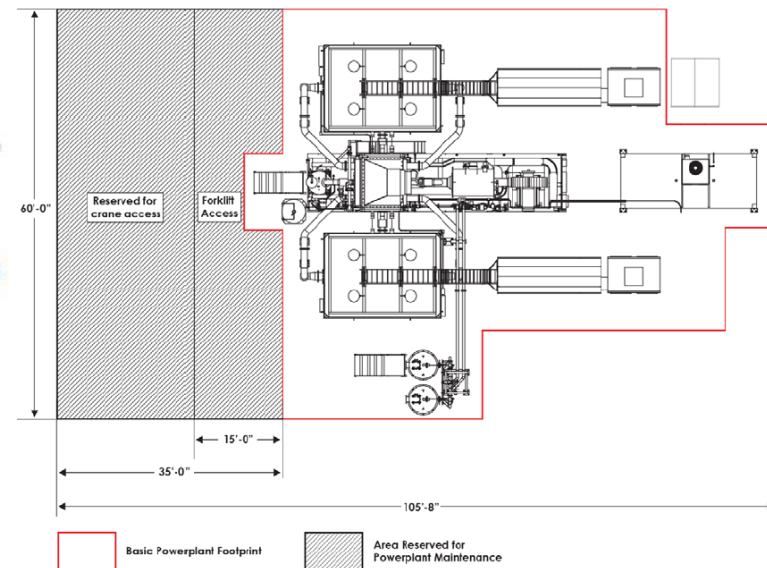
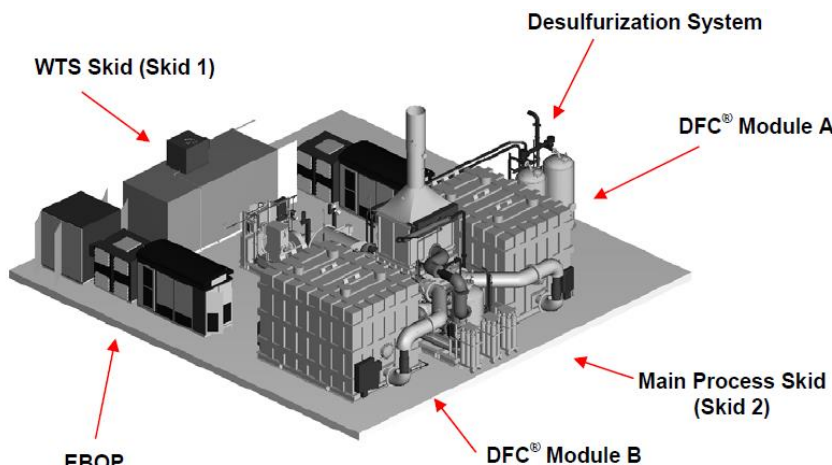
Exhaust Temperature	700 +/- 50 °F
Exhaust Flow	36,600 lb/h
Allowable Backpressure	5 iwc
Heat Energy Available for Recovery (to 250 °F)	4,433,000 Btu/h
(to 120 °F)	7,460,000 Btu/h

Pollutant Emissions

NOx	0.01 lb/MWh
SOx	0.0001 lb/MWh
PM10	0.00002 lb/MWh

Greenhouse Gas Emissions

CO ₂	980 lb/MWh
CO ₂ (with waste heat recovery)	520-680 lb/MWh



Direct FuelCell[®] Power Plant

Key

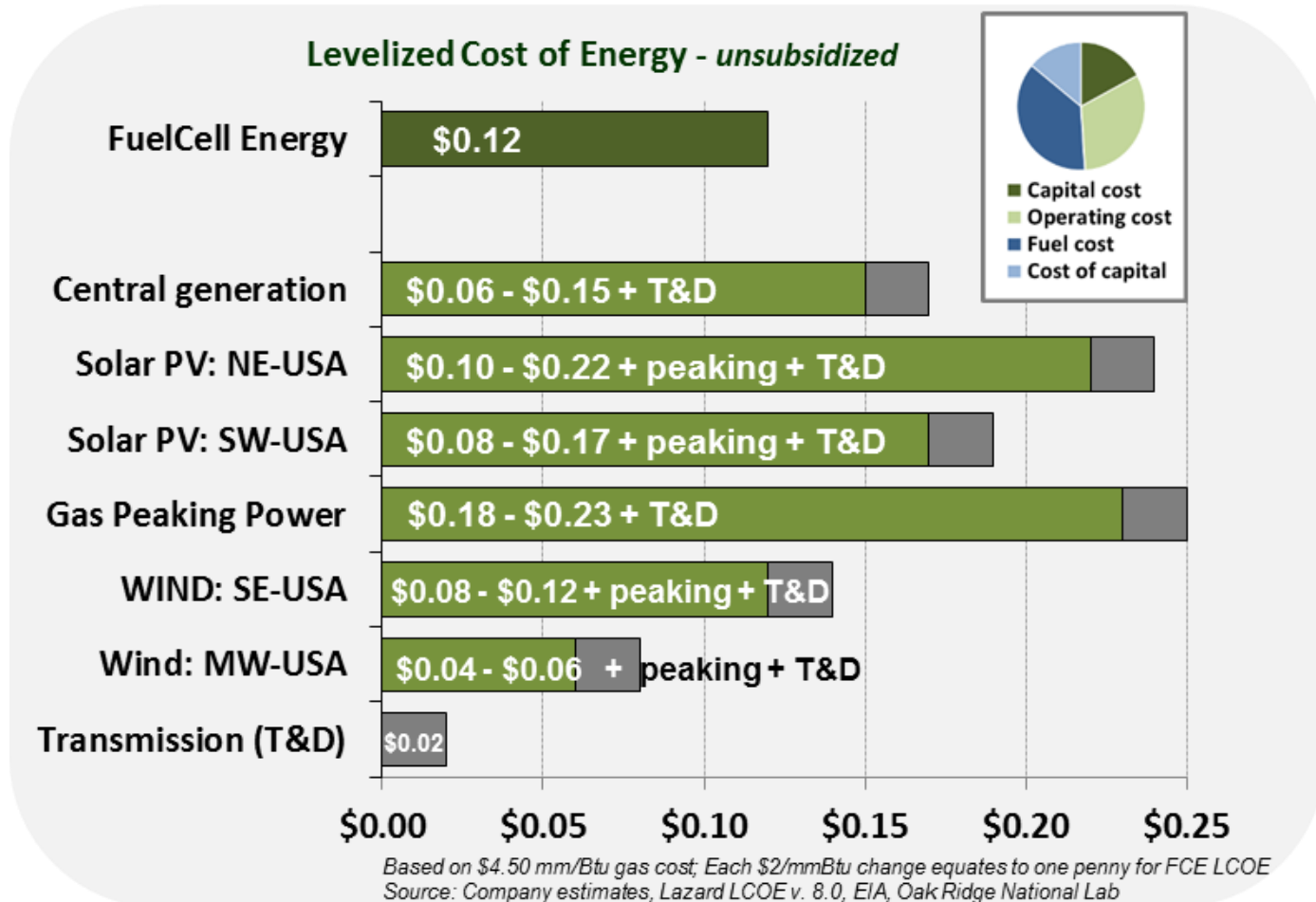
Fuel cell module

Mechanical
Balance of
Plant (MBOP)

Electrical
Balance of
Plant (EBOP)



Levelized Cost of Electricity



Grid-Independent Capability

Fuel cells provide dependable, clean electricity and heat for microgrids, either alone or in parallel with other generation sources

Grid Connected mode

In normal operation the fuel cell synchronizes to local utility grid and offsets part or all of the load demand of the facility, reducing power needed from the utility

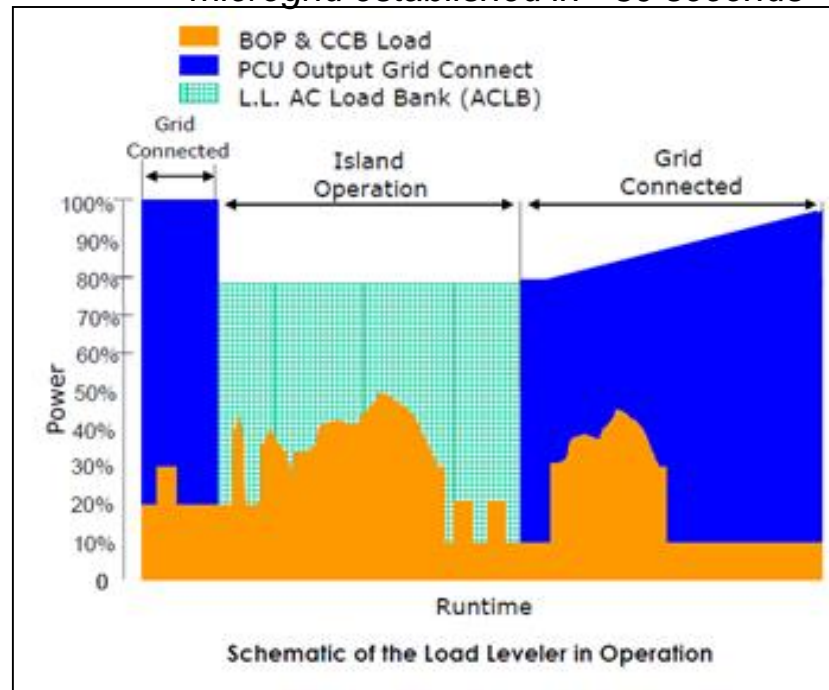
Microgrid mode

After a grid outage, facility loads see a brief interruption, and are then reconnected in a controlled manner to the fuel cell and other on-site sources

Critical Supply mode

Upon grid outage, disconnects from the grid and enters standby mode. Seamless backup power available to hard-wired customer critical loads up to 85% of fuel cell output

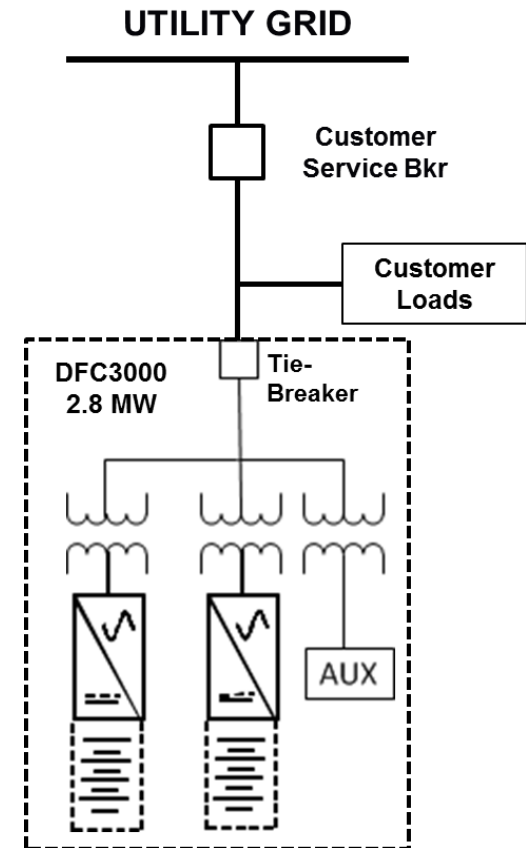
*Load Leveler operation profile:
microgrid established in ~30 seconds*



Grid Connected Mode

Powerplant synchronizes to local utility grid and reduces local power demand or exports power to grid. Grid must meet stringent requirements for voltage and frequency or powerplant will disconnect and go into grid independent mode

- Baseload, Full Power Production
- Current Control Mode
- Match & Follow Grid Voltage
- UL-1741 Anti-Islanding Detection
 - Abnormal Volt. & Freq.
 - Active anti-islanding algorithm



Micro-Grid Mode

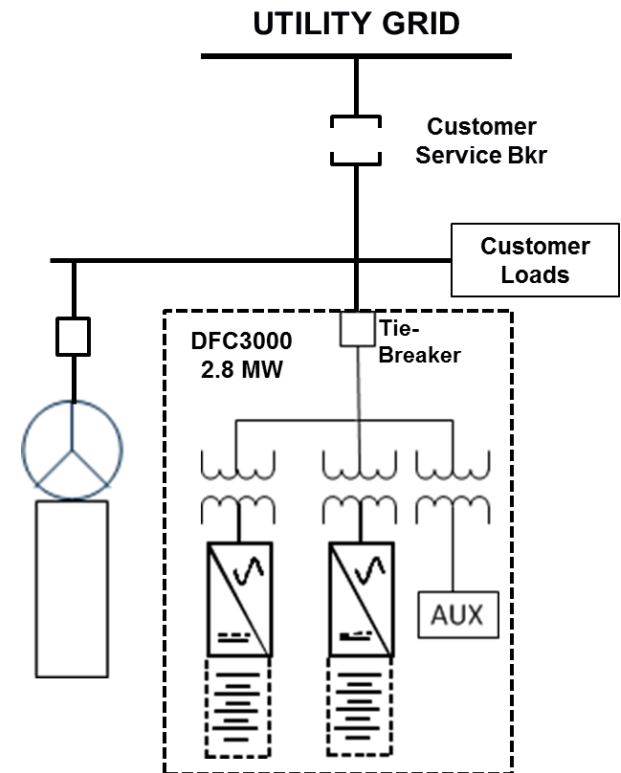
Powerplant synchronizes to microgrid either as a baseload current source, reducing output from local power generation systems, or as a load following voltage source in parallel with other local generators or as a stand-alone generator

Current Source Micro-Grid Mode

- Gen set connects to bus at rated voltage and freq
- DFC syncs with gen set and connects to bus with wider V&F relay settings and active anti-islanding disabled.

Voltage Source Micro-Grid Mode

- Multiple fuel cells or fuel cell / gen set combination.
- No master sync setting, units synchronize autonomously
- Compliant with CERTS philosophy

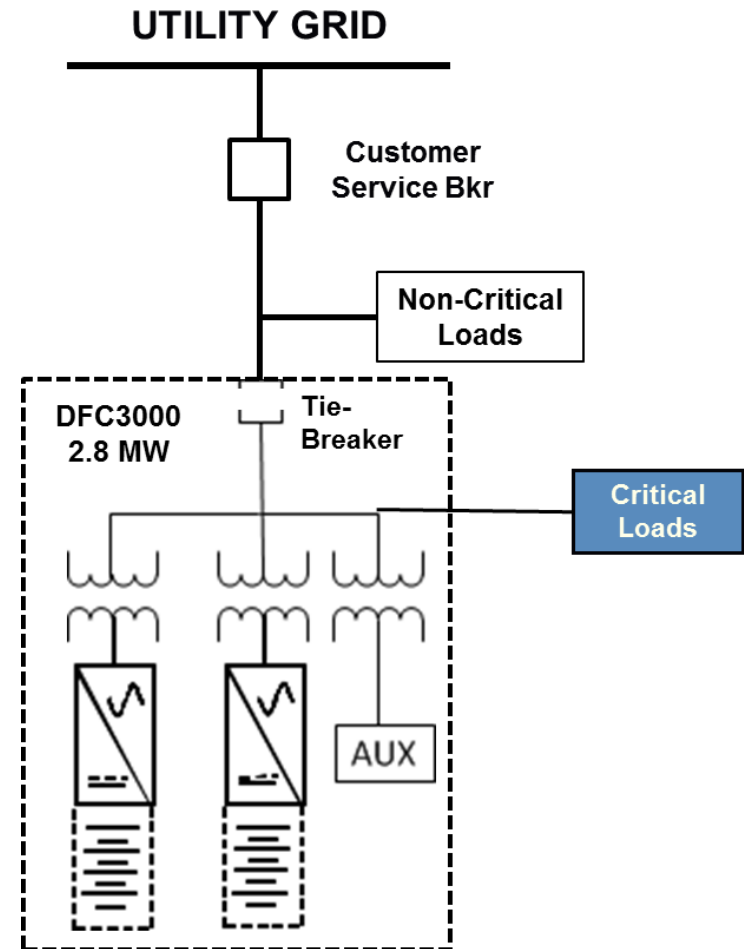


Critical Supply Mode

Powerplant is not connected to grid, generates its own frequency signal. Supports powerplant parasitic loads in standby mode, and can support local critical loads

Upon detection of abnormal Voltage & Frequency:

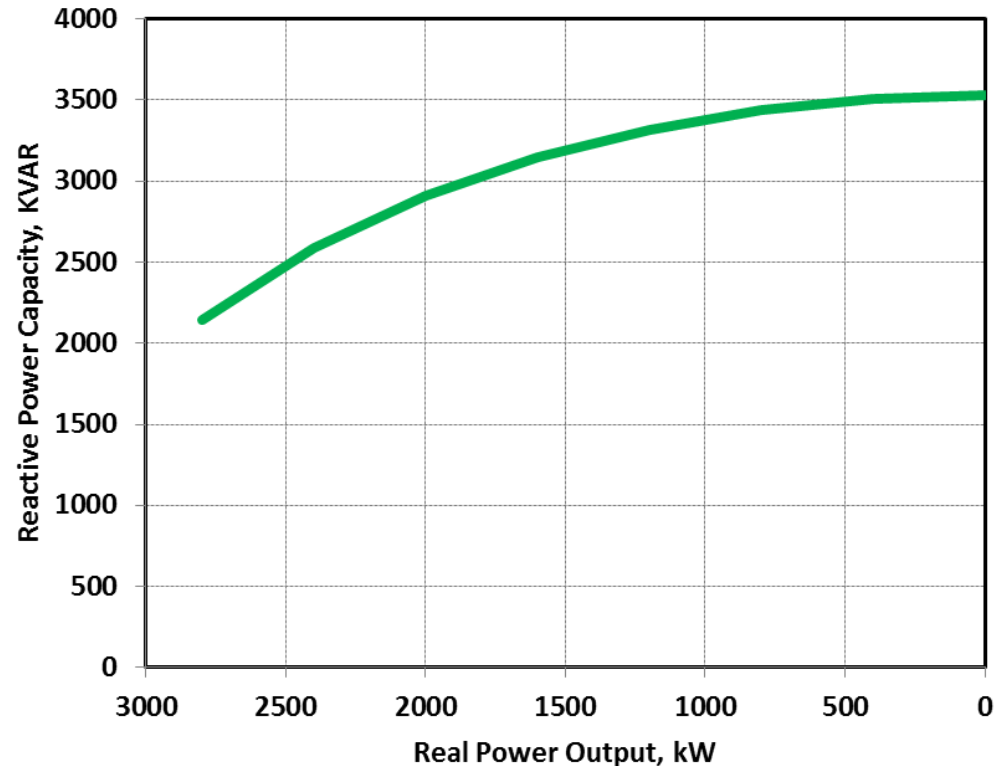
- Tie Breaker Opens
- Switch to Voltage Control Mode
- Parasitic and Critical loads recovered <4 cycles



Reactive Power Capabilities

By supplying reactive current locally, less KVA is needed from the local utility or micro grid system.

- Frees up capacity in the local grid or micro-grid.
- Reduces total electric system losses
- Fast and precise power factor correction



All DFC plants are capable of generating rated output from better than (-) 0.9 to (+) 0.9 pf

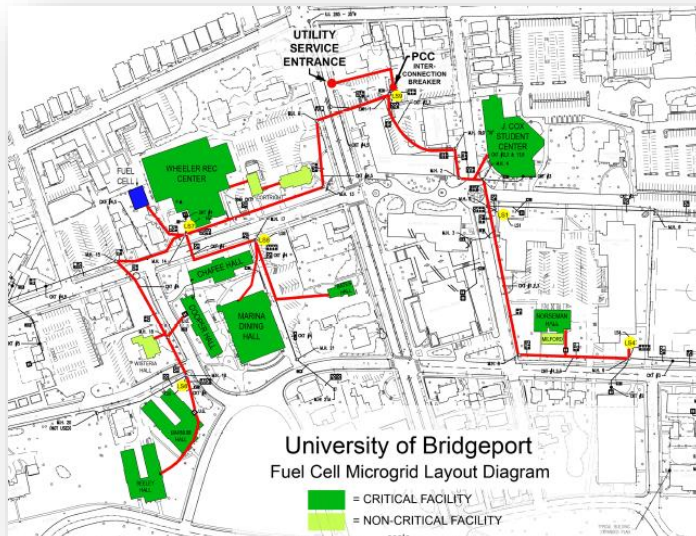
- 2.8 MW System can provide more than 2 MVAR @ 2800kW, with higher reactive capabilities at lower kW output

Project Overview

- 1.4 MW combined heat & power fuel cell power plant
- Supplies 80% of campus power needs
- Waste heat converted to hot water and supplied to three locations on campus

Benefits

- ~20% cost savings during normal operations
- In a grid outage, power to critical facilities – shelter, security, dining
- Renewable Energy Research Lab – “practice what we teach”
- Emissions reductions:
7,000 tons CO₂, 64 tons SO_x, 28 tons NO_x



Fuel Cell only

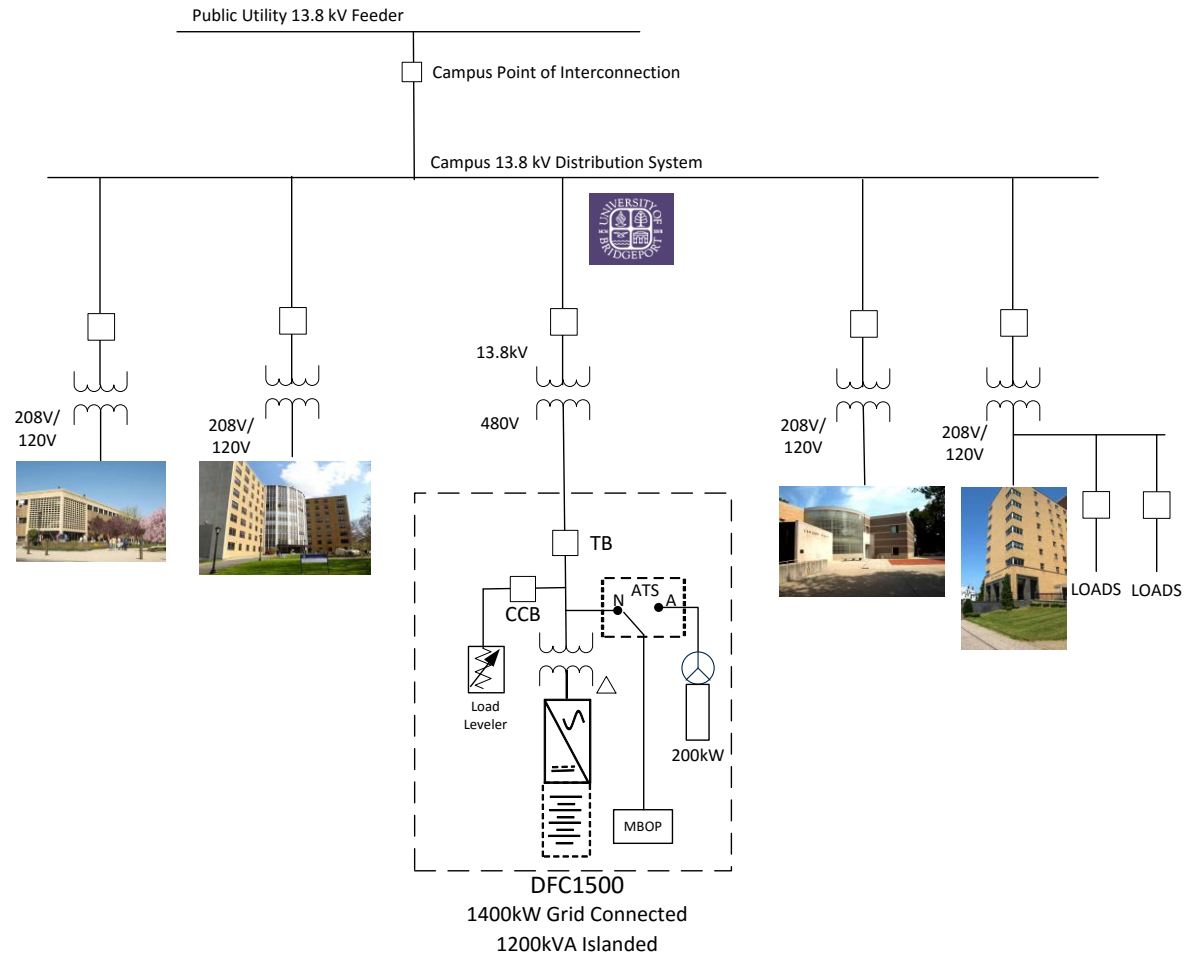
- 1.4 MW Fuel Cell
- Load Follow Capable
- Black-Start Capable

Grid Connected Operation

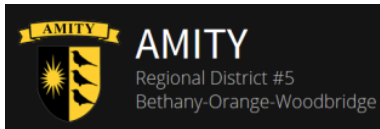
- Base Load, Net Metering
- Heat to Campus

Microgrid Operation

- “Drop & Pickup”
- Microgrid controller sequences critical facilities
- Inverter follows microgrid load
- Load Leveler maintains fuel cell power constant



Town of Woodbridge, CT



Project Overview

- 2.2 MW combined heat & power fuel cell power plant
- Power to UI grid during normal operation
- Supplies 100% of Town microgrid power needs during grid outage
- Heat supplied to Amity High School
- Connecticut Microgrid Program Award

Benefits

- Helps UI achieve its Class I RPS goals
- In a grid outage, power to critical facilities – police, fire, community services
- Savings to Amity High School ~ \$100K per year from avoided natural gas
- Enabled upgrade to local gas grid delivery infrastructure

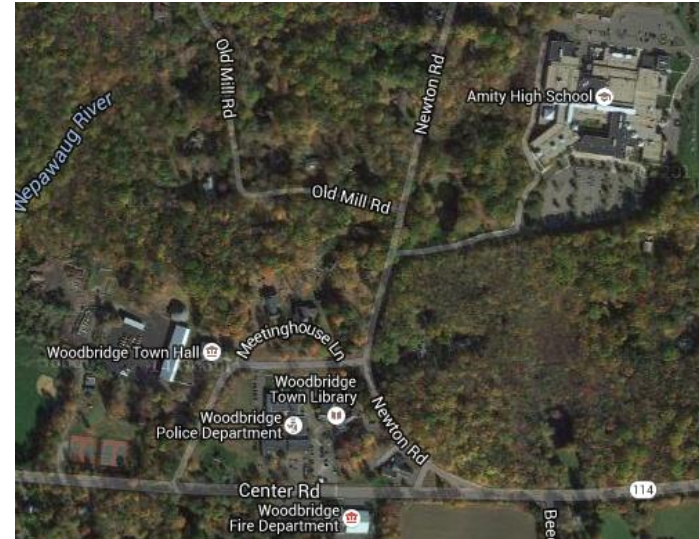
Town of Woodbridge, CT

Fuel Cell only

- 2.2 MW Fuel Cell
- Hot water to High School
- Load Follow Capable
- Black-Start Capable

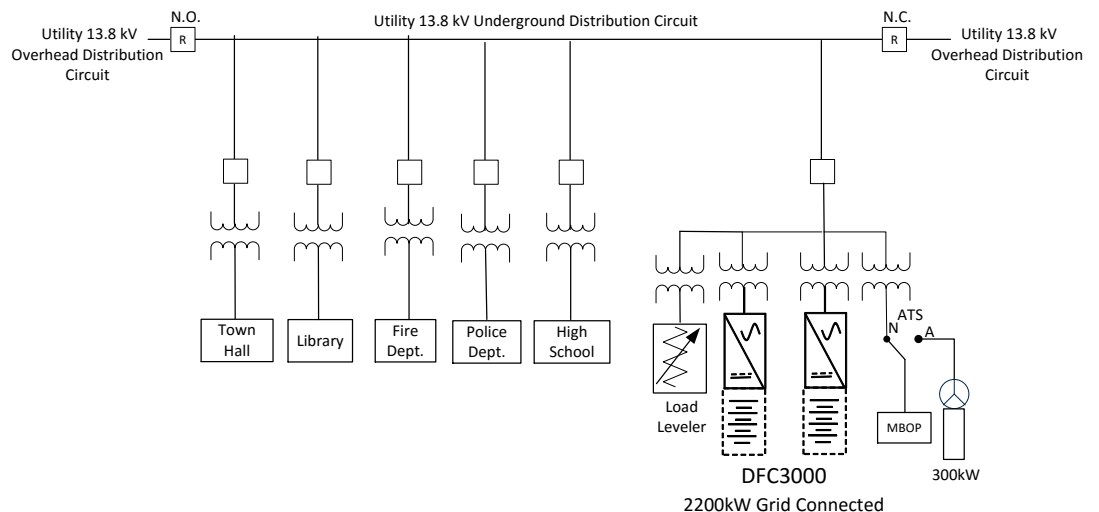
Grid Connected Operation

- Base Load
- Heat to High School

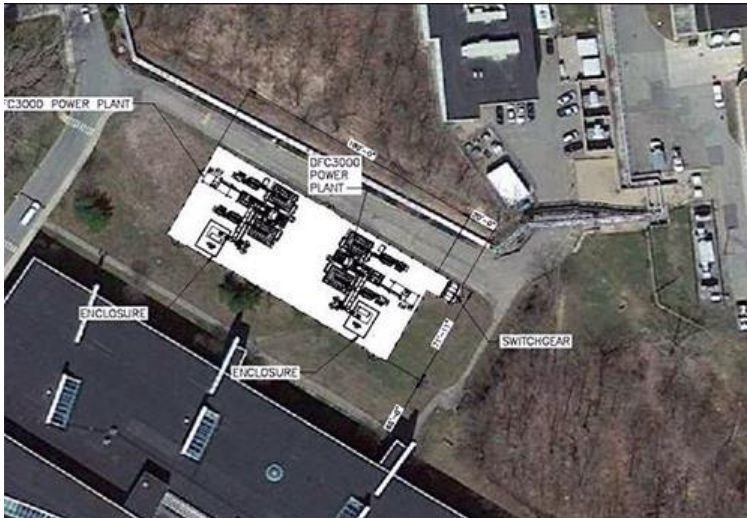


Microgrid Operation

- “Drop & Pickup”
- Microgrid controller sequences critical loads
- Inverter follows microgrid load
- Load Leveler maintains fuel cell power constant



Pfizer R&D Center, Groton CT



Pfizer Groton installation site



5.6 MW fuel cell installation in South Korea

Project Overview

- Grid-connected 5.6 MW fuel cell powered by Natural Gas
- Provides electricity and steam to Pfizer Groton campus
- Seamless grid independent capability
- Private, Critical Facility Microgrid

Benefits

- Closes electrical generation gap with a more reliable source than the commercial grid – makes site independent year round
- PPA structure with no up-front capital cost, delivers energy cost savings to Pfizer
- Enhances site sustainability profile (green energy source)
- Clean profile reduces permitting hurdles

Pfizer R&D Center, Groton CT

Fuel Cell – Gas Turbine

- 10 MW Gas Turbine
- (2) 2.8 MW Fuel Cells
- Load Follow Capable
- 2 Levels of Seamless Backup.

Grid Connected Operation

- Fuel Cells Base Loaded
- Steam to Campus
- Gas Turbine follows campus load to maintain zero utility import/export.

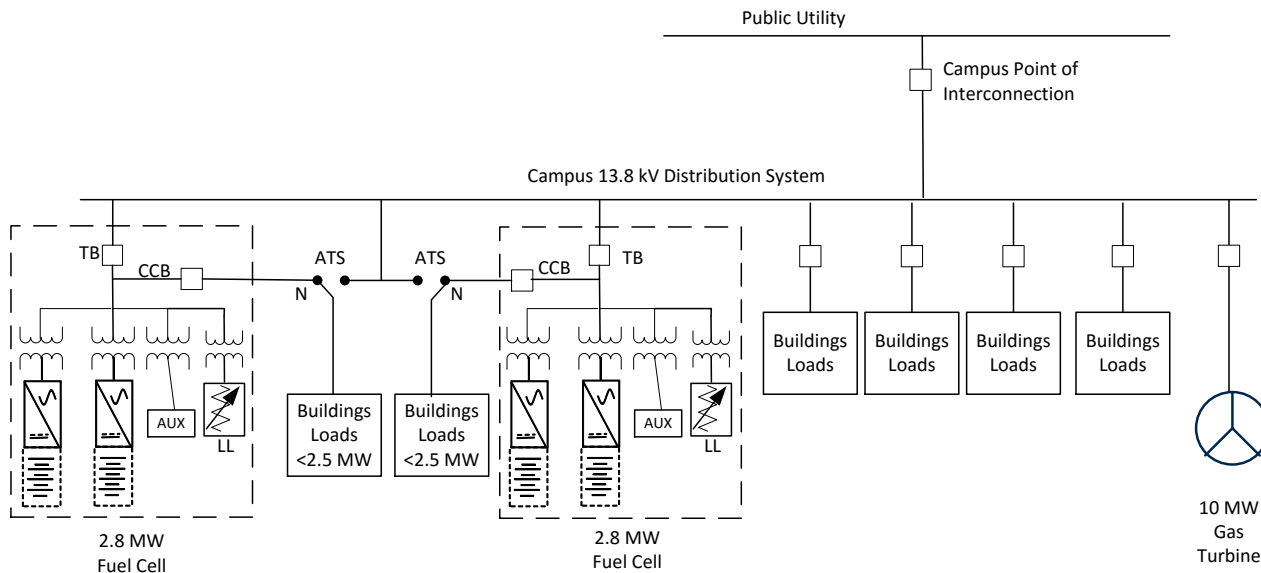
Microgrid Operation

Loss of Utility

- Seamless disconnect from utility
- FC base load
- Turbine Load Following

Loss of Gas Turbine & Utility

- Seamless disconnect from Campus.
- FC maintains critical building loads.



- Fuel cell advantages in microgrids:
 - Low emission, quiet distributed generation solution
 - High efficiency, low carbon
 - Reactive power support
 - Energy Cost savings
- Technology proven and gaining acceptance globally
- Complex projects requiring staged development with CHP as the cornerstone
- Clean, Efficient & Financeable





Ben Toby | Vice President, Sales

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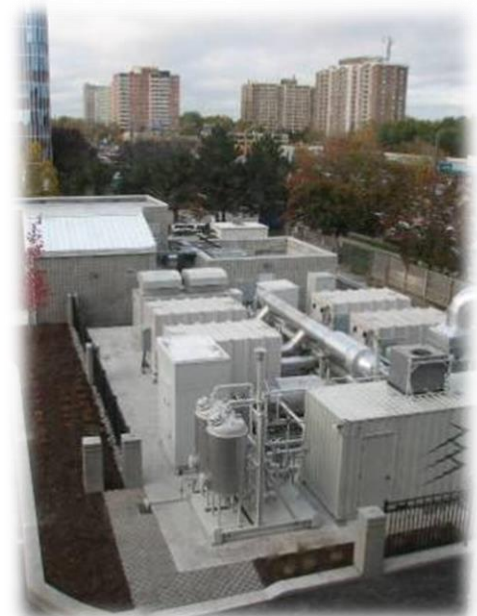
www.fuelcellenergy.com

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