Use of Stationary Fuel Cells as the Backbone of the Modern Microgrid

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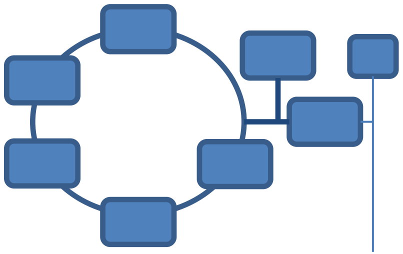
Michael Palmer, Director, Business Development

Fuel Cells for Microgrids

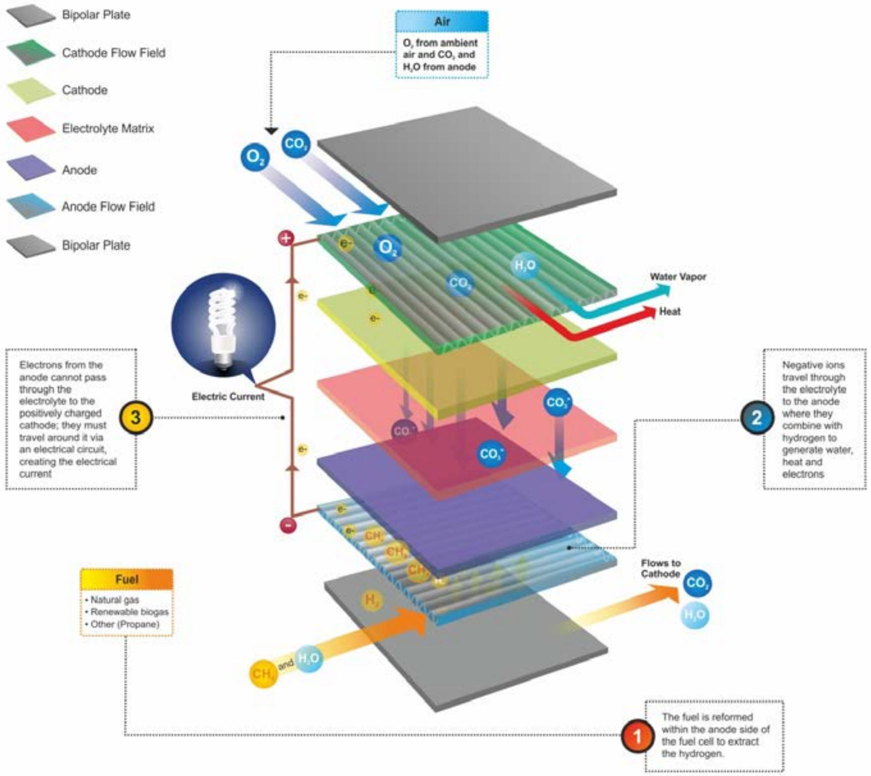


- **Microgrids offer many benefits**: Savings, GHG reduction, and improved Resiliency
- **Stationary Fuel Cells are ideally suited to support microgrid goals**:
  - Complex projects requiring staged development with CHP as the cornerstone
  - **Clean** – next to no emissions and easily permitted
  - **Resilient** – on-site continuous power generation
  - **Quiet** – no combustion and minimal mechanical parts
  - **Efficient** – higher electrical efficiency than traditional generation sources
  - **Affordable** – financing flexibility allow for immediate savings and creative project development

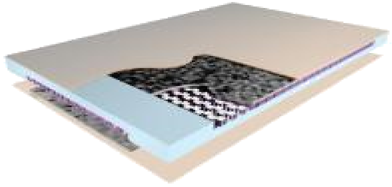
How a Fuel Cell Works

Electrochemical Conversion of Fuel to Electricity

- Consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte
- Fuel and water is fed to the anode and air is fed to the cathode
- A catalyst at the anode separates hydrogen molecules into protons and electrons, creating a flow of electricity between cathode and anode
- The chemical reaction also produces water and heat



Fuel Cell Configuration



Individual fuel cell component

400 components are used to build one 350 kW fuel cell stack

4 stacks are combined to build a 1.4 MW plant

The stacks are enclosed, creating the fuel cell module

Two modules are used for a 2.8 MW power plant

Technical Data

	Power Output (kW)	Electric Eff.	NOX (lb/MWh)	SOX (lb/MWh)	PM10 (lb/MWh)	CO2 (lb/MWh; electric only)	CO2 (lb/MWh; w / heat recovery)	Heat Output @ 250 F (MMBtu/h)
Average US Grid		33%	3.43	7.9	0.19	1,408		
Average US Fossil Plant		36%	5.06	11.6	0.27	2,051		
SureSource™ Fuel Cells	1,400	47%	0.01	Negligible	Negligible	980	520-680	2.216
	2,800	47%	0.01	Negligible	Negligible	980	520-680	4.433
	3,700	60%	0.01	Negligible	Negligible	725	550-680	0.734

** - fuel flexible (natural gas, H2, biogas, propane)*

Power Source	Size (MW)	Land Required (acres)	Annual Output (MWh)
Fuel Cell	10	1	~83,000
Solar PV	50	375	~83,000
Solar PV	0.13	1	~220

Source: FCE & NREL

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UC San Diego

BioCycle energy

92% SELF-GENERATED ENERGY

SYMPHONY OF THE MICROGRID AT AN URBAN UNIVERSITY

The University of California San Diego's microgrid produces 92 percent of its annual electricity load and 95 percent of its heating and cooling load. A fuel cell powered by directed biogas is a cornerstone of the operation.

Marsha W. Johnston

Project Overview

- Grid-connected 2.8 MW fuel cell powered by Directed Biogas providing electricity and absorption chilling to campus grid

Benefits

- Cost savings during normal operations
- Microgrid satisfies 90% of campus electric needs
- Carbon neutral by utilizing directed biogas
- PPA delivers sustainability, resiliency & cost savings with no up-front expense

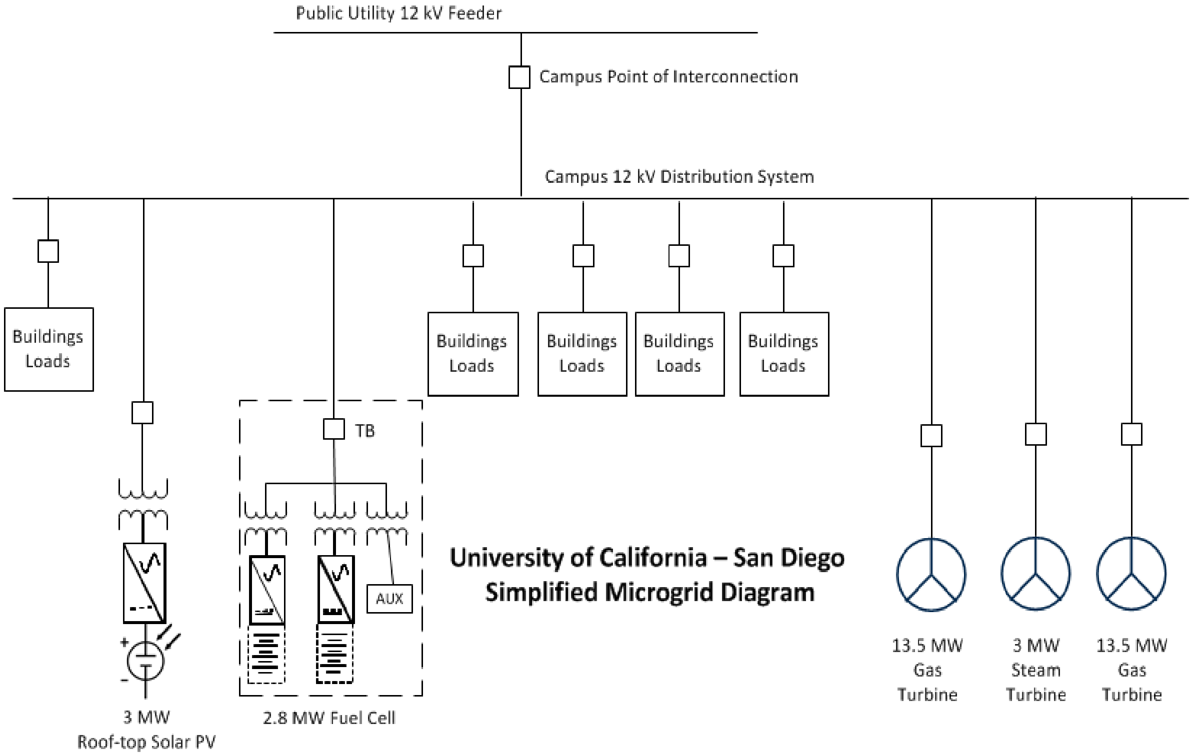
"The University of California San Diego's micro-grid produces 92 percent of its annual electricity load and 95 percent of its heating and cooling load. ***A fuel cell powered by directed biogas is a cornerstone of the operation."***
Marsha W. Johnston, BioCycle July 2014

Generator Dominant

- 30 MW CCGT
- 2.8 MW Fuel Cell
- 3 MW Roof-top Solar

Operation

- Load following by turbine-generators
- Fuel Cell base-load contribution. (treats turbine generators as grid)
- Solar PV intermittent contribution



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University of Bridgeport

UNIVERSITY OF BRIDGEPORT

- The University of Bridgeport, an independent and non-sectarian institution, offers career-oriented undergraduate and graduate degrees

- Comprised of 5,500 students with 1,250 on-campus residents

- 52 buildings including Academic, Administrative, Dormitory and Apartments equaling approximately 1.5M square feet

- Over 53 acres crossing several city streets

"… this micro-grid helps power the campus with reliable and affordable power on a 24/7 basis, and also keeps critical faculties up and running to serve the campus and larger community in the event of a power outage."

Commissioner Robert Klee, CT DEEP Jul-2017

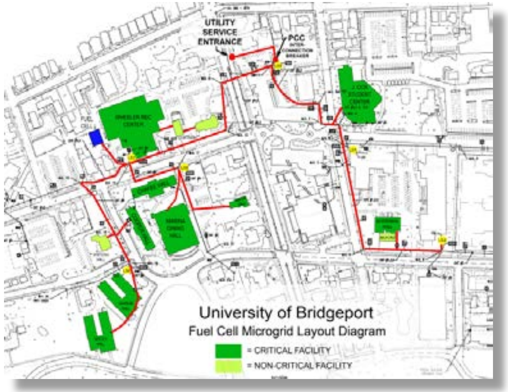
University of Bridgeport

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
- Connecticut Microgrid Program Award

Benefits

- Cost savings
- Maintain power to critical facilities
- Renewable Energy Research Lab
- Emissions reductions: 7,000 T CO_2, 64 T SO_x, 28 T NO_x

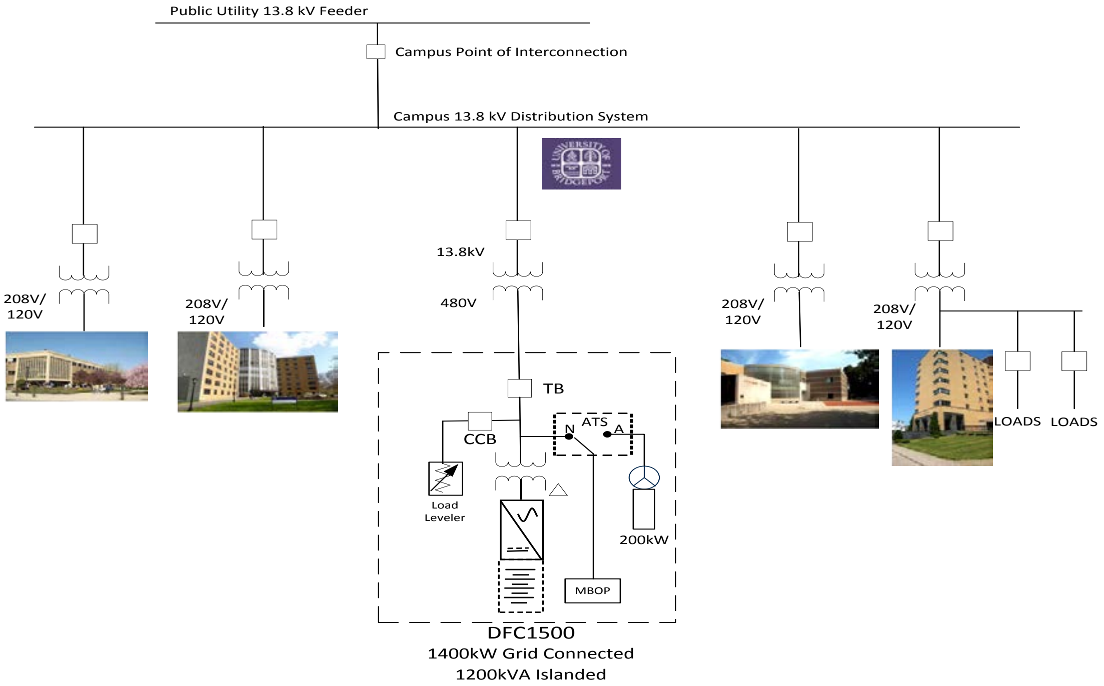


Project structure

- UB pays for power as produced via Power Purchase Agreement
- $300,000 annual savings to UB
- Project investor owns the fuel cell power plant

UNIVERSITY OF BRIDGEPORT

University of Bridgeport



Fuel Cell - Only

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

Grid Connected Operation

- Base Load, Net Metering
- Heat to Campus

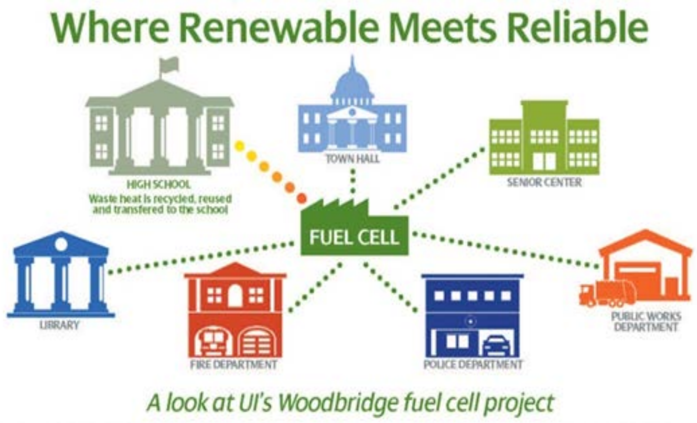
Microgrid Operation

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

"The new fuel cell on campus is cutting our energy costs, uses clean and efficient fuel cells that protect our students and the environment, and as a designated community shelter, provides critical energy to all"
Neil A. Salonen, President, University of Bridgeport

Municipal/Utility Microgrid

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

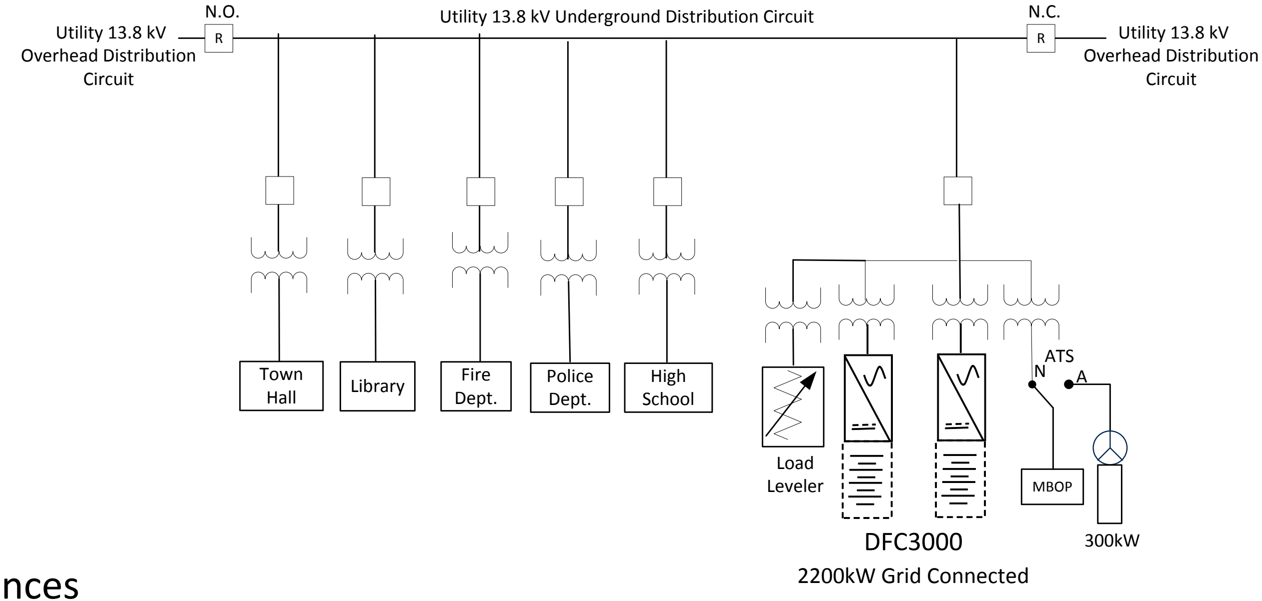
Municipal/Utility Microgrid

Town of Woodbridge, CT

Fuel Cell - Only
- 2.2 MW Fuel Cell
- 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



“Microgrids, and the fuel cells that are helping support them, are an essential part of our strategy to make certain that we harden our infrastructure in order to better withstand the type of catastrophic storms we have experienced in recent years”
Gov. Dannel P Malloy on the Woodbridge project

Industrial/Commercial Microgrid

PFIZER-Groton, CT

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

"The self-reliance this plant affords us provides that stability and reliability of operation that we need"
Michael Lallier, Site Operations Manager, Pfizer

Industrial/Commercial Microgrid

PFIZER-Groton, CT

Fuel Cell – Gas Turbine

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

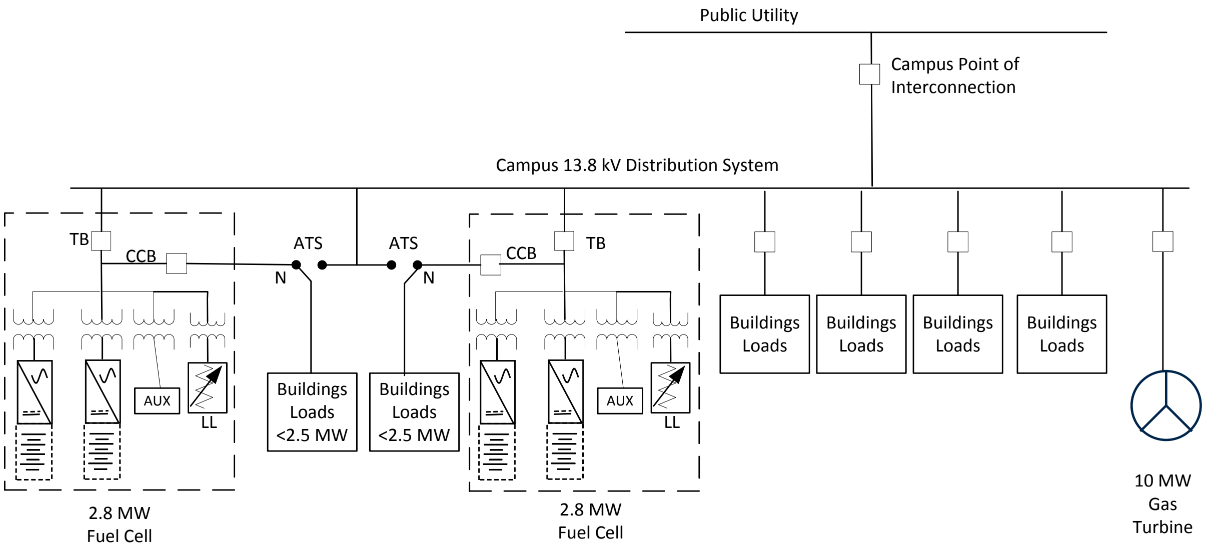
Grid Connected Operation

- Fuel Cells Base Loaded
- Heat 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

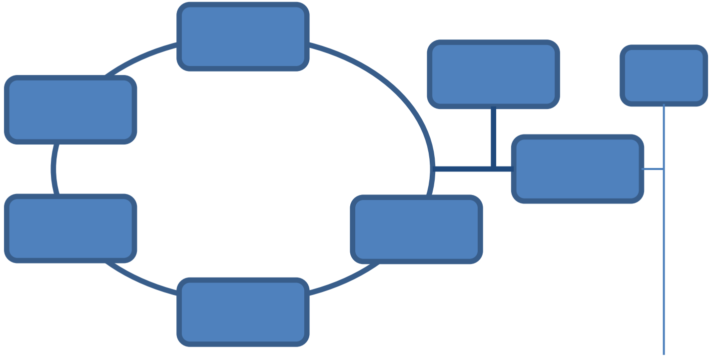


"Our critical buildings are going to be supported by these facilities."

Michael Lallier, Site Operations Manager, Pfizer, Nov-2016

Summary

- Reliable and resilient
- Reduces energy costs
- Delivers improved energy value
- Provides continuous electric and thermal energy
- Supports sustainability goals



- Grid independent operation
- Clean, quiet and efficient
- Easy to site, clean air permitting
- Flexible project development

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Thank You

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