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

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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
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
Individual fuel cell component

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

Two modules are used for a 2.8 MW power plant

The stacks are enclosed, creating the fuel cell module

4 stacks are combined to build a 1.4 MW plant
### Power Source Size and Annual Output

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Size (MW)</th>
<th>Land Required (acres)</th>
<th>Annual Output (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell</td>
<td>10</td>
<td>1</td>
<td>~83,000</td>
</tr>
<tr>
<td>Solar PV</td>
<td>50</td>
<td>375</td>
<td>~83,000</td>
</tr>
<tr>
<td>Solar PV</td>
<td>0.13</td>
<td>1</td>
<td>~220</td>
</tr>
</tbody>
</table>

Source: FCE & NREL

### Technical Data

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

* - fuel flexible (natural gas, H2, biogas, propane)
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
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
Benefits
• Cost savings
• Maintain power to critical facilities
• Renewable Energy Research Lab
• Emissions reductions: 7,000 T CO2, 64 T SOx, 28 T NOx

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

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

**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
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
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
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
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
• 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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