FuelCell Energy

Ultra-Clean, Efficient, Reliable Power

Fuel Cell Micro-grids: Enhancing Power Reliability for Critical Infrastructure

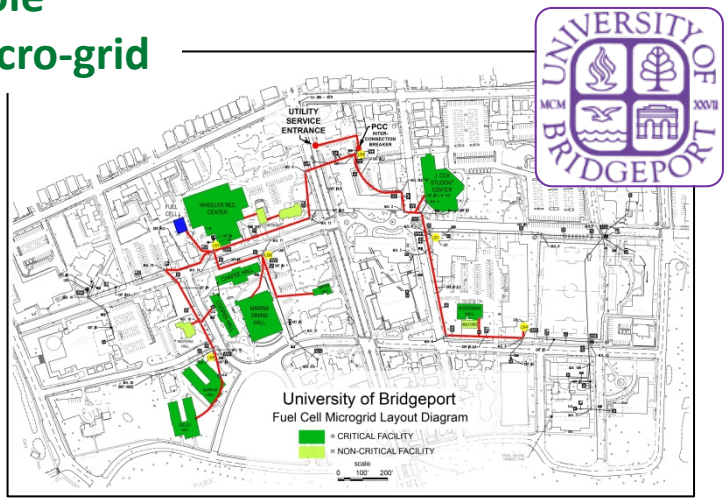
February 11, 2016

Ultra-Clean | Efficient | Reliable Power

Multi-Generation Source Options

Fuel cells only:

Fuel cells can be the sole energy source for a micro-grid



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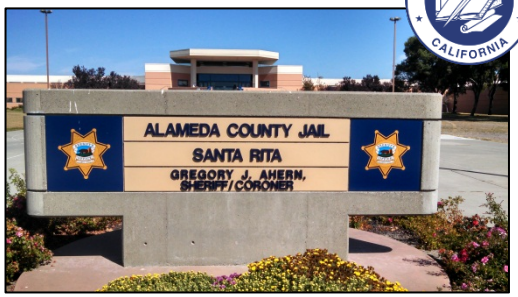
Turnkey solution includes:
designing and modeling the micro-grid
&
building, operating and maintaining the fuel cell power plant

Combined with other power generation systems:

Fuel cell micro-grids can operate in tandem with other on-site power generation technologies

"A fuel cell powered by directed biogas is the cornerstone of the micro-grid operation."



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Case Study – Univ. of Bridgeport

- Private Institution
- Founded in 1927
- Enrollment ~4,800 students
- Beautiful urban campus. 50 acres of seaside campus along Long Island Sound.
- Diverse student population: 45 States & 80 Countries

Case Study – Univ. of Bridgeport

Project Overview

- 1.4 MW combined heat & power fuel cell power plant
- Supplies 80% of campus power needs
- First fuel cell project placed into a yieldCo

Benefits

- 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 SOx, 28 tons NOx

"Sustainable and affordable energy is an increasingly important component of the new energy mix at the University of Bridgeport.
-Neil Albert Salonen, President, University of Bridgeport

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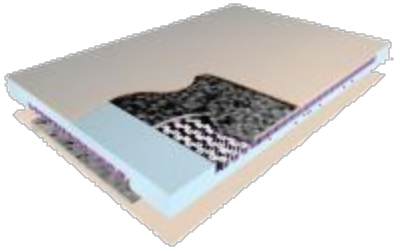
Fuel Cell Stack Configuration



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

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Dominion Bridgeport Fuel Cell Park

14 MW Fuel Cell + 0.9 MW ORC Power Plant in Bridgeport Connecticut

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Why Fuel Cells?

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

Cal State East Bay, 1.4 MW

Central CT State University, 1.4 MW

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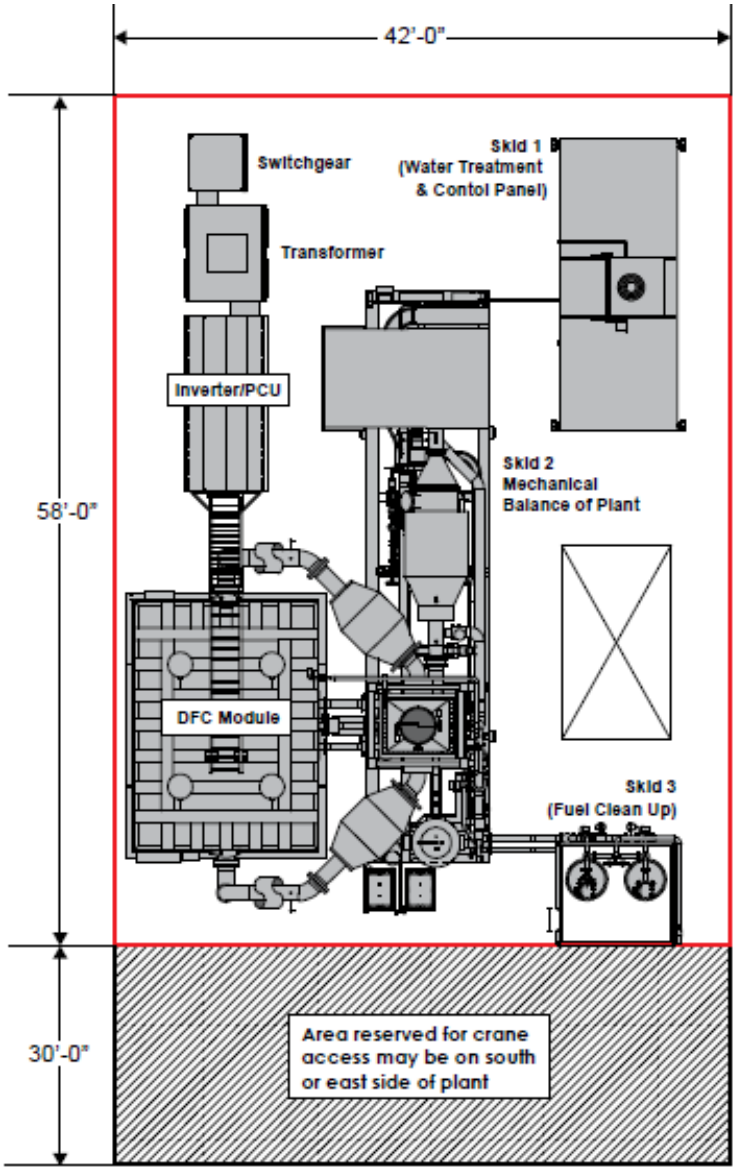
Easy to Site

- **Space requirement: 42 ft x 58 ft**
  - additional 30 ft. for maintenance
- **Electric production ~11 million kWh per year**
- **Natural gas, water, sewer**
- **Heat load for hot water, steam, and/or absorption cooling**
- **CARB 2007 certification facilitates clean air permitting**

Steam Example:

Steam Pressure (psig)	Estimated Steam Production (lb/hr)
15	1913
60	1563
125	1342
250	1120



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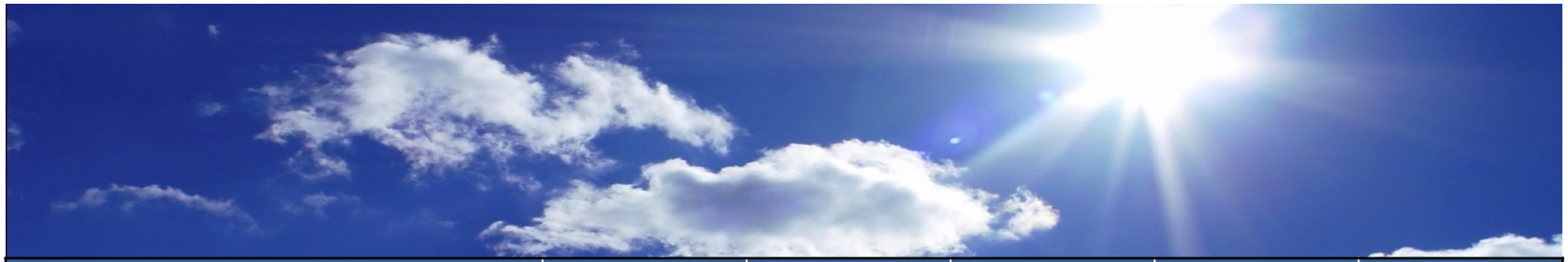
Near-zero Emissions



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

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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

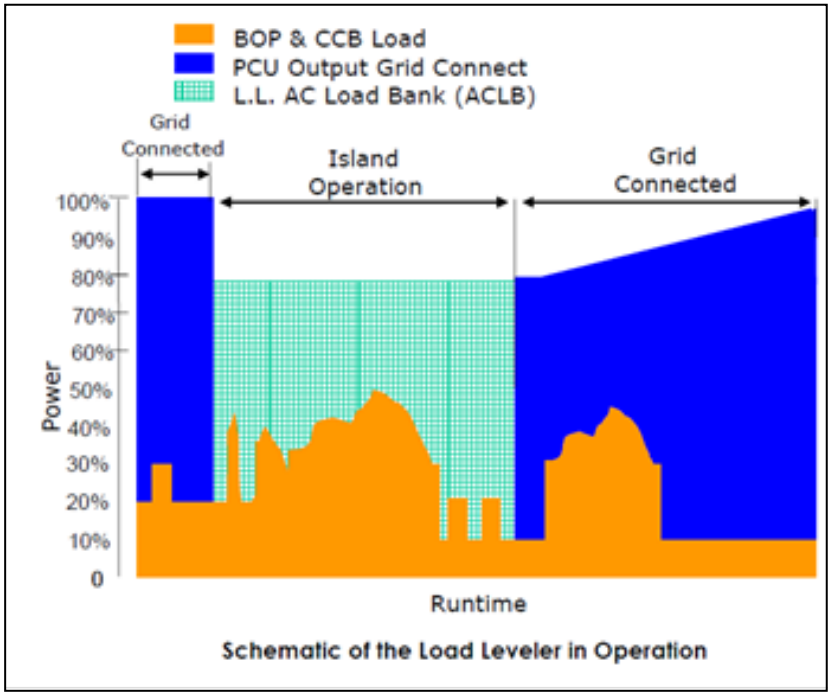
Microgrid mode

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 ~1 minute



Schematic of the Load Leveler in Operation

Case Study – Pfizer

- One of the world's largest pharmaceutical firms (NYSE: PFE, $190BN)
- 5.6 MW fuel cell as a part of the micro-grid on the 160 acre R&D campus in Groton, CT
- PPA provides immediate savings
- Supports the company sustainability goals and helps ensure around the clock reliability for their critical pharmaceutical tests.

Pfizer Campus, Groton, CT

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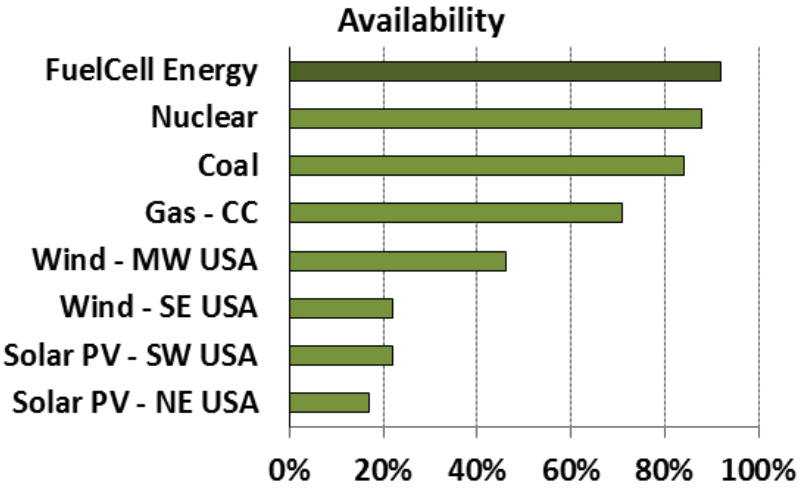
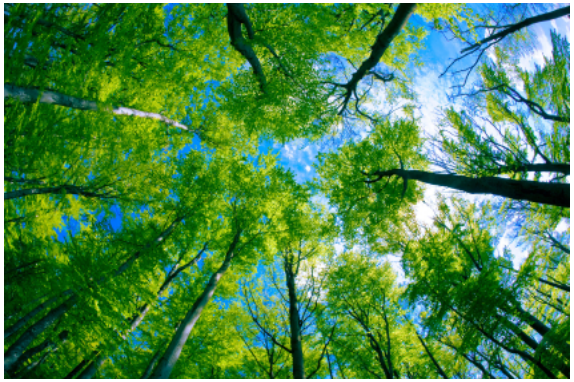
Fuel Cell Value Drivers

High fuel cell plant availability



Source: FCE & NREL



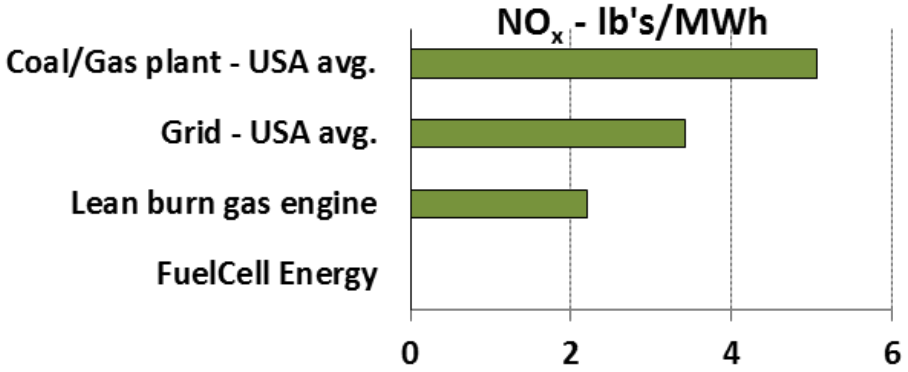
Favorable land density

Power Source	Size (MW)	Land Requirement (acres)	Annual Output (MWh)
FCE	10	1	~83,000
Solar	50	375	~83,000

FCE	10	1	~83,000
Solar	0.13	1	~220

Source: FCE & NREL

Near-zero emissions



Source: FCE & NREL

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Micro-grid Success Factors

BARRIER	MOST COMMON ISSUES	FUEL CELLS
TECHNICAL	• Dual-mode switching from grid-connected to island mode • Power quality and control • Protection	• Island: tie-breaker opens, creating seamless transition for critical loads

Sources: sciencedirect.com, FuelCell Energy

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Case Study – UCSD

- Public Institution
- Founded in the early 1900s
- Enrollment >31,000 students
- 1 of 10 campuses in the University of California system

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Case Study – UCSD

Project Overview

- 2.8 MW plant using biogas from the Point Loma Wastewater Treatment plant
- Operates in conjunction with other on-site generation, solar pv and a cogeneration plant – 85% of electricity demand onsite

Benefits

- Cost savings during normal operations
- Carbon neutral by utilizing directed biogas

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Global Technical Assistance Center

Global Technical Assistance Center (GTAC)
Danbury, CT, USA

Remotely monitor and operate plants globally, including:

- Monitor operating status
- Remote troubleshooting, diagnostics and resolution
- Quality tracking system
- Dispatch field service technicians

The Center is staffed around-the-clock, 365 days per year

Highly trained field service technicians provide on-site maintenance

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Project Finance Options

- Comprehensive Engineering, Procurement, and Construction services – leverages FCE strength and experience, lowers risk and distractions to Client
- PPA, Lease, Debt Financing
- PPA, Operating lease enable 30% ITC at Universities, Municipals, Non-Profits
- $40M revolving fuel cell project finance fund with NRG
- Comprehensive Service Agreements with guarantees of fuel cell performance

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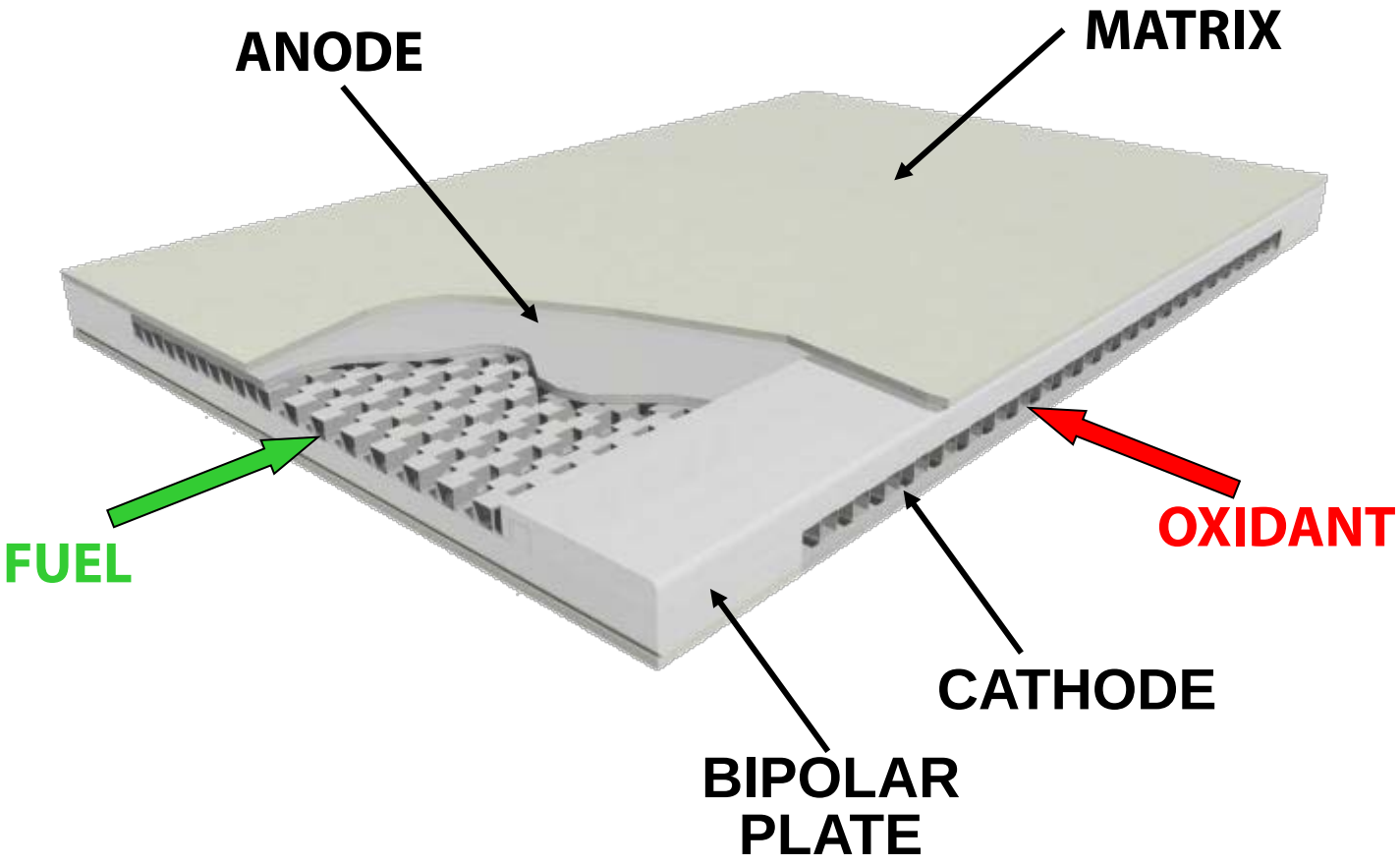
Fuel Cell Configuration



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Global Manufacturing Footprint

North America

Manufacturing
Torrington, CT

- Module Assembly & Stacking
- 65,000 ft² facility *(before expansion)*
- Opened 2001

Corporate
Danbury, CT

- Research labs
- Engineering design
- Global Service center
- Conditioning

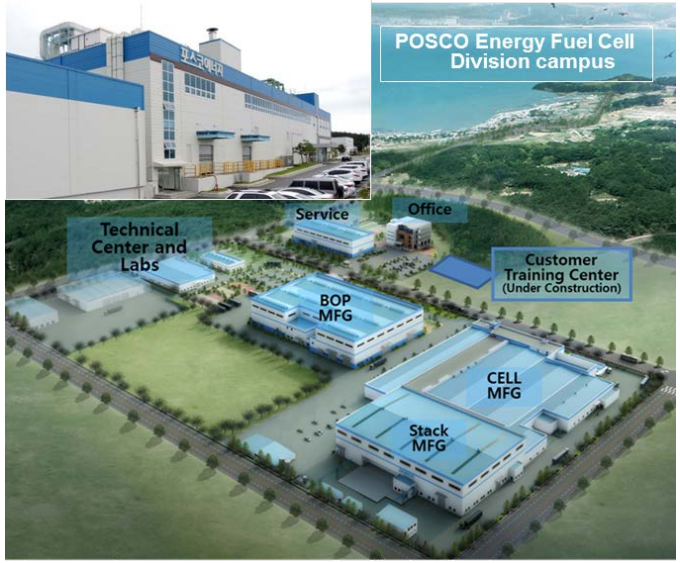
SOFC Research
Littleton, Colorado
Calgary, Canada

- Research labs

Asia & Europe

Manufacturing
Pohang, South Korea

Capacity for Asian market via partner, POSCO Energy



Manufacturing
Ottobrunn, Germany

Capacity for European market via FCES, GmbH

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Integrated Fuel Cell Company

Research & Development

- *Global fuel cell technology platform*
- *Robust intellectual property portfolio*
- *Leveraging core technology for new market opportunities*

Sales, Manufacture & Project Execution

- *Project development – Direct Sales*
- *Global manufacturing (200+ MW capacity)*
- *Engineering, Procurement and Construction*

Services

- *Operate & Maintain power plants*
- *100+ DFC® plants operating at 50+ sites globally*
- *>4 billion kWh ultra-clean power produced*
- *> 300 MW installed/backlog*

Fuel cell stack

Four-Stack Module 1.4 megawatts

Completed module 1.4 megawatts

2.8 MW power plant

5 unit fuel cell park

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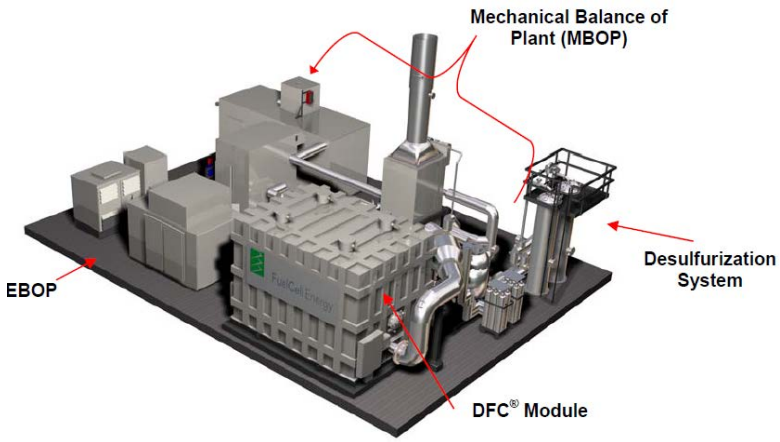
DFC®1500 Fuel Cell Power Plant

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	
Power @ Plant Rating	1,400 kW
Standard Output AC voltage	480 V
Standard Frequency	60 Hz
Optional Output AC Voltages	By Request
Optional Output Frequency	50 Hz
Efficiency	
LHV	47 +/- 2 %

Available Heat	
Exhaust Temperature	700 +/- 50 °F
Exhaust Flow	18,300 lb/h
Allowable Backpressure	5 iwc
Heat Energy Available for Recovery	
(to 250 °F)	2,216,000 Btu/h
(to 120 °F)	3,730,000 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



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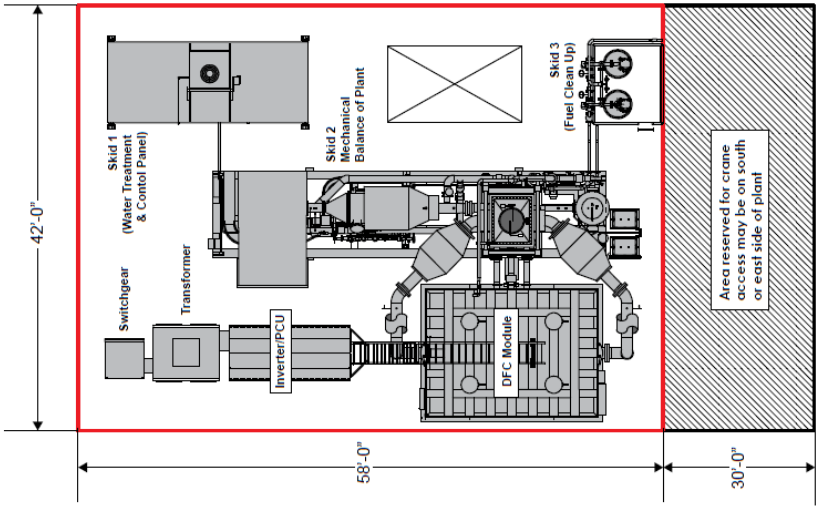

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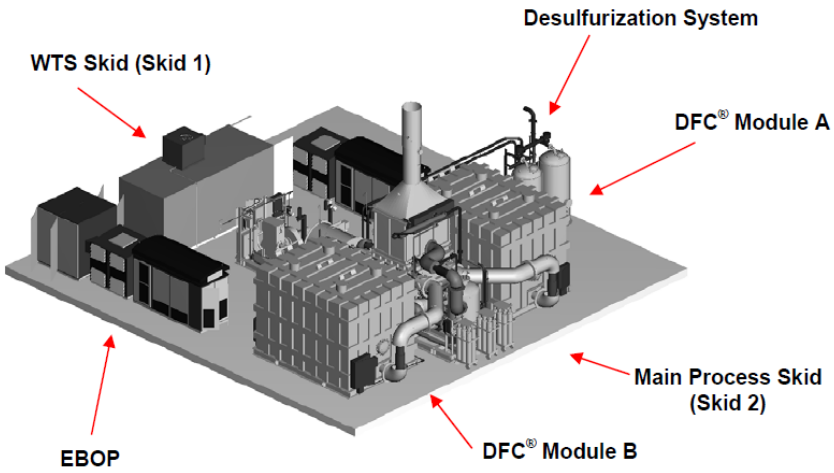
DFC®3000 Fuel Cell Power Plant

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		**Available Heat**		**Pollutant Emissions**	
Power @ Plant Rating	2,800 kW	Exhaust Temperature	700 +/- 50 °F	NOx	0.01 lb/MWh
Standard Output AC voltage	13,800 V	Exhaust Flow	36,600 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				
Optional Output Frequency	50 Hz	Heat Energy Available for Recovery		**Greenhouse Gas Emissions**	
		(to 250 °F)	4,433,000 Btu/h	CO_2	980 lb/MWh
Efficiency		(to 120 °F)	7,460,000 Btu/h	CO_2 (with waste heat recovery)	520-680 lb/MWh
LHV	47 +/- 2 %				



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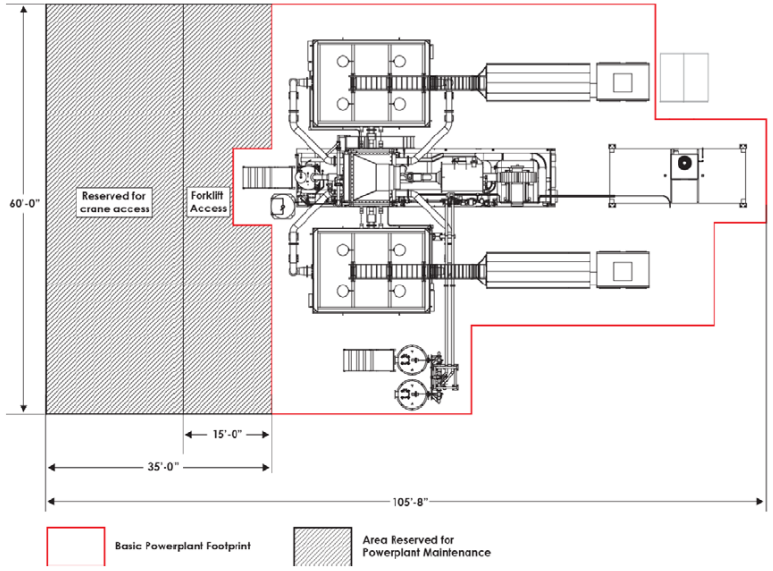

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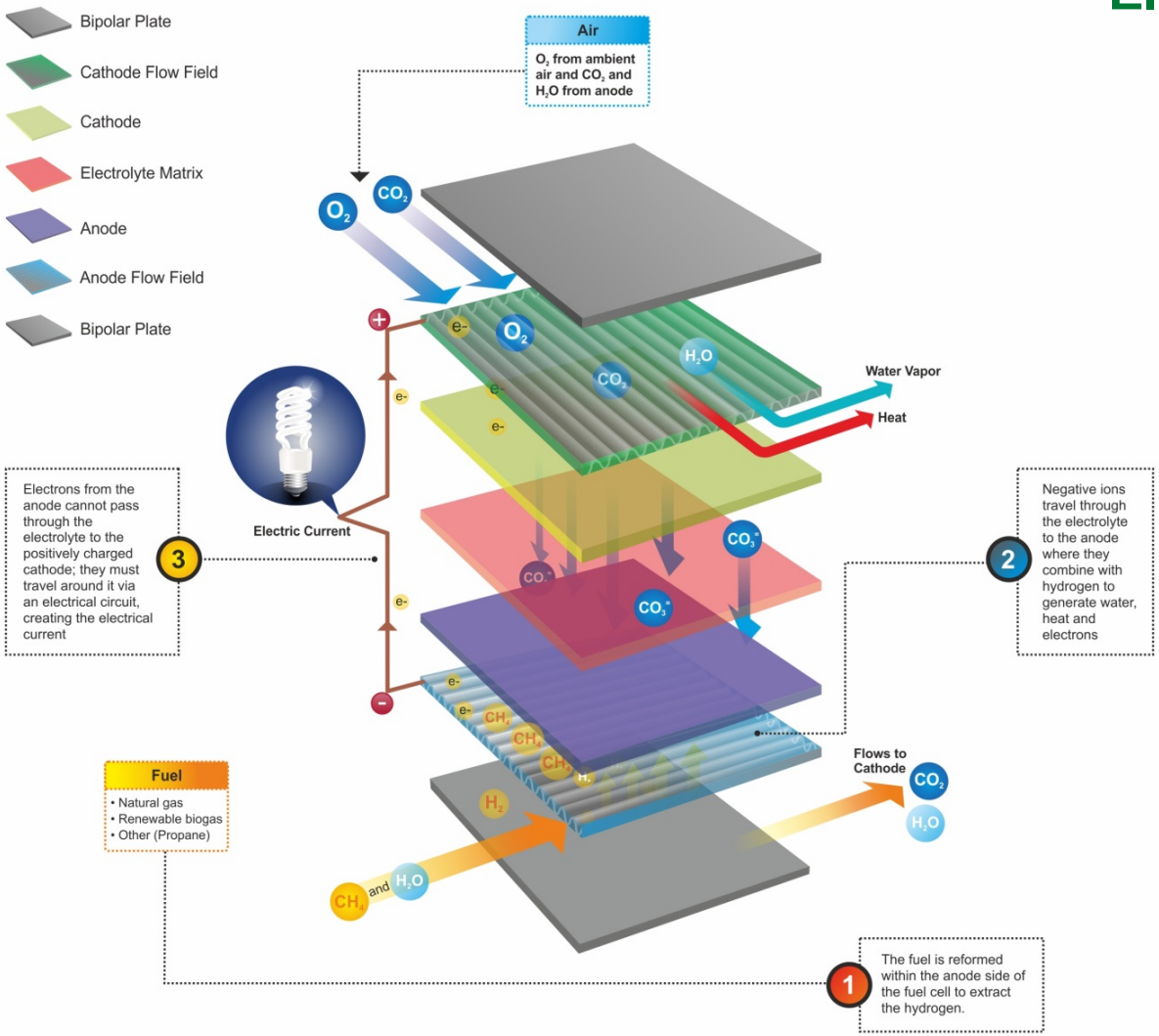
How the Direct FuelCell® Works



Electrochemical Conversion of Fuel to Electricity

- Highest electrical efficiency for its size class
  - Combined heat and power (CHP)
- Ultra-clean
  - No combustion
  - Negligible NO_x (*smog*), SO_x *(acid rain),* PM^{10} *(asthma)*
- Continuous power
- Easy to site
  - Low emissions, quiet, only modest space needs
- Fuel flexible
  - Clean natural gas
  - Renewable biogas
  - Directed biogas
  - Propane

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Scalable Solutions

Global platform – scale enhances economics

Individual fuel cell & 350 kW fuel cell stack

Completed module 1.4 megawatts

Four-Stack Module 1.4 megawatts

59MW fuel cell park
- *Utilizes 21 DFC3000 plants*

2.8 MW DFC3000®
- *Utilizes two modules*
- *Adequate to power 2,800 homes*

1.4 MW DFC1500®
- *Utilizes one module*
- *Adequate to power 1,400 homes*

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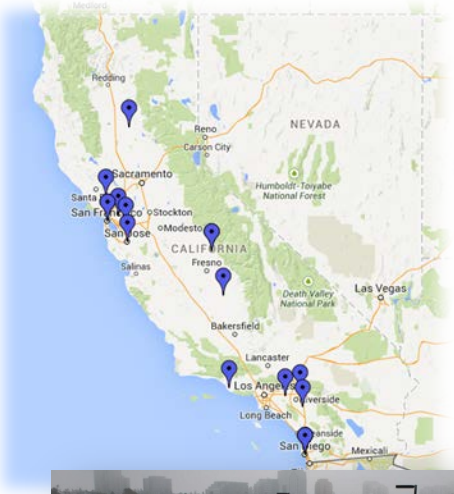
Direct FuelCell® Power Plant

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

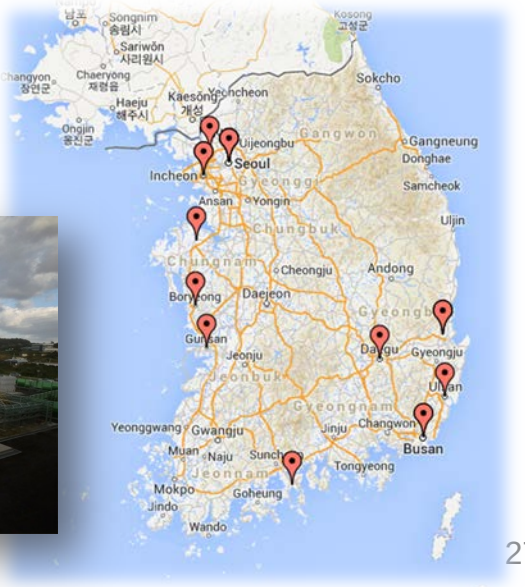
Growing Global Fleet

More than 110 fuel cell power plants in operation on 3 continents – over 300 MW installed and in backlog

15 MW Fuel Cell Park, Bridgeport CT



Proven Capability to Deliver Clean, Cost-Competitive, Local Power



2.8 MW University CHP Fuel Cell in California

59 MW District Heating, Seoul, Korea