Fuel Cells and Hydrogen for Greater Sustainability
Using Natural Gas
Pinakin Patel
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FCE Products and Services

Design
Megawatt-class distributed power generation solutions

Manufacture
Global manufacturing footprint
- North America
- Europe
- Asia via partner

Sales
Direct & via Partners
Installations & orders in 9 countries

EPC*
Project Development and Project Finance, Engineering & Construction
Over 300 megawatts installed and in backlog
* Engineering, Procurement & Construction

Services
Operate & maintain power plants
- Over 100 DFC® plants operating at more than 50 sites globally
- Three billion kWh ultra-clean power produced

Providing turn-key distributed power generation solutions that meet both economic and sustainability goals
Scalable Solutions

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

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

59MW fuel cell park

Individual fuel cell & 350 kW fuel cell stack

Four-Stack Module 1.4 megawatts

Completed module 1.4 megawatts

Completed module 1.4 megawatts

59MW fuel cell park
World’s Largest Fuel Cell Park

“The scale of this installation is contributing to the power and heating needs of an urban population and generating the electricity in a highly efficient and ultra-low emission profile that supports our National renewable portfolio standard,”

Tae-Ho Lee
Chief Executive Officer
Gyeonggi Green Energy

- Scalable consisting of 21 DFC3000® power plants
  - Only ~ 5.2 acres for 59 MW
- Supplying electric grid and district heating system
- Constructed in only 14 months
- Adequate to power ~ 140,000 S. Korean homes
Distributed Hydrogen Production

Industrial Hydrogen Use
Existing market

Vehicle Fueling
Emerging market

Ongoing Projects:
- Orange County Sanitation District, CA – Hydrogen from wastewater treatment digester gas for vehicle fueling
- Village Farms, Vancouver Canada - Hydrogen from landfill gas for vehicle fueling
- Torrington DFC Manufacturing Plant – Hydrogen for industrial heat treating

Orange County Sanitation District
Renewable Hydrogen for Vehicle fueling

Zero or low-carbon $H_2$ economically produced near end users
What Can We Do With By-Product Hydrogen?

<table>
<thead>
<tr>
<th>Co-product</th>
<th>DFC300®</th>
<th>DFC1500®</th>
<th>DFC3000®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power, kW</td>
<td>250</td>
<td>1,150</td>
<td>2,300</td>
</tr>
<tr>
<td>Hydrogen, kg/day</td>
<td>125</td>
<td>700</td>
<td>1,400</td>
</tr>
<tr>
<td>Heat, mmBtu/hr</td>
<td>0.5</td>
<td>2.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

**Refueling Capacity**

<table>
<thead>
<tr>
<th>Types</th>
<th>DFC300®</th>
<th>DFC1500®</th>
<th>DFC3000®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars, 4.2 kg/day</td>
<td>30</td>
<td>140</td>
<td>280</td>
</tr>
<tr>
<td>Buses, 25 kg/day</td>
<td>5</td>
<td>24</td>
<td>48</td>
</tr>
<tr>
<td>Fork Lifts, 2.1 kg/day</td>
<td>60</td>
<td>280</td>
<td>560</td>
</tr>
<tr>
<td>Plug-in Battery Hybrid, 12 kWh/day</td>
<td>500</td>
<td>2,400</td>
<td>4,800</td>
</tr>
</tbody>
</table>
Enabling Renewable Energy Use for Grid Independent Operation

- Enhanced Energy Security
- Maximize Green Energy Use
- Water Independent
- Load Following
- Fuel Flexible
- Ultra Clean
- Provides Distributed $\text{H}_2$ for Multiple Uses
- Compensates for Intermittent Supplies

[Diagram showing a micro-grid with fuel cell energy system, fuel storage, and connections to grid, heat, power, and fuel cell cars.

Chemical integration opportunities include $H_2$ to CO ratio adjustment, $H_2$ recycle from processing off-gas and $CO_2$ for other uses.
Carbon Capture with DFC Powerplants

- Carbonate electrochemical process transfers CO$_2$ from Air Electrode (Cathode) to Fuel Electrode (Anode)
- CO$_2$ is easily separated from Fuel Electrode exhaust gas because it is no longer diluted with air
- Demonstrated in small cells, 9 kW test starting this year
Application Examples

Back-up slides
Hydrogen can also reduce size of battery storage needed by increasing average wind + battery + \( H_2 \) output.

Hydrogen converts soft to hard, reliable power.
Megawatt-class distributed power generation solutions

• Highly Efficient
  o High electrical efficiency
  o Combined heat & power supports economics and sustainability

• Ultra-clean
  o Virtual lack of pollutants eliminates future clean air compliance concerns
  o Low carbon footprint / net-zero carbon using renewable biogas

• Enhances grid resiliency
  o Continuous power close to the point of use
Commercialization Roadmap

**Present**

- Multi-MW fuel cell parks
- MW-class On-site & Biogas
- Sub-MW Distributed H$_2$ Generation

**New Markets**

- MW Distributed H$_2$ Generation
- High Efficiency DFC
- SOFC | Storage | Carbon Capture
**Global Business**

**MW-class distributed generation solutions**
- Grid support and on-site CHP power generation
- ~650 employees on 3 continents
- > 2.6 billion kWh produced

**Office Locations**
- R&D and Service
- ~275 employees

**Manufacturing**
- ~325 employees USA
- ~15 employees Germany
- S. Korea via partner

**Countries with Installations**
- 50 sites in 9 countries
- > 300 MW installed/backlog
**Unsubsidized Levelized Cost of Energy**

- **FuelCell Energy** 2.8 MW
  - $0.14 - $0.15

- **Distributed Solar PV** 10 MW
  - $0.20 to $0.18
  - $0.23 to $0.18

- **Utility Solar PV** 10 MW
  - $0.10 to $0.07
  - $0.10 to $0.05

- **Wind** 100 MW
  - $0.09 to $0.06

- **Gas** Peaking 100-200 MW
  - $0.12 to $0.07
  - $0.15 to $0.07

- **Combined Cycle** 550 MW
  - $0.09 to $0.06

- **Nuclear** 1,100 MW
  - $0.09 to $0.06

- **Coal** 600 MW
  - $0.09 to $0.06

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(a) LCOE of $0.15/kWh with natural gas at $8/mmBtu or $0.14/kWh at $6/mmBtu; each $2/mmBtu change equates to about $0.01/kWh.
(b) Mid-term LCOE target of $0.09-$0.11/kWh based on global production volume of approximately 210 MW annually.
(c) Distributed solar based on rooftop installation in SW USA with 20-23% capacity factor; Utility solar based on tracking technology and 27-28% capacity.
(d) Installation and maintenance cost of Transmission & Distribution (T&D) is estimated to add up to $0.024/kWh.
(e) Gas peaking addresses intermittency of solar and wind when power is required but sun not shining/wind not blowing.
(f) Does not include waste disposal costs, incremental emission clean-up costs or nuclear-related security costs.

On-site Power & Heat

Project Overview
1.4 MW combined heat & power fuel cell plant located at Central Connecticut State University
  - Providing ~1/3 of campus power needs

Benefits
- High efficiency drives favorable economics
  - CHP for heating and absorption chilling
- Ultra-clean emission profile supports CCSU sustainability goals
- Micro-grid enhances campus energy security
- Private capital providing public benefits

“This power plant is a significant step in helping CCSU achieve our aggressive goals for reducing greenhouse gases and improving energy efficiency on campus,” said Central Connecticut State University President Jack Miller.
**Project Overview**
14.9 MW of ultra-clean, efficient and continuous power generation on a remediated brownfield site in Bridgeport, CT

**Benefits**
- Clean & quiet on ~ 1.5 acres
- Hardens electric grid by supplying 3 substations
- Tax revenue for City of Bridgeport
- Sustainable jobs for State of Connecticut
- 15 year service contract for FuelCell Energy
- Diversify power generation for utilities/consumers

"The Dominion Bridgeport Fuel Cell is another important step in our efforts to identify and develop opportunities to produce clean energy that is reliable and cost effective," said Thomas F. Farrell II, Dominion Chairman, President and Chief Executive Officer. “We are now adding fuel cell technology to our energy portfolio that already includes wind, hydro, biomass and, soon, solar. This project supports Connecticut’s clean energy goals while producing significant economic development benefits for the State and the City of Bridgeport.”
Challenge for a Water treatment facility
• Compliance with clean air regulations
• Meet ambitious sustainability goals

Solution
World’s largest fuel cell power plant converting renewable biogas into electricity and heat
  ◦ adequate to power 2,800 homes

Benefits
• Converts waste disposal problem into multiple value streams
• Ultra-clean power facilitates clean air permitting
• Distributed generation enhances power reliability and energy security
• High efficiency drives economics

“The clean electrical generation process and the reliable 24/7 operating nature of the fuel cell will help us attain the objectives of our strategic energy plan and position us to meet ever more stringent clean air emission requirements,” said Terry Catlin, Board President, Inland Empire Utilities Agency.
Clean CO\textsubscript{2} Increases Biomass Production

Clean CO\textsubscript{2}
(Cathode exhaust, Low O\textsubscript{2}, Higher N\textsubscript{2})

Biomass Growing
(such as Algae)

Biomass Processing

Gasification

DFC-H2\textsuperscript{®} Unit

EHS System

Bio Refining

Crude Bio oil

Liquid Biofuel

Power

Hydrogen

Bio Hydrogen

Low Level Heat

High Level Heat

Low Level Heat

Processing Waste

H\textsubscript{2}, CO, CO\textsubscript{2}, CH\textsubscript{4}

CO\textsubscript{2}, CH\textsubscript{4}

Optional other biomass
Low Carbon On-Site Power from Natural Gas

• 3.8MW ultra low carbon system for on-site power generation from natural gas – larger systems possible
• Captured CO$_2$ can be sequestered or sold commercially

2.8 MW AC
Power

Natural Gas Fuel Input to DFC3000:
20.3 MMBtu/h LHV

DFC3000 Exhaust with
2600 lbs/h CO$_2$
31 Tons per day

Captured CO$_2$
3200 lbs/h CO$_2$
38 Tons per day
2000 psi

1 MW AC
Power

Natural Gas Fuel Input to DFC1500:
8 MMBtu/h LHV

DFC1500 Exhaust with
320 lbs/h CO$_2$
4 Tons per day

Only 80 lbs CO$_2$
per MWh