Integrated Gasification Fuel Cell (IGFC) Power Plants Utilizing Solid Oxide Fuel Cells (SOFC)

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FuelCell Energy, Inc

- Premier developer of stationary fuel cells with >40 years of experience
- Headquarters and R&D in Danbury, CT (USA), manufacturing facility in Torrington, CT (USA)
- Delivering Direct FuelCell® (DFC®) power plants to commercial and industrial customers
- Product sales and service backlog in excess of $200 million
- Established commercial relationships with major distributors in the Americas, Europe, and Asia
- Developing large-scale coal-based power plants as well as natural gas fueled distributed generation (DG) systems utilizing planar SOFC

600 kW plant at a food processor  
1.4 MW at a municipal building  
2.4 MW plant owned by an IPP  
11.2 MW plant owned by an IPP
Integrated Fuel Cell Company

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<tr>
<th>Manufacture</th>
<th>Sell (direct &amp; via partners)</th>
<th>Install</th>
<th>Services</th>
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<td><img src="image1" alt="Manufacture Image" /></td>
<td><img src="image2" alt="Sell Image" /></td>
<td><img src="image3" alt="Install Image" /></td>
<td><img src="image4" alt="Services Image" /></td>
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**Growing Market Presence**

- **182 MW installed and in backlog**
- **Over 80 Direct FuelCell® plants generating power at more than 50 sites globally**
- Providing:
  - On-site power
  - Utility grid support

**Advanced Technology Programs**

- **Renewable hydrogen for vehicle fueling**
- **Solid Oxide Fuel Cell Development (SECA program) Versa Power Systems (Partner)**
- **Carbon capture**
SOFC Cell and Stack Technology

- Planar anode supported cells (up to 1000 cm²)
- Capable of operating from 650°C to 800°C
- Ferritic stainless steel sheet metal interconnect
- Cross-flow gas delivery, with integrated manifolding
- Standardized stack blocks configurable into stack towers for various power applications
**System Scale-Up Approach**

- **Manufacturing Cost Reduction Through Building Block Approach Using Planar SOFC**

  - **Lab-Scale Planar Cell**
  - **Scaled-up Cell**
  - **Stack Building Block for Large SOFC Plants**
  - **15 kW 96-Cell Stack**
  - **30 kW Stack Tower (2 Stacks)**
  - **1.2 MW Stack Module**
    - 20 Horizontal Towers (4 Stacks Each)
  - **250 kW Stack Module**
    - 8 Vertical Towers (2 Stacks Each)
Endurance Test of 96-Cell Stack Block Using TSC3 Cells

GT058116-0003 TC1 Hold
Average Voltage and Stack Power
62F15A 62%DIR 200Amps S/C=3 (H2=32%, N2=25%, CH4=13%, H2O=30%)

1.1%(9.7mV)/1000hrs over 960hrs

- Average Voltage
- Stack Power

Elapsed Time (hours)
Stack Tower Testing

• Thermally self-sustaining test environment (gas preheated only)
• Provisions for simulated anode gas representative of both coal-derived syngas and natural gas fueled systems
• Simulates commercial system operation: Providing valuable lessons for future larger stack module designs
Grid Connected Operation of 60 kW SOFC Module Assembly Installed in the Power Plant Facility (Danbury, CT) Has Been Started.

Achieved >65% Stack Module Gross DC Efficiency (LHV Natural Gas).
Uniform Voltage Distribution Confirmed the Outstanding 60 kW SOFC Module Design and Stack Blocks Performance.
Coal-Based SOFC System with Catalytic Gasification

Combined with high methane producing gasification, coal based atmospheric-pressure SOFC systems are capable of achieving ~ 59% efficiency and 99+% carbon capture.
Lower temperature and higher pressure results in increased Cold Gas Efficiency (CGE) in conversion of coal to syngas.
Effect of Gasification Temperature on Syngas Compositions

Lower temperature and higher pressure results in higher Cold Gas Efficiency (CGE) in conversion of coal to syngas.
Factory Equipment Cost Estimate

Phase I Estimate: 597 $/kW (2002 USD)

- Balance-of-Plant (BOP) $400/kWac, 67%
- Fuel Cell Stacks $197/kWac, 33%

Phase II Estimate: 372 $/kW (2000 USD)

- Balance-of-Plant (BOP) $287/kW ac, 77%
- Fuel Cell Stacks $85/kW ac, 23%

Phase III Estimate: 635 $/kW (2007 USD)

- Balance-of-Plant (BOP) $487/kWac, 77%
- Fuel Cell Stacks $147/kWac, 23%

- From 2002 to 2007, stainless steel prices increased 97%, Ni increased 125%, and zirconia increased 118%.

- Due to cost reduction efforts, cost estimate only increased 6% (38 $/kW) from 2002 to 2007.

Cost Envelope

Gasification Island
- ASU
- Catalytic Gasifier
- Gas Cleanup System

Power Island
- Gas Expanders
- SOFC Power System
- HRSG / Steam Turbines

AC Power
- Clean Syngas
- Steam

CO₂ Separation & Compression
- Direct Contact Cooler
- CO₂ Compressors

Product CO₂

Coal
Air (to ASU)

WorleyParsons
resources & energy
43,008 units/per year production

- Majority of stack cost is driven by the cost of materials.
- Manufactured cell cost is < 25% of total stack cost.
Extended FCE’s commercial DFC MW-scale module design to SOFC MW class applications.
670 MW Coal-Based SOFC Power Island

SOFC power island includes:

> 8 Sections of 42 fuel cell stack modules
> Steam turbine
> Two syngas expanders

SOFC power island lay-out takes advantage of well-thought clustering concept using repeated arrangements of grouped components.
SOFC cluster design takes advantage of modularity of fuel cells.
Lay-out of 670 MWac IGFC plant includes 336 SOFC stack modules, two syngas expanders, and a steam bottoming cycle.
Representative Foot Print Comparison: IGFC & IGCC

- A similarly sized (MW) IGCC and IGFC will be comparable in real estate requirement.
FCE’s long-term plan is development of SOFC power plants capable of using a variety of fuels such as natural gas, biogas, and coal syngas.
Acknowledgements

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