Stationary Fuel Cells: Overview of Hydrogen and Fuel Cell Activities

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United States Department of Energy

Federal Utility Partnership Working Group
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• DOE Fuel Cell Market Transformation Overview
• Overview of CHP Concept
• Stationary Fuel Cells for CHP Applications
• Partnering and Financing (Sam Logan)
• Example Project
Fuel Cells: Addressing Energy Challenges

Energy Efficiency and Resource Diversity
→ Fuel cells offer a highly efficient way to use diverse fuels and energy sources.

Greenhouse Gas Emissions and Air Pollution:
→ Fuel cells can be powered by emissions-free fuels that are produced from clean, domestic resources.

**Diverse Energy Sources & Fuels** → **Clean, Efficient Energy Conversion** → **Diverse Applications**

- Biomass
- Conventional Fuels
- Renewable Resources
  - Nuclear
  - Natural Gas
  - Coal (with carbon sequestration)
- Methane
- Methanol
- Natural Gas
- Propane
- Diesel
- Hydrogen

**Benefits**
- Efficiencies can be 60% (electrical) and 85% (with CHP)
- > 90% reduction in criteria pollutants

Stationary Power (including CHP & backup power)
Auxiliary Power
Portable Power
Transportation
Overview of CHP Concept

Electricity

Natural Gas

Power

Heat

Fuel Cell

Natural Gas or Biogas

Excess power generated by the fuel cell is fed to the grid
**Stationary Fuel Cell Product Example**

**400 kW Phosphoric Acid Fuel Cell**

**1. Fuel Processor**
Converts natural gas fuel to hydrogen

**2. Fuel Cell Stack**
Generates DC power from hydrogen and air

**3. Power Conditioner**
Converts DC power to high-quality AC power

**Electric Output:**
- 400 kW, 480V, 60 Hz

**Fuel Input:**
Natural gas
- 3.2 MMBtu/hr (950 kW) LHV
- 3.6 MMBtu/hr (1054 kW) HHV

**Internal Heat Exchanger Provides Either:**
- 1.5 MMBtu/hr @ 140°F (450 kW @ 60°C)
  - OR
- 0.7 MMBtu/hr @ 250°F & 0.9 MMBtu/hr @ 140°F (200 kW @ 121°C & 250 kW @ 60°C)
Key Market Sectors

Data Centers

Supermarkets

Hotels

Hospitals

Educational Institutions

- Energy intensive
- Power, heating, cooling
- Benefits
  - On-site energy/security
Stationary Fuel Cell Applications

**Assured Power**
First National Bank of Omaha
Omaha, Nebraska

**On-Line Emergency Power**
Verizon
Garden City, New York

**Indoor Green Power / Cogeneration**
4 Times Square
New York, New York

**Renewable Fuel (ADG)**
Wastewater treatment plants
New York, New York

**Off-Grid Power**
Central Park Police Station,
New York, New York
Stationary Fuel Cells Have A Small Footprint

USPS facility in San Francisco, California
300 kW Molten Carbonate fuel cell system.
FCPower Model Hourly Energy Analysis Module

- Physical Property Data
- Feed and Utility Prices
- Financial Inputs
- Hourly Solar Wind Profiles
- Cost Inputs
- Electricity Heat Hydrogen Demand Profiles

New Hourly Energy Supply & Demand Analysis Module

Yearly Cash Flow Analysis

Cost of Energy Output
- Cost of Purchased Electricity & Heat
- Credit for “Avoided” Electricity & Heat Purchase
- Greenhouse Gas Emissions

Energy analysis done for 8,760 h of one year

H2A model inputs
- H2A database
- User inputs
Preliminary Test Results

- Fuel cell with water-gas shift in operation > 6,000 hours
- Tri-generation results:
  - Coproduced 2 to 5 kg/hr hydrogen with > 200 kW electricity
  - Estimated hydrogen recovery at 80 to 85%
  - Product purity <0.2 ppm CO; <2 ppm CO₂
  - Operation with simulated digester gas feed
  - PSA operating map developed (cycle time vs. feed rate)
  - Implemented automated system to switch to CHP mode when hydrogen tanks are filled.
Partners in Market Transformation
Providing Tangible Benefits to Federal Energy Consumers

- Distributed CHP Generation...Energy Efficiency
- Reduce Harmful Emissions and GHG
- Increase Energy Security, Reliability & Reduce Demand on Grid
- Comply with Legal Mandates
- Upgrade Facility Infrastructure Reduced Capital Appropriations
- Insulate Against Rising Energy Costs
Green House Gas Comparison

- ~680lbs per MWH with 65% efficient CHP application ...
- ~50% GHG reduction compared to incumbent technologies

<table>
<thead>
<tr>
<th></th>
<th>CO₂ (lb/MWh)</th>
<th>NOₓ (lb/MWh)</th>
<th>SOₓ (lb/MWh)</th>
<th>PM₁₀ (lb/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average US Fossil Fuel Plant</td>
<td>2031</td>
<td>5.06</td>
<td>11.6</td>
<td>0.27</td>
</tr>
<tr>
<td>Average US Generation</td>
<td>1408</td>
<td>3.4</td>
<td>7.9</td>
<td>0.19</td>
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<tr>
<td>Typical Small Gas Turbine</td>
<td>1494</td>
<td>1.1</td>
<td>0.008</td>
<td>0.08</td>
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<tr>
<td>DFC (Baseline products)</td>
<td>980</td>
<td>0.01</td>
<td>0.0001</td>
<td>0.00002</td>
</tr>
<tr>
<td><strong>DFC Potential (at 65% Efficiency)</strong></td>
<td><strong>680</strong></td>
<td><strong>0.007</strong></td>
<td><strong>0.00007</strong></td>
<td><strong>0.00001</strong></td>
</tr>
</tbody>
</table>

Data source, FuelCell Energy, UTC, NREL
Financing CHP Projects

- Federal Investment Tax Credits (ITC’s) or Grants in lieu of ITC's (an energy services contract with a third-party project developer is required for a tax-exempt customer to benefit)
- State Tax Credits
- State and Local Incentives and Grants
- Utility Incentives and Grants
- Demand Response and other Capacity Payments
- Energy Conservation Credits (White Tags)
- Renewable Energy Credits (Mandatory and Voluntary)
- Internal Cash Flow From Operating Efficiencies
- Private Capital (Debt and Investor Equity – also requires an energy services contract with a third-party project developer)
- Green Procurement Requirements
• Install 1,500 kW Carbonate Fuel Cell
• Government customer in CT
• Utility Rates:
  – Electricity: $0.125 average cost per kWh
  – Natural Gas: $7.00 per thousand cubic feet (Mcf)
  – Average Cost of Heat: $9.30 per million British thermal unit (MMBTU)
• Net Metering Revenue Available
  – Public Utilities Code Section
• CT Clean Energy Fund
  – Up to $2.50/W Installed Capacity
  – Capacity Payment Program
  – Renewable Energy Credits
• Ten-Year Service Contract
Government Owned Example

- 1500kW (net 1400kW) Carbonate Fuel Cell
- 90% Operating Availability
- Long Term Service Agreement & Warranty
- Initial 10 Year Service Term

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<th>Installed CHP System</th>
<th>$7,862</th>
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<tr>
<td>Incentive Payments</td>
<td>$(2,475)</td>
</tr>
<tr>
<td>Govt Investment</td>
<td>$5,387</td>
</tr>
<tr>
<td>Govt % Investment</td>
<td>69%</td>
</tr>
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### Operating Specifications
- Fuel Cell Output kW (EOY) 1,385
- Fuel Flow (MMBtu/hr LHV) 10.2
- Avg Plant Thermal Recovery (MMBtu/hr) 1.62

### Annual Totals
- Power Generation Net (MWh) 10,919
- Plant Fuel (MMBtu LHV) 80,417
- Plant Thermal (MMBtu) 12,772

### Project Revenue (000)
- Avoided Electric Utility Cost - Fuel Cell $1,365
- Electricity - RECs / Other $273
- Electricity - Capacity $58
- Avoided Thermal Cost $96

### Annual Savings (000)
- $1,792

### Operating Costs (000)
- LTSA & Fuel $1,150

### Net Annual Savings (000)
- $642

### Payback Yrs.
- 8

### NPV (000)
- $(1,000)
**Developer Owned Example**

- **Installed CHP System**: $7,540
- **Incentive Payments**: $(4,878)
- **Govt Investment**: $2,662
- **Govt Investment %**: 35%

**Operating Specifications**
- Fuel Cell Output kW (EOY): 1,385
- Fuel Flow (MMBtu/hr LHV): 10.2
- Avg Plant Thermal Recovery (MMBtu/hr): 1.6

**Annual Totals**
- Power Generation Net (MWh): 10,919
- Plant Fuel (MMBtu LHV): 80,417
- Plant Thermal (MMBtu): 12,772

**Annual Avoided Costs**
- Avoided Electric Utility Cost - Fuel Cell: $1,365
- Electricity - RECs / Other: $273
- Electricity - Capacity: $58
- Avoided Thermal Cost: $96
- **Total Avoided Costs**: $1,792

**Operating Costs**
- LTSA & Fuel: $1,100
- Annual Developer Service Fee: $325

**Net Annual Savings**: $367

**NPV**: $(496)

- 1500kW (net 1400kW) Carbonate Fuel Cell
- 90% Operating Availability
- Long Term Service Agreement & Warranty
- Initial 10 Year Service Term

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![1500kW Carbonate FC Installation](image)
## Ownership Cost Comparison

### Project Ownership Comparison

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<th>Developer (000)</th>
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<td>$7,862</td>
<td>$7,540</td>
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<td>Incentives</td>
<td>$(2,475)</td>
<td>$(4,878)</td>
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<tr>
<td>Net Gov Investment</td>
<td>$5,387</td>
<td>$2,662</td>
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<tr>
<td>% Investment</td>
<td>68.5%</td>
<td>35.3%</td>
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<tr>
<td>Annual Avoided Costs</td>
<td>$1,792</td>
<td>$1,792</td>
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<tr>
<td>Annual Fuel Cell O&amp;M</td>
<td>$550</td>
<td>$550</td>
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<td>Annual Fuel Costs</td>
<td>$600</td>
<td>$600</td>
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<td>Annual Costs</td>
<td>$1,150</td>
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<tr>
<td>Annual Savings</td>
<td>$642</td>
<td>$317</td>
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<td>NPV</td>
<td>($1,000)</td>
<td>($496)</td>
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Developer Derived Benefits

1. Upgrade infrastructure with half the investment.
2. Lower life cycle costs.
3. Site two units for same price as one government owned unit.
4. Gov't investment may be developer financed.
5. Capture benefits of federal tax policy without risk of ownership.
Financing

- IRS Section 48 Tax Credits or Grant if under construction prior to 31 Dec 2010
- Fed ITC qualifying Contract
- Bankable Transaction...Payment Guarantor
- Other incentive or investment.

Relationships Among Parties

- Project Owner/Developer purchases units from Vendor
- Project Owner/Developer may accept investors) and exchange ITCs for $$ in qualified transaction. ...(Not required for 1603 transaction.)
- Project owner to furnish, install, maintain FC units under ITC qualifying Service Agreement. Receives monthly service payments.
- Project owner provides services to Customer through 10-Year Services Agreement

Cash Flows RED Numbers above

1. Project Owner/Developer (e.g. a Limited Liability Company, or LLC) issues PO to Vendor... purchases units on schedule.
2. Bank provides LLC with debt funds for installations and receives monthly debt service.
3. Investors exchange $$ for LLC investment through Operating Agreement...(Not required for 1603 transaction)
4. Customer pays monthly energy service fee (PPA or other form of agreement) to Project Owner/Developer
Thank you

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http://www.eere.energy.gov/hydrogenandfuelcells
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Using the Model: Four Simple Steps

Model users are first directed to this screen.

1. Click Process Flow Diagram

2. Configure system • Click Input sheet button

Simple: just click!

Configure the system on the Process Flow Diagram then click the “Input Sheet” button to enter cost & performance values.
Using the Model: Four Simple Steps

3. **Enter cost and performance values using the Input Sheet as “Home Base”**

- The “Input_Sheet_Template” sheet is the main model interface
- The subsequent slides will describe each section of the interface
- Tools and defaults are available for most values
- A lot of customization is possible for special case evaluations

4. **Run the model by clicking the “Run Hourly Energy Profile” button**

Once all inputs are complete, click here.