Fuel Cell Backup Power Technology Validation

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What is a Fuel Cell?

Fuel cells efficiently convert chemical energy into electricity through an electrochemical process without burning.

Represent an alternative to batteries, generators, internal combustion engines to provide power for portable electronics, stationary, transportation & other applications.

H₂ PEM Fuel Cell

- Advantage
  - High efficiencies for energy conversion
  - 40%-50% electrical efficiency (LHV of H₂)
  - ≥80% including utilization of waste heat
  - High energy density
  - Indefinite operating time as long as fuel is provided (refuel vs. recharge)
  - Scalable from mW to MW
  - Emission-free for H₂ PEMFC
  - Quiet operation

- Disadvantage
  - Cost
  - Lack of fuel infrastructure
    - Production
    - Storage
    - Distribution
Objectives – Relevance

Assess the technology status in real world operations, establish performance baselines, report on fuel cell and hydrogen technology, and support market growth by evaluating performance relevant to the markets’ value proposition.

• **Assess Technology**
  - Independent technology assessment in real world operation conditions
  - Focused on fuel cell system and hydrogen infrastructure: performance, operation, and safety
  - Leverage data processing and analysis capabilities developed under the fuel cell vehicle Learning Demonstration project
  - Material handling equipment, backup power, portable power, and stationary power.

• **Support Market Growth**
  - Analyses and results relevant to the markets’ value proposition
  - Reporting on technology status to fuel cell and hydrogen communities and other key stakeholders like end users
Hydrogen Secure Data Center – Approach

Bundled data (operation & maintenance/safety) delivered to NREL quarterly

Internal analysis completed quarterly

**Detailed Data Products (DDPs)**
- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months¹

**Composite Data Products (CDPs)**
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months²

1) Data exchange may happen more frequently based on data, analysis, and collaboration
2) Results published via NREL Tech Val website, conferences, and reports
Backup power CDP count and category

- **Deployment**
  - (1, 2, 3, 14)

- **Infra. Operation**
  - (6)

- **Fuel Cell Operation**
  - (5, 7, 8, 9, 11, 12, 13, 15)

- **Fuel Cell Reliability**
  - (4, 10)
Deployment: 75% sites are between 4 – 6 kW
Deployment: Over 1.45 MW capacity is deployed with 649 systems
Deployment: Sites in 15 states

<table>
<thead>
<tr>
<th>State</th>
<th>kW Capacity</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>84</td>
<td>16</td>
</tr>
<tr>
<td>California</td>
<td>567</td>
<td>122</td>
</tr>
<tr>
<td>Colorado</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>Connecticut</td>
<td>121</td>
<td>26</td>
</tr>
<tr>
<td>Florida</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Georgia</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Illinois</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Indiana</td>
<td>50</td>
<td>16</td>
</tr>
<tr>
<td>Kentucky</td>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Michigan</td>
<td>164</td>
<td>40</td>
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<tr>
<td>New Jersey</td>
<td>110</td>
<td>27</td>
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<tr>
<td>New York</td>
<td>186</td>
<td>44</td>
</tr>
<tr>
<td>South Carolina</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Utah</td>
<td>36</td>
<td>9</td>
</tr>
</tbody>
</table>

Totals: 1484 Site Capacity (line height proportional to installed site kW capacity)
Reliability: 99.5% successful starts

1526 of 1533 Starts Successful (99.5%)
52% Conditioning Starts

1) FC system conditioning is an automated operation for regular system checks; activated after long periods of no operation.
Reliability: Only 7 unsuccessful starts out of 1,533 attempted starts

Unsuccessful Operation Categories

- EStop: 1
- No Fuel: 1
- System Failure: 5
Operation: Runtime hours tend to be low due to low required operation but some months and systems see high operation time.

845 Total Runtime Hours

- Run Hours: Calculated Runtime Hours
- Conditioning Hours

Operation Hours

Number of Systems [%]
Operation: Systems are capable of extended runtimes (72-hour capacity)

Max Continuous Run Time = 29 hours
Grid outages: Association of system starts and grid outages

Some states see double digit grid outages a year with a few hours per outage

Often an outage has had extended down time

Couple fuel cell system operation data with OE-417 Electric Emergency and Disturbance (OE-417) Events, 2010-2012*

Operation: Automatic system operation is capable of rapid restarts as well as long durations between starts.

![Bar chart showing time between starts in days and frequency in percentage.](Image of bar chart)
Operation: 42% of starts occur off-peak between midnight and 5 a.m.

1) FC system conditioning is an automated operation for regular system checks; activated after long periods of no operation.
Operation: Systems demonstrated operation in a wide range of ambient temperature with a keep warm strategy in ambient conditions below freezing.

![Histogram of Ambient Temperature at Start](image)

- **Frequency [%]**
- **Ambient Temperature [°C]**
- **Ambient Temperature at Start**
Cost of ownership: Example of annualized cost analysis for material handling that will be applied to backup power systems
### Cost of ownership: Backup power

<table>
<thead>
<tr>
<th></th>
<th>Fuel Cell*</th>
<th>Diesel</th>
<th>Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reliability</strong></td>
<td>+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td><strong>Capital Cost ($/kW)</strong></td>
<td>-</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Extended Run Time</strong></td>
<td>++</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
<td>++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>~</td>
<td>-</td>
<td>~</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>+</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td><strong>Annual Fuel Cost</strong></td>
<td>+</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td><strong>Annual Maintenance Cost</strong></td>
<td>+</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td><strong>Maintenance Frequency</strong></td>
<td>++</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td><strong>Refurbishment</strong></td>
<td>+</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td><strong>Conditioning Tests</strong></td>
<td>+</td>
<td>-</td>
<td>~</td>
</tr>
<tr>
<td><strong>Operation Lifetime</strong></td>
<td>+</td>
<td>++</td>
<td>--</td>
</tr>
</tbody>
</table>

*Tax credit $3,000/kW or 30% total

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Gathering data on:
- Site Description
- System Description
- System Requirements
- Capital Cost
- Operating & Maintenance Cost
- Operating Lifetime for fuel cells, batteries, and generators
Fuel Cell Backup Power

- Operating reliability in 15 states with 99.5% successful starts
- Maximum continuous run time of 29 hours due to an unplanned grid outage
- Aggregated data showcases growth over the last two years

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All published results can be found at
Backup Slides
Cumulative Hydrogen Consumed by Month

- 76.9 kgs Total Consumed H₂
- 30,222 scf Total Consumed H₂

Calendar Month

Hydrogen kgs Consumed

NREL cdp_bu_06
Created: Sep-13-12 12:04 PM
Fuel Cell System Starts by Day of Week

System Starts by Day of Week

- Sun
- Mon
- Tues
- Wed
- Thur
- Fri
- Sat

Starts [%]