ARRA Fuel Cell Deployment and Operation

FC Seminar
COM34-4
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Contents

Overview of ARRA Fuel Cell Project

NREL Data Analysis Objectives

Deployment CDPs

Backup Power CDPs

Material Handling Technical CDPs

Summary
American Recovery and Reinvestment Act (ARRA) Fuel Cell Early Market Project

**Project Objective**

Deploy ~1,000 fuel cells to accelerate the commercialization and deployment of fuel cells and fuel cell manufacturing, installation, maintenance, and support services

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>AWARD</th>
<th>APPLICATION</th>
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<tbody>
<tr>
<td>Delphi Automotive</td>
<td>$2.4 M</td>
<td>Auxiliary Power</td>
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<td>FedEx Freight East</td>
<td>$1.3 M</td>
<td>Specialty Vehicle</td>
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<td>GENCO</td>
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<td>Specialty Vehicle</td>
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<td>Jadoo Power</td>
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<td>MTI MicroFuel Cells</td>
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<td>Portable</td>
</tr>
<tr>
<td>Nuvera Fuel Cells</td>
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<td>Specialty Vehicle</td>
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<td>Plug Power, Inc. (1)</td>
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<td>CHP</td>
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<td>Plug Power, Inc. (2)</td>
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<tr>
<td>ReliOn Inc.</td>
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<td>Backup Power</td>
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<tr>
<td>Sprint Comm.</td>
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<td>Backup Power</td>
</tr>
<tr>
<td>Sysco of Houston</td>
<td>$1.2 M</td>
<td>Specialty Vehicle</td>
</tr>
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</table>

12 awards with >$40 million ARRA & ~$53 million cost share
Innovation for Our Energy Future

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

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

HSDC Data Flow

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

Internal analysis completed quarterly

NREL’s Hydrogen Secure Data Center

Results

CDPs

1) Data exchange may happen more frequently based on data, analysis, & collaboration
2) Results published via NREL Tech Val website, conferences, and reports
NREL Data Analysis Objectives – ARRA Demonstrations

• Independent technology **assessment**: focused on fuel cell system and hydrogen infrastructure: performance, operation, and safety.

• **Leverage** data processing and analysis capabilities developed from the fuel cell vehicle Learning Demonstration project and DoD Forklift Demo.

• Establish a **baseline** of real-world fuel cell operation and maintenance data and identify technical/market barriers.

• **Support market growth** through analyses relevant to the **value proposition** and reporting on **technology status** to fuel cell and hydrogen communities and **stakeholders**
Delivered Fuel Cell Units & Deployment Sites

Some site locations TBD

211

2010 Q1
2010 Q2

0 50 100 150 200 250 300

Delivered Quantity

Calendar Quarter

DOE ARRA Funded Early Fuel Cell Markets: Delivered Units

1) American Recovery and Reinvestment Act
Fuel Cell Units in Operation
Current and Projected Quantities

DOE ARRA\(^1\) Funded Early Fuel Cell Markets: Units in Operation

Projected Operation Quantities

- APU
- Backup Power
- Material Handling Equipment
- Stationary

Calendar Quarter

2009 Q4 2010 Q1 2010 Q2 2010 Q3 2010 Q4 2011 Q1 2011 Q2 2011 Q3 2011 Q4

1) American Recovery and Reinvestment Act
FC Backup Power

Deployment & Operation Data

High level summary of operation
First cycle of CDPs (IA A & ARRA Sites)
Trends still developing
Many additional analyses planned for future CDP cycles
Backup Power Sites

Units Deployed

<table>
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<tr>
<th>State</th>
<th>KW Capacity</th>
<th>Sites</th>
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<tr>
<td>California</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>South Carolina</td>
<td>50</td>
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</tr>
<tr>
<td>Utah</td>
<td>20</td>
<td>3</td>
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</table>

Total Capacity 90 kW

Backup Power Deployments

Number of Sites in State

Site Capacity (line height proportional to installed site kW capacity)
Total Starts (Thru June 2010)  201
Total Successful Starts  199 (99%)
Total Run Time       88 hours
Total Hydrogen       12.4 kg
FC Material Handling Equipment

Deployment & Operation Data

High level summary of operation
First cycle of CDPs
Trends still developing
Many additional analyses planned for future CDP cycles
FCMHE Fall 2010 CDPs

Analysis Topics
- Units Deployed, Operation Hours, Refueling, Maintenance, Safety, FC Performance, Site Usage

ARRA FCHMHE CDPs
- 22

ARRA & DLA Infrastructure CDPs
- 4

Data Files Analyzed
- 23,307 (1.7GB)
MHE FC Units & Sites

<table>
<thead>
<tr>
<th>Sites</th>
<th>2010 Q1</th>
<th>2010 Q2</th>
</tr>
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<tbody>
<tr>
<td>Operational MHE Units/Site</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>Operating Shifts/Site</td>
<td>2</td>
<td>3</td>
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<tr>
<td>9 hrs</td>
<td>2</td>
<td>8 hrs</td>
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<tr>
<td>Facility Square Footage (1,000)</td>
<td>1,000</td>
<td>75</td>
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<tr>
<td>FC Units/MHE Unit</td>
<td>1.0</td>
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Fuel Cell Units Deployed - ARRA

- Class III: 122 units (2010 Q1), 136 units (2010 Q2)
- Class II: 49 units (2010 Q2)
- Class I: 35 units (2010 Q2)
**FC Operation Summary**

149,046 Total Hours Accumulated

66% FC Stacks > 1000 hours

- **Cumulative Fuel Cell Operation Hours - ARRA**
  - 65.9% FC Stacks > 1000 Hours
  - Min Fleet Average = 599 fuel cell hours
  - Max Fleet Average = 1338 fuel cell hours

- **Fuel Cell Operation Hours by Quarter - ARRA**
  - Total Hours = 149,046
  - 2010 Q1: 52613
  - 2010 Q2: 96433

- **Fuel Cell Operation Hours**

  - Total Operation Hours = 149,046

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*National Renewable Energy Laboratory*
FC Daily Operation

Average Daily Fuel Cell Operation Hours per System - ARRA

50.4% Fuel Cell Systems Average 5-7 Hours Daily
Hydrogen Fill Event Summary

Total Hydrogen Dispensed 6,198 kg
Total Hydrogen Fill Events 13,329 fills
Hydrogen Fill Event Rates and Amounts

Average Fill Time: 1.9 minutes
Average Fill Amount: 0.47 kg

Histogram of Fueling Times
ARRA
13,329 Events
Average = 1.93 min

Histogram of Fueling Amounts
ARRA
Average = 0.47 kg

Fill data for class 1, 2, and 3 trucks
1. Some refueling events not recorded/detected due to data noise or incompleteness.
2. The outer arc is set at 40% total refuelings.
3. Full Pressure is either 3600 psi or 5000 psi.
**Operation Time between Fueling**

Operating Time Between Fuelings - ARRA

- **Average of 4.1 op hours between fills**

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<th>Count</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
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<td>11</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
</tr>
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</table>

1) Some fueling events not recorded/detected due to data noise or incompleteness.
2) Data indicative of actual use and does not represent the max capability of the systems.
Shaded areas represent the min and max site average hydrogen use and fill frequency.
Fuel Cell System Maintenance by Category

Number of Events
Total Events = 789
73% were unscheduled

Labor Hours
Total Hours = 1165
69% were unscheduled

- Controls, Electronics, Sensors: 24%
- Preventative maintenance: 10%
- Thermal management: 13%
- Energy Storage System: 23%
- Fuel System: 14%
- Other: 20%
- Electrical: 9%
- Operator Error: 17%
- Air System: 28%
- FC Stack: 13%
- Scheduled equip upgrade: 20%
- Air system: 28%

73% Unscheduled Maintenance Events
38% Events for Controls, Electronics, Sensors or Thermal Mgmt
Average Fuel Cell System Quarterly Maintenance - ARRA

Average FC Maintenance Events

Average # of Events per System

10Q1 | 10Q2
---|---
0 | 4.5
1.5 | 3
2.5 | 2

Average FC Maintenance Hours

Average Hours per System

10Q1 | 10Q2
---|---
0.5 | 5
3.5 | 4
1) Near Miss is an event that under slightly different circumstances could have become an incident - unplanned H2 release insufficient to sustain a flame

2) Incident is an event that results in:
   - a lost time accident and/or injury to personnel
   - damage/unplanned downtime for project equipment, facilities or property
   - impact to the public or environment
   - any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
   - release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)
Infrastructure Maintenance

Total Hydrogen Dispensed 19,831 kg
Total Hydrogen Fill Events 36,468 fills
Total FC Hours 251,177 hours
Maintenance Events 173 (71% Unscheduled)
Safety Incidents 0

Infrastructure Maintenance Scheduled vs. Unscheduled
Number of Maintenance Events by Category

- compressor
- H2 production unit
- system control & safety
- preventative maintenance
- dispenser
- valves & piping
- electrical
- other
- storage

Total Events = 173
71% were unscheduled

Number of Labor Hours by Category

- compressor
- H2 production unit
- system control & safety
- preventative maintenance
- dispenser
- valves & piping
- electrical
- other
- storage

Total Hours = 1599
73% were unscheduled

Average Infrastructure Site Quarterly Maintenance

- Average Site Maintenance Events
- Average Site Maintenance Hours

ARRA & DLA Sites Combined
Summary

• 206 MHE Units in operation at 4 sites with more than 13,300 fills, 6,200 kgs dispensed, and 149,000 hours accumulated without a safety incident.

• 24 BU Units (90 kW installed capacity) in operation at 5 sites with 199 of 201 Starts successful and 88 total hours run time.

• Operation trends unclear because we are in early stage of deployment and analysis.

• Many more sites coming on-line in the next 6-12 months.

• Many more planned analyses like fuel cell durability, system reliability, and application value proposition.
Early Fuel Cell Market Demonstrations

Early fuel cell market demonstrations are focused primarily on using fuel cell technologies for material handling, backup power, and prime-power applications. The Department of Energy-sponsored demonstration projects support fuel cell market transformation activities and help foster the growth of fuel cell markets. In addition, the Department of Defense funds early fuel cell demonstration projects.

NREL receives operational data from these early market fuel cell demonstrations, analyzes, and reports on these data. By aggregating data across numerous industry teams and sites, NREL develops composite data products (CDPs), which provide relevant data results on the technology status and fuel cell performance without revealing proprietary data. These publicly available CDPs will help the development community understand the state of fuel cell technologies, identify areas for continued improvement, and provide data metrics that are important to the business case for these fuel cell markets.

This page provides the following resources:

- Composite Data Products
- Presentations and Publications
- Presentations Containing All CDPs

Composite Data Products

The public technical analysis results are generated in the form of composite data products. The following CDPs can be sorted by title, category, CDP number, and date updated. Download the CDPs as PowerPoint or JPEG files using the links in the two columns on the right. Download the current presentation containing all CDPs (PowerPoint 2.7 MB) or see the archived presentations containing all CDPs.

<table>
<thead>
<tr>
<th>Sort by</th>
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<th>JPEG</th>
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<tr>
<td>Operating Hours between Fueling</td>
<td>Fuel Cell Fuel Economy Range and Efficiency</td>
<td>FL89</td>
<td>2009-11-08</td>
<td>JFG</td>
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<td>Accumulated Forklift Operating Hours</td>
<td>Fuel Cell Usage and Operation Behavior</td>
<td>FLB2</td>
<td>2009-11-08</td>
<td>JFG</td>
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<td>Forklifts Deployed by Quarter</td>
<td>Fuel Cell Usage and Operation Behavior</td>
<td>FLB1</td>
<td>2009-11-08</td>
<td>JFG</td>
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<td>Forklifts Delivered to Site</td>
<td>Fuel Cell Usage and Operation Behavior</td>
<td>ARR201</td>
<td>2010-02-19</td>
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