Spring 2014 Composite Data Products: Backup Power

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Backup Power Fuel Cell Systems Deployed

Cumulative Systems Deployed

- Sites may have more than one FC system
- Not all FC systems are supplying operation data
Deployed kW Capacity for Backup Power

Cumulative Deployed Capacity [kW]

- 2009 Q3: 50
- 2009 Q4: 70
- 2010 Q1: 70
- 2010 Q2: 104
- 2010 Q3: 130
- 2010 Q4: 444
- 2011 Q1: 500
- 2011 Q2: 761
- 2011 Q3: 1377
- 2011 Q4: 1452
- 2012 Q1: 1491
- 2012 Q2: 1599
- 2012 Q3: 1858
- 2012 Q4: 1917
- 2013 Q1: 1932
- 2013 Q2: 1943
- 2013 Q3: 1993
- 2013 Q4:
Backup Power Deployments

<table>
<thead>
<tr>
<th>State</th>
<th>kW</th>
<th>Sites</th>
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<tbody>
<tr>
<td>Arizona</td>
<td>84</td>
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<tr>
<td>California</td>
<td>635</td>
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<td>Washington</td>
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<td>1</td>
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<tr>
<td>Wyoming</td>
<td>2</td>
<td>1</td>
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</table>

Totals: 1993, 418

Site Capacity (line height proportional to installed site kW capacity)
Fuel Cell System Starts by Month

Starts by Month

Starts
Conditioning\(^1\) Start
Successful Start

2583 of 2596 Uninterrupted Operation (99.5%)
60% Conditioning Starts
1034 of 1047 Unscheduled Operation (98.8%)

1) FC system conditioning is an automated operation for regular system checks; activated after long periods of no operation.
1764 Hours Total Runtime
120 Systems
0.8 Hours Average Fleet Runtime

1) FC system conditioning is an automated operation for regular system checks that are run after long periods of no operation.
Fuel Cell System Starts by Day of Week

System Starts by Day of Week

<table>
<thead>
<tr>
<th>Day</th>
<th>Starts [%]</th>
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</thead>
<tbody>
<tr>
<td>Sun</td>
<td>5</td>
</tr>
<tr>
<td>Mon</td>
<td>5</td>
</tr>
<tr>
<td>Tues</td>
<td>25</td>
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<td>Wed</td>
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<td>Thur</td>
<td>17</td>
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<tr>
<td>Fri</td>
<td>12</td>
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<tr>
<td>Sat</td>
<td>3</td>
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Created: Apr-02-14  1:42 PM | Data Range: 2010Q1-2013Q3
FC system conditioning is an automated operation for regular system checks; activated after long periods of no operation.

1) FC system conditioning is an automated operation for regular system checks; activated after long periods of no operation.
Uninterrupted Operation

99.5%

< 1%

Interrupted Operation Categories

EStop: 3
No Fuel: 2
System Failure: 8

2583 out of 2596 uninterrupted operation

13 interrupted operations
CDP-BU-11
Time Between System Starts

Time Between Starts

Frequency [%]

Days

All Starts
Conditioning Starts

Created: Apr-02-14 1:43 PM | Data Range: 2010Q1-2013Q3
CDP-BU-12
System Start Ambient Temperature

Ambient Temperature at Start

Frequency [%]

Ambient Temperature [°C]

All Starts
Conditioning Starts

Created: Apr-02-14  1:43 PM | Data Range: 2010Q1-2013Q3
Site Capacity

Capacity by Site

Number of Sites

Capacity [kW]

Capacity [kW]

78%

78%
Operation Hours Per Month

Monthly Run Time

Average Run Hours Per Month

Percent of Systems

NREL cdp_bu_16
Created: Apr-02-14 1:43 PM | Data Range: 2010Q1-2013Q3
Average Starts Per Month

% of systems above 5 starts per month: 3%
Continuous System Run Time

- **Average Hurricane**
  - Sandy: 142.5 hours
  - Irene: 55.5 hours
  - Isaac: 61.4 hours
  - Total: 86.5 hours

- **Average Grid Outage**
  - Duration: 44.4 hours

- **Median Grid Outage**
  - Duration: 11.7 hours

- **Max Demonstrated**
  - Duration: 65.4 hours

- **Average Demonstrated**
  - Duration: 0.9 hours

- **Median Demonstrated**
  - Duration: 0.3 hours

Durations demonstrated from ARRA project data

1) Grid data from Electric Disturbance Event (OE-417) Annual Summaries 2002-2013/12
2) Fuel cell operations less than 5 minutes apart have been combined to address intermittent operation.
3) Does not include conditioning starts.
FC Unit Locations - Backup Power

Backup Power (418 Sites and 852 FC Units)
Power Outages per Year

Average number of outages by year = 123
Average outage time by year = 51 hours

Power Outages\(^1\) (2002-2013\(^2\))

- Number of Outages
- Average Time per Outage

1) Grid data from Electric Disturbance Event (OE-417) Annual Summaries 2002-2013
2) 2013 data through 12/2013
System Operation Hours vs. Calendar Days

Calendar Days = span from first to last use

1 hour per 10 days

30 mins per 10 days

Operating Hours vs. Calendar Days

Created: Apr-02-14 1:43 PM | Data Range: 2010Q1-2013Q3
Annualized Cost by Runtime

- Battery
- Diesel
- Fuel Cell
- Fuel Cell*

Data Range: 2010Q1-2013Q3

Created: Apr-15-14 4:54 PM | Data Range: 2010Q1-2013Q3
CDP-BU-23
Annualized Cost of Ownership

Annualized Cost of Ownership - Backup Power

<table>
<thead>
<tr>
<th></th>
<th>8 Hours</th>
<th>52 Hours</th>
<th>72 Hours</th>
<th>176 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>$6300</td>
<td>$24800</td>
<td>$31300</td>
<td>$67200</td>
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<tr>
<td>Diesel</td>
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<td>FC</td>
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<tr>
<td>FC*</td>
<td>$4600</td>
<td>$5100</td>
<td>$5100</td>
<td>$7400</td>
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</tbody>
</table>
CDP-BU-24
8-hour Annualized Cost of Ownership

Annualized Cost of Ownership 8-hour Scenario

- **Battery**
  - Capital: $3500
  - Install: $2500
  - Maintenance: $300
  - Fuel: $6300

- **Diesel**
  - Capital: $2300
  - Install: $800
  - Maintenance: $1800
  - Fuel: $4700

- **FC**
  - Capital: $2300
  - Install: $2200
  - Maintenance: $700
  - Fuel: $5300

- **FC**
  - Capital: $1600
  - Install: $2200
  - Maintenance: $700
  - Fuel: $4600

1. Includes hydrogen storage rent
2. Actual fuel cost negligible when rounded to the nearest hundred
52-hour Annualized Cost of Ownership

Annualized Cost of Ownership 52-hour Scenario

- Diesel:
  - Capital: $2100
  - Install: $1800
  - Maintenance: $200
  - Fuel: $4900

- FC:
  - Capital: $3600
  - Install: $2200
  - Maintenance: $400
  - Fuel: $6100

- FC*:
  - Capital: $2600
  - Install: $2200
  - Maintenance: $100
  - Fuel: $5100

1. Includes capital costs for fuel storage
72-hour Annualized Cost of Ownership

Annualized Cost of Ownership 72-hour Scenario

- **Capital**: Includes capital costs for fuel storage
- **Install**: $2100
- **Maintenance**: $2200
- **Fuel**: $2600

**Diesel**
- Capital: $200
- Install: $1800
- Maintenance: $2100
- Fuel: $4900

**FC**
- Capital: $100
- Install: $3600
- Maintenance: $2200
- Fuel: $6100

**FC**
- Capital: $100
- Install: $3600
- Maintenance: $2200
- Fuel: $5100

1. Includes capital costs for fuel storage

NREL cdp_bu_26
Created: Apr-07-14 10:05 AM | Data Through: 2013Q4
176-hour Annualized Cost of Ownership

Annualized Cost of Ownership 176-hour Scenario

- **Capital**: $8500
- **Install**: $500
- **Maintenance**: $100
- **Fuel**: $2200

**Diesel**
- **Capital**: $5300
- **Install**: $600
- **Maintenance**: $800
- **Fuel**: $1800

**FC**
- **Capital**: $7400
- **Install**: $500
- **Maintenance**: $100
- **Fuel**: $2200

**FC+**
- **Capital**: $4600
- **Install**: $500
- **Maintenance**: $100
- **Fuel**: $2200

1. Includes capital costs for fuel storage
Annualized Cost Breakdown For Three Backup Power Technologies

**Battery:** $6,300

**Diesel:** $4,700

**FC**: $4,600

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**Battery**: $24,800

**Diesel**: $4,900

**FC**: $5,100

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**Battery**: $31,300

**Diesel**: $4,900

**FC**: $5,100

---

**Battery**: $67,200

**Diesel**: $5,300

**FC**: $7,400

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*Battery costs above chart axis limit, not shown.*
Mean Time Between Interrupted Operation

Median = 465* days
*Only includes systems with Interrupted Operation
Annualized Cost of Ownership—Zoomed In

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CDP-BU-31
72-hour Annualized Cost of Ownership Sensitivity

Annualized Cost Sensitivity
72 hour runtime

- Capital
- Install
- Discount Rate
- Operation Life
- Maintenance
- Fuel
- Avg

Created: Apr-15-14  4:32 PM | Data Range: 2010Q1-2013Q3
72-hour Annualized Cost of Ownership Sensitivity—Zoomed In

Annualized Cost Sensitivity
72 hour runtime

- Diesel
- FC
- FC*
- Capital
- Install
- Discount Rate
- Operation Life
- Maintenance
- Fuel

Avg

NREL cdp_bu_32
Created: Apr-15-14 4:32 PM | Data Range: 2010Q1-2013Q3
Fuel Cell Capital Cost Breakdown

Fuel Cell Capital Cost

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<td>$40,000</td>
<td>$70,000</td>
</tr>
<tr>
<td>$50,000</td>
<td>$80,000</td>
</tr>
</tbody>
</table>

8 Hours
52 Hours
72 Hours
176 Hours

HSM = Hydrogen Storage Module