Spring 2014 Composite Data Products: Backup Power

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Backup Power Fuel Cell Systems Deployed

1) Sites may have more than one FC system
2) 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: 1064
- 2011 Q4: 1377
- 2012 Q1: 1452
- 2012 Q2: 1491
- 2012 Q3: 1599
- 2012 Q4: 1858
- 2013 Q1: 1917
- 2013 Q2: 1932
- 2013 Q3: 1943
- 2013 Q4: 1993

Created: Apr-16-14 5:05 PM | Data Range: 2010Q1-2013Q4
## Backup Power Deployments

### State Data

<table>
<thead>
<tr>
<th>State</th>
<th>kW</th>
<th>Sites</th>
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<td>1</td>
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<tr>
<td>Wyoming</td>
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<td>1</td>
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</tbody>
</table>

### Totals

| Totals | 1993 | 418  |

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Site Capacity (line height proportional to installed site kW capacity)
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

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

Starts [%]
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

![Bar chart showing time between system starts.](chart.png)

- **All Starts**: Orange bars represent the frequency of all system starts.
- **Conditioning Starts**: Gray bars represent the frequency of conditioning starts.

Days:
- 0 days
- 1-2 days
- 7 days
- 14 days
- 28 days
- 31 days
- Inf

Frequency [%]:
- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40

**Legend**:
- All Starts
- Conditioning Starts

**Notes**:
- 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

NREL cdp_bu_12
NATIONAL RENEWABLE ENERGY LABORATORY
CDP-BU-14
Site Capacity

Capacity by Site

Number of Sites

Capacity [kW]

78%

0 2 4 6 8 10 Inf

Capacity by Site

Created: Apr-02-14 1:43 PM | Data Range: 2010Q1-2013Q3
CDP-BU-16
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%

NREL cdp_bu_17
Created: Apr-07-14 10:58 AM | Data Range: 2010Q1-2013Q3
Sandy 142.5 hours
Irene 55.5 hours
Isaac 61.4 hours

Max Demonstrated^2,3

Average Demonstrated^2,3

Median Demonstrated^2,3

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

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

Data Range: 2010Q1-2013Q3

Created: Apr-02-14 1:43 PM
CDP-BU-22
Annualized Cost of Ownership

Annualized Cost by Runtime

- Battery
- Diesel
- Fuel Cell
- Fuel Cell*

8 Hour Runtime

$0

$2,000

$4,000

$6,000

$8,000

$10,000

176 Hour Runtime

52 Hour Runtime

72 Hour Runtime

NREL cdp_bu_22
Created: Apr-15-14 4:54 PM | Data Range: 2010Q1-2013Q3
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>
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<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>$4900</td>
<td>$4900</td>
<td>$5300</td>
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<td>FC</td>
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<td>$6100</td>
<td>$8500</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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Created: Apr-07-14 10:05 AM | Data Through: 2013Q4
Annualized Cost of Ownership 8-hour Scenario

- **Battery**
  - Capital: $3500
  - Install: $1800
  - Maintenance: $2100
  - Fuel: $0
  - Total: $6300

- **Diesel**
  - Capital: $2500
  - Install: $800
  - Maintenance: $800
  - Fuel: $1800
  - Total: $4700

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

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

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1. Includes hydrogen storage rent
2. Actual fuel cost negligible when rounded to the nearest hundred
CDP-BU-25
52-hour Annualized Cost of Ownership

Annualized Cost of Ownership 52-hour Scenario

- Capital
- Install
- Maintenance
- Fuel

1. Includes capital costs for fuel storage

Diesel:
- Capital: $2100
- Install: $4900
- Maintenance: $800
- Fuel: $200

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

FC*:
- Capital: $2600
- Install: $5100
- Maintenance: $200
- Fuel: $100

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

Annualized Cost of Ownership 72-hour Scenario

- **Diesel**
  - Capital: $4900
  - Install: $200
  - Maintenance: $800
  - Fuel: $1800

- **FC**
  - Capital: $6100
  - Install: $200
  - Maintenance: $2200
  - Fuel: $3600

- **FC***
  - Capital: $5100
  - Install: $200
  - Maintenance: $2200
  - Fuel: $2600

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

Annualized Cost of Ownership 176-hour Scenario

1. Includes capital costs for fuel storage
Annualized Cost of Ownership Heat Map

Battery: $6,300
Diesel: $4,700
FC*: $4,600

8 Hours of Backup

Battery*: $24,800
Diesel: $4,900
FC*: $5,100

52 Hours of Backup

Battery*: $31,300
Diesel: $4,900
FC*: $5,100

72 Hours of Backup

Battery*: $67,200
Diesel: $5,300
FC*: $7,400

176 Hours of Backup

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

Median = 465* days
*Only includes systems with Interrupted Operation

System Count

Calendar Days

No Interrupted Operation

Inf
CDP-BU-30
Annualized Cost of Ownership—Zoomed In

### Annualized Cost of Ownership - Backup Power

<table>
<thead>
<tr>
<th></th>
<th>Battery</th>
<th>Diesel</th>
<th>FC</th>
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<tr>
<td>176 Hours</td>
<td>$67200</td>
<td>$5300</td>
<td>$8500</td>
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Annualized Cost Sensitivity
72 hour runtime

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

Avg
Annualized Cost Sensitivity
72 hour runtime

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

Avg

CDP-BU-32
72-hour Annualized Cost of Ownership Sensitivity—Zoomed In
Fuel Cell Capital Cost Breakdown

Fuel Cell Capital Cost

HSM = Hydrogen Storage Module

<table>
<thead>
<tr>
<th>Hours</th>
<th>Fuel Cell Cost</th>
<th>HSM Cost</th>
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Created: Apr-16-14  8:59 AM | Data Range: 2010Q1-2013Q4