Fall 2013 Composite Data Products – Backup Power

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CDP-BU-01
Backup Power Fuel Cell Systems Deployed

Backup Power Fuel Cell Systems Deployed

Cumulative Systems 1,2 Deployed

1) Sites may have more than one FC system
2) Not all FC systems are supplying operation data

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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

Data Range: 2009Q3-2013Q3
Backup Power Deployments

<table>
<thead>
<tr>
<th>State</th>
<th>kW</th>
<th>Sites</th>
</tr>
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<tbody>
<tr>
<td>Arizona</td>
<td>84</td>
<td>19</td>
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<tr>
<td>California</td>
<td>585</td>
<td>129</td>
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<td>6</td>
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<td>Connecticut</td>
<td>130</td>
<td>28</td>
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<td>Florida</td>
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<td>1</td>
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<td>Georgia</td>
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<td>Illinois</td>
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<tr>
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<tr>
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<tr>
<td>Mississippi</td>
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<td>2</td>
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<td>1</td>
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<td>New Jersey</td>
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<td>1</td>
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<td>Washington</td>
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<td>1</td>
</tr>
<tr>
<td>Wyoming</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Totals         | 1943| 417   |
Fuel Cell System Starts by Month

2565 of 2578 Uninterrupted Operation (99.5%) 60% Conditioning Starts

1) FC system conditioning is an automated operation for regular system checks; activated after long periods of no operation.
Fuel Cell System Run Hours by Month

- **Run Hours by Month**
  - 1749 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.
Cumulative Hydrogen Consumed by Month

- 91.2 kgs Total Consumed \( \text{H}_2 \)
- 35,812 scf Total Consumed \( \text{H}_2 \)

Calendar Month

Hydrogen kgs Consumed

0 10 20 30 40 50 60 70 80 90 100

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Fuel Cell System Starts by Day of Week

System Starts by Day of Week

- **Starts [%]**
- **Day**
  - Sun
  - Mon
  - Tues
  - Wed
  - Thur
  - Fri
  - Sat

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Fuel Cell System Starts by Time of Day

1) FC system conditioning is an automated operation for regular system checks; activated after long periods of no operation.
Continuous Fuel Cell System Run Time

Max Continuous Run Time = 65 hours
Average Runtime Per System = 0.7 hours
Average Conditioning Run Time Per System = 0.7 hours

1) Fuel cell operations less than 5 minutes apart have been concatenated due to battery interactions that may cause apparently intermittent operation.
Uninterrupted Operation

Interrupted Operation Categories

- EStop: 3
- No Fuel: 2
- System Failure: 8

99.5 %

< 1%

2565 out of 2578 uninterrupted operation

13 interrupted operations

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Time Between System Starts

The chart illustrates the frequency of system starts over different time intervals. The data is categorized into 'All Starts' and 'Conditioning Starts'. The y-axis represents the frequency in percentage, while the x-axis shows the days between system starts. The peak frequency is observed for 28 days, with a notable number of conditioning starts also occurring around 31 days. The data range is from Q1 2010 to Q2 2013.
System Start Ambient Temperature

Ambient Temperature at Start

- Frequency [%]
- Ambient Temperature [°C]

- All Starts
- Conditioning Starts

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Average System Hours = 0.8
Average Fleet Hours = 14.7
Max system hours = 73.0
25% of systems have hours > 16.4
CDP-BU-15
Backup Power Operation With Grid Outage from 01/2010 to 08/2013
CDP-BU-16
Operation Hours Per Month

Monthly Run Time

Percent of Systems

Average Run Hours Per Month

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Average Starts Per Month

% of systems above 5 starts per month: 3.19%
Continuous System Run Time

- **Average Hurricane^1**: Sandy 142.5 hours, Irene 55.5 hours, Isaac 61.4 hours
  - Average: 86.5 hours

- **Average Grid Outage^1**: 44.3 hours

- **Median Grid Outage^1**: 11.8 hours

- **Max Demonstrated^2,3**: 65.4 hours

- **Average Demonstrated^2,3**: 0.9 hours

- **Median Demonstrated^2,3**: 0.3 hours

Durations demonstrated from ARRA project data

1) Grid data from Electric Disturbance Event (OE-417) Annual Summaries 2002-2013/08
2) Fuel cell operations less than 5 minutes apart have been combined to address intermittent operation.
3) Does not include conditioning starts.
Power Outages per Year

Average number of outages by year = 119
Average outage time by year = 50 hours

Power Outages^1 (2002-2013^2)

Number of Outages

Outage time (hr)

1) Grid data from Electric Disturbance Event (OE-417) Annual Summaries 2002-2013
2) 2013 data through 08/2013
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Operation Hours vs. Calendar Days

System Operation Hours vs. Calendar Days

1 hour per 10 days
30 mins per 10 days

Calendar Days = span from first to last use

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CDP-BU-22
Annualized Cost by Runtime

Annualized Cost by Runtime

- Battery
- Diesel
- Fuel Cell
- Fuel Cell*
Annualized Cost of Ownership for 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>Diesel</td>
<td>$4,711</td>
<td>$4,950</td>
<td>$5,059</td>
<td>$5,626</td>
</tr>
<tr>
<td>Battery</td>
<td>$6,880</td>
<td>$25,817</td>
<td>$32,741</td>
<td>$69,897</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>$5,245</td>
<td>$6,058</td>
<td>$6,104</td>
<td>$8,470</td>
</tr>
<tr>
<td>Fuel Cell*</td>
<td>$4,121</td>
<td>$4,934</td>
<td>$4,980</td>
<td>$7,346</td>
</tr>
</tbody>
</table>
CDP-BU-25
52-hour Annualized Cost of Ownership

52-hour Annualized Cost of Ownership

- Diesel
  - Amortized Capital
  - Amortized Install
  - Annual Maintenance Cost
  - Fuel Storage Rent per Year
  - Electricity/Hydrogen/Diesel

- FC
  - Amortized Capital
  - Amortized Install
  - Annual Maintenance Cost
  - Fuel Storage Rent per Year
  - Electricity/Hydrogen/Diesel

- FC + Incentives
  - Amortized Capital
  - Amortized Install
  - Annual Maintenance Cost
  - Fuel Storage Rent per Year
  - Electricity/Hydrogen/Diesel
CDP-BU-26
72-hour Annualized Cost of Ownership

72-hour Annualized Cost of Ownership

- Amortized Capital
- Amortized Install
- Annual Maintenance Cost
- Fuel Storage Rent per Year
- Electricity/Hydrogen/Diesel

Diesel
- $2,000.00
- $3,000.00
- $4,000.00
- $5,000.00
- $6,000.00
- $7,000.00

FC
- $5,000.00
- $5,000.00
- $5,000.00
- $5,000.00
- $5,000.00
- $5,000.00

FC + Incentives
- $5,000.00
- $5,000.00
- $5,000.00
- $5,000.00
- $5,000.00
- $5,000.00
176-hour Annualized Cost of Ownership

- **Amortized Capital**
- **Amortized Install**
- **Annual Maintenance Cost**
- **Fuel Storage Rent per Year**
- **Electricity/Hydrogen/Diesel**
CDP-BU-28
Annualized Cost of Ownership Heat Map

Annualized Cost Breakdown For Three Backup Power Technologies

- **8 Hours of Backup**
  - Battery: $6,880
  - Diesel: $4,711
  - FC + Incentives: $4,121

- **52 Hours of Backup**
  - Battery*: $25,817
  - Diesel: $4,950
  - FC + Incentives: $4,934

- **72 Hours of Backup**
  - Battery*: $32,741
  - Diesel: $5,059
  - FC + Incentives: $4,980

- **176 Hours of Backup**
  - Battery*: $69,897
  - Diesel: $5,626
  - FC + Incentives: $7,346

*Battery costs above chart axis limit, not shown.