Fuel Cell Electric Vehicle Performance Composite Data Products: Spring 2018

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# CDP-FCEV-175: Summary of Key FCEV Metrics

## Summary of Key FCEV Metrics

<table>
<thead>
<tr>
<th>Vehicle Performance Metrics</th>
<th>DOE Target (Year 2020)(^a)</th>
<th>LD3(^b)</th>
<th>LD2(^c)</th>
<th>LD2(^c)</th>
<th>LD1(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Fuel Cell Durability Projections (hours)</td>
<td>5,000</td>
<td>4,130</td>
<td>--</td>
<td>2,521</td>
<td>1,807</td>
</tr>
<tr>
<td>Average Fuel Cell Durability Projection (hours)</td>
<td>2,442</td>
<td>1,748</td>
<td>1,062</td>
<td>821</td>
<td></td>
</tr>
<tr>
<td>Max Fuel Cell Operation (hours)</td>
<td>5,648</td>
<td>1,582</td>
<td>1,261</td>
<td>2,375</td>
<td></td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted Dyno (Window Sticker) Range (miles)</td>
<td>200 - 320</td>
<td>--</td>
<td>196 - 254</td>
<td>103 - 190</td>
<td></td>
</tr>
<tr>
<td>Median On-Road Distance Between Fuelings (miles)</td>
<td>124</td>
<td>98</td>
<td>81</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Fuel Economy (Window Sticker) (mi/kg)</td>
<td>53 (median)</td>
<td>--</td>
<td>43 - 58</td>
<td>42 - 57</td>
<td></td>
</tr>
<tr>
<td>Fuel Cell System Efficiency at 1/4 Power</td>
<td>65</td>
<td>57% (average)</td>
<td>--</td>
<td>53% - 59%</td>
<td>51% - 58%</td>
</tr>
<tr>
<td>Fuel Cell System Efficiency at Full Power</td>
<td>43% (average)</td>
<td>--</td>
<td>42% - 53%</td>
<td>30% - 54%</td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Power (W/kg)</td>
<td>650</td>
<td>240 - 563</td>
<td>306 - 406</td>
<td>183 - 323</td>
<td></td>
</tr>
<tr>
<td>Power Density (W/L)</td>
<td>650</td>
<td>276 - 619</td>
<td>300 - 400</td>
<td>300 - 400</td>
<td></td>
</tr>
<tr>
<td><strong>Specs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Gravimetric Capacity (kg H2/kg system)</td>
<td>5.5%</td>
<td>2.5% - 3.7%</td>
<td>2.5% - 4.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Volumetric Capacity (kg H2/L system)</td>
<td>0.04</td>
<td>0.018 - 0.054</td>
<td>0.018 - 0.025</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^b\) Current results are available at http://www.nrel.gov/hydrogen/proj_fc_vehicle_evaluation.html (Updated 5/2017)  
CDP-FCEV-174: FCEV Summary of Key Metrics vs. DOE Targets

Summary of Key FCEV Metrics vs DOE Targets

- Power Density
  - 650 W/L
- Peak Energy Efficiency
  - 65%
- Specific Power
  - 650 W/kg
- Durability
  - 5,000 hrs
- System Volumetric Capacity
  - .04 kg H2/L system
- System Gravimetric Capacity
  - .055 kg H2/kg sys


b. MYRDD Fuel Cell section 3.4 (last updated May 2017), table 3.4.3.
c. MYRDD Hydrogen Storage section 3.3 (last updated May 2015), table 3.3.3.
Deployment
CDP-FCEV-33: FCEV Evaluation Phases, Participants, Publications, and Trip Count

FCEV Evaluation Phases

LD Evaluation Trip Count

1) Not all fleets in operation in 2015; chart includes trips through December 2017.
2) LD = Learning Demonstration Phase
Vehicle Count

Total Vehicle Count = 239

Cumulative Miles

Total Miles = 7,390,424

Vehicle Count

Number of Vehicles


On Road Retired

54

1. Vehicle reporting data to NFCTEC for the DOE fuel cell vehicle evaluation project. Some vehicles were in operation prior to 2013.
Driving Behavior
CDP-FCEV-102: Vehicle Miles

Total Miles Traveled = 2,675,280
Max Vehicle Odometer = 296,830 miles
Vehicles > 100k miles = 5%
Vehicles > 175k miles = 4%
CDP-FCEV-104: Fuel Cell Stack Operation Hours

Total Operation Hours = 83,466
Max FC Stack Operation Hours = 5,648
22% Stacks with >= 2000 Operation Hours
CDP-FCEV-118: Driving Start Time by Time of Day

Driving by Time of Day

Total Drive Events
= 177,428

1. Some events not recorded/detected due to data noise or incompleteness.
2. UTC adjusted to local time using meridian-based adjustments and does not account for statutory deviations from the meridian-based system.
3. 2009 NHTS Data includes Car, Truck, Van, & SUV day trips
ASCII Source: http://nhts.ces.cmu.edu/download.shtml#2009

75.5% of NREL-analyzed trips and 6 a.m. and 6 p.m.
84.4% of NHTS trips occurred between 6 a.m. and 6 p.m.
CDP-FCEV-119: Driving by Day of Week

Driving by Day of Week

- **FCEV**
- **NHTS\(^1\)**

177,428 Trips

% of Trips in a Day

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

1. 2006 NHTS Data Includes Car, Truck, Van, & SUV day trips

CDP-FCEV-126: Average Trip Speed

Histogram of Average Trip Speed

1) Excludes trips <= 1 mile (10.0%)
2) 2009 NHTS data includes Car, Truck, Van & SUV day trips

Average trip speed 27.1 mph

157,170 trips
CDP-FCEV-108: Vehicle Fill Amounts

Hydrogen Fill Amount$^{1,2}$

Average Fill Amount = 1.5 kg
Total Number of Fills = 18,568

1. Data comes from fcev onboard sensors, includes fills from 2012 to 2018
2. Tanks range from 3.8 to 6.3 kg
CDP-FCEV-114: Average Vehicle Fuel Economy

Average On-Road Vehicle Fuel Economy

- Min: 34
- Median: 51.1
- Max: 57.5

Average EPA adjusted fuel economy for comparable gasoline car:
- Model year 2004 = 22.8 mpg
- Model year 2008 = 24.5 mpg
- Model year 2013 = 27.6 mpg

1. Calculated from on-road fuel cell stack current.
2. Excludes trips < 1 mile.
3. EPA Combined Rating.
4. 1 kg of hydrogen has the same energy content as 1 gallon (3.2 kg) of gasoline.
CDP-FCEV-141: Effect of Average Trip Speed on Fuel Economy

Effect of Average Trip Speed on Fuel Economy

3.3% of trips had an average speed of 55 mph or more

1. Data binned every 5 mph for calculating median and percentiles.
CDP-FCEV-144: Average On-Road Fuel Economy by Vehicle Odometer
CDP-FCEV-169: GHG Emissions by Fuel Economy

Well-to-Wheels CO₂ and GHG Emissions¹ by FCEV On-road Fuel Economy²

2. See CDP-FCEV-114: Calculated from on-road fuel cell stack current. Excludes trips < 1 mile.
3. On Road fleet average FE plus/minus one standard deviation Min 42.7 miles/k and Max 56.1 miles/kg; 1 kg of hydrogen has the same energy content as 1 gallon (3.2 kg) of gasoline.
4. Greenhouse Gas includes CO₂ and the CO₂ equivalent global warming potential of CH₄, N₂O, VOC, CO, NOₓ, Black Carbon, and Organic Carbon
5. Median FCEV EPA Combined Rating 52.9 miles/kg
6. GREET Baseline FE for Model Year 2015, gasoline passenger car 26.8 mpg and gasoline light duty truck 1.26.8 mpg.

Scenario Description:
A. FCEV - Central SMR Liquid H₂
B. FCEV - Central SMR Gaseous H₂
C. FCEV - Onsite Renewable Electrolysis H₂
D. FCEV - Onsite 33% Renewable Electrolysis H₂
E. FCEV - Onsite CA Grid Mix Electrolysis H₂
Fueling Behavior
CDP-FCEV-106: Average Calendar Days Between Refueling per Vehicle

Calendar Days Between Refueling

% of Fills with > 100 miles traveled between fills

75%  68.6%  68.6%  67.5%  68.8%  67.7%  69.9%

Days between fills

1  2  3  4  5  6  7

3.6% fills more than 14 days apart.

1. Data includes fills from 2012 - 2017. Fills < 1 hour apart are excluded.

2. Some vehicles included in the data have scheduled driving aimed at accumulating high miles and operation time over a variety of conditions. These vehicles typically fill at least once a day. These vehicles are operated on public roads and driving is typical for the region.
CDP-FCEV-116: Refueling by Time of Day

Refueling by Time of Day

Total Fill Events\(^1\) = 18,568

1. Some events not recorded/detected due to data noise or incompleteness.
2. UTC adjusted to local time using meridian-based adjustments and does not account for statutory deviations from the meridian-based system.
CDP-FCEV-117: Refueling by Day of Week

Refueling by Day of Week

- FCEV Fills
- Sample Gasoline Station Profile

18,568 Fills

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

% of Fills in a Day

CDP-FCEV-146: Vehicle Tank Temperatures versus Ambient Temperatures

Vehicle Tank Temperatures: Before Fill versus Ambient Fill Events

- 88.2% of fills started with the ambient temperature greater than the incoming hydrogen temperature.
- 18,038 fills.
CDP-FCEV-149: Fill Pressure and Temperatures Compared with SAEJ2601 Limits

Fill Pressures and Temperatures Compared to SAE J2601 Limits

- Overpressure (P > 87.5 MPa)
- SOC > 100%
  (density > 40.2 g/L)
- H70 SOC = 100%
  (density = 40.2 g/L)
- H35 SOC = 100%
  (density = 24.0 g/L)

Total number of fills = 18,568
Hydrogen Performance
CDP-FCEV-129: Vehicle Tank Temperatures: Before and After a Fill
CDP-FCEV-130: Vehicle Tank Temperatures and Pressures after Fill Events

Vehicle Tank Temperature and Pressures after Fill Events

Temperature After Fill (°C) vs. Pressure After Fill (MPa)

- Maximum Pressure Limit
- Maximum Temperature Limit

1. SAEJ2601 Limit

18,568 Fills

Number of Fill Events

0 500 1000 1500 2000

NREL | 29
Thank you