Sustainable Transportation Vision

NREL RD&D accelerates the process of bringing sustainable transportation technologies to the market with the ultimate goals of:

- Reduction of greenhouse gas emissions in the transportation sector to meet a 2050 goal of 80% below 2005 levels
- Diversification of transportation energy sources to reduce petroleum consumption and promote U.S. energy security

Figure by NREL
Why Hydrogen Fuel Cell Electric Vehicles

Hydrogen FCEVs are clean, efficient, refuel quickly, and provide long driving range

Challenges include hydrogen infrastructure cost and reliability, fuel cell durability and reliability
The Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) Project

Ensure that FCEV customers have a positive fueling experience relative to conventional gasoline/diesel stations as vehicles are introduced (2015–2017), and transition to advanced refueling technology beyond 2017.

1. Reduce the installation cost of a hydrogen fueling station to be competitive with conventional liquid fuel.
2. Improve the availability, reliability, and cost while ensuring the safety of high-pressure components.
3. Focus a flexible and responsive set of technical experts and facilities to help solve today’s urgent challenges and the future unpredicted needs.
4. Enable distributed generation of renewable hydrogen in a broader energy ecosystem.
Hydrogen and Fuel Cell Technology Validation at NREL

Confirmation of component and system technical targets in real-world settings

Evaluation, optimization, and demonstration in integrated energy systems
**Key Analysis Topics**

<table>
<thead>
<tr>
<th>Critical</th>
<th>Important</th>
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<tbody>
<tr>
<td>• Fuel cell durability</td>
<td>• Drive behaviors</td>
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<tr>
<td>• Vehicle operation (hours, miles)</td>
<td>• Fill behaviors</td>
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<tr>
<td>• Specs (power density, specific power)</td>
<td>• Power management</td>
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<tr>
<td>• Range, fuel economy, and efficiency</td>
<td>• Energy</td>
</tr>
<tr>
<td>• Fill performance</td>
<td>• Transients</td>
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<tr>
<td>• Reliability</td>
<td>• Comparisons to conventional vehicles</td>
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These key topics were selected based on review of past composite data products, targets, most commonly referenced topics, and DOE feedback.
FCEV Technology Validation Phases

FCEV Evaluation Phases

LD1 | LD2 | LD2+ | LD3

Number of Participating OEMs

LD3 Evaluation Trip Count

1) Not all fleets in operation in 2015 and only includes trips through June 2015.
FCEV Technology Validation Phases

Vehicle Count

Cumulative Miles

Total Vehicle Count = 222

Total Miles = 6,157,016


FCEV Data Partners and Vehicles

Six Data Providers

Range of FCEV Model Years

1DOE project overview:
- $5.5 million DOE funding
- Data to be collected from up to ~90 vehicles

2Project managed by Electricore
Award completed
NFCTEC Analysis and Reporting of Real-World Operation Data

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

**Detailed Data Products (DDPs)**
- Individual data analyses
- Identify individual contribution to CDPs
- Shared every six months only with the partner who supplied the data

www.nrel.gov/hydrogen/proj_tech_validation.html
Data Templates and Tools

Templates enable collection of similar data from all the projects.
FCEV Deployment and Operation Summary in Evaluation Project through 2015CYQ2

55 FCEVs

50 Average on-road fuel economy miles/kg

4,100 Max fleet voltage durability (hours to 10% degradation metric)

22 FCEVs retired

> 2,890,000 miles traveled

> 178,000 Max FCEV odometer miles

> 95,700 Fuel cell operation hours

5,600 Max fuel cell operation hours
FCEV Operation Hours and Durability

FCEV operation hours and durability projections to 10% voltage degradation. Each fleet has a max and average fuel cell operation hours value and a weighted average hours to 10% voltage degradation.

1) Range bars created using one data point for each fleet. Some stacks have accumulated hours beyond 10% voltage degradation.
2) Voltage degradation is measured based on a projected time to a voltage drop, at a high current, level 10% lower than beginning of life voltage. 10% voltage drop level is a DOE metric for assessing fuel cell durability.
3) Projections using on-road data are calculated at approximately 55 - 65% rated stack current.
4) 10% voltage drop is NOT an indication of an OEM's end-of-life criteria and projections do not address catastrophic stack failure.
5) Each fleet has one voltage projection value that is the weighted average of the fleet's fuel cell stack projections.
FCEV Durability Trend

Comparison of Fuel Cell Operation Hours and Durability

- Max Op Hours
- Max Fleet Ave Durability$^{1,2,3}$
- Ave Fleet Ave Durability$^{1,2,3}$

1. Durability based on voltage degradation to 10% lower than beginning of life voltage. 10% voltage drop level is a DOE metric for assessing fuel cell durability.
2. Projections using on-road data are calculated at approximately 55 - 65% rated stack current.
3. 10% voltage drop is NOT an indication of an OEM's end-of-life criteria and projections do not address catastrophic stack failure.
4. Percent increases are calculated relative to LD1 (2006-2007).
5. Maximum operational hours not reported in LD2+ (2010-2011).

FCEV voltage durability has continually improved over time.

Included Vehicles: Partial

- NREL cdp_fcev_31
  Created: Oct-31-15 12:51 PM | Data Through: 2015Q2

169% increase$^4$

129% increase$^4$
All fuel cell stacks with operation hours greater than 3,000 have more than 10% voltage degradation.
Fuel cell efficiency shown for stack and average (stack and balance of plant) of the fleets. Efficiency close to DOE 2020 target at 25% rated power.
The median on-road vehicle fuel economy is ~50 miles per kg, nearly twice the 2013 EPA adjusted fuel economy for gasoline.
The on-road fuel economy has consistently increased over the last 10 years.
High mileage and low mileage vehicles have similar on-road fuel economy averages.
Accomplishment: Driving Distance between between Refuelings

The median distance between refuelings is 122 miles. Distance is based on actual driving and not the full vehicle range.
Average On-Road Range per FCEV

Wide range of min and max window sticker range 200–320 miles, includes different vehicle platforms and generations.
Fueling Pressures and Temperatures

All fills analyzed (>14,800) have followed the SAE J2601 guidelines for on-board tank pressure and temperature after fill.
The tank temperature is typically 10°C to 20°C (approximately ambient) before a fill and 40°C to 65°C after a fill. The tank temperature after a fill has not exceeded 85°C.
Steady progress has been demonstrated over the four evaluation periods with FCEV technology improvements especially in key technical areas like fuel cell durability, range, and fuel economy.
Future Work

• Regular analysis (once a quarter) and published results twice a year (as data is available)

• Future analysis topics include:
  o Validation of technical targets for durability, fuel economy, range, reliability and safety, transient performance, power management and specifications, and refueling performance
  o Relationship between FCEVs and new stations coming online
  o Impacts of hydrogen demand increasing over time
  o Identify technology gaps and needs based on the on-road performance data
  o Define technology validation efforts as more and more FCEVs are commercial

• Other research areas
  o Infrastructure
  o Fleet operation, education, and outreach
  o Renewable hydrogen
  o Safety, codes, and standards
Learn more at
www.nrel.gov/transportation
and
www.nrel.gov/hydrogen/
proj_tech_validation