Fuel Cell Electric Vehicle Evaluation

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This presentation does not contain any proprietary, confidential, or otherwise restricted information.
Overview

Timeline and Budget

• Project start date: 10/2012*
• Total DOE funds received to date: $1,265k
• FY14 DOE funding: $415k
• FY15 planned DOE funding: $365k

Barriers

• Lack of current controlled and on-road hydrogen fuel cell vehicle data

Partners

• Project partners supplying data include:
  – Daimler  –  Hyundai
  – GM  –  Nissan
  – Honda  –  Toyota

*Project continuation determined annually by DOE
Project Objectives, Relevance, and Targets:
Fuel Cell Electric Vehicle Evaluation

• Objectives
  o Validate hydrogen fuel cell electric vehicles (FCEV) in real-world setting
  o Identify current status and evolution of the technology

• Relevance
  o Objectively assess progress toward targets and market needs
  o Provide feedback to hydrogen research and development
  o Publish results for key stakeholder use and investment decisions

FY15 Objectives
Analysis and reporting on FCEV durability, fuel economy, range, vehicle specifications, and driving.
Approach: NFCTEC Analysis and Reporting of Real-World Operation 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

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

www.nrel.gov/hydrogen/proj_tech_validation.html
Approach: FCEVs

Six Data Providers

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

2Project managed by Electricore
Approach: Milestones

Regular project activities include:

Quarterly analysis
Bi-annual technical CDPs
Detailed data and analysis reviews with project partners
Publishing and presenting results
Collaborating with infrastructure evaluation
Accomplishment: 32 FCEV CDPs—Count and Category

<table>
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<th>Specifications (#11, 12, 13)</th>
<th>Fuel Cell Durability (# 21, 22, 23, 31)</th>
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<td>H2 Performance (# 25, 28, 29, 30)</td>
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Data included through 12/2014

Results are not all presented here but are available online at www.nrel.gov/hydrogen/proj_tech_validation.html
Accomplishment: FCEV Deployment and Operation Summary through 2014CYQ4

- **48** FCEVs
- **51** Average on-road fuel economy miles/kg
- **3,930** Average fleet voltage durability (Hours to 10% degradation metric)

- **20** FCEVs retired
- **> 2,400,000** miles traveled
- **> 178,000** Max FCEV odometer miles

- **> 79,000** Fuel cell operation hours
- **5,600** Max fuel cell operation hours
Accomplishment: FCEV Durability Trend

FCEV voltage durability has continually improved over time.

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The median on-road vehicle fuel economy is ~51 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.
Accomplishment: Driving Distance between Refuelings

The median distance between refuelings is 119 miles. Distance is based on actual driving and not the full vehicle range.
Accomplishment: Fueling

The average time spent at station is 10 minutes. The average fill time (gas flowing) from the station data is 5.6 minutes. The remaining time at the station is for connection, point-of-sale, and other (CDP-FCEV-09).

The median tank level at fill is 29% and the majority of fills are between 1 and 2 kg, per vehicle data (CDP-FCEV-08).
Accomplishment: On-Board Hydrogen Tank Pressures

There are 350 bar and 700 bar fills, with the average final pressure onboard at 344 and 713 bar.

*The line at 450 bar separates 350 bar fills from 700 bar fills. It is slightly over the allowable 125% of nominal pressure (437.5 bar) from SAE J2601.*
The tank temperature is typically 10° to 30°C (approximately ambient) before a fill and 45° 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.
Accomplishments and Progress: Responses to Previous Year Reviewers’ Comments

• This project was not reviewed last year.
Collaborations

• Six participating OEMs – Daimler, GM, Honda, Hyundai, Nissan, Toyota. These OEMs:
  - Supply data
  - Review detailed data analysis and approve published results
  - Review current and future analysis topics.

• Industry working groups (CaFCP, H2USA, and FCHEA)
  - Participation and briefings

Detailed view of a typical data cycle with OEMs
Remaining Challenges and Barriers

• **Validation of technical targets**
  - Durability
  - Fuel economy
  - Range
  - Efficiency
  - Reliability & Safety
  - Power specifications
  - Refueling performance

• **Relationship between FCEV and new stations coming online**

• **Impacts of hydrogen demand increasing over time**
Proposed Future Work

• **Fall 2015**
  - Complete quarterly analysis of CY15 Q1 and Q2 data
  - Publish analysis results (10/2015)

• **Spring 2016**
  - Complete quarterly analysis of CY15 Q3 and Q4 data
  - Publish analysis results (4/2016)

• **Identify new opportunities to document fuel cell and hydrogen progress publicly**

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

• **Relevance**
  - Independent validation of FCEV on-road performance against DOE and industry targets

• **Approach**
  - Collaborate with industry partners
  - Continue to develop core NFCTEC and analysis capability and tools
  - Leverage 7+ years of analysis and experience from the Learning Demonstration

• **Technical Accomplishments and Progress**
  - Analyzed data from six OEMs
  - Performed detailed reviews of individual OEM data results
  - Published results via 32 CDPs that cover topics such as deployment, fuel cell performance, durability, fuel economy, range, and driving.

• **Collaborations**
  - Working closely with industry partners to validate methodology and with other key stakeholders to ensure relevance and accuracy of results

• **Future Work**
  - Analyze on-road FCEVs and publish updated results in Fall 2015, and add new analysis topics
  - Identify new opportunities to document fuel cell and hydrogen progress publicly
  - Identify technology gaps
Technical Back-Up Slides
### Key Analysis Topics

#### Critical
- Fuel cell durability
- Vehicle operation (hours, miles)
- Specs (power density, specific power)
- Range, fuel economy, and efficiency
- Fill performance
- Reliability

#### Important
- Drive behaviors
- Fill behaviors
- Power management
- Energy
- Transients
- Comparisons to conventional vehicles

These key topics were selected based on review of past CDPs, targets, most commonly referenced topics, and DOE feedback.
FCEV operation hours and durability projections to 10% voltage degradation. Each fleet has a max and average FC operation hours value and a weighted average hours to 10% voltage degradation.
On-Road Data Processing

More than 120,000 trips and 11 GB data analyzed

Total Operation Hours = 79,468
Max FC Stack Operation Hours = 5,605
Critical Assumptions and Issues

• **Relationship between vehicle and station**
  - We are working on ways to fully understand the vehicle and station performance by studying refueling from both the vehicle and station perspective. We want to confirm performance gaps with increased hydrogen demand and new stations.

• **Availability of on-road vehicle data**
  - Vehicle OEMs are at different stages of technology generations and deployments. This can create an issue with regular data delivery and analysis.
  - We are working with vehicle OEMs to understand data availability and incorporating that into what analysis topics can be published.

• **Legacy data**
  - Supplied on-road data includes current operation, as well as legacy data if it wasn’t already supplied in the Learning Demonstration project. This can create a challenge with publication of trends over time.
  - We are not able to publish all of the trend data if only one OEM has supplied data during a time period. We are also looking into ways to identify data categories based on either durability vehicles or customer vehicles.
Publications and Presentations

