Controlled Hydrogen Fleet and Infrastructure Analysis

2009 U.S. DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting

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May 20, 2009 Washington, DC

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

- Validate H₂ FC Vehicles and Infrastructure in Parallel
- Identify Current Status and Evolution of the Technology

### Relevance

- Objectively Assess Progress Toward Technology Readiness
- Provide Feedback to H₂ Research and Development

### Key Targets

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>2009</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell Stack Durability</td>
<td>2000 hours</td>
<td>5000 hours</td>
</tr>
<tr>
<td>Vehicle Range</td>
<td>250+ miles</td>
<td>300+ miles</td>
</tr>
<tr>
<td>Hydrogen Cost at Station</td>
<td>$3/gge</td>
<td>$2-3/gge</td>
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![Solar Electrolysis Station, Sacramento, CA](Photo: NREL)
Project Overview

Timeline
- Project start: FY03
- Project end: FY10
- ~80% of Task III complete (see timeline slide)

Tech. Val. Barriers
A. **Vehicles** – lack of controlled & on-road H₂ vehicle and FC system data
B. **Storage** – technology does not yet provide necessary 300+ mile range
C. **Hydrogen Refueling Infrastructure** – cost and availability
D. **Maintenance and Training Facilities** – lack of facilities and trained personnel
E. **Codes and Standards** – lack of adoption/validation
H. **Hydrogen Production from Renewables** – need for cost, durability, efficiency data for vehicular application
I. **H₂ and Electricity Co-Production** – cost and durability

Budget
- Context: Overall DOE project is ~$170M over 5 years
  - Equal investment by industry
- NREL funding prior to FY08: $3042K
- NREL FY08 funding: $900K
- NREL FY09 funding: $700K

Partners
- See partner slide
### Project Timeline and Major Milestones

**Task I – Project Preparation [100% Complete]**
1. Support development of RFP, statement of objectives (Appendix C)
2. Bidder’s meeting in Detroit – launch of RFP
3. Create data analysis plan and presentation for discussion with industry

**Task II – Project Launch [100% Complete]**
4. Announcement of successful bidders (4/04)
5. Kick-off meetings and cooperative agreement awards

**Task III – Data Analysis and Feedback to R&D activities (partial list) [80% Complete]**
6. Preliminary data collection, analysis, and first quarterly assessment report
7. Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles
8. Publication of first “composite data products”
9. Evaluate FC stack time to 10% voltage degradation relative to 1000-hour target
10. Decision for purchase of additional vehicles based on performance, durability, cost
11. Preliminary evaluation of dominant real-world factors influencing FC degradation
12. Introduction of 2nd generation FC systems into vehicles begins
13. FCVs demonstrate 250-mile range without impacting passenger cargo compartment
14. Validate FCVs with 2,000 hour durability and $3.00/gge (based on volume production)
15. Decision to proceed with Phase 2 of the Learning Demonstration

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<thead>
<tr>
<th>FY03</th>
<th>FY04</th>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
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<tr>
<td>Task I</td>
<td>Task II</td>
<td>Task III</td>
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<td>8</td>
</tr>
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</table>

- NREL Monthly/Quarterly Analysis of Data: 5/07
- 5/04
- 5/05
- 5/06
- 5/07
- 6/08
- 5/09
Industry Partners: 4 Automaker/Energy-Supplier Teams; Gen 2 Fleet Is Now Fully Deployed, Some Vehicles Retired

Gen 1 & 2

21 vehicles retired
119 still on road

Vehicle Deployment by On-Board Hydrogen Storage Type

- 700 bar on-road
- 350 bar on-road
- Liquid H2 on-road
- 700 bar retired
- 350 bar retired
- Liquid H2 retired

*Retired vehicles have left DOE fleet and are no longer providing data to NREL*
DOE Learning Demo Fleet Has Surpassed 85,000 Vehicle Hours and 1.9 Million Miles

- Total Vehicle Hours = 85,244
- Total Vehicle Miles Traveled = 1,924,869

Gen 2 vehicles make up most of 2nd bulge at low hours/miles

Some Gen 1 vehicles have now been retired (red bars)
Majority of Project’s Fixed Infrastructure to Refuel Vehicles Has Been Installed – Examples of 4 Types

- **Mobile Refueler**
  - Sacramento, CA

- **Delivered Liquid, 700 bar**
  - Irvine, CA

- **Steam Methane Reforming**
  - Oakland, CA

- **Water Electrolysis**
  - Santa Monica, CA

- **Total of 90,000 kg H₂ produced or dispensed**

- **Stations added since June 2008**:
  - Burbank, Long Beach, Ardsley, LAX-east
  - 20 stations now deployed through Dec.

**Infrastructure Hydrogen Production Methods**

- Delivered Compressed H₂
- Natural Gas On-site Reforming
- Electrolysis
- Delivered Liquid H₂

Production Technology

- Existing Stations
- Retired Stations

**Online Stations**

- Number of Stations
- Reporting Period

- 20 stations
Refueling Stations Test Performance in Various Climates; Learning Demo Stations Comprise ~1/3 of all U.S. Stations

Legend
- Chevron & Hyundai/Kia
- DaimlerChrysler & BP
- Ford & BP
- General Motors & Shell
- Air Products
- Other Companies

SF Bay Area
- 5

Detroit Area
- 7

Los Angeles Area
- 17

DC to New York
- 5

Orlando Area
- 2
Distribution of Average Ambient Temperature During Vehicle Operation

Expanded analysis of data shows normal distribution around 20°C

- 1.1% trips below 0°C
- 29.6% trips above 28°C
- Max Op = 140°F
- Min Op = -2.2°F
Project Approach

• Provide facility and staff for securing and analyzing industry sensitive data
  – NREL Hydrogen Secure Data Center (HSDC)
• Perform analysis and simulation using detailed data in HSDC to:
  – Evaluate current status and progress toward targets
  – Feed back current technical challenges and opportunities into DOE H₂ R&D program
  – Provide analytical results to originating companies on their own data (detailed data products)
  – Collaborate with industry partners on new and more detailed analyses
• Publish/present progress of project to public and stakeholders (composite data products)
Approach: Providing Data Analysis and Results for Both the Public and the Industry Project Teams

Hydrogen Secure Data Center (HSDC)

- Located at NREL: Strictly Controlled Access
- Detailed Analyses, Data Products, Internal Reports

Composite Data Products
- Aggregate data results for public
- No confidential information


Detailed Data Products
- Only shared with company/team that originated the data
- DDPs now provided at time of CDP review
Accomplishment: 15 Quarters of Data Analyzed to Date, Two New Sets of Composite Data Products Published

Through March 2009:
- 346,000 individual vehicle trips
- 76 GB of on-road data

Cumulative On-Road Data Received for Learning Demonstration

CDP = Composite Data Products Published
Accomplishment: Expanded NREL’s Data Analysis Tool – Fleet Analysis Toolkit (FAT)
Accomplishment: Successfully Communicating Results, Papers, and Presentations Available to Public through Web Site

- Spike in activity after NHA conference
- Sustained activity Over the last year at ~100 visitors/month

Top 5 CDPs viewed
- Vehicle Range
- Vehicle Fuel Economy
- H₂ Production Method
- Vehicle Safety
- # of Refueling Stations

Report downloaded 2607 times (11th most popular on NREL’s H₂ web site)

Visitor Summary
- Visitors: 1,462
- Visitors Who Visited Once: 1,266
- Visitors Who Visited More Than Once: 196
- Average Visits per Visitor: 1.68

Accomplishment: 60 Public Composite Data Products Have Been Published; New Results and Updates Every 6 Months

Results presented at: FC Seminar, ECS, ASME FC, NHA, SAE, EVS

A subset of the 60 latest results follow
Ranges of Fuel Economy from Dynamometer and On-Road Data Similar for Gen 1 & 2

(1) One data point for each make/model. Combined City/Hwy fuel economy per DRAFT SAE J2572.
(2) Adjusted combined City/Hwy fuel economy (0.78 x Hwy, 0.9 x City).
(3) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.
(4) Calculated from on-road fuel cell stack current or mass flow readings.
Driving Range for Gen 1 and Gen 2 Vehicles: Based on Fuel Economy and Usable H₂

Vehicle Range

(1) Range is based on fuel economy and usable hydrogen on-board the vehicle. One data point for each make/model.
(2) Fuel economy from unadjusted combined City/Hwy per DRAFT SAE J2572.
(3) Fuel economy from EPA Adjusted combined City/Hwy (0.78 x Hwy, 0.9 x City).
(4) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.
(5) Fuel economy calculated from on-road fuel cell stack current or mass flow readings.

250-mile 2008 milestone met

Gen 2 Vehicle Range Shows Significant Improvement from 700 bar Storage

Note: All Learning Demo Vehicles Based on Existing Platforms

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Spread of On-Road Range from Four Teams as a Percentage of Dyno Range

Significant variability in on-road fuel economy vs. dyno fuel economy: Gen 1 vs. Gen 2, between companies.

1. Calculated using the combined City/Hwy fuel economy from dyno testing (non-adjusted) and usable fuel on board.
2. Applying window-sticker correction factors for fuel economy: 0.78 x Hwy and 0.9 x City.
3. Using fuel economy from on-road data (excluding trips > 1 mile, consistent with other data products).
Majority (80%) of Vehicles Travel <1/2 of Dyno Range Between Refuelings

Percentage of chassis dyno range \(^1\) b/w refuelings

Contributing factors:
- Fear of running out of H\(_2\)
- Limited H\(_2\) Infrastructure
- On-Road Fuel Economy

1. Range calculated using the combined City/Hwy fuel economy from dyno testing (not EPA adjusted) and usable fuel on board.
2. Some refueling events are not detected/reported due to data noise or incompleteness.

Total refuelings\(^2\) = 18799

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Large Spread in H₂ Tank Level at Refueling Peak at ~1/4 Full, Median at ~3/8 Full

Median Tank Level (At Fill) = 40%

Total refuelings¹ = 20639

1. Some refueling events not recorded/detected due to data noise or incompleteness.
2. The outer arc is set at 20% total refuelings.
3. If tank level at fill was not available, a complete fill up was assumed.

¹ Some refueling events not recorded/detected due to data noise or incompleteness.
Improved Approach for Calculating Projected Time to 10% Voltage Drop for Stack and Fleet

1. **FC Stack** voltage & current polarization fit
2. **FC Stack** voltage decay estimate using robust, improved **segmented linear fit** instead of linear fit (follows non-linear decay trends & early voltage decay)
3. **Fleet** weighted average using FC Stack operating hour projections and weights (based on data and confidence in fit)

Note, 10% voltage drop is a DOE target/metric, not an indicator of end-of-life
Gen 1 Stack Operating Hours and Projected Time to 10% Voltage Drop

DOE Learning Demonstration Fuel Cell Stack Durability:
Based on Data Through 2008 Q4

- Actual Operating Hours Accumulated To-Date
- Projected Hours to 10% Degradation

(1) Range bars created using one data point for each OEM. Some stacks have accumulated hours beyond 10% voltage degradation.
(2) Range (highest and lowest) of the maximum operating hours accumulated to-date of any OEM's individual stack in "real-world" operation.
(3) Range (highest and lowest) of the average operating hours accumulated to-date of all stacks in each OEM's fleet.
(4) Projection using on-road data -- degradation calculated at high stack current. This criterion is used for assessing progress against DOE targets, may differ from OEM's end-of-life criterion, and does not address "catastrophic" failure modes, such as membrane failure.
(5) Using one nominal projection per OEM. "Max Projection" = highest nominal projection, "Avg Projection" = average nominal projection.
(6) Projection method was modified beginning with 2008 Q2 data.

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More data required to make Gen 2 projections (late 2009)
Most of FC *Time* is Spent at Idle, Bulk of *Energy* is at 20-50% Power

~50% time at <5% FC power

~1/2 of low power is At 0 vehicle speed
Stack Duty Cycle: Time Fuel Cell Spends at Various Voltage Levels Was Requested by FC Developers

Operating Time at Fuel Cell Stack Voltage Levels: DOE Fleet

- ~17% of time spent at <70% of max voltage
- ~ Open-circuit voltage (~15% time)
Fuel Cell Stack Trips Per Hour Histogram Provided to FC Durability Protocol Task Force

Segmented Trips/Hour Histogram: DOE Fleet

- ~4 trips (starts) per hour is a representative average from our fleet data

*Trips/Hour based on 50 hour segments spanning stack operating period

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Average Trips/Hour as a Function of Stack Operating Hour

Statistics of Trips/Hour vs Operating Hour: DOE Fleet

- Data Range
- 25th & 75th Percentiles
- Group Median
- Outlier

Stacks that have demonstrated long hours show lower average trips/hour

*Trips/Hour based on 50 hour segments spanning stack operating period

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Comparison of FC System Specific Power and Power Density Between Gen 1 to Gen 2

Significant Improvements Seen in Specific Power (…systems getting lighter)

Freeze Capability of Gen 2 Systems May Have Increased Volume

Power Density Did Not Improve Between Gen 1 and Gen 2 (…same size or larger)
Energy Flow Through Major FCV Powertrain Components by Percentage of Trips

Chart showing the energy consumption and frequency of trips for different energy levels. The chart indicates:

- ~1/3 trips use <0.5 kWh of energy from FC
- Charge-sustaining hybridization shows 80% of net trip battery energy is within +/- 0.5 kWh

Legend:
- Battery
- Vehicle Motor
- FC

Energy Consumed [kWh]

Trip Frequency [%]
New Analysis of Vehicle Maintenance Data Highlights Areas for Improvement

Fuel Cell Vehicle Maintenance Events and Labor Hours

Fuel Cell Vehicle Events (9357)
- Vehicle (non-powertrain): 5%
- Fuel Cell System: 34%
- Powertrain: 5%
- Battery: 4%

Fuel Cell System Events (3175)
- Thermal Management: 11%
- Air System: 11%
- Controls, Electronics, Sensors: 14%
- Fuel System: 26%
- Fuel Cell Stack: 36%
- Other: 3%

Fuel Cell Vehicle Labor (10216 hours)
- Vehicle (non-powertrain): 22%
- Fuel Cell System: 57%
- Powertrain: 5%
- Battery: 4%

Fuel Cell System Labor (5035 hours)
- Fuel Cell Stack: 31%
- Air System: 13%
- Controls, Electronics, Sensors: 24%
- Fuel System: 12%
- Other: 20%

Non-powertrain responsible for >1/2 maintenance events
FC system responsible for 1/3 of maintenance events, which take 1/2 the time
Within FC system, stack is only the 5th most (11%) frequent maintenance, but responsible for 1/3 of repair time
Minimal Vehicle Safety Reports Continue to Demonstrate a Strong Vehicle Safety Record

Safety Reports - Vehicle Operation

- Tank Scratch
- Traffic Accident
- H2 Leak - During Fueling
- H2 Alarm - Fuel System
- H2 Alarm - Passenger Compartment

4 traffic accidents without H₂ incident

NREL enters H₂ reports of interest into H2incidents.org (with associated company permission)

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Overall Infrastructure Reports Correlated with Increase in New Stations Coming Online

Type of Infrastructure Safety Reports by Quarter Through 2008 Q4

- **Incident**: An event that results in:
  - a lost time accident and/or injury to personnel
  - damage/unplanned downtime for project equipment, facilities or property
  - impact to the public or environment
  - any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
  - release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)

- **Near Miss**: An event that under slightly different circumstances could have become an incident

- **Non-Event**: Unplanned H2 release insufficient to sustain a flame

- **Stations Online**

- **Avg # Reports/Station**

Created: Feb-27-09 8:18 AM
Most of Infrastructure Safety Reports Continue to Be Non-Events (and Most of Those, Alarms Only)

An INCIDENT is an event that results in:
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
- release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)

A NEAR-MISS is:
- an event that under slightly different circumstances could have become an incident
- unplanned H2 release insufficient to sustain a flame

Note: All “incidents” are reported to H2incidents.org (with associated company permission)
New Hydrogen Quality Results Show that the Overall Quality Index Met the Target for Last 2 Years

H₂ Calculated Quality Index by Year and Production Method

Results presented to USFCC H₂ quality working group on regular basis

All quality and impurity results now detailed by year and production technology

Calculated H₂ Index (%)

Data is from Learning Demonstration and California Fuel Cell Partnership testing
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:17 PM
Hydrogen Constituents by Year and Production Method – Example of Sulfur

There are 18 individual constituents analyzed, with a separate graph (like this one) for each.

Data is from Learning Demonstration and California Fuel Cell Partnership testing.
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4.

*Total S calculated from SO2, COS, H2S, CS2, and Methyl Mercaptan (CH3SH).
Hydrogen Fueling Station Maintenance by System Shows ~Equal Responsibility of Major Components

By Number of Events
Total Number of Events = 1860

- 22% system control & safety
- 17% compressor
- 16% electrolyzer
- 14% reformer
- 11% dispenser
- 10% valves & piping
- 9% storage
- 9% other

By Labor Hours
Total Hours = 9093

- 22% system control & safety
- 19% compressor
- 17% electrolyzer
- 11% reformer
- 10% dispenser
- 9% valves & piping
- 7% storage
- 6% other

Note that “system control and safety” cause more issues than the production components
Actual Vehicle Refueling *Rates* from 16,000 Events: Measured by Stations or by Vehicles

**Histogram of Fueling Rates**
All Light Duty Through 2008Q4

- Average rate = 0.78 kg/min
- 24% of refueling events exceeded 1 kg/min

- 5 minute fill of 5 kg at 350 bar
- 3 minute fill of 5 kg at 350 bar
Refueling Rates by Year: Highest Number of Fills in 2008; ~1/4 Now Exceed 1 kg/min

Histogram of Fueling Rates
All Light Duty by Year Through 2008Q4

<table>
<thead>
<tr>
<th>Year</th>
<th>Avg (kg/min)</th>
<th>%&gt;1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>0.66</td>
<td>16%</td>
</tr>
<tr>
<td>2006</td>
<td>0.74</td>
<td>21%</td>
</tr>
<tr>
<td>2007</td>
<td>0.81</td>
<td>26%</td>
</tr>
<tr>
<td>2008</td>
<td>0.78</td>
<td>24%</td>
</tr>
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Comparison by Year

5 minute fill of 5 kg at 350 bar

3 minute fill of 5 kg at 350 bar

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Communication H₂ Fills Achieving 35% Higher Average Fill Rate than Non-Communication

Histogram of Fueling Rates
Comm vs Non-Comm Fills - All Light Duty Through 2008Q4

<table>
<thead>
<tr>
<th>Fill Type</th>
<th>Avg (kg/min)</th>
<th>% &gt; 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comm</td>
<td>0.88</td>
<td>32%</td>
</tr>
<tr>
<td>Non-Comm</td>
<td>0.65</td>
<td>15%</td>
</tr>
</tbody>
</table>

5 minute fill of 5 kg at 350 bar
3 minute fill of 5 kg at 350 bar
Comm Fills Can Achieve Higher Fill Rates
Comm.
Non-Comm.
Non-Comm Has a 2nd Peak at ~0.2 kg/min

Created: Feb-25-09 4:26 PM
Comparison of Fueling Rates for 350 and 700 bar Pressure Fueling Events

Histogram of Fueling Rates
350 vs 700bar Fills - All Light Duty Through 2008Q4

<table>
<thead>
<tr>
<th>Fill Type</th>
<th>Avg (kg/min)</th>
<th>%&gt;1</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>350 bar</td>
<td>0.81</td>
<td>27%</td>
<td>14375</td>
</tr>
<tr>
<td>700 bar</td>
<td>0.59</td>
<td>3%</td>
<td>2033</td>
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</tbody>
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Comparison by Pressure

700 bar fills are currently 27% slower than 350 bar fills

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On-Site Production Efficiency from Natural Gas Reformation and Electrolysis Compared to Targets

Hydrogen Production Conversion Efficiency

1Production conversion efficiency is defined as the energy of the hydrogen out of the process (on an LHV basis) divided by the sum of the energy into the production process from the feedstock and all other energy as needed. Conversion efficiency does not include energy used for compression, storage, and dispensing.

2The efficiency probability distribution represents the range and likelihood of hydrogen production conversion efficiency based on monthly conversion efficiency data from the Learning Demonstration.
On-Site Hydrogen Production Efficiency vs. Capacity Utilization

Many Learning Demonstration Stations Currently Have Excess Capacity; Higher Utilization Helps Efficiency

1) 100% production utilization assumes operation 24 hrs a day, 7 days a week.
2) Production conversion efficiency is defined as the energy of the hydrogen out of the process (on a LHV basis) divided by the sum of the energy into the production process from the feedstock and all other energy as needed. Conversion efficiency does not include energy used for compression, storage, and dispensing.
3) High correlation with electrolysis data ($R^2 = 0.87$) & low correlation with natural gas data ($R^2 = 0.018$)

1. Well-to-Wheels greenhouse gas emissions based on DOE’s GREET model, version 1.8b. Analysis uses default GREET values except for FCV fuel economy, hydrogen production conversion efficiency, and electricity grid mix. Fuel economy values are the Gen 1 and Gen 2 window-sticker fuel economy data for all teams (as used in CDP #6); conversion efficiency values are the production efficiency data used in CDP #13.

2. Baseline conventional passenger car and light duty truck GHG emissions are determined by GREET 1.8b, based on the EPA window-sticker fuel economy of a conventional gasoline mid-size passenger car and mid-size SUV, respectively. The Learning Demonstration fleet includes both passenger cars and SUVs.

3. The Well-to-Wheels GHG probability distribution represents the range and likelihood of GHG emissions resulting from the hydrogen FCV fleet based on window-sticker fuel economy data and monthly conversion efficiency data from the Learning Demonstration.

4. On-site electrolysis GHG emissions are based on the average mix of electricity production used by the Learning Demonstration production sites, which includes both grid-based electricity and renewable on-site solar electricity. GHG emissions associated with on-site production of hydrogen from electrolysis are highly dependent on electricity source. GHG emissions from a 100% renewable electricity mix would be zero, as shown. If electricity were supplied from the U.S. average grid mix, average GHG emissions would be 1241 g/mile.
Other CDP Results Not Discussed Here Today
Highlights of Interactions and Collaborations in the Last Year

Auto/Energy Industry Partners
- Site visits with industry (at OEM site or NREL) to discuss detailed results and NREL methodology
- Focused on 2-way sharing of voltage degradation calculations and multivariate analyses
- Completed implementation for producing detailed data results and CDPs at same time for easier industry review

FreedomCAR and Fuel Technical Teams
- Fuel Cell (7/08, 4/09) and H₂ Storage (10/08, 4/09) Tech Teams

US Fuel Cell Council Technical Working Groups
- Transportation Working Group
- Joint H₂ Quality Task Force
- FC Durability Testing Protocol Working Group

California Organizations
- CaFCP: NREL now includes H₂ impurity test results in CDPs
- CARB: Agreement for data from new stations to be sent to NREL

Department of Defense (DLA)
- Leveraging experience to evaluate FC forklifts and backup power
Future Work

Remainder of FY09:

- Create new and updated composite data products (CDPs) based on data through June 2009 (Fall 2009 CDPs)
  - Prepare results for publication at 2009 Fuel Cell Seminar
- Key upcoming September 2009 DOE MYPP and Joule milestones on:
  - Hydrogen production cost from project compared to $3/gge target
  - Gen 2 stack voltage degradation time to 10% compared to target of 2000 hours
  - Gen 2 vehicle freeze capability and start-up energy requirements compared to targets
- Support OEMs, energy companies, and state organizations in California in coordinating early infrastructure plans

FY10:

- Continue to identify opportunities to feed findings from project back into VT/H₂ programs and industry R&D activities to maintain project as a “learning demonstration”
- Publish Spring 2010, Fall 2010 composite data products as the last anticipated results from the project
- Write final summary report for the project
Summary

• Learning Demo evaluation is ~80% complete
  – 140 vehicles and 20 stations deployed
  – 1.9 million miles traveled, 90,000 kg H₂ produced or dispensed
  – 346,000 individual vehicle trips analyzed
  – Project to continue through 2010

• Many new technical results since last AMR presentation
  – All but 2 updated since last AMR
  – 52 new/updated results since Fall 2008, 8 unchanged (total of 60)
    • H₂ production efficiency, compressor efficiency, vehicle GHG emissions
    • 350 vs. 700 bar refueling rates
    • Several new FC stack usage statistics
    • Time between trips & ambient temperature
    • H₂ fueling station maintenance by system
    • Fuel cell vehicle maintenance by system
  – All results available on web site

• Roll-out of 2nd generation vehicles is now complete

• Station deployment nearing completion
Questions and Discussion

Project Contact: Keith Wipke, National Renewable Energy Lab
303.275.4451 keith.wipke@nrel.gov

All public Learning Demo papers and presentations are available online at http://www.nrel.gov/hydrogen/proj_tech_validation.html