VII.12 Controlled Hydrogen Fleet and Infrastructure Analysis

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Start Date: October 2003
Projected End Date: September 2010

Objectives

- By 2008, validate that hydrogen vehicles have greater than a 250-mile range without impacting passenger or cargo compartments.
- By 2009, validate 2,000-hour fuel cell durability in vehicles and hydrogen infrastructure that results in a hydrogen production cost of less than $3.00/gge (untaxed) delivered, and safe and convenient refueling by drivers (with training).
- Assist DOE in demonstrating the use of fuel cell vehicles (FCVs) and hydrogen infrastructure under real-world conditions, using multiple sites, varying climates, and a variety of sources for hydrogen.
- Analyze detailed fuel cell and hydrogen data from vehicles and infrastructure to obtain maximum value for DOE and industry from this "learning demonstration."
- Identify the current status of the technology and its evolution over the project duration; generate composite data products (CDPs) for public dissemination.
- Provide feedback and recommendations to DOE to assist hydrogen and fuel cell research and development (R&D) activities and assess progress toward technology readiness.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section (3.6.4) of the Hydrogen, Fuel Cells & Infrastructure Technologies (HFCIT) Program Multi-Year Research, Development, and Demonstration Plan:

(A) Lack of Fuel Cell Vehicle Performance and Durability Data
(B) Hydrogen Storage
(C) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data
(D) Maintenance and Training Facilities
(E) Codes and Standards
(H) Hydrogen from Renewable Resources
(I) Hydrogen and Electricity Co-Production

Contribution to Achievement of DOE Technology Validation Milestones

This project will gather data and provide technical analysis over a five-year period that will contribute to achieving the following DOE technology validation milestones from the HFCIT Program Multi-Year Research, Development, and Demonstration Plan:

- **Milestone 2: Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles (Q3, FY 2005).** Vehicle chassis dynamometer testing was completed on 11 vehicles to obtain accurate fuel economy data from the four industry teams. While some of the Learning Demonstration vehicles are not sold in the United States, and therefore don't have a benchmark U.S. fuel economy to compare to, data show that the fuel economy of the FCVs was >50% higher than the conventional gasoline vehicles. This milestone has been achieved.
- **Milestone 3: Decision for purchase of additional vehicles based on projected vehicle performance and durability, and hydrogen cost criteria (Q4, FY 2006).** At the end of FY 2006, NREL used all available fuel cell data to analyze performance against DOE 2006 targets. Based on high fuel cell system efficiency results, good refueling times, and fuel cell voltage degradation that straddled DOE's 1,000-hour target, we recommended that DOE proceed with purchasing 2nd generation FCVs to validate the 2009 targets. This milestone has been achieved.
- **Milestone 4: Operate fuel cell vehicle fleets to determine if 1,000 hour fuel cell durability, using fuel cell degradation data, was achieved by industry (Q4, FY 2006).** In September 2006, NREL analyzed the fuel cell data to date and made projections about fuel cell durability to a 10% voltage degradation. These results were then compared to the 1,000-hour target and formed the basis for a public CDP. At the time of the milestone, the highest projected team average was 950 hours with a four-team average of just over 700 hours.

After a year and a half of additional on-road data (through December 2007), the latest results show a four-team average of around 1,200 hours. This milestone has been achieved.

- **Milestone 5: Validate vehicle refueling time of 5 minutes or less for a 5 kg tank [1kg/min] (Q4, FY 2006).** NREL used all available project refueling data to compare the refueling rate to the DOE target of 5 kg in five minutes (1 kg/min). At the time of the milestone, analyzing over 2,000 vehicle refueling events, we calculated an average rate of 0.69 kg/min and median rate of 0.72 kg/min, with 18% of the events exceeding the 1 kg/min target. Updates 1.5 years later using 8,700 refueling events showed improved results with an average rate of 0.79 kg/min with 24% of refueling events exceeding 1 kg/min. This milestone has been achieved.
- **Milestone 7: Validate refueling time of 5 minutes or less for 5 kg of hydrogen (1 kg/min) at 5,000 psi through the use of advanced communication technology (Q4, FY 2007).** While similar to Milestone 5, this milestone specifically addresses communication fills. At the time of the milestone, we calculated an average rate of 0.76 kg/min based on all refueling events, with 23% of the events exceeding the 1 kg/min target. As mentioned in Milestone 5 above, refueling rates have continued to improve since then. We also analyzed the difference in refueling rates of communication and non-communication fills; the data show that communication fills can refuel at a higher rate (up to 1.8 kg/min) and have an average fill rate 42% higher than non-communication fills (0.94 kg/min vs. 0.66 kg/min). This milestone has been completed.
- **Milestone 8: Fuel cell vehicles demonstrate the ability to achieve 250-mile range without impacting passenger cargo compartment (Q4, FY 2008).** NREL will perform a preliminary assessment of the 2nd generation FCVs to determine whether they meet the 250-mile range target based on vehicle chassis dynamometer results and usable hydrogen carried onboard.
- **Milestone 10: Validate FCVs 2,000 hour fuel cell durability, using fuel cell degradation data (Q4, FY 2009).** On-road fuel cell voltage data from 2nd generation fuel cell systems will be analyzed in a similar manner as in 2006 (including any improvements to the methodology) to evaluate the durability and compare it to the 2,000-hour target at the end of this project.
- **Milestone 11: Decision to proceed with Phase 2 of the Learning Demonstration (Q2, FY 2010).** Based on the progress made between first- and second-generation FCV technologies, NREL will support DOE in the decision to proceed with Phase 2 of the Learning Demonstration.
- **Milestone 23: Total of 10 stations constructed with advanced sensor systems and operating procedures (Q1, FY 2008).** This milestone has been achieved.
- **Milestone 24: Validate a hydrogen cost of $3.00/gge (based on volume production) (Q4, FY 2009).** Hydrogen costs will be estimated at volume using the hydrogen analysis (H2A) tool with support from industry at the end of the project.

Accomplishments

- Created and published 47 CDPs (the fifth such set of public results) representing results from analyzing almost three years of Learning Demonstration data.
- Published three public progress reports summarizing key take-aways from each of the CDPs.
- Presented project results publicly at EVS-23, the Fuel Cell Seminar, the National Hydrogen Association conference, the Fuel Cell Durability & Performance Conference, and the 2008 DOE Hydrogen Program Merit Review meeting.
- Kept NREL's Web page up-to-date at http://www.nrel.gov/hydrogen/cdp_topic.html to allow direct public access to the latest CDPs organized by topic, date, and CDP number. This also allowed the results to be indexed directly by Web search engines.
- Made major improvements to NREL's Fleet Analysis Toolkit (FAT) for automatically processing and analyzing every vehicle trip file and presenting the results graphically in an interactive manner.
- Received and processed a total of 211,000 individual vehicle trips, amounting to over 50 gigabytes of on-road data, since inception of the project.
- Updated an NREL-created MATLAB analysis program to analyze dominant operational factors affecting fuel cell degradation, including integrating it into the FAT.
- Shifted from writing internal (protected data) quarterly validation assessment reports to self-documenting and archiving each quarter's analysis results in the FAT graphical user interface.
- Further developed a collaborative technical relationship with all four industry teams by giving presentations to each team, including detailed results from NREL's multivariate study on factors affecting stack degradation.
- Provided presentations of results to stakeholders, including three FreedomCAR and Fuel technical teams (storage, delivery, and fuel cells), the U.S. Fuel Cell Council Transportation Working Group, the Hydrogen Quality Working Group, and both the Vehicle Technologies Program and the HFCIT Program.

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Introduction

The primary goal of this project is to validate vehicle/infrastructure systems using hydrogen as a transportation fuel for light-duty vehicles. This means validating the use of FCVs and hydrogen refueling infrastructure under real-world conditions using multiple sites, varying climates, and a variety of sources for hydrogen (see Figure 1 for photographs representing the four types of hydrogen refueling stations). Specifically, by 2009 we will be validating hydrogen vehicles with greater than 250-mile range, 2,000-hour fuel cell durability, and $3/gasoline gallon equivalent (gge) hydrogen production cost (based on volume production). We will identify the current status of the technology and track its evolution over the five-year project duration, particularly between the first- and second-generation FCVs. NREL's role in this project is to provide maximum value for DOE and industry from the data produced by this "learning demonstration." We seek to understand the progress toward the technical targets, and provide it to the HFCIT R&D activities to move more quickly toward a cost-effective, reliable hydrogen FCV and supporting refueling infrastructure.

Approach

Our approach to accomplishing the project's objectives is structured around a highly collaborative relationship with each of the four industry teams, including Chevron/Hyundai-Kia, Chrysler/BP, Ford/BP, and General Motors/Shell. We are receiving raw technical data from both the hydrogen vehicles and refueling infrastructure that allows us to perform unique and valuable analyses across all four teams. Our primary objectives are to feed the current technical challenges and opportunities back into the DOE Hydrogen R&D Program and assess the current status and progress toward targets.

To protect the commercial value of these data for each company, we established the Hydrogen Secure Data Center (HSDC) to house the data and perform our analysis. To ensure value is fed back to the hydrogen community, we publish CDPs twice a year at technical conferences to report on the progress of the technology and the project, focusing on the most significant results. Figure 2 shows the periodic publication of CDP sets relative to the inflow of vehicle data to NREL. Additional CDPs are being conceived as additional trends and results of interest are identified. We also provide our detailed analytical results (not public) on each individual company's data back to them to maximize the industry benefit of NREL's analysis work and obtain feedback on our methodologies.

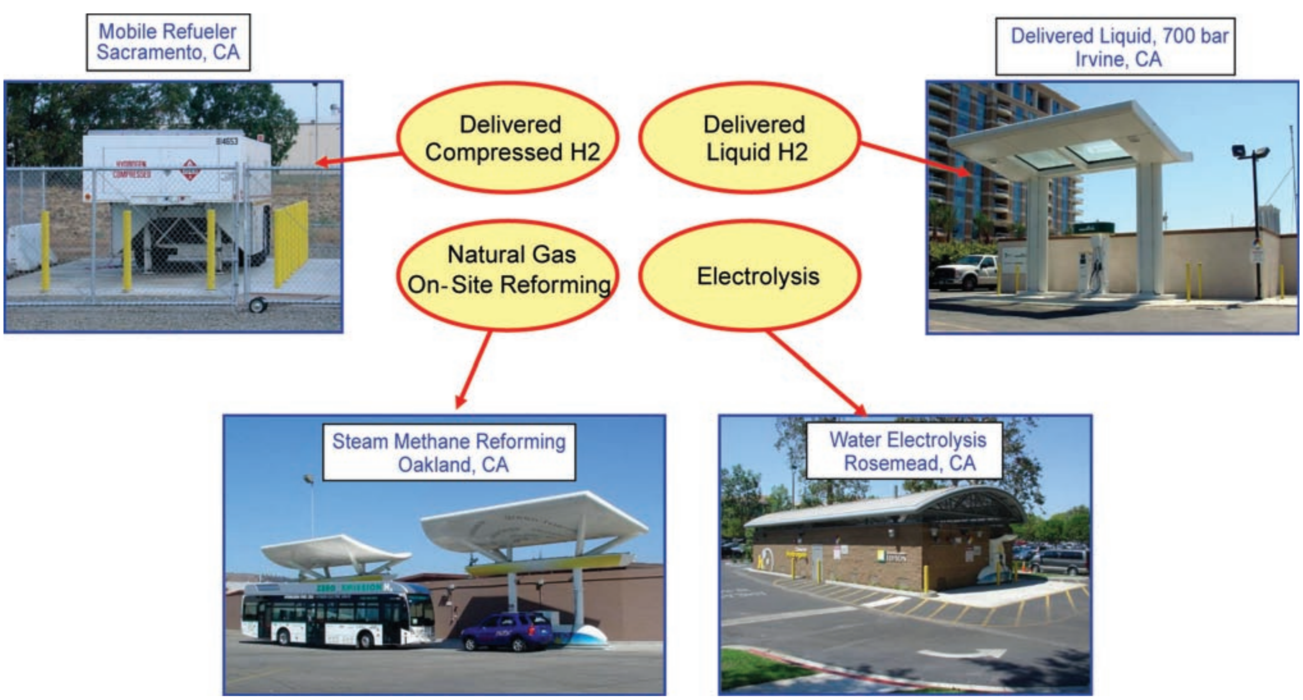

FIGURE 1. Four Types of Hydrogen Refueling Stations are Being Tested

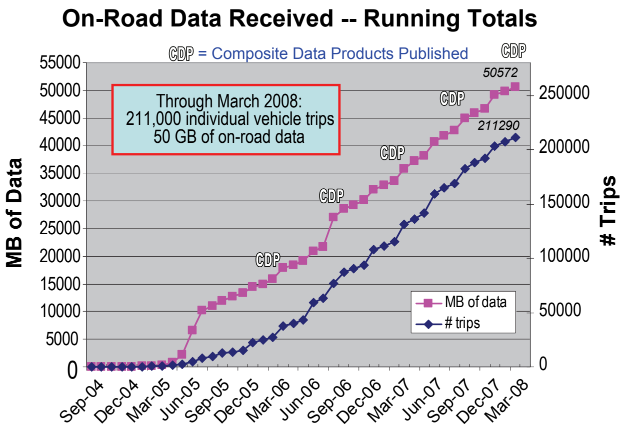

FIGURE 2. Composite Data Products are Published at Six-Month Intervals

Results

The results in FY 2008 came from analyzing an additional year of data (January – December 2007), creating a total of 47 new or updated CDPs, and presenting these results at five technical conferences. To accomplish this, we significantly improved and revised our in-house analysis tool, FAT. Since there are now so many technical results from the project, they cannot all be listed here or be fully presented during brief conference presentations. Therefore, in 2007 NREL launched a new Web page at http://www.nrel.gov/hydrogen/cdp_topic.html to provide the public with direct access to the results. Portions of these results have also been presented publicly at the Fuel Cell Seminar (10/07), the ZERO REGIO conference (10/07), the Fuel Cell Durability and Performance Conference (11/07), the EVS-23 conference (12/07), and the 2008 National Hydrogen Association meeting (4/08) as two distinct sets of results (labeled "Fall 2007" and "Spring 2008"). Since all 47 of the results are available now on the Web site, this report will just include some of the highlights.

- **Fuel Cell Efficiency:** The baseline fuel cell system efficiency was measured from selected vehicles on a vehicle chassis dynamometer at several steady-state points of operation. DOE's technical target for net system efficiency at ¼-power is 60%. Data from the four Learning Demonstration teams showed a range of net system efficiencies from 52.5% to 58.1%, which is very close to the target. These results have not changed since they were first published because they are baseline results for first-generation vehicles, but the teams will test second-generation systems as soon as they are introduced to evaluate any efficiency changes as the systems get closer to technology readiness.
- **Fuel Cell Operating Points:** Since a fuel cell system's peak efficiency is normally at low power levels (typically 10% to 25%), we evaluated the fuel cell system operation from a number of different perspectives to better understand whether the unique performance characteristics of the fuel cell system were being maximized. We found that a significant amount of time is being spent at low fuel cell system power with the teams' average amount of time spent at <5% of peak power being over 50%. However, for overall vehicle fuel efficiency, the amount of energy spent at various power levels and the efficiency at those power levels is the critical metric; we found that much of the fuel cell energy (about 40%) is expended at fuel cell power levels between 20% and 50% of peak power (Figure 3). This matches up very well with the peak fuel cell system efficiency points (at ~25% power) previously discussed. Only about 20% of the energy is expended at powers <15% of peak power, indicating that low power efficiency is not as important as the percentage of time spent there would imply.
- **Trip Length Evaluation:** In order to understand why so much time was spent at low power, we analyzed the length of trips and compared the results to national statistics (Figure 4). With more than 40% of the Learning Demonstration trips being less than one mile long, it is clear that the amount of time spent at low fuel cell power is due in part to a large number of short trips for which the vehicle is not likely accelerated to higher speeds and powers. This differs from the national driving statistics, which show that only about 10% of the trips are less than one mile long. If a large number of starts/hour is one of the major degradation factors, as has been reported at the laboratory scale, then this large number of short driving trips could be prematurely shortening the life of the Learning Demonstration fuel cells. This is being investigated as part of our multivariate study discussed later.

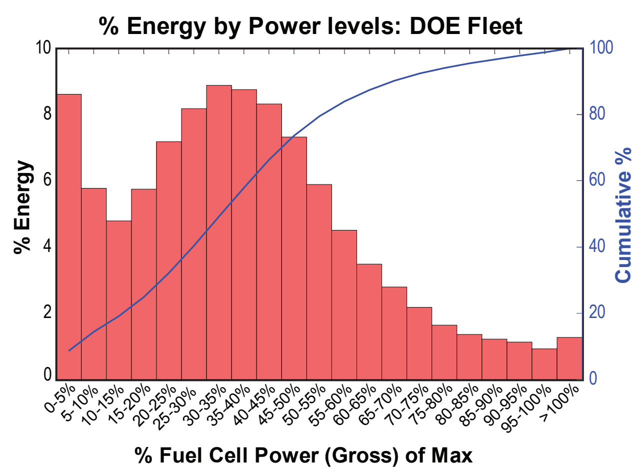

FIGURE 3. Fuel Cell System Energy within Power Levels

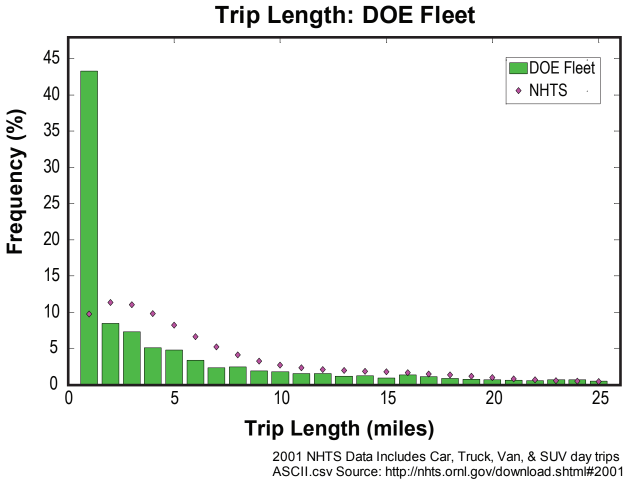

FIGURE 4. Vehicle Trip Lengths Compared to National Statistics

- **Vehicle Fuel Economy:** Vehicle fuel economy was measured using city and highway drive-cycle tests on a chassis dynamometer using draft Society of Automotive Engineers J2572. These raw test results were then adjusted according to U.S. Environmental Protection Agency methods to create the "window-sticker" fuel economy that consumers see when purchasing the vehicles (0.78 x highway, 0.9 x city). This resulted in an adjusted fuel-economy range of 42 to 56.5 miles/kg hydrogen for the four teams.
- **Vehicle Driving Range:** Vehicle range was calculated using the fuel economy results discussed above and multiplying them by the usable hydrogen stored onboard each vehicle, resulting in a range from just over 100 miles up to 190 miles from the four teams for their first-generation vehicles. The second-generation vehicles will strive to push this range up to 250 miles to reach the 2009 DOE target, and will be evaluated for a September 2008 Multi-Year Program Plan (MYPP) milestone (#8).
- **On-Board Hydrogen Energy Storage System Status:** In the last six months, additional hydrogen storage data have been reported to NREL using a more detailed hydrogen storage system breakdown spreadsheet. These new data included information on the breakdown of the mass and volume due to the hydrogen itself, the pressure vessel, and the balance-of-plant. The percentage breakdown by each of these categories was averaged across the four teams so that pie-charts of the differences between 350 bar and 700 bar could be examined for mass and volumetric characteristics (Figure 5). The comparison shows that, while the average hydrogen weight percentages are similar for 350 and 700 bar, and the pressure vessel and balance-of-plant for 700 bar take up a larger percentage of the system volume, the 700 bar systems still allow for a more compact package and extended range.

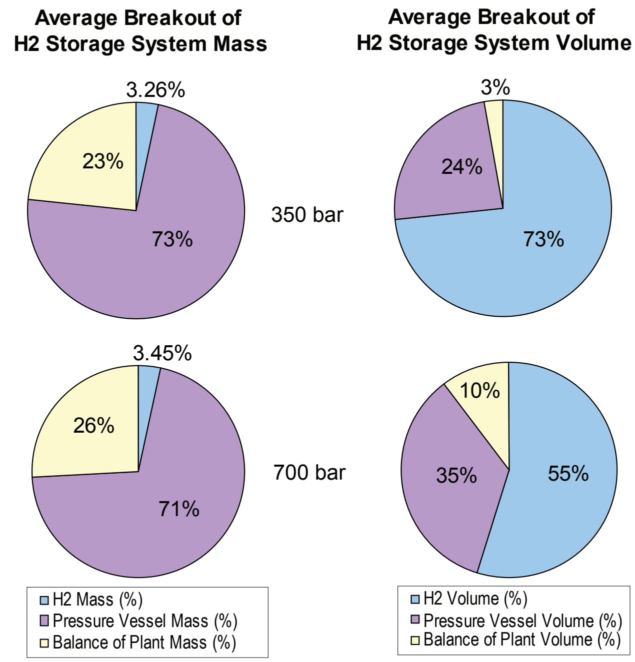

FIGURE 5. Hydrogen Storage System Mass and Volume Breakdown

- **Fuel Cell Durability:** Fuel cell stacks will need roughly a 5,000-hour life to enter the market for light-duty vehicles. Preliminary durability estimates were first published in the fall of 2006 because most stacks at that time only had a few hundred hours of operation or less accumulated on-road. NREL developed a methodology for projecting the gradual degradation of the voltage based on the data received to date. This involved creating periodic fuel cell polarization curve fits from the on-road stack voltage and current data, and calculating the voltage under high current. This enabled us to track the gradual degradation of the stacks with time and do a linear fit through each team's data. We then compared these results to the first-generation target of 1,000 hours for 2006.

  In the past year and a half, many more hours have been accumulated on the fuel cell stacks, and the range of fleet averages is now ~200 to 700 hours, with the range of fleet maximums spanning ~300 to 1,200 hours (Figure 6). This is the first time, to our knowledge, that a light-duty passenger fuel cell car has accumulated more than 1,000 hours in real-world operation without repair to the fuel cell stack, which is a significant project accomplishment. Therefore, the amount of data extrapolation we have to make using the slope of the linear voltage degradation method (10% voltage drop target divided by the mV/hour slope), continues to decrease. However, with the additional data we have received, we are also finding that the accuracy of the 10% voltage degradation projection could

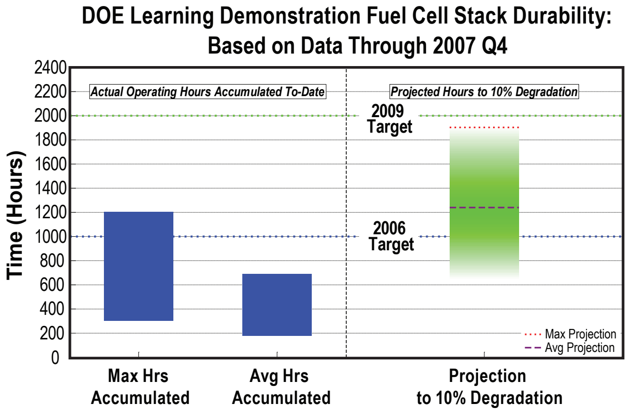

FIGURE 6. Hours Accumulated and Projected Hours to 10% Stack Voltage Degradation

be improved by using a non-linear fit to account for the more rapid degradation that occurs within the first few hundred hours. It appears as though the current linear fit may be overestimating the projected time to a 10% voltage drop for the stacks that have a significant number of accumulated hours, and we will be pursuing a non-linear or two-step linear fit to improve the accuracy in the future.

The projected times to 10% fuel cell stack voltage degradation from the four teams using the linear technique had an average of more than 1,200 hours. Note that the 10% criterion, which is used for assessing progress toward DOE targets, may differ from the original equipment manufacturer's end-of-life criterion and does not address "catastrophic" failures such as membrane failure. The second-generation stacks introduced in this project beginning in late 2007 will be compared to the 2,000-hour target for 2009.

- **Factors Affecting Fuel Cell Durability:** We continued the multivariate analysis that was initiated in 2007 to determine the dominant factors that are affecting the rates of degradation. We performed a partial least squares regression analysis on the stack data from all four teams to see if there were any overall trends that covered all of the technology involved. The trends across all four teams were not strong, which we soon discovered was because the trends among the companies were often different. Looking at each team's data individually improved the connection between the voltage degradation rate and the variables, and we were able to pull out groupings of factors that appeared to cause either higher or lower than average decay rates within each team, but the models were not very robust and results are scattered. While there were some common factors among several team's results, there were also normally contradictory trends from one of the teams. This analysis effort is continuing in close collaboration with each of our industry partners to carefully examine the inputs and outputs from this analysis and see if there are valuable lessons that can be fed back into the companies' research as well as into DOE's R&D program.
- **Vehicle Safety:** The Learning Demonstration has had a very strong safety record to date. In the last six months there have been two safety report additions: one traffic accident and two hydrogen tanks that were removed from service due to minor scratches noted during inspection. In the case of the traffic accident, there was no hydrogen release and only minor injuries due to the two-vehicle impact (not hydrogen related). In the case of the two tanks that were removed for service, the team determined that the tanks had been scratched during service of a nearby system and that the scratches could be easily repaired without affecting the safety of the tanks.
- **Infrastructure Safety:** With respect to hydrogen refueling infrastructure, there has been one new report that was classified as an incident (making for a total of two over the entire project). This new report involved a hydrogen compressor that shut down due to excessive vibration. Upon inspection technicians discovered that some of the bolts on the compressor had fallen out, which could have caused a serious problem later if it had not been discovered. At a less severe level, there were 23 events categorized as near-misses and over 100 non-events (over 70 were alarms-only). All but five of the near-misses involved a minor release of hydrogen with no ignition.
- **Vehicle Hours and Mileages:** A total of over 50,000 vehicle driving hours have been accumulated with a median vehicle operating time of about 600 hours. The median distance traveled by the vehicles is between 10,500 and 14,000 miles. The fleet has now accumulated a total of over 1.1 million miles.
- **Vehicle Refueling Rates:** Hydrogen vehicle refueling needs to be as similar as possible to conventional vehicle refueling to allow an easier commercial market introduction. Over 8,700 refueling events have been analyzed to date, and the refueling amount, time, and rate have been quantified. The average time to refuel was 3.43 minutes with 87% of the refueling events taking less than five minutes. The average amount per fill was 2.25 kg, reflecting both the limited storage capacity of these vehicles (~4 kg max) and peoples' comfort level with letting the fuel gauge get close to empty. DOE's target refueling rate is 1 kg/minute, and these Learning Demonstration results indicate an average of 0.79 kg/min, with 24% of the refueling events exceeding 1 kg/minute.
- **Communication vs. Non-Communication Fills:** The previously discussed refueling rates included

all types of refueling events. There has been much interest from industry and from the codes and standards community about the potential for communication fills to occur at a higher rate and with a more complete fill. A communication fill means that the vehicle communicates data about the state of its hydrogen storage tank(s), such as tank temperature, pressure, and max pressure rating, to the refueling station. Figure 7 shows two curves: the red/dashed curve is a spline fit to the histogram for non-communication fills while the blue/solid curve represents the communication fills. The center part of the graph shows a similar overall rate of fill for the communication and non-communication fills, however the communication fills are capable of having a higher fill rate (up to around 1.8 kg/min). There is also a group of vehicle/station combinations still doing non-communication fills at the slower rate of ~0.2 kg/min on the left portion of the graph. This rate of fill was established many years ago in California to provide a conservative and safe approach for refueling vehicles before much real-world experience had been gained. Further analysis of the fill rates by year revealed that this slower refueling rate was heavily used in 2006 but has been almost completely phased out in 2007. With these distribution differences in mind, the average fill rate for all communication fills is 0.94 kg/min vs. 0.66 kg/min for non-communication fills, with 36% and 20% of the fills, respectively, exceeding DOE's 1 kg/min target.

- **Level in Fuel Tank When People Refuel:** With limited hydrogen refueling infrastructure and limited on-board hydrogen storage, some drivers do not like to let the tank get close to empty to minimize the risk of running out of fuel. To investigate this further, NREL used the data submitted in a new and unique way, which was to look at what the fuel level in the tank was just prior to each refueling event. Figure 8 shows the results from this analysis, where a histogram has been placed radially on an image of a fuel gauge to make interpreting the graph as intuitive as possible. The level at which people most commonly refuel the Learning Demonstration vehicles is at just over ¼ full. While some drivers are letting the tank get even lower than that, few let it get very close to being empty. Additionally, we have placed a green needle on the chart which indicates the median tank level at fill (½ above, ½ below), which is a little above ⅜ of a tank (40% of full). In the future, we would like to compare these data results to data from conventional liquid fueled vehicles, if they exist, to see if people are refueling their fuel cell vehicles differently than their conventional vehicles.

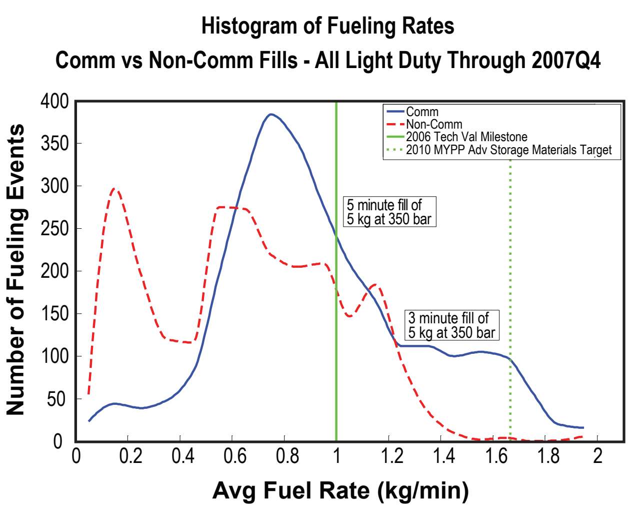

FIGURE 7. Fueling Rates – Communication and Non-Communication Fills

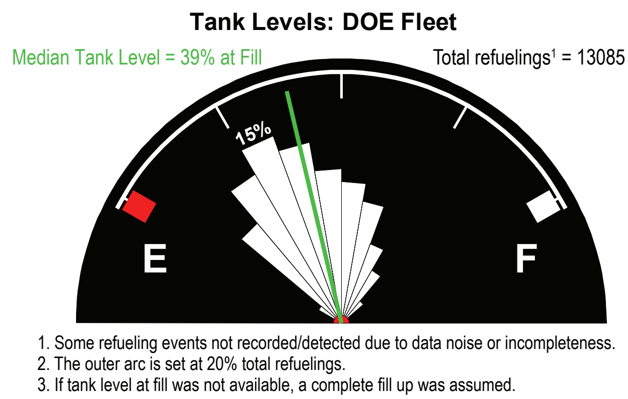

FIGURE 8. Hydrogen Tank Level at Refueling

Conclusions and Future Directions

- Completed the first two years of the five-year project with 92 vehicles now in fleet operation, 15 project refueling stations in use, and no major safety problems encountered.
- Analyzed data from 211,000 individual vehicle trips covering 1.1 million miles traveled and 40,000 kg H_2 produced or dispensed.
- Analyzed fuel cell system efficiency at ¼-power and compared it to DOE target of 60%: system efficiency results from the four teams ranged between 52.5% and 58.1%.
- Published 47 CDPs to date and made them directly accessible to the public from a NREL's Web site.
- Continued to examine the factors affecting fuel cell degradation and collaborate with each team to understand results and refine inputs and analysis. This triggered a more thorough analysis of vehicle/stack duty cycles, such as time between trips, trip length, and fuel cell power levels.

- NREL will create new and updated CDPs based on data through June 2008, and prepare results for publication at the 2008 Fuel Cell Seminar and the Electro-Chemical Society annual meeting.
- NREL will support the September 2008 DOE MYPP and Joule milestone by evaluating second-generation vehicle range and comparing it to the 250-mile target.
- We will semi-annually (spring/fall) compare technical progress to program objectives and targets for the remainder of the project, providing public outputs through publication at conferences.
- We will actively identify opportunities to feed project findings back into HFCIT Program R&D activities to maintain the project as a "learning demonstration."

FY 2008 Publications/Presentations

1. Wipke, K., Sprik, S., Kurtz, J., "Controlled Hydrogen Fleet and Infrastructure Analysis," DOE Annual Merit Review Meeting, Washington, DC, May 2008. (presentation)

2. Wipke, K., Sprik, S., Kurtz, J., "Learning Demonstration Progress Report–Spring 2008," National Renewable Energy Laboratory Technical Report NREL/TP-560-42986, April 2008. (paper)

3. Wipke, K., Sprik, S., Kurtz, J., Garbak, J., "Fuel Cell Vehicle Learning Demonstration: Spring 2008 Results Presentation," National Hydrogen Association Annual Hydrogen Conference, March 2008. (paper and presentation)

4. Wipke, K., Sprik, S., Kurtz, J., "Composite Data Products for the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project," Golden, CO: National Renewable Energy Laboratory, updated March 2008. (presentation)

5. Wipke, K., "Hydrogen Secure Data Center: Procedures to Protect Technical Data Submitted under the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project," Golden, CO: National Renewable Energy Laboratory, updated December 2007. (HSDC document)

6. Wipke, K., Sprik, S., Kurtz, J., Thomas, H., "FCV Learning Demonstration: Project Midpoint Status and Fall 2007 Results," EVS-23 Conference, Anaheim, CA, December 2007. (paper and presentation)

7. Kurtz, J., Wipke, K., Sprik, S., "FCV Learning Demonstration: Factors Affecting Fuel Cell Degradation," Fuel Cell Durability & Performance Conference, Miami, Florida, November 2007. (presentation).

8. Wipke, K., Sprik, S., Kurtz, J., Thomas, H., Garbak, J., "FCV Learning Demonstration: Project Midpoint Status and First-Generation Vehicle Results," ZERO REGIO Conference, Montecatini Terme, Italy, November 2007. (presentation)

9. Wipke, K., Sprik, S., Thomas, H., Welch, C., Kurtz, J., "Controlled Hydrogen Fleet and Infrastructure Analysis Project," 2007 DOE HFCIT Program Annual Progress Report, System Analysis Section VI.D.1, November 2007. (paper)

10. Wipke, K., presentation of Learning Demonstration results to FreedomCAR and Fuels Delivery Tech Team, November, 2007. (presentation)

11. Wipke, K., Sprik, S., Kurtz, J., Thomas, H., Garbak, J., "FCV Learning Demonstration: First-Generation Vehicle Results and Factors Affecting Fuel Cell Degradation," Fuel Cell Seminar, San Antonio, TX, October 2007. (presentation and extended abstract).

12. Wipke, K., Sprik, S., Kurtz, J., Thomas, H., Garbak, J., "Fuel Cell Vehicle and Infrastructure Learning Demonstration: Activities in California," H2 Infrastructure Forum Between National & Local Governments and Industry, hosted by USFCC, Washington, D.C., October 2007. (presentation)

13. Wipke, K., Sprik, S., Kurtz, J., Thomas, H., "Learning Demonstration Progress Report – September 2007," National Renewable Energy Laboratory Technical Report NREL/TP-560-42264, October 2007. (paper)

14. Wipke, K., presentation of Learning Demonstration results to Vehicle Technologies Program at DOE, October 2007. (presentation)

15. Wipke, K., presentation of Learning Demonstration results to FreedomCAR and Fuels Hydrogen Storage Tech Team, October, 2007. (presentation)

16. Wipke, K., presentation of Learning Demonstration results to HFCIT Program at DOE, October 2007. (presentation)

17. Wipke, K., Sprik, S., Thomas, H., Welch, C., Kurtz, J., "Learning Demonstration Interim Progress Report – Summer 2007," National Renewable Energy Laboratory Technical Report NREL/TP-560-41848, July 2007. (paper)

18. Wipke, K., Welch, C., Thomas, H., Sprik, S., Kurtz., J., "DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project: Quarterly Validation Assessment Reports," (HSDC papers only)

- 1Q 2007, June 2007.
- 2Q 2007, September 2007.