CHAPTER TWELVE

DOE's National Fuel Cell Vehicle Learning Demonstration Project — NREL's Data Analysis Results

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Prepared for the US Department of Energy under
DOE Contract No. DE-AC36-08G028308

Electric and Hybrid Vehicles
ISBN 978-0-444-53565-8, DOI: 10.1016/B978-0-444-53565-8.00012-9

1. INTRODUCTION

The primary goal of this project is to validate vehicle and infrastructure systems using hydrogen as a transportation fuel for light-duty vehicles. This means validating the use of fuel cell vehicles (FCVs) and hydrogen refueling infrastructure under real-world conditions using multiple sites, varying climates, and a variety of sources for hydrogen. Specific objectives include validating hydrogen vehicles with more than a 250-mile range, 2,000 h fuel cell durability, and a $3 per gasoline gallon equivalent ($3/gge [gallon of gasoline equivalent], U.S. dollars) hydrogen production cost (based on modeling for volume production). We are identifying the current status of the technology and tracking its evolution over the duration of the 5-year project, particularly between first- and second-generation FCVs.

The role of the National Renewable Energy Laboratory (NREL) in this project is to generate the maximum value for the U.S. Department of Energy (DOE) and industry from the data produced by this "learning demonstration." We seek to understand the progress being made toward achieving our technical targets and to provide information that will help move the program's research and development (R&D) activities toward more quickly developing cost-effective, reliable hydrogen FCVs and supporting refueling infrastructure.

2. APPROACH AND INDUSTRY PARTNERS

Our approach to accomplishing the project's objectives is structured around a highly collaborative relationship with each of the four industry teams, which includes Chevron/Hyundai-Kia, Daimler/BP, Ford/BP, and GM/Shell. We are receiving raw technical data for both the hydrogen vehicles and the refueling infrastructure that enable us to perform unique and valuable analyses across all four teams. This allows us to feed the current technical challenges and opportunities back into the DOE Fuel Cell Technologies R&D Program (FCT) 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) in 2004 to house the data and perform our analysis, as shown in Fig. 12.1. To ensure that value is fed back to the hydrogen community, we publish composite data products (CDPs) twice a year at technical conferences to report on the progress of the technology and the project, focusing on the most significant and recent results [1–4]. Additional CDPs are being conceived as additional trends and results of interest are identified, and as we receive requests from DOE, industry, and codes and standards committees. We also provide detailed analyses (which are not public) of data for each individual company back to them to maximize the benefit to industry of NREL's analysis work and to obtain

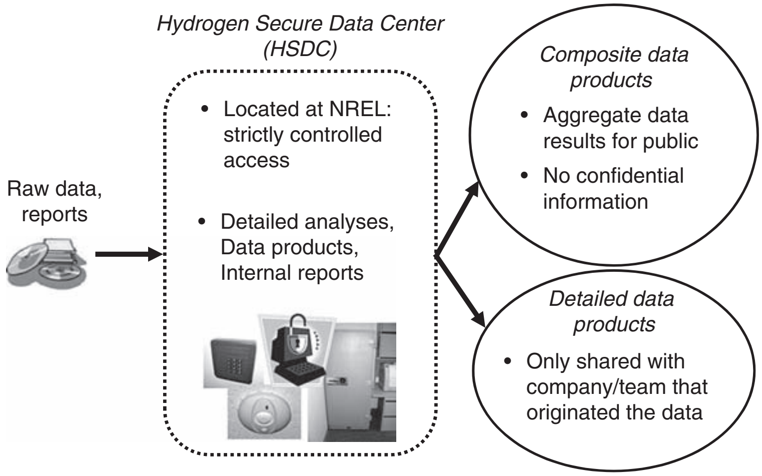


Figure 12.1 Data flow into NREL's Hydrogen Secure Data Center, resulting in public Composite Data Products and nonpublic Detailed Data Products.

feedback on our methodologies and results. These nonpublic results are known as detailed data products.

3. DEMONSTRATION LOGISTICS

3.1 Geographic regions

This project focuses on five geographic regions in the United States, in part to include climatic differences—cold, hot, humid, or dry—in the study as well as to include different driving patterns:

1. San Francisco to Sacramento region (California)
2. Los Angeles metropolitan area (California)
3. Detroit metropolitan area (Michigan)
4. Washington, D.C., to New York region (Northeast U.S.)
5. Orlando metropolitan area (Florida)

3.2 Vehicle rollout

Beginning in 2005, the automotive companies in the study deployed vehicles in the five geographic regions listed above, and full deployment of both first- and second-generation vehicles occurred by the third quarter (Q) of 2008, as shown in Fig. 12.2. The total number of vehicles deployed was 140. The graph also shows that three onboard hydrogen storage systems were used: liquid hydrogen, 350 bar compressed hydrogen, and 700 bar compressed hydrogen. As discussed later, the 700 bar compressed hydrogen was necessary to achieve the >250-mile driving range target for 2008.

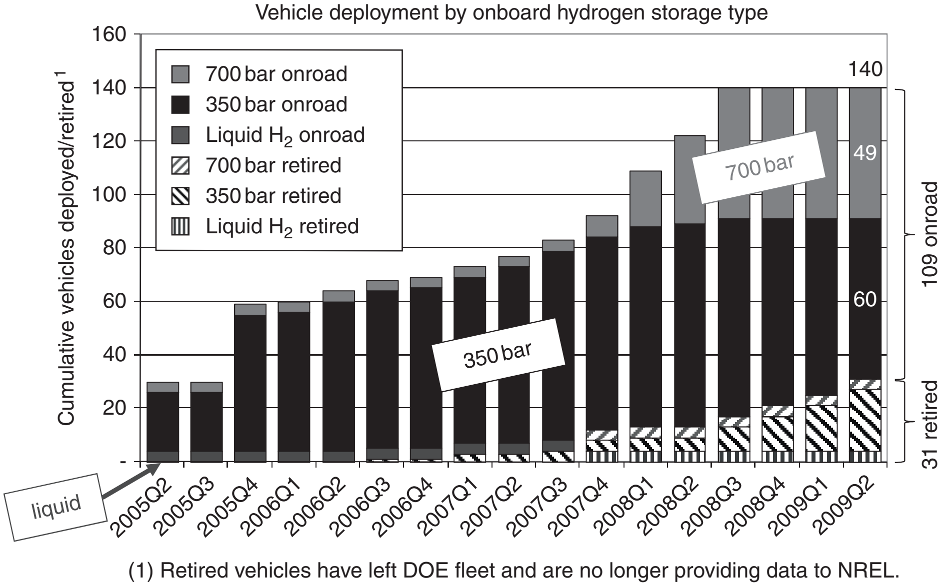


Figure 12.2 Vehicle deployment by onboard hydrogen storage type.

This figure also shows that as the vehicles age and specific customers complete the usage planned for them, some of the vehicles are being retired or returned to the manufacturers (as indicated by hatched bars). Of the total of 140 vehicles deployed, 31 have been retired (or otherwise removed from the set of vehicles provided to NREL) and 109 are still on the road (as of June 2009).

3.3 Hydrogen production technologies

To support these vehicles, four different types of hydrogen refueling stations were installed. Of the 20 stations, just over half featured on-site production of hydrogen from either reforming natural gas (four stations) or electrolyzing water (seven stations). The remaining stations used hydrogen that was delivered to the site, either as compressed gas cylinders (six stations) or as liquid hydrogen (three stations). As of June 2009, three of the 20 stations had been retired, with more stations being retired as the project approaches completion.

3.4 Process for publishing results

The most recent public results were generated by analyzing all of the data received since the inception of the project and creating a total of 72 new or updated CDPs [5]. The analyses include second-by-second data from every one of the 140 vehicles and data from each refueling event, along with monthly data on hydrogen production efficiencies. To accomplish such a massive data analysis activity, we developed and revised an in-house analysis tool—the Fleet Analysis Toolkit, or "FAT." Because there are now so many technical results from this project, they cannot all be discussed in any individual paper or presentation. Therefore, in 2007 NREL launched a new page on the Internet at http://www.nrel.gov/hydrogen/cdp_topic.html to provide the public with direct access to the latest published results. Since all 72 CDPs are now available on the Internet, this discussion will include just some of the highlights and key findings.

4. RESULTS

4.1 Vehicle fuel economy

Vehicle fuel economy was measured using city and highway drive-cycle tests on a chassis dynamometer according to the draft SAE J2572 standard. These raw test results were then adjusted according to U.S. Environmental Protection Agency (EPA) methods to create the fuel economy that consumers would see on window stickers when purchasing a vehicle (22% reduction for Hwy, 10% reduction for City). Since the project began in 2005, the EPA adjustments were made using the pre-2007 model year algorithms. We acknowledge that new vehicles sold today use a new set of cycles and adjustment algorithms; however, these were not retroactively implemented on the project vehicles or their previously generated results. We will likely add another set of results using the new EPA algorithms to see how well they capture the real-world fuel economy that we have observed.

Generation 1 vehicles had an adjusted fuel-economy range of 42–57 miles/kg hydrogen for the four teams, and generation 2 vehicles showed a slight improvement in fuel economy, to 43–58 miles/kg. Onroad fuel economy from first-generation vehicles was 31–45 miles/kg; from second-generation vehicles, it was 35–52 miles/kg. All of the Learning Demonstration vehicles were built using existing vehicle platforms that were originally designed for gasoline combustion engines.

4.2 Vehicle driving range

Vehicle driving range was calculated using the fuel economy results discussed above and multiplying them by the usable hydrogen stored onboard each vehicle. Generation 1 vehicles had a range from just over 100 miles up to 190 miles from the four teams, whereas generation 2 vehicles using 700 bar pressure hydrogen tanks showed a significantly improved window-sticker driving range of 196–254 miles, as shown in Fig. 12.3. This demonstrated that DOE's September 2008 milestone of 250 miles had been achieved. As mentioned earlier, all of the Learning Demonstration vehicles are based on existing platforms, and higher driving ranges are expected when the vehicles are designed around hydrogen, which allows larger quantities of hydrogen to be stored as well as an optimized vehicle structure, mass, aerodynamics, and layout.

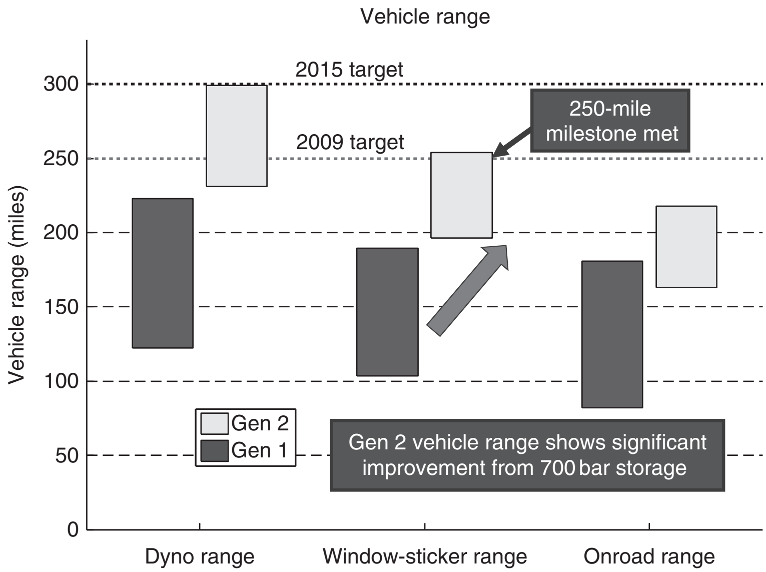
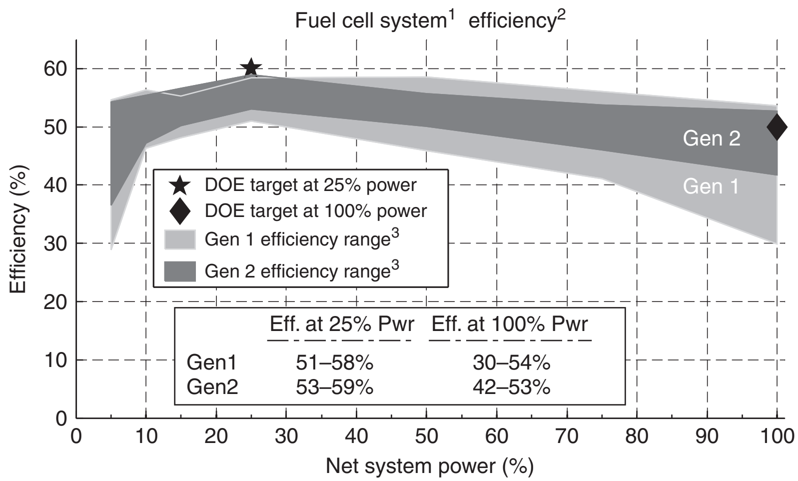


Figure 12.3 Vehicle driving range for first- and second-generation vehicles, based on fuel economy and usable hydrogen.

4.3 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. The system, as defined here, includes any parasitic loads responsible for the care and feeding of the stack, including air compressors, water pumps, fans, and the like. DOE's technical target for net system efficiency at ¼ power is 60%; the target at full power is 50% efficiency. Results that we had published earlier showed efficiency data at only ¼ power, but the new results, shown in Fig. 12.4, show the span of efficiency data from all four teams over the entire power range, from 5% up to 100% for both first- and second-generation systems. At ¼ power, first-generation systems were 51–58% efficient, while second-generation systems were 53–59% efficient; this is compared with DOE's ultimate 60% efficiency target. At full power, where the target is 50% efficiency, the first-generation systems were 30–54% efficient and second-generation systems were 42–53% efficient. So the efficiency target at 100% power has been met, and the target at ¼ power is within one percentage point of being met.

Perhaps the most important finding relative to fuel cell system efficiency is that these high efficiencies were maintained while simultaneously improving stack durability and cold-start freeze tolerance. This demonstrates a significant achievement resulting from the project. The improvements in both stack durability and cold-start tolerance are discussed later.



1. Gross stack power minus fuel cell system auxiliaries, per DRAFT SAE J2615. Excludes power electronics and electric drive.
2. Ratio of DC output energy to the lower heating value of the input fuel (hydrogen).
3. Individual test data linearly interpolated at 5,10,15,25,50,75, and 100% of max net power. Values at high power linearly extrapolated due to steady state dynamometer cooling limitations.

Figure 12.4 Fuel system efficiency as a function of power.

4.4 Fuel cell system specific power and power density

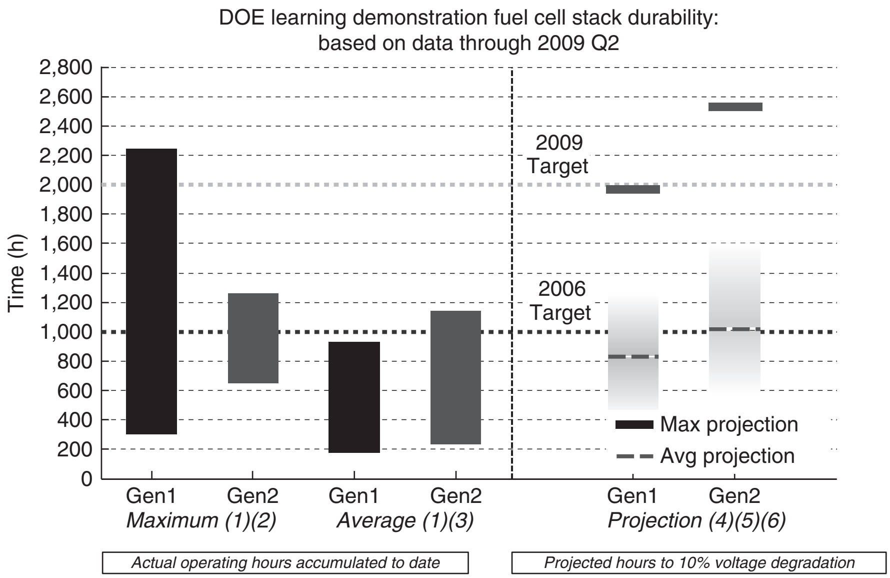
Data were received on total fuel cell system mass, volume, and power. Both the specific power (W/kg) and the power density (W/L) were evaluated for generation 1 and compared with generation 2 fuel cell systems. We found that while the fuel cell system power density stayed about the same between the two generations (ranging from 300 to 400 W/L), there were significant improvements in fuel cell system specific power, improving from generation 1 results of 200–300 W/kg up to generation 2 results of 300–400 W/kg. It appears as though it may take another generation or two before the fuel cell systems achieve DOE's 2010 and 2015 target of 650 W/kg.

When the fuel cell system is combined with the hydrogen storage system, we can compare that result with DOE 2010 and 2015 R&D goals to allow comparisons with other energy and power systems, such as batteries. We found that the system, which includes the fuel cell and the hydrogen storage, can be over 200 W/L, just shy of the target of 220 W/L. The combined system specific power was as high as 250 W/kg from generation 2 vehicles, compared with the target of 325 W/kg.

4.5 Fuel cell durability

Fuel cell stacks will need roughly a 5,000 h life to compete in the light-duty vehicle market. Preliminary durability estimates were first published on this project in the fall of 2006 when most stacks only had a few hundred hours or less of on-road operation accumulated. 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 h for 2006.

In the past 3 years, many more hours have been accumulated on the first-generation fuel cell stacks (consistent with a staged rollout), and the range of fleet average hours accumulated is now ~200–900 hours. The range of fleet maximum hours accumulated spans ~300–2,200 hours, as shown in Fig. 12.5. This is the first time, to our knowledge,



(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. The shaded projection bars represents an engineering judgment of the uncertainty on the "Avg Projection" due to data and methodology limitations. Projections will change as additional data are accumulated.
(6) Projection method was modified beginning with 2009 Q2 data, includes an upper projection limit based on demonstrated op hours.

Figure 12.5 Stack hours accumulated and projected hours to 10% voltage degradation.

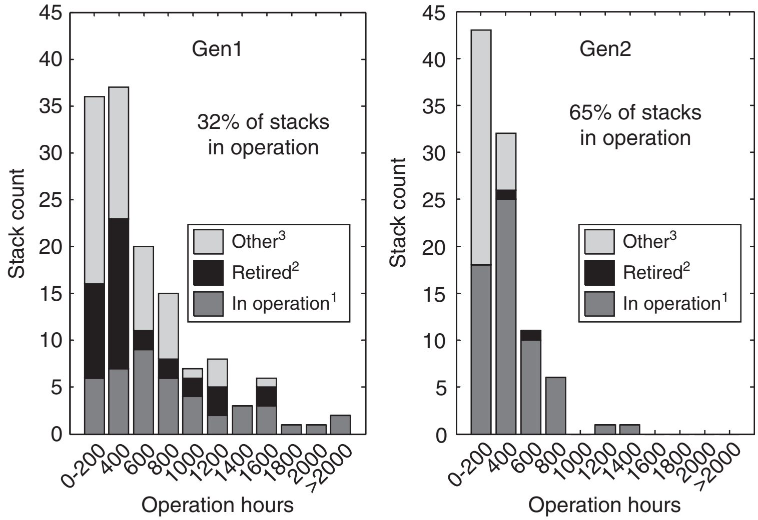
that a light-duty passenger fuel cell car has accumulated over 2,000 h in real-world operation without the need to repair the fuel cell stack, which is a significant project accomplishment. We now also have sufficient data on second-generation stacks, and we found that the range of average hours accumulated was 200–1150 h, while the span of maximum hours accumulated was 600–1,250 h.

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 as we receive additional data. However, with the additional data we have also found that the accuracy of the 10% voltage degradation projection could be improved by using a nonlinear fit to account for the more rapid degradation that occurs within the first few hundred hours [6]. Fuel cell stack degradation results for this project in 2008 began using a two-segment linear fit and a weighting algorithm to come up with a more robust fleet average that was less sensitive to an individual stack. Note that the 10% criterion, which is used for assessing progress toward DOE targets, may differ from the manufacturer's end-of-life criterion and does not address "catastrophic" failures such as membrane failure. One of the results not included here (CDP number 73) varies this percentage from 10% up to 30% to show the sensitivity to this threshold. The projected times to 10% fuel cell stack voltage degradation from the four teams using this two-step linear fit technique have an average of 833 h for first-generation stacks and 1,020 h from second-generation stacks.

In addition to this voltage degradation technique, five new CDPs have been generated to flesh out the complete picture of the performance and durability of the stacks. Specifically, relative to fuel cell stack durability, the following new results have been created:

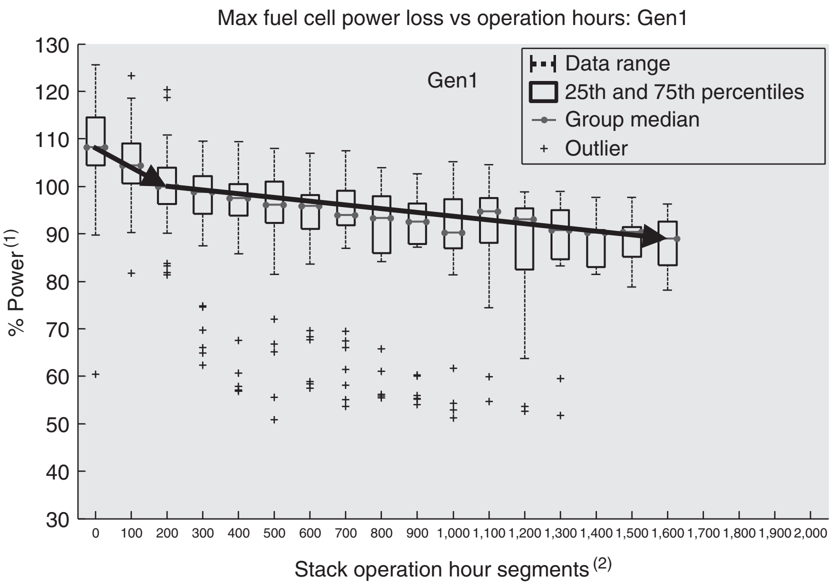
- Histogram of fuel cell stack operating hours for first- and second-generation stacks separately, identifying how many of these stacks are (1) still in operation, (2) have been retired, or (3) are not currently accumulating hours (but not removed because of low performance).
- Histogram of power drop during fuel cell stack operation period with the same classifications described above.
- Graphs of the drop in the maximum power capability of the stacks as a function of their operational hours: separate results for first-generation and second-generation stacks.
- Histogram of projected hours to low power operation limit.

Fig. 12.6 shows a histogram of the hours accumulated on each stack for both first- and second-generation stacks. It shows that many first-generation stacks have been retired with <400 h, while a few have very high hours. Second-generation stacks have lower accumulated hours, but very few stacks have been retired because of low performance and most are still in operation. Based on the shape of the power drop shown in Fig. 12.7 for first-generation stacks (which follows a similar pattern so far for second-generation stacks),



(1) Stack currently accumulating hours.
(2) Stack removed for low performance.
(3) Stack not currently accumulating hours, but not removed because of low performance.

Figure 12.6 Histogram of operating hours for first- and second-generation stacks.



(1) Normalized by fleet median value at 200 h.
(2) Each segment point is median FC power (+–50 h).
Box not drawn if fewer than 4 points in segment.

Figure 12.7 Power loss as a function of operating time for first-generation stacks.

we conclude that there is an initial power drop in roughly the first 200 h and that afterward a much lower degradation rate is observed. Therefore, with much fewer hours accumulated to date on second-generation stacks, current durability projections are expected to be lower than they will be after more data are accumulated (making this a conservative estimate). These stack durability results will be updated as additional data are accumulated.

4.6 Factors affecting fuel cell durability

We continued investigating factors that are affecting the rates of fuel cell stack degradation. Two of these factors that our industry partners asked us to examine were the amount of time the fuel cell spends at various voltage levels and the average number of trips per operating hour. We found that about 15% of the time was spent at roughly the open-circuit voltage and very low current, while only 17% of the time was spent at <70% of the maximum voltage (corresponding to high load). We examined the average number of trips per hour, shown in Fig. 12.8, and found a relatively normal distribution around the median of roughly four trips per hour. This information was also provided to an international fuel cell durability task force that was formulating durability test protocols, as they wanted to make sure they knew the actual number of average trips per operating hour from real stacks in everyday use. We also examined whether there was a trend of average trips per hour as a function of stack operating hours, and we found that the stacks that have demonstrated long hours (to date) show lower average trips per hour. We need to accumulate more data before we can attribute a causal relationship between the two.

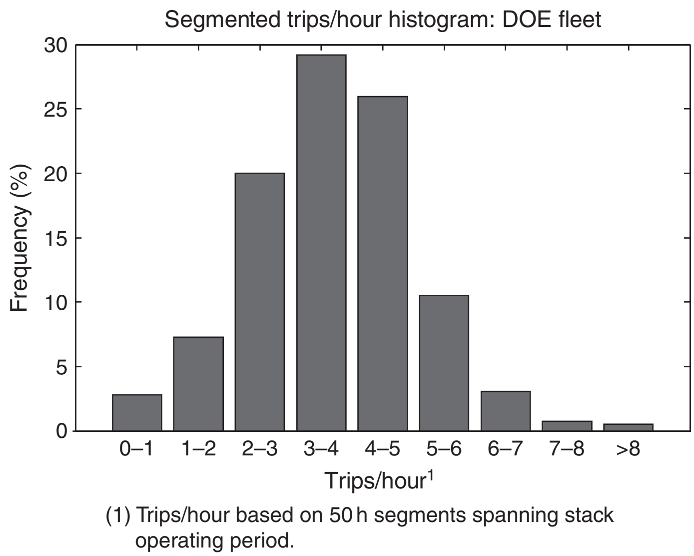


Figure 12.8 Histogram of average trips per hour.

4.7 Vehicle maintenance

Over the 4 years of vehicle operation, a large set of data has been collected on all of the vehicle maintenance events. There were a total of 11,075 maintenance events consuming 11,849 h. We found that 33% of the vehicle maintenance events were associated with the fuel cell system, consuming 49% of the maintenance labor. Over half (58%) of the vehicle maintenance events were not related to the power train. Breaking down the details of the fuel cell system into all of its subsystems, we found a surprising result: only 10% of the fuel cell system events were associated with the fuel cell stack, while the most frequently serviced parts of the fuel cell system were the thermal management system (38%); the air system (24%); controls, electronics, or sensors (13%); the fuel system (11%); and then the fuel cell stack (number 5 on the list). This indicates that other components in the fuel cell system rather than the fuel cell stack itself need more attention and potentially more R&D before these vehicles reach the point of commercialization.

4.8 Infrastructure maintenance

Like vehicle maintenance, the hydrogen fueling station maintenance data were also analyzed. There were a total of 2,291 infrastructure maintenance events, requiring 11,119 h. While we assumed that one of the production components would top the list, it was actually the system control and safety systems that accounted for the most maintenance events (21%) and labor (20%). The four major components of the system—compressor, electrolyzer, reformer, and dispenser—were roughly equal in terms of maintenance requirements. The hydrogen storage system required the least maintenance, just a few percent.

4.9 Vehicle refueling rates

More than 21,000 refueling events have been analyzed to date, and the refueling amount, time, and rate have been quantified. The average time to refuel was 3.26 min, and 86% of the refueling events took less than 5 min. The average amount per fill was 2.14 kg, reflecting both the limited storage capacity of these vehicles (~4 kg, maximum) and drivers' comfort level with letting the fuel gauge get close to empty. DOE's target refueling rate is 1 kg/min, and these Learning Demonstration results indicate an average of 0.78 kg/min, with 24% of the refueling events exceeding 1 kg/min.

4.10 Fueling rate comparison between fills for 350 and 700 bar

The previously discussed refueling rates included all types of refueling events that occurred within the project. There has been much interest from industry and from the codes and standards community on the effect of communication versus noncommunication and 350 bar versus 700 bar pressure on fill rates. A communication fill means that the vehicle communicates data about the state of its hydrogen storage tank(s), such as tank

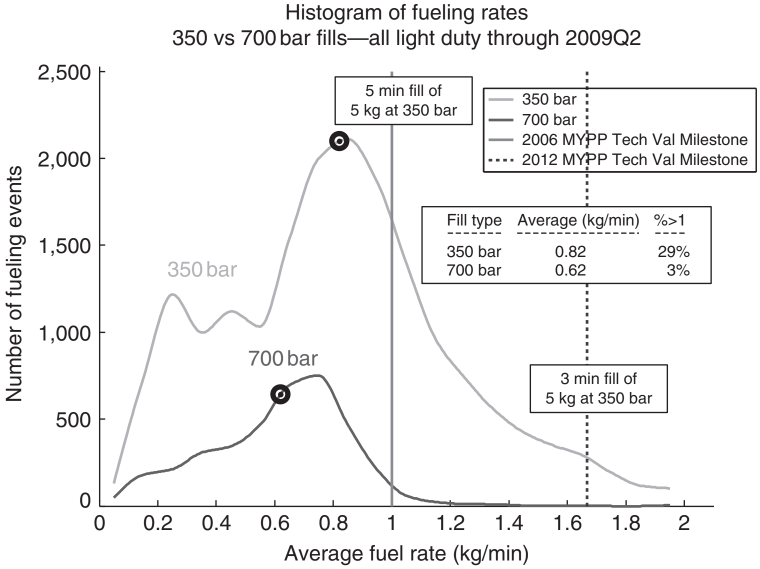


Figure 12.9 Comparison of fueling rates for 350 and 700 bar pressure refueling rates.

temperature, pressure, and maximum pressure rating, to the refueling station. We found that communication fills are capable of having higher average fill rates (0.82 kg/min) than noncommunication fills (0.62 kg/min). We also examined the difference in fill rates based on fill pressure, as shown in Fig. 12.9, and found that 700 bar fills were currently 24% slower than 350 bar fills. The average 350 bar fill rate was 0.82 kg/min, while the average 700 bar fill rate was only 0.62 kg/min.

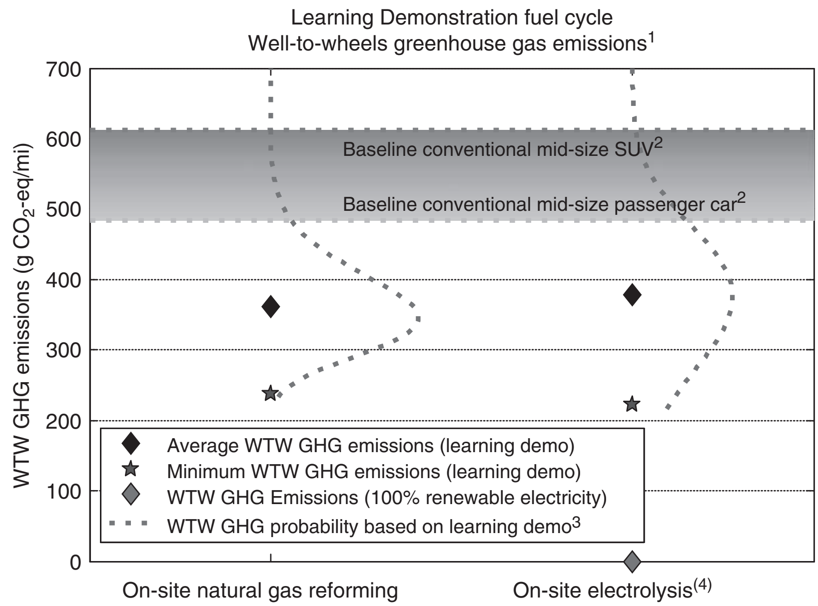
4.11 On-site production efficiency from natural gas reformation and electrolysis

Detailed data on all of the energy inputs required to produce hydrogen on site were gathered and analyzed and compared with DOE's 2010 program targets for natural gas reformation and 2012 targets for water electrolysis. The results indicate that natural gas reformation efficiency was demonstrated close to the 2010 target of 72% through achieving a best quarterly efficiency of 67.7% and a best monthly efficiency of 69.8%. The best quarterly efficiency for water electrolysis was 61.9%, with a best monthly efficiency also of 61.9% (compared with the 2012 target of 69%). Note that targets for both of these technologies are for future years (2010 and 2012) and results from the Learning Demonstration time frame (2005–2009) were not expected to have achieved future targets. Additionally, the targets are set for significantly larger stations (1500 kg/day of H_2) and much higher utilization (70% capacity factor) than we have in the Learning Demonstration. The purpose of comparing our actual results to these future targets is to benchmark demonstrated progress toward the targets while technical R&D

development continues to improve the state of the art. Note that the on-site hydrogen production costs have also been evaluated but the results are still under review.

4.12 Vehicle greenhouse gas emissions

Greenhouse gas emissions from the Learning Demonstration fleet have been assessed and compared to greenhouse gas emission estimates for conventional gasoline vehicles. The results shown in Fig. 12.10 indicate that when using hydrogen produced on site via



(1) Well-to-Wheels greenhouse gas emissions based on DOE's GREET model, version 1.8b. Anlaysis uses default GREET values except for FCV fuel economy, hydrogen production conversion efficiency, and electricity grid mix. Fuel economy values are the Gen1 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 1245 g/mile.

Figure 12.10 WTW greenhouse gas emissions results from Learning Demonstration vehicles using hydrogen produced through natural gas reformation and water electrolysis.

either natural gas reformation or water electrolysis, Learning Demonstration hydrogen FCVs offer significant reductions of greenhouse gas emissions relative to conventional gasoline vehicles . Conventional gasoline mid-sized passenger vehicles emit 484 g CO_2-eq/mi (grams CO_2 equivalent per mile) on a well-to-wheels (WTW) basis and conventional mid-size sport utility vehicles (SUVs) emit 612 g CO_2-eq/mi on a WTW basis. The WTW greenhouse gas emissions for the Learning Demonstration FCV fleet (which includes both passenger cars and SUVs) were analyzed based on the window sticker fuel economy of the Learning Demonstration fleet and the actual distribution of hydrogen production conversion efficiencies from on-site hydrogen production. Average WTW greenhouse gas emissions for the Learning Demonstration fleet operating on hydrogen produced from on-site natural gas reformation were 362 g CO_2-eq/mi, and the lowest WTW GHG emissions for on-site natural gas reformation were 237 g CO_2-eq/mi. For the Learning Demonstration fleet operating on hydrogen produced from on-site water electrolysis (including some renewable sources of electricity), average WTW GHG emissions were 378 g CO_2-eq/mi, and the lowest emissions were estimated to be 222 g CO_2-eq/mi for the month with the best electrolysis production conversion efficiency.

4.13 Fuel cell vehicle freeze capability

First-generation FCVs in this project were not freeze capable. They were either limited to warm climates only or were stored indoors during freezing conditions in colder climates. Second-generation vehicles, however, were freeze capable and able to be deployed in places like New York and Detroit without special compensation for the overnight soak temperatures.

As part of this project, the industry partners performed special start-up tests to measure the time required to both drive the vehicle away from being parked overnight and the time to reach maximum fuel cell power. They performed this test using both a 12 h soak (simulating an overnight soak) and an equilibrium soak (in which all parts of the vehicle reach ambient conditions, simulating being parked at the airport) at -20°C. The results are shown in Fig. 12.11. It should be noted that DOE's target was for a start-up time of 30 s to 50% of rated power from -20°C. Since this is a metric that the consumer would not be able to observe directly, we chose the time from key-on to drive-away and time to full power, which the consumer would be much more conscious of.

We found a large spread in the start-up results, with one team having around 20 s to drive-away and one having almost 5 min. For the time to maximum power, the best team was around 1.5 min while the longest was almost 9 min. Therefore, we can conclude that the fuel cell systems have now been made freeze-tolerant, but more work is needed to provide the level of cold-start convenience that consumers will expect.

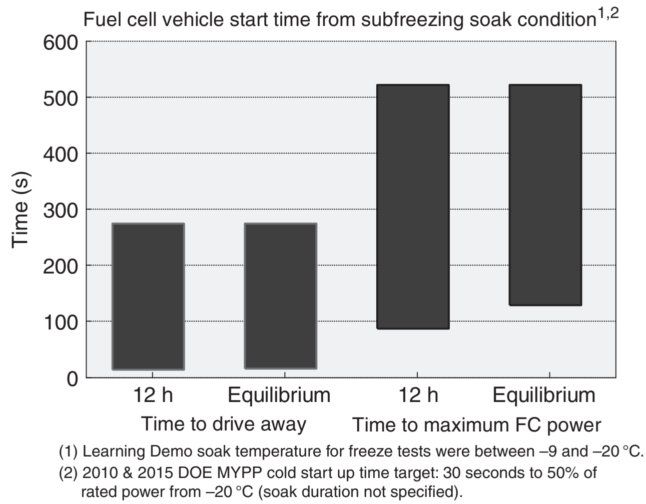


Figure 12.11 FCV start time from subfreezing soak condition.

5. CONCLUDING REMARKS

We have now completed the first 4 years of the project with 140 FCVs and 20 project refueling stations deployed. This allowed us to analyze data from over 400,000 individual vehicle trips covering 2.3 million miles traveled and 115,000 kg H_2 produced or dispensed. We have published 72 CDPs to date and made them directly accessible to the public from NREL's Internet site. Thirty-one of the vehicles and three of the stations have now been retired, with more to be retired soon as the project begins to wind down.

We found that the fuel cell system efficiency for both first- and second-generation systems was very close to or exceeded the targets at ¼ power and full power. This impressive performance was maintained while the stacks improved in both durability and freeze capability.

On the key topic of fuel cell durability, we found that the best performing first- and second-generation teams' vehicles met DOE's 1,000 and 2,000 h durability targets, respectively. Second-generation stack durability results should be considered preliminary because, although some of the projections are above 2,000 h, most stacks have not yet accumulated 1,000 h.

NREL will continue to identify opportunities to send findings from the project back to the DOE programs and industry R&D activities to maintain the project as a "learning demonstration." As the last deliverable from this project, we will write a final comprehensive summary report for publication that summarizes the final analysis results.

ACKNOWLEDGMENTS

The Technology Validation part of the U.S. Department of Energy Fuel Cell Technologies Program funded this project. In addition, the authors wish to thank the auto industry and energy companies for their contributions of detailed raw data provided to NREL as well as their valuable feedback on our methodologies and results.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

CDP	composite data product
FAT	Fleet Analysis Toolkit (software tool developed at NREL)
FCV	fuel cell vehicle
Gge	gallon of gasoline equivalent
FCT	Fuel Cell Technologies Program (DOE program)
HSDC	Hydrogen Secure Data Center (at NREL)
NREL	National Renewable Energy Laboratory
Q	quarter
R&D	research and development
WTW	well-to-wheels

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