

## VII.2 Hydrogen Vehicle and Infrastructure Demonstration and Validation

Gary P. Stottler  
General Motors (GM)  
10 Carriage Street  
Honeoye Falls, NY 14472  
Phone: (585) 624-6709  
E-mail: gary.stottler@gm.com

DOE Managers  
HQ: John Garbak  
Phone: (202) 586-1723  
E-mail: John.Garbak@ee.doe.gov  
GO: Doug Hooker  
Phone: (720) 356-1578  
E-mail: Doug.Hooker@go.doe.gov

Contract Number: DE-FC36-04GO14284, A018

Project Start Date: October 1, 2004  
Project End Date: September 30, 2011

### Contribution to Achievement of DOE Technology Validation Milestones

This project contributes to the achievement of the DOE Technology Validation milestones listed below from the Technology Validation section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 2:** Demonstrate FCEVs that achieve 50% higher fuel economy than gasoline vehicles. (3Q, 2005)
- **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. (4Q, 2006)
- **Milestone 22:** Six stations and two maintenance facilities constructed with advanced sensor systems and operating procedures. (4Q, 2006)

### Accomplishments Through Fiscal Year (FY) 2011

GM has accomplished the following project milestones:

- Deployed 60 vehicles demonstrating two generations of GM's proprietary fuel cell technology in various terrains, driving conditions, and climates (see Figure 1).
- Constructed and utilized first-class maintenance and training facilities located in Ardsley, NY; Ft. Belvoir, VA; and Burbank, CA with a satellite hub located in Lake Forest, CA.
- Established retail and retail-like hydrogen stations for public fueling:
  - Six fueling stations in operation spreading across the Eastern and Western regions.
  - Different types of hydrogen generation/delivery options are demonstrated such as delivered compressed gas and on-site electrolysis.
  - Two stations are infrared-capable and able to fast-fill 3+ vehicles back-to-back.
  - Hydrogen quality testing has been completed in both Eastern and Western regions, among the first stations in the U.S. to be tested at 700 bar.
- Shell Hydrogen opened new stations in the New York City metropolitan area at the John F. Kennedy (JFK) airport and in Bronx during 2009. They also commissioned a station in Culver City, California (Los Angeles [LA]). These stations utilize hydrogen compressed gas delivered by truck and dispense hydrogen at 700 bar utilizing equipment supplied by several companies.
- Gathered comprehensive feedback on all elements of customer experience and vehicle performance to guide future FCEV and infrastructure development.

### Objectives

GM and energy partner Shell Hydrogen, LLC, will deploy a system of hydrogen fuel cell electric vehicles (FCEVs) integrated with a hydrogen refueling infrastructure to operate under real world conditions. With this deployment GM and Shell Hydrogen will:

- Demonstrate progressive generations of fuel cell system technology.
- Demonstrate multiple approaches to H<sub>2</sub> generation and delivery for vehicle refueling.
- Collect and report operating data.

### Technical Barriers

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

- (A) Lack of Fuel Cell Electric Vehicle Performance and Durability Data
- (C) Lack of Hydrogen Fueling Infrastructure Performance and Availability Data
- (D) Maintenance and Training Facilities
- (E) Codes and Standards

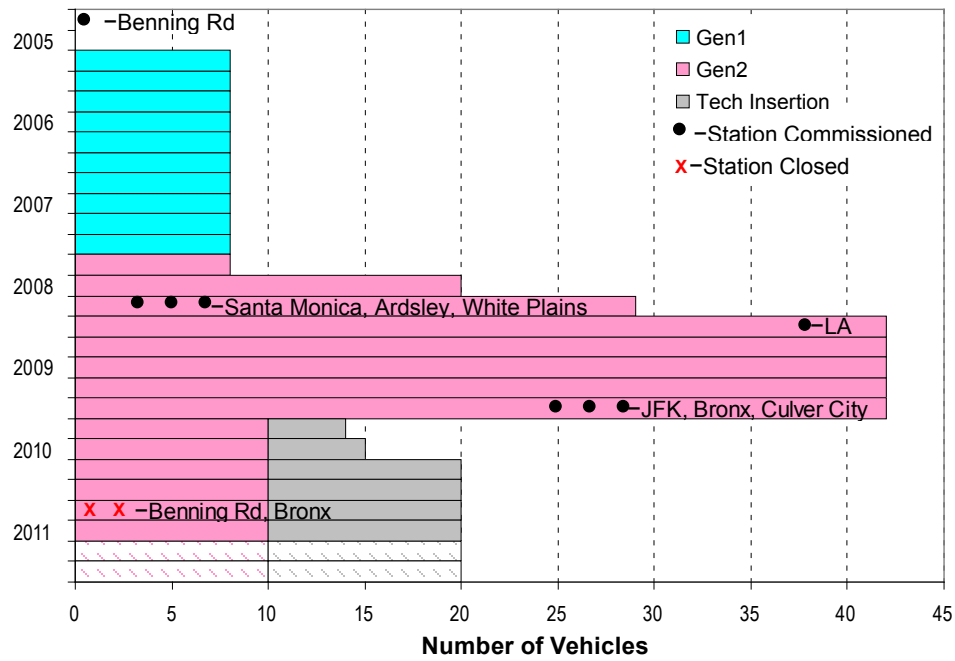


FIGURE 1. GM FCEV and Refueling Station Implementation

- Collected vehicle and station data using automated logbook entry and automated wireless data transfer from vehicles to a data server.
- Conducted and verified extensive cold weather performance testing; additionally, vehicles were deployed in the northeast United States through several winters and performed as customers expected (see Figure 2).
- GM continues to operate and maintain 10 baseline Phase 2 FCEVs through 2011 or until failure.
- Ten additional Phase 2 FCEVs equipped with technology developed during the initial part of Phase 2 were added in 2010 in order to extend learnings. These “Technology Insertion” vehicles were deployed and are accumulating miles (see Figure 3).
- Three fuel cell systems were instrumented with the same hardware as the Technology Insertion vehicles and are running accelerated durability tests on test stands.

For the rest of the project, GM will continue to operate and maintain 10 baseline Phase 2 FCEVs. These baseline Phase 2 FCEVs will continue to operate through 2011 or until failure. The purpose is to demonstrate long stack durability with extended vehicle operating hours (see Figure 4). In addition, 10 new Phase 2 FCEVs were equipped with the most recent materials and controls technology in order to demonstrate the progress made in the project to date. These “Technology Insertion” vehicles are currently deployed and are accumulating miles and generating data for submission to DOE according to the National Renewable Energy Laboratory (NREL) Data Reporting Templates.



**Introduction**

Over the six-year period to date, the project has made significant progress in support of the long-term goals of DOE’s Technical Validation sub-program. GM has deployed eight Phase 1 FCEVs and 42 of its commercially developed Phase 2 FCEVs and has maintained them through the use of two primary maintenance and training hubs and two additional satellite locations.

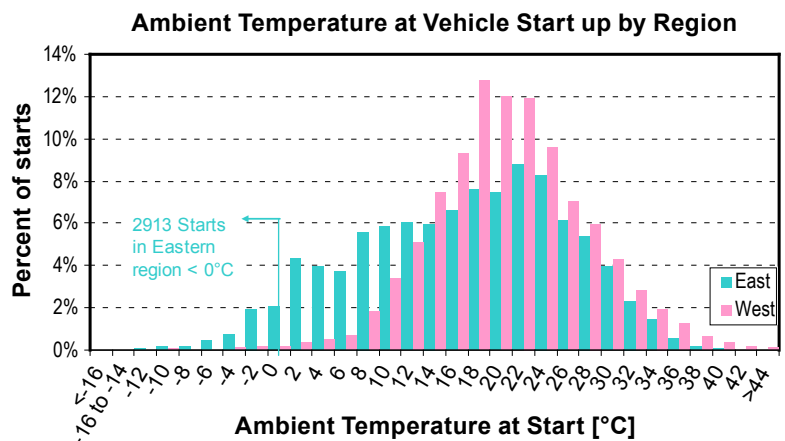


FIGURE 2. 2,913 Vehicle Starts at Ambient Temperatures <0°C

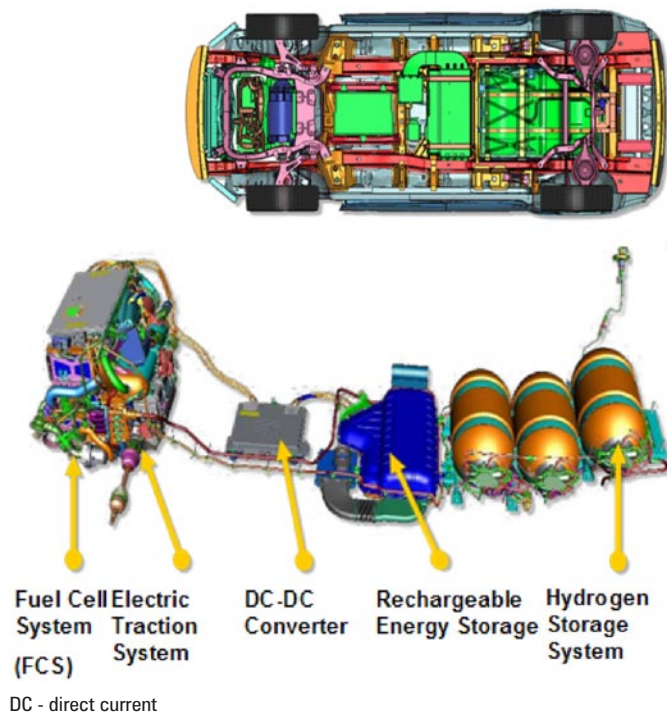


FIGURE 3. Gen2 Chevrolet FCEV with Technology Insertion

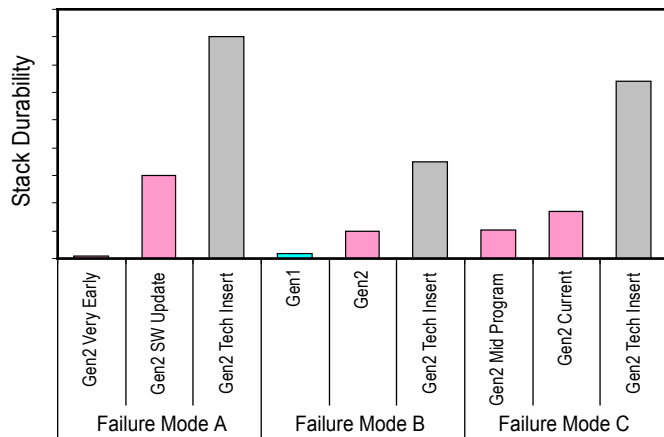


FIGURE 4. Stack Durability Projections: Stack Durability Improves as Successive Iterations Mitigate Failures

**Approach**

- Demonstrate FCEVs:
  - Deploy FCEVs in various terrains, driving conditions, and climates including cold weather.
  - Demonstrate two generations of fuel cell technology.
- Insert technology with recent advances to test Phase 2 learnings.
- Establish retail-like hydrogen stations for public fueling:

- Install and operate total of six fueling stations on east and west coasts.
- Explore hydrogen generation/delivery options such as electrolysis.
- Set up maintenance and service operations in support of FCEVs:
  - Train personnel in maintenance, fueling, technical support, and safety.
- Generate and report data required under the project:
  - Capture vehicle on-road and dynamometer test data.
  - Capture hydrogen infrastructure production/fueling data.
- Evaluate vehicle performance against targets:
  - Vehicle range, stack durability, cold weather performance.
- Focus on accumulating durability hours:
  - More intensive operation of vehicle fleet.
  - Work with commercial customers.
  - Fuel cell system accelerated durability testing.

**Results**

Phase 2 FCEVs were launched in the fourth quarter of 2007 in the Eastern and Western regions. All 42 Phase 2 vehicles were deployed by the end of the third quarter of 2008. Thirty-two vehicles completed their deployment at the end of the third quarter of 2009, and 10 baseline Phase 2 vehicles will continue to report data thru the third quarter of 2011 or until failure in order to support stack durability estimates. All 10 Technology Insertion vehicles were deployed by the end of the second quarter of 2010. Twenty project vehicles are now over three years old with 40-50 thousand miles.

Beginning-of-life chassis dynamometer testing was conducted for Phase 2 Chevrolet Equinox FCEVs, which included cold weather tests. Dynamometer testing was completed on one Phase 2 vehicle in September 2009 and one “Technology Insertion” vehicle in June 2010. Another round of dynamometer testing was completed in December 2010 on one Technology Insertion vehicle so the results can be compared to previous testing.

Shell Hydrogen is no longer participating in the project but GM will continue to utilize the Shell stations at JFK, Culver City, West LA, Torrance and the new opening of Newport Beach, CA in 2011. GM will continue to submit refueling data for the Ardsley, NY station, Los Angeles Airport station, and the Culver City station according to the DOE data templates. In addition, the FCEVs may refuel at any of the non-project refueling stations including Honeoye Falls, Rochester Institute of Technology, Monroe County, Fort Belvoir, White Plains, Santa Monica Blvd, Camp Pendleton, University of California, Irvine, and Shell, Torrance.

GM is also anticipating the opening of numerous hydrogen stations in California over the next 18 months, which are supported by Air Resources Board and Energy Commission grants. In total, 18 new and upgraded stations, a majority which will be located in the LA metropolitan area, will be able to support the FCEV fleet.

The hydrogen orientation program for emergency first responders continues to be delivered on request in cities where GM's DOE vehicles operate. To date over 1,500 people trained have been trained and new training sessions continue to be requested on a regular basis.

NextEnergy Center chaired task groups made up of a consortium of industry experts on hydrogen to provide feedback on the National Fire Protection Agency (NFPA) hydrogen codes. Task Groups completed their review of the latest NFPA revision. NextEnergy Center has successfully transferred hydrogen permitting database tools to new website. They coordinated with DOE and its partners to transfer the databases' layout and functionality to DOE ownership, for public benefit. NextEnergy has concluded their participation in the project as of the fourth quarter of 2009.

Three fuel cell systems began running accelerated durability testing in November 2010 and will continue to operate through 2011. In order to accelerate the learnings on the most recent technology stack design, these systems were instrumented with the same hardware as the Technology Insertion vehicles and are running accelerated durability cycles on test stands. These fuel cell systems operate under a stressful, accelerated protocol in order to capture early learnings.

## Conclusions and Future Directions

- FCEVs fully meet all functional needs for day-to-day use by individual customers.
- FCEVs are fully functional in sub-freezing cold weather conditions. GM FCEVs exhibited very fast cold-start/driveaway times under sub-freezing temperatures.
- Hydrogen Infrastructure has been demonstrated to be customer friendly in daily use by individual/retail and fleet vehicle operators in a "retail-like" self-service mode.

- Fuel cell stack durability rapidly increased and is expected to meet or exceed the DOE target of 2,000 hours during the completion of the demonstration project.
- GM is taking a significant step by introducing elements of our next generation fuel cell stack and system into a small group of Equinox FCEVs for continued Gen2 operation/demonstration during 2010 and 2011. GM believes that the learnings from the project so far have helped enable materials and operating controls within the fuel cell system that will clearly demonstrate the ability of the Gen2 vehicles to meet and exceed the project stack durability goal of 2,000 hours.
- Furthermore, GM looks forward to a continued relationship and collaboration with NREL in the areas of fuel cell stack and FCEV data analysis methods. GM believes that this work is helping establish a strong foundation for future work throughout the fuel cell industry to develop universally accepted metrics for assessing the performance of fuel cells and FCEV.
- GM will continue to provide data for baseline and Technology Insertion vehicles that are deployed and operating until the end of the project in the fourth quarter of 2011.
- GM will continue to provide lab data from accelerated durability testing to enhance understanding of fuel cell durability until the end of the project in the fourth quarter of 2011.
- GM negotiated its first agreements to purchase fuel "by the kilogram." GM continues to launch new relationships with hydrogen station partners outside original project stations:
  - Rochester Institute of Technology
  - Town of Hempstead, NY
  - SunHydro, Wallingford, CT

## FY 2011 Publications/Presentations

1. On May 9, 2011, GM participated and presented at the 2011 U.S. DOE HYDROGEN and FUEL CELLS PROGRAM and VEHICLE TECHNOLOGIES PROGRAM ANNUAL MERIT REVIEW and PEER EVALUATION MEETING.
2. An onsite review meeting with NREL, DOE, and GM personnel is planned for July 2011.