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FINAL TECHNICAL REPORT

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**Controlled Hydrogen Fleet and Infrastructure
Demonstration and Validation Project**



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1.0 Executive Summary

This report summarizes the work conducted under U.S. Department of Energy (DOE) under contract DE-FC36-04GO14285 by Mercedes-Benz & Research Development, North America (MBRDNA), Chrysler, Daimler, Mercedes Benz USA (MBUSA), BP, DTE Energy and NextEnergy to validate fuel cell technologies for infrastructure, transportation as well as assess technology and commercial readiness for the market. The Mercedes Team, together with its partners, tested the technology by operating and fueling hydrogen fuel cell vehicles under real world conditions in varying climate, terrain and driving conditions. Vehicle and infrastructure data was collected to monitor the progress toward the hydrogen vehicle and infrastructure performance targets of \$2.00 – 3.00/gge hydrogen production cost and 2,000-hour fuel cell durability. Finally, to prepare the public for a hydrogen economy, outreach activities were designed to promote awareness and acceptance of hydrogen technology.

DTE, BP and NextEnergy established hydrogen filling stations using multiple technologies for on-site hydrogen generation, storage and dispensing. DTE established a hydrogen station in Southfield, Michigan while NextEnergy and BP worked together to construct one hydrogen station in Detroit. BP constructed another fueling station in Burbank, California and provided a full-time hydrogen trailer at San Francisco, California and a hydrogen station located at Los Angeles International Airport in Southern, California. Stations were operated between 2005 and 2011.

The Team deployed 30 Gen I Fuel Cell Vehicles (FCVs) in the beginning of the project. While 28 Gen I F-CELLs used the A-Class platform, the remaining 2 were Sprinter delivery vans. Fuel cell vehicles were operated by external customers for real-world operations in various regions (ecosystems) to capture various driving patterns and climate conditions (hot, moderate and cold). External operators consisted of F-CELL partner organizations in California and Michigan ranging from governmental organizations, for-profit to and non-profit entities. All vehicles were equipped with a data acquisition system that automatically collected statistically relevant data for submission to National Renewable Energy Laboratory (NREL), which monitored the progress of the fuel cell vehicles against the DOE technology validation milestones. The Mercedes Team also provided data from Gen-II vehicles under the similar operations as Gen I vehicles to compare technology maturity during program duration.

Objectives

The main objectives of this project are summarized below:

- Record, collect and report data from fuel cell vehicles and the hydrogen fueling operations to validate Department of Energy (DOE) targets:

Performance Measure	2009	2015
Fuel Cell Stack Durability	2000 hours	5000 hours
Vehicle Range	250+ miles	300+ miles
Hydrogen Cost at Station	\$3/gge	\$2-3/gge

- Demonstrate the safe installation of hydrogen fueling stations and fuel cell service facilities as well as the safe operation of all Fuel Cell Vehicles (FCVs)
- Continuously update safety manuals and provide training
- Participate in various working groups to ensure continuous progress towards establishing Codes and Standards essential for FCV commercialization
- Raise public awareness of hydrogen technology and demonstration projects

Technical Barriers

This project addressed the following technical barriers from the 3.5.4.2 section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- A. Vehicles
- B. Storage
- C. Hydrogen Refueling Infrastructure
- D. Maintenance and Training Facilities
- E. Codes and Standards
- H. Hydrogen from Renewable Sources

Accomplishments

The following accomplishments stand out as the most important achievements of the program:

- Submitted over 120 CD/DVDs to demonstrate that fuel cell vehicles are on track to be commercially viable by 2015
- Successfully completed 7 years of external operations of 30 Gen I vehicles (5 years past the original target date)
- Internally and externally operated Gen II vehicles in a variety of driving patterns and weather conditions as well as validated the 250 mile range and cold-start capability down to -17°C
- Upgraded and operated Gen I vehicles with 70MPa tank system as well as optimized and tested Gen II's computer processing unit (CPU) software to further improve fuel economy and start-up time
- Transitioned fuel cell vehicle activities from R&D to mainstream commercial effort
- Completed construction of City of Burbank station with data acquisition (IRDA) communication as well as 35MPa and 70MPa fueling dispenser
- Finalized the development, construction and training for the NextEnergy hydrogen station for Michigan external customers fuelings

- Operated PG&E mobile refueler as well the LAX and CaFCP hydrogen fueling stations
- Conducted more than 640 vehicle refills since the beginning of the program at the PG&E mobile refueler and DTE Energy fueling station.
- Worked with California Energy Commission (CEC), California Air Resources Board (CARB) and other Original Equipment Manufacturers (OEMs) to prepare fueling infrastructure
- Organized over 180 media/outreach events to raise public knowledge of hydrogen technology and demonstration projects
- Participated in various working groups to ensure continuous progress with regards to Codes and Standards
- Demonstrate the safe installation of hydrogen fueling stations and fuel cell service facilities as well as the safe operation of all FCVs

2.0 Contribution to Achievement of DOE Technology Validation Milestones

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

- *Milestone 2: Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles (3Q2005)*

The best method to do a comparative fuel economy assessment is to utilize the DOE and EPA estimates published on web site

<http://www.fueleconomy.gov>. In addition to providing unbiased information, the DOE and EPA ensure that all vehicles are tested in the same manner so consumers can easily compare the fuel efficiencies of different vehicles. The EPA fuel economy for the F-CELL is 57 mi/kg H₂ (58 MPG gasoline equivalent) for the city and 58 mi/kg (59MPG gasoline equivalent) on the highway.

- *Milestone 5: Validate fuel cell demonstration vehicle range of ~200 miles and durability of ~1,000 hours (year-end 2006)*

The Mercedes Team, as well as three other industry teams, is providing National Renewable Energy Laboratory (NREL) with on-road vehicle data collected from the fuel cell vehicles operated in various climate regions. DaimlerChrysler is also providing NREL dynamometer testing data from a representative sample of the hydrogen vehicles. NREL published and presented composite data products that report on the progress of the technology made towards the DOE milestones.

- *Milestone 6: Validate vehicle refueling time of 5 minutes or less (4Q2006)*

Due to regular use by customers, the fuel cell vehicles were refueled on a consistent basis at a variety of fueling stations. Various technologies were tested and demonstrated throughout the infrastructure network and results were reported within the project. This supported the continued improvement of refueling time. The permanent station utilizing electrolysis at the DTE/BP station in Southfield, Michigan currently provides an average refueling time of 3.6 minutes. Average fill volumes have been less than 1 kg at fueling rates of about .25 kg/minute. Although this refueling time is within the 5 minute objective, a target of less than 3 minutes is essential for customer friendly operation, even as filling volumes increase. With new technologies including pre-cooling and proper communication between the vehicle and fueling station, it is expected that this refueling time can be maintained or reduced.

- *Milestone 8: Demonstration (on a vehicle) 2.0kWh/kg and 1.2kWh/L compressed storage tanks (2Q2008)*
The compressed hydrogen storage tank (5000 psi) that was used in both the F-CELL and Sprinter fuel cell vehicles realize an energy density of 0.6 kWh/l.
- *Milestone 9: Validate FCVs with 250-mile range, 2,000-hour fuel cell durability, and a hydrogen cost of \$2.00-\$3.00/gge (based on volume production) (2Q2008)*
The Mercedes Team collected raw data from the fuel cell vehicles currently under daily operation. The data was provided to NREL which shared the composite data of four industry teams.
- *Milestone 10: Validate FCV's 2,000 hour fuel cell durability using fuel cell degradation data (4Q2009)*
- *Milestone 11: Validate cost of producing hydrogen in quantity of \$3.00/gge untaxed(2Q2008)*
BP, through its continuing and future testing of technologies, developed the necessary tools to understand how the hydrogen cost target can be achieved economically and efficiently. BP assessed with its suppliers several technologies to understand their current status and potential of meeting the \$3.00/gge target untaxed by 2008. The following is a list of a few of the technologies reviewed to date: H₂Gen 2000, Idatech Combined Heat and Power technology, Air Products Harvester, Proton Energy High Pressure PEM system with Electrochemical Compression, and GE Autothermal Reformer.
- *Milestone 12: Validate cold start capability at -20C (2Q2011)*
The Mercedes Team provided Gen II Raw Data to NREL to demonstrate that the fuel cell vehicles meet cold start capability at -17C, while reaching 50% of max. power within 30 seconds. Additionally, engineers tested Gen II fleet in temperatures ranging from -30°C (Sweden) to 50°C (Death Valley).
- *Milestone 22: Five stations and two maintenance facilities constructed with advanced sensor systems and operating procedures (4Q2006)*
 - Maintenance Facility: The Mercedes Team established three service stations, one for each of the three geographical areas (Northern California, Southern California, and Southeast Michigan). Detailed safety procedures and precautions were implemented from the initial design to the continued operations. Maintenance facilities underwent simulation modeling exercises and were upgraded with the appropriate sensors and safety equipment.

- Fueling Stations: The BP hydrogen station at NextEnergy in Detroit complied with NFPA52 guidelines for fire and gas detection systems. Detailed safety procedures and processes were implemented in the design and construction of the unit (i.e. HAZID, etc.). These rigorous safety analysis tools, including third party peer review, were also applied for station commissioning

3.0 Vehicle

3.1 Introduction

To achieve the project goals, the Mercedes Team deployed 30 Gen-I vehicles into customer hands for real-world operations in various climatic regions of the United States. The Team provided data from Gen-II vehicles under the similar operations as Gen-I vehicles to compare technology maturity during program duration. All of the vehicles within the DOE demonstration program were equipped with a customer friendly FDA data acquisition system that automatically collected statistically relevant data for submission to NREL as well as engineer analysis for technology improvement. The Mercedes Team created a broad database so that NREL could thoroughly evaluate the progress of fuel cell vehicles and hydrogen infrastructure against the DOE technology validation milestones.

To raise public awareness of hydrogen technology and demonstration projects, the Mercedes Team aligned its communication activities with the goals of the DOE. In addition, project safety was maintained through continued inter-team communication, vehicle and infrastructure training, employee and customer education, and emergency responders training.

3.2 Data Collection

Data recording, data collection, and data integrity is paramount for the Department of Energy project. The Fleet Data Acquisition (FDA) included two phases corresponding to each generation of fuel cell vehicle, A-Class F-CELL and B-Class F-CELL, as the focus of the project progressed. The Gen I A-Class exclusively consisted of fleet customers while US Gen II B-Class exclusively consisted of private individuals. Each customer type presents unique challenges for data collection that were met to provide high quality data.

For Gen I, an IBM supported FDA infrastructure was implemented. This consisted of an in-vehicle computer (“CarCube”), site specific Local File Servers (LFS) at each customer location, a central file server and necessary infrastructure to create a secure network. Each time an A-Class F-CELL returned to the customer site, all data stored on the CarCube was securely and automatically transferred wirelessly to the LFS as shown in Figure 3.2.1. Next, the LFS, serving as a data gateway, transferred the on-road data via Virtual Private Network (VPN) to a Central File Server (CFS) for aggregate fleet wide storage and management, and was subsequently deleted from the LFS. With this system, on-road data was exported to the Mercedes Data Management Team for verification before submittal to NREL.

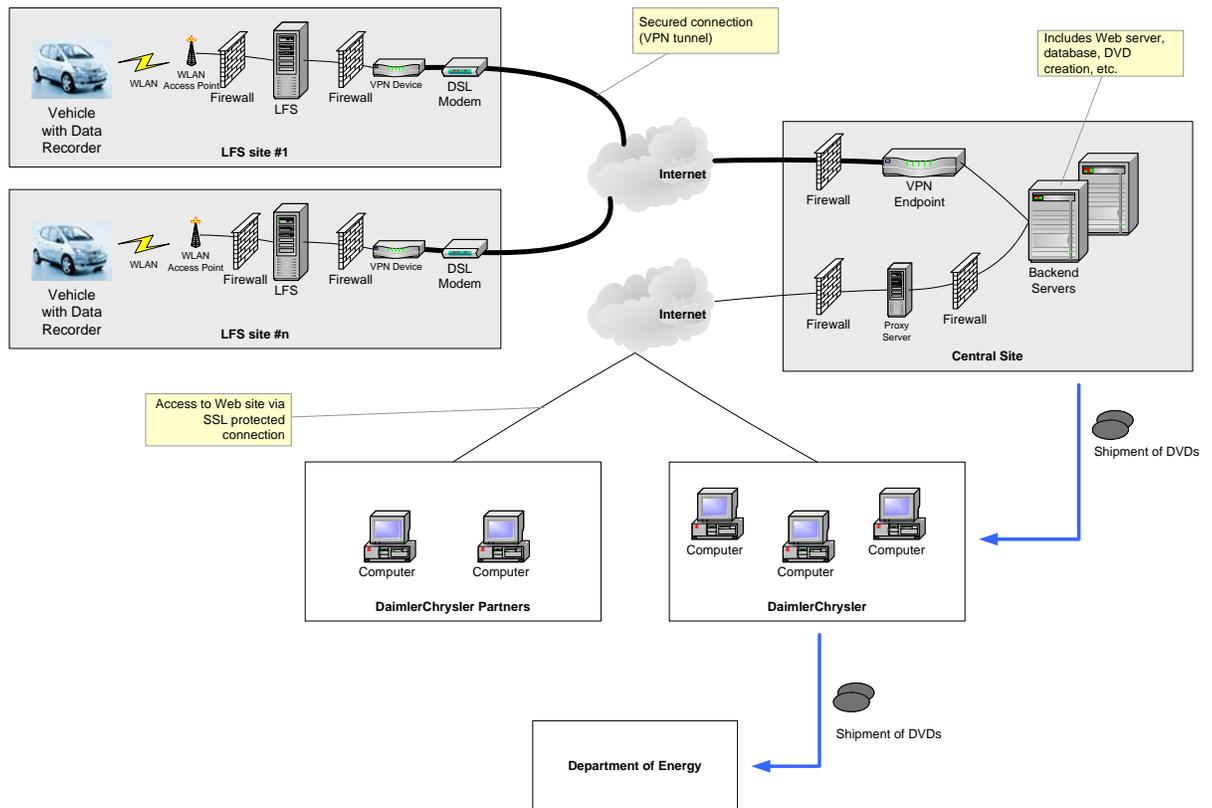


Figure 3.2.1 Overall Infrastructure and Data Transmission Setup for Gen I

As fuel cell vehicles progressed toward commercialization so that FCVs may be operated as conventional vehicles, it became apparent that the Gen I F-CELL FDA infrastructure was not optimal for private individuals. As a result, a different FDA strategy was developed and implemented. In parallel to the Gen II research and development phase in 2010, the Mercedes-Benz Team developed and implemented a new in-house FDA infrastructure as shown in Figure 3.2.2. This new design included a scaled back infrastructure consisting of a workshop LFS placed at each maintenance facility as opposed to each customer location. The data was downloaded each time Gen II vehicles entered the workshop for scheduled maintenance, and then the LFS securely transferred the data to the CFS. Due to the amount of data accumulating between transfers, an upgraded CarCube with increased performance as well as storage capacity was built into each vehicle within the project.

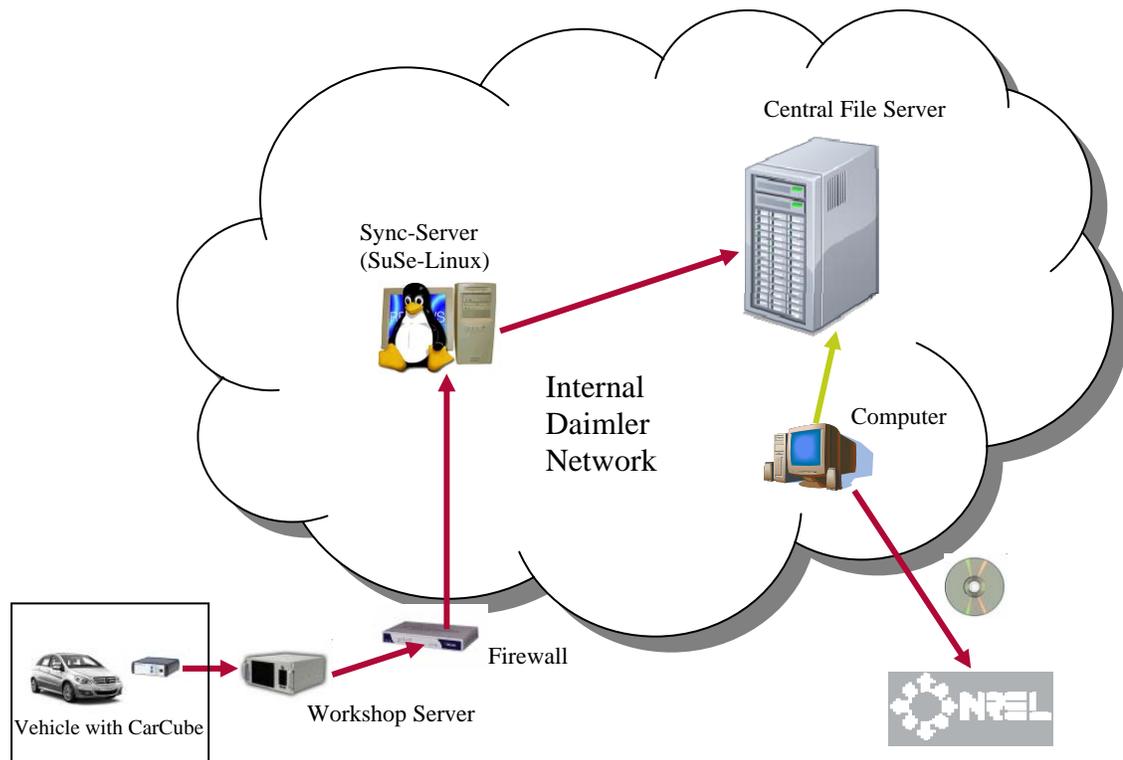


Figure 3.2.2 Overall Infrastructure and Data Transmission Setup for Gen II

High quality data and data integrity is a high priority and was maintained throughout the transition and after implementation of the new FDA infrastructure.

3.3 Service Facilities

As shown in figure 3.3.1, the Mercedes Team established three regional stations, one for each of the three geographical areas (Northern California, Southern California, and Southeast Michigan) to support the fuel cell vehicles. All three regional facilities had the tools, equipment and infrastructure required to ensure that all of the customer service needs were met and that all vehicle maintenance and data collection were performed in a timely fashion.

The Team was among the first to build a cost effective hydrogen safe maintenance facility utilizing Computational Fluid Dynamic (CFD) modeling. The Southern California (Long Beach) facility was constructed specifically for hydrogen vehicles and allowed service of the vehicles with full hydrogen tanks. Prior to the construction of this facility, all fuel cell vehicles had to be completely defueled prior to servicing in this maintenance site. The Team shared the innovative methodology and recommendations with the DOE through a demonstration tour as well as a 12 page summary report.

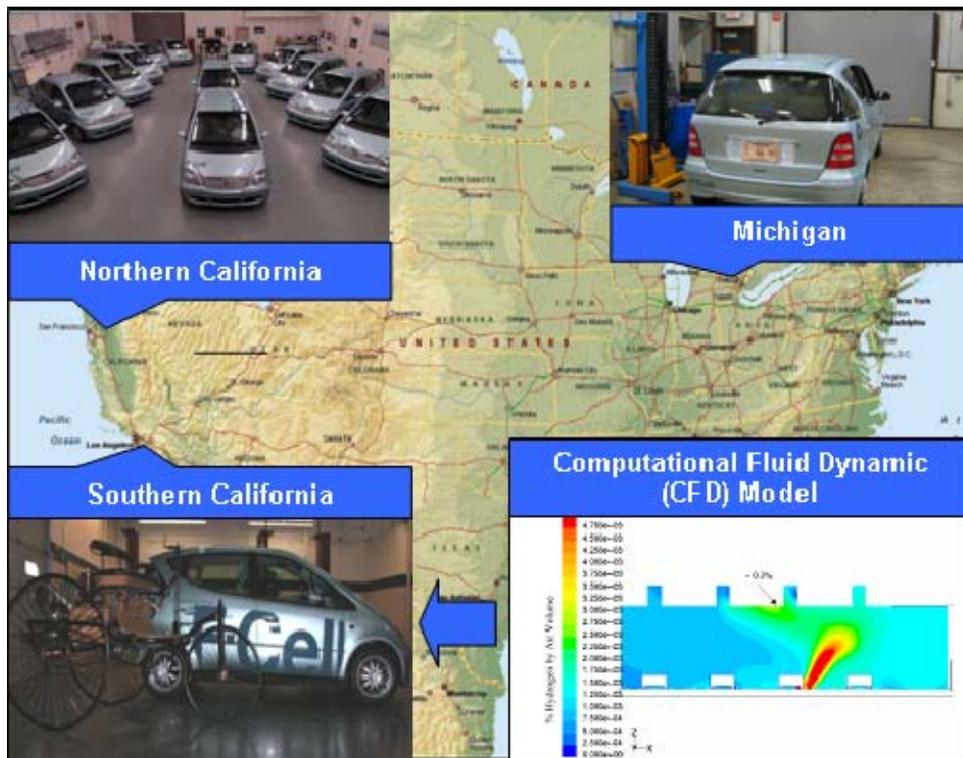


Figure 3.3.1 Locations of Vehicle Workshops

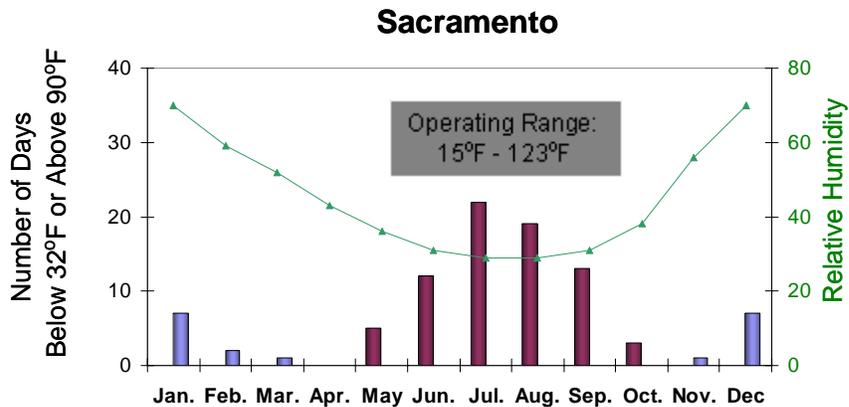
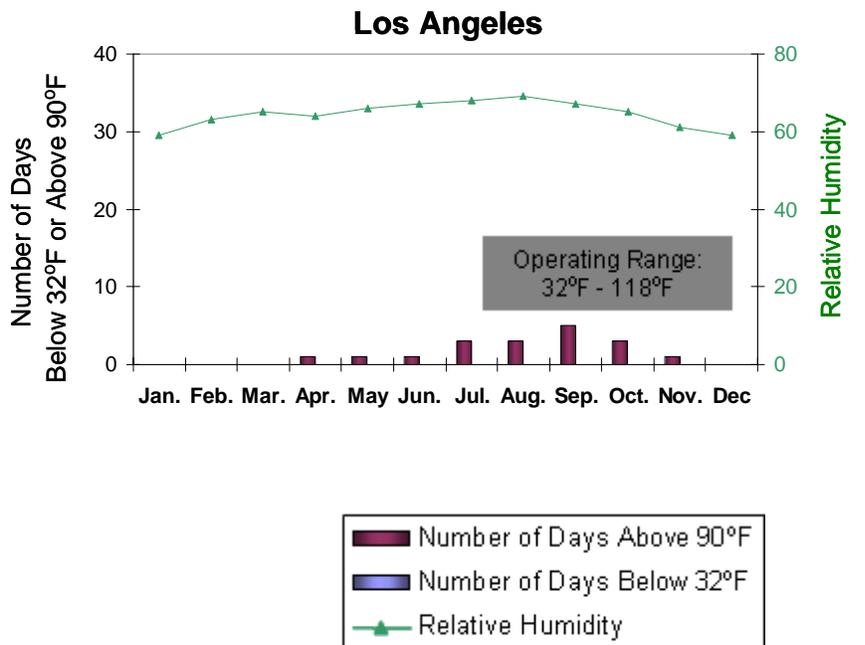
To embrace DOE’s “lighthouse” vision, the primary workshop was relocated from Sacramento to Long Beach, California. One service center remained in Palo Alto for Northern California customer support. The move

to Southern California provided an impetus to more closely analyze the infrastructure landscape and station access for near-future fuel cell vehicle commercialization as well as for immediate need to fuel 70MPa vehicles for testing and operating purposes.

3.4 GEN I Fuel Cell Vehicles

3.4.1 GEN I Vehicle Deployment

Gen I vehicles were deployed in 2005 and were driven by customers until 2009. Throughout the years, the Gen I fleet was driven approximately 350,000 miles under real world conditions in three ecosystems including Michigan, Northern California and Southern California. As shown in Figure 3.4.1.1, these selected regions provided a complete breadth of climate conditions, ranging from 3°F in Michigan to 123°F in Sacramento and 93% relative humidity in San Francisco to 51% relative humidity in Michigan.



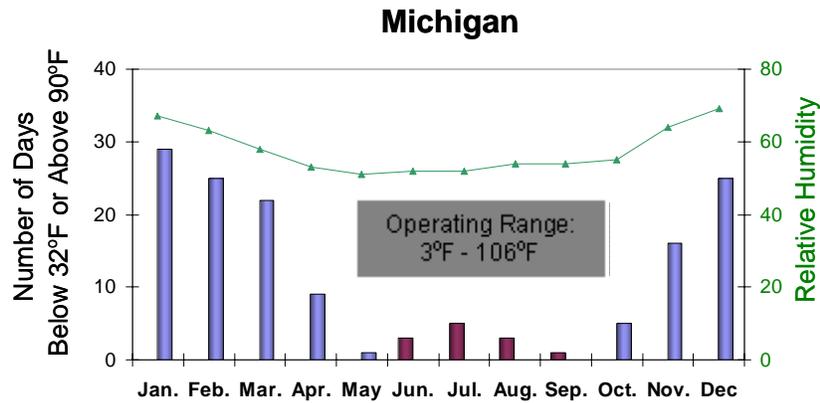


Figure 3.4.1.1 Graphs Demonstrating Gen I F-CELLs Operated Under a Variety of Climate Conditions

The three regions also provided a full range of terrain and traffic conditions, from congested city driving highways in Southern California to rural roads in Michigan (see Figure 3.4.1.2).



Figure 3.4.1.2 Operations of Gen I Vehicles

The A-Class fuel cell vehicle deployment commenced in 2005 after a two year period of preparation. The fleet consisted of 28 A-Class vehicles deployed in California and Michigan. In addition, two fuel cell Sprinter vans were operated in Southern California. Over the next four years, the Team serviced, repaired and maintained the vehicles, cultivated customer relationships and worked to facilitate station access. In support of this deployment, a hydrogen safe workshop was built in 2006 at the Long Beach facility with funding provided in part by South Coast AQMD. A second hydrogen safe workshop was constructed at the headquarters of MBRDNA in Palo Alto from which technicians were able to support vehicles deployed in Sacramento after the main fuel cell office moved down to Long Beach from Sacramento in 2008.

Over the course of 2005, 16 vehicles were delivered to a total of nine customers. By 2006, all vehicles had been deployed. Customers were mostly public sector institutions, university or governmental, and a few were private sector entities. Despite a limited infrastructure, many of them put a good number of miles on their cars by incorporating them into their daily work routines and using them as commute vehicles. Other customers had less flexibility in terms of how they could use the vehicle and were otherwise more constrained by the very limited hydrogen infrastructure. 2007 saw the addition of a couple of new customers who replaced those which did not extend their lease. By 2008, the Mercedes Team was also operating two 700 bar A-Class vehicles and fueling at the new 700 bar station in Burbank, California.

During 2008 and into 2009 as vehicle leases expired, ever more A-Class F-CELLs were removed from operation as the focus shifted to preparations for deployment of the B-Class vehicle.

Altogether, the A-Class fleet was driven much longer than originally anticipated and more than proved its worth. Although Gen I FCVs were designed for a 2-year operation, A-Class F-CELLs outperformed engineering expectations as the vehicles operated for over seven consecutive years. Since the inception of this demonstration project, the Mercedes Team submitted CDs of Gen I Raw Data to NREL and demonstrated that A-Class F-CELLs exceed the 2,000 hour stack durability target.

3.4.2 GENI Vehicle Upgrade and Deployment

Software Improvement

The Gen I software was recoded to incorporate a new start/stop operating design. The revised software disconnected the fuel cell stack during idle phase to optimize vehicle operation. The modified code was verified through dynamometer and in-vehicle endurance testing as well as through real world operation. The tests clearly showed a positive effect on the

vehicles performance, especially on fuel consumption. In 2008, selected F-CELLs within the DOE project were reprogrammed (flashed) with the revised software after it met all engineering specifications and Daimler's corporate guideline. Data pertaining to performance test and operation were provided to NREL.



Figure 3.4.2.1 Dynamometer Testing of Gen I Vehicle

Start/stop software improvements were also developed for second generation vehicles, or the B-Class F-CELLs. The new Gen II start/stop algorithm optimized the interface between the fuel cell and energy management system, thereby decreasing the time to restart the fuel cell system after being disconnected. This software was integrated into the design of all Gen II vehicles.

Tank Upgrade

The 28 original Gen I F-CELLs attained 5,000 psi hydrogen tanks. During the course of the program, multiple Gen I Vehicles were replaced with A-Class F-CELLs upgraded with 10,000 psi hydrogen tanks and corresponding components such as pipes, valves and tank controller units. The 10,000 psi storage system substantially increased hydrogen storage capacity when compared with the previous 5,000 psi hydrogen storage system. The main purpose of the tank upgrade was to take advantage of increased hydrogen storage capacity and increase demand for 10,000 psi infrastructure required for GEN II Vehicles and future generations of vehicles.

In 2008, the upgraded vehicles began internal operations in Southern California so that the 70MPa Burbank hydrogen fueling station may be utilized and vehicle/infrastructure data may be collected and submitted to NREL (see Figure 3.4.2.2). Data collection and internal driving operation for the upgraded GEN I Vehicles were completed in the same manner as the

original vehicles with 5,000 psi tanks. During the last California Fuel Cell Partnership (CaFCP) Road Rally from Mexico to Vancouver, Canada, this particular vehicle held its ground admirably vis-à-vis the newer fuel cell models driven by the other automakers.



Figure 3.4.2.2 A-Class F-CELL with Upgraded Tank System

3.4.3 Customer Acceptance and Perception Study (CAPS)

The Mercedes Team and the California Partners for Advanced Transit and Highways (PATH) at University of Berkeley conducted a Customer Acceptance and Perception Study (CAPS) of F-CELL Fleet drivers' attitudes and perceptions towards hydrogen and alternative fueled vehicles over time. Samples were taken in calendar year 2006 from F-CELL partner organizations in California and Michigan consisting of governmental organizations, for-profit, and non-profit entities. The study employed a longitudinal study design with three rounds of surveys in order to examine potential trends in F-CELL driver perceptions over time. The driver assessments, not being represented for the broader U.S customer base, yielded several key findings:

- Respondents believed the F-CELL was easy to use and did not require much time to learn how to operate.
- Both F-CELL and refueling perceptions were positive. Those who were initially uneducated and cautious with the F-CELL grew to be more comfortable over time. This finding was consistent with the customer driving pattern as they doubled the average weekly mileage from 2005 to 2006 due to their increased driving and fueling experience.
- The limited network of hydrogen which existed during this study placed constraints on participants. Respondents indicated they would be willing to drive approximately 9 miles to find a hydrogen fueling station.
- Range was a crucial point for the acceptance of the technology. This was of particular importance with regard to the switch from 35MPa to 70MPa.

As a follow up to the 2006 CAPS, the Mercedes Team initiated another research study to gain insight on the impact of the intensifying media coverage on electric drivetrain (fuel cell, battery electric vehicles, hybrids and plug-in hybrids) on consumer adoption of hydrogen fuel cell technology in the United States through 2020.

The 2007/2008 CAPS research also consisted of quantitative analysis performed on data gathered from F-CELL drivers as part of the 2006 Study. This analysis showed that the following attributes were important in selecting Gen II fuel cell partners:

- Drivers with scientific background/training
- Drivers with alternative fueling experience
- Drivers who are willing to train and do own vehicle fueling
- Partners who are open to a minimum mileage requirement in their contract

- Partners with approximately 15-25 drivers per vehicle
- Drivers who will travel along both city AND highway
- Drivers with “close” proximity to fueling station
- Partners who will make vehicles available for constant driver rotations, i.e. drivers can expect to drive the vehicles frequently (almost daily)
- Drivers who are informed and aware of the limitations (i.e., range limitations) of fuel cell vehicles

3.5 Gen II Fuel Cell Vehicles

3.5.1 Internal Operations and Testing of GEN II Vehicles

Thorough testing of the Gen II vehicle and component/system was essential to validate the new powertrain and overall B-Class F-CELL reliability since it was the first Mercedes fuel cell vehicle to be driven by private customers. A variety of tests were completed on Gen II fuel cell vehicles including durability, dynamometer and performance tests executed in extreme hot and cold climates. Gen II fuel cell vehicles were also tested through internal customer operations in multiple climates, terrains and driving environments to simulate real world conditions.

Gen II testing commenced in 2007 with fuel cell and fuel cell system bench tests performed by a research facility. The data generated from the bench tests were submitted to NREL for analysis and served as a basis to verify 2,000 hour stack lifetime requirement as specified in DOE's Technology Validation Milestone 10. Once the fuel cell system was validated, dynamometer testing was performed to confirm fuel economy, range, and power specification of the B-Class F-CELL vehicle. These tests included warm/cold UDDS cycles, highway cycle, and Step Test (Ramp Up / Ramp Down).



Figure 3.5.1.1 B-Class F-CELL Performing Dynamometer Tests

After dynamometer testing was completed, Gen II vehicles were internally operated in a plethora of climates conditions including diverse ambient temperatures, pressures, and humidity with the purpose of validating engineering requirements, including reliability and durability. In extreme cold conditions, the B-Class F-CELL was subjected to a thorough schedule of vehicle cold start (-30°C) and performance tests. These tests included

successfully and repeatedly starting FCVs with frozen fuel cell stacks and reaching 50% maximum power within 30 seconds.



Figure 3.5.1.1 Gen II B-Class F-CELL During Cold Weather Testing

B-Class FCVs were also operated in the harsh deserts of Idiada, Spain as well as Death Valley, USA in an additional extensive schedule of engineering and customer satisfaction tests. For example, multiple vehicles were tested in high temperatures (50 °C) and dry climates to verify cooling systems as well as refine control strategies. In both extreme climates, the Gen II vehicles performed to customer expectations and provided data to validate DOE targets.



Figure 3.5.1.2 Hot Weather Testing of Gen II B-Class

In addition to extreme hot weather testing, road durability analysis was imperative to ensure that FCVs meet customer expectations and vehicle reliability requirements set for by Daimler engineers. As a result, extensive real world durability tests were conducted within cities of prospective FCV markets as well as in regions with extreme climates. To simulate real world conditions, carefully crafted test plans and routes were driven by test

operators around the clock in many locales. Durability tests were also used to compare control strategies effect on fuel cell stacks.



Figure 3.5.1.3 Stop/Start Gen II Durability Vehicles

Engineers optimized and improved the stop/start functionality in the B-Class F-CELL software compared to the Gen I A-Class. The improvements in the interface between the fuel cell and the energy management system decreased the time required to restart the fuel cell system after being disconnected. This additional software improvement was included in the design and verification process.

Through testing, Stop/Start strategies were proven to have a significant impact on fuel cell stack degradation. For example, durability tests were conducted on two vehicles, one with stop/start enabled and the other vehicle with the functionality disabled. Specific routes were chosen and additional idle phases added to stress and exaggerate the differences between the fuel cell stacks. The vehicles were also carried out in benchmark dynamometer tests to monitor powertrain performance at specific intervals throughout the duration of the 2,000 operation hour test period.



Figure 3.5.1.4 Stop/Start Gen II Durability Vehicles

3.5.2 External Operations of GEN II Vehicles

Prior to deploying Gen II vehicles into customer hands, the Mercedes Team transitioned FCV activities from R&D to mainstream commercial activities. B-Class F-CELL vehicles were incorporated into Mercedes' "normal processes" within departments such as Warranty, Customer Assistance, Parts & Distribution as well as Roadside Assistance and Sales.

Unfortunately, due to limitation of fuel availability, the Mercedes Team had to hand select Gen II FCV customers to ensure that these individuals were in close proximity to the few hydrogen fueling stations functioning in Southern California. Once the customers were chosen, the customer acquisition process became the responsibility of the dealership. Customers were then required to undergo the same documentation review and qualification processes as typically expected.

Mercedes-Benz began leasing B-Class F-CELL vehicles to external customers in Southern California at the end of 2010. The first delivery took place on December 14, 2010 at the Mercedes-Benz Dealership in Newport Beach, California. Subsequently, an additional 19 cars were leased to customers in Southern California, all within a short driving distance of a hydrogen fueling station located near two Mercedes-Benz dealerships.



Figure 3.5.2.1 Gen II Customers

Customers fuelled and drove B-Class F-CELL vehicles in a variety of regions providing a complete range of climate and traffic conditions from congested city driving to open road highways to rural roads. All Gen II vehicles were equipped with extensive data acquisition and reporting capability, allowing the Mercedes Team to generate substantial vehicle raw data for submission to NREL.

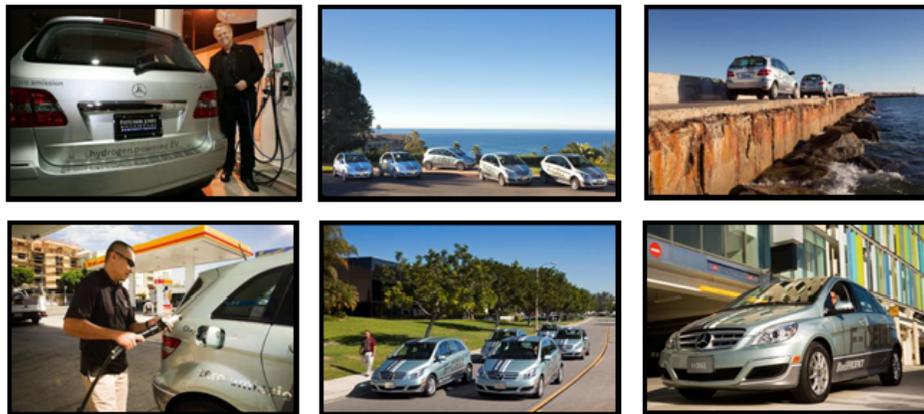


Figure 3.5.2.2 Operations of Gen II Fuel Cell Vehicles

The Customer Research Center in Germany devised a survey for initial customer feedback. Five interviews were conducted with the first customers. A follow-up interview will be conducted in one year with a larger sampling to gauge feedback relative to long-term satisfaction. Preliminary feedback shows that the customers are very satisfied with the vehicle and excited about the technology. All of them expressed frustration with the lack of an adequate infrastructure and the fact that the few stations that do exist are sometimes not working.

The greatest challenges in delivering vehicles to customers centered on issues related to fuel availability. A significant number of interested parties do not reside within a conveniently short enough distance to an available hydrogen station. With the small number of available stations, their limited dispensing capacity, and sporadic downtimes, deliveries of vehicles were necessarily centered around fuel and station availability. For example, because of the uncertainty as to whether the 700 bar Culver City station will remain open beyond 2011, the customer search was confined to the areas of Torrance and Orange County. In the meantime, the one station in Orange County at UC Irvine has reached capacity. Customers can often expect to have to wait in order to fill their vehicle. This had led to a situation where the only truly viable geographic area from which to select customers at present is Torrance.

While many of the challenges associated with the deployment of the B-Class were present during the operation of the A-Class, progress has been made on many fronts, and not only in terms of the technological maturity of the vehicle itself. Over the years, automakers have learned to work together to find a common solution to many of their mutual problems. For example, based on their common efforts, uniform customer fueling training was initiated and automakers themselves were able to train their customers as opposed to relying solely on the station owners and operators. Since 2008, the automakers have been working together to find a common understanding of where to build the next stations in order to accommodate the needs of the various fleets. This information, together with estimated deployment numbers, has proven invaluable to state agencies which are awarding funds for the hydrogen fueling stations. Much work lies ahead, but the commitment remains and MBRDNA will continue to work towards the goal of commercializing the technology by 2015 by perfecting its B-Class fleet operations over the next two years and working together with other stakeholders to move the emerging California market further to maturity.

3.5.3 World Drive

To compliment the internal and external operations of the Gen II vehicles, three B-Class F-CELLs were driven around the world, including four continents and 14 countries. Setting out from Stuttgart in Germany, three B-Class F-CELLs commenced a 125-day circumnavigation of the world to confirm technical maturity of fuel cell technology, as well as the suitability for everyday use of the vehicles. On February 25th, the F-CELL World Drive embarked on the second leg of its tour when three B-Class F-CELL set out from Fort Lauderdale on the East Coast of the United States across 8 cities including New Orleans, Miami, San Antonio, Phoenix, Los Angeles, Sacramento, Salem and Seattle.



Figure 3.5.3.1 Operations of Gen II Fuel Cell Vehicles

On March 23rd, the World Drive ended the US leg in Seattle and continued the tour in Australia. On April 22nd, the F-CELL World Drive departed from the "Auto Shanghai" show in China for the last and longest leg of its round-the-world tour. From Shanghai, three B-Class F-CELLs set out to Kazakhstan, Russia Finland, Sweden, Norway and Denmark back to Germany, where the tour began in January. Local events in these various countries ensured that fuel cell technology makes a lasting impression. On June 1st, the fuel cell vehicles went back in the Mercedes-Benz Headquarters in Stuttgart. Hundreds of people welcomed the convoy after its 125-day trip. On that day, Daimler AG and Linde Group announced joint project for building of 20 hydrogen filling stations in Germany.



Figure 3.5.3.2 World Drive Tour

Vehicle Raw Data generated from the 70,000 miles generated from the World Drive was collected and submitted to NREL for analysis.

4.0 Infrastructure

4.1 BP

Introduction

The first objective of the project was to evaluate the operational performance and economic feasibility of distributed hydrogen sites, including the safety of these systems. To this end, hydrogen sites in Detroit, Michigan and Burbank, California were developed for this DOE demonstration program. In addition, BP provided a full-time hydrogen trailer at San Francisco (at PG&E Inc.) and at Burbank to support the refueling program when on-site hydrogen was unavailable. The energy partner also allowed fueling at an Air Products hydrogen station located at the Los Angeles Airport and CAFCP station located in Sacramento, California. Site performance, safety, and costs were evaluated. The second objective was to glean key lessons and knowledge on such operations, so that future efforts could build on this knowledge base for scale-up purposes.

Burbank Station

Station Specifications

- On-site SMR hydrogen production
- 240 kg
- Up to 108kg/day
- 350 and 700 bar



Figure 4.1.1 Burbank Station

Permitting and Construction

A great deal of time was spent up front with local permitting authorities to make the individuals aware of BP's design and of the applicable codes and standards, as well as to address any questions. The City of Burbank's local government and permitting authorities were extremely proactive in working with BP to meet the city's needs and also achieve an efficient successful project outcome. This included areas like

the following: site permitting; meeting the requirements for third-party certification of the reformer module; and rapid approval of the California Environmental Quality Act (CEQA) assessment.

During the fourth quarter of 2007, BP selected Air Products as the primary engineering and construction contractor for the new Burbank station. A site survey was completed and the station layout agreed and approved by the City of Burbank. All equipment was ordered and detailed engineering design efforts were largely completed by the end of the third quarter.

In the second quarter of 2008, P&ID's and necessary project safety reviews were completed and necessary project safety reviews were finished. Also, the station equipment and the facility underwent a Hazard Identification Analysis (HAZID) study. No major findings in either safety review were found and the minor items were incorporated into the station design. A Mitigated Negative Declaration / Environmental Assessment was issued on June 26th for a 20-day public comment period and all permit applications were filed by the end of the June.

In the third quarter, all CEQA and National Environmental policy Act (NEPA) permits were received and construction began August 4, 2008. Most of the construction project was completed in October with Air Products completing the hydrogen construction, testing and commissioning for a mid-November startup.

Finally, during the fourth quarter, construction of the hydrogen station was completed with very good cooperation from the City of Burbank. Their strong participation was a key contributor to the overall success and relative "ease" with which the station was the completed.

Operations

The Mercedes Team participated in training at the new permanent hydrogen station at the SMUD facility on February 5 and 6th of 2008. In addition to the Mercedes Team, SMUD customers, California Department of Food and Agriculture customers and Sacramento Municipal Fire Department customers also participated in the training.

The fueling system was filled with hydrogen from a tube trailer and filled 350 bar vehicles the City of Burbank operated. Additionally, 70MPa vehicles with IRDA system were fueled to full capacity.



Figure 4.1.2 70MPa Fueling at Burbank Station

PG&E Mobile Refueler

Station Specifications

- Hydrogen produced by Remote SMR
- Storage capacity of 150kg
- 10-15 kg/day



Figure 4.1.3 PG&E Mobile Refueler

Operations

PG&E, BAAQMD and Mercedes A-Class vehicles regularly used the mobile unit located until 2008. The unit was also used for refueling Ford vehicles located in Sacramento. The station was used by other customers such as the CaFCP and some of the other OEM's. The unit was refilled a number of times and produced refueling data that was provided to the DOE on a regular basis. At the completion of the

demonstration project timeframe, the mobile refueler was removed from service.

Southern California – LAX (Non-DOE)

Station Specifications

- Hydrogen produced by on-site electrolysis
- Capacity of about 25 kg/day



Figure 4.1.3 LAX Station

Operations

While the station was not funded under this Demonstration and Validation Project, it regularly served Mercedes/DOE customers as well as Ford, Toyota and Honda. BP terminated its operation of Praxair LAX station during the third quarter of 2008. BP de-branded the station and the site remained available to customers that had contracts with Praxair until the second quarter of 2009.

Northern California – CAFCP (Non-DOE)

Station Specifications

- Liquid hydrogen supply with gaseous onboard storage
- HF-150 mobile fueler
- Can fuel 17-20 cars/day

Operations

The station was open to non-CaFCP customers. A number of Mercedes and Ford customers successfully used the station on a regular basis. The station had the highest number of refuelings per month.

During the third quarter of 2008, BP and its partners successfully transferred operational responsibility for this station. As part of the transfer, the energy partners had the site evaluated for any remaining/residual environmental impact, and the independent inspection showed no environmental issues or concerns, freeing the property for transfer. The station remained open and functioned normally after the completion of the transfer.

Detroit, Michigan Station

As BP and NextEnergy collaborated on the Detroit, Michigan site, the details are summarized in the NextEnergy portion of the report.

Summary of Lessons Learned***Cost of Hydrogen Production-Delivery***

Currently, site costs (\$mm) are spread over little volume (kg), leading to high (\$/kg) values for hydrogen. Site real estate costs add further expenses. In spite of these high costs, it is believed that as hundreds of large, commercial stations (i.e. 1500 kg/day) with multiple dispensers are built, the costs will stabilize and eventually trend lower due to standardization, wider acceptance, and increasing number and competitiveness of the available suppliers.

Manufacturing and Supplier Base

The supplier base is currently a constraint and will likely be an issue for a considerable period of time. There are only two reliable industrial gas companies, with an estimated combined capability to design and start up five to ten hydrogen stations per year in the near term. Additionally, equipment such as compressors, storage tubes and dispensers require long lead times (i.e. 6-12 months). These issues will pre-empt the ability of the USA to construct hundreds of sites for the next several years. Only when supplier resources increase in capability and competitiveness can the supplier costs diminish significantly and site development times shorten.

In addition, future projects should incorporate innovative technological approaches to refuel fuel cell vehicles. For example, rather than maintaining three discrete pressure levels and, therefore, three sets of pressurized tubes, future efforts could incorporate a “cascade fill” approach in which the compressors raise the hydrogen’s pressure from a relatively low value up to 350 bar (using a single storage pressure and inter-stage compressor cooling). This may be accomplished by incorporating novel hydrogen storage technologies, such as using metal powders to store high volumes of hydrogen on high surface substrates. Such a technological approach would reduce the tube storage requirements and capital required, plus, it would eliminate the use of 700 bar pressures, which add costs and complexities to the system due to the safety concerns at these pressures. This type of approach would require future designs of FCVs and refueling sites to be “co-designed” by the OEMs and hydrogen producers to ensure an optimum design and most efficient use of capital in both the vehicles and at the hydrogen refueling sites.

Engineering and Permitting

As the infrastructure for hydrogen evolves, new standards will be required for the design, fabrication, inspection, testing, certification, and permitting for hydrogen stations; likewise, amendments of existing regulations, codes and standards, and the creation of new standards will be required. This process has already begun with efforts by California’s Department of Weights and Measures. These efforts have

highlighted the need to ensure that designs and regulations proceed in an aligned step-wise fashion. Should states promulgate a typical retail site type of regulation regarding dispenser precision, no existing dispenser could meet the accuracy that would be required of retail sites; today's hydrogen dispensers are precise to only several percent error while typical required precisions for retail fueling sites are about 0.1%.

As for the permitting process, in general, it is filled with many unknowns. Permitting through local authorities, especially fire and electrical authorities, is different from city to city, from inspector to inspector, and it varies with their familiarity (or lack thereof) with hydrogen specifications and safety requirements. For example, as mature as the current gasoline retail business is today, there are still vastly different requirements from local fire officials, let alone from state agencies. Standardization and training may help offset this issue, but getting the local authorities involved early in the process can generally be a valuable timesaver. Also, with the number of stations planned for California, streamlining the CEQA and AQMD requirements and the NEPA guidelines (if the effort's funding is federally supported) will be needed to facilitate the development of a large number of stations.

Because of the industrial aspect of the equipment used, third-party certification has been demanded as an additional assurance measure by some electrical inspectors who are unfamiliar with industrial processes, and it has often been challenging, costly, and time-consuming to obtain. This can be attributed to unfamiliarity of the inspectors with the new technologies used at a hydrogen site and lack of process experience with this type of equipment. Therefore, a lack of third-party certification can prevent a station from starting up and can be very expensive for the equipment manufacturer to perform. In the future this must be assessed through the municipality's building department before a commitment is ever made to purchase or develop a location. Such efforts could be streamlined with well conceived permitting requirements and federal codes, such as NFPA standards.

Forecasting Infrastructure Availability and Cost Viability

In the short term we estimate that the industry as a whole could construct between five and ten stations per year dependent on the source of hydrogen and station size. Given the lack of a near term business case and the limited resources and expertise now available, the time to transition to 1000 stations per year will be determined by the level of government support funding to drive adoption of this technology and the rate of growth in the supplier resources to design and construct such a large number of sites.

4.2 DTE

Station Specifications

- Hydrogen produced by electrolysis
- Storage capacity of 135 kg
- Capable of dispensing 15kg/day
- 350 bar

Key Features

- Onsite hydrogen production from a HySTAT-A which uses the patented Alkaline IMET® technology (Inorganic Membrane Electrolysis Technology) to produce 30 Nm³/hr of 99.98% pure hydrogen or 2.7 kg/hr, 60 kg/day.
- Ten, 5kW stationary fuel cell output 40 kW of 120/208V, 3 ph, 60 Hz electrical power to the grid
- Onsite storage setup in the three bank cascade fueling arrangement
- Renewable on-site solar energy 31 kW connected with 26 kW usable
- Grid-connected biomass energy



Figure 4.2.1 DTE Hydrogen Technology Park

Permitting and Construction

DTE Energy went through the permitting and construction two times on this project, first time with the Stuart electrolyzer and a second time with the Hydrogenics replacement electrolyzer.

The first time there were no State of Michigan codes for a hydrogen facility. DTE Energy had to educate local and state officials on hydrogen. The National Fire Protection Association's (NFPA) 50A, "Standard for Gaseous Hydrogen Systems at Consumer Sites" was a key standard used in this education of officials. DTE also

held safety training classes for local fire departments and city officials on hydrogen safety. The permitting took about six months for the first station.

Through the permitting effort of the first hydrogen station the State of Michigan moved to set up a group of interested parties to formulation Hydrogen Rules for the State. DTE Energy was one of the members on the panel.

By the time DTE was permitting the replacement unit the State of Michigan had developed Hydrogen Rules “Storage and Handling of Gaseous and Liquefied Hydrogen Systems” in acted April 24, 2008.

The second time was a 30 day process with the State Hydrogen Rules in place.

Operations

In the first years of operation of the Stuart electrolyzer the Park experienced a number of failures:

- A pulsation vessel before the compressor. The pulsation vessel has a rubber bladder with lithium grease that failed due to the hydrogen drying the grease and leaking into the bladder.
- The diaphragm compressor plates and o-rings failed a number of times.
- The KOH would be siphon up the return to the separator into the demister because of a small pressure loss in the hydrogen gas stream.
- Equipment in the electrolyzer failed due to cold weather.

These problems were all addressed with the replacement electrolyzer. The replacement Hydrogenics electrolyzer did not have any recurring failures.

The operation of the ten stationary fuel cells reviled several problems.

- Fuel cell low temperature ratings did not take into account the heat transfer effects of low temperature days compounded by wind. The manufacturer’s specification states that the GenCore 4AC is rated to -40°C. But operational failures occurred on windy days with temperatures of -10°C. It was believed that the -40°C represents a stagnant air, no-wind environment which was a common condition present in laboratory cold testing chambers. One reason for this operating difficulty was due to the PGM’s housing vents, which were open to the outside environment to vent hydrogen gas. These vents provided a wind path directly into the PGM reducing its actual operating temperature. The failure was that the cell would freeze and crack.
- When the unit was not operating the energy to keep the fuel cell warm was about 2 kW on very cold days.
- The operational life of the fuel cell stack needed to be maximized due to the expense of this component and the down time associated with this failure. One proactive measure was to ensure that the PGM unit was equipped with a coolant filtration system to remove containments from the circulating coolant. These containments caused shorting between cells. This issue

impacted all ten fuel cells and was corrected by incorporating a deionizing filter.

- The loss of hydrogen to a running fuel cell during vehicle fueling caused by the open transition between storage banks caused a momentary starvation of fuel to the fuel cell and had a negative impact on the fuel cell stack life.

Cost of Hydrogen based to the DTE Energy Hydrogen Technology Park was about \$ 21.70/kg while the cost of electricity generated from the fuel cells was about \$ 4.50/kWh.

Lessons Learned

- Dispenser:
 - Hydrogen flow rate should be improved with a variable flow valve to maintain a steady fill rate as pressure differential between storage and the vehicle decrease, thereby improving the fill time for the customer.
 - Tilt switch should close hydrogen supply to dispenser on impact.
 - Shear valve should be closed except during filling and should be below the shear plane of the dispenser.
 - Ufer grounded concrete fueling pad should be used to minimize danger of fires due to static electricity.
- Electrolyzer:
 - The compressor required a small storage vessel between the electrolyzer and the compressor to improve the life of the compressor.
 - The first electrolyzer was placed outdoors but was not able to handle the Michigan winters. The replacement unit was inside a climate control ISO shipping container to eliminate all the cold weather problems. However, the operational cost for energy went up.
- Fuel Cells:
 - Manufacturers need to rate the fuel cell unit based on temperature and wind exposure.
 - Design a better way of removing all water out of the fuel cell so that no external heating is required and the fuel cell can withstand freezing weather conditions.
 - Design a fuel cell that can withstand removal of fuel without any adverse effects.

4.3 Preparation for Fueling Infrastructure

While the stations associated with this project were by themselves successful, in the end, they reinforced the notion that a group of stations is not the same as fueling infrastructure. Still, the stations deployed as a part of the Mercedes Team's project helped to move the overall technology forward.

At the height of the project in 2007, Gen I F-CELL drivers had access to nine hydrogen stations, nearly all of which were offered by BP, Next Energy and DTE. BP offered one station in San Francisco, two in Sacramento, and two in the Los Angeles area, though one of these stations was made possible by BP's involvement with Ford's demonstration program (the S.M.U.D. station in Sacramento), and another one by BP's involvement in the California Fuel Cell Partnership. Next Energy and DTE each provided a station in the Detroit area. In these deployments, on-site production via electrolysis and reformation was tested, as was gaseous and liquid hydrogen delivery. BP also experimented with 70 MPa fueling, though they left the program before the 70 MPa Burbank station could be utilized by customers and any data could be collected. In addition, Mercedes customers were able to use the AC Transit hydrogen station in Richmond, CA; and the South Coast Air Quality Management District hydrogen station in Diamond Bar, CA.

Despite the number of stations that the customers had access to, most of the customers felt range limited by the vehicles. Put simply, there were not enough stations available to provide an extended operating area, and most customers stayed well within a 40 mile radius from the driver's home station. In applications where the customers incorporated the F-CELLs into their traditional vehicle fleet, the fleet drivers often chose to take a conventional vehicle over the F-CELL due to the range limitation. Having the Program stations spread over four metropolitan areas created a situation where the Team's resources were distributed too widely, and ultimately limited the travel area, usefulness and versatility of the vehicles, as well as the overall success of the demonstration. Were the Team to attempt a second demonstration program, Mercedes would choose to focus in areas where there were at least three, but preferably a minimum eight stations, available for customer use in a given deployment area. This would help to give the drivers a seven minute travel time to stations, as recommended by UC Irvine, NREL, and others.

A number of infrastructure related lessons learned came to light during the project. One was that there was no mechanism to keep the program stations open after the conclusion of the project, or in our case, the exit of our energy partner, BP, from the project. This was true of Chevron, with the Hyundai project, Shell with the GM project, and BP, with the Ford and Daimler projects. In nearly every case, the Program stations were dismantled at the conclusion of the program, because there was no way for the DOE to transfer ownership of the stations to other interested parties. The only exception to this was the Burbank station. Luckily, the DOE was able to find a way to transfer ownership for that station to the City of Burbank.

Two years later, the Burbank station still exists, but is not in a state where it is able to reliably refuel fuel cell vehicles. The primary reason for this is funding.

Even if the best examples of the DOE funded stations had remained open, and a reasonable fuel price was charged for fuel, the present number of vehicles on the road would be insufficient to financially sustain their operation without additional funding for operation and maintenance (O&M). This is equally true for non-DOE funded stations. In some ways, this O&M cost is the more crucial aspect of a station project. It is relatively easy to get a loan for what a station would cost to build today. The capital cost is not the prohibitive cost. It is the uncertainty about when the station will break even, let alone be profitable, the so called Valley of Death, that causes vital stations to close, and potential station projects to be abandoned. There is little to no incentive for existing stations to stay open through the Valley of Death. Over this time, government intervention is needed to keep existing and planned stations open until fuel cell vehicle commercialization has occurred, and viable business cases for hydrogen fueling stations can be acted upon. Once sales reach sufficient vehicle numbers, and the Valley of Death is no longer a threat, the amount of government support can be scaled back.

Federal agencies such as the DOE need to continue participate with state and local agencies to ensure that adequate funding is available to support the fledgling hydrogen and fuel cell vehicle technologies and to support their shared governmental policy goals.

Shifting focus to the B-Class F-CELL operation, the Mercedes team began working in 2008 to prepare the hydrogen infrastructure for the arrival of 70 MPa fuel cell vehicles, due to the fact that stations on the ground in 2008 were only capable of giving the B-Class F-CELL a 60% fill. The Mercedes team worked very closely with the State of California and the other OEMs operating fuel cell vehicles in California to develop a strategy for deploying retail-like stations, in locations that would most benefit the aggregated OEM plans.

Although the projects have been subject to delays, approximately eight stations funded by the California Air Resources Board (CARB) are in operation, or will open before the end of 2011. Funding for an additional 11 station projects is about to be released by the California Energy Commission. This should bring the number of 70 MPa hydrogen stations in operation in California to approximately 22 by the end of 2012. An additional \$18 million may also become available to fund additional station projects in the next year. With each of these rounds of funding, the OEMs have provided crucial input into the process, by providing vehicle deployment plan data, station deployment location requests, and letters of support for station project teams. Daimler has invested time and effort into these projects, and we hope they are all successful projects; our commercialization plans depend on these stations and others like them.

Should all of these station projects come to fruition, the bare minimum number of hydrogen stations needed to enable a commercial launch of fuel cell vehicles should be in place in the year 2015. Despite this, there is a significant risk that some of these projects will experience similar delays to those being experienced by the CARB station projects. If this is the case, there very well may not be enough stations for a commercial launch. This would be a great disappointment to those who have had the vision and fortitude to invest in hydrogen and fuel cell vehicles in the face of the aforementioned Valley of Death.

In doing our part, we plan to deploy the B-Class F-CELLs through this time period to help maintain a reasonable level of throughput, in order to keep as many stations as possible in operation until the market introduction of our commercial fuel cell vehicle. We have been very forthright with our intentions to deploy vehicles, and we maintain our commitment to those station projects for which we have voiced support. We feel it is very important to maintain our commitments, even in the face of tough economic and political times.

In many ways, following through with commitments and encouraging others to do “good” in trying times is an important form of leadership. We strive to lead by example, and we encourage others to do so as well. Right now, we need stronger leadership from the DOE; not just in terms of financial support, but in terms of project coordination as well. Many of the participants in this pre-commercial hydrogen economy, be they: automakers, state government agencies, industrial gas companies, or energy companies, have been operating in a manner that is not well coordinated. As such, vehicle and station deployments are often out of phase with each other, and do not maximize investment dollars. If the DOE were able to play a coordinating role, the probability of all of our projects transitioning to a commercially viable product would increase substantially. We hope very much that this sort of role is attractive to the DOE, and we encourage you to take the opportunity to help lead hydrogen and fuel cell vehicles to a commercial reality.

5.0 NextEnergy

Introduction

In October 2002, NextEnergy was organized as an independent 501(c)(3) non-profit corporation located in Detroit, Michigan to advance alternative energy technologies. Shortly thereafter, the Michigan Economic Development Corporation (MEDC) provided a \$30 million seed grant to NextEnergy for facility build out, energy infrastructure, and associated programs. Figure 5.1 below shows the layout of the facility in Detroit. Subsequently, NextEnergy was approached by partners in industry (predominantly automotive OEMs) with interest in utilizing a hydrogen fueling station at the site to serve their needs for hydrogen-related demonstration and validation. This opportunity resulted in a DOE administrated award, which envisioned a site capable of generating, storing and distributing hydrogen for vehicle fueling as a demonstration site for education and outreach.

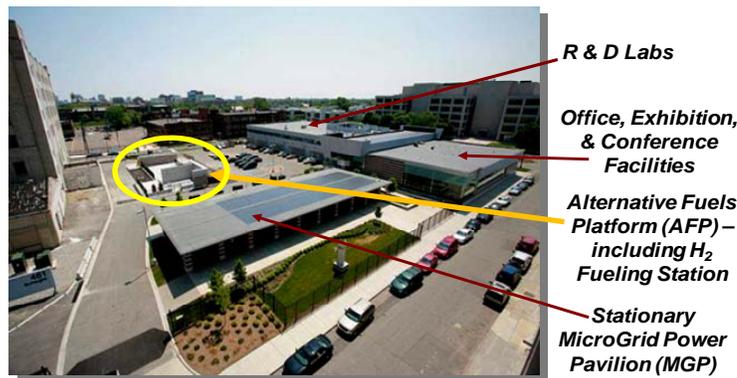


Figure 5.1 Facility Layout

Program Background and Objectives

In collaboration with BP, NextEnergy installed a hydrogen fueling station in Detroit, Michigan to provide hydrogen fuel to the Mercedes Team's FCVs and to evaluate the technologies which achieved DOE's hydrogen targets.

In addition to providing hydrogen fuel to the Mercedes Team, NextEnergy also addressed three key elements to provide a foundation for government agencies to ease in permitting and oversight of hydrogen fuel used in the transport sector. These objectives included:

1. Develop a database of permitting experiences that span all aspects of a hydrogen/fuel cell transportation system;
2. Develop templates for the implementation of codes and standards to define responsible Authorities Having Jurisdiction (AHJ's) and requirements for issuance of permits;
3. Establish annual conference on the progress in the establishment of formal codes and standards is provided to local AHJ's.

NextEnergy/BP Fueling Station

Station Specifications

- Hydrogen produced by remote SMR
- 10-15 kg/day
- Capacity of 50 kg
- 350 bar

Key Features

The NextEnergy hydrogen station included an integrated compression and storage suitable to service a multi-vehicle fleet operating at 35MPa (5,000 psig). NextEnergy supplied the hydrogen load using 12 packs delivered by an industrial gas supplier. The station used Air Products' Series 200 fueling technology with a Pdc compressor attaining capacity of 50 kg.



Figure 5.2 NextEnergy Fueling Station

Permitting and Construction

The NextEnergy hydrogen refueling station, located in downtown Detroit, was completed in February of 2007. All BP and NextEnergy safety processes were successfully implemented during construction of the facility and during commissioning of the equipment. The Mercedes Team performed a number of test refills with and without vehicles.

Early and frequent discussions regarding the hydrogen fueling station were entered into with all stakeholders including emergency responders and the general public represented by NextEnergy's neighbors. This resulted in "no dissention" and often times "enthusiastic support" of the project.

Operations and Performance

The station fueled a small fleet of FCVs, including a fuel cell vehicle used by Wayne State University's campus police, and operated with no major issues. However, in 2010, the station was decommissioned after approval from DOE, as the fleet was not using the station anymore. Currently, the station is idle, but would be

able to be brought back online with some minor tweaks and in a short (a few days) time period.



Figure 5.3 F-CELL fueling at the NextEnergy Station

Lessons Learned: Technology and Component Issues

The original plans included an in-line filter design allowing industrial grade hydrogen (i.e. 99.95% pure, <10 ppm CO, <5 ppm H₂O) to be supplied, then purified to deliver hydrogen in compliance with the new SAE J2719 Hydrogen Purity Specification. But the industrial gas supplier could not accommodate delivering small quantities of high purity GH₂ (cost prohibitive). Additionally, the in-line filter supplier could not meet flow requirements specified in vehicle fuel standards. Also, due to contamination issues with the typically used “drop & swap” method, low mass and high purity loads, several suppliers recommended that NextEnergy use 12 packs. NextEnergy found one supplier that could consistently supply acceptable purity hydrogen in bulk, and this supplier relied on tube trailers always filled from the same liquid source (so the “residual” gas purity is not a problem) to transport the hydrogen and off load it.

Due to the modifications of NFPA 52 Vehicular Fuel Systems Code 2006 Edition sec. 9.2.15, NextEnergy incorporated a more robust gas & flame detection system on the alternative fuels platform. The system was incorporated in the fall of 2006 and provided a lesson on keeping up to date on the constantly evolving hydrogen codes and standards, especially for permitting.

Permitting Database

NextEnergy published DOE’s Permitting Guide for Hydrogen Technologies and Specifications for the 70/35 MPa SHFA online at www.nextenergy.org. Both of these links may be accessed at: <http://www.nextenergy.org/industrysuccess.html>.

Codes and Standards

During the codes and standards program, NextEnergy participated as a voting member in the continued development of NFPA 2 – Hydrogen Technologies Code. During FY10, which was the last highly active period for NextEnergy, the key activity relating to NFPA 2 was a turnaround for the Report On Comments (ROC) phase of this process. During the ROC phase, the public was invited to submit comments on the approved, public draft version of the code that was compiled from the Report On Proposals (ROP) phase. NFPA 2 Technical Committee (TC) met previously regarding 294 public comments and 18 TC comments. NFPA 2 was revised based on these comments and re-released in preparation for the Intent To Make A Motion (ITMAM) phase. Although this is a new code that is approaching 300 pages in length, no ITMAMs have been received to-date.

Additionally, NextEnergy played an active role in two the National Hydrogen Association (NHA), which later merged with the U.S. Fuel Cell Council to form the Fuel Cell and Hydrogen Energy Association (FCHEA), and The National Hydrogen and Fuel Cells Codes and Standards Coordinating Committee (NHFCCSCC).

Annual Conferences

During the course of the program, NextEnergy hosted five consecutive hydrogen codes and standards conferences at its facility in Detroit, Michigan. These events attracted first responders, local officials, hydrogen industry experts, and national code development organizations that provided updates on the latest developments of national and international hydrogen codes and standards. These conferences featured updates from such organizations as: Society of Automotive Engineers (SAE), Sandia National Laboratories, National Fire Protection Association (NFPA), American Society of Mechanical Engineers (ASME), Compressed Gas Association (CGA), International Code Council (ICC), International Organization for Standardization (ISO), CSA International, U.S. DOE (National Renewable Energy Laboratory), automotive Original Equipment Manufacturers (OEM's), such as Ford Motor Company, and industry partners. Due primarily to its diverse group of experts from around the globe and balance of technical and social networking sessions, these events were all very well received and helped inform both permitting processes and codes and standards developments.



Figure 5.4 NextEnergy Annual H2 Codes and Standards Conference – Technical Presentations

6.0 Codes and Standards

The Mercedes team actively participates in various working groups and technical advisory groups relating to hydrogen vehicle technology to support and assist the standards necessary for FCV commercialization. It has been key that Mercedes, along with other industry representatives, share their vast experience from fleet and customer operation from an OEM perspective.

The Society of Automotive Engineers (SAE) includes two main working groups for hydrogen vehicles, the Fuel Cell Vehicle Interface group and the Safety Working Group. The Interface working group of SAE published J2601, "Fueling Protocols for Gaseous Hydrogen Surface Vehicles" which will include J2799, "70 MPa Compressed Hydrogen Surface Vehicle Fueling Connection Device and Optional Vehicle to Station Communications" with the next revision. This standard was the first publication to establish a fueling baseline for FCVs. The terminology to differentiate refueling protocols will be changed to reflect the refueling protocol instead of an arbitrary letter. This will allow for the standard to be more easily updated in the future as technology evolves and as needed from continued station experience.

Many future stations will use this protocol and specification. In addition, stations funded by CARB and the CEC are currently expected to meet J2601. The next version of J2601 is already in intense discussion and will refine the current document and will also be expanded to include bus, forklift, and residential (home) refueling. Leaders for these individual topics have been identified and the Mercedes group will support where applicable. Additional topics within the SAE Interface working group are J2600, "Compressed Hydrogen Surface Vehicle Fueling Connection Devices," which was published in June 2010, and J2719, "Information Report on the Development of Hydrogen Quality Guideline for Fuel Cell Vehicles." J2719 is published but the Mercedes team will continue to participate as the group is still active and is an important standard.

Topics within the Safety Working Group include J2578, "Recommended Practice for General Fuel Cell Vehicle Safety" and J2579, "Technical Information Report for Fuel Systems in Fuel Cell and Other H₂ Vehicles." J2579 is moving to a TIR and is sparking the first exo-company discussions of this kind. Also within this working group, discussions are taking place defining test procedures for localized fire and tank rupture simulations.

In addition to the SAE working group, the Mercedes team also participated in the Canadian Standards Authority (CSA) America and the International Organization of Standardization (ISO). Related to J2601, CSA HGV 4.3 will validate hydrogen stations with using specific test hardware and test methodology. Currently, this document will use J2601 in reference in creating their documents and test

apparatus. Of particular note, the ISO made an important consensus to adapt the refueling nozzle and receptacle design primarily used in the United States and Europe in 17268, “Gaseous Hydrogen Land Vehicle Refueling Connection Devices.” In consequence, both SAE and ISO working groups agreed on the same design creating more commonality. Similarly, language and terms continue to be aligned with greater commonality between SAE, ISO, and CSA.

7.0 Safety

The Team is proud to announce that no serious safety incidents occurred during the Program. This is a testament to the design and build quality of the vehicles. In fact, the vehicles have reached a level of refinement, such that the B-Class vehicles are being handled in a fashion similar to the way Mercedes-Benz USA is handling the hybrid vehicles. In other words, the vehicles are being treated just like a regular car. Because of this, Mercedes-Benz USA will be taking a greater role in the program activities in 2011. Responsibilities such as: vehicle hand-over, customer service, warranty claims and parts logistics have been transferred to them. Proper knowledge transfer will be important to maintaining the safety record during the operation of the B-Class F-CELL vehicle fleet.



Figure 7.1 Vehicle handover at the Fletcher Jones Mercedes Benz Dealership

In addition to the success of the vehicles, the stations operated with an excellent safety record. No serious issues occurred, and the customers reported good experiences at the fueling stations. Partly due to this, the Mercedes Team determined that hydrogen station technology was mature enough to remove the personal protective equipment (PPE) requirements at the City of Burbank Station for both 35MPa and 70MPa fueling in 2009. This trend of no PPE requirement continues today at all of the hydrogen stations that the customers are using (UC Irvine, Culver City and Torrance Pipeline stations).

The excellent safety record of the Demonstration and Validation Project has contributed to the positive regard of hydrogen stations and fuel cell vehicles with the local fire communities. This has been an important accomplishment as it has benefited the permitting process of both hydrogen stations and workshops for fuel cell vehicles in the State of California. Approximately six 70 MPa hydrogen

stations have been commissioned in the State of California since the beginning of this project. Over this time, the average time to permit has dropped from nine months to five months. With the next round of stations to be built with California AB-118 funds, the average time to permit is expected to drop even lower.



Figure 7.2 Commissioning of the Shell Hydrogen Station in Torrance, CA

The developments regarding hydrogen safe workshops has been similar, but more noteworthy. Rather than requiring an array of 12 hydrogen sensors and blow-off roof panels, as was the case when the Mercedes-Benz RDNA facility in Long Beach was designed, the Mercedes-Benz RDNA workshop built years later in Palo Alto required only six sensors, and an office workspace was allowed on the second floor above the workshop. The positive experiences at the workshops, and those of other OEMs, will set an important precedent when fuel cell vehicles go commercial and fuel cell vehicle repairs are performed in standard dealership workshops.

In summary, all of the safety related learnings collected during the F-CELL project has helped improve the reputation of the technology among many of the industry stakeholders. This work has laid the foundation for the commercialization of hydrogen and fuel cell vehicles. A lot more work remains to be done, but the industry is off to an excellent start.

8.0 Training

As with the introduction of any new technology, the pace of introduction of the F-CELL vehicle was controlled and deliberate. The trainings offered during the course of the program were designed to provide the necessary knowledge to individual participants to perform their intended function, while giving a broad basis for understanding of the project as a whole.

One of the first priorities of the Project was to prepare the vehicles for the launch. In preparation for this, all of the technical staff was brought up to speed on the various technical aspects of vehicle, and the hands-on training was administered for performing maintenance work. The thrust of this training effort began in July, 2005 in Nabern, Germany. There, the comprehensive trainings dealt with the following topics:

- Service of the F-CELL
- Technology of the F-CELL
- Diagnosis
- Technology of the F-CELL Sprinter
- Hydrogen Safety Training
- High Voltage Training
- H2 Technology Training

As with any program, the program experienced some employee turn-over. As new personnel was brought on-board, they received the exact same education as their predecessors, though the training was performed at the local facility to save cost.

For the customer operation, two stage training methodology was used. With the execution of each customer lease contract, the key customer contact and an initial pool of drivers were educated on the vehicle technology, fueling process and data recording requirements. As new drivers were brought in to the program by a customer, the key customer contact was given training materials which he could then use to train those drivers. Judging by number of drivers trained, both training approaches were favorably received. All of the drivers that were informally surveyed reported a positive experience with the training strategy, and felt that the quality of education was sufficient to help them feel comfortable to operate the vehicle within a small number of vehicle trips.



Figure 8.1 Hydrogen Fuel Cell Technology Training

Unlike the customer training, which tended to be one-on-one, fuel training tended to occur in a classroom setting, with class sizes varying from five to thirty people. These trainings were always performed by the station operator, often in conjunction with the station hardware supplier (as was always the case with the BP stations). The customers were not limited to Program stations, and indeed once BP left the Program, all of the customers used non-program stations. Regardless of who operated the stations, the customers seemed very much at ease with hydrogen refueling.

In addition to operator and fueling training, a significant amount of time and effort was devoted toward Emergency Responder education. In all deployment locations, emergency responder staff who had jurisdiction where the F-CELLs were operating were offered education on the various technologies in the vehicle (fuel cell, hybrid battery, etc.) and emergency response recommendations for vehicle collisions and station related emergencies. In general, the fire fighters were shown how the vehicles had similar systems to vehicle they were already familiar with, such as CNG and hybrid vehicles, and reminded them to rely on their training for those vehicles.

In California, the Project team contributed its training materials to the California Fuel Cell Partnership, and worked through the organization to develop a standardized training for hydrogen and fuel cell vehicles with the California State Fire Marshall's office. The training materials are presently a part of the State of California F-Step curriculum.

Overall, the response to the training materials developed during the Project was very positive, and well received. The learnings gathered during the program were used to shape the training strategies for the next generation B-Class F-CELL vehicle program. In retrospect, the training strategies used during the A-Class F-CELL program were rather conservative, but helped to establish a feeling of safety and trust among the participants. Moving forward, the training strategies will be a

little less rigorous, more refined, and more targeted. This change in strategy will dovetail well with the change in customer strategy from fleet customers to individual customers.

9.0 Outreach

Outreach and communication activities were essential components of the Mercedes Team's overall strategy to demonstrate and promote fuel cell technology within the context of the DOE program. The Mercedes Team participated in ride-n-drives, supported static displays of all shapes and sizes, and took part in numerous state and nation-wide tours. The most effective communication tool was the vehicle itself, including interactive cutaway vehicle displays. Other tools used to support our messages and promote the technology were a variety of banners and informational brochures which highlighted the vehicle, Mercedes's commitment to the technology, and the DOE program itself. Promotional giveaways such as calendars, pens and notepads were always on-hand as takeaways to instill a more lasting impression of the experience with a new technology. Over the course of the program, MBRDNA participated in events at the local, state and national levels. Target audiences included the general public, environmental groups, technology experts, emergency responders, teachers, and, last but not least, local and national new and traditional media representatives.

In the first year of the Demonstration and Validation Project, the Mercedes Team was engaged in the usual variety of outreach and communication activities. These included on-site ride-n-drives at the Fuel Cell Partnership, a road rally in the San Francisco Bay Area (see Figure 9.1), and participation in such varied events as the U.N. sponsored World Environment Day in San Francisco, the National Clean Cities Conference in Palm Springs and the National Hydrogen Association Conference in Washington, D.C. where the DOE program was officially launched.



Figure 9.1 Road Rally in the San Francisco Bay Area

2005 was also the first year of vehicle deployment of the A-Class F-CELL. New avenues for communication became available starting with the first customer deliveries. From 2005-2007, numerous vehicle handover activities were planned in

conjunction with the customer, often including a staged backdrop in front of which brief statements were given by MBRDNA and customer representatives. In many instances, the local press was invited and press releases issued. The Mercedes Team's customers were ambassadors for both the product and the technology. Numerous customers made concerted efforts to engage in public outreach themselves with MBRDNA support when needed. Otherwise, all customers and drivers interacted with interested parties as a matter of course over the span of the vehicle loan. Furthermore, having a uniquely decorated vehicle out on the roads was advertisement in and of itself.

Once the media had seen and driven the vehicle, creative solutions were often required in order to keep them interested and engaged. Offering journalists an F-CELL to test drive for several days was one tactic used which resulted in some features. Media attention was generated by one press release about people taking their driver license test using an F-CELL. The Sacramento Fire Department F-CELL painted bright red with sirens and lights certainly captured media attention, as was it always a well-received static display item, similar to the dressed-up F-CELL used by the Wayne State University Police Department as a patrol vehicle.



Figure 9.2 Sacramento Fire Department F-CELL

When the A-Class F-CELL demonstration program started winding down, communications and outreach continued in support of the technology as a whole, with messaging which focused on the introduction of the next generation B-Class F-CELL. A press release in May 2009 announced the end of the A-Class program during the Hydrogen Road Tour in which Daimler participated with its 700 bar A-Class F-CELL.



Figure 9.3 Hydrogen Road Tour

In the lead-up to the introduction of the B-Class F-CELL and the ever increasing role to be played by MBUSA in the lease of this vehicle, outreach activities started to include representation of the F-CELL at such Mercedes-Benz sponsored events as the Aspen Ideas Festival in Colorado and the U.S. Tennis Open in New York. The B-Class F-CELL was also featured more than once at the Mercedes-Benz exhibits at the Washington, New York and Los Angeles Auto Shows (see Figure 9.4). In the Fall of 2010, the lease program was officially announced and customers began leasing the first vehicles at the end of 2010.



Figure 9.4 F-CELL at LA Auto Show

With the initial media outreach for the B-Class F-CELL behind us, MBRDNA will continue to target specific journalists and provide them with the opportunity to get behind the wheels of the vehicle for a few days. The primary communications focus at this juncture will be to engage with the ever increasing number of individual customers leasing the B-Class and have them share their stories and relay their first adopter enthusiasm to the public at large. With the advent of social media, customers now more than ever have the potential to become our best advocates not only for the product itself, but the technology as a whole.

10.0 Recommendation

The recent (July 2011) announcement by the Obama administration stating that fuel efficiency will be raised to 35.5 mpg and the next round of standards will require performance equivalent to 54.5 mpg by 2025, combined with a previous memorandum of understanding endorsed by several major OEM's to commercialize FCV's by 2015, both serve as favorable market drivers for FCV's. However, without a continuation of the DOE Project, critical activities will progress slowly, if at all. There would be minimal, if any, guidance to constantly assess the ability of the technology to meet the "2015" commercially competitive targets defined as fuel cell vehicles attaining greater than 300-mile range and 5,000 hours fuel cell durability. In addition, there would be no learning demonstrations to continuously provide feedback on progress and to identify problems that can be addressed through research and development. The Team is requesting a continuation of the existing Projects for the following reasons:

1. Key Choice for Long-Term Energy, Environmental Security and Consumer Acceptance

Near-zero emission technologies are needed for a low carbon future (80% CO₂ reduction by 2050). Fuel cell vehicles decrease greenhouse gases by 50-60% compared to today's vehicles, even when hydrogen is produced from natural gas. Fuel cell vehicles are full-function, long-range, zero-emission vehicles that are refueled in minutes with low-carbon fuel. Since no other option provides all these benefits, the US government should continue investing in fuel cell technology.

2. Data Acquisition

Daimler, as well as other OEMs, has been continuously sharing real world vehicle data with the Department of Energy and National Renewable Energy Laboratory (NREL) so that the agencies may monitor and evaluate technology/commercial readiness of fuel cell vehicles. To date, Daimler has submitted over 120 CD/DVDs of Raw Data to NREL for its evaluation. A continuation of the Project will validate that hydrogen vehicles have greater than 300-mile range and 5,000 hours fuel cell durability, and hydrogen infrastructure that results in a hydrogen production cost of \$2.50 gge (untaxed), and safe and convenient refueling by drivers.

3. Pre-commercialization Phase

NREL, together with DOE, have concluded that all 2009 milestones, including the 2,000 hour stack durability and 250 mile range, have been achieved or exceeded, thus concluding that fuel cell vehicles are on track to be commercially viable by 2015. In other words, the Technology Validation

Program may be transitioned from a Controlled Fleet Test/Evaluation phase to a Technology Readiness Demonstration phase in which industry, with the help of DOE, may make the necessary investments to establish manufacturing plants, sales/service organizations and infrastructure network necessary to start pre-commercialization hydrogen fuel cell vehicles. Government incentives and funding are needed to be available to build-up volume in a pre-commercial phase prior to mass volume production.

Coordination between OEMs, suppliers, infrastructure providers and government is needed to insure the commercial success of hydrogen fuel cell vehicles. Collaborative efforts, cooperation and alignment from all stakeholders are necessary to fully realize all potential cost reductions and customer convenience.

4. Infrastructure

A proper infrastructure network, in which customers feel confident that they have an adequate number of fueling stations near their home/work and locations near leisure activities, need to be in place before the average customer will even consider buying/leasing a fuel cell vehicle. Without the hundreds of FCVs fueling at hydrogen stations, energy partners will not have enough drivers to utilize and therefore buy the hydrogen fuel necessary to offset the capital costs needed to initially invest in hydrogen fueling stations.

5. Keep US Competitive:

The United States needs to keep pace to compete in a global market. Governmental agencies from other countries are aggressively investing and setting challenging goals. For example, Japan has committed \$2.4B of funding in its JHFC Demonstration and Validation Program. Germany, with 220M less citizens than the US, is funding \$1.8B in fuel cell vehicle and hydrogen infrastructure while the European Union is investing an additional \$1.4B.

OEMs will naturally be drawn to countries that support and fund the hydrogen economy. In order to maintain the current plan to ramp up the number of fuel cell vehicles offered in the United States, OEMs need a sound commitment from the US government.

6. Competitive Supply Base

Although a supplier network already exists for components/systems to be manufactured for Gen II vehicles, the number of suppliers is somewhat limited for future generation FCVs. Suppliers are reluctant to accept the high risk/investment and long lead time associated with the extensive research and development process necessary for commercialization of fuel cell technologies.

As a well established supply industry is necessary for the commercialization of fuel cell vehicle, the Mercedes Team recommends that an additional

government funded program be established to help support targeted small and medium sized suppliers as well as assist in research and development activities.

7. Codes and Standards

Codes and standards have repeatedly been identified as a major barrier to deploying hydrogen technologies and developing a hydrogen economy. The Mercedes Team is working with domestic/international organizations to develop and implement practices that will ensure safety in operating, handling and using hydrogen and hydrogen systems. With respect to hydrogen and fuel cell vehicles, bodies like Society of Automotive Engineers (SAE) and International Organization for Standardization (ISO) are developing standards and technical information reports on vehicle design, station interface and fuel quality. Similarly, American Society for Testing and Materials (ASTM) is developing hydrogen quality analysis methods and fuel metering standards while American Society of Mechanical Engineers (ASME) is developing standards for composite storage vessels. Continued support and progress toward the completion of these codes and standards are essential for the early commercialization and market entry of hydrogen technologies.

11.0 Conclusion

Not only has it been a great honor to be part of such an important federal government program, but the Controlled Hydrogen fleet and Infrastructure Demonstration and Validation Program has been an invaluable source of data for the development of fuel cells for automotive application. The Team deployed 30 GEN I and 20 GEN II fuel cell vehicles to over 37 customers located in various regions in the United States, which provided real-world lessons for our Team and overall program. All vehicles were equipped with data acquisition and reporting capability, allowing real-world lessons for the Team and overall program. In addition, data was collected from three B-Class F-CELLs driven around the world, including 4 continents and 14 countries. On road data was provided on a monthly and quarterly basis to DOE/NREL for analysis. Approximately 530,000 miles were accumulated during the entirety of the program and over 120 CD/DVDs was submitted to NREL for analysis.

The Team met all DOE milestones, including the 2,000 hour stack durability and 250 mile range, thus concluding that fuel cell vehicles are on track to be commercially viable by 2015.

Before concluding this report, we would like to express our gratitude for the DOE's support, leadership and expertise that the department has provided over the last eight years. We can't thank you enough for the existing program and hope to continue collaborating together to successfully commercialize fuel cell vehicles and infrastructure.

ACRONYMS

AHJ: Authorities Having Jurisdiction
ASME: American Society of Mechanical Engineers
ASTM: American Society for Testing and Materials
CaFCP: California Fuel Cell Partnership
CAPS: Customer Acceptance and Perception Study
CARB: California Air Resources Board
CEC: California Energy Commission
CEQA: California Environmental Quality Act
CFS: Central File Server
CGA: Compressed Gas Association
CSA: Canadian Standards Authority
DOE: Department of Energy
F-CELL: Fuel Cell
FCHEA: Fuel Cell and Hydrogen Energy Association
FCV: Fuel Cell Vehicle
FDA: Fleet Data Acquisition
GTR: Global Technical Regulations
ICC: International Code Council
ISO: International Organization for Standardization
ITMAM: Intent To Make A Motion
LFS: Local File Servers
MBRDNA: Mercedes-Benz & Research Development, North America
MBUSA: Mercedes Benz USA
MEDC: Michigan Economic Development Corporation
NEPA : National Environmental policy Act
NFPA: National Laboratories, National Fire Protection Association
NHA: National Hydrogen Association
NHFCCSCC: National Hydrogen and Fuel Cells Codes and Standards Coordinating Committee
NREL: National Renewal Energy Laboratory
OEM: Original Equipment Manufacturer
O&M: Operation and Maintenance
PATH: Partners for Advanced Transit and Highways
SAE: Society of Automotive Engineers
TC: Technical Committee
VPN: Virtual Private Network
ZEV: Zero Emission Vehicles