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FINAL RESEARCH PERFORMANCE PROGRESS REPORT

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Light-Duty Fuel Cell Electric Vehicle Validation Data

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Executive Summary

Since 2005, Mercedes-Benz Research & Development North America (MBRDNA) participated in the DOE's Technology Validation Programs to help accelerate the market introduction of fuel cell vehicles. Under the U.S. Department of Energy (DOE) contract DE-EE0005971, which ran from 2013 - 2019, MBRDNA collaborated with the DOE to evaluate overall vehicle degradation effects of fuel cell vehicles, as well as evaluate the generational improvements from one vehicle generation to another. The goal was to achieve a mileage target of 10,000-12,000 miles per vehicle per year and 750 to 1,000 operating hour accumulation per fuel cell stack.

The MBRDNA Project Team (Project Team) leased a total of 69 fuel cell vehicles to regular Mercedes-Benz customers through select dealerships in Northern and Southern California. Of these 69 vehicles, a minimum of 20 active vehicles were chosen to participate in this project based on customer driving habits, average daily miles, and geographic conditions. These vehicles were equipped with a data acquisition system that automatically collected statistically relevant data for submission to the National Renewable Energy Laboratory, which monitors the progress of fuel cell vehicle technology for the DOE.

As customer operation of GEN II vehicles ended in Q4 2017, a decision was made to focus GEN III vehicle operation in Europe and Japan only, and not to deploy the vehicle in the United States. Despite the intention to include three GEN III vehicles in durability runs in Southern California for purposes of data collection for this project, the plan could not be realized given the decision not to deploy GEN III vehicles in the U.S. market at this time.

In total, over 1.3 million miles and 60,000 operational hours of fuel cell system and powertrain operation were submitted to DOE under this project. The data provided revealed insights into real-world customer operation and system durability of fuel cell vehicles, enabling the DOE to observe the technology maturity and readiness of fuel cell vehicles outside of the controlled corporate research and development environment.

Mercedes-Benz Research and Development North America (MBRDNA) has been promoting fuel cell technology in the U.S. since 2000. Over this time, it has been a pleasure to work in conjunction with the Department of Energy (DOE) on two separate projects surrounding fuel cell vehicle and market readiness. MBRDNA looks forward to future opportunities to collaborate in the interest of helping to further a sustainable transportation future.

Introduction

The Project

Mercedes-Benz Research & Development North America (MBRDNA) has a long history of fuel cell vehicle operations in the United States. Since 2005, MBRDNA has demonstrated two generations of fuel cell vehicles, first in fleet applications and most recently through traditional vehicle leases to everyday people. Over this time, MBRDNA has demonstrated the robustness and market viability of fuel cell vehicles in real-world applications. By way of these demonstration programs, we have accumulated a vast amount of knowledge and experience relating to fuel cell vehicle data collection and analysis.

For each of these vehicle fleets, MBRDNA participated in the DOE's Technology Validation Programs to help accelerate the market introduction of these vehicles, to help share the status of technology development, and to support DOE activities to further focus research efforts and research funding to areas with the greatest need.

Under the U.S. Department of Energy (DOE) contract DE-EE0005971, MBRDNA collaborated with the DOE to evaluate overall vehicle degradation effects of fuel cell vehicles, as well as evaluate the generational improvements from one vehicle generation to another. Specifically, the objectives of the project were to:

- Track progress of FCEVs for up to 7 years by validating light-duty FCEV performance and durability and determine if technical targets have been met with a minimum of 20 and up to 50 vehicles.
- Collect and submit real-world vehicle performance data and, if available and plausible, provide dynamometer data to NREL for analysis and aggregation into composite data products to be used to validate FCEV performance.
- Provide engineering data from progressive generations of fuel cell technology, fuel cell systems and batteries, including Gen II and Gen III FCEVs with newly integrated powertrains, fuel cell systems and batteries
- Achieve expected mileage and operating hour accumulation: 10,000-12,000 miles per vehicle per year and 750 to 1,000 hours per fuel cell stack.
- Accumulate 5,000 hours of operation from one FCEV

This report summarizes the findings from the study. To provide more context and to share additional learnings acquired by MBRDNA over the many years of operating fuel cell vehicles in California, this report also includes some information related to, but outside the scope of the DOE project.

Methodology

The MBRDNA Project Team (Project Team) deployed a total of 69 fuel cell vehicles on the California market from 2010-2017 by leasing them to regular Mercedes-Benz customers through select dealerships in Northern and Southern California. Of these 69 vehicles, 20 were chosen that were active at one time to participate in this project based on customer driving habits, average daily miles, and geographic conditions. These 20 vehicles were equipped with a data acquisition system that automatically collected statistically relevant data for submission to the National Renewable Energy Laboratory (NREL), which monitored the progress of fuel cell vehicle technology for the DOE.

In addition to these data collection efforts, the Project Team engaged in a variety of other activities to help prepare the market for fuel cell vehicle commercialization. The Project Team played an extensive role in helping to further infrastructure development, as well as the development of codes and standards. Equally significant was the educational component of the deployment, which sought to introduce and explain the technology to both customers, stakeholders, Mercedes-Benz USA (MBUSA) and select dealerships alike.

The Gen II B-Class F-CELL deployment provided ample opportunity to collect data, in actuality more than originally anticipated. The lease program as originally conceived was to have run over the course of a two to three year period. A decision to extend the mileage limit and approve a pre-owned program made it possible for the vehicle to be operated for several more years. It also allowed many of the original F-CELL customers to experience a more advanced infrastructure network, thereby giving them a more positive hydrogen fuel cell vehicle experience. It also gave MBRDNA more time to work on the many aspects of market preparation.

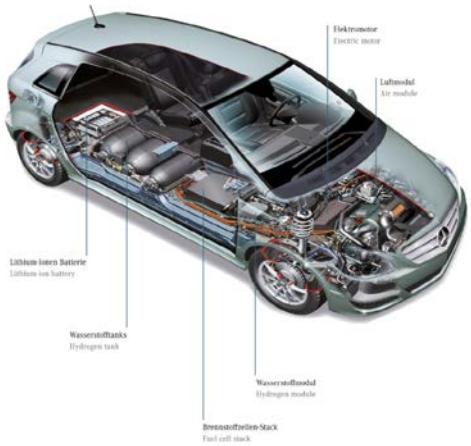
Customer operation of GEN II vehicles ended in Q4 2017. What then transpired was a decision to focus GEN III vehicle operation in Europe and Japan only, and not to deploy the vehicle in the United States. Therefore, despite concrete plans developed to include three GEN III vehicles in durability runs in Southern California for purposes of data collection for this project, ultimately, the plan could not be realized given the decision not to deploy GEN III vehicles in the market in the United States at this time.

Vehicle Fleets

Gen II: B-Class F-CELL

The B-Class F-CELL was introduced in 2009. It was the first series-produced fuel cell car from Daimler. Considerable improvements over its predecessor, the A-Class F-CELL, were achieved in terms of output, torque, operating range, reliability, starting characteristics and comfort. The electric motor had a peak performance of 100 kW/136 hp and a maximum torque of 290 Nm. The lithium-ion battery produced an output of 35kW with a capacity of 1.4kWh to boost power and recover braking energy. It employed the unique sandwich floor architecture known from

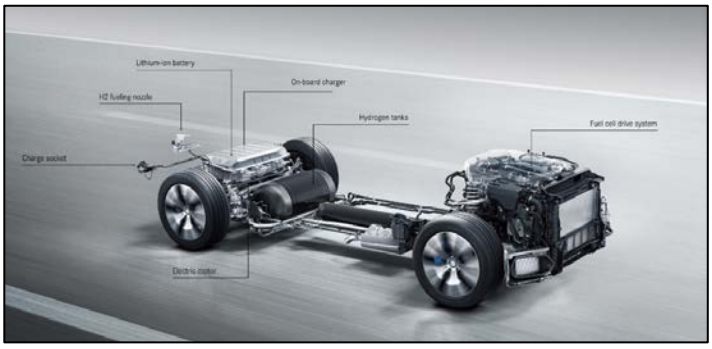
the A-Class and B-Class gasoline engine vehicles which allowed drive components to be located in the sandwich floor so that the vehicle's interior remained fully usable, including the trunk. A total of 170 B-Class F-CELL vehicles were leased by both fleet customers and private citizens in Europe and the United States.



Picture 1: The B-Class F-CELL Drive Components

Gen III: GLC F-CELL

The GLC F-CELL was first presented in 2017 and introduced into the market in 2018. It is a unique plug-in hybrid capable of running on electricity as well as hydrogen. Two carbon-fiber encased tanks in the vehicle floor hold 4.4 kg of hydrogen, allowing for an approximate 270 mile range. In hybrid mode, the vehicle delivers up to an additional 30 miles of range on a fully charged battery. The power output is 155 kW. This plug-in fuel cell drive combines the advantages of both zero-emission drive technologies and continuously optimizes the use of both energy sources depending on the operating situation. In all operating modes, the system features an energy recovery function, which makes it possible to recover energy during braking or coasting and to store it in the battery. The GLC F-CELL is planned to be deployed in Germany and Japan.



Picture 2: The GLC F-CELL Drive System

Data Collection and Reporting

Approach

As previously stated, the data reporting goals included the collection, processing, and submission of vehicle powertrain on-road data in real world conditions, as well as maintenance data for a minimum of 20 and up to 50 Gen II B-Class F-Cell vehicles.

Each B-Class F-Cell was equipped with an onboard data recorder which continuously captured powertrain data during operation. Each time a vehicle entered the workshop for maintenance or repair, the onboard data recorder was downloaded to the local server as described in the Statement of Project Objectives. This data was then processed to identify driving and refueling events, filtered for specific signals of interest, and evaluated for quality before being transmitted to an SFTP site hosted by the National Fuel Cell Technology Evaluation Center (NFCTEC). Due to the variability of customer driving behavior, some vehicles only visited the workshop once in a six to twelve month period. This system proved to be robust. Occasional field retrievals were coordinated for vehicles with high operation rates to aid the acceleration of data transfer.

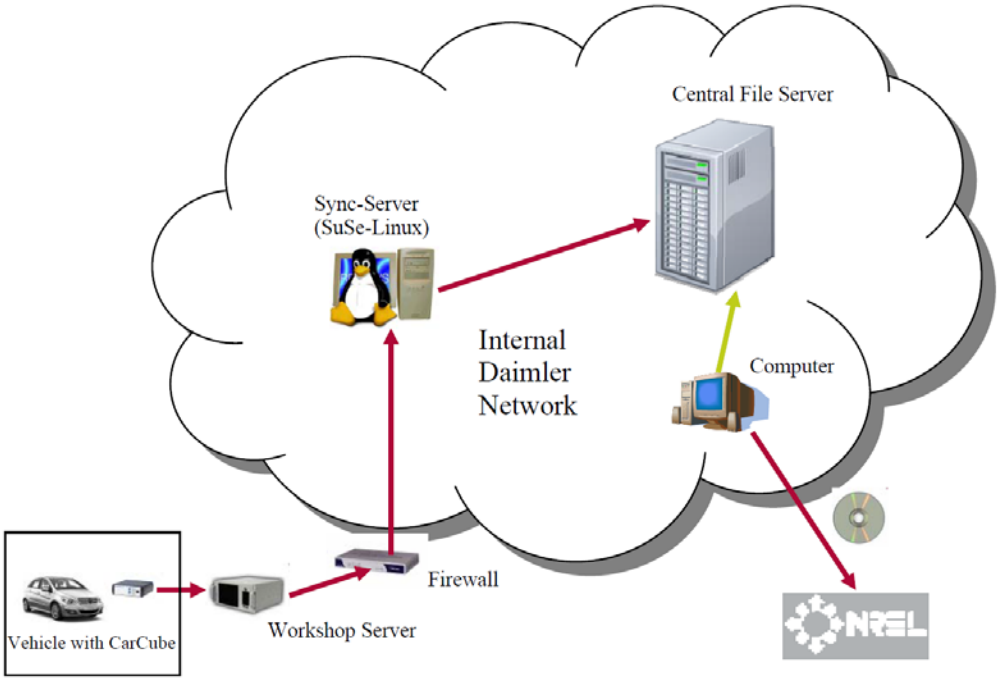
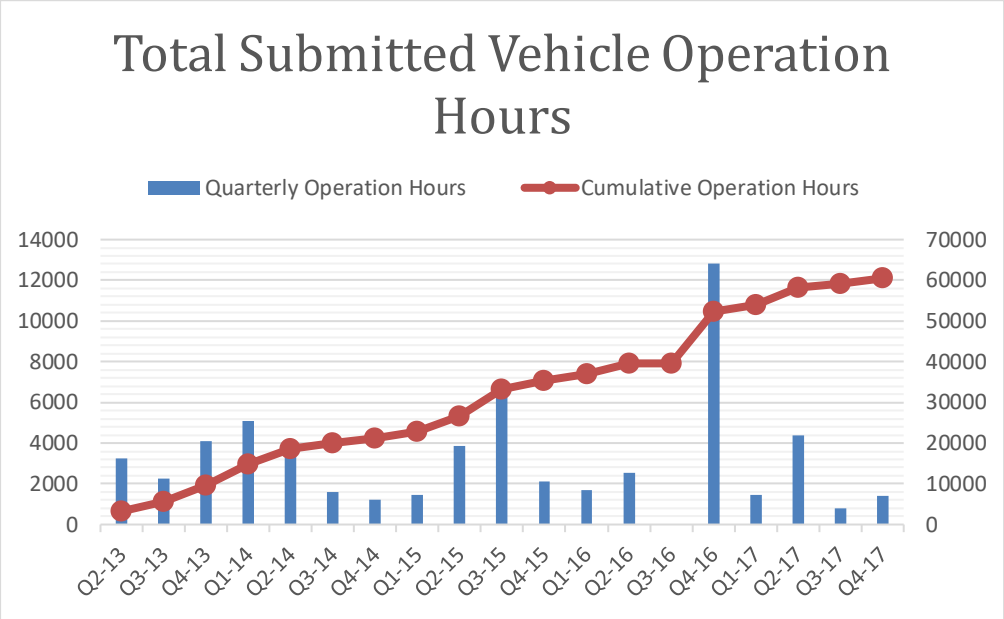


Figure 1: Overall Infrastructure and Data Transmission Setup

Accomplishment

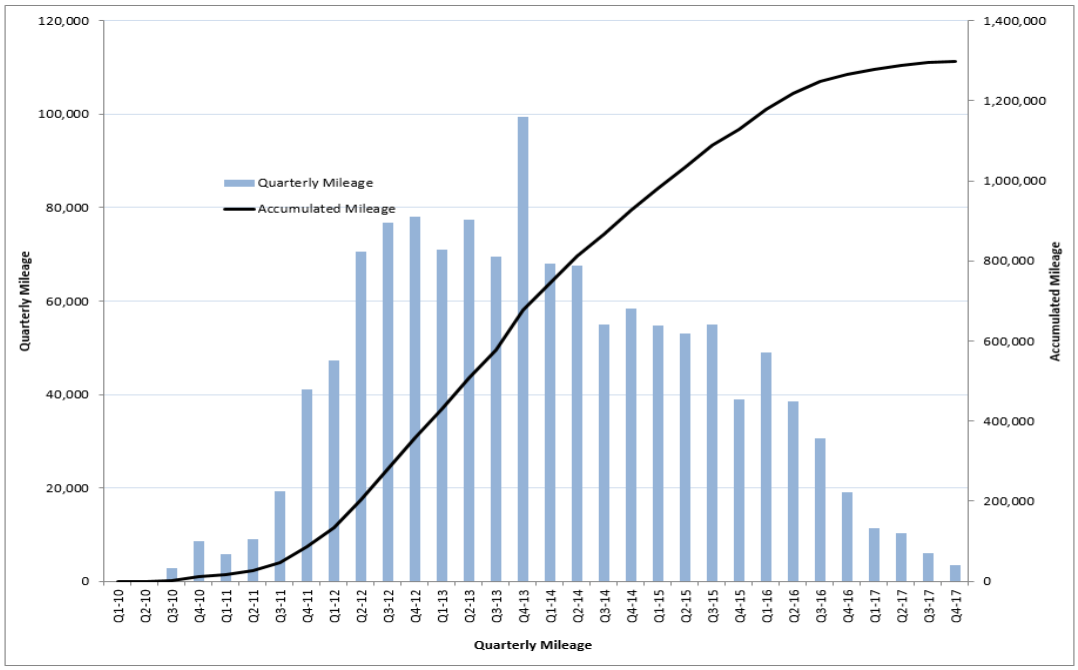
Data Production

Over the course of the project, data from 37 Gen II B-Class F-Cells was submitted - including one vehicle in Germany - with a minimum of 20 active vehicles collecting data for the project at all times. In all, 60,000 hours of fuel cell system and powertrain operation, and tens of thousands of fueling events were recorded. This data included on-road powertrain data in the form of Matlab data files and other vehicle data deliverables including maintenance history as outlined in the Statement of Project Objectives. A subset of this data included the operation data of a German durability vehicle which ran for nearly 6,000 operation hours and drove over 200,000 miles.



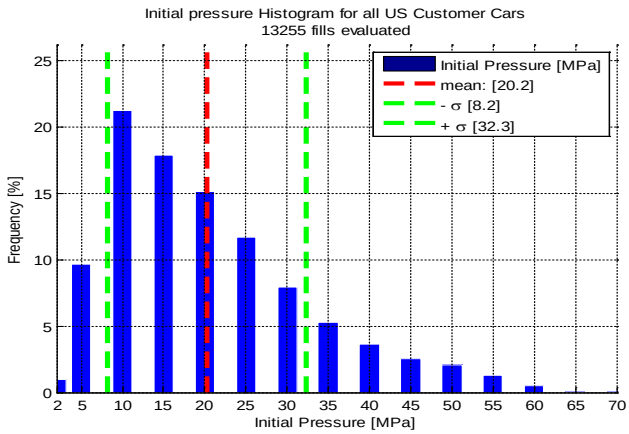
Graph 1: Total Submitted Vehicle Operation Hours. No new submission in Q32016 pending project status decision.

The extension of vehicle operation from 40,000 miles to 60,000 miles allowed for more data from customers to be collected and transmitted to meet the project milestones of Fuel Cell System durability. The creation of a pre-owned program for vehicles being returned from lease also made additional mileage accumulation possible. In some instances, initial customers chose to extend their leases. In others, new customers were acquired. In total, over 1.3 million miles of data was submitted to the DOE. Over the course of deployment, the entire fleet itself accumulated more than 2.6 million miles.



Graph 2: Total Accumulated Mileage of DOE vehicles

The Project Team also collected and analyzed hydrogen fueling events. This data was used to not only track the operation of the station and vehicles – but also to aid codes and standards development. The data provided real-world customer fill data and patterns to make data driven decisions on fueling protocols. The types of data submitted to the SAE Interface Working Group responsible for hydrogen fueling codes and standards included initial and final tank information, including temperatures and pressures. Additionally, the team supported future hydrogen fueling protocols commonly referred to as the MC Method and MC Formula fill which have the capability to maximize fill quantity and minimize refueling times.



Graph 3: Example of fueling data provided to Codes and Standards Groups

Challenges included the failure of the in-vehicle Fleet Data Acquisition (FDA) recorder as well as managing software updates. Over the entire project, there were two recorder failures that led to the data being irretrievable due to hardware failure. Software updates modified signal names which required additional support to ensure continuous, seamless transition to the National Fuel Cell Technology Evaluation Center (NFCTEC) and corresponding analysis. The data reporting team implemented a translation tool which automatically changed signal names for data submitted to the original format.

The data provided revealed insights into real-world customer operation and system durability of fuel cell vehicles – a first of its kind. This data enabled performance and lifetime analysis to understand technology maturity and readiness outside of the controlled corporate research and development environment.

Codes and Standards

Codes and Standards efforts included but were not limited to interface topics to enable the successful commercialization of light duty hydrogen fuel cell vehicles. The Data Manager participated in CSA Group and International Standards Organization (ISO) working groups and led the SAE Interface Working Group which was responsible for topics such as the physical hardware interface between the vehicle and the station, hydrogen quality for light duty vehicles, and a standardized fueling protocol. Standards that received significant contribution are:

- SAE J2601 *Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*
- SAE J2600 *Compressed Hydrogen Surface Vehicle Fueling Connection Devices*
- SAE J2719 *Hydrogen Fuel Quality for Fuel Cell Vehicles*
- CSA HGV 4.3 *Test methods for hydrogen fueling parameter evaluation*
- CSA HGV 4.9 *Hydrogen Fueling Stations*

There were several marked accomplishments including elevating a baseline hydrogen fueling protocol from a Technical Information Report (TIR) to a full standard, revising SAE J2600 for the hardware interface, publishing the initial CSA 4.3 which allowed conformance testing to SAE J2601, and participating in international hydrogen workshops to share experiences, status, and harmonize standardization.

Impact

The Project Team's involvement in the Codes and Standards helped to build the required core set of standards that enabled the successful launch of the commercial hydrogen infrastructure by allowing complete compatibility between vehicles and stations. Data from this project made data driven decisions possible that directly impacted customer experiences such as compatibility, refueling time, and receiving a full fill.

HySTEP Project

The Project Team created an in-house tool which automated the evaluation of protocol conformance for internal station qualification. This tool enabled the engineers to determine quickly if a fill met the requirements and specifications of a fueling protocol (e.g. SAE J2601) and if it failed, where and why it failed. Members of the Project Team also participated in the Hydrogen Station Equipment Performance (HySTEP) working meetings where it was identified that an analysis tool was required. The MBRDNA tool was handed over to government agencies to seed the public analytic toolset for conformance testing. It was first successfully implemented and demonstrated in California with the HySTEP project.

Vehicle Operations

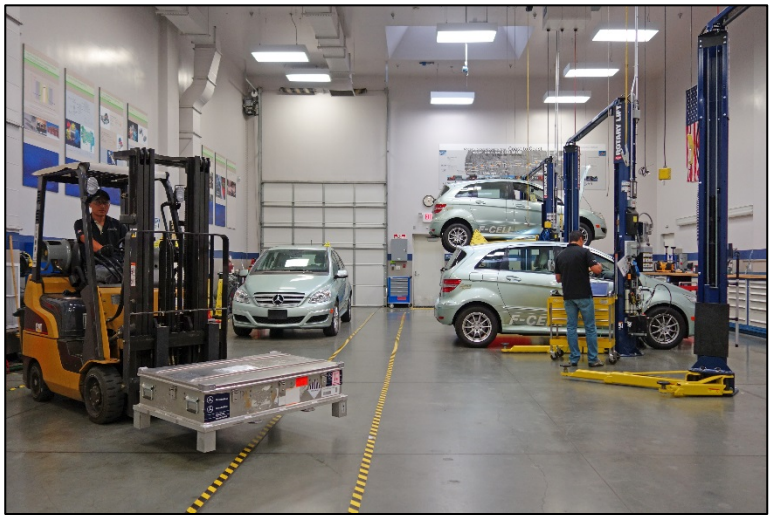
Approach

Deployment of the B-Class F-CELL started at the end of 2010. The "Light Duty Fuel Cell Electric Vehicle Validation Data" project commenced two years later in January 2013. At the time, the B-Class F-CELL had already been leased to 49 customers who had accumulated 650,000 miles.

Two hydrogen safe workshops, located in Long Beach and at the MBRDNA headquarters in Silicon Valley, were outfitted to service and maintain the 49 and all subsequent vehicles, as well as provide the necessary technical expertise for vehicle upgrade. Using advanced diagnostics, the Project Team also monitored and analyzed vehicle malfunction data, performed software updates, and ordered replacement parts, all the while working closely with their Daimler and MBUSA counterparts. Aside from servicing customer cars, the Project Team also prepared non-customer fleet vehicles for outreach events, hydrogen fueling station testing, short-term vehicle loans and the refurbishment of vehicles for the pre-owned program.

Accomplishment

The Project Team ensured the seamless operation of 69 B-Class F-CELLs from 2010-2017. Vehicle operation peaked in the 4th quarter of 2013 with 50 vehicles being driven on public roads at that time. Special attention was given to the 20+ vehicles selected to be included in the project from which data was accumulated, downloaded and prepared for submission.



Picture 3: The Fuel Cell Workshop in Long Beach, CA

The technical support and service provided made a 95% availability rate to customers possible, including an average down time of less than 3 days. Mileage and data accumulation continued

unabated with the introduction of a pre-owned program in 2014. MBRDNA re-leased vehicles to the general public which thereby extended the program and kept vehicle operation robust.

After seven continuous years of customer operation, the last vehicles were returned to MBRDNA in December of 2017 and decommissioned. A handful of vehicles were driven internally throughout 2018 and beyond as staff continued to test the fueling infrastructure.

Impact

Pre-owned Lease

The decision to extend operation and initiate a pre-owned program proved fortuitous for several reasons. For one, the infrastructure landscape at the start of the program was so limited that customers were unable to enjoy their vehicle to the fullest extent possible. By extending the program, customers had the chance to operate their vehicles in a more expansive station environment and were thus able to experience their hydrogen fuel cell vehicle as it was intended. Extending the program not only allowed for more mileage accumulation, but also gave more people the opportunity to participate in the program as did some of the original lessees end up participating for the entire seven years of deployment. Lastly, the decision to initiate a pre-owned program led to the establishment of a remanufacturing process for drivetrain components to minimize operational costs. Select vehicles, such as those involved in accidents, were sent to Daimler in Germany for disassembly and components were then shipped to a facility for remanufacturing.

Dealerships, Training, Education

Approach

The B-Class F-CELL represented the next step towards market launch following deployment of the pre-production A-Class F-CELL. The expectation was that Daimler's U.S. sales organization MBUSA would be launching the B-Class successor, the GLC F-CELL, on the U.S. market. In preparation for that, it followed that the B-Class F-CELL should be deployed in as near market conditions as possible. The Project Team thus worked closely with MBUSA and its financial arm Mercedes-Benz Financial Services (MBFS) to create a program which made it possible for everyday customers to lease a fuel cell vehicle through select dealerships. In doing so, both organizations started acquiring knowledge about fuel cell vehicle technology which would serve them well when the time came for actual market deployment.

The select dealerships acted as the face to the customer, with the Project Team in the background performing all work on the vehicles. Over time, the dealerships gradually assumed some of the responsibility for vehicle service as it related to non-fuel cell specific service and repairs. The bulk of the work remained in the hands of the Project Team, but the exposure dealerships received to this new technology was invaluable. The following dealerships were involved in the program:

- Fletcher Jones Motors Cars in Newport Beach, CA
- Mercedes-Benz of South Bay, Torrance, CA
- Mercedes-Benz of Beverly Hills, Beverly Hills, CA
- Mercedes- Benz of San Francisco, San Francisco, CA

Accomplishment

Dealership Preparation and Education

Knowledge about fuel cell technology accumulated over the years by MBRDNA was transferred to other entities through a variety of means. The Project Team worked together with the Learning and Performance division of MBUSA to create fuel cell and hydrogen technology training modules for the dealerships. These learnings were reinforced over time through the team's frequent interactions with dealership sales and service associates. MBUSA Engineering Support acquired a working knowledge about fuel cell vehicles, and MBFS was also able to familiarize itself with this new technology while managing a uniquely structured lease for both new and pre-owned fuel cell vehicles.

Dealerships initially received a one day introductory training prior to vehicle launch. The Project Team and the concierge service then continued to educate them over the course of the deployment, sharing program updates and information about fueling station development which they were able to pass along to existing and potential customers. Some dealer

technicians participated in hydrogen safety trainingsoffered by their local Fire Departments. MBRDNA also supported outreach efforts to the dealer customer base in order to encourage greater knowledge and awareness about zero emission vehicles and the benefits of fuel cell technology.

Impact

Concierge Service

Given the limited number of fueling stations and the newness of fuel cell technology, the Project Team determined that a concierge service to support the F-CELL customers was necessary to ensure a level of customer satisfaction to which Mercedes-Benz drivers are accustomed, as well as to encourage these drivers to accumulate the maximum possible amount of miles and operating hours. A local contractor provided 24/7 service to customers concerning all matters vehicle and hydrogen fuel related. The concierge interacted daily with dealerships, MBRDNA and customers and helped to ensure a seamless communication regarding all customer service issues. Customers relied on it when they had problems with their vehicle, when they required information about station availability, for arranging towing and fueling services when stations did not work, and for scheduling service and maintenance. The service was considered indispensable by all those involved in the program and inspired other OEMs to offer a similar type of service to their fuel cell customers to help them better navigate the early hydrogen fuel cell landscape in California.

Outreach

Aside from dealership engagements, the Project Team performed outreach at a variety of venues with static displays, ride-n-drives and presentations. These included industry, community and internal company events, all undertaken in the interest of promoting the technology and sharing what Mercedes-Benz was doing to move commercialization forward.

Picture 4: F-CELL Outreach at the NorCal Alt Car Expo

Picture 5: MBFS visits MBRDNA and learns about the F-CELL

All these communication and outreach efforts underscored the commitment by MBRDNA to ensure that all partners within the program, first and foremost the customers, had the information they required to participate in and contribute to the program as effectively as possible, thereby enhancing the overall experience and helping to contribute to the acceptance of a new technology.

Customer Engagement

Approach

The B-Class F-CELL was available for lease only. Individuals interested in leasing were required to complete a questionnaire which provided insight into their knowledge about alternative fueled vehicles, their motivation to drive one and, most importantly, their proximity to a hydrogen fueling station. In some instances, the customers initiated first contact at the dealership and the dealers took the lead in arranging a sale; in most other instances, customers were chosen through consensus by MBUSA and MBRDNA.

Once customers had been welcomed into the program, they had a range of contacts who were there to support them on a daily basis, from the dealer to the concierge to the Project Team, all of whom were in frequent contact with them, especially concerning hydrogen station developments. MBRDNA also had an open door policy, extending a standing invitation for customers to visit the fuel cell office and workshop for a tour and discussion. A number of customers took advantage of this opportunity.

Accomplishments

Customer Events

F-CELL drivers who understood the vehicle and its operating environment were far more likely to have a positive experience with the vehicle, compared to those who were less informed. The Project Team recognized this and understood how crucial it was to customer satisfaction that F-CELL drivers knew as much as possible about the vehicle, the technology, the program, and the infrastructure. Regular customer events created opportunities to do just that – educate the customer as well as build and foster a new community of fuel cell drivers in the U.S.

At least twice a year, customers were invited to dinners where the Project Team presented on topics germane to the program such as hydrogen infrastructure development, program updates and a well-to-wheels analysis of low and zero emission vehicles. These events also provided a forum for customers to interact with each other and share their experiences outside of day-to-day vehicle operation.

Customer appreciation events were also organized at least once a year. The most popular was what was dubbed “The World’s Greenest Autocross”, where customers were given the opportunity to drive the F-CELL in a racetrack setting.

Picture 6: F-CELL Customers at the "World's Greenest Autocross"

Another very successful event was the customer road rally "Crossing California on Hydrogen". For this event, F-CELLs caravanned from Southern California to Northern California with the support of a few members of the Project Team. The purpose of the event was to demonstrate the level of reliability and maturity of the California hydrogen infrastructure network to other stakeholders. This 3-day event was made possible by the completion of a hydrogen fueling station along the I-5 interstate between Los Angeles, Sacramento and San Francisco. The customers were thrilled to take part and experience driving their F-CELLs beyond the confines of greater Los Angeles for the very first time.

Picture 7: F-CELL Customers and the Project Team arrive in the Bay Area after crossing California on hydrogen

Impact

Leveraging Customer Experiences

Customers themselves had a great deal of information to impart regarding their vehicle experience which was of great interest to many stakeholders. B-Class F-CELL customers were, after all, some of the first retail fuel cell customers in the United States. As such, every opportunity was taken to provide them with a forum where they could share their knowledge and experience. They met with members of the Governor's office responsible for infrastructure development, as well as public officials from the California Energy Commission (CEC) and Air Resources Board (ARB), both of whom are charged with allocating hydrogen station funding. Several of our more savvy and communicative customers served as excellent spokespersons while conducting interviews at a variety of news outlets. Others gladly participated in outreach events where they engaged with fellow alternative fueled vehicle enthusiasts. The Project Team was proud to have one of its most vocal and informed drivers represented at the annual Fuel Cell Seminar where he gave an impassioned talk about his experiences, where the industry was headed and what was needed to get us there.

Infrastructure Development

Approach

Achieving the operational objectives of 10,000 miles per year, and 750 operational hours for each fuel cell vehicle stack was sometimes challenging. MBRDNA had direct control over the vehicles and customer selection, but it did not have control over the hydrogen supply for the vehicles. The problem was compounded by the overall lack of maturity of hydrogen stations in comparison to that of the F-CELL. To compensate for this, the Project Team continuously monitored the hydrogen station network to: (1) ensure that customers only used stations demonstrated to follow industry known safety best practices, and industry accepted codes and standards; (2) provide customers with unrestricted access to those stations; (3) ensure that customers were informed about which stations were off-line at any given time; and (4) ensure the program's long-term viability by fostering hydrogen infrastructure development in areas that displayed high levels of customer demand for Mercedes-Benz F-CELL vehicles.

Throughout the course of the project, it was evident that the size and resiliency of the hydrogen station network, and the underlying hydrogen production and distribution infrastructure affected the number of customer miles driven more than any other factor in the program.

Maintaining data production required the Project Team to act as liaison and turntable for information between station operators and F-CELL customers. Oftentimes, the customers were the first to become aware that a station was having a malfunction, and they were encouraged to report such issues back to the Project Team. This helped minimize station downtime, and allowed the information to be cascaded to other drivers, enabling those other drivers to adjust their fueling plans and avoid problematic stations.

Accomplishment

In addition to the day-to-day activities needed to ensure F-CELL customer access to hydrogen to keep vehicles in operation and support mileage production, the Project Team also worked to ensure the long-term viability of both the F-CELL program and the long-term market viability of Mercedes-Benz F-CELLs through targeted activities focusing on market development.

Customer Access to Hydrogen

Over the course of the Program, the Project Team worked to gain customer access to every open retail hydrogen station in the state, and every demonstration station to which customers requested access and which satisfied our safety requirements. During the seven years of B-Class F-CELL vehicle operation, customers performed over 10,000 hydrogen refuels dispensing over 30,000 kg of hydrogen, and driving over 2.6 million miles. Had fewer station outages occurred over the life of the program, the total mileage accumulation and total number of refuels would have been noticeably higher. On the other side, if it were not for the efforts of

the Project Team performing this function, the number of miles produced might have been much lower, and customer retention would have suffered.

Hydrogen Station Network Development

The expansion of the hydrogen station network over the term of the program played a significant role in ensuring the program's success, and increased the likelihood of market success for future Mercedes-Benz fuel cell vehicles. Expanding the network made the following possible:

- Allowed vehicles to be deployed to a larger geographic area in Southern California, thereby reducing the congestion at stations during peak hours;
- Enabled the deployment of F-CELL vehicles into the San Francisco Bay Area;
- Introduced open retail hydrogen stations into the network, which made a gasoline station-like customer experience possible;
- Allowed existing customers to drive their vehicles over a larger geographic area, such as, from Northern to Southern California.

Together, all of these results improved the customer experience for F-CELL customers and increased the utility of the vehicles overall. As a side benefit, it increased the overall value proposition for all fuel cell vehicles in California, and helped ensure the long-term viability of the marketplace.

Impact

Station Product Development

Unlike most automotive vehicles, which are developed behind a fence, hydrogen stations are developed in public. Like any product development, the most valuable learnings occur when something breaks, and then a successful fix is implemented. In order to expedite the development of hydrogen stations from early demonstration stations to fully functional open retail stations, the Project Team shared customer feedback with station operators to help them more quickly refine their products. Customer complaints about issues like nozzles freezing onto vehicles, dispenser order of operations being non-intuitive, point of sale controllers authorizing a fill after payment were just some of the bugs F-CELL customers helped to work out of stations. The ease of operation of hydrogen stations today are the direct result of F-CELL customer input and station product testing.

Picture 8: F-CELL Drivers at a Demonstration Station (l) and a Retail Station (r)

Regulatory Affairs

One of the greatest contributions to the development of the hydrogen station network in California was the application of F-CELL customer knowledge, experience, requests and feedback into the CEC hydrogen grant solicitation process. This took the form of one-on-one discussions with individual station providers, letters to the CEC regarding station location needs, public testimony and docket submissions.

In one particularly successful event, the Project Team arranged a dinner meeting between a group of long-time F-CELL customers, and representative from the CEC and the Governor's Office of Economic and Business Development. The staff were given full access to the customers and allowed to ask whatever questions they wanted, and get answers unfiltered, directly from the customers. To the best of our knowledge, no such meeting has ever taken place anywhere in the United Stated before or since.

At the start of this project in 2013, there were seven hydrogen stations in Southern California, and one in Northern California. Following the hydrogen station solicitations, that number grew to 22 stations in Southern California, 12 stations in Northern California, and one in the Central Valley which allowed customers to drive from one market area to another. All of these stations were proposed and awarded with the input from F-CELL customers, including station location requests and technical capabilities to better align with customer preferences. As of Q1 2019, over 6,000 fuel cell vehicle customers were driving are on the roads in CA using stations vetted by the MBRDNA Project Team.

From the June 2018 AB8 Report, CARB showed that a network of 1000 carefully placed hydrogen stations would put a station within 15 minutes of 95% of the population in California. Presently, there are 39 hydrogen refueling stations in California today. The pathway to 1,000 stations may seem long and the goal a long way off, but the approach to building out that network is nearly fully established; now it is just a matter of follow-through and implementation. The Project Team is proud to have contributed to this effort to commercialize hydrogen fuel cell vehicles.

Conclusion

From Q1 2013 through Q4 2017, the "Light Duty Fuel Cell Electric Vehicle Validation Data" project successfully submitted 60,000 hours of data for 20 active Gen II fuel cell vehicles and data from a fuel cell vehicle with over 5,000 hours of operation, thereby contributing to the body of knowledge upon which the relative maturity of fuel cell vehicle technology will be determined.

Within the context of this project, MBRNDA was able to make substantial contributions to the development of a more robust infrastructure by working together with a myriad of stakeholders on a daily basis to improve station development, access and reliability. While chairing the SAE committee responsible for interoperability between vehicles and stations, MBRDNA guided the passage of codes and standards which created a uniform hydrogen fueling experience on par with what one experiences at a gasoline fueling station available to any FCEV.

The fuel cell program developed by MBUSA and MBRDNA proved to be a successful model for subsequent fuel cell vehicle deployments by other OEMs. In particular, it was the Project Team's focus on customer service and education that was instrumental to the success of the program. The 24/7 F-CELL concierge service was one of the distinguishing program features, especially at the beginning of the program when the infrastructure network was in its infancy.

The opportunity this program otherwise presented to introduce fuel cell vehicles to MBUSA and participating dealerships helped to expand the knowledge base in the company about alternative vehicle technologies. Learnings acquired will certainly also be applicable for the introduction of other new technologies and thus beneficial to future customers who choose to lease or purchase the next Mercedes-Benz zero emission vehicle.

On behalf of the MBRDNA Project Team, MBUSA and Daimler AG, we would like to express our gratitude for the opportunity to shape the automotive technological landscape in the United States and in California in partnership with the Department of Energy. This project allowed Mercedes-Benz the fiscal support to gather critical real-world data and further develop F-CELL technology for use in future vehicle generations.

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