

FINAL SCIENTIFIC REPORT FOR DOE/EERE
Cooperative Agreement No. DE-EE0005968
“Light Duty Fuel Cell Electric Vehicle Validation Data”

SUBMITTED BY

Electricore, Inc.
27943 Smyth Drive, Suite 105
Valencia, CA 91355

SUBMITTED TO

U. S. Department of Energy
Fuel Cell Technologies Office
Mr. James Alkire
James.alkire@go.doe.gov

PRINCIPAL INVESTIGATOR

Ms. Deborah Jelen
Electricore Executive Director
(661)607-0230
jelen@electricore.org

PROJECT TEAM MEMBERS

Honda R&D Americas, Inc.
Nissan Technical Center North America
Toyota Motor Engineering & Manufacturing North America, Inc.
University of California, Irvine
Quong & Associates, Inc.
TG Energy

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1. Executive Summary

Electricore, along with partners from Quong & Associates, Inc., Honda R&D Americas (Honda), Nissan Technical Center North America (Nissan), and Toyota Motor Engineering & Manufacturing North America, Inc. (Toyota), participated in the Light Duty Fuel Cell Electric Vehicle (FCEV) Validation Data program sponsored by the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) (Cooperative Agreement No. DE-EE0005968).

The goal of this program was to provide real world data from the operation of past and current FCEVs, in order to measure their performance and improvements over time. The program was successful; 85% of the data fields requested were provided and not restricted due to proprietary reasons. Overall, the team from Electricore provided at least 4.8 GB of data to DOE, which was combined with data from other participants to produce over 33 key data products. These products included vehicle performance and fuel cell stack performance/durability. The data were submitted to the National Renewable Energy Laboratory's National Fuel Cell Technology Evaluation Center (NREL NFCTEC) and combined with input from other participants. NREL then produced composite data products (CDP) which anonymized the data in order to maintain confidentiality. The results were compared with past data, which showed a measurable improvement in FCEVs over the past several years. The results were presented by NREL at the 2014 Fuel Cell Seminar, and 2014 and 2015 (planned) DOE Annual Merit Review.

The project was successful. The team provided all of the data agreed upon and met all of its goals. The project finished on time and within budget. In addition, an extra \$62,911 of cost sharing was provided by the Electricore team. All participants believed that the method used to collect, combine, anonymize, and present the data was technically and economically effective.

This project helped EERE meet its mission of ensuring America's security and prosperity by documenting progress in addressing energy and environmental challenges. Information from this project will be used by the hydrogen and vehicle industries to help advance the introduction of FCEVs and associated hydrogen infrastructure.

2. Accomplishments

The Light Duty Fuel Cell Electric Vehicle (FCEV) Validation Data program was successful in meeting its goals to conduct a joint FCEV validation data project in conjunction with Honda R&D Americas (Honda), Nissan Technical Center North America (Nissan), and Toyota Motor Engineering & Manufacturing North America, Inc. (Toyota). A major project objective was to provide accurate forecasts for key FCEV parameters, including the reliability, durability and operating characteristics of fuel cells and related components.



Figure 1: Participating Japanese OEM Vehicles

The project was conducted over two (2) phases, during which each of the participating OEMs provided real world operational data from their fleets of light duty fuel cell vehicles.

Phase 1 - Prior Collected Data from Current Generation FCEVs

The automotive OEMs provided data, collected during prior operation of fifteen current generation FCEVs, following NREL National Fuel Cell Technology Evaluation Center (NFCTECC) protocols for handling and submitting the data.

Phase 2 - Newly Collected Data from Current Generation FCEVs

The automotive OEMs collected and submitted new data from fifteen FCEVs currently in operation, following NREL NFCTEC protocols for handling and submitting the data.

Table 1: Program Phases and OEM participation

| Phase # | Vehicle Generation | Data | Honda | Nissan | Toyota |
|---------|--------------------|---------|-------|--------|--------|
| 1 | Current | Prior | | X | X |
| 2 | Current | Current | X | | X |

During each of the phases, the OEMs individually negotiated the details of their participation, including number of vehicles, duration, and data submitted. The following data was collected and submitted to the NREL National Fuel Cell Technology Evaluation Center over the course of the entire project period of performance:

- From May 1, 2013 to April 30, 2015, Honda submitted data for 5 vehicles covering January 2011 through March 2015
- From May 1, 2013 to April 30, 2015, Nissan submitted data for 8 vehicles operating from October 2006 through December 2014.
- From May 1, 2013 to April 30, 2015, Toyota submitted data for 5 vehicles covering September 2010 through December 2014

3. Project Activity Summary

Activities under this contract were limited solely to the submission and processing of vehicle data directly provided by our OEM partners - Honda, Nissan, and Toyota. The project can be broken into three tasks discussed below.

Task 1—Project Management and Reporting

This included developing a project plan, negotiating the data submitted to NREL, and developing a secure transfer method. Although this task was challenging due to the confidential nature of the data, 85% of the data fields were available and not restricted due to proprietary reasons and made available to NREL for analysis. The data provided by the team included DOE high priority topics, such as fuel cell stack durability and vehicle and stack performance.

The team also determined the method to provide the data directly to NREL in this task.

Task 2 Prior Collected Data from Current Generation FCEVs (Phase 1)

Task 3: Newly Collected Data from Current Generation FCEVs (Phase 2)

In these tasks, each OEM selected a minimum of five (5) FCEV vehicles for which they provided past and/or current vehicle data according to the data field matrix approved in Task 1. The individual OEMs processed and formatted their data into a format that was supported by the National Renewable Energy Laboratory (NREL), and securely transferred to NREL's NFCTEC following its protocols for handling and submitting the data. NREL then processed the data and combined it with data from other technology validation program participants. In addition, each of the OEMs and Electricore participated in an iterative process for the review and approval of multiple Composite Data Products (CDP) and Detailed Data Products (DDP) developed by NREL. Specific methods, problems, and benefits for each OEM are listed below.

Honda R&D Americas, Inc.

a) Data Collection Method

Honda processed the data internally with in-house software on a monthly basis and submitted data files to NREL via secure FTP that was password protected.

b) Problems Encountered

The software and effort to format the data was more time-intensive than originally planned by Honda engineers internally.

c) Publications

Honda shared the data within its company, both the Research & Development group and Corporate.

d) Project Benefit

The refueling data (e.g., time to fill) helps support other efforts such as implementing the MC Method as an SAE Standard to reduce the refueling time and improve customer appeal.

Nissan Technical Center North America

a) Data Collection Method

Data was collected via Nissan proprietary equipment and then processed in MATLAB into the appropriate format for NREL. Data was then encrypted and transferred to NREL via the secure WingServer FTP site setup by NREL.

b) Problems Encountered

Time stamps in the recorded data had to be corrected for time-zone and clock setting errors to align properly with other paper logs and system computer data sources. With the time stamps corrected it was possible to properly align all of the data sources to meet the agreed NREL data submission. The process also identified occasional instances of corrupt data and other minor data problems which were resolved prior to transmittal of data. As a result of this process, submission of data was delayed from the original plan, but completed before the end of the project period.

c) Publications

No external publications or presentations were made during the term of the project, but the NREL data products were shared within Nissan R&D departments.

d) Project Benefit

The detailed data products have provided a useful overview and summary of vehicle performance and activity.

Toyota Motor Engineering & Manufacturing North America, Inc.

a) Data Collection Method

Toyota processed the data using MATLAB and submitted it to NREL via Toyota's secure FTP site.

b) Problems Encountered

For Toyota, there were no significant problems encountered or departures from planned methodology regarding data processing, transfer, and reporting.

c) Publications

Toyota has not prepared any publications or presentations referring to the DOE FCEV Technology Validation program.

d) Project Benefit

Toyota has used the NREL DDPs to compare against internal Toyota analysis, and to better understand Toyota technology status relative to that of other participating OEMs.

4. Products Developed / Technology Transfer Activities

The information contained in the CDPs was presented by NREL on multiple occasions, including the 2014 DOE Annual Merit Review and 2014 Fuel Cell Seminar.

The CDPs that NREL will present at the 2015 DOE Annual Merit Review tentatively include:

| | | |
|-------------------------------|---|--|
| Vehicle Count | Vehicle Speed and Acceleration Parameters | Fuel Cell Stack Power Level Operation Time |
| Vehicle Miles | Average Vehicle Fuel Economy | Final Fueling Pressure – FCEV Onboard Sensors |
| FCEV Miles Driven by Calendar | H2 Tank Level at Refueling | Average Trip Speed |

| | | |
|--|---|---|
| Fuel Cell Stack Hours | Refueling by Time of Day | Trip Speed Comparison with Standard Drive Cycles |
| Average Calendar Days between Refueling per vehicle | Refueling by Day of Week | Fuel Cell Stack Power Level Operation Time |
| Distance Driven Between Refueling | Driving Start Time – Day | Vehicle Tank Temperatures: Before and After a Fill |
| FCEV Fill Amounts | Driving by Day of Week | Vehicle Tank Temperatures and Pressures after Fill Events |
| FCEV Fill Duration Time | Driving by Day of Week | FC Operation Hours and Voltage Degradation Trend |
| Data Files & Size | Operation Hours and Voltage Durability | On-road Fuel Economy Trends |
| Vehicle Size Parameters | Projected Hours to 10% Voltage Degradation | OEM Participant Trend |
| Fuel Cell System Power & Useable H ₂ Parameters | Fuel Cell Stack Voltage Durability as a Function of Voltage Drop Levels | |

Under this award, Electricore was granted an “Advance Patent Waiver,” on behalf of its project partners, from the DOE Patent Counsel. The FCEV data shared under this agreement are direct vehicle operational data that were gathered by each of the individual OEMs from current generation vehicles. These FCEVs are either commercially available or no more than one generation from commercial production.

Honda, Nissan, and Toyota have all made large financial and technological investments in their vehicle fleets that will directly promote further development of fuel cell vehicles and the associated technologies. Although this project was limited to data collection, the intent was to provide improved understanding and insight regarding plans and timing for the commercialization of fuel cell vehicles. Electricore and its project partners believe this objective has been accomplished, and have been pleased to participate in DOE’s FCEV technology validation program.