FedEx Express Hydrogen Fuel Cell Extended-Range Battery Electric Vehicles

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Project Partners:
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Plug Power Inc, Latham, NY

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October 1, 2015

Project End Date:
April 30, 2019

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Overall Objectives:

- To convert an existing electric parcel delivery unit (PUD) into a zero-emission extended range electric vehicle by utilizing hydrogen fuel cell technology.
- Understand, demonstrate and deploy hydrogen fuel cell technologies in real-world environment.

Objectives throughout project:

- Optimize, test and complete the integration between the fuel cell and the Electric vehicle (EV).
- Identify and analyze the proper route and location for the asset's placement.
- Determined the optimal hydrogen storage quantity and location.
- Test and verify the performance of the fuel cell.
- Optimize, test and complete the integration between the fuel cell and the Electric vehicle (EV).
- Determined the optimal hydrogen storage quantity and location.
- Complete the body manufacturing and installation.
- Optimize the power generation and charge strategy.
- Create fueling strategy for vehicle in Latham, NY.
- Work with Menands station on route selection, charging, and maintenance.
- Complete integration of Fuel Cell and EV communication.
- Prepare vehicle for On-road testing and implementation.
- Complete and submit Safety Plan.
- Conduct durability testing.
- Deliver vehicle to station.
- Train FedEx drivers and maintenance tech on Hydrogen safety.
- Start and continue data collection through BP1.
- Transmit Data to NREL regularly throughout BP1.
- Make go/No-Go decision.

Technical Barriers:

This project addresses the following technical barriers from the Market Transformation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- High hydrogen fuel infrastructure capital costs for Polymer Electrolyte Membrane (PEM) fuel cell applications.
- Market uncertainty around the need for hydrogen infrastructure versus timeframe and volume of commercial fuel cell applications.
- Inadequate user experience for many hydrogen and fuel cell applications.
- Insufficient numbers of trained and experienced servicing personnel.
- Lack of qualified technicians for maintenance.
- Lack of certified service providing organizations for installation and maintenance.

Contribution to Achievement of DOE Technology Acceleration/Systems Analysis Milestones:

This project will contribute to achievement of the following DOE milestones from the Market Transformation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- Milestone 1.8: Complete deployment and evaluation of short haul/drayage trucks and range extenders. (1Q, 2014)

Accomplishments:

- Identified replacement EV OEM.
- New EV sub recipient has experience with range extension.
- Technical kick-off meeting among program partners at manufacturing facility to discuss component requirements and placement.
- Program kick-off meeting among program partners at Memphis Headquarters.
- Site and product review visit to Workhorse.
- Analysis of 150-mile drive cycle with up to 60-mile stem length at beginning and end.
- Planning in process for dyno testing.
    - Variable payloads.
    - Temperature effects.
    - Parasitic loads.
- Integration activity kick off.
- Integration hardware identified and tested.
- Upcoming testing planned and finalized.
- PUD placement location identified.
- Fueling challenges discussed and mitigated.
- Hydrogen Tank location and storage finalized.
- Design integration between the partners was launched.
- Fuel cell fabrication.
- Fuel cell validation and testing.
- CAD models finalized.
- EV and FC integration.
- Bracketry design and production.
- Power generation and charge strategy optimization.
- Hydrogen tanks storage and location.
- Body modification for hydrogen tank compartmentation.
- Body design, manufacture and installation.
- Dilution and vent testing.
- Optimized thermal management.
- CAN messaging and instrument cluster integration.
- Final placement location site preparation.
- Durability test preparation.
- Proposed plans for truck fueling at Plug Power Latham.
- Build plans for H2 dispenser in Latham.
- Planned route selection, driver selection, charging, and maintenance with Menands management.
- Installed fuel cell systems and converter in truck engine compartment.
- Created control strategy for battery charging.
- Created software for communications between fuel cell system and truck.
- Installed/debugged remaining items on truck.
- Provided EVSE charger for truck to Menands ship center.
- Registered vehicle.

- Submitted safety plan to DOE.
- Conducted durability test.
- Received permit for H2 dispenser at Plug Power.
- Installed outdoor H2 dispenser at Plug Power.
- Delivered truck to Menands ship center.
- Trained FedEx employees on H2 safety.
- Started data collection.
- Sent first set of Data to NREL.
- Sent request for Extension of BP1 to the DOE.
- Completed Extended BP1 to the end of April 2019.
- Completed data collection and working with the NREL to determine how to analyze the data.
- Made decision for Go / No-Go gate.

Introduction:

The ability to reduce fuel consumption and emissions while delivering packages is an immense challenge, particularly with the available technology. This is further complicated by the diversity of the different duty cycles utilized by the Pick-up and Delivery vehicles (PUD's) at FedEx. This has created enormous opportunities for an extended range, zero emission electric PUD.

As a part of this project, we were tasked with converting 20 existing Electric vehicles into Hydrogen Fuel cell powered extended range electric vehicles (eREV), in two different phases/Budget Periods (BP).

Successful utilization of fuel cell technologies in real world environments will help foster a better understanding while providing the opportunity to identify and utilize additional duty cycles, eventually reducing costs by achieving economies of scale, while providing clean, safe, secure and affordable energy.

Approach:

The first step was to find industry partners that had the experience, capabilities and the knowledge to collaborate with us in embarking on this project. As a result, FedEx has collaborated with Workhorse for the EV, Plug Power for Fuel Cell and Morgan Olson for the body of the eREV. Integration of the systems was performed by Plug Power in collaboration with Workhorse.

The project was divided into two separate phases/budget periods (BP1 & BP2). The first period concentrated on the conversion of one asset. This enabled the project team to test, analyze and measure the performance, collect data and observations for lessons learned and allow for adjustments before making the Go/No-Go decision regarding the viability to proceed into BP2.

During BP1, the team made significant progress evaluating the first eREV PUD. The route identified and chosen for the evaluation included Plug Power as a daily stop, allowing fueling when necessary and daily discussions with the Plug Power team. This was to allow for quick identification and resolution to issues identified. An optimized charge strategy and power generation for the fuel cell was implemented.

The data collection period was determined to be six months initially. After a few unexpected issues we were requested to extend it to thirteen months.

Project Results:

This was a multi-year project with evaluated milestones and tasks thorough each year. All of the milestones and tasks were accomplished in order to get the vehicle on the road for real world testing. The most important milestone for the evaluation of Project Results was the data collection and analysis performed over the course of the last 12 months of budget period 1. Durability testing was conducted by Plug Power, before the vehicle was commissioned and put into service on January 30, 2018. There were some challenges at the beginning of the real-world validation. In the first months, there where various problems with both the Fuel Cell and the Electric Vehicle. The figure below depicts out of service time by systems and Planned Maintenance (PM), in days. In the last nine months of service, the fuel cells have been nearly perfect apart from a controller issue in December that was repaired in a few days.

The vehicle was down and out of service for nearly two months in October and November of 2018 due to a bad battery pack. Support from the EV manufacturer for the battery pack issue was not as timely and reliable as expected.

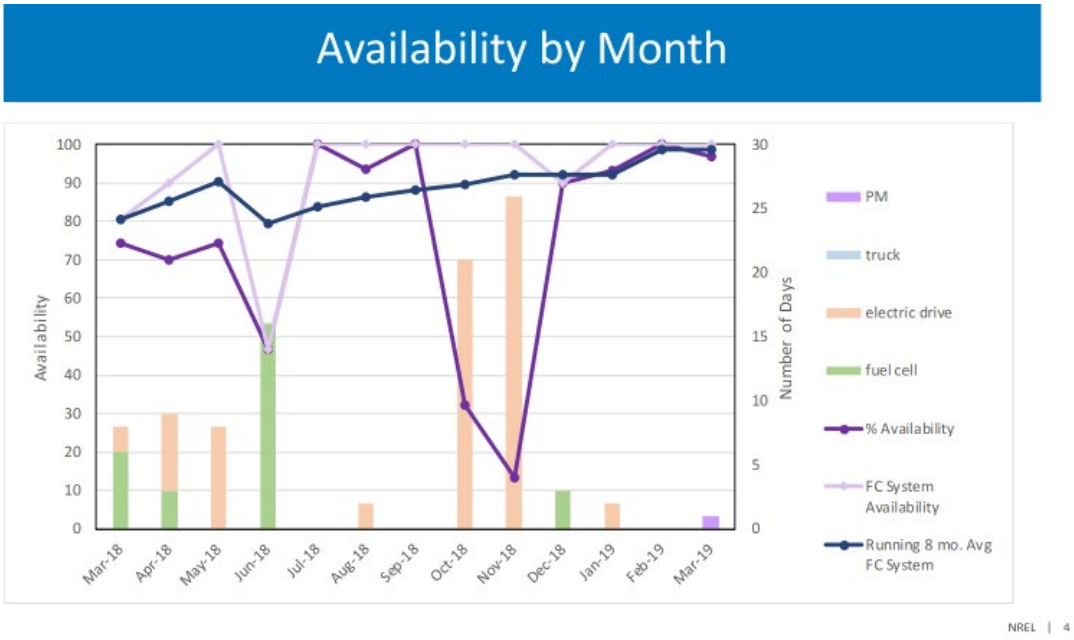

Figure 1- Availability by Month

In Figures 2 and 3 you will see that the total cost of the FCET vehicle is higher per mile than the baseline Diesel vehicle. The cost for the FCET is much higher but is largely due to the early issues that have been corrected.

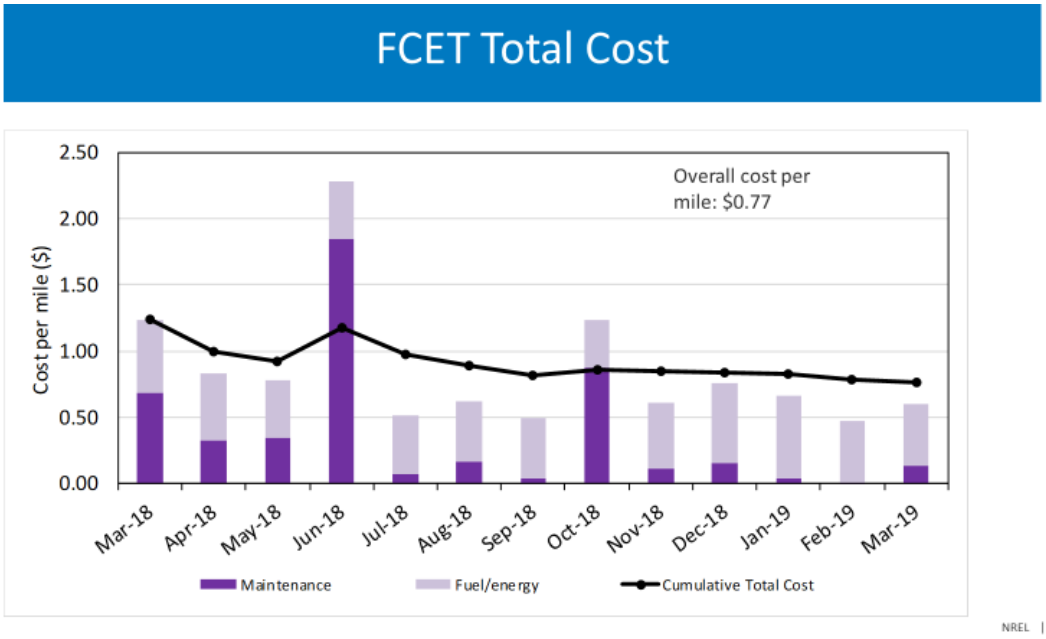

Figure 2 - FCET Total Cost

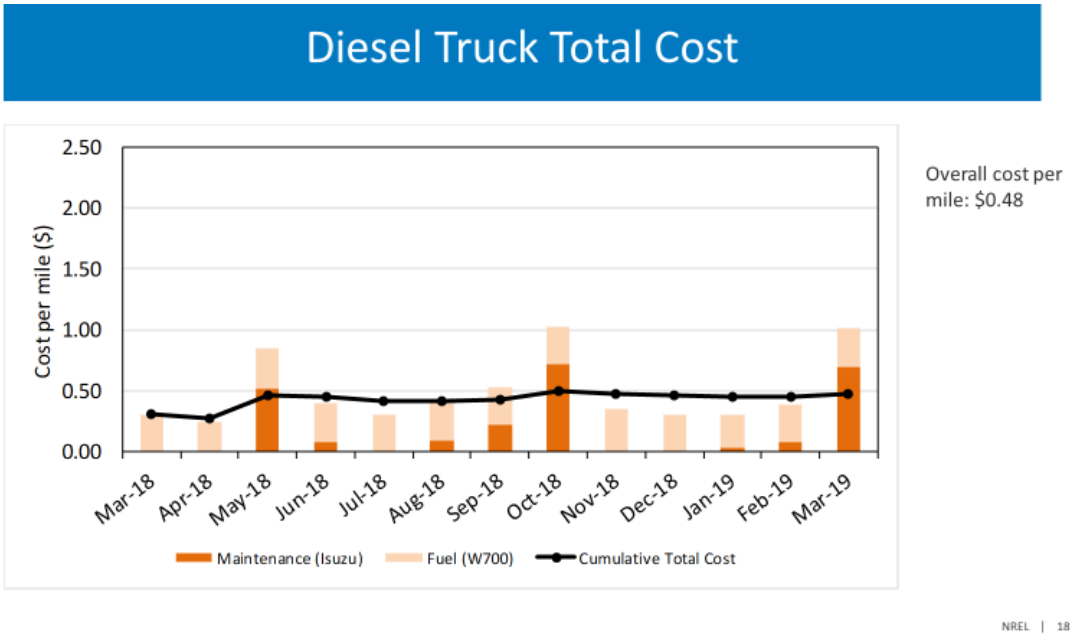

Figure 3 - Diesel Truck Total Cost

The next figure shows the overall availability of the vehicle broken down by system. The target for the fuel cell and fuel cell integration reliability is less than 7% down time. Because of a few early issues the system availability is at 7%. When you look at the last 8 months of data

collected, the availability of the fuel cell rose dramatically, only being unavailable 1% of the time, even though EV related issues rose during the same period.

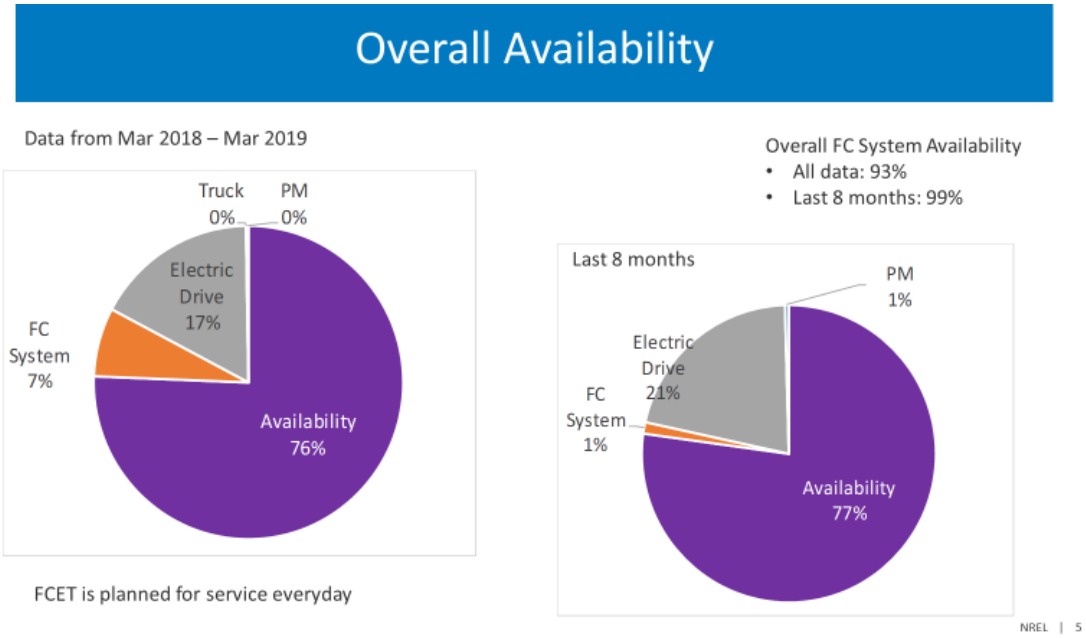

Figure 4 - Overall Availability

Conclusions[1]:

Because of the performance of EV and manufacturer's support during this BP1, we determined the following were the options moving forward on this project.

- End the project now, concluding BP1 and forgo BP2 due to unreliable EV manufacturer's support.
  - Recommending a No-Go
- Find another EV manufacturer / Integrator.
  - Recommending a Go.

    Would take 18+ months for a mature enough platform by a reliable OEM.

With the only reasonable path to move the project forward being, find another EV manufacturer and start over, the best business decision FedEx can make is to recommend a No-Go.

This project has proven that the technology is viable in this application, providing it is integrated into a reliable electric vehicle and that costs for fueling and the technology itself can be brought within reach of current operators.

[1] Projects that are awarded by FCTO through competitive Funding Opportunity Announcement (FOA) selections are fully funded for the project's full period of performance (subject to go/no-go decisions) in the year the project is awarded. Future direct-funded work at the national laboratories is subject to change based on annual appropriations.

Special Recognitions & Awards/Patents Issued:

No patents have been issued.

Publications/Presentations:

1. Thomas Griffin, "MT017: Medium Duty Parcel Delivery Truck" presented at the DOE Annual Merit Review, Washington, DC, June 6-9, 2016.
2. Imran Ahmed, "FedEx Express Hydrogen Fuel Cell Extended Range Battery Electric Vehicles" presented at the DOE Annual Merit Review, Washington, DC, June 5-9, 2016.
3. Phillip Galbach, "FedEx Express Hydrogen Fuel Cell Extended Range Battery Electric Vehicles" presented at the DOE Annual Merit Review, Washington, DC, June 13-15, 2018.
4. Phillip Galbach, "H2@Scale DOE Truck Workshop FedEx Express –Fleet Logistical Considerations, Chicago, July 30-31, 2018.
5. Phillip Galbach, "FedEx Express Hydrogen Fuel Cell Extended Range Battery Electric Vehicles" presented at the DOE Annual Merit Review, Washington, DC, April 29-May 1, 2019.

References:

1. DOE Hydrogen and Fuel Cells Program Annual Progress Reports (APR) Preparation Instructions
2. "FedEx FCET Results through Mar 2019.pptx", Leslie Eudy, National Renewable Energy Laboratory.

Acronyms:

PUD: Pick up Delivery
EV: Electric Vehicle
FC: Fuel Cell
EREV: Extended Range Electric Vehicle
BP: Budget Period

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