# X.3 Fuel Cell Hybrid Electric Delivery Van Project

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Subcontractors
- United Parcel Service (UPS), Sandy Springs, GA
- University of Texas Center for Electromechanics (UT-CEM), Austin, TX
- Unique Electric Solutions, Stony Brook, NY
- Hydrogenics, Mississauga, Ontario, Canada
- Valence, Austin, TX

Project Start Date: July 15, 2014
Project End Date: October 15, 2018

## Overall Objectives

- Increase the zero emission driving range and commercial viability of medium-duty trucks
- Phase 1 – develop a fuel cell hybrid electric delivery van and validate its design and construction through in-service operation
- Phase 2 – build the Phase 1 delivery van at precommercial volume (up to 16 vehicles) and perform at least 5,000 operation hours of in-service demonstration
- Develop an Economic/Market Opportunity Assessment for medium-duty fuel cell hybrid electric trucks

## Fiscal Year (FY) 2015 Objectives

- Perform application specific modeling and simulation to guide component selection and predict vehicle performance on delivery routes
- Perform trade study of vehicle powertrain and energy storage components to optimize commercial viability
- Complete vehicle design, order long lead time components, and begin fabrication
- Coordinate fueling infrastructure needs at demonstration site

## Technical Barriers

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

Technology Validation

(A) Lack of Fuel Cell Electric Vehicle and Fuel Cell Bus Performance and Durability Data

Market Transformation

(D) Market uncertainty around the need for hydrogen infrastructure versus timeframe and volume of commercial fuel cell applications

(F) Inadequate user experience for many hydrogen and fuel cell applications

## Technical Targets

This project directly addresses Section 3.9.4 Sub-Program Targets. This project lays out a very specific and rational pathway for the introduction of fuel cell technologies into the medium-duty vehicle market. The project has a technology validation phase and a follow-on deployment of precommercial volumes of the vehicles. The project is built upon the initial structure that DOE prescribed in the funding opportunity announcement and is augmented by the active participation and guidance of a major commercial fleet operator, UPS. UPS operates 46,000 medium-duty vehicles worldwide. Further, the vehicles will be deployed in California to take advantage of that state's focused growth of fueling infrastructure and desire to deploy zero emission vehicles. CTE has coordinated with station providers early in the project in order to identify and overcome fueling station barriers for this emerging application of fuel cell technologies, such as the limitation of SAE J2601 fueling protocol described below. This project further leverages the resources and support of the State of California. The project team has also focused on upfront design to ensure that (1) selection the fuel cell size will take advantage of volume growth from other applications and markets, and (2) that the design will meet the needs of our commercial fleet operator by matching the performance of incumbent technologies, while meeting the range requirements for over 97% of delivery van duty cycles.

## FY 2015 Accomplishments

- Collected real-world duty cycle data, modeled various fuel cell hybrid electric vehicle configurations, and simulated vehicle performance on anticipated delivery routes

- Defined the vehicle specifications
- Developed vehicle solid models and completed preliminary physical layout of battery, fuel cell, and hydrogen storage system
- Identified an absence of accepted standards for fueling medium-duty vehicles with greater than 7 kg of hydrogen storage (at 350 bar) at public fueling stations utilizing SAE J2601 protocol
  - Issue has been brought to the attention of several industry partners, and solutions are being discussed with Linde Industrial Gases and SAE J2601 committee members, among others
- Developed maps and proximity data that relate existing or expected hydrogen fueling stations with UPS service centers
  - Long-term commercialization will see fueling stations deployed by and at fleet properties, properly selecting fueling station locations and organizing the associated infrastructure is vital to the precommercial viability of these zero emission vans

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## INTRODUCTION

Parcel delivery van fleets are currently dominated by diesel- and compressed natural gas (CNG)-powered Class 3–6 trucks. In recent years, some parcel delivery services have integrated battery-electric trucks into their fleet; however, these battery-electric vehicles have been unable to match the performance of existing delivery vans and their limited range significantly impacts deployment strategy. The intent of this project is to develop a hydrogen fuel cell hybrid electric van that provides fleet operators with a zero emission vehicle capable of meeting route range requirements while matching the performance characteristics of its existing fleet vehicles. According to Fleet DNA data compiled by the National Renewable Energy Laboratory (NREL), a vehicle with a 125-mile range will meet 97% of Class 3–6 daily delivery driving distances [1]. Meeting this 125-mile range threshold will increase the attractiveness of zero emission trucks to fleet operators and increase their commercial viability.

## APPROACH

This project develops and demonstrates a hydrogen fuel cell hybrid electric van with a 125-mile operational range, which will be validated through in-service deployment in a California UPS fleet. This project has two phases:

- Develop a fuel cell hybrid electric delivery van and validate its design and construction through in-service operation.
- Build the Phase 1 delivery van at precommercial volume (up to 16 vehicles) and perform at least 5,000 operation hours of in-service demonstration.

During Phase 1, real-world delivery van route data are collected to define the expected duty cycle requirements. All potential fuel cell hybrid electric van powertrain configurations are then modeled and simulated on the duty cycles to assess vehicle performance and aid final design. Trade studies (including cost and projected costs at high volumes) are accomplished and vehicle components are then down-selected and the physical layout is completed. The first delivery van can then be built and validated through in-service operation. If the delivery van meets Phase 1 performance requirements, the project team will build and deploy up to 16 additional vans in Phase 2. All of the vans will be demonstrated in California. Vehicle performance data during the demonstration periods will be collected and provided to NREL's National Fuel Cell Technology Evaluation Center for analysis.

The project team benefits from having members with extensive hydrogen fuel cell experience, including UT-CEM and Hydrogenics, and one of the largest medium-duty truck fleet operations in the world, UPS. UPS has deployment experience with delivery vans powered by various fuels, including gasoline, diesel, CNG, and battery-electric. This experience gives them a unique perspective on the commercial viability of alternative fueled vehicles and their project contributions are invaluable. Project funding is provided by the DOE, the California Energy Commission, and the South Coast Air Quality Management District. UPS is providing cost share during the demonstration periods by supplying operation, maintenance, and fueling costs.

## RESULTS

The teams' modeling activity showed that a 32 kW fuel cell module, 45 kWh battery energy storage, and 10–15 kg of hydrogen are required to meet the 125-mile driving range objective on actual UPS delivery routes. These propulsion system configuration will allow the van to outperform existing battery-electric vans in UPS' fleet, as shown in the example simulation results in Figure 1. The simulated fuel cell van operates for over 500 minutes and drives 125 miles. The comparable battery electric van cannot reach 400 minutes of operation and only travels 70 miles.

After the modeling activity, the team established the vehicle specifications listed in Table 1.

Initial solid models of the van's physical layout and component packaging are shown in Figures 2 and 3.

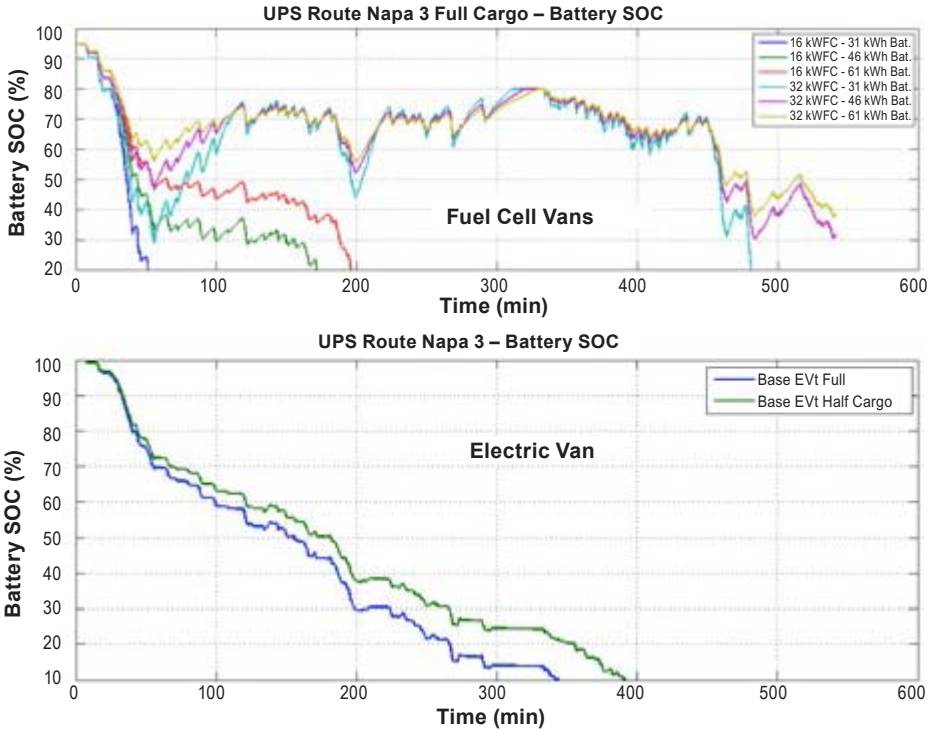


**FIGURE 1.** Simulated performance of fuel cell and battery electric vans on UPS delivery route

**TABLE 1.** Vehicle Specifications for Hydrogen Fuel Cell Hybrid Electric Van from Modeling Activity

| Physical Specifications | |
|---|---|
| Vehicle Chassis | Navistar International 1652SC 4X2 |
| Maximum Speed | 65 mph |
| Maximum Range | 125 mi |
| Acceleration (0–60 mph) | 26 s at 19,500 lb |
| Gross Vehicle Weight | Class 6 (23,000 lb) |
| Wheel Base | 176 in |
| Capacity | 970 $ft^3$ |
| **Battery System** | |
| Chemistry | $LiFeMgPO_4$ |
| | 45 kWh |
| | 110 Volts Alternating Current |
| | 1,500 cycles / 5 years |
| **Fuel Cell** | |
| Rated Power | 32 kW continuous |
| Peak Efficiency | 55% |
| **Hydrogen Storage** | |
| Capacity | 9.78 kg |
| Pressure | 350 bar |

**FIGURE 2.** Physical layout and component packaging with van body

## CONCLUSIONS AND FUTURE DIRECTIONS

The Fuel Cell Hybrid Electric Delivery Van project is utilizing team member experience with hydrogen fuel cell technologies, alternate fuel vehicle fleet familiarity, and

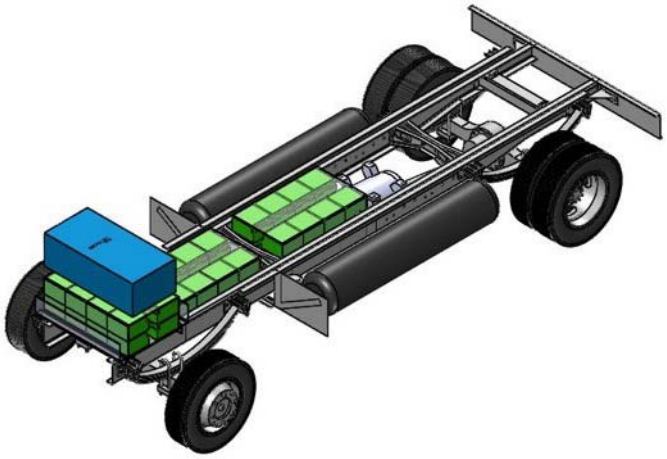

**FIGURE 3.** Energy storage system locations in van chassis frame

stakeholder feedback to develop commercially viable zero emission medium-duty trucks. The team has developed:

- Vehicle specifications to promote commercial acceptance.
- Component selection to ensure performance on real-world delivery duty cycles.
- Solid models of major components within vehicle body.
- Strategy to ease UPS fleet acceptance and fueling procedures.

Future work includes:

- Completing safety hazard analysis with support from the Hydrogen Safety Panel.
- Coordinating fueling availability and continue coordinating the development of medium-duty hydrogen fueling protocol.
- Completing the final design for the vehicle.
- Building and commissioning initial van design.
- Validating prototype van through in-service operation.
- Building final van design at precommercial volume (up to 16 vehicles).
- Training and educating end-user fleet operations personnel.
- Deploying and supporting vans in UPS California fleets.
- Collecting and evaluating in-service data during demonstration period.
- Developing an economic/market opportunity assessment for the vehicles.

## FY 2015 PUBLICATIONS/PRESENTATIONS

**1.** J. Hanlin, "Fuel Cell Hybrid Electric Delivery Van Project," presented at the DOE Annual Merit Review, Washington, DC, June 8–12, 2015.

## REFERENCES

**1.** Walkowicz, K.; Kelly, K.; Duran, A.; Burton, E. (2014). *Fleet DNA Project Data*. National Renewable Energy Laboratory. http://www.nrel.gov/fleetdna