CENTER FOR TRANSPORTATION
AND THE ENVIRONMENT

Fuel Cell Hybrid Electric Delivery Van Project

Project ID: TA016

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Center for Transportation and the Environment (CTE)
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Overview

Timeline

Project Start: 07/15/2014
Project End: 07/31/2022

Budget

Total Project Budget:	$ 11,264,505
Total Recipient Share:	$ 8,282,434
Total Federal Share:	$ 2,982,071
Total DOE Funds Spent:	$ 1,547,130*

*through Feb. 2020

Partners

US DOE, CARB, SCAQMD, CEC: Project Sponsors
UPS: Commercial Fleet Partner and Operator
CTE: Prime Contractor and Project Manager
Hydrogenics, UES, UT-CEM: Subcontractors

Barriers

Technology Validation

A. Lack of Fuel Cell Electric Vehicle 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

Relevance – Project Objectives

Overall Objectives

- Substantially increase the zero emission driving range and commercial viability of electric drive medium-duty trucks
  - **Phase 1:** develop a demonstration vehicle in order to prove its viability to project sponsors, commercial fleet partner (UPS), and other stakeholders [Barriers A & F]
  - **Phase 2:** build and deploy a pre-commercial volume (15) of the same vehicle for at least 5,000 hours of in-service operation [Barriers A & F]
- Develop an Economic & Market Opportunity Assessment for medium-duty fuel cell hybrid electric trucks [Barrier D]

Current Year Objectives (April 2019 – March 2020)

- Demonstrate and evaluate vehicle in UPS fleet service
- Complete manufacturing plan and engineering updates for Phase 2
- Complete DOE Go/No-Go to authorize Phase 2
- Begin Phase 2 vehicle assembly

Relevance – DOE Program Goals

Alignment with DOE Program Goals

- The project promotes commercialization of hydrogen fuel cell vehicles by:
  - designing energy storage and drive system for new-builds and conversion kit retrofits,
  - deploying multiple vehicles within the UPS delivery fleet,
  - utilizing hydrogen fueling infrastructure at multiple locations, and
  - publishing an Economic & Market Opportunity Assessment
- The project will help determine how competitive hydrogen FC hybrid electric vehicles are to existing technologies by deploying the FC vans on routes that are also served by diesel, natural gas, and electric vans.
- The project increases end-user's experience and knowledge of H2 fuel cell vehicles and ensures the team creates a commercially viable product by involving UPS in design activity
- The project pushes industry to address need for H2 infrastructure in medium-duty market

Approach – Project Scope

16 Fuel Cell Hybrid Electric Walk-In Delivery Vans

- **Phase 1: Convert, demonstrate, and validate 1 vehicle**
  - Convert existing UPS diesel-powered van to a base electric-drive vehicle [out of DOE project scope]
  - Integrate FC, power electronics, hydrogen storage system, and controls
  - Train UPS fleet operators and support staff
  - Demonstrate and validate in UPS fleet for 6 months
- **Phase 2: Build and deploy 15 additional vehicles**
  - UES is responsible for full integration activities, with CEM assistance
  - CTE will coordinate training of UPS fleet operators and support staff
  - UPS will operate vehicles at multiple distribution centers in California
  - 2 years of data collection and project reporting
  - Develop an Economic & Market Opportunity Assessment

Any proposed future work is subject to change based on funding levels.

Approach – Project Milestones

Task	Description	% Complete	Estimated Completion Date
Phase 1 Demonstration			
1	Vehicle Build	100%	Jan. 2019
2	Training and Education	100%	Feb. 2019
3	Demonstration Vehicle Test and Evaluation	100%	Oct. 2019
4	Project Management Phase 1	100%	Oct. 2019

Go / No-Go Decision Point	**Oct. 2019**

Phase 2 Deployment			
5	Vehicle Build	25%	Dec. 2020
6	Training and Education	0%	Oct. 2020
7	Vehicle Test and Evaluation	0%	Dec. 2022
8	Project Management Phase 2	0%	Feb. 2023

Any proposed future work is subject to change based on funding levels.

Accomplishments and Progress

Demonstrated with UPS in revenue service for a full year

- ✓ Demonstrated in West Sacramento for 5 months and in Gardena for 6 months in 2019 – original workscope only required 6 months
- ✓ Trained operators, mechanics, and supervisors at both UPS facilities
- ✓ Demonstration was actively supported by project partners for entire duration
- ✓ Addressed fueling station issues as they were encountered throughout the demonstration
- ✓ Extended demonstration supported additional data collection and the ability to prove out Phase 2 technologies
  - ✓ Gen2 DC-to-DC, parking pall, vehicle controls

Photo: UES

Photo: CTE

Accomplishments and Progress

Outcomes of Phase 1 demonstration:

- ✓ Successfully operated out of multiple UPS centers utilizing public fueling infrastructure
- ✓ Public fueling station downtime prevented significant number of demonstration days

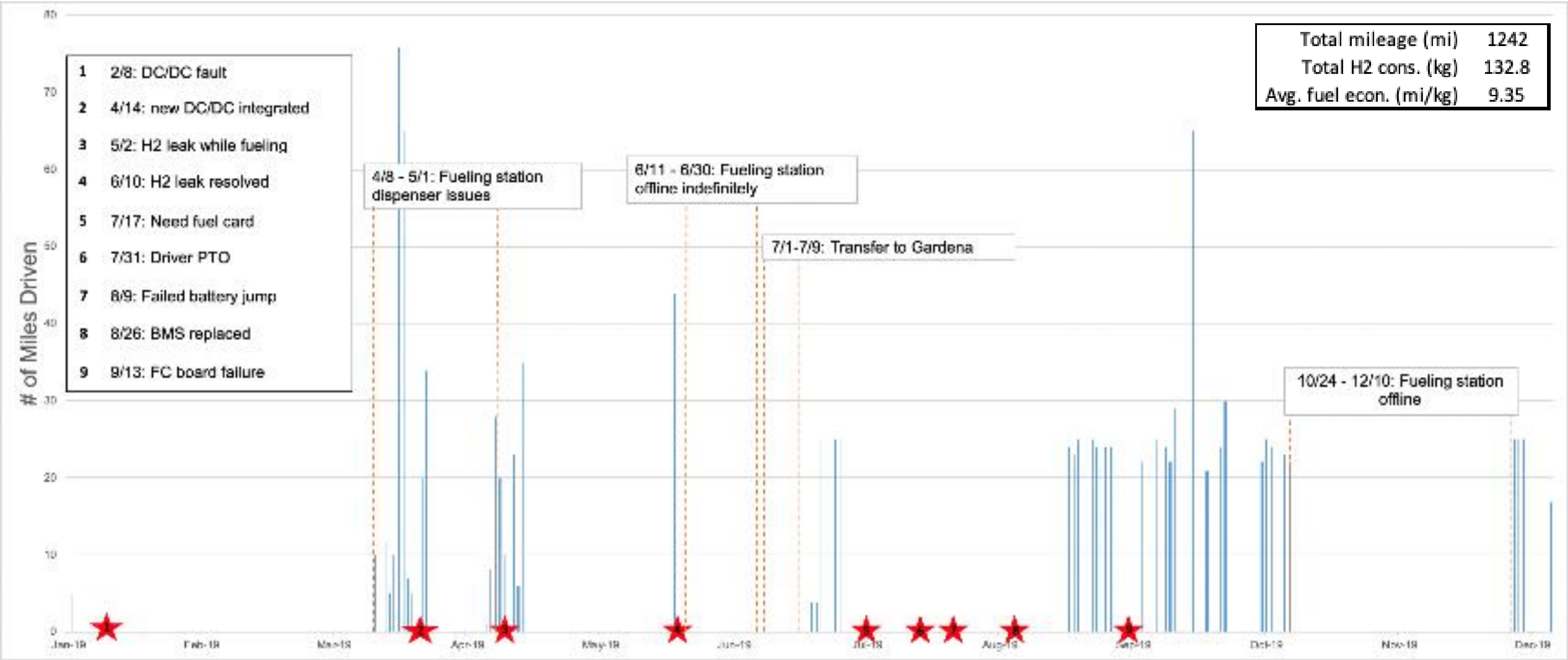


Chart: CTE

Accomplishments and Progress

Real Performance Data from October 1, 2019:

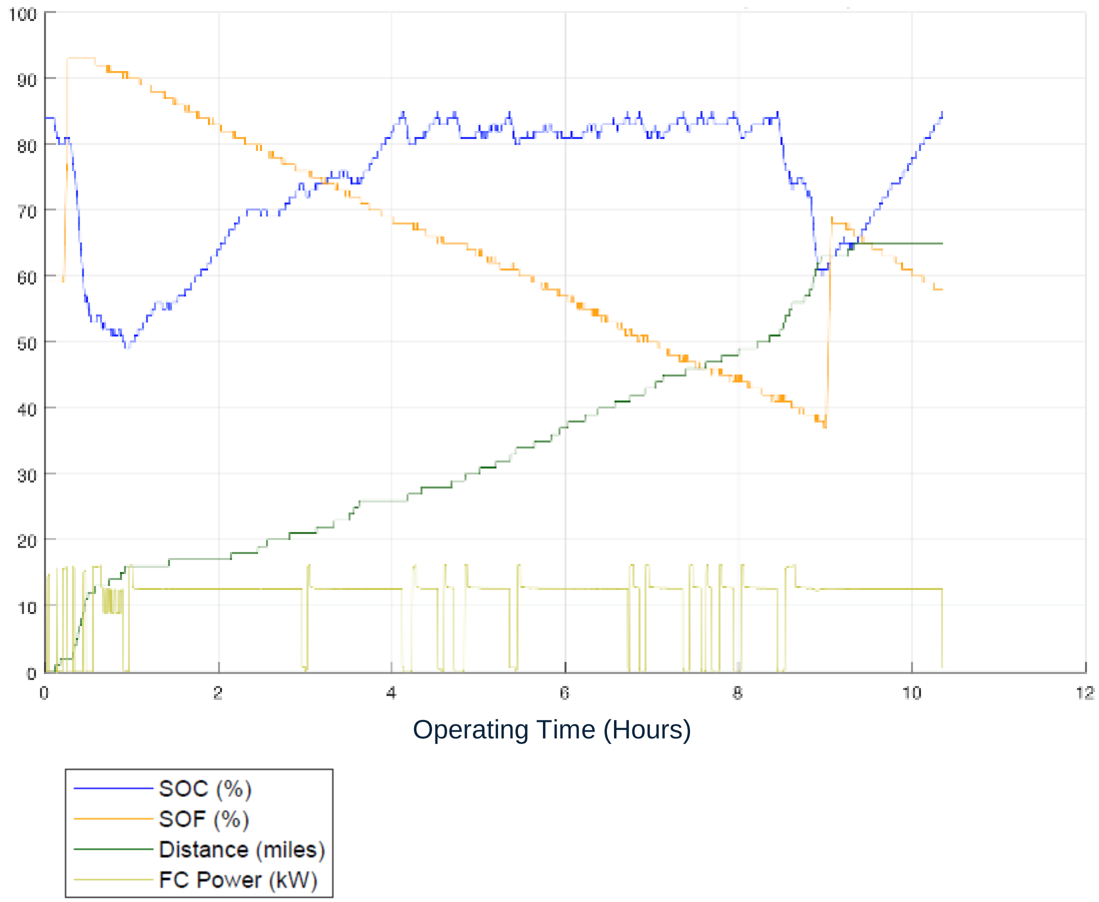


Chart: CTE

- Real performance data confirms expectations for SOC vs time during specification of vehicle configuration
- SOC "valleys": extended highway operation
- SOC "peaks": residential or commercial deliveries
- Consistent and efficient FC power across duty cycle – 65mi service route

Accomplishments and Progress

Completed Go/No-Go assessment and kicked off Phase 2

- Completed go/no-go assessment and authorized Phase 2 in Q4 2019
- Updated vehicle modeling and performance simulations
  - Production vehicle significantly lighter than original model
  - Fuel economy gains between 5-20% over original, depending on duty cycle
- Completed manufacturing plan and engineering design updates
  - Upsized battery to handle longer highway stretches
  - Design updates are tied to specific root cause of issues encountered in Phase 1
- Partnering with W.W. Williams for Phase 2 build – currently completing the first vehicle
  - All 15 propulsion system kits have been ordered, first 5 delivered

Photo: UES

Responses to Last Year AMR Comments

"The project demonstrates a sound approach to accomplishing tasks. The data collection and analysis of the performance of fuel cell trucks in this application should help the industry develop a fully commercial product … The team should encourage maximum usage during the demonstration to help identify and correct issues before the Phase II trucks are built"

- Shortcomings in uptime (due to a combination of issues between vehicle and infrastructure) are being made up in operation time exceeding one year to-date, more than twice the requirement
- Extended demonstration continues to be fully supported by the project team, including the UPS Gardena team
- The demonstration vehicle has been upgraded with Phase 2 systems to mitigate risk during Phase 2 vehicle build and validation
- All vehicle data was collected and submitted to NREL and the project team is seeking additional baseline vehicle data to support performance comparisons

Responses to Last Year AMR Comments

“There is a need for all problems to have root cause solutions and appropriate validation … it is critical in bringing the demonstration from a one-vehicle demonstration up to the planned fifteen-vehicle “pilot” fleet, which is a critical next step to commercialization.”

“It is unclear whether the conversion to 700 bar tanks is a good idea, given all the other problems encountered.”

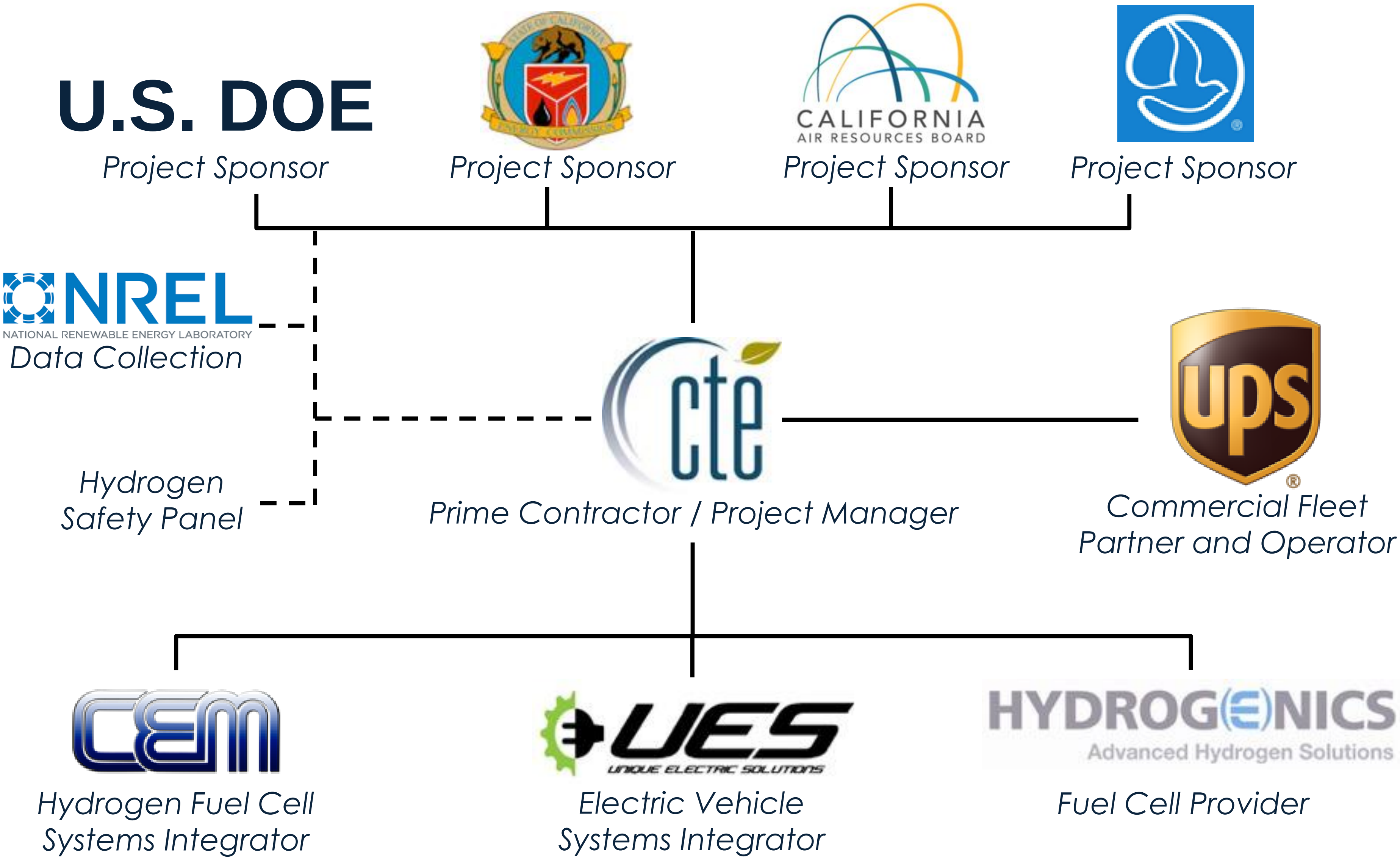
- The updated Phase 2 design specifically addresses the root cause of issues encountered in the Phase 1 demonstration at the component and subsystem level
- The updated vehicle design was reviewed by the full project team over multiple iterations
- The project team elected to build on the success of the 350 bar system rather than introduce an untested system to the Phase 2 vehicles
- 350 bar further accelerates commercialization as fleet owners prioritize “return to base” fueling, as seen in transit

Responses to Last Year AMR Comments

"This project continues to be well-aligned with DOE objectives. MD trucks are a large segment of the market, with the potential for high-volume production that would lead to lower costs for many components shared with other platforms. The growth of fuel cell trucks in the market could also help increase hydrogen station utilization and justify the need for more station coverage"

- CTE agrees that this project maintains relevance in a highly attractive market for fuel cell propulsion system applications
- The project team has prioritized cost effectiveness in design of the propulsion system kit as it reaches commercial status
- There are multiple ongoing development projects in this space:
  - CARB awarded another UPS delivery van project under the ZANZEFF program (4 total fuel cell delivery vans)
  - Plug Power truck developed under DOE sponsored program
  - SCAQMD-sponsored fuel cell delivery van being developed with UES and others

Collaborations and Project Partners



Remaining Barriers and Challenges

Issue – Utilizing public hydrogen refueling infrastructure prevented a significant number of demonstration days

- Phase 1 demonstration utilized multiple fueling sites as the vehicle operated out of multiple UPS facilities
- The project observed total station downtime of 46% of available demonstration days due to technical issues

Resolution

- Worked cooperatively with station operations staff to identify issues early and mitigate impacts to fuel availability
- Adjusted operational strategy to refuel the demonstration vehicle at the end of a shift so that the vehicle would not go out for service and be unable to fuel, thereby unable to complete its service
- Received letter of commitment from Shell to fuel out of their upcoming station in Ontario, funded under same CARB program

Remaining Barriers and Challenges

Issue – Project impacts due to COVID-19 are unknown

- Travel restrictions have industry-wide impacts to procurement schedules and component support
- Local and regional restrictions have impacted production environment across the country
- Scope and depth of impacts evolve as international response adapts to new information

Resolution

- Proactively monitoring for impacts to project progress and ability of the project team to complete work
- Identifying immediate concerns for risk mitigation and reporting
- Making alternative arrangements for in-person meetings, e.g. virtual program reviews

Proposed Future Work (Next Year)

Task 5 – Phase 2 Vehicle Build

- Complete vehicle assembly, commissioning, and delivery in batches of 5 vehicles [2Q 2020 – 4Q 2020]

Task 6 – Phase 2 Training and Education

- Conduct operations training at UPS Ontario facility [3Q 2020 – 4Q 2020]

Task 7 – Phase 2 Vehicle Test and Evaluation

- Provide vehicle operational support [3Q 2020 – 1Q 2021]
- Conduct in-service data collection [3Q 2020 – 1Q 2021]

Task 8 – Phase 2 Project Management

- Fueling station coordination for upcoming Shell H2 station [3Q 2020]
- Monitor budget, schedule, risk, and mitigation [2Q 2020 – 1Q 2021]

All quarters are calendar quarters – “1Q” is January 1 to March 31.
Any proposed future work is subject to change based on funding levels.

Technology Transfer

- UES has incorporated lessons learned from NYSERDA all-electric truck development into this DOE project

- UES is incorporating lessons learned from the DOE truck development into the development of the fuel cell truck for SCAQMD

- Oakland City Council has inquired about operation of these fuel cell delivery vans in their jurisdiction

Photo: CEC

Summary

Objective: To substantially increase the zero emission driving range and commercial viability of electric drive medium-duty trucks.

Relevance: Fuel cell hybrid electric delivery van design, build, validation, deployment, and data collection project in the UPS fleet environment. Multi-location demonstration that utilizes multiple hydrogen fueling stations. Deployment data will be comparable to existing diesel, CNG, and BEB vehicles that are used in the same application. Performance objectives includes 125 mile range and over 95% of UPS routes.

Approach: Two phase project, with go/no go decision. Phase 1 includes the design, build, validation, and demonstration of one vehicle. Phase 2 includes the build, deployment, and data collection of 15 additional vehicles. Each phase includes training and end-user education tasks.

Accomplishments: Operated Phase 1 vehicle in revenue service for full year between two UPS centers, conducted training for UPS Gardena, coordinated hydrogen fueling, completed Phase 2 manufacturing plan and design updates, completed DOE Go/No-Go, kicked off Phase 2 vehicle build.

Collaborations: Full project team dedicated to commercialization of viable technology, including a world-class and internationally recognized commercial fleet operator in UPS. Strong set of project sponsors leveraging federal, state, and private funding.

Questions and Comments

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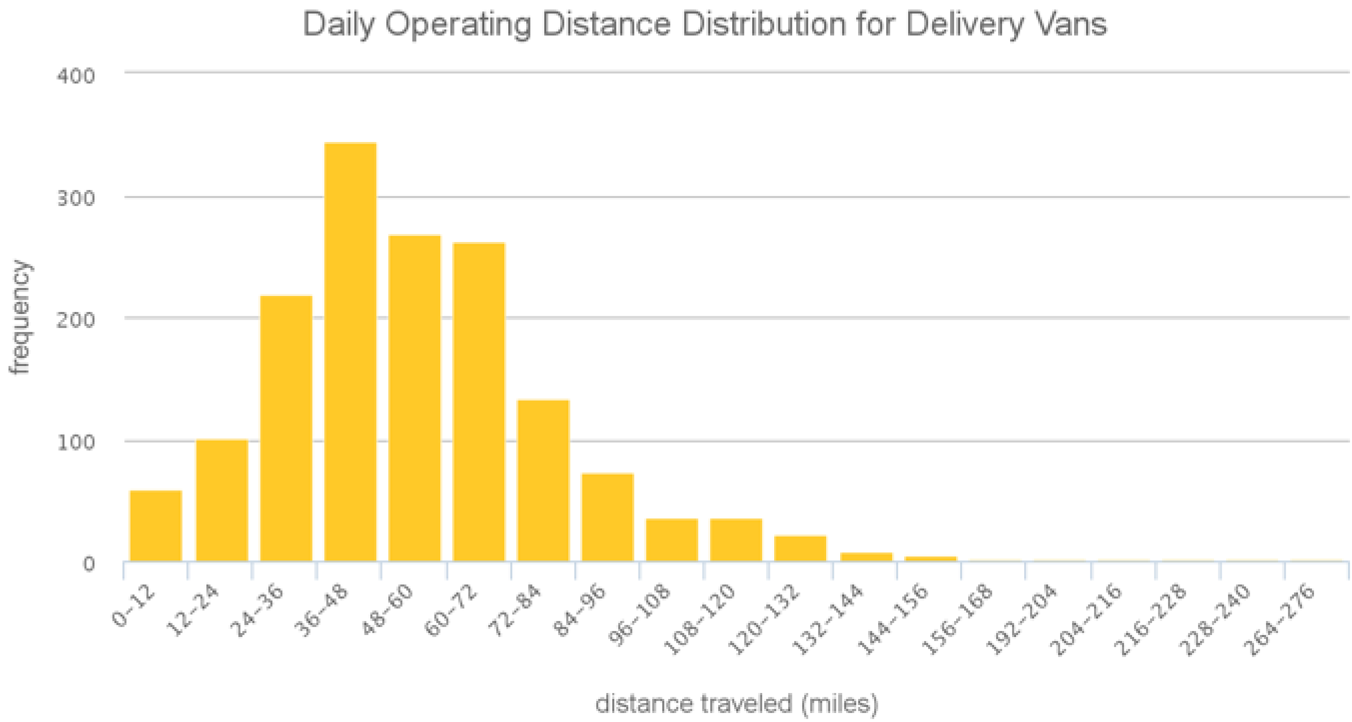
Technical Backup Slides

Delivery Van Range

Goal: Meet vehicle performance specifications (contractual and fleet operator)

- Meet performance of existing delivery vans (diesel, CNG, electric)
- Increase existing route length capability of zero-emission delivery van from 70 miles to 125 miles. **97% of Class 3-6 Delivery Van deployments require < 125 mile range.**
- Model the project vehicle to ensure components are sized appropriately for 125 mile range

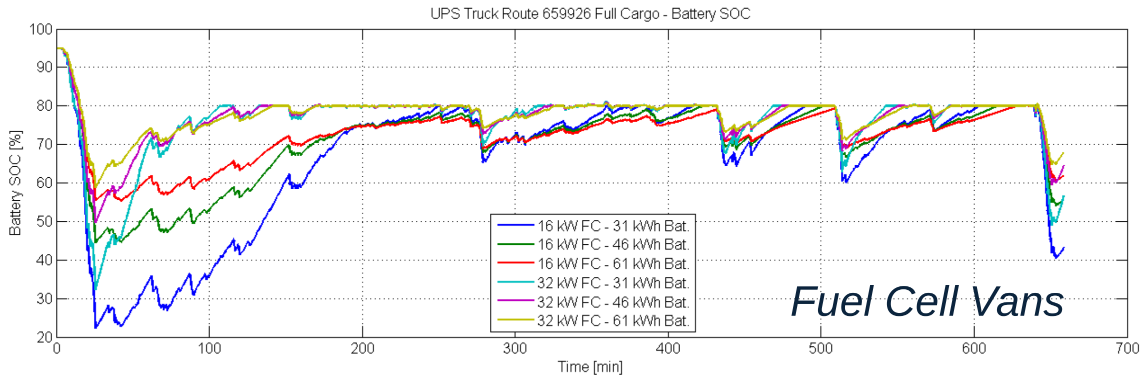


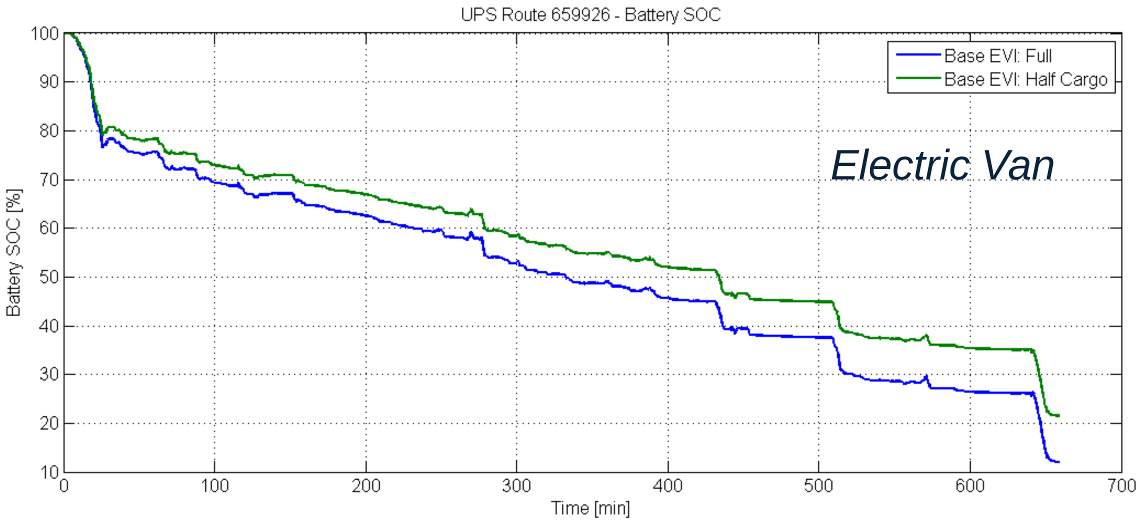
Source: Walkowicz, K.; Kelly, K.; Duran, A.; Burton, E. (2014). Fleet DNA Project Data. National Renewable Energy Laboratory.]

Modeling and Simulation Results

Route	Van Configuration	Distance	Missed Route	Min SOC	H2 Use	Ave Battery Current	Battery Temp (°C)	Ave Motor Power
HTUF PD Class 4 125 miles	16 kW - 33 kWh	124.45 mi	0.33%	66%	9.88 kg	92.59 A	n/a	37.56 kW
	16 kW - 49 kWh	124.44 mi	0.33%	68%	9.87 kg	94.92 A	n/a	39.26 kW
	32 kW - 33 kWh	124.45 mi	0.34%	76%	10 kg	87.77 A	n/a	38.15 kW
	32 kW - 49 kWh	124.44 mi	0.34%	78%	9.91 kg	87.94 A	n/a	38.6 kW
	99 kWh Electric Van	101.37 mi	18.67%	10%	n/a	42.47 A	n/a	36.01 kW
HTUF PD Class 6 125 miles	16 kW - 33 kWh	124.54 mi	0.22%	68%	9.96 kg	88.5 A	n/a	36.51 kW
	16 kW - 49 kWh	124.53 mi	0.22%	71%	9.96 kg	90.93 A	n/a	38.24 kW
	32 kW - 33 kWh	124.54 mi	0.23%	76%	10.02 kg	70.27 A	n/a	37.07 kW
	32 kW - 49 kWh	124.53 mi	0.23%	79%	9.92 kg	70.84 A	n/a	37.52 kW
	99 kWh Electric Van	100.11 mi	19.66%	10%	n/a	34.39 A	n/a	34.75
Oakland / Berkley 64 miles	16 kW - 33 kWh	11.80 mi	82.66%	20%	0.24 kg	187.65 A	n/a	101.66 kW
	16 kW - 49 kWh	63.81 mi	0.23%	44%	6.52 kg	114.17 A	n/a	55.16 kW
	32 kW - 33 kWh	63.86 mi	0.20%	31%	8.09 kg	41.79 A	55C	54.1 kW
	32 kW - 49 kWh	63.84 mi	0.21%	52%	7.68 kg	43.21 A	35C	54.67 kW
	99 kWh Electric Van	63.98 mi	0.11%	11%	n/a	35.57 A	n/a	52.21 kW
Napa 125 miles	16 kW - 33 kWh	18.75 mi	85.21%	20%	0.48 kg	136.64 A	n/a	84.45 kW
	16 kW - 49 kWh	38.49 mi	69.85%	20%	2.41 kg	172.74 A	n/a	78.23 kW
	32 kW - 33 kWh	97.79 mi	22.10%	20%	13.99 kg	175.46 A	95C	78.76 kW
	32 kW - 49 kWh	123.68 mi	1.04%	33%	15.65 kg	179.96 A	55C	77.05 kW
	99 kWh Electric Van	62.37 mi	49.60%	10%	n/a	74.72 A	n/a	73.45 kW
Houston 102.5 miles	16 kW - 33 kWh	14.75 mi	85.80%	20%	0.2 kg	194.96 A	n/a	105.52 kW
	16 kW - 49 kWh	102.3 mi	0.19%	24%	8.03 kg	126.65 A	n/a	53.41 kW
	32 kW - 33 kWh	17.62 mi	83.58%	20%	0.62 kg	184.89 A	n/a	105.81 kW
	32 kW - 49 kWh	102.03 mi	0.19%	40%	9.78 kg	47.98 A	n/a	52.83 kW
	99 kWh Electric Van	74.41 mi	27.11%	10%	n/a	38.39 A	n/a	45.64 kW

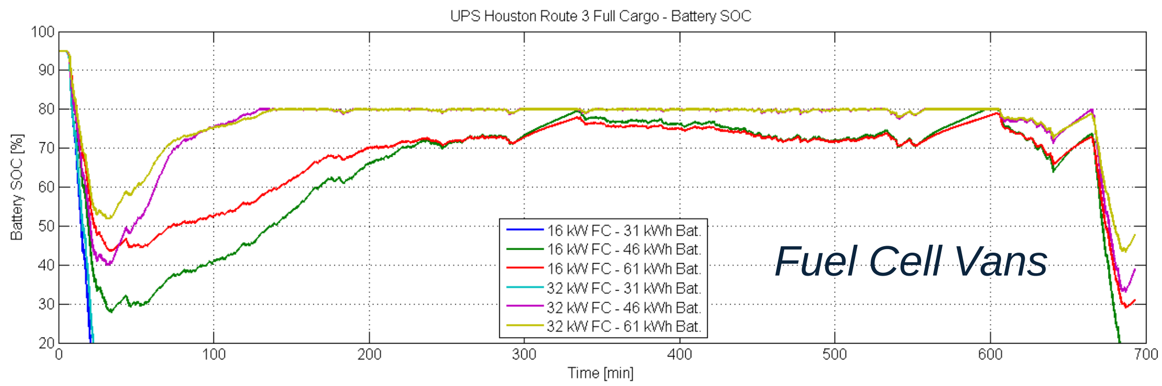
Results – Oakland / Berkeley Hills





- 65 miles in length with significant grades
- All fuel cell vehicle configurations make the route
- 16 kW fuel cell with 30 kWh battery is marginal
- All-electric van is marginal in completing the route
- Requires 8 kg of hydrogen storage

Results – Houston



- 100 miles in length with little to no grade
- All initial highway cycle requires 45 kWh or more of battery, no matter 16 kW or 32 kW fuel cell
- 16 kW fuel cell with 45 kWh battery is somewhat marginal
- All-electric van falls just short of completing the full route.
- Requires 10 kg of hydrogen storage

Result Summary

Route	Load (lb)	Start SOC	Final SOC	Battery kWh consumption	Fuel consumption (kg)	Miles	Efficiency * (kWh/mi)	Hydrogen Fuel Economy * (mi/kg)
Napa3	0	95%	71.03%	14.2	10.49	124.06	3.05	10.94
Napa3	3000	95%	65.51%	17.4	12.78	124.23	3.71	8.99
Napa3	6000	95%	52.49%	25.1	14.74	124.06	4.37	7.64
Houston3	0	95%	61.97%	19.5	7.41	102.29	2.80	11.92
Houston3	3000	95%	57.49%	22.2	8.37	102.25	3.17	10.54
Houston3	6000	95%	53.95%	24.3	9.56	102.18	3.60	9.27
Sacramento_A	0	95%	72.95%	13	4.33	49.01	3.48	9.59
Sacramento_A	3000	95%	72.04%	13.6	5.16	48.98	4.07	8.20
Sacramento_A	6000	95%	70.52%	14.5	5.96	48.94	4.66	7.17
659926 Oakland/ Berkley	0	95%	73.75%	12.6	4.89	64.1	2.94	11.35
659926 Oakland/ Berkley	3000	95%	71.80%	13.7	5.78	64.1	3.44	9.71
659926 Oakland/ Berkley	6000	95%	72.25%	13.5	6.88	64	4.01	8.32

* Efficiency and fuel economy calculations account for net battery consumption being recovered by the hydrogen fuel cell at 50% efficiency