Hydrogen Fuel-Cell Electric Hybrid Truck & Zero Emission Delivery Vehicle Deployment

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Houston-Galveston Area Council
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Project ID: GI116

Project Relevance

Primary Objective: Accelerate introduction and penetration of electric transportation technologies into the cargo transportation sector, specifically:

- 3 hydrogen fuel cell – electric hybrid Class 8 trucks*
- 18 all-electric delivery vehicles (i.e. step vans)*

Barriers	Project Activities
High cost of vehicles	Provide grant funding to incentivize deployment and testing of medium/heavy-duty zero emission vehicles
Risk associated with uncertain production capabilities and project financing	Restructure the process for granting ZECT funding through H-GAC. Allowed fleets to select own OEM.
Financing vehicles & coordinating multiple funding sources is very complicated	Simplification of funding sources—specifically removing state air quality funding that conflicted with original partners' desired financing structure. Provide incentives to delivery companies to ease concerns about vehicle costs.
Challenges to fleet acceptance related to lack of infrastructure and matching vehicles to appropriate routes or applications.	Provide funding for required infrastructure. Conduct data collection and analysis on vehicle performance to demonstrate emission reductions

Project Approach and Strategy

To be successful, the deployed technologies (both all-electric and hydrogen fuel-cell trucks) must be:

- Available
- Cost effective
- Meet performance expectations for operation and emission reductions

Therefore, current and future activities include:

- Providing remaining grant funding to selected partners to provide incentive for vehicle deployment and reduce barriers due to incremental costs of advanced technologies
- Begin/continue manufacture, deployment, vehicle monitoring, data collection, and performance / benefits analysis

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Overview

Hydrogen Fuel-Cell Electric Hybrid Truck Project

Timeline

- Start date: October 1, 2012
- End date: September 30, 2017

Budget

- Total funding
  - DOE share: $3,400,823
  - Contractor share: $4,210,524
- Funding Received In FY16:
  - DOE Share: $1,607,307.00
  - Contractor Share: $1,039,599.26
- FY17 Expected Expenditure:
  - DOE Share: $2,745,406
  - Contractor Share: $2,619,810

Barriers

1. High cost of Class 8 hydrogen fuel-cell electric hybrid trucks
2. Uncertainty related to deploying hydrogen fueling infrastructure and vehicle technologies in typical fleet use
3. Financing vehicles & coordinating multiple funding sources is very complicated

Partners

- Collaborators
  - Original project partners – *Total Transportation Services, Inc (TTSI), Vision Industries Corporation, Air Products,* Environmental Defense Fund.
  - Final project partners – Gas Technologies Institute, US Hybrid (OEM), University of Texas Center for Electromechanics, Environmental Defense Fund.
- Project Lead
  - Houston-Galveston Area Council

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Milestones

Hydrogen Fuel-Cell Electric Hybrid Truck Project

Activity	Timeline	Status
Revise Project Scope, Survey OEMs and Fleets, and Release Call for Project to select partners	2/2014 – 12/2016	Completed
Locate and secure and commitment from new project fleet	1/2016 – 4/2017	Ongoing
Final Design, Procurement of Components and Build out of ZECT Power System	5/2017 – 2/2018	Ongoing
Deployment of Vehicles for Testing and Integration of Hydrogen fueling station components	2/2018 – 2/2020	Future

- Next Steps:
  - Finalize new partner commitment and secure project modification
  - Continue equipment purchases and begin to manufacture the three (3) hydrogen-electric hybrid Class 8 drayage trucks
  - Deploy project vehicles for two-year demonstration period

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Accomplishments & Progress

Hydrogen Fuel-Cell Electric Hybrid:

2 of the 3 Prostar International trucks to be delivered to Air Liquide - currently in Torrence, CA.

Truck shown with Hydrogen fuel tanks installed behind cab (truck shown is identical to Air Liquide trucks).

Project trucks have been procured and are at US Hybrid facilities for conversion to fuel cell – electric hybrid drive

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Overview

Zero Emission Delivery Vehicle Deployment

Timeline

- Start date: October 1, 2012
- End date:
  - Currently Scheduled: September 30, 2017
  - Demonstration Ends: November 31, 2019

Budget

- Total funding
  - DOE share: $2,430,177
  - Contractor share: $2,760,000
- FY16 Expenditure:
  - DOE Share: $134,721.60
  - Contractor Share: $112,172.30
- FY17 Expected Expenditure:
  - DOE share: $1,610,000
  - Contractor share: $905,000

Barriers

1. High cost of low volume orders for all-electric medium- and heavy-duty trucks
2. Uncertainty in production capabilities and timeline for all-electric trucks
3. Fleet acceptance of electric drive vehicle by showing reliability and matching trucks to the correct applications and routes

Partners

- Collaborators
  - Center for Transportation and the Environment
  - Fleet Partner – UPS
  - OEM Partner – Workhorse
- Project Lead
  - Houston-Galveston Area Council

Accomplishments & Progress

Project Outcomes for FY16:

- *Zero Emission Delivery Vehicles:*
  - Completed the manufacture of 18 Workhorse medium duty delivery vehicles. Final vehicle delivered in July 2016, deployed in November 2016
  - Due to project delays, the decision was made to reduce the number of project vehicles from 30 to limit project to the already deployed 18 trucks.
  - Final project vehicles were deployed in November 2016 after vehicles were subjected to on-site preparations and readiness tests.
  - Next Steps:
    - Continue to collect operational data from project vehicles for two years.
    - Analyze demonstration data.

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Milestones

Zero Emission Delivery Vehicle Deployment

Activity	Timeline	Status
Call for Projects *(for fleet partners with all-electric delivery vehicle OEM)*	5/2014 – 5/2016	Complete
Select Partners & Issue Notice to Proceed	6/2014 – 9/2016	Complete
Purchase & Manufacture of Vehicles	9/2014 – 7/2016	Complete
Delivery of Vehicles	10/2015 – 8/2016	Complete
Full Demonstration of All Vehicles	11/2016 – 11/2018	Ongoing

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Accomplishments & Progress

<u>Zero Emission Delivery Vehicles</u>:

Workhorse E-100 Electric Delivery Van

- *Range: 80 to 90 miles*
- *Motor: 180 kW*
  1,106 ft-lbs torque
- *Batteries: 145 kWh*

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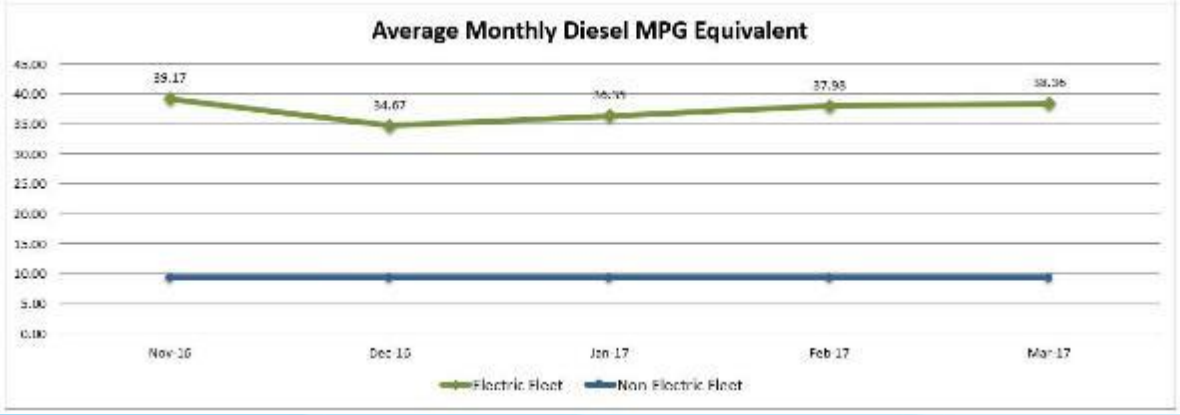
Accomplishments & Progress

Demonstration Vehicle Efficiency: November 2016 – March 2017

Efficiency by Vehicle							
Vehicle	Miles	# Stops	kWhs	Stops/Mile	kWh/mile	MPGde	Non-Electric
E-100 150472	1,933	4,025	1,741	2.08	0.90	42.27	9.28
E-100 150473	167	301	161	1.80	0.97	39.43	9.28
E-100 150474	3,437	6,550	3,459	1.91	1.01	37.84	9.28
E-100 150475	6,502	15,194	6,037	2.34	0.93	41.01	9.28
E-100 150476	3,888	7,256	4,176	1.87	1.07	35.45	9.28
E-100 150477	4,801	8,842	4,875	1.84	1.02	37.50	9.28
E-100 150478	3,126	6,044	3,105	1.93	0.99	38.34	9.28
E-100 150479	3,859	5,434	3,875	1.41	1.00	37.93	9.28
E-100 150480	1,092	1,550	1,422	1.42	1.30	29.24	9.28
E-100 150481	3,841	5,974	3,583	1.56	0.93	40.83	9.28
E-100 150482	3,405	4,900	3,410	1.44	1.00	38.02	9.28
E-100 150483	2,711	7,818	3,069	2.88	1.13	33.63	9.28
E-100 150484	1,383	3,536	1,500	2.56	1.08	35.12	9.28
E-100 150485	1,700	4,037	2,177	2.38	1.28	29.72	9.28
E-100 150486	990	1,883	1,142	1.90	1.15	33.00	9.28
E-100 150487	771	1,477	967	1.92	1.25	30.35	9.28
E-100 150488	261	604	278	2.31	1.07	35.69	9.28
E-100 150489	1,399	3,724	1,706	2.66	1.22	31.21	9.28
Fleet Average	**2,515**	**4,953**	**2,594**	**2.01**	**1.07**	**35.92**	**9.28**
Cumulative Totals	**45,265**	**89,149**	**46,686**	**1.97**	**1.03**	**36.92**	**9.28**



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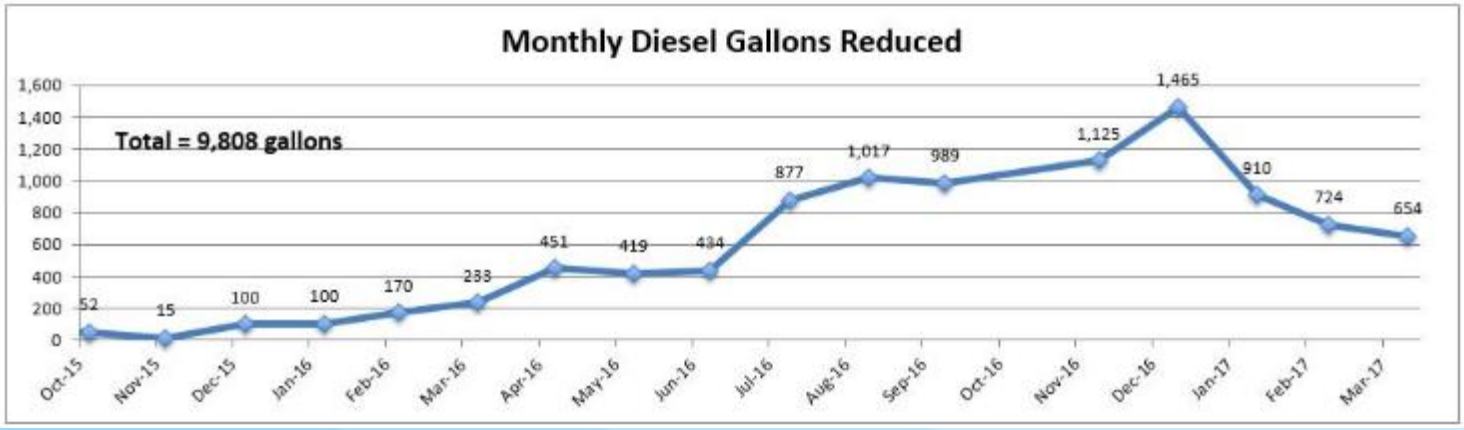
Accomplishments & Progress

Demonstration Fuel Use: October 2015 – March 2017

Monthly Diesel Gallons & Emissions Reduced							
Month	Electric Mileage	Diesel Gallons Reduced	Cumulative Diesel Gallons Reduced	Lbs. CO2 Reduced	Cumulative lbs. CO2 Reduced	Tons NOx Reduced	Cumulative Tons NOx Reduced
Oct-15	692	75	75	1,669	1,669	0.0003	0.0003
Nov-15	482	52	127	1,162	2,831	0.0002	0.0005
Dec-15	139	15	141	335	3,166	0.0001	0.0005
Jan-16	924	100	241	2,228	5,395	0.0004	0.0009
Feb-16	928	100	341	2,238	7,633	0.0004	0.0013
Mar-16	1,579	170	511	3,808	11,441	0.0006	0.0019
Apr-16	2,160	233	744	5,209	16,650	0.0009	0.0028
May-16	4,181	451	1,195	10,083	26,733	0.0017	0.0045
Jun-16	3,884	419	1,613	9,367	36,100	0.0016	0.0061
Jul-16	4,028	434	2,047	9,714	45,814	0.0016	0.0078
Aug-16	8,137	877	2,924	19,623	65,437	0.0033	0.0111
Sep-16	9,441	1,017	3,941	22,768	88,206	0.0039	0.0149
Oct-16	9,178	989	4,930	22,134	110,340	0.0038	0.0187
Nov-16	10,444	1,125	6,056	25,186	135,526	0.0043	0.0230
Dec-16	13,592	1,465	7,520	32,778	168,304	0.0056	0.0285
Jan-17	8,447	910	8,430	20,370	188,674	0.0035	0.0320
Feb-17	6,718	724	9,154	16,202	204,876	0.0027	0.0347
Mar-17	6,065	654	9,808	14,627	219,503	0.0025	0.0372
Cumulative Total	**91,018**	**9,808**	-	**219,503**	-	**0.0372**	-



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Accomplishments & Progress

Demonstration Vehicle Utilization: November 2016 – March 2017

Utilization by Vehicle									
Vehicle	Possible Service Days	Actual Service Days	% Utilization	Miles	Stops	kWhs	Miles/Trip	kWh/Trip	Stops/Mile
E-100 150472	126	31	25%	1,933	4,025	1,741	62	56	2.08
E-100 150473	126	2	2%	167	301	161	84	81	1.80
E-100 150474	126	57	45%	3,437	6,550	3,459	60	61	1.91
E-100 150475	126	97	77%	6,502	15,194	6,037	67	62	2.34
E-100 150476	126	72	57%	3,888	7,256	4,176	54	58	1.87
E-100 150477	126	81	64%	4,801	8,842	4,875	59	60	1.84
E-100 150478	126	66	52%	3,126	6,044	3,105	47	47	1.93
E-100 150479	126	98	78%	3,859	5,434	3,875	39	40	1.41
E-100 150480	126	29	23%	1,092	1,550	1,422	38	49	1.42
E-100 150481	126	75	60%	3,841	5,974	3,583	51	48	1.56
E-100 150482	126	89	71%	3,405	4,900	3,410	38	38	1.44
E-100 150483	126	55	44%	2,711	7,818	3,069	49	56	2.88
E-100 150484	126	35	28%	1,383	3,536	1,500	40	43	2.56
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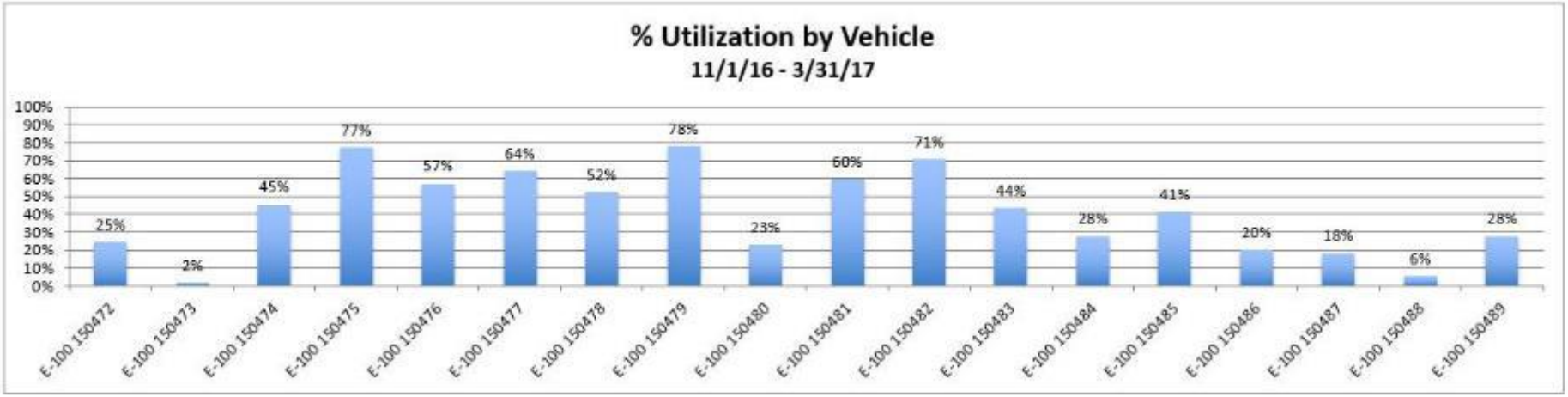
E-100 150487	126	23	18%	771	1,477	967	34	42	1.92
E-100 150488	126	7	6%	261	604	278	37	40	2.31
E-100 150489	126	35	28%	1,399	3,724	1,706	40	49	2.66
Fleet Average	**126**	**52**	**41%**	**2,515**	**4,953**	**2,594**	**48**	**51**	**2.01**
Overall Fleet	**2268**	**929**	**41%**	**45,265**	**89,149**	**46,686**	**872**	**916**	**36**



Response to Previous Years Comments

Comment from 2016 AMR	Response
"The presenter indicated metrics would be figured out later, which is the wrong way to approach a project, as design choices need to be made up front to meet the metrics."	I apologize for giving the wrong impression during last year's presentation. Project analysis and project metrics were determined prior to project start. Through this process it was determined that the OEMs and vehicles that were chosen would meet project goals.
"It would have been helpful if the specifications were provided as part of the reporting presentation."	We tried to make attempts during this year's presentation to be provide additional, specific information regarding project vehicle specifications as well as other project details.
"Because the project ends in September 2017, it is not clear how two years' worth of data will be collected on all of the UPS trucks, and it is even more of a question regarding the 12 additional trucks for which a partner is not selected yet."	It is for this reason that the number of project vehicles was reduced to the already deployed 18. It is anticipated that DOE will allow for a project modification to allow time for full completion of the deployment period.

Collaboration

- Contract Lead – Houston-Galveston Area Council
- ***Zero Emission Delivery Truck***
  - Project Administration & Technology Partner – Center for Transportation and the Environment
  - Fleet Partner – UPS
  - OEM Partner – Workhorse
  - *Remaining Fleet/OEM partners will be selected through call for projects.*
- ***Hydrogen Fuel-Cell Electric Hybrid Truck Project***
  - Project Administration & Technology Partner – Gas Technology Institute
  - Fleet Partner – TBD
  - OEM Partner – US Hybrid
  - Additional Technical/Outreach Partners – University of Texas CEM, Environmental Defense Fund.

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Remaining Challenges & Barriers

1) ***Finding additional local fleet partners***

   - Solicitation of local fleet for participation in the Fuel-Cell Hybrid project

2) ***Addressing project delays***

   - Ensure timely vehicle/infrastructure deployment for the Fuel-Cell Hybrid project to deploy project vehicles and infrastructure as quickly as practicable

3) ***Ensuring reliability of project technologies related to project vehicles***

   - Work with Electric Delivery Vehicle OEM and fleet to ensure that vehicles are meeting reliability needs to the greatest extent possible

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Future Work

Next Steps for FY17:

- *Hydrogen Fuel-Cell Electric Hybrid:*
  - Secure participation of new local demonstration fleet
  - Complete ZECT and infrastructure system design
  - Complete procurement of critical components for vehicle and infrastructure
  - Manufacture ZECT powertrain system
  - Integrate ZECT and hydrogen fueling station components
  - Deploy vehicles.
- *Zero Emission Delivery Vehicles:*
  - Continue two-year performance monitoring period for all 18 Workhorse electric vehicles deployed with UPS
  - Work with Workhorse and UPS when possible to ensure optimal performance for project vehicles

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

Summary

Hydrogen Fuel-Cell Electric Hybrid Truck Project

- After substantial delays caused by challenges of multiple funding sources (federal, state and private), H-GAC started to move forward with a simplified project budget and new partners at the beginning of FY16.
- At the end of FY16, the project was, again, delayed due to the loss of project demonstration fleet.
  - Project partners worked throughout the latter half of FY16 into FY17 to find and received commitments from a replacement fleet. This task is nearly complete.
- It is anticipated that once this process is completed and the revised project team is approved by DOE, that GTI, H-GAC, and partners will quickly make progress toward the deployment of three hydrogen-hybrid electric class-8 drayage vehicles.

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Summary

Zero Emission Delivery Vehicle Deployment

- H-GAC and project partners completed the delivery and deployment of 18 Workhorse manufactured, UPS delivery vehicles in the Houston region
- Data collection and analysis of these vehicles is ongoing
- H-GAC and DOE opted to not procure the final 12 planned project vehicles. Instead, H-GAC and CTE will focus on ensuring the success of the currently extant vehicles

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Technical Back-Up Slides

Anticipated Vehicle Specs.

Hydrogen Fuel-Cell Electric Hybrid:

- GVWR: 80,000 lbs
- Wheel Base: 189” min
- Vehicle Make/Model: International ProStar

- Fuel Cell Model/Type: US FuelCell PC80 PEM Fuel Cell
- Fuel Cell Voltage/Current/Power: 140-300, 600A, 80kW

- Battery Type/Power: Li-Ion / 300 kW
- Traction Drive Power: 320 kW / 429 hp

- Range (H2 and Battery): 200 miles
- Range (Battery): 5 miles

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