




Truck/Bus Development Challenges - Fueling, Fuel System, Powertrain

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DOE H2@Scale – FC Truck R&D Activities and
Target Review



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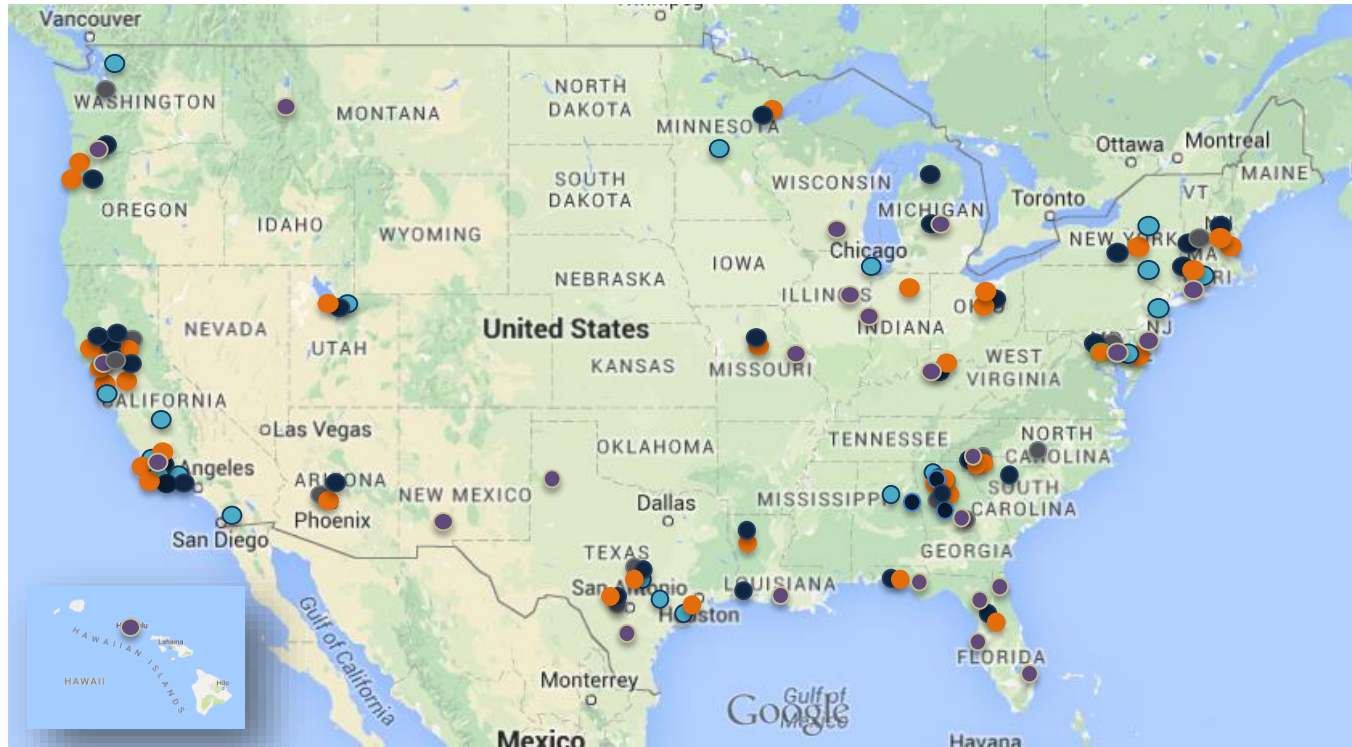
About CTE

- Mission: To advance clean, sustainable, innovative transportation and energy technologies
- 501(3)(c) non-profit
- Portfolio - \$425+ million
 - Research, demonstration, deployment
 - Alt. fuel and advanced vehicle technologies
- National presence
 - Atlanta, Berkeley, Los Angeles, St. Paul

CTE ZEB Services

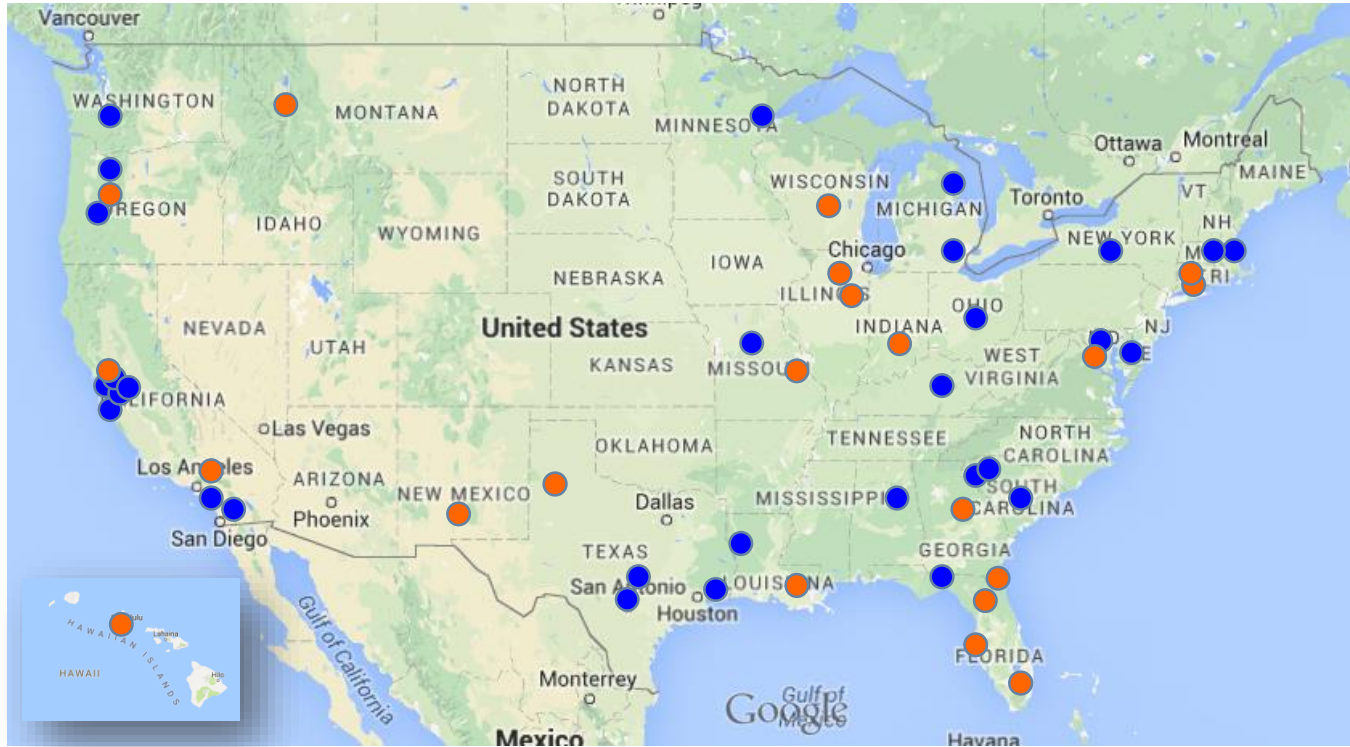
- Grant Applications
- Fleet Transition Strategy and Planning (ZEB Roadmap)
- Market Surveys
- Requirements Analysis and Technology Assessment
- Technical Specifications and Procurement Evaluation
- Production Oversight, Buy America Audits, and Quality/Resident Inspections
- Deployment Project Management and Technical Assistance
- Benefits Analysis and Key Performance Indicator Reporting

CTE Activity Map



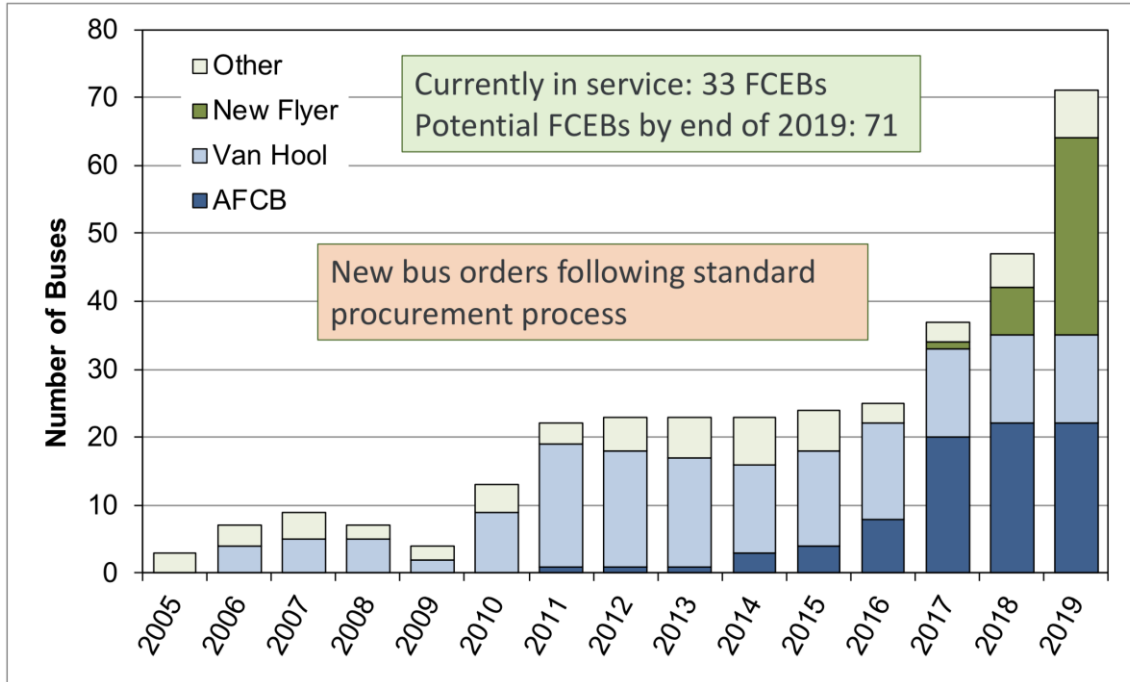
- Current Projects
- Pending Projects
- Members
- Transit
- Past Projects

CTE Zero Emission Bus Projects



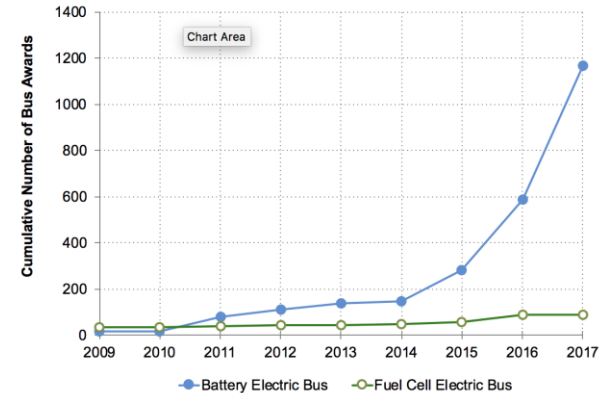
- Existing Zero Emission Bus (ZEB) Projects (more than 140 ZEB's with over 30 Transit Agencies)
- 2017 Low-No Awards with CTE (more than 50 ZEB's with 25 Agencies)

Fuel Cell Bus Deployment



Source: 2018 DOE AMR, NREL, L. Eudy – Fuel Cell Bus Evaluations

Year	FC Bus Price
2008	\$3.2M
2011	\$2.2M
2016	\$1.1M
2019	Under \$1M



Source: CTE ZEB Market Survey

FC Bus Performance Summary

	2017 Fleet Average	2018 Fleet Max	2018 Fleet Average	2016 Target	Ultimate Target	Target Met
Bus lifetime (years)	4.7	7.5	5.5	12	12	
Bus lifetime (miles)	118,989	189,168	128,656	500,000	500,000	
Powerplant lifetime ^a (hours)	13,801	27,330	13,041	18,000	25,000	2016
Bus availability (%)	76	90	71	85	90	
Roadcall frequency ^b (bus)	4,710	4,715	4,516	3,500	4,000	Ultimate
Roadcall frequency (fuel cell system)	20,705	23,741	18,026	15,000	20,000	Ultimate
Maintenance cost (\$/mi)	1.03	0.56	0.53	0.75	0.40	
Fuel economy (mpdgc) ^c	6.51	7.82	7.01	8	8	
Range (miles) ^d	247	357	300	300	300	

Source: 2018 DOE AMR, NREL, L. Eudy – Fuel Cell Bus Evaluations

^a Fuel cell hours accumulated to date from newest FCPP to oldest FCPP. Does not indicate end of life.

^b MBRC: average for current designs.

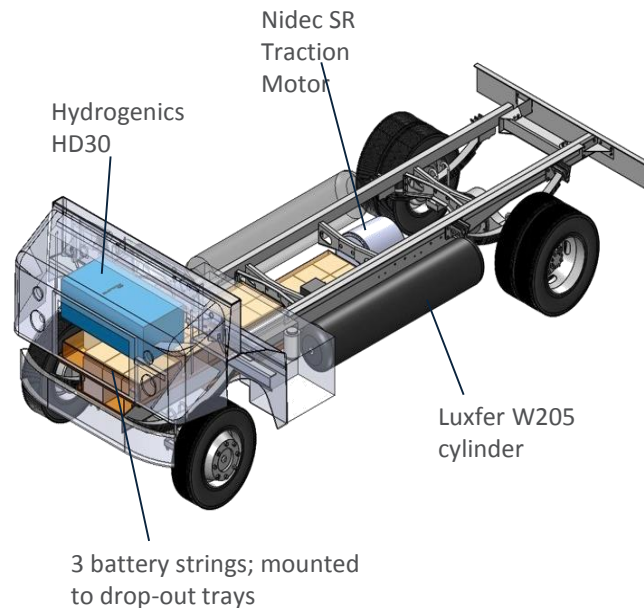
^c Miles per diesel gallon equivalent.

^d Estimated range based on fuel economy and 95% tank capacity. Transit agencies report lower real-world range.

UPS FC Delivery Van



Key Specifications	Fuel Cell Hybrid Van
Vehicle Chassis	Navistar International 1652SC 4X2
Maximum Speed	65 mph
Maximum Range	125 miles
Acceleration (0-60 mph)	26 seconds at 19,500 lbs
GVW	Class 6 (23,000 lbs)
Battery System	Valence Technology P40-24
Chemistry	LiFeMgPO ₄
Energy	45 kWh
Fuel Cell	Hydrogenics HD30
Rated Power	32 kW continuous
Peak Efficiency	55%
Hydrogen Storage	Luxfer W205 (x2)
Capacity	9.78 kg
Pressure	350 bar



ZECT Fuel Cell Drayage Truck

Key Specifications

Vehicle Chassis	Kenworth T680
Maximum Speed	65 mph
Range	130 miles (30 miles all-electric)
GCWR	80,000 lbs

Propulsion System

Propulsion System	BAE HybriDrive
Traction Battery	100 kWh (NMC)
Traction Motor	420 kW constant / 1,850 ft-lb torque
Fuel Cell	Ballard FCveloCity® 85 kW continuous

Hydrogen Storage

Capacity	30 kg (6 tanks)
Pressure	350 bar

Hydrogen Fueling

San Pedro, CA	Air Products 2 x HF150 Mobile Refueler
Renton/Mt Vernon	Air Products 1 x HF150 Mobile Refueler



Photo: Kenworth



Illustration: Kenworth



Fuel Cell Electric Top Loader

Key Specifications	
Vehicle Chassis	Hyster-Yale H800-1050HD/S class
Operation	24-hr
Capacity	105,000 lbs
Propulsion System	
Fuel Cell	2 x 45kW Nuvera Fuel Cells
Wireless Charging	250 kW WAVE Inductive Charger
Hydrogen Storage	
Capacity	35 - 40 kg
Pressure	350 bar
Hydrogen Fueling	
	Luxfer GTM Mobile Refueler
Capacity	186 kg @ 350 bar



FC Bus and Truck Deployment Challenges



- Matching H2 fueling with fleet deployments
- Matching supply and demand with H2 fueling infrastructure
- Constraints on funding opportunities
- Wide variety of pricing structures for HFI
- Commercial procurements can be difficult



FC Bus and Truck Technical Challenges

- Need reduced FCS costs
- Need improved FCS power density for trucks
- Need greater HSS storage capacity and reduced costs for trucks
- FCS power conversion can be challenging
- Need reduced H2 Fuel costs


Opportunities for Volume

- Need ZE transportation system that utilizes a universal energy carrier as a fuel source
- Battery-electric technologies, while more efficient and currently more popular, still have challenges with range and charge time
- Need coordinated larger fuel cell truck and hydrogen infrastructure deployments – 10 to 100 trucks
- Need continued vehicle-OEM involvement
- Take advantage of California funding opportunities (CEC fueling station, CARB Cap and Trade, HVIP)
- We learn with every deployment



Questions?

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