

Zero Emission Heavy-Duty Truck Technology: Fuel Cell & Wayside Power

Joseph Impulliti

Clean Fuels Advisory Group

September 1, 2016

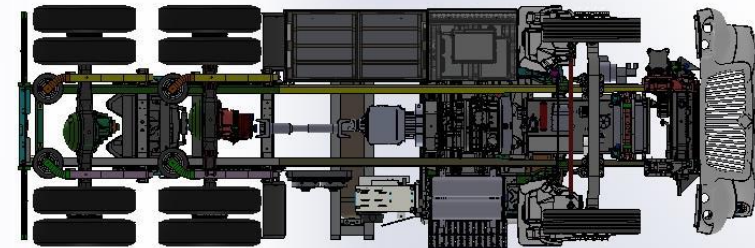
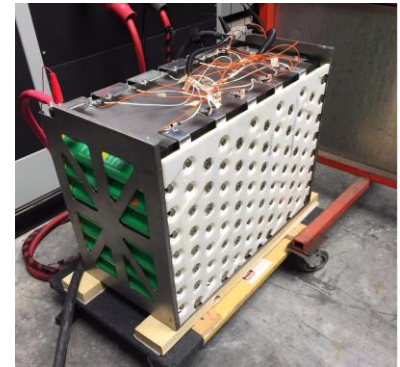
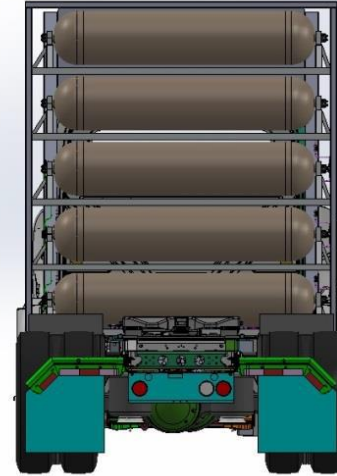


Goals & Objectives

- Promote the implementation of zero emission goods movement technology
- Determine commercial viability of fuel cell and catenary truck technologies in cargo transport sector
- Demonstrate:
 - Vehicle and system architectures
 - Infrastructure
- Assess:
 - Vehicle technical and cost challenges
 - Infrastructure implementation and cost challenges

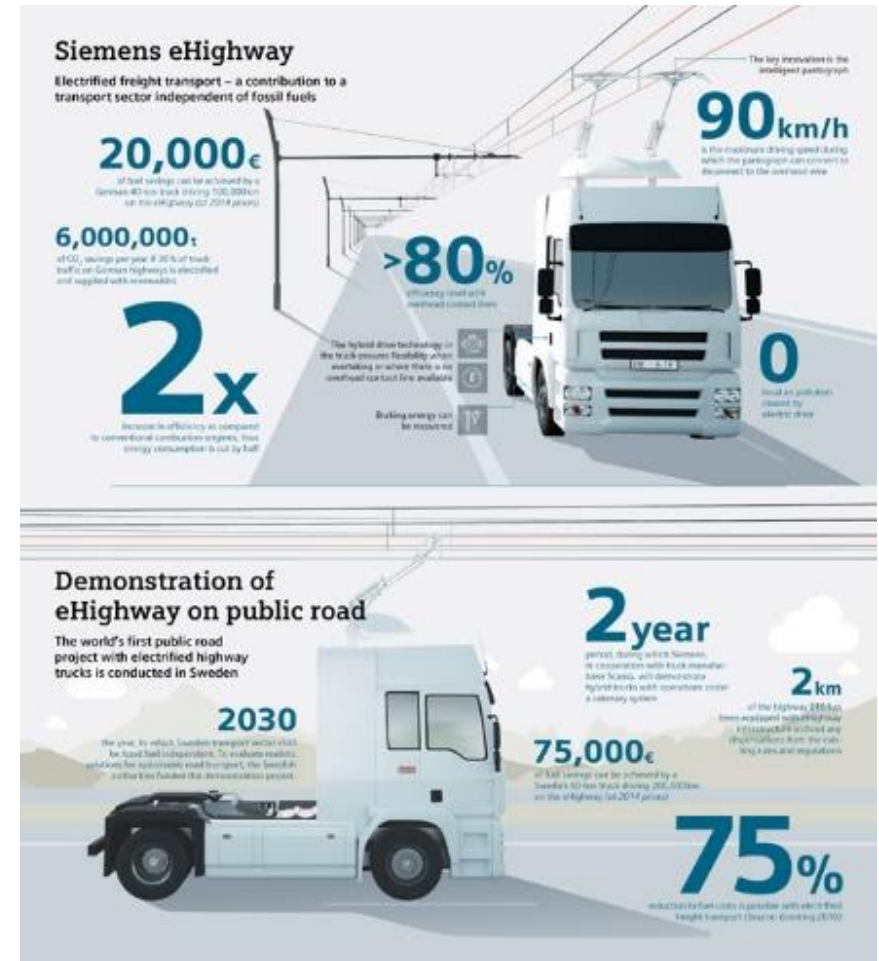
Fuel Cell Truck Technology

- Fuel cell increases the range of an electric truck
- Two configurations:
 - Battery dominant –
 - Fuel cell acts as a range extender charging battery at low SOC
 - Batteries charged from grid
 - Fuel cell dominant –
 - Fuel cell used as primary power source
 - Battery used for start-up and regen braking
 - Operated in charge depletion mode
- Hydrogen infrastructure:
 - Need high capacity large vehicle access stations



Catenary Truck Technology

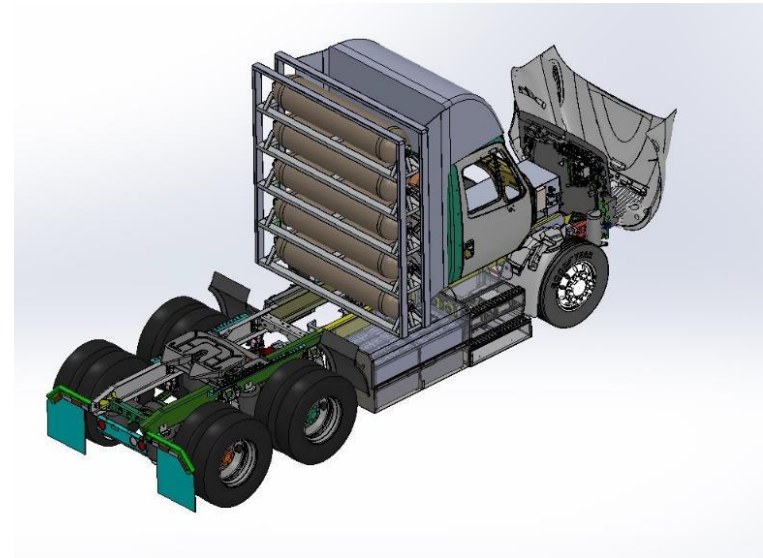
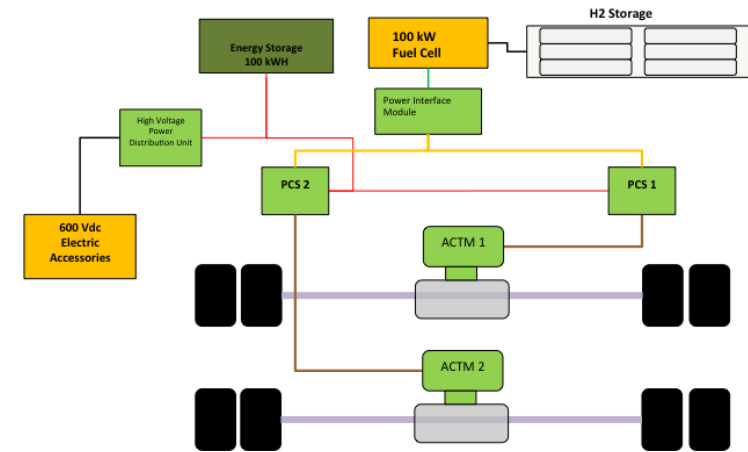
- Catenary infrastructure
 - Pole spacing similar to street lights (possibility of dual-use poles, but not existing poles)
 - DC power substation with remote monitoring approximately one per mile
 - Communication links between truck and infrastructure
- Catenary accessible trucks
 - Any truck configuration with electric propulsion system
 - Pantograph installed on truck connects vehicle to overhead lines
 - Sensors detect catenary lines are present
 - Vehicle interface allows manual or automatic control of pantograph
 - DC-DC converter converts line voltage to vehicle system voltage



Vehicle Technical Challenges

Fuel Cell Truck

- System Integration: Efficient use of battery and fuel cell energy
- Safety – high voltage faults and hydrogen containment
- Reducing the costs of fuel cells and batteries



Vehicle Technical Challenges

Catenary Truck

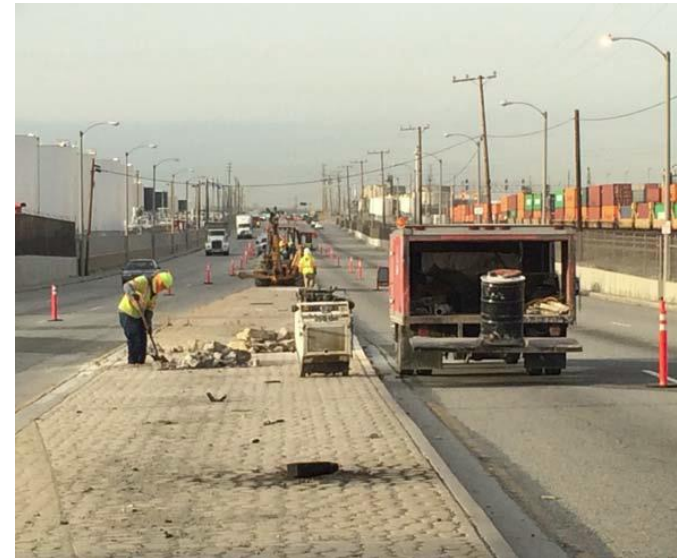
- Integration of pantograph and components into vehicle system
- Packaging pantograph on vehicle
- Transitioning on/off grid power
- Maintaining contact with catenary lines
- Added weight and cost of components



Infrastructure Technical Challenges

Overhead Catenary System

- Construction of system in urban/industrial environment
- Bridges, overpasses and turns
- Available power from grid
- Aesthetics



Infrastructure Technical Challenges

Hydrogen Stations – Medium and Heavy-duty Vehicles

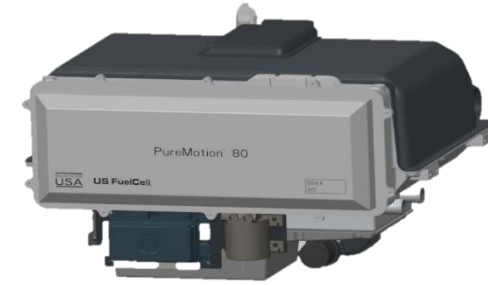
- Difficult to collocate with light duty stations or transit stations
- Refueling protocol for heavy duty vehicles not yet developed
- Regulatory approval for sale of hydrogen
- Need high capacity stations



Commercial Challenges

Fuel Cell Truck

- Sizing FC stack and battery vs cost of each vs range and power
- Lack regulatory “Z-Truck” mandate
- Cost
- OEM Interest



Commercial Challenges

Catenary Truck

- Infrastructure Siting and Regulatory:
 - Right-of-way, permitting and CEQA
 - Sale of electric fuel
 - Availability of incentives
- Finding an owner operator of infrastructure
- Infrastructure/trucks - timing of availability
- Load impact to the grid
- High cost of infrastructure and truck



DOE ZECT II Project

Contractors & Projects



- BAE/Kenworth – 1 Fuel cell range extended drayage truck
- TransPower – 2 Fuel cell range extended drayage truck
- U.S. Hybrid – 2 Fuel cell powered drayage truck
- Hydrogenics/Daimler – 1 Fuel cell powered drayage truck
- BAE/Kenworth – 1 CNG hybrid with catenary accessibility
- Total Cost:\$20,259,820

DOE ZECT II Project (Cont'd.)

- Project has experienced many delays due to contracting with our technology partners and securing funding agreements with our financial partners
- Now that all of the contracts have been executed and the program is fully funded we expect our progress to improve



DOE ZECT II Project (Cont'd.)

- U.S. Hybrid – First FCEV truck to be demonstrated in Q4 2016
- TransPower – First FCEV truck to be demonstrated in Q1 2017
- BAE/Kenworth – Kicked off project, CNG Hybrid truck expected Q4 2017
- BAE/Kenworth – Kicked off project, FCEV truck expected Q4 2017
- Hydrogenics/Daimler – Project replaces IR, FCEV truck due Q1 2018*



*Needs Governing Board approval – Expected October 2016

Fuel Cell Truck Assessment

- Potential for emission reductions
 - Zero emission operation in highly impacted areas
 - Need high volume of vehicles to make impact
- Pathway to commercialization
 - Can meet customer desire for long and short haul capability
 - OEM partners BAE and Kenworth have ability to engineer, manufacture, market and distribute large volumes
- Formula needed for success
 - Incentives to encourage future deployment
 - Eventually will need regulatory push to keep OEM's engaged



Fuel Cell Truck Assessment (Cont'd.)

- Lessons learned
 - Make the terms and conditions of agreements clear to the proponents during the proposal process to avoid delays in negotiations
- Future success
 - Need more OEM involvement
- Public policy goals
 - Significant emission reductions in highly impacted environmental justice communities



Catenary Truck Project

- Underground obstructions caused Siemens to redesign the catenary pole foundations to be above ground
- Construction has had extended delays due to the redesign and permitting
- Construction has restarted in July and is expected to be completed in December



Catenary Truck Project (Cont'd.)

- TransPower CNG Hybrid and Battery Electric trucks have been built and demonstrated on the off-the-road test track in Q4 2015
- Volvo Diesel Hybrid is being sent to Berlin to test on Siemens track and will be completed and sent to U.S. in Q1 2017
- BAE/Kenworth CNG Hybrid from ZECT II project will be ready in Q4 2017
- Demonstration to begin Q1 2017



TransPower Truck



Volvo Truck

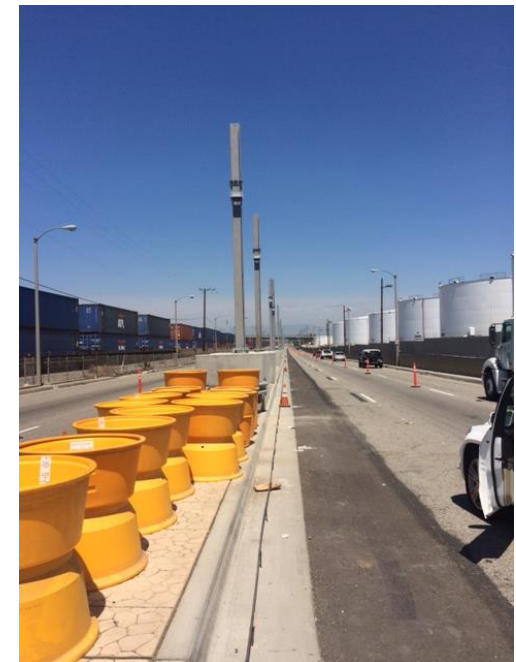
Swedish Demonstration



- First eHighway system on a public road opened in June 2016
- Siemens catenary system for trucks will be tested on a two-kilometer stretch of highway north of Stockholm
- Trial will use two diesel hybrid vehicles manufactured by Scania
- Demonstration cost is \$14.7M

Swedish Vs. U.S. Demonstration

- The U.S. infrastructure is on the median foundations above ground; in Sweden, poles are on the side of road with foundations in ground
- The Swedish demonstration is on a highway with passenger traffic; in U.S., it is in an industrial area with commercial traffic
- In Sweden the eHighway includes a curve, an ecological area and bridge; in U.S., the catenary is very straight, with one bridge and an intersection
- In the U.S. the focus is on air quality; in Sweden, greenhouse-gas reductions



Future of Catenary Truck

International

- Siemens AG is working on a new generation of the pantograph to achieve cost and weight reductions
- The German federal cabinet has decided to fund a field trial of catenary truck technology; announcement expected Q4 2016
- Siemens is also in contact with interested parties in several other countries; announcements TBD

California

- Siemens has discussed the catenary truck technology with CARB, CEC and Caltrans – they received positive responses
- California Sustainable Freight Action Plan (CSFAP), has identified the LA area as a place for “Advanced Technology for Truck Corridors” pilot project
- Siemens has identified the CSFAP as a globally important effort and they will continue to advocate the lead agencies to consider a follow up eHighway project

Catenary Truck Assessment

- Potential for emission reductions
 - Zero emission operation in highly impacted areas
 - Near Zero emission operation off catenary
 - Need high volume of vehicles to make impact
- Pathway to commercialization
 - Global partners Siemens, Volvo and Kenworth
- Formula needed for success
 - Cost reductions on infrastructure and trucks
 - Identify business case and system operator



Catenary Truck Assessment (Cont'd.)

- Lessons learned
 - Construction limitation in urban industrial environment
 - Developed dual strategy: above/below ground foundations
 - Siemens trained a third party company to do the construction of the contact line in Sweden, confirms that there can and will be competitive pressure on the construction side
- Future success
 - Leverage former and ongoing project vehicles
 - Engage national and global manufactures
- Public policy goals
 - Significant emission reductions in highly impacted environmental justice communities



Summary

- In January 2017, the following project vehicles will be operating at the ports:
 - ZECT I Electric Drayage Trucks
 - ZECT II Fuel Cell Drayage Trucks
 - OCS Catenary Drayage Trucks
- Recommend next Advisory Committee meeting convene at or near ports
 - View a demonstration of ZECT trucks
 - Bus tour of Overhead Catenary System and trucks

