Zero Emission Cargo Transport II
San Pedro Bay Ports Hybrid & Fuel Cell Electric Vehicle Project

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South Coast Air Quality Management District

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(This presentation does not contain any proprietary, confidential, or otherwise restricted information) [Project ID # VSS158]
ZECT II Overview

Timeline

• Project Award: 10/1/14
• Contractor Kickoff: 6/16/15
• Project Completion: 9/30/18

Contractors & Projects

• BAE/CTE - Fuel cell range extended drayage truck
• BAE/GTI - CNG hybrid with catenary accessibility
• TransPower - Fuel cell range extended drayage truck
• U.S. Hybrid - Fuel cell powered drayage truck
• International Rectifier – Diesel hybrid with quick charge capability

Barriers & Challenges

• Fueling Infrastructure: Availability and location
• Costs: Fuel Cells, batteries and infrastructure
• System Integration: Safe and efficient deployment of the technology

Budget

• DoE: $10,000,000
• Funding partners: $7,183,979
• Contractors: $3,075,841
Total Cost:$20,259,820
ZECT II Goals

• Reduce criteria pollutants in South Coast Air Basin by reducing diesel emissions from transportation and movement of goods
• Accelerate introduction and penetration of zero and near-zero emission fuel cell and hybrid technologies in cargo transport sector
ZECT II Approach and Strategy

- Require contractors to have experience with fuel cell or battery electric truck and bus development
- Require contractors to partner with a major OEM
- Use existing fueling infrastructure and set aside funds for temporary infrastructure
- Leverage previous and ongoing project’s vehicle technologies and infrastructure
BAE Electric Drayage Truck with Fuel Cell Range Extender

American Fuel Cell Bus Experience

OEM Partner: Kenworth
Collaboration: BAE/CTE Project Team

- **BAE Systems**
  - Electric propulsion system
  - Prime system integrator
  - Fuel cell bus experience
- **Ballard**
  - Fuel cell manufacturer
- **Kenworth**
  - Vehicle manufacturer
- **World CNG**
  - Vehicle builder
- **TTSI**
  - Vehicle operator
- **Center for Transportation and the Environment (CTE)**
  - Project manager
- **Fuel Supplier:** TBD
BAE Electric Drayage Truck with Fuel Cell Range Extender

• **Primary Power Source**
  - 100 kWh Lithium technology batteries

• **Auxiliary Power Unit (Range Extender)**
  - 100 kW Fuel Cell providing power to charge batteries

• **Electric Drivetrain**
  - Drivetrain will be based on BAE Systems HybriDrive® Series propulsion system
  - 2 dual propulsion control systems
  - 2 180 kW AC traction motors

**Hydrogen Fuel**
- 30 kg Onboard hydrogen fuel storage system
TransPower Electric Drayage Truck with Fuel Cell Range Extender

BC Transit Fuel Cell Bus Experience

OEM Partner: International
TransPower Electric Drayage Truck Approach

Using existing ElecTruck developed in ZECT I project as a platform...

Build an extended range zero-mission truck using fuel cell technology

Hydrogenics HyPM™ Fuel Cell
TransPower Electric Drayage Truck
Performance Goals

Road performance capabilities of current ElecTruck™ battery-electric trucks
• Haul 80,000 lb. loads
• Sustain 65 mph highway speeds
• Match or surpass diesel truck acceleration and gradeability

Extend operating range
• 40 miles all electric range
• 200 miles total range without refueling or recharging
U.S. Hybrid Electric Drayage Truck with Fuel Cell Range Extender

Component Manufacturer
For Electric and Fuel Cell Powertrains Experience

OEM Partner: Kenworth
US Hybrid FC Truck Overview

Development of 2 Fuel Cell Electric Plug-In Drayage Trucks using ZECT I Electric Truck Experience

• Fuel cell dominant
• US Hybrid 80kW power plant
• 320kW direct electric drive
• 26kWhr battery system
• Expected range 150-200 miles
• 20kg @ 350bar
• 6.6kW on-board charger

Vehicle OEM: International

Customer: TTSI
BAE CNG Hybrid Electric Drayage Truck

American Fuel Cell Bus Experience

OEM Partner: Kenworth
BAE CNG Hybrid Electric Drayage Truck

Solution:
• Battery, catenary and a CNG genset to provide near-zero and zero emission heavy duty truck operation
• CNG genset used as an APU for range extension via battery charging
• A 50 – 100 kWh energy storage system
• The propulsion system based on BAE systems HDS300 with one SCU to control the system operation
• Two drive motors one on each rear axle to increase propulsion capability
International Rectifier (IR) Diesel Hybrid Electric Drayage Truck

Component Manufacturing and Integration Experience

OEM Partner Peterbuilt
IR Diesel Hybrid Drayage Truck

- **Goal:** Create Zero Emissions Bubble around Ports of LA & Long Beach and surrounding communities
- **Technology:** Conversion of existing trucks to PHEV with Ultra-Fast-Charge
  - All-electric operation in and near ports for zero emissions
  - Hybrid-electric operation outside ports and communities for fuel savings
  - Ultra-fast charging for maintaining established fleet logistics and operations
IR Vehicle Specifications

**EV Architecture: Parallel PHEV**

**Modes of Operation:**
1. All-electric drive mode
2. Hybrid mode
   a) Motor-assisted start and acceleration
   b) Brake regeneration
   c) Engine start/stop
3. Zero-emissions Idle: IR EADS™ Electric Accessory Drive System

**Recharging modes**
1. Ultra-fast charging (15-20 minutes)
2. Diesel generation
3. Regenerative braking
ZECT II Performance Evaluation

- Capital, operating, and maintenance costs
- Reliability and performance advantages and challenges
- Impact of technology and requirements on existing goods movement operations
- Infrastructure requirements of large scale adoption and deployment
ZECT II Status & Future Activities

• Contracts are in process with SCAQMD
• Some technical teams are proceeding on project tasks
• Vehicle design, analysis, equipment purchase and integration will be completed in the first year for IR, U.S. Hybrid and TransPower projects
• Vehicle design and analysis will be completed within second year for both BAE projects
• Equipment purchase and integration as well as vehicle testing and validation will be accomplished in the following year for the BAE projects
• All projects will conduct 24 month on-road demonstration and data collection after vehicles are completed.
ZECT II Summary

• ZECT II goal: reduce criteria emissions from goods movement by accelerating introduction and penetration of fuel cell and hybrid technologies

• Seven zero emission vehicles to be developed and demonstrated

• Experienced integrators assures timely, safe and efficient deployment of technologies

• Leveraging previous projects maximizes future benefits

• OEM involvement will help develop a path to commercialization of zero emission technology
Response to Reviewers Comments

• This project is a new start.
Technical Backup Slides
# Electric Drayage Truck with Fuel Cell Range Extender Specifications

<table>
<thead>
<tr>
<th>Platform</th>
<th>Kenworth T370, Class 8</th>
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</thead>
<tbody>
<tr>
<td>GVWR</td>
<td>80,000 lbs.</td>
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<tr>
<td>Fuel Cell Make</td>
<td>Ballard</td>
</tr>
<tr>
<td>Fuel Cell Size</td>
<td>HD-7, 100 kW (Net 80 kW)</td>
</tr>
<tr>
<td>Battery Capacity</td>
<td>100 kWh</td>
</tr>
<tr>
<td>Drive System</td>
<td>BAE Systems HybriDrive®</td>
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<tr>
<td>Traction Motors</td>
<td>2x 180 kW (approx. 500 hp)</td>
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<tr>
<td>Range (per fueling)</td>
<td>Approx. 100 miles</td>
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<tr>
<td>H₂ storage</td>
<td>30 kg @350 bar (25 kg useable)</td>
</tr>
<tr>
<td>Type</td>
<td>Battery dominant</td>
</tr>
<tr>
<td>Fuel Supply</td>
<td>Temporary Mobile Fueling &amp; existing stations</td>
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</tbody>
</table>
US Hybrid FC Truck Configuration

- US Hybrid Integrated PureMotion™ 80 Fuel Cell APU
- Hydrogen Tanks
- US Hybrid Auxiliary Drive
- Compressed Air Tanks
- US Hybrid DC-DC Converter
- Electronics Cooling Unit
- US Hybrid Motor Control Unit and Charging System
- Differential
- 26kWhr Battery System
- US Hybrid 320kW Direct Electric Traction Drive
- Transmission
How existing ElecTruck™ platform will be modified to achieve desired goal

- Main Drive Motor(s)
- Electrically-Driven Accessories
- Automated Manual Transmission
- EV Control System
- Inverter-Charger Unit (ICU)
- Battery Enclosure Behind Cab to be Replaced with Fuel Cells and Hydrogen Fuel System
- Battery Energy Storage Capacity to be Reduced by 50% to Free Up Space and Weight
- DC-DC Converter to be added to Existing PCAS Assembly
IR PHEV Concept

- Drayage routes can vary greatly: One size battery pack cannot serve all route types
- Ultra-Fast Charging (15-20 minutes) with hybrid electric operation enables use of smaller battery packs
- Strategy: Place Ultra-Fast Chargers (UFC) near pollution impacted areas to enable all-electric-range
CNG Hybrid Electric Drayage Truck
Key Performance Parameters

• Modes of operation:
  • Battery electric: Zero emissions near port operation
  • Catenary: Zero emissions operation
  • CNG: Extends range beyond all-electric-range

• Range per fill: ~ 150 miles
• Fuel economy: significant improvements over current state-of-the-art CNG trucks
• Top Speed: 70 mph
• Power: 300 HP continuous (charge sustaining mode), 480 HP (charge depleting mode) and 536 HP peak