Zero Emission Drayage Truck Demonstration (ZECT I)

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Overview

Timeline
- Project start date: Oct. 2012
- Project end date: Sept. 2017

Budget
- Total project cost: $9,374,641
  - DOE share: $4,169,000 (45%)
  - $2,437,754 expended
  - Cost share: $5,205,641 (55%)

Barriers & Targets
- Evaluate market viability
- Promote market acceptance
- Data collection and analysis

Partners
- SCAQMD
- TransPower
- U.S. Hybrid
- NREL
- TTSI & other fleets
Objectives

- Demonstrate zero emission capable heavy-duty truck technologies in real world drayage operations
- Promote market acceptance through demonstration with fleet partners
- Collect and analyze performance and operational data
Project Approach/Scope

- Develop 11 Class 8 electric drayage trucks consisting of:
  - Six battery electric trucks (BETs):
    TransPower (4), US Hybrid (2)
  - Five plug-in hybrid electric trucks (PHETs):
    TransPower (2), US Hybrid (3)
- At least one truck from each technology tested on chassis dynamometer to validate vehicle performance
- Up to two years of demonstration in port drayage service with fleet partners
- Collect and analyze performance and operational data against baseline trucks
## Demonstration Technologies

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>BET</th>
<th>PHET</th>
</tr>
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<tbody>
<tr>
<td>TransPower US Hybrid</td>
<td>TransPower US Hybrid</td>
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<tr>
<td>TransPower US Hybrid</td>
<td>TransPower US Hybrid</td>
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| No. of Trucks | 4                             | 2                             | 2                             | 3                             |

| Chassis         | International Prostar         | International Prostar         | International Prostar         | Peterbilt 384                  |

| Traction Motor  | Dual Motor 300 kW            | Induction Motor 320 kW        | Dual Motor 300 kW            | PM Motor 223 kW                |

| Transmission    | Automated Manual             | Direct Drive                  | Automated Manual             | Automatic                      |

| APU             | N/A                          | N/A                          | Ford 3.7L CNG                | Cummins 8.9L LNG               |

| Battery/Storage Capacity | 215 kWh | 240 kWh | 115 kWh/60 DGE | 80 kWh/82 DGE |

| Charger         | On-board ICU 70 kW           | On-board 60 kW                | On-board ICU 70 kW           | On-board 20 kW                 |

| Recharge/Refuel Time | 3-4 hrs | 4 hrs | 2 hrs/10-15 min | 4 hrs/10-15 min |

| Range           | 70-100 miles                  | 70-100 miles                  | 200+ miles/30 AER miles      | 250+ miles/30 AER miles        |
Technical Accomplishments and Progress

BETs - TransPower

- Completed all four Electric Drayage Demonstration trucks (EDDs)
- Three EDDs currently deployed in drayage service
  - EDD2 (TTSI), EDD3 (Cal Cartage), EDD4 (NRT)
  - Near dock and local operations within 20-mile radius from port terminals
  - Positive feedback on quiet and smooth operations with comparable power and torque
  - Improvement needed on operating range and tractor weight
- EDD1 to be upgraded with new battery cells and BMS
  - 60% higher energy density
  - 311 kWh in the same system weight as for 215 kWh battery pack
  - 120-150 miles in operating range
Data Collection & Analysis

TransPower BETs
- 1/15 through 3/16
- EDD 2, 3 & 4
- 209 days of operation
- 9,440 miles traveled
- More local operations

Baseline Trucks
- 10/14 through 2/15
- Two diesel trucks (2013 Mack)
- 166 days of operation
- 23,590 miles traveled
- More regional operations
BET vs Baseline Diesel Drayage Routes

Blue = BETs
Red = Diesel
## Average Daily Use

<table>
<thead>
<tr>
<th></th>
<th>BETs</th>
<th>Baseline Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation Time</td>
<td>4.9 hrs</td>
<td>8.1 hrs</td>
</tr>
<tr>
<td>Idle Time</td>
<td>2.6 hrs</td>
<td>3.3 hrs</td>
</tr>
<tr>
<td>Distance</td>
<td>45 miles</td>
<td>142 miles</td>
</tr>
<tr>
<td>Trailer Distance</td>
<td>26 miles</td>
<td>N/A</td>
</tr>
<tr>
<td>Average Total Speed</td>
<td>10.4 mph</td>
<td>17.0 mph</td>
</tr>
<tr>
<td>Average Driving Speed</td>
<td>20.1 mph</td>
<td>27.3 mph</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>2.1 kWh/mi</td>
<td>6.2 kWh/mi</td>
</tr>
<tr>
<td></td>
<td>(18.6 MPGde)</td>
<td>(6.2 mpg)</td>
</tr>
<tr>
<td>Regen Energy</td>
<td>0.37 kWh/mi</td>
<td>N/A</td>
</tr>
<tr>
<td>Ending SOC</td>
<td>54%</td>
<td>N/A</td>
</tr>
<tr>
<td>Kinetic Intensity</td>
<td>1.18</td>
<td>0.57</td>
</tr>
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Technical Accomplishments and Progress BETs – US Hybrid

- Completed first BET in 9/15
  - Developed and integrated on-board charger
  - Modified drive train to direct drive (cost & weight benefits)
- Chassis dyno testing at UC Riverside in 10/15
  - DTP and UDDS Cycles with 70,000 lbs. GCWR
  - Preliminary results show 2.2 to 2.8 kWh/mi (DTP) & 3.0 kWh/mi (UDDS)
- On-road testing including Vincent Thomas Bridge (7% grade) with a fully loaded container
- In discussion with TTSI for deployment in drayage service
Technical Accomplishments and Progress

PHETs - TransPower

- Contract executed in 12/15
- Vehicle/system design based on EDD drive train
- Engine test cell for calibration and validation
- Long lead components ordered
- First PHET integration to be completed by 9/16
Technical Accomplishments and Progress
PHETs – US Hybrid

• Contract executed in 11/15
• System design completed, leveraging CEC-funded PHET project
• Simulation and validation of subsystems and components
• Procurement and fabrication of subsystems in process
• First PHET to be completed by 6/16
Proposed Future Work

- **Remainder of FY 15-16**
  - BETs
    - US Hybrid to deploy both BETs
    - TransPower to re-deploy upgraded EDD1
  - PHETs
    - US Hybrid to complete first LNG PHET
    - The LNG PHET to be chassis dyno tested at UCR
    - TransPower to complete first CNG PHET

- **FY 16-17**
  - US Hybrid and TransPower to deploy first PHETs by Q1
  - Complete and deploy remaining PHETs by Q2
Response to Reviewer Comments

- What mechanisms are in place to capture operational issues for each truck type, including performance anomalies, that can potentially dissuade fleet operators from acquiring the technology?

  Response: Vehicle integrators monitor and record such issues and anomalies for product improvement. Also, fleet operators are surveyed for feedback on their experience and recommendations.

- Vehicle integrators, TransPower and US Hybrid, should play a larger role to provide adequate support during the deployment phase given that the demonstration vehicles are essentially pre-commercial prototypes.

  Response: Both TransPower and US Hybrid are directly engaged with fleet partners to provide proper training in operations and maintenance, as well as to promptly resolve technical issues and glitches during deployment.
Collaboration and Coordination

- TransPower and US Hybrid each to develop Class 8 BETs and PHETs for demonstration in drayage service
- University of California, Riverside to perform chassis dynamometer testing to validate the performance of demonstration vehicles
- TTSI and other fleet partners to deploy demonstration vehicles in drayage service for up to two years
- TTSI is also providing two baseline diesel trucks
- NREL to analyze vehicle performance and operations data during demonstration
Summary

Objective/Relevance

- Demonstrate zero-emission capable drayage trucks in real world drayage service to promote market acceptance and analyze performance and cost data

Approach

- Develop a total of eleven demonstration trucks consisting of:
  - Six BETs: TransPower (4), US Hybrid (2)
  - Five NG PHETs: TransPower (2), US Hybrid (3)
- Chassis dynamometer testing to validate vehicle performance
- Up to two years of demonstration in drayage service
- Two baseline diesel trucks for comparison analysis
- Collect and analyze performance and operational data
Summary (Continued)

Technical Accomplishments

- TransPower completed all four BETs (EDD1 – EDD4)
- EDD2, 3 and 4 currently deployed with fleet partners
- US Hybrid completed first BET
- TransPower and US Hybrid each completed system design for PHETs

Future Work

- US Hybrid to complete second BET by 4/16
- TransPower to re-deploy upgraded EDD1 by 9/16
- TransPower and US Hybrid each to complete first PHET by 9/16