Plug-In Hybrid Medium-Duty Truck Demonstration and Evaluation Program

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Program Objectives

- Nationwide demonstration and evaluation of approximately 250 medium-duty PHEV’s
- Develop a production-ready, commercializable PHEV system for class 4 to 7 vehicles
- Develop production-ready “smart charging” capability for the vehicle
- Build customer familiarity
- Quantify performance attributes and environmental impact
- Use project results for system development to optimize performance and reduce costs
Project Status

• March 22, 2011, Eaton advised that the best case delivery of the first F550 hybrid system would occur in March of 2012
  – Eaton has advised that there is no commercial potential for their PHEV system in an F550
• May 5, 2011, DOE suspended performance, requesting corrective action plan
• Program was restructured to include Class 4 – 7 vehicles
• DOE approved the restructured program on December 16, 2011
Vehicle Overview

- **Azure Shuttle Bus Application (Class 4)**
  - Ford E450 Chassis
  - Ford 5.4L Gasoline Engine
  - Azure Dynamics Plug-in Hybrid Drive System

- **Odyne Utility Truck Application (Class 6/7)**
  - Class 6/7 Chassis
  - Diesel Engine
  - Odyne Plug-in Hybrid Drive System

- **Azure Utility Truck Application (Class 5)**
  - Ford F550 Chassis
  - Ford 6.7L Diesel Engine
  - Azure Dynamics Plug-in Hybrid Drive System
Vehicle Deployment Schedule

- **Azure E450s**
  - First Vehicle: Oct 2012
  - Last Vehicle: Dec 2012

- **Odyne Class 6 – 7s**
  - First Vehicle: Dec 2012
  - Last Vehicle: Jul 2013

- **Azure F550s**
  - First Vehicle: Q4 2013
  - Last Vehicle: Q2 2014
E450 Shuttle Bus

- **Vehicle Design:**
  - Azure Hybrid System
  - Ford 5.4L Gasoline Engine
  - High Energy Lithium-Ion Battery
  - Blended Regenerative Braking
  - Engine Off at Zero Speed
  - On-board Charger (3.3 kW)
  - Charging-Level 1 (120 Vac) and Level 2 (240 Vac)
  - Electrified Accessories (Steering, Brakes, and HVAC)

- **Performance Specifications:**
  - At least 20 miles of charge depleting range
  - Charge time less than 4 hours with Level 2
Class 6/7 Aerial Truck- Odyne

• **Vehicle Design**
  – Odyne Hybrid System with Allison automatic transmission
  – Diesel Engine
  – High Energy Lithium-Ion Battery- JCS 28.4 kWh
  – Blended Regenerative Braking
  – Launch Assist
  – On-board Charger (>3.3 kW)
  – Charging-Level 1 (120 Vac) and Level 2 (240 Vac)
  – Export Power (>5 kW, 120/240 Vac, 60 Hz)
  – Redundant system that can be returned to conventional driving

• **Performance Specifications:**
  – ePTO operation (>5 Hours with Engine-Off)
  – Up to 10 miles equivalent all electric range
  – Charge time less than 6 hours with Level 2
Work Truck Applications

Hybrid Bucket Truck

Hybrid Digger Derrick

Hybrid Compressor Truck

Hybrid Crane Truck
Parallel Hybrid Solution

- Provides redundant system to operator to minimize downtime.
- Low validation and capital equipment costs,
- Ability to retrofit to existing vehicles.
Core Components

40 Hours Estimated Install Time

Hybrid System Weight: 1600 lbs.

All Components Accessible for Easy Service

Battery Location Does Not Compromise Ground Clearance

Battery Packs Mount from Underneath – Hidden by Body
Minimally Intrusive Design

Power Take Off

Traction Motor
300Volts

Bell Housing Allows
Installation of Numerous
Hydraulic Pumps

Hydraulic Pump
Ancillary Components

- Exportable Power Inverter (Installed in body by Final Stage Manufacturer)
- Cooling System with AC Compressor & Condenser
- AC Evaporator & Controller (Installed in cab by Odyne)
- Hydronic Heater
Fuel Savings - Utility Bucket Truck

Fuel Consumption (Gallons)  
Conventional Vehicle vs. Odyne PHEV

<table>
<thead>
<tr>
<th></th>
<th>Baseline Vehicle</th>
<th>Odyne PHEV</th>
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<tbody>
<tr>
<td>Driving (32 miles/day)</td>
<td>5.26</td>
<td>4.89</td>
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<tr>
<td>ePTO at job site (4.2 hours/day)</td>
<td>4.02</td>
<td>0.00</td>
</tr>
<tr>
<td>Hydraulic Load (1.0 hours/day)</td>
<td>1.47</td>
<td>0.00</td>
</tr>
<tr>
<td>Work Day Total</td>
<td>10.74</td>
<td>4.89</td>
</tr>
</tbody>
</table>

Total Savings: 54.5%

Estimated results based upon SWRI testing of 1st generation system and actual duty cycle measurements.
Overview F550 Aerial Truck – Azure

• **Vehicle Design**
  – Azure Hybrid System with Ford automatic transmission
  – Ford 6.7L Diesel Engine
  – High Energy Lithium-Ion Battery- JCS 14.4 kWh
  – Blended Regenerative Braking
  – Engine Off at Zero Speed
  – On-board Charger (>3.3 kW)
  – Charging-Level 1 (120 Vac) and Level 2 (240 Vac)
  – Electrified Accessories (Steering, Brakes, and HVAC)
  – Export Power (>5 kW, 120 Vac, 60 Hz)

• **Performance Specifications:**
  – ePTO operation (>2 to 3 Hours with Engine-Off)
  – Up to 10 miles pure electric range (25 mph max)
  – Charge time less than 4 hours with Level 2
Azure PHEV F-550 Super Duty
Preliminary Packaging

Motor Controllers, Charger, etc

Battery (14 kWh)

Universal Gear Box (UGB),
electric Motor (drive motor and
ePTO function)
Azure PHEV F-550 Super Duty

Technical Targets

• Engine off at zero speed, electric-only operation at low speed
• Engine off time at worksite: 2 to 3 hours
• 10 mile equivalent electric range (may reduce available kWh at worksite)
• Fuel Economy Improvement: 50% target (depending on duty cycle)
• Exportable Power: Target 5 kW minimum
Supporting Program Activities

• A charging infrastructure is purchased and installed for each vehicle

• A Smart Charging Module is provided with each vehicle and allows smart charging with the grid

• A data acquisition system is provided with each vehicle and data is recorded and analyzed for two years of the program

• Emissions testing based on measured use-profiles from the field study
Questions