Status of Medium and Heavy Hybrids: Commercial Momentum & Directions

Advanced Transportation Technologies
Clean Transportation Solutions

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Hybrid Happenings Briefing
HARC - October 17, 2006
Agenda

- The Truck World Is Changing: Hybrid Momentum
- HTUF Role and Model for Change
- First Tangible Results
- Next Steps
Truck World is Changing: Hybrid Momentum
HTUF National Meeting 2005

- 275+ attendees (60% increase in 2 years)
  - One quarter fleet
- 13 med. & heavy hybrid vehicles
- 3 Working Group Meetings
- EPA hybrid testing meeting
- 2006 Meeting Set for San Diego
Recent Hybrid News – Momentum Growing

- Peterbilt developing Class 7 hybrid utility truck (to unveil at HTUF)
- Oshkosh to show hybrid refuse truck at HTUF
- Freightliner unveils Class 7 utility hybrid truck on M2 chassis
- Eaton developing hybrid system for Class 8 OTR trucks
- UPS testing advanced series hydraulic hybrid prototype
- **Bosch-Rexroth buys Dana hydraulic hybrid drive unit**
- Misubishi-Fuso Unveil Hybrid work truck (Class 4-5 delivery cube)
- Wright Group, ISE building 50 advanced hybrid buses for Las Vegas (62-foot articulated series drive)
- Volvo announces hybrid heavy trucks for 2009 production
- Peterbilt (Paccar) completes second hydraulic hybrid refuse truck
- FedEx adds 75 hybrid delivery vans, 75 more in 2006; UPS buying 50; Purolator orders 115 Azure hybrid delivery vans
- NYC orders 500 DaimlerChrysler (Orion/BAE) hybrid buses
- GM, DCX, BMW to partner on hybrids
- Transit bus hybrid orders between 1000-2000 units
- International/Eaton report 40-60% fuel reduction in utility hybrid
- Eaton testing hydraulic hybrid shuttle bus
Pre-Production & First Products

- International: First Limited Production Fall 2006; delivery early 2007
  - Building 100 Class 6/7 hybrids
  - HTUF assisting fleet commitment orders
  - HTUF to assist fleets finding funding

- Peterbilt testing hydraulic hybrid refuse truck (63,000 pound GVWR)
  - Building multiple prototypes
  - Pre-production in 2006/2007
FedEx Parcel Delivery Hybrids: More Than 90 On Road

Diesel-Electric Hybrid System for FedEx W700s

Built by Freightliner Custom Chassis and Eaton

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UPS Buying Hybrid Vehicles

- UPS to order 50 HEV delivery vehicles
- HEVs will be produced by International Truck and Engine using Eaton drivetrain
- UPS has a global fleet of around 91,000 vehicles
Freightliner Unveils Hybrid M2

- Class 7 hybrid electric work truck first shown at Great American Truck Show
- Eaton parallel hybrid driveline uses 44 kw drive motor, features electric PTO system for engine-off at work site
- 33,000 pound truck uses 230 HP MBE 900 engine – combined with electric drive can deliver significant torque
- Freightliner says it plans to lead the expansion of hybrid vehicle offerings in North America
Volvo to Mass- Produce Hybrid Diesel Truck Engine

- Volvo to mass produce hybrid diesel-electric truck engines in 2009
- Engine system called – I-SAM - to cut fuel consumption by up to 35%
- I-SAM consists of combined starter motor, drive motor, alternator, electronic control unit; batteries recharged by diesel engine, braking
- New engine economically viable mainly for short-haul trucks, buses, construction equipment

Volvo expects to produce “several tens of thousands of vehicles per year”
- CEO Leif Johansson
Eaton Developing Class 8 Hybrid Drivetrain

- Eaton has begun development of a hybrid drivetrain for over-the-road Class 8 trucks
- Looks to improve fuel efficiency on road; forecasts 5-7% fuel savings; reduce idling time
- Eaton’s Class 8 drive to be similar to its medium duty hybrid electric for Class 4-7
- Parallel-type direct hybrid system
- To be commercial by 2010
Prototype Series Hydraulic Hybrid in Testing

- Test project of EPA, Army/NAC, Eaton, International and UPS
- Series hydraulic design eliminates transmission and driveshaft, operates engine in narrow range
- Early testing has shown up to a 70% increase in fuel economy over conventional truck
- Still several years from commercialization

UPS will field test prototype truck for several months in delivery operation
Eaton Hydraulic Hybrid

• Eaton receives $2.15 million from DoD to accelerate commercial development of its energy-saving Hydraulic Launch Assist™ (HLA®) system technology
• Working under a program with the US Army National Automotive Center and Impact Engineering
• Eaton will focus on designing third generation HLA system and optimizing for specific vehicle applications
• Eaton’s HLA regenerative braking system has demonstrated significant fuel economy, reduction in emissions, brake wear in stop and go driving applications
Broad-based Development and Emerging Products

• Driveline makers Azure, ISE, Odyne and Enova active
• Chassis suppliers Workhorse and IC emerging
• Allison and BAE strong in buses
Several U.S. Manufacturers of Hybrids….But Competition Increasing

- Emerging and robust collection of U.S. companies
- Japanese companies dominating hybrid passenger car market
- Core technology of the future – need domestic production – oppy to create mfg jobs in U.S.
Why Hybrids Are Gaining Traction with Fleets

- Rising fuel costs: Optimizing urban truck drivelines is becoming critical for fuel efficiency, emissions.
- Major engine changes – and increased cost/complexity – coming in 2007-2010 to comply with EPA emissions requirements.
- Trend toward integrated engine/drivelines in trucks.
- Increasing electrical power needs in heavy vehicles and equipment.
- Idle Management is a growing issue.
- Productivity/performance complaints from cleaner engines.
HTUF Role and Model for Change: A Process for Commercialization
Hybrid Truck Users Forum (HTUF)

- **User-driven process** to facilitate the commercialization of medium- and heavy-duty hybrid trucks in the U.S.
- Joint WestStart-U.S. Army/NAC program
- Also supported by Hewlett Foundation
- HTUF focuses on commercializing hybrid trucks with dual-use benefits; helping speed commercialization and lower overall costs (leveraging investments)
- Army supports because wants to see commercial hybrid market to lower costs
HTUF in 4 Years has Proven an Effective Tech Model

- Proven process to build HD hybrid volumes
  - Four fleet Working Groups active, more forming
  - First 24 utility Pre-Production Trucks tested & deployed for assessment
  - Two additional deployments ready
  - Parcel hybrid RFP on street Aug 2006
  - Refuse hybrid RFP by end 2006
- Over 80 national fleets, including DOD, involved in process
- Five National Meetings of top truck OEMs, suppliers, fleets (attendance up 60% in 2 yrs)
- Military receiving first in-use hybrid field data from geographically dispersed nationwide deployment

HTUF Now Central Industry Contact Point for Dual-Use Heavy Hybrid Technologies
HTUF: User-Based Program Expands

Goal for 2006: expand in targeted fleets and most promising segments

Total of over 80 North American Fleets representing nearly 1-million trucks on road participating

Selected OEM/Supplier locations shown

Selected fleet locations shown

Utility Working Group (FPL)

Refuse Working Group (City of Chicago)

Parcel Delivery Working Group (FedEx/UPS)
Focus Area for HTUF: Top Early Hybrid Applications

“Beach Head” Markets Show Best First Promise

<table>
<thead>
<tr>
<th>Class 7/8 Refuse trucks</th>
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<tbody>
<tr>
<td>Class 3-6 Urban delivery trucks</td>
</tr>
<tr>
<td>- package delivery</td>
</tr>
<tr>
<td>- beverage delivery</td>
</tr>
<tr>
<td>Specialty Truck Applications (Class 4-7)</td>
</tr>
<tr>
<td>- Utility “Bucket” trucks</td>
</tr>
<tr>
<td>- Telecom/cable trucks</td>
</tr>
<tr>
<td>Class 6-8 Heavy Urban delivery trucks</td>
</tr>
<tr>
<td>- regional heavy distribution (beverage, grocery, postal)</td>
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</table>
HTUF Working Groups

• 4 Working Groups of fleet truck users now operating
  – Utility/Specialty trucks – George Survant, Florida Power & Light, lead
  – Parcel Delivery trucks – Sid Gooch, Fed Ex Express; Bob Dengler, FedEx Ground; Robert Hall, UPS – user leads
  – Refuse Truck Working Group – Kevin Campbell, City of Chicago Sanitation, lead
  – Bus Working Group – launched with support of Federal Transit Administration
HTUF “Commercialization Funnel”

**Familiarization & Outreach**
- Indianapolis Forum 1
- Chattanooga Forum 2

**Target Application Market Assessment**
- Working Groups Launched

**Recruitment & Info**

**Commercialization Barriers Assessment**

**WG Application 1**
- Fleet Characterization
- Spec Development
- Business Case
- OEM Negotiations
- Purchase Agreements

**WG 2+**
- Spec Development
- Business Case
- OEM Negotiations
- Purchase Agreements

**Pre-Production Deployment**
- 15-50 Vehicles per application

**Testing Evaluation Validation**

**Enact EPAct tax credits**

**Develop additional Purchase funds/ incentives**
- 100 Truck Utility First Production

**Early Production: 500+ Truck Deploy Launches Commercial Phase**

**Review Phase**
- 2002

**Commitment Phase**
- 2003

**Early Market Phase**
- 2004
- 2005
- 2006
- 2007
- 2008
First HTUF Commitment: Hybrid Electric Utility Truck

24 Pre-production Trucks Being Deployed Summer 2006

Similar Driveline to Class 5-7 truck, FMTV, shuttle bus markets

Class 6/7 Hybrid Electric
40-60% Fuel Economy Improvement
Greatly Improved Total Emissions
Idle Reduction (shuts off at work site)
25 kW power export
Meets or exceeds driving performance requirements
24 pre-production trucks to be assessed in 14 fleets
Additional Working Group Activities

- **Parcel Delivery Working Group** - Involvement from key national fleets
  - *(including FedEx Ground; UPS; USPS; FedEx Express; Corporate Express; Purolator)*

- **Joint purchase RFP for preproduction hydraulic hybrid** in Class 4 (14,000 lb GVWR) and Class 6 (22,000 lb GVWR) – on street now

- **Refuse Working Group**
  - 8 major fleets to date including private and municipal players
    - *(Waste Management; Onyx; Cities of New York, Houston and Chicago)*
  - **Joint purchase RFP by end 2006**
Bus Working Group

- Urban heavy transit hybrid bus market growing: 1000-2000 on road/in delivery
- Formed WG to assist faster growth of hybrid transit bus and supporting markets
- Have drafted a hybrid business case for urban transit users to share with policy leaders
- Now focusing on shuttle and paratransit buses that use truck chassis
HTUF Targets Increased Volumes Across Multiple Platforms

Each Hybrid Driveline Range Supports Multiple Uses

- Light Food & Delivery
- HUMVEE Light Military
- Light Parcel & Delivery
- Cutaway/Shuttle Van
- Small Trouble/Service Truck
- Heavy Parcel & Delivery
- Shuttle/school buses
- Heavy Truck
- Beverage & Regional Delivery
- Medium Military Delivery
- FMTV

GVWR

10,000 14,500 17,000 19,000 22,000 26,000 33,000 40,000

Supports Multiple Uses
• Project kicks off with port tenant in 2006
• Project Goals:
  – Establish requirements for a hybrid in yard hostler duty cycle
  – Seek commercial industry proposals to meet requirements
  – Build and test proof of concept prototype
  – Evaluate and analyze hybrid truck business case and commercialization potential and barriers
  – Considering linking HTUF WG to this effort to expand fleet involvement, explore military non-tactical truck interest

Other partners:
Kalmar, LBCT, EPA

Yard tractors are a common terminal vehicle at ports, distribution and shipping yards
First Tangible Results

hybrid truck users forum
North American Deployment & Assessment

Data Will Assist Commercial & Military Hybrid Decisions

Supplier Team to Build Additional 100 Trucks

24 Truck Deployment Locations
Hybrid Testing Complete

• Tested the validator hybrid truck against similar baseline truck over representative utility truck duty cycles
• Baseline truck 2004 International 4300 with 215 hp engine, Allison automatic transmission
• Tested on chassis dynamometer for driving portion of duty cycle and stationary in work portion
• Overall results are better than expected for duty cycle results
Four “Missions”

- **Mission A**
  - 70 miles driving; 3 service/site calls; 1.5 hours hydraulic operation (cycle 1)

- **Mission B**
  - 70 miles driving; 3 service/site calls; 1.5 hours hydraulic operation (cycle 1); 1.5 hours 2 kW

- **Mission C**
  - 48 miles driving; 3 service/site calls; 3 hours hydraulic operation (cycle 1)

- **Mission D**
  - 38 miles driving; 2 service/site calls; 3 hours hydraulic operation (cycle 2)
Fuel Use by Mission

Fuel Use Reduction Over Baseline:

• Mission A – 40% reduction in fuel use
• Mission B – 38% reduction in fuel use
• Mission C – 58% reduction in fuel use
• Mission D – 60% reduction in fuel use
Where do Benefits Come From?

- Roughly 1/3 of the improvements come from the driving part of the duty cycle.
- 2/3 of improvement comes from on-site work component of duty cycle (shutting engine off at work site).
Emissions Reductions by Mission

Reductions just from hybrid system, no additional after treatment

CO2 reductions closely tracked fuel reduction percentages

<table>
<thead>
<tr>
<th>Mission Cycle ID</th>
<th>HC (g/mi)</th>
<th>CO (g/mi)</th>
<th>NOx (g/mi)</th>
<th>PM (g/mi)</th>
<th>Fuel (mpg) % (increase)</th>
<th>Miles Driven</th>
<th>Hours of Operation (hydraulic + electric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>58</td>
<td>50</td>
<td>34</td>
<td>25</td>
<td>68</td>
<td>70</td>
<td>1.5</td>
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<td>B</td>
<td>73</td>
<td>94</td>
<td>34</td>
<td>34</td>
<td>80</td>
<td>70</td>
<td>4.5</td>
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<tr>
<td>C</td>
<td>78</td>
<td>73</td>
<td>61</td>
<td>37</td>
<td>139</td>
<td>48</td>
<td>3</td>
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<tr>
<td>D</td>
<td>80</td>
<td>74</td>
<td>58</td>
<td>32</td>
<td>150</td>
<td>38</td>
<td>3</td>
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</tbody>
</table>

TABLE 10 AND FIGURE 9. PERCENT DECREASE IN RATE OF EMISSIONS (g/hr) AND PERCENT INCREASE IN FUEL ECONOMY (mpg) OBTAINED BY USING THE HEV TRUCK COMPARED TO THE BASELINE USING FOUR EATON-SPECIFIED MISSION CYCLES.
Next Steps
What’s Next?

Increase Volumes in Markets With Similar Drivelines to Lower Costs

Driveline Incremental Cost in $

Yearly Similar Driveline Volumes

Target Price Points

Driveline Volumes Needed for Price Points

2,000-3,000

10,000
Hybrid Business Case

Operational Savings
- Fuel (the higher fuel goes, the shorter the payback)
- Maintenance
- Extended engine life

Productivity Gains
- Faster Launch from Stop, More Effective Braking
- Idle Reduction – engine shut off

Emission Reductions

Incentives
- EPAct HD hybrid incentives
- Regional/state funding grants and incentives
**EPAct National HD Hybrid Tax Credits**

- Credit is based on weight of vehicle and fuel efficiency gains of hybrid system
- Provides increasing credit for greater efficiency
- Limits incremental cost
- *Credit available for five years starting in 2005*

<table>
<thead>
<tr>
<th>Vehicle weight</th>
<th>Maximum Tax Credit for 30% Fuel Economy Increase*</th>
<th>Maximum Tax Credit for 40% Fuel Economy Increase*</th>
<th>Maximum Tax Credit for 50% Fuel Economy Increase*</th>
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<tr>
<td>8,501 – 14,000 lb</td>
<td>$1,500</td>
<td>$2,250</td>
<td>$3,000</td>
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<tr>
<td>14,001 - 26,000 lb</td>
<td>$3,000</td>
<td>$4,500</td>
<td>$6,000</td>
</tr>
<tr>
<td>&gt;26,000 lb</td>
<td>$6,000</td>
<td>$9,000</td>
<td>$12,000</td>
</tr>
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* based on maximum qualified incremental cost
Hybrid Incremental Cost – The “Wedges”

- Federal Tax Credit
- Regional/State Incentives
- Project "Buy Down"
- Fuel savings, Maintenance savings, Increased productivity – use $2.50-$3.00/gal fuel prices
- Business Case

Rewards high fuel economy
Gains: 30-50%

Must work together to get these two
In Next 1-3 Years, Need Additional Incentives

How Do We Develop Regional Hybrid Incentives?

Air Districts; Clean Cities; State Energy Offices; CMAQ Funds; Others
Potential Hybrid Truck
Introduction Timing under HTUF Plan

HTUF Working Groups
- Utility 24 trucks deploy
- Delivery WG Pre-Production (20-30)
- Refuse WG Pre-Production (15-30)
- Utility Truck First Production (100)
- Utility Truck Next Phase (500+)
- Refuse Truck Next Phase (500+)

Industry Launches
- FedEx II (18+75)
- FedEx III (75)
- Purolator II (115)
- UPS (50)

Product Releases
- Allison & BAE Bus Driveline production?
- International/Eaton 1st Production
- Freightliner CC/Eaton 1st Production?
- Azure 1st Production
- Freightliner/Peterbilt Unveil Class 7 Hybrid

Estimated Volumes
- 150+
- 400+
- 1000
- 2000

HTUF Creating Demand In First Hybrid Applications
- Freightliner/Peterbilt Unveil Class 7 Hybrid
- Shuttle/Paratransit (15-50)
- Shuttle Next Phase (500+)

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*Transit hybrids not included*
HTUF Multi Year Plan: “Expanding the Funnel”

**Deployment, Testing & Production Ramp-up**

- **Early Production:** 500+ Truck Deployment Launches Commercial Phase

**Testing Evaluation Validation**

**First Commercial Volumes**

- Biofuel hybrids
- GTL/BTL/CTL Synthetics

**Commercial Vehicles**

- Increased Truck Volume Refuse Hybrid Segment
- Increased Truck Volume Shuttle Hybrid Segment
- Increased Truck Volume Delivery Hybrid Segments
- Increased Truck Volume Industrial Hybrid Segment
- Increased Truck Volume Utility 5-7 Hybrid Segment

**Military Benefits**

- Coml. Field Data Support FTTS/TWV Hybrid Decisions
- Grow Experience, Volumes for Non-Tactical Base Hybrids
- Coml. Industry “Primed” to support Mil Needs

**Outcomes:**

- 4+ hybrid system suppliers each at min. 2500 system/year volumes
- 6 truck/chassis OEMs active
- Industry volume 20k hybrids/year
- 40-50% fuel use reductions per vehicle
- Increased capabilities of silent watch, power gen

**Capabilities Enhancement**
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