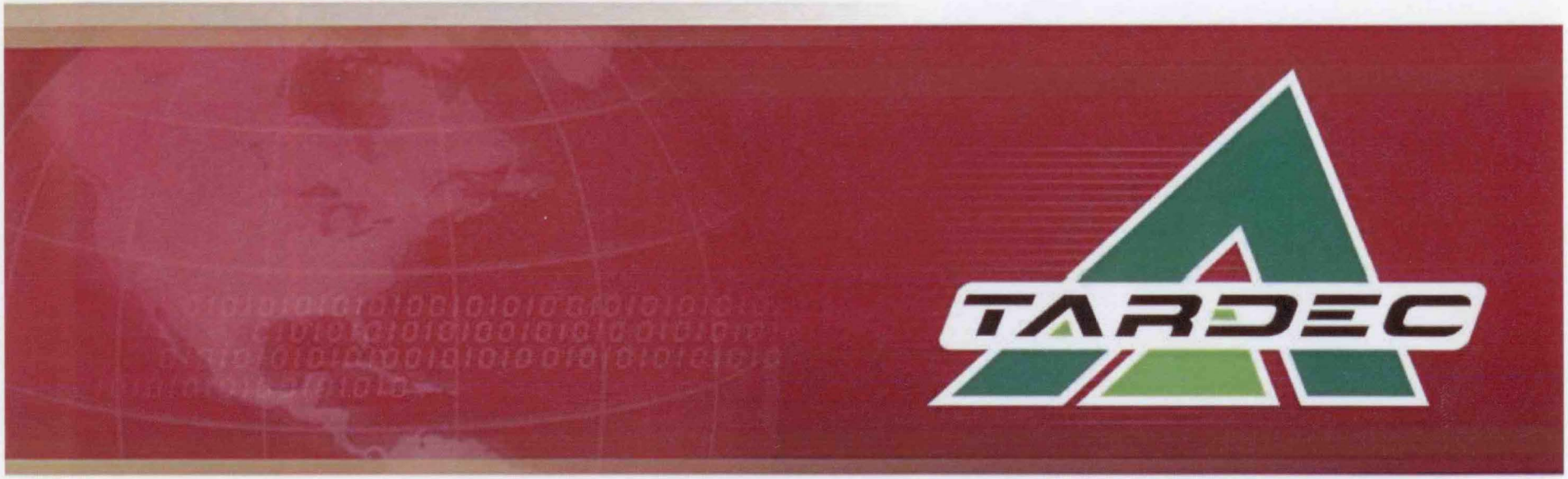
#23300



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

American Trucking Associations/Technology & Maintenance Council 2012 Fall Meeting & National Technician Skills Competition Integrating Hybrid Powertrain Technologies for Commercial Vehicle Applications Panel Session "HD Diesel Hybrid Truck Powertrain Study" Briefing – Tom Smart

11 Sep 2012

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
15 SEP 2012	**Briefing Charts**	**01-05-2012 to 17-08-2012**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
American Trucking Associations/Technology & Maintenance Council	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Tom Smart	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
U.S. Army TARDEC,6501 East Eleven Mile Rd,Warren,Mi,48397-5000	**#23300**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000	**TARDEC**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) **#23300**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
American Trucking Associations/Technology & Maintenance Council 2012 Fall Meeting & National Technician Skills Competition Integrating Hybrid Powertrain Technologies for Commercial Vehicle Applications Panel Session

14. ABSTRACT
One of the U.S. military's highest priorities is increasing the fuel efficiency of its ground vehicle fleet. The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) commissioned this study to explore the range of commercial Medium-Duty (MD) and Heavy-Duty (HD) trucks and transit buses with diesel-electric hybrid powertrains, and to document the experiences of fleet users of these vehicles. Unclassified - The primary powertrain focus is diesel engines and electric hybrid architectures - The vehicle focus includes Class 4 through Class 6 MD trucks, vans, and shuttle buses (14,001 - 26,000 lb Gross Vehicle Weight [GVW]), and Class 7 and 8 HD trucks and transit buses (>26,000 lb GVW) that are primarily available in the North American market. - Interviews were conducted with hybrid vehicle and powertrain manufacturers and the largest fleet users of hybrid-electric trucks and buses to obtain detailed insight into present and future product plans plus usage opinions and experiences not documented in other literature

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Public Release**	**26**	

Command Chain

Command Chain

Army Materiel Command (AMC) – Huntsville, AL

Research, Development & Engineering Command (RDECOM) – Aberdeen, MD

Tank Automotive Research, Development & Engineering Center (TARDEC) – Warren, MI

Ground Vehicle Power and Mobility (GVPM) – Warren, MI

TARDEC: Tank Automotive Research, Development & Engineering Center

TARDEC "Branding" Mission Statement

"The DOD's Primary Source for Ground Vehicle Technology Solutions"

TARDEC Institutional Competencies

Integrated Ground Vehicles	Ground Vehicle Sub-Systems and Components	Technical Capabilities and Resources
(System Competencies)	(Product Competencies)	(Engineering Competencies)

TARDEC Technology Competencies

Systems Engineer-ing	Product Support Engineer-ing	Integration	Design & Analysis	Product Assurance & Test Support	Mobility	Robotics	Electronics Architect-ure & Software	Force Projection	Power & Operational Energy	Survivability

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Primary Technology Support Customers

Army Materiel Command (AMC)

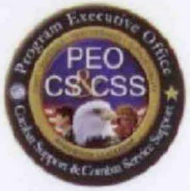
Research, Development & Engineering Command (RDECOM)

TARDEC

Ground Materiel Enterprise Partners

Office of the Assistant Secretary of the Army(ASA(ALT))

TACOM LCMC


TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

GVPM

Ground Vehicle Power and Energy Technology

Power Generation


Diesel Engines


Rotary Engines

Transmissions

Traction Motors


JP-8 Fuel Cells

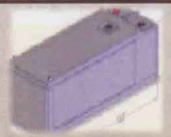

Turbine Engines

Integrated Starter Generator


Alternators


Drivelines

Energy Storage


Li-Ion / Ultracap Hybrid Energy Storage


Capacitors


Advanced Batteries

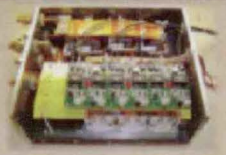
Thermal Mgmt & Power Distribution


Radiators


Microgrids


Power Controllers for Power Management


Heat Recovery


Power Converters /Inverters


Advanced Electronics Cooling


Thermal Architecture

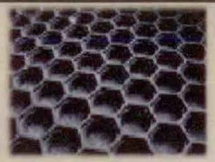
Materials


Lightweight Materials


Thermal Interface Materials


Wide Band Gap Materials (SiC)


High Temperature SiC Modules


Lightweight Structures


High Temp Inductors

Fuels & Lubricants


Qualifications & Specifications


Biomass Energy (Renewable)


Conversion Process


Single Fuel

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Study Overview

- One of the U.S. military's highest priorities is increasing the fuel efficiency of its ground vehicle fleet.
- The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) commissioned this study to explore the range of commercial Medium-Duty (MD) and Heavy-Duty (HD) trucks and transit buses with diesel-electric hybrid powertrains, and to document the experiences of fleet users of these vehicles.
  - The primary powertrain focus is diesel engines and electric hybrid architectures
  - The vehicle focus includes Class 4 through Class 6 MD trucks, vans, and shuttle buses (14,001 – 26,000 lb Gross Vehicle Weight [GVW]), and Class 7 and 8 HD trucks and transit buses (>26,000 lb GVW) that are primarily available in the North American market.
  - Interviews were conducted with hybrid vehicle and powertrain manufacturers and the largest fleet users of hybrid-electric trucks and buses to obtain detailed insight into present and future product plans plus usage opinions and experiences not documented in other literature.

Truck Hybrid Powertrains

- A vehicle with a hybrid powertrain utilizes two or more sources to produce, store, and deliver power to the drive wheels or power take-off (PTO).
  - In a hybrid-electric vehicle (HEV), these two sources are normally an internal combustion engine (ICE) and an electric motor with power storage (typically a battery pack and/or ultracapacitor).
- Hybrid trucks and buses offer the same range of customer benefits as do light-duty hybrids, including increased fuel efficiency and decreased maintenance costs.
  - Many of these larger vehicles can particularly benefit from hybrid technology because they consume large amounts of fuel, are in near-continuous operation, and, in many cases, do mostly "stop-and-go" driving, the scenario in which hybrids perform best.
- Hybrid transit buses have been in the U.S. market for over a decade, similar to light-duty hybrids, but the technological development and market acceptance of hybrid trucks lags behind.
  - The first passenger hybrid electric vehicle (Honda Insight) entered this market in 1999 while the first commercial diesel-electric hybrid truck was produced by Navistar in 2007.
  - The number of hybrid truck entries is now growing rapidly, but still lags the 30+ passenger hybrid models now available in this market.

Key Drivers for Hybrid Trucks

- The key drivers for the recent expansion of diesel-electric hybrid medium- and heavy-duty truck and bus offerings include:
  - Proposals to regulate the fuel consumption of medium-duty and heavy-duty trucks for the first time
  - Government fleet efficiency mandates and Alternative Fuel Vehicle (AFV) purchase requirements
  - Federal and state government purchase incentives
  - Increasing fuel prices plus a growing price premium for diesel fuel over gasoline
  - Increasing availability of hybrid-electric truck and bus offerings and supporting technologies with declining cost

Hybrid Truck Fuel Savings Potential

- The fuel savings potential from hybridizing trucks and buses is a key benefit, since fuel cost makes up a significant portion of their annual operating cost.
  - A tractor-trailer truck uses over 20 times as much fuel annually as the average light duty vehicle due to lower relative fuel efficiency and higher annual vehicle miles traveled.
  - Hybridizing this truck powertrain can therefore save up to 20 times as much fuel annually as a light duty hybrid.

Vehicle Type	Conventional Powertrain	Hybrid – 20% Fuel Savings	Hybrid – 50% Fuel Savings
	Fuel Use (gal/yr)	Fuel Saved (gal/yr)	Fuel Saved (gal/yr)
Light-duty Vehicle	517	103	258
Single-Unit Truck	1,956	391	978
Tractor-Trailer Truck	10,748	2,150	5,374

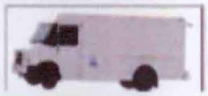
Customer Benefits

- Hybrid trucks offer a wide range of customer benefits that can encourage demand, including significantly lower emissions, increased efficiency, and decreased maintenance costs.
  - Performance: Hybrids typically exhibit performance levels comparable to their non-hybrid counterparts. A hybrid truck can potentially increase its load carrying capacity if the powertrain is calibrated appropriately.
  - Fuel Efficiency: Savings vary by truck or bus type and application.
    - Eaton Corp. reports that MD package and delivery trucks with their HEV system typically average up to 30 percent fuel savings, while utility and telecomm trucks that need worksite power can see up to 60 percent savings by avoiding idle periods.
  - Quieter Operation: Hybrids can reduce noise through down-sized engines and "engine-off" periods during idle or at low speeds that result in silent running.
  - Maintenance Costs: Hybrid trucks have proven to have longer maintenance intervals with lower cost than conventional vehicles.
    - Brake life can be extended by 50 – 100 percent since deceleration is accomplished primarily through regeneration which conserves brake pads.
    - By reducing reliance on the engine, hybrids can also potentially extend engine time in service between routine maintenance or overhauls.
    - In addition, the electric drive typically has fewer parts, requiring less maintenance than a conventional transmission.

Diverse Configurations & Uses

- One of the challenges in electrifying truck and bus powertrains is that there are so many different configurations, weights, uses, and duty cycles for these vehicles that a wide range of technical solutions may be required to meet all of the operational demands.







	Potential Range
• Energy Storage:	2 – 20 kWh
• Power:	20 – 80 kW
• Torque:	200 – 1000 Nm
• EV mode:	None – 10 mile range
• IC engine:	Diesel, Gasoline, NG
• Electrification:	None – full
• Plug-in:	Yes – no
• Export power:	Yes – no
• Other unique requirements	
– Emergency power, anti-idle, reefer, etc	







TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Diesel-Hybrid Electric Architectures

- A hybrid electric vehicle combines power from a combustion power source and an electric power source to deliver propulsion at the drive wheels.
- There are three primary types of hybrid electric powertrain systems presently being utilized in MD and HD vehicles:
  - **Hybrid electric:** Charge-sustaining hybrid electric vehicles (HEVs) generate all their power on board, and deliver that power to the wheels either in parallel with an internal combustion engine (ICE) or in series with no connection between the engine and the wheels.
  - **Plug-in hybrid electric:** Plug-in hybrid electric vehicle (PHEV) systems store electric power in a battery pack that is replenished from an off-vehicle source. They typically utilize this power to drive the vehicle in electric-only mode for some distance before the ICE is actuated to provide additional range or charge the battery. The ICE power can be transmitted through either a parallel or series configuration.
  - **Mild electric power take-off (EPTO) hybrids**: These systems typically do not provide any power to the wheels from electricity; rather, they power all PTO equipment via battery storage. As a result, these vehicles do not require the ICE to idle for extended periods during equipment usage. Some manufacturers offer an EPTO option along with a full HEV powertrain.
- For additional details on Diesel-Electric Hybrid Architectures, please contact the POCs for a copy of the full report.

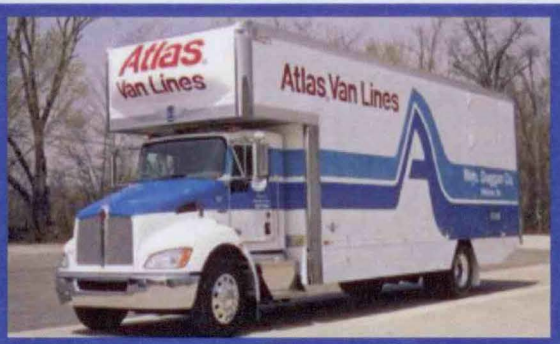
Hybrid Truck Examples – Light Duty

Truck Types	Class/GVW	Example of Available Hybrid
Light Duty ▪ Compact Van ▪ Delivery Van ▪ Mini-bus ▪ Pickup ▪ Step van ▪ Utility Van	Class 1 0 – 6,000 lb	 Light-duty Pickup Chevrolet Silverado 1500 Dual-Mode Hybrid
	Class 2 6,001 – 10,000 lb	 Light Delivery Van Iveco Daily Hybrid 35S12 used by FedEx UK
	Class 3 10,001 – 14,000 lb	 USPS Postal Van 2-Ton step van converted by Azure Dynamics

Hybrid Truck Examples – Medium Duty

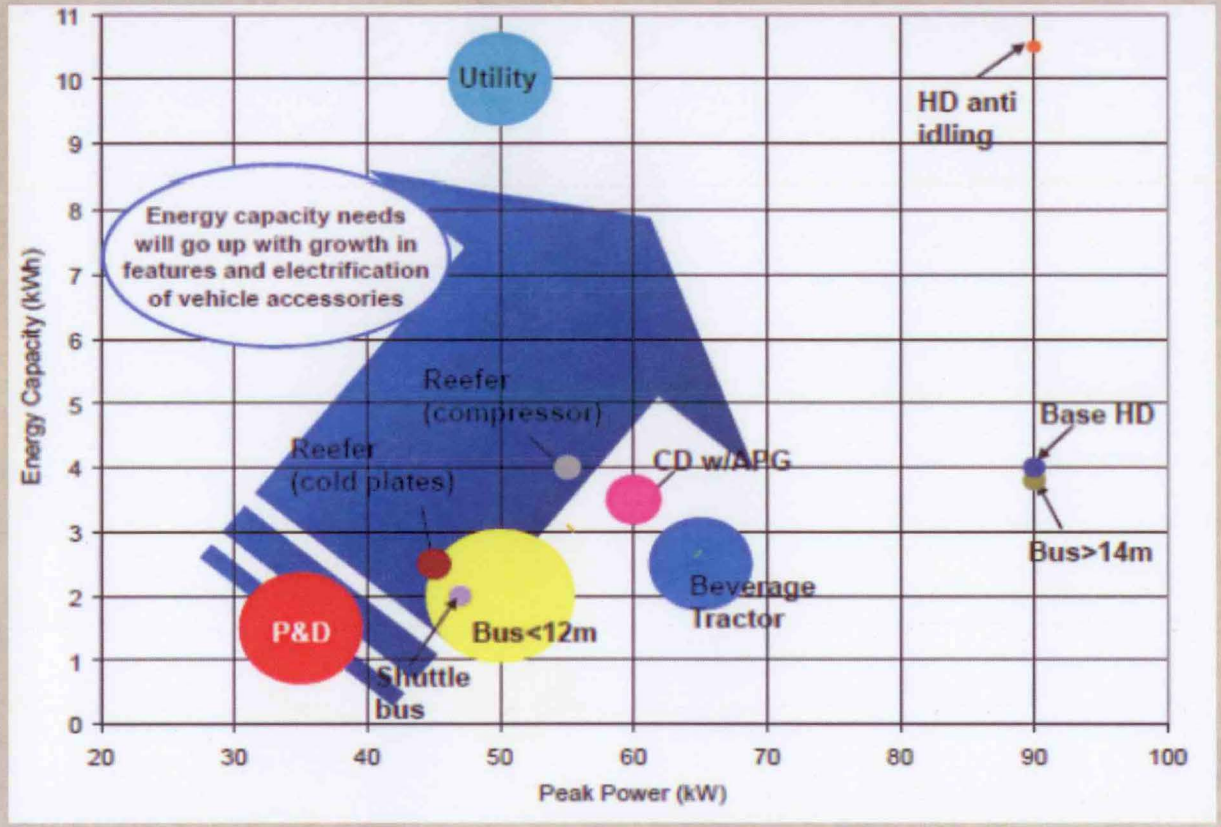
Truck Types	Class/GVW	Example of Available Hybrid
Medium Duty ▪ Boom/Bucket ▪ Cargo Van ▪ Delivery Van ▪ Light Tractor ▪ Pickup ▪ Shuttle Bus ▪ Utility ▪ Walk-in Van	Class 4 14,001 – 16,000 lb	 Shuttle Bus Ford E-450 w/Azure Balance hybrid system
	Class 5 16,001 – 19,500 lb	 Cargo Van Hino Truck 195h Diesel-electric hybrid COE
	Class 6 19,501 – 26,000 lb	 Truck or Tractor Freightliner M2-106 Hybrid w/Eaton HEV system and Cummins 6.7L ISB diesel

Hybrid Truck Examples – Heavy Duty

Truck Types	Class/GVW	Example of Available Hybrid
Heavy Duty • Cement • Dump • Local Delivery Tractor • Moving Van • Over-the-road Tractor • Refuse Hauler • Tanker • Transit Bus • Utility • Yard Hostler	Class 7 26,001 – 33,000 lb	 Moving Van Kenworth T370 hybrid w/280 hp PACCAR PX-6 diesel
	Class 8 33,001 lb and up	 Over-the-Road Tractor Peterbilt 386 Hybrid w/PACCAR PX-6 diesel

Hybrid Truck Battery Requirements

- The wide range of MD and HD truck and bus types and applications requires a variety of battery power and energy capabilities.
  - Batteries are rated in terms of both their peak power in kilowatts (kW) and their energy capacity in kilowatt-hours (kWh).

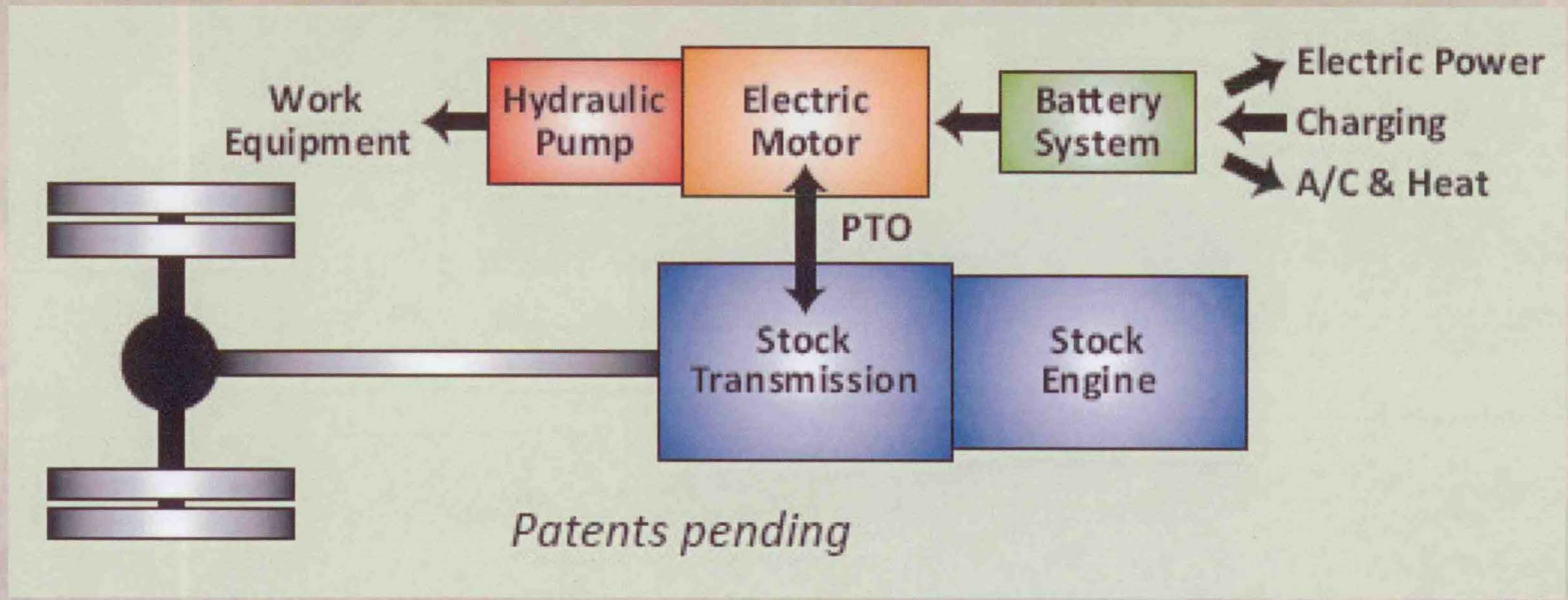


On Board or Exportable Power

- A key potential benefit of hybridizing a truck powertrain is the ability to generate power to satisfy other needs on-board the vehicle or at a work site.
  - Many trucks have a generator or hydraulic pump to provide power for on-board equipment such as lifts and booms or refrigeration units. These are typically connected through a power take-off on the transmission or in the drivetrain.
  - Other trucks such as over-the-road tractors need power for the electrical loads of a sleeper cab when the truck is parked. This can require the engine to be idled for extended periods to supply this power, using fuel and shortening maintenance intervals.
  - Sometimes a separate auxiliary power unit (APU) is fitted to handle these electrical loads, allowing the primary engine to be turned off.
- A hybrid-electric powertrain with an appropriately sized battery pack has the potential to replace these on-board power methods.
  - If hardware such as a separate generator or APU can be replaced, this can reduce the incremental cost for hybridization.
  - It can also lead to additional fuel savings and reduced engine wear if long engine idle periods can be eliminated.

Plug-in Hybrid Utility Truck

- Several manufacturers offer plug-in hybrid systems designed to provide on-board and exportable power from a battery system that can be plugged in at night to recharge.
  - One plug-in hybrid system shown below for >14,000 GVW work trucks can power the hydraulic pump that moves the boom on a utility truck
  - This system can provide up to 8 hours of engine-off job-site power, 7 kW of exportable 110/220V power for job-site needs, and an overall fuel savings of 50%
  - It can also heat or cool the vehicle when the engine is off



Commercial Hybrid Manufacturers

- A large number of new hybrid MD and HD truck models have been introduced to the North American market in the last five years.
  - Most of the major U.S. truck and bus manufacturers now offer at least one model with a diesel hybrid-electric powertrain, and some have several spanning multiple classes and chassis configurations.
  - Other smaller manufacturers have focused on specific truck types such as utility boom trucks to develop specialized hybrid powertrains that are better able to meet unique requirements.
- There are also multiple manufacturers of complete hybrid powertrains and components with offerings in this market.
  - The TARDEC study referenced by this presentation provides extensive detail on the model offerings and technology in each of these categories

Diesel Hybrid Customer Experience

- Some truck and bus fleets have been testing diesel-electric hybrid vehicles in low volume since the late 1990's.
- The TARDEC study examined the fleet user experiences with hybrid vehicles as summarized in the table below.

Company	UPS	FedEx	Coca-Cola Enterprises	King County Metro Transit	Verizon
Diesel-Electric Hybrid Fleet Size	380	367	699	468	13
Application	Delivery Vehicle (Step in Van)	Delivery Vehicle (Step in Van)	Delivery Vehicle (Tractor Trailer)	Urban Bus	Bucket Truck
MPG Improvement	Neg. to 40%	3-5%	12-35%	30-50%	N/A
Gov't Funded Purchases	Yes	Yes	Yes	Yes	No
Maintenance Reduction	~50%	<25%	Improvement	~10%	TBD
Business Case Demonstrated	No	No	No	Yes	No
Top Product Wants	Smaller Engine Series Hybrid; PHEV or EV	Smaller Engine Series Hybrid; PHEV or EV	PHEV or EV	Extended electric range	Lower Cost Battery; EV

Key Fleet User Observations

- Actual fuel savings have fallen short of expectations in many delivery vehicle and urban bus applications.
  - Route selection for hybrid delivery vehicles plays a big role in fuel savings realized, so fleet managers are learning to assign hybrids to route where they will be most effective.
  - Driver behavior also impacts actual fuel savings.
- Maintenance savings have been significant, with a particular improvement in brake pad life since regeneration lessens brake load.
  - Battery durability has also been significantly better than expected across all vehicle applications.
- Drivers generally like the hybrids, finding that they are easy to drive, offer equivalent or better performance, and may be less fatiguing.
  - Getting greatest benefit from hybrids requires training so that drivers understand how best to operate their new vehicles.
  - On-board driver feedback devices also help coach the driver to maximize the effects of regeneration and reduce fuel consumption.

Alternate Truck Technologies

- Progress is being made in other powertrain technologies for MD and HD trucks and buses that may be provided as options for customers.

- Hydraulic Hybrid drivetrains- uses a pressurized hydraulic fluid storage system to capture and deploy the vehicle's energy
- Natural gas vehicles – uses Natural Gas instead of Diesel. They are also becoming increasingly available in the medium and heavy-duty truck market.
- Fuel cell APU – A power generation system that uses electrochemical reactions to generate electricity. This is being developed for truck auxiliary power units (APUs)

Implications for U.S. Military

- Technology transition from commercial vehicles to Tactical Vehicles as it is developed.
- The development of commercial hybrid truck and bus powertrain technology supports increased capabilities of tactical vehicles through technology transfer.
- One of the U.S. military's priorities is increasing the fuel efficiency of its ground vehicle fleet.
  - The Department of Defense (DOD) owns/operates over 200,000 non-tactical vehicles and has started deploying electrified vehicles into this fleet.
- A large number of MD and HD diesel-hybrid trucks and buses are now listed on the 2012 GSA Vehicle Schedule, with trucks including chassis-cabs, dump, stake bed, refrigerated, tractors, and cargo vans.

Upcoming Events Schedule

Events

- 18 → 20 Sep, Hybrid Truck Users Forum (HTUF) National Conference and Exposition, Charlotte Convention Center, Charlotte, NC.
- 2 → 3 Oct, SAE Commercial Vehicle Engineering Congress (ComVec), Donald E. Stephens Convention Center, Rosemont, IL.
- 2 → 4 Oct, Pentagon Energy Security Event, Pentagon, VA.
- 22 → 24 Oct, Association of the U.S. Army (AUSA) Annual Meeting and Exposition, Walter E. Washington Convention Center, Washington, DC.

Points of Follow-up Contact

Ground Vehicle Power and Mobility (GVPM)

- Mr. Steven Eick, Project Engineer, GVPM
  - Office Phone: 586.282.1770
  - Mobile Phone: 586.202.0979
  - E/M: steven.t.eick.civ@mail.mil

- Mr. Scott Schramm, Government & Industry Collaboration Manager
  - Office Phone: 586.282.4122
  - Mobile Phone: 586.306.4365
  - E/M: scott.w.schramm.civ@mail.mil

Automotive Insight

- Mr. Tom Smart, Technology and Strategy Director, Automotive Insight
  - Office Phone: 248.563.8643
  - E/M: tsmart@automotiveinsight.net

Summary

The Subject Briefing Presented:

- Overview of the TARDEC Command Chain
- TARDEC Primary Technology Support Customers
- HD Diesel Hybrid Truck Powertrain Study
- Upcoming Events Schedule
- Points of Contact