

Class 8 Electric Hybrids – Opportunities and Challenges

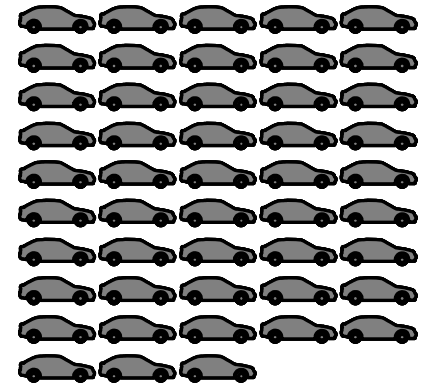
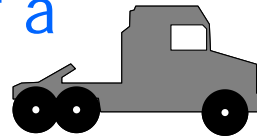
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ArvinMeritor

Scope of Discussion

- **ICE-Electric Hybrid For Class 8 Market**
 - ≡ Why Class 8 is appropriate for Hybrids
 - ≡ Opportunities and Advantages
 - ≡ Challenges
 - ≡ Hybrid Types for Class 8
 - ≡ One approach for a Class 8 Hybrid
 - ≡ Market Projections
- **To Be Covered In Another Presentation:**
 - ≡ Hybrids for Medium Duty Market
 - ≡ Hydraulic Hybrids

Why Class 8 Vehicles Are A Good Target For Hybrid Technology – Energy Security

- **48 cars:** The number it takes to match the annual fuel use of a typical line-haul truck [1]



- **One fourth:** Portion of total on-highway transportation fuel that is used in U.S. commercial trucks and buses [2]

- **39 Billion:** Gallons per year of diesel fuel used by U.S. commercial trucks [3]

Sources:

[1] Calculated assuming 12,500 miles / year per car and 25 mpg versus 120,000 miles / year per truck and 5.5 mpg plus 1500 hours of overnight idling of the diesel engine

[2] U.S. Energy Information Administration (www.eia.doe.gov)

[3] American Trucking Associations Fuel Facts (www.truckonline.com)

Why Class 8 Vehicles Are A Good Target For Hybrid Technology – Emissions

- **69%:** Increase in green-house-gas emissions from the U.S. commercial truck fleet between 1990 and 2005 (versus a 23% increase in emissions from passenger cars over the same time frame) [1]
- **70%:** Portion of on-highway related particulate matter emissions attributed to heavy-duty trucks [2]
- **40%:** Portion of on-highway related NOx emissions attributed to heavy-duty trucks [2]

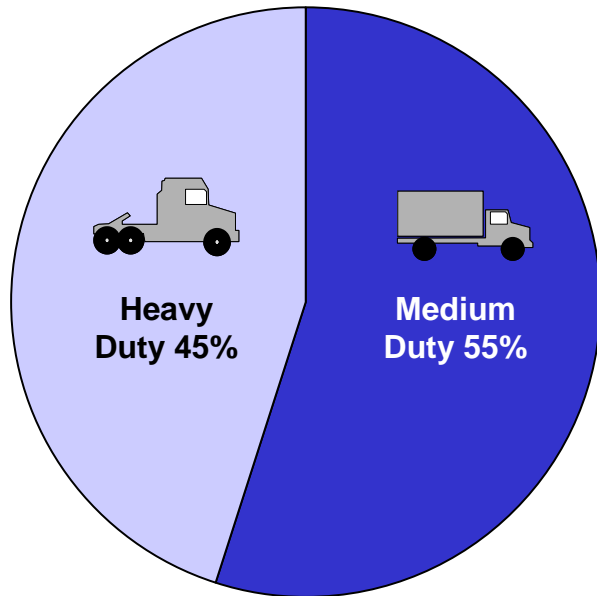
Sources:

[1] www.truckinfo.net/trucking/stats.htm

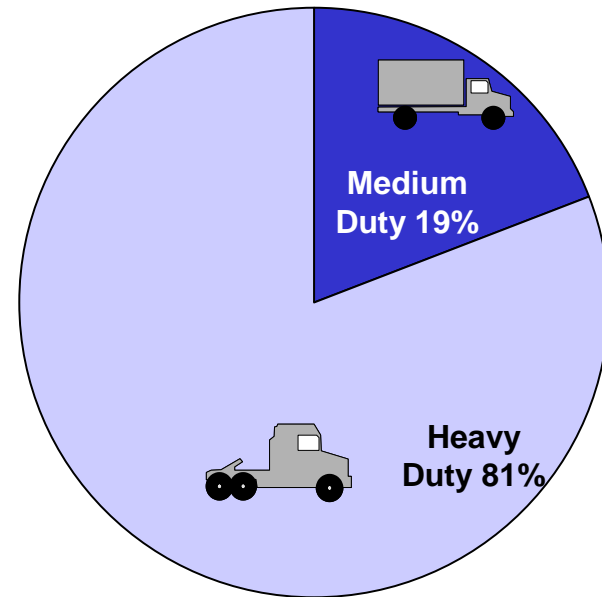
[2] U.S. EPA Emissions Inventory (www.epa.gov)

Class 8 Focus: Fewer total units but significantly higher total fuel consumption than Medium Duty vehicles.

Vehicle Park Distribution



Annual Fuel Use



Class 8 vehicles consume more than 4 times the amount of fuel used by Medium Duty vehicles.

Hybrid Electric Vehicles Annual Fuel Savings



~20% Improvement
138 Gal. Saved
12,500 miles/year



~40% Improvement
615 Gal. Saved
20,000 miles/year



includes 1,800 hours of
idle/year

~15% Improvement
3,270 Gal. Saved
125,000 miles/year

Engine Idle/Hotel

Normal Drive

- Due to driving cycles and idling savings the commercial vehicles fuel consumption reduction equates to **taking 7-10 cars off the road**.
- Class 8 hybrid vehicles have a lower percentage reduction in fuel savings and emissions reduction, but due to the substantial amounts of fuel consumed, the benefits are still attractive.

Class 8 Hybrid Opportunities

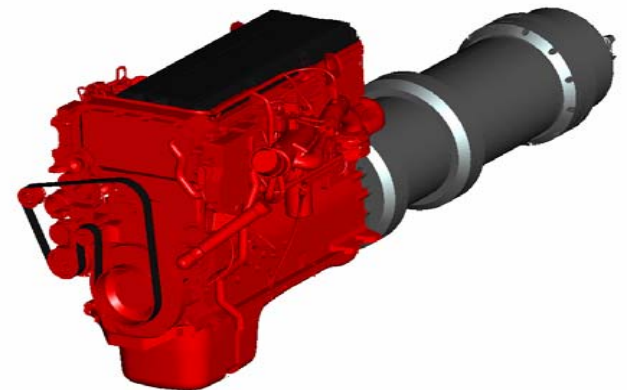
Fuel Economy and Emissions Reduction

■ Regenerative Braking

- ⌘ Benefit of CI 8 Hybridization (like all hybrid applications) is duty cycle dependent.
- ⌘ Long, straight run, minimal grades or braking – less desirable
- ⌘ Limited start and stop, some grades and idling – better opportunity



■ Engine-Hybrid Integration Strategies



Class 8 Hybrid Opportunities

Fuel Economy and Emissions Reduction

■ Anti-Idle / Hoteling

- ⌘ Idling Time is Significant (up to 1800 hrs. per year)
- ⌘ Overnight hoteling consumes 6-9 gallons of fuel (8 hrs.)

■ Electrification of Accessories

- ⌘ Accessories can consume from 6-12kW of power
- ⌘ Air Compressor
- ⌘ Power Steering
- ⌘ AC Compressor
- ⌘ Eliminate alternator

■ Route Planning (GPS)

- ⌘ Potential Battery Management Strategy
- ⌘ When to store energy, when to consume



Electric Air Compressor



Electric Power Steering



Electric AC Compressor

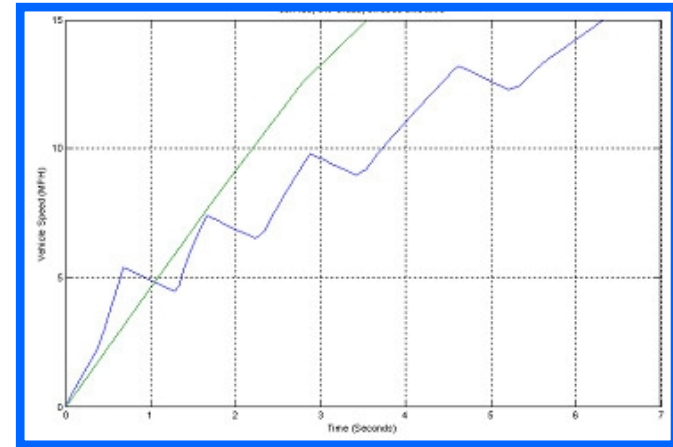


Class 8 Hybrid Opportunities

Other Advantages

■ Continuous Torque Delivery

- ⌘ No Shifting by Driver
- ⌘ Reduced Driver Fatigue
- ⌘ Better average acceleration



■ Reduced Noise Levels

- ⌘ Reduction of Engine Brake Usage
- ⌘ For systems with “electric-only” mode
- ⌘ Significant in high congestion areas

■ Power source for ancillary equipment



Challenges to Hybridization of Class 8 Vehicles

- **Not All Duty Cycles Lend Themselves to Hybridization**
- **Industrialization of Robust, Electrical Components**
 - ⌘ “Chicken and Egg” regarding Sales Volumes
- **Size and Weight of E-Machines**
 - ⌘ Power Density Dependent Upon Cooling Capabilities
- **Business Case**
 - ⌘ Most Fleets Require 3 year payback or less
 - ⌘ Currently may be dependent upon Government Incentives
 - ⌘ Fuel Prices – Huge Variable
 - ⌘ Battery Costs – Huge Variable
- **Batteries**

Challenges to Hybridization of Class 8 Vehicles

Batteries

- **High Cost**
 - ⌘ Currently at 1000-1200 per kW-hr
 - ⌘ Objective: 300-500 kW-hr
- **High Weight and Size**
 - ⌘ Energy Density of Li-Ion Batteries
~ 10% of Diesel fuel
- **Durability**
 - ⌘ For Class 8, Require up to 3000 full cycles
 - ⌘ 7 years of Life
 - ⌘ Replacement compromises business case.
- **Battery Condition**
 - ⌘ Predicting Battery Life
 - ⌘ State of Charge Determination

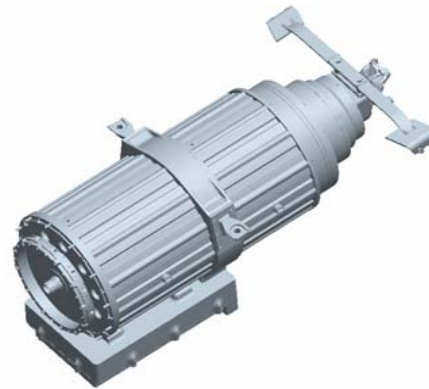


Hybrid Systems for Class 8 Trucks

Parallel

- 25-80 kw-hr motors
- Transmission based
- Emission reduction related to fuel economy
- Limited production
- Limited electric mode

Dual Mode



- Combines benefits of Series and parallel
- 150-200 kw-hr Motors
- No conventional transmission
- Zero emission mode
- Proof of concept
- Full electric mode

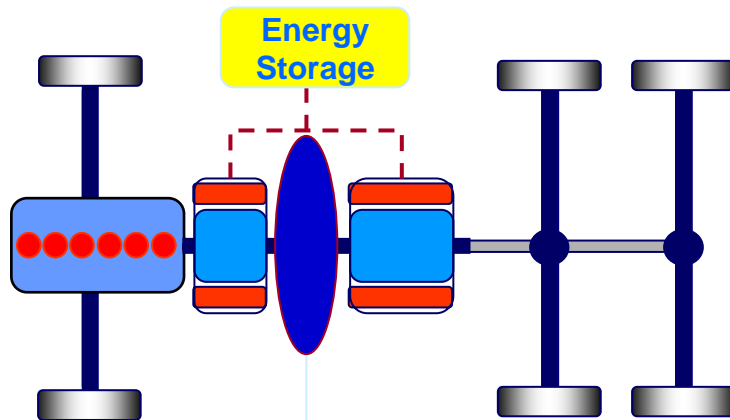
Series

- 200-450 kw-hr Motors
- No conventional transmission
- Zero emission mode
- Production in buses
- Proof of concept
- Full electric mode

One Approach For Class 8 Dual Mode Hybrid System

System operates as pure electric or a series hybrid in slow driving and maneuvering. Transitions to parallel at high speeds

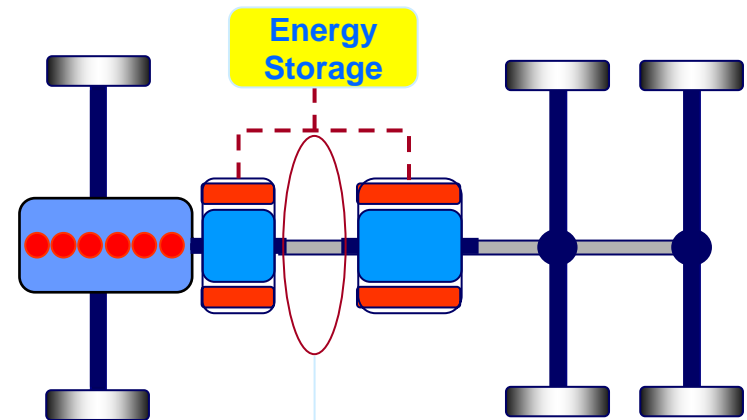
Series Mode (<50 MPH)*



No Mechanical Connection

Engine decoupled from driveline.
Engine is off or operating depending
on battery SOC

Parallel Mode (>50 MPH)



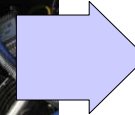
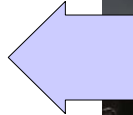
Engaged Mechanical Connection

Engine operates based on driveline
speed, hybrid drive gear ratios and
truck load requirement

“Dual Mode” Hybrid is Actually “Multi-Mode”

ZEV Operation

Providing the ability to deliver zero emissions, engine off operation over a broad speed range ... a potential benefit for vocational applications such as drayage trucks



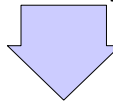
Series Operation

Maximizing efficiency in highly transient, lower speed (<50 mph) driving and changing the performance requirements of the engine to drive efficiency gains

Parallel Operation

Maximizing efficiency in highway, high speed driving while still providing hybrid functionality such as regenerative braking and torque assist

Meritor Dual Mode Hybrid Powertrain



Hoteling and Stationary Export Power

Providing significant energy and electrical power for over night hoteling as well as more demanding applications such as vocational accessories (e.g., cement mixers, fire and rescue, military, bulk gas pumping systems, etc.)

Dual Mode Hybrid

Components Removed

- Conventional Transmission
- Clutch
- Starter
- Alternator
- Flywheel



New Content

- Hybrid Drive
- Hybrid Controller
- Li-ion Battery Packs
- Power Electronics

- Engine Driven Air Compressor
- Engine Driven A/C Compressor
- Engine Driven Power Steering



- Electric Air Compressor
- Electric A/C Compressor
- Electric Power Steering

Fuel Economy & Emissions Benefits

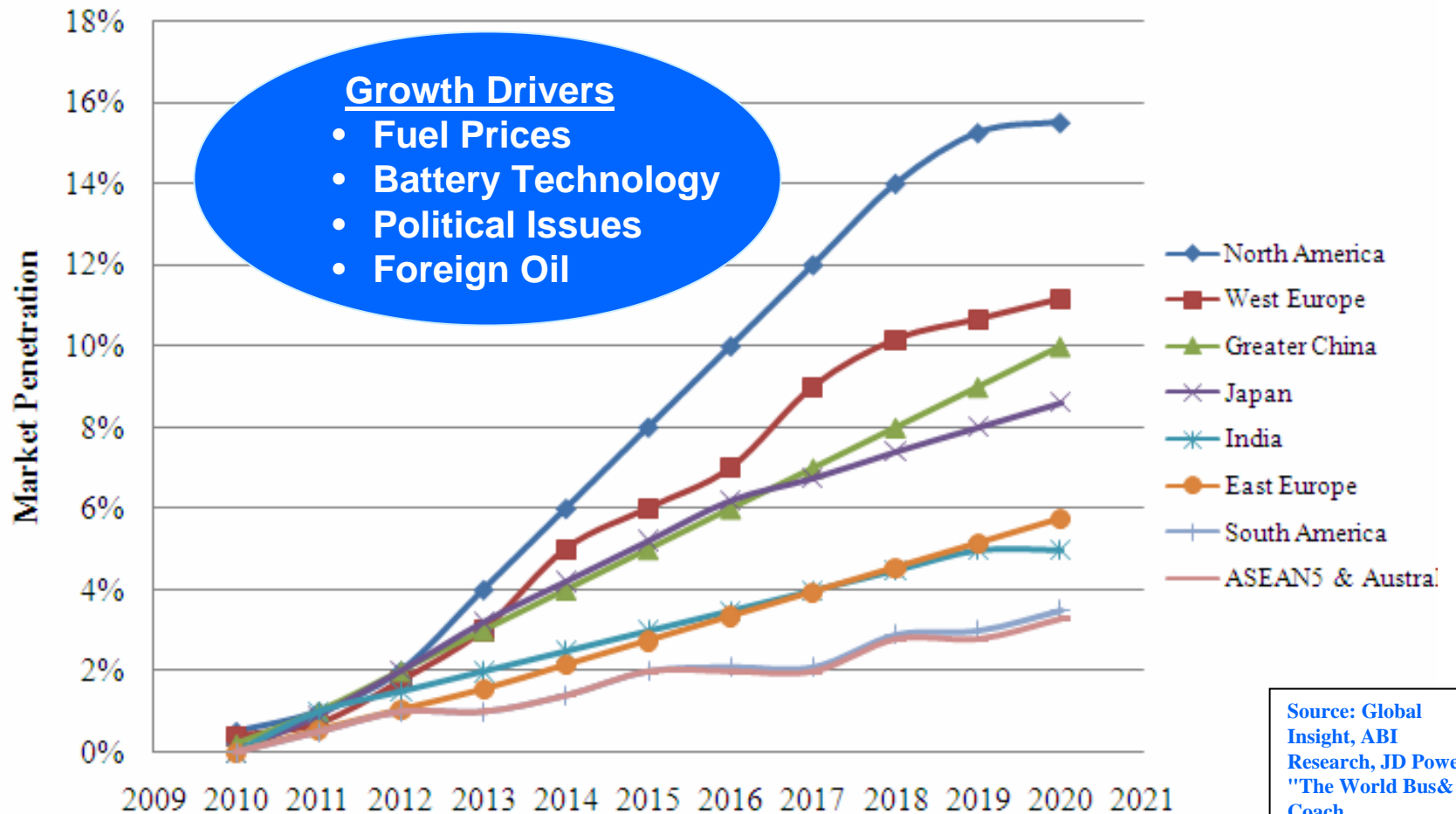
- Regenerative Braking
- Optimized Engine-Hybrid Integration
- Reduced Idling (stops and hoteling)
- Zero Emissions Mode

Other Benefits

- Reduced Noise
- Improved Acceleration
- Fully Automatic
- Significant Export Power

Projected Growth of Class 8 Hybrids

Global Hybrid Penetration into Class 8 Heavy Duty Truck Markets



Source: Global Insight, ABI Research, JD Power, "The World Bus & Coach Manufacturing Industry 2006", Internal Analysis



Potential Class 8 Hybrid Applications



Linehaul



Regional Haul



Intra City



Dump



Concrete Mixer



Refuse



Yard Spotter



Ports Drayage

Class 8 Electric Hybrids Summary



- **Class 8 Vehicles are good candidates for hybridization.**
 - ⌘ % of fuel savings less than medium duty, but more actual fuel saved.
- **Fuel and Emissions savings derived from Several Areas**
 - ⌘ Regenerative Braking
 - ⌘ Engine-hybrid Integration and Optimization
 - ⌘ Electrification of Accessories
 - ⌘ Anti-Idle/Hoteling
 - ⌘ Route Planning
- **Challenges**
 - ⌘ Size and Weight of E-machines
 - ⌘ Industrialization of components (volume sensitivity)
 - ⌘ Battery Technology
 - ⌘ Business Justification
- **Projection – Class 8 Hybrid Market will grow Globally to ~10-16% in N. America and Western Europe by 2020**

Thank You!

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