Future Directions in Engines and Fuels

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DEER Conference
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Overview

- Research on Improving the Efficiency of HD/MD Diesel Engines
- Research on Improving the Efficiency of LD Diesel Engines
- Research on Improving the Engine Efficiency with Alternative Fuels

Energy Balance for Advanced HD Engine with Electrification of the Vehicle

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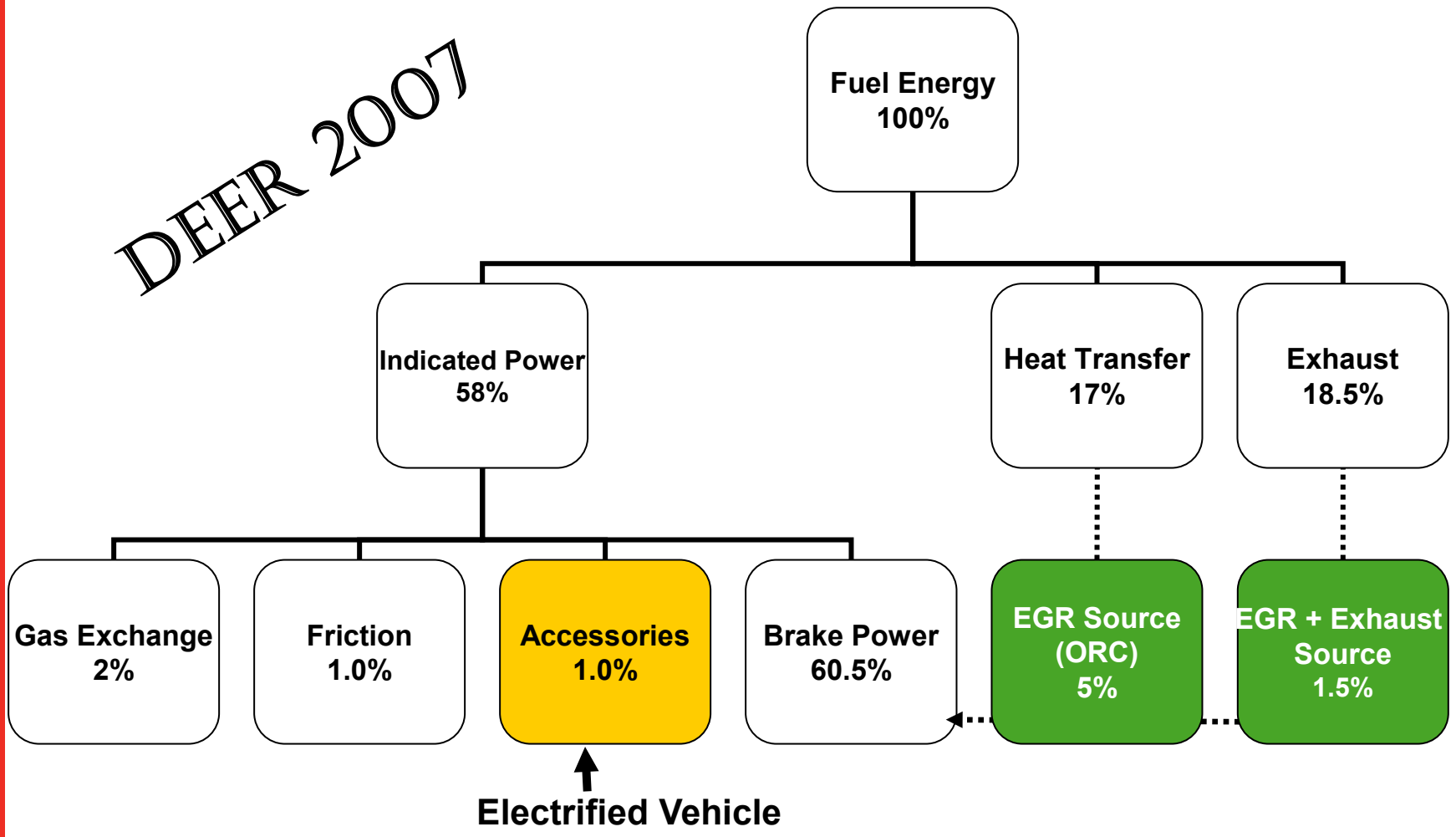

Technology Roadmap for HD/MD Efficiency Improvement

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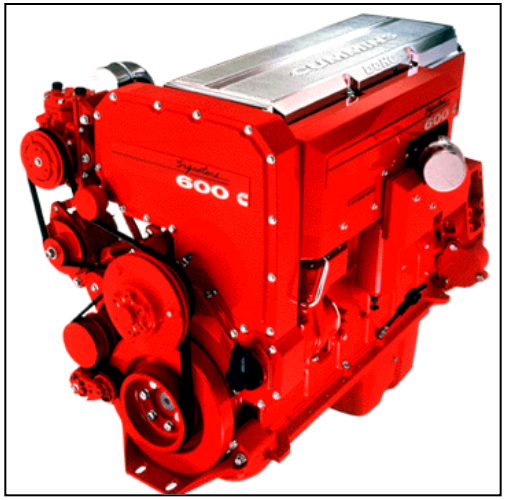
Base Engine

Fuel System

Clean Combustion

Variable Valve Actuation



Controls

EGR Loop

Electrically Driven Components

Turbo Technology

Aftertreatment

Waste Heat Recovery

Vehicle Freight Efficiency Path to Target

Technology	Drive Cycle Vehicle Demonstration Freight Efficiency Improvement (%)	24 Hour Duty Cycle Vehicle Demonstration Freight Efficiency Improvement (%)
Vehicle Aerodynamics	Harmonized Tractor-Trailer	Harmonized Tractor-Trailer
Engine	WHR, Low Temperature Combustion, Base Engine, AT, etc..	WHR, Low Temperature Combustion, Base Engine, AT, etc.
Transmission/ Road Load Management	Advanced Transmission, GPS, Adaptive Cruise, Driver Feedback	Advanced Transmission, GPS, Adaptive Cruise, Driver Feedback
Rolling Resistance	Robustness to wear, low resistance	Robustness to wear, low resistance
Axles	Smart axle technology	Smart axle technology
Idle Management	N/A	Solid Oxide Fuel Cell APU
Total	**50%**	**> 50%**

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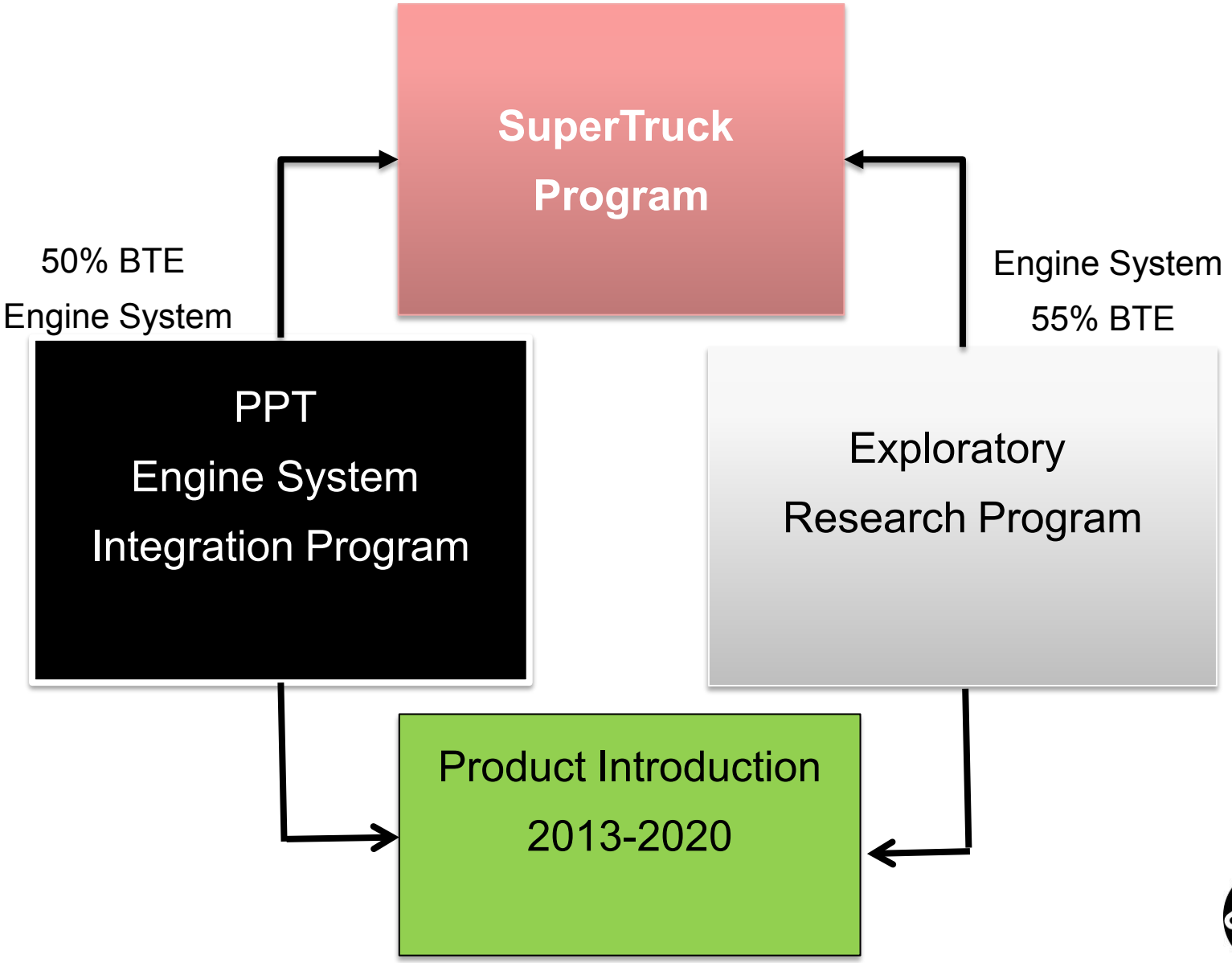
Engine Development Efforts with SuperTruck Funds



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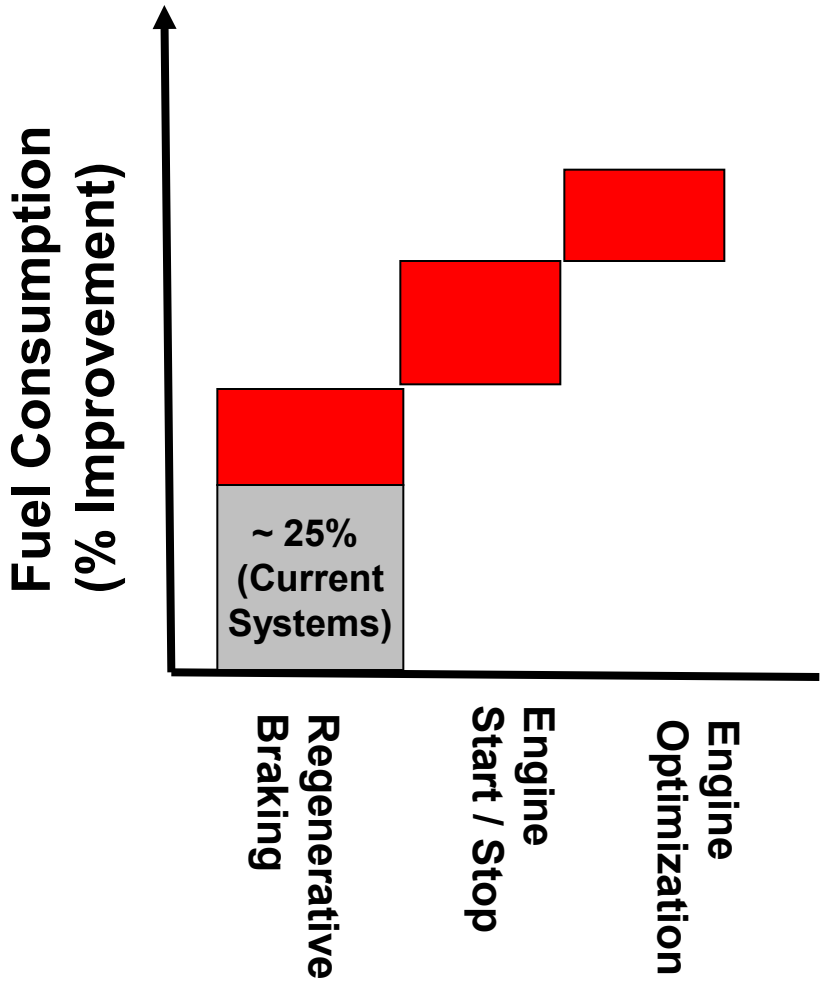
HD Engine Technology Highlights

- Waste Heat Recovery
  - ORC
  - Turbocompounding
- Base engine redesign
  - Increased PCP
  - Lower friction/parasitics
  - Low viscosity oil compatibility
- Highly efficienct aftertreatment
  - Minimal to No EGR
  - Alternative NH_3 delivery systems
- Engine downspeeding
- Cost reduction

Fuel Consumption Improvement of "Engine-Centric" Hybrid



- **Current systems are approximately 20-25% better than diesel only**
- **Engine-Centric system estimated to be 40-50% better than diesel only**

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Diesel Path to Light Duty Market

- There is a need for the utility of a light pick up truck.
- Fuel Economy/GHG requirements are driving cost into gasoline products. Future regulations will also add cost to the gasoline emission control systems.
- Diesel aftertreatment and emission controls will mature, becoming more effective at a lower cost.
- Diesel will become more acceptable from a cost standpoint as gasoline engines and advanced powertrains become more complex.

DOE ATLAS Project Description

- 40% Fuel Economy improvement over the current gasoline technology offering (MPG Measure)
- Meet Tier 2 Bin 2 Tailpipe Emission Standards
  - 0.02 g/mi NOx
  - 0.01 g/mi NMHC
- Four year program
- Baseline vehicle
  - 5.6 L gasoline
    - 15.4 MPG City
    - 24 MPG Highway
    - Automatic Transmission
    - 5500 lb Emission Test Weight
- Engine Development (No hybrid/weight redxn/etc.)

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LD Engine Technology Highlights

- High effectiveness aftertreatment system
- Close coupled DOC/DPF
- Variable Valve Timing
- Dual loop EGR
  - High Pressure system, cooled and bypass routes
  - Low Pressure system, post DPF, cooled and bypassed
- Engine parasitic reduction
  - Friction improvements
  - Smart accessories
- Cost

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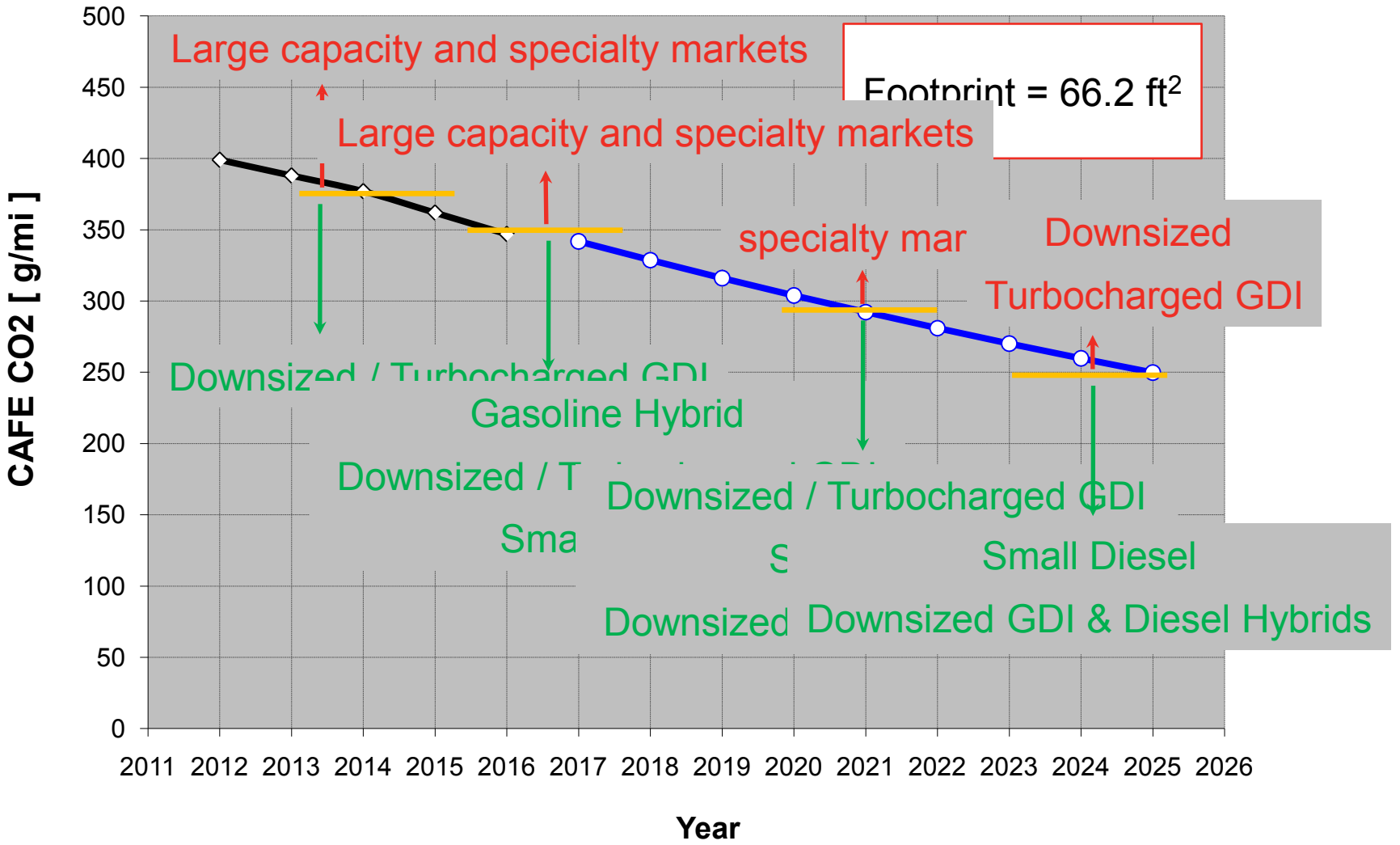
Projected Path for Diesel in Light Duty



Assumption of constant vehicle utility

Vehicle design improvements will account for 15% of overall CO2 reduction

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Alternative Fuels

- Natural Gas
  - CWI for automotive products worldwide
    - Recent DOE award
  - High Efficiency High Horsepower
    - Low BTU gas for Power Generation
    - DOE/CEC ARICE/ARES programs
    - Pathway to >50% BTE
- Biodiesel
  - Focus on soy biodiesel in the U.S.
  - Ensure quality of fuel – industry initiative
  - Certify engines to B20 (20% biodiesel)
  - Significant more changes required for B100

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Summary

- Engine Technology Development will play an important role in fuel consumption reduction
  - 20 to 30% fuel consumption reduction for HD LH
  - Fuel consumption reduction potential for HD Vocational MD depends on the application
  - Optimized integration of engine/power train
  - Need time to develop the technology into a product
- Diesel is a fit for LD applications
- Alternative fuels
  - Natural Gas, Producer Gas and Biodiesel
- Total Cost of Ownership drives introduction dates for HD/MD-Legislation will for LD

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Acknowledgement

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