SuperTruck – An Opportunity to Reduce GHG Emissions while Meeting Service Demands

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Truck Fuel Use Is Projected to Increase

- Global commercial transportation energy demand projected to grow by 70% (2010-2040)
  - By 2040 world fuel use for trucks is projected to grow significantly faster than personal vehicles
- HD fuel efficiency technology options limited
  - Limited opportunity for electrification (vs. light-duty)
  - Technology and infrastructure hurdles for alternative fuels

Increased truck fuel efficiency needed to mitigate projected increases

*Source - ExxonMobil 2012 The Outlook for Energy: A View to 2040*
Figure 4.3  Freight demand and modal shares, 2009 and 2040  (data source: FHWA FAF3)

Opportunity for Reduction in Freight Transportation Energy Use and GHG Emissions

<table>
<thead>
<tr>
<th>Probability of Implementation</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Provide tax incentives for locating freight staging areas closer to city centers. Deregulate U.S. coastal shipping.</td>
<td>Restructure U.S. trade policies to promote in- and near-sourcing.</td>
<td>Increase heavy-duty engine efficiency and emission standards.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Increase investment in freight infrastructure. Increase federal motor fuel tax. Implement road pricing (VMT user fees)</td>
<td></td>
<td>Impose low-carbon fuel standards</td>
</tr>
<tr>
<td>High</td>
<td></td>
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</table>


The Why of SuperTruck
The SuperTruck Project provide one of the best opportunity to reduce GHG emissions while meeting service demands in growing urban regions.
SuperTruck Initiative

- **June 2009**: Solicitation ... develop and demonstrate a 50% improvement in overall freight efficiency on a heavy-duty Class 8 tractor-trailer measured in ton-miles per gallon, achieve 50% engine thermal efficiency at 65 mph and show a pathway to 55% engine efficiency.

- Both **engine and vehicle** system technologies included
- Vehicle target for freight efficiency (ton-miles per gallon) improvement based on 65,000 pound GVW
- 40% of the total improvement is required to be **from engine technologies** (50% thermal efficiency) and the remainder from vehicle system technologies
SuperTruck Initiative

- **2010:** Four competitively selected projects awarded;
  - Cummins Inc. with Peterbilt (ARRA Funded)
  - Daimler Trucks North America (ARRA Funded)
  - Navistar, Inc.
  - Volvo Trucks North America

- Total project funding: DOE + Industry = $284 Million
Why Long-Haul Heavy-Duty Trucks?

- Impact will be large and immediate
  - Heavy-duty trucks comprise 4% of on-road vehicles but 18% of fuel consumption
  - Heavy trucks move 73% of freight value, 73% of freight tonnage, and log 49% of ton-mileage

- High return on investment
  - Truck operators and
  - Federal Government

- Industry is ready and willing to adopt new technology

- Growing domestic and international markets

- Saves domestic jobs

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U.S. Oil Use in 2010

- Light Duty
- Heavy Duty
- Non-Highway
- Industry
- Buildings
- Electric Utilities

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Fuel Use by Truck Class

- Class 2B
- Class 3
- Class 4
- Class 5
- Class 6
- Class 7
- Class 8
Challenge: Heavy Truck Market

- **Expectations**
  - Low operating costs
  - High uptime
  - Low maintenance
  - High residual value

- **Requirements**
  - Low fuel consumption
  - High performance
  - Safe operation
  - Ease of operation
  - Driver satisfaction
  - Information systems
  - Emissions compliance

- *SuperTruck* projects help expedite technology development/deployment
Class 8 Truck Energy Balance – Base Configuration

Base Tractor-Trailer Configuration
Ave. Payload: 11,800 kg (26,000 lbs.)
Total Mass: 27,220 kg (60,000 lbs.)
Fuel Use: 14.7 gallons/1,000 ton-miles
Fuel Economy: 5.8 mpg

Heavy-duty trucks use 18% of the fuel consumed in the United States.
Fuel economy improvements in these trucks directly and quickly reduce petroleum consumption.
Class 8 Truck Energy Balance – Achievement of 21CTP Goals

21st Century Truck Goals
Ave. Payload: 11,800 kg (26,000 lbs.)
Total Mass: 25,220 kg (55,600 lbs.)
Sp. Fuel Use: 9.0 gallons/1,000 ton-miles
Fuel Economy: 9.4 mpg

Average Power Use Inventory (Line Haul)

<table>
<thead>
<tr>
<th>Fuel Input (211 kW)</th>
<th>Engine Output (106 kW)</th>
<th>Tractive Power (92 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Losses</td>
<td>Accessory Loads</td>
<td>Aerodynamic Losses</td>
</tr>
<tr>
<td>105 kW ((\eta_{\text{eng}}=0.50))</td>
<td>8 kW</td>
<td>53 kW ((C_D=0.52))</td>
</tr>
<tr>
<td>Auxiliary Power Unit</td>
<td>Drivetrain Losses</td>
<td>Rolling Resistance</td>
</tr>
<tr>
<td>0.8 kW</td>
<td>5 kW</td>
<td>32 kW ((C_{RR}=0.0055))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inertia/Braking Losses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 kW (60% regeneration efficiency)</td>
</tr>
</tbody>
</table>

Key Enhancements:
- Engine efficiency
- Aerodynamic Improvements
- Low rolling resistance tires
- Regenerative braking (HEV)
DOE Heavy Truck Engine Goals Support the *SuperTruck* Project

- By 2015, improve heavy truck fuel economy (engine thermal efficiency) by 20 percent with demonstration in commercial vehicle platforms.
- By 2020, improve heavy truck fuel economy by 30 percent compared to 2009 baseline.

<table>
<thead>
<tr>
<th>Heavy-Duty Vehicles</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine brake thermal efficiency</td>
<td>50%</td>
<td>55%</td>
</tr>
<tr>
<td>Fuel economy improvement</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>NOx emissions, g/bhp-hr</td>
<td>&lt;0.20</td>
<td>&lt;0.20</td>
</tr>
<tr>
<td>PM emissions, g/bhp-hr</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Stage of development</td>
<td>Prototype</td>
<td>Prototype</td>
</tr>
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</table>
SuperTruck Project Status & Highlights
Cummins/Peterbilt SuperTruck Team

**Cummins**: highly efficient and clean diesel engine, advanced waste heat recovery

**Peterbilt**: tractor and trailer combination, aerodynamic, lightweighting, battery powered auxiliary unit to reduce engine idling.

- Modine – Cooling Module
- Eaton – Transmission
- Dana – Drivetrain
- Bridgestone – Fuel Efficient Tires
- Alcoa – Wheels
- Bergstrom – eSHVAC
- Garmin – 3D Map and Display
- Exa – CFD Analysis
- Utility Trailer Manufacturing – Trailer
- US Xpress – End User

DOE Share $38.8M
Contractor Share $38.8M
Cummins/Peterbilt SuperTruck Status and Highlights

- Developed and demonstrated 51 percent brake thermal efficiency for an engine on a dynamometer:
  - Demonstrated waste heat recovery system improvements, including system simplification.
  - Selected and tested advanced transmission.
  - Compression ratio and PCP increased
  - Engine system optimized and calibrated

- Demonstrated 61% freight efficiency surpassing 50% freight efficiency goal:
  - Advanced Automated Manual Transmission (AMT) completed.
  - Demonstrated 25% improvement in aerodynamics
  - Predictive cruise control in place.
  - The driver communication interface has been interlaced within the vehicle network and truck display systems.
  - Demo 2 truck design - froze
Daimler SuperTruck Team

**Priority:** hybridization, engine downsizing, electrification of auxiliary systems such as oil and water pumps, waste heat recovery, improved aerodynamics, weight reduction.

- DTNA – Vehicle Development
- Detroit Diesel – Powertrain
- Daimler Research – Waste Heat
- Oregon State University –
  - Composite Frame Analysis
  - Fuel Efficient Routing
- Schneider National – End User
- Wal-Mart – End User
- Great Dane – Trailer
- ARC – Aerodynamics
- Solar World Industries America – Auxiliary Power

**DOE:** $39,559,861  
**Daimler:** $39,559,898
Daimler SuperTruck Status and Highlight

- **Daimler Trucks North America**
  - **ENGINE:**
    - Achieved *48% Brake Thermal Efficiency* System Level Tests.
    - Analysis projects >50% BTE with waste heat recovery and reduced parasitic loads.
    - Developed *predictive engine control* system
    - *Down-speeding and down-sizing* engine (15L – 11L)
    - Developing *advanced generator* (non-permanent magnet) for Waste Heat Recovery system

- **FREIGHT EFF.**
  - 27% Vehicle Freight Efficiency increase measured to date with further improvements in Aerodynamics, Powertrain and Hybridization under development
  - *Testing of components* for 50% freight efficiency improvement completed
  - *Drive train improvements* completed
Navistar SuperTruck Team

Priority: **aerodynamics** truck-trailer aerodynamics, combustion efficiency, waste heat recovery, hybridization, idle reduction, and reduced rolling resistance tires.

- **Navistar** - Principal Investigator, Vehicle Systems Integrator Controls Systems, Engine & Vehicle Testing
- Alcoa - Lightweight Frame & Wheel Materials
- AT Dynamics - Trailer Aerodynamic Devices
- ArvinMeritor - Hybrid Powertrain, Axles
- Behr America - Cooling Systems
- Michelin - Low Rolling Resistance Tires
- TPI - Composite Material Structures
- Wabash National - Trailer Technologies
- Argonne National Lab - Hybrid Drive Simulation and Controls & Battery Testing
- Lawrence Livermore National Lab - Aerodynamic modeling

**Project Funding:**
- DOE: $37,328,933
- Navistar: $51,808,146
Navistar SuperTruck Status and Highlights

**Navistar, Inc.**

- **ENGINE:**
  - Achieved >47% Brake Thermal Efficiency System Level Tests.
  - Analysis projects >50% BTE possible with friction, pumping, turbo accessory, and air system enhancement.

- **FREIGHT EFF.**
  - Achieved 23.7% of needed 30% target with aerodynamic improvement, and battery weight reduction.
  - New designs developed for path to attain >50% freight efficiency improvement:
    - Hybrid powertrain simulation shows improvement between 5-12%.
    - CFD shows potential for 20% improvement in Cd.
    - Additional reductions in Friction/Rolling Resist and Weight.
Volvo SuperTruck Team

Priority: **truck/engine efficiency integration**; engine efficiency, truck-trailer aerodynamics, waste heat recovery, hybridization, idle reduction, and reduced rolling resistance tires.

- Mack Trucks, Inc.
- Volvo Powertrain NA
- Volvo Powertrain Sweden
- Volvo technology
- Ricardo - waste heat recovery
- UCLA - waste heat recovery
- Penn State Univ. – CFD models and biodiesel studies
- West Virginia Univ. - powertrain development

**Funding:**
- Volvo (U.S.) - $19,066,700
- DOE - $18,929,194
- Sweden - $15M
- Volvo (Sweden) - $15M
Volvo SuperTruck Status and Highlights

**ENGINE:**
- Demonstrated **48% Brake Thermal Efficiency** of integrated powertrain system in test cell **1.5 years ahead** of schedule
- **Improvements include:** turbocompounding, Rankine WHR, higher pressure fuel injection system, down-spied engine, advanced aftertreatment, next generation axles, dual clutch transmission, etc.

**FREIGHT EFFICIENCY.**
- **Validated initial trailer aero improvements** on-road (11% FE impact)
- **Completed** trailer optimization in CFD (target 14-16% total FE impact)
  - Optimized key parameters of tail and skirts through CFD simulations
  - Produced devices for optimum geometry and installed on test trailer
  - Validation road test on schedule
  - Reduced weight and parts through structural simplification and incorporated new materials & bonding methods
SuperTruck Summary of Progress

Status of 50 percent engine efficiency:
- All teams are on track to meet the 50 percent efficiency goal

Status of 50 percent freight efficiency improvement:
- All teams are on track and expect to achieve between 50 percent and 60 percent freight efficiency based on on-road vehicle evaluation.

Technologies developed under SuperTruck will begin to enter the market over the next decade.
SuperTruck technologies projected to reduce fuel consumption nearly 30 percent and save 6 billion barrels of oil by 2050 (ROI of 500:1)

Source: DOE SuperTruck Program Benefits Analysis Final Report (http://www.transportation.anl.gov/pdfs/TA/903.PDF)
SuperTruck technologies projected reduce GHG emissions by 30 percent, averting 3 billion metric tonnes of CO$_2$e emissions by 2050.

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SuperTruck provides a real world opportunity to reduce GHG emissions NOW while meeting the demands of the global community