Sustainable TRANSPORTATION

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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

Roland Gravel
Vehicle Technologies Office
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Conference on Climate Policy in an Energy Boom
Session VI - Delivering the Goods in an Urban World
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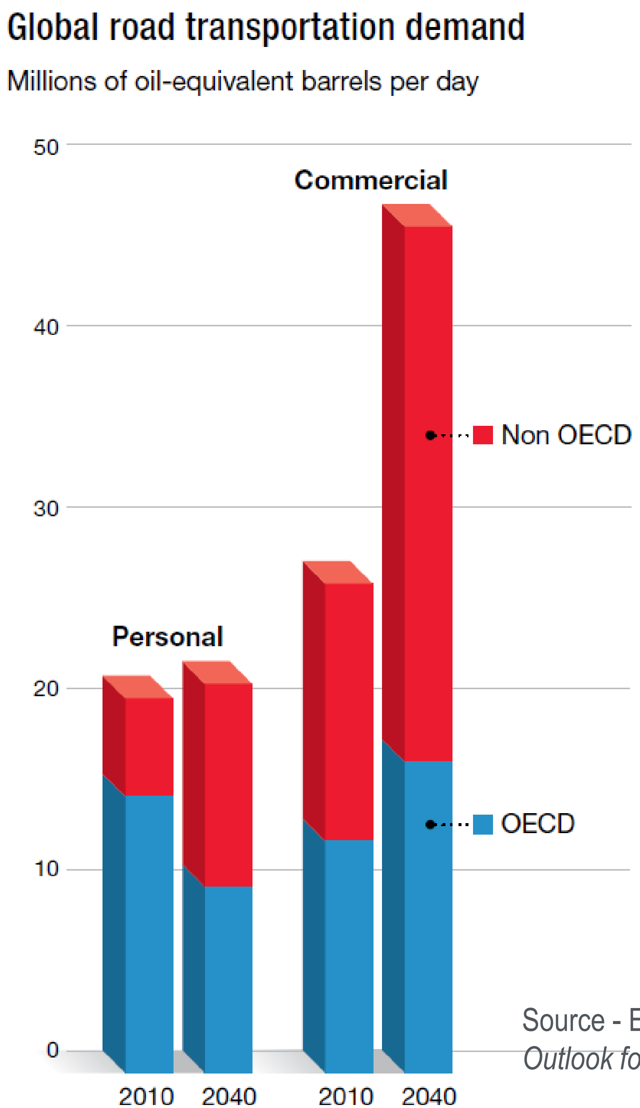
Truck Fuel Use Is Projected to Increase



Source - ExxonMobil *2012 The Outlook for Energy: A View to 2040*

- 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

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Freight Demand and Modal Shares

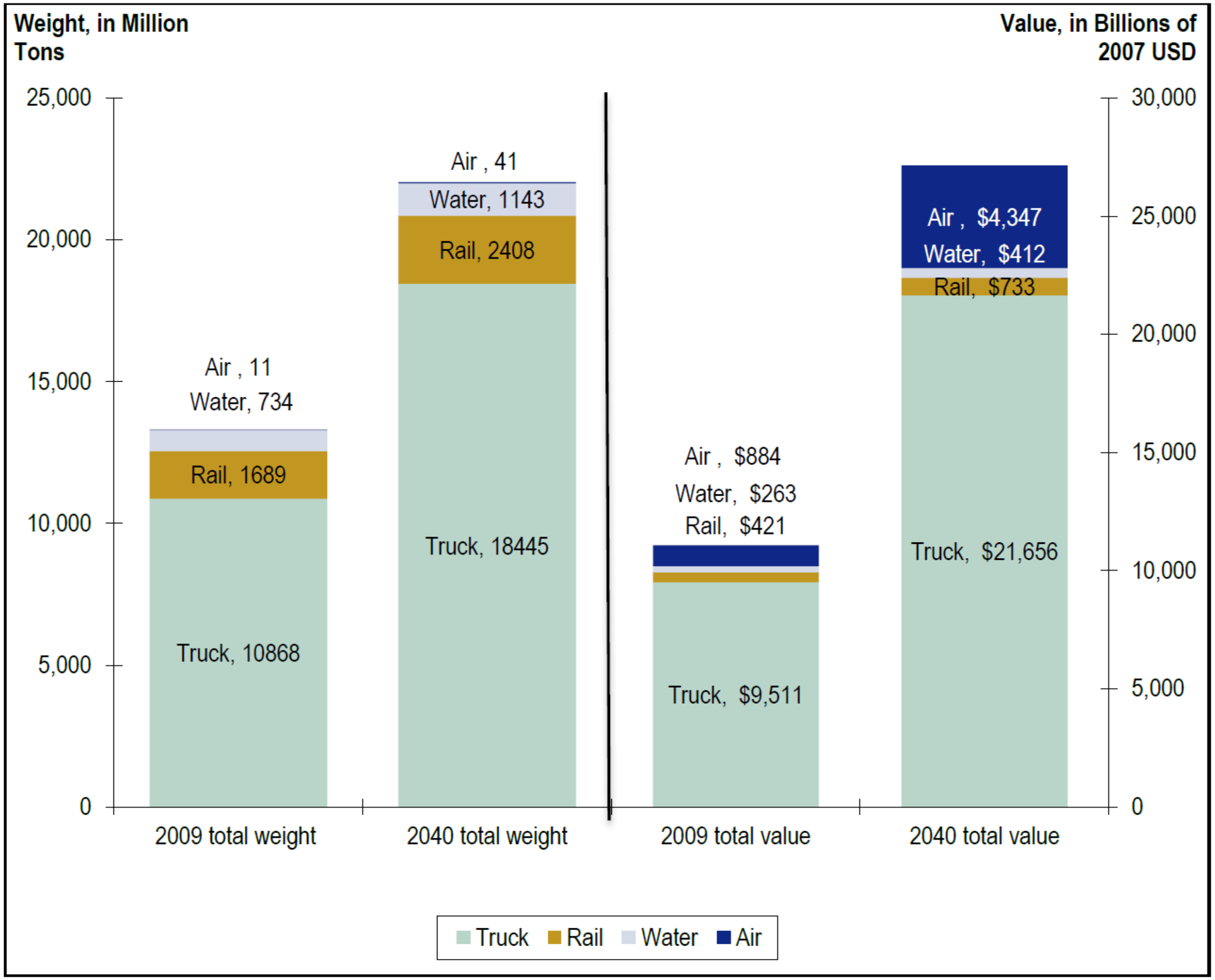
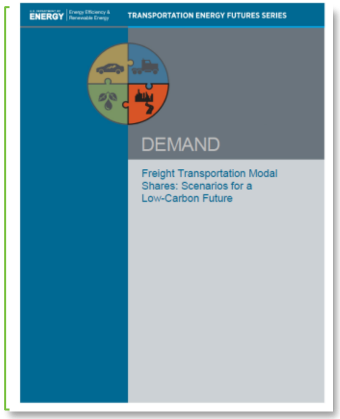


Figure 4.3 Freight demand and modal shares, 2009 and 2040 *(data source: FHWA FAF3)*



Source: *Freight Transportation Modal Shares: Scenarios for a Low-Carbon Future*, prepared by Cambridge Systematics under subcontract to National Renewable Energy Laboratory, March 2013

Opportunity for Reduction in Freight Transportation Energy Use and GHG Emissions

Probability of Implementation	Potential Reduction in Freight Transportation Energy Use and GHG Emissions: Low	Moderate	High
High			Increase heavy-duty engine efficiency and emission standards.
Moderate		Increase investment in freight infrastructure. Increase federal motor fuel tax. Implement road pricing (VMT user fees)	Impose low-carbon fuel standards
Low	Provide tax incentives for locating freight staging areas closer to city centers. Deregulate U.S. coastal shipping.	Restructure U.S. trade policies to promote in- and near-sourcing.	

The Why of SuperTruck

Source: *Freight Transportation Demand: Energy-Efficient Scenarios for a Low-Carbon Future*, prepared by Cambridge Systematics under subcontract to National Renewable Energy Laboratory, March 2013

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.

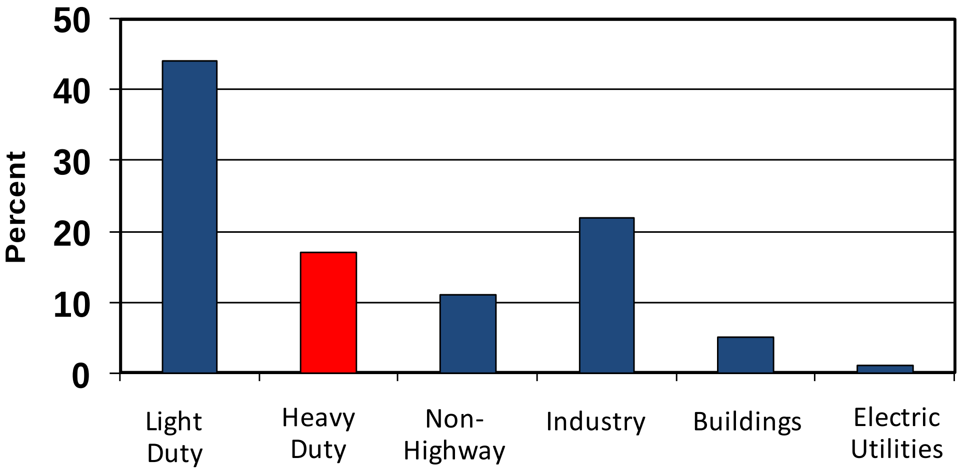
  - Both engine and vehicle system technologies included
  - Vehicle target for freight efficiency (ton-miles per gallon) improvement based on 65,000 pound GVW
  - 40% of the total improvement is required to be from engine technologies (50% thermal efficiency) and the remainder from vehicle system technologies

SuperTruck Initiative

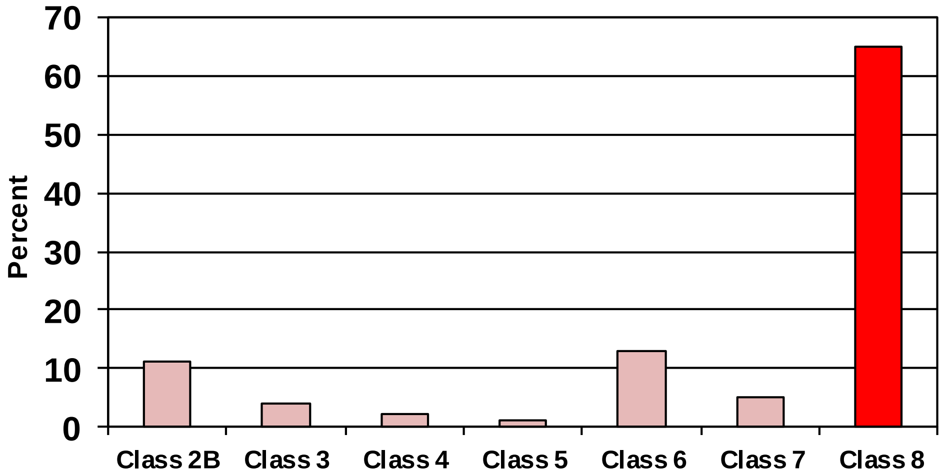
- **2010:** Four competitively selected projects awarded;
  - ***Cummins Inc. with Peterbilt*** *(ARRA Funded)*
  - ***Daimler Trucks North America*** *(ARRA Funded)*
  - ***Navistar, Inc.***
  - ***Volvo Trucks North America***
- Total project funding: DOE + Industry = $284 Million

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



U.S. Oil Use in 2010



Fuel Use by Truck Class

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Challenge: Heavy Truck Market

- *SuperTruck* projects help expedite technology development/deployment

- **Expectations**
  - Low operating costs
  - High uptime
  - Low maintenance
  - High residual value
- **Requirements**
  - Low fuel consumption
  - High perfomance
  - Safe operation
  - Ease of operation
  - Driver satisfaction
  - Information systems
  - Emissions compliance

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

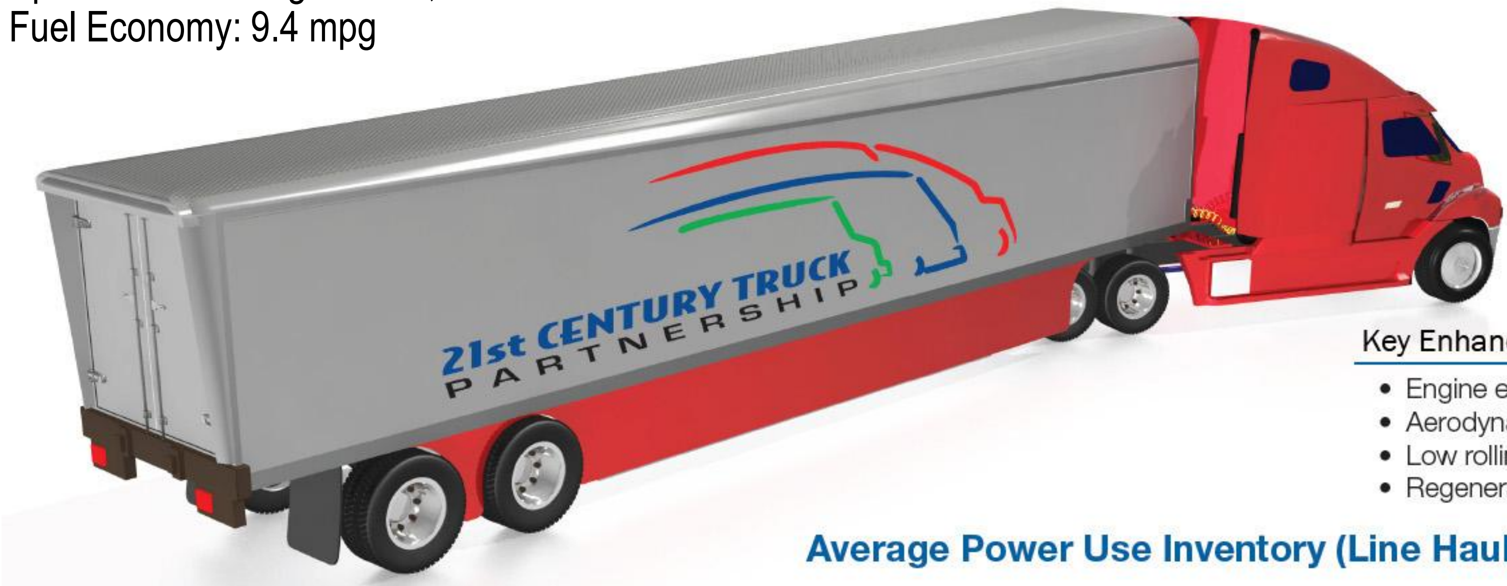
Average Power Use Inventory (Line Haul)

Fuel Input (343 kW)	**Engine Output** (146 kW)	**Tractive Power** (121 kW)
Engine Losses 193 kW (η_{eng}=0.43)	Accessory Loads 15 kW	Aerodynamic Losses 61 kW (C_D=0.60)
Idling Fuel Use 3.6 kW	Drivetrain Losses 10 kW	Rolling Resistance 44 kW (C_{RR}=0.007)
		Inertia/Braking Losses 16 kW

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



Key Enhancements:

- Engine efficiency
- Aerodynamic Improvements
- Low rolling resistance tires
- Regenerative braking (HEV)

Average Power Use Inventory (Line Haul)

Fuel Input (211 kW)	Engine Output (105 kW)	Tractive Power (92 kW)
Engine Losses 105 kW (η_{eng}=0.50)	Accessory Loads 8 kW	Aerodynamic Losses 53 kW (C_D=0.52)
Auxiliary Power Unit 0.8 kW	Drivetrain Losses 5 kW	Rolling Resistance 32 kW (C_{RR}=0.0055)
		Inertia/Braking Losses 7 kW (60% regeneration efficiency)

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

	Heavy-Duty Vehicles	
	2015	2020
Engine brake thermal efficiency	50%	55%
Fuel economy improvement	20%	30%
NOx emissions, g/bhp-hr	<0.20	<0.20
PM emissions, g/bhp-hr	<0.01	<0.01
Stage of development	Prototype	Prototype

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

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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

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Daimler SuperTruck Team

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

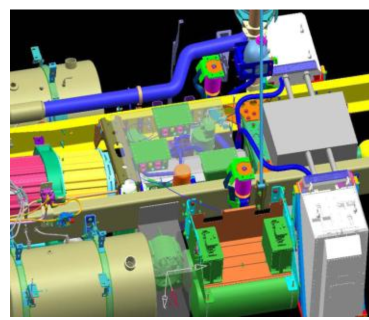
- **Navistar** - Principal Investigator, Vehicle Systems Integrator Controls Systems, Engine & Vehicle Testing
- Alcoa - Lightweight Frame & Wheel Materials
- AT Dynamics - Trailer Aerodynamic Devices
- ArvinMeritor - Hybrid Powertrain, Axles
- Behr America - Cooling Systems
- Michelin - Low Rolling 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: <u>truck/engine efficiency integration;</u> 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-sped 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

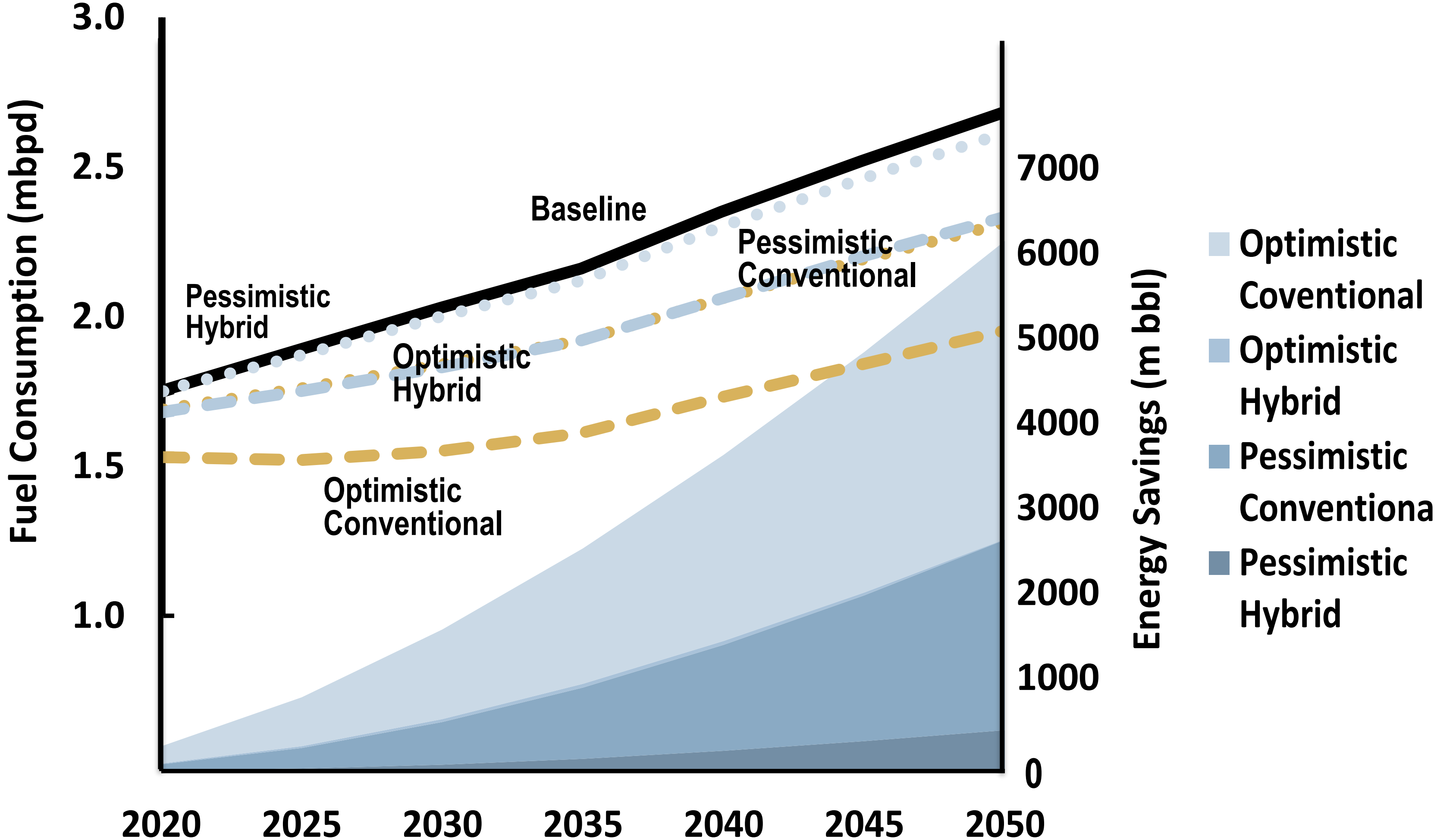
Status of 50 percent freight efficiency improvement:

- ❑ 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 Technology Benefits Analysis

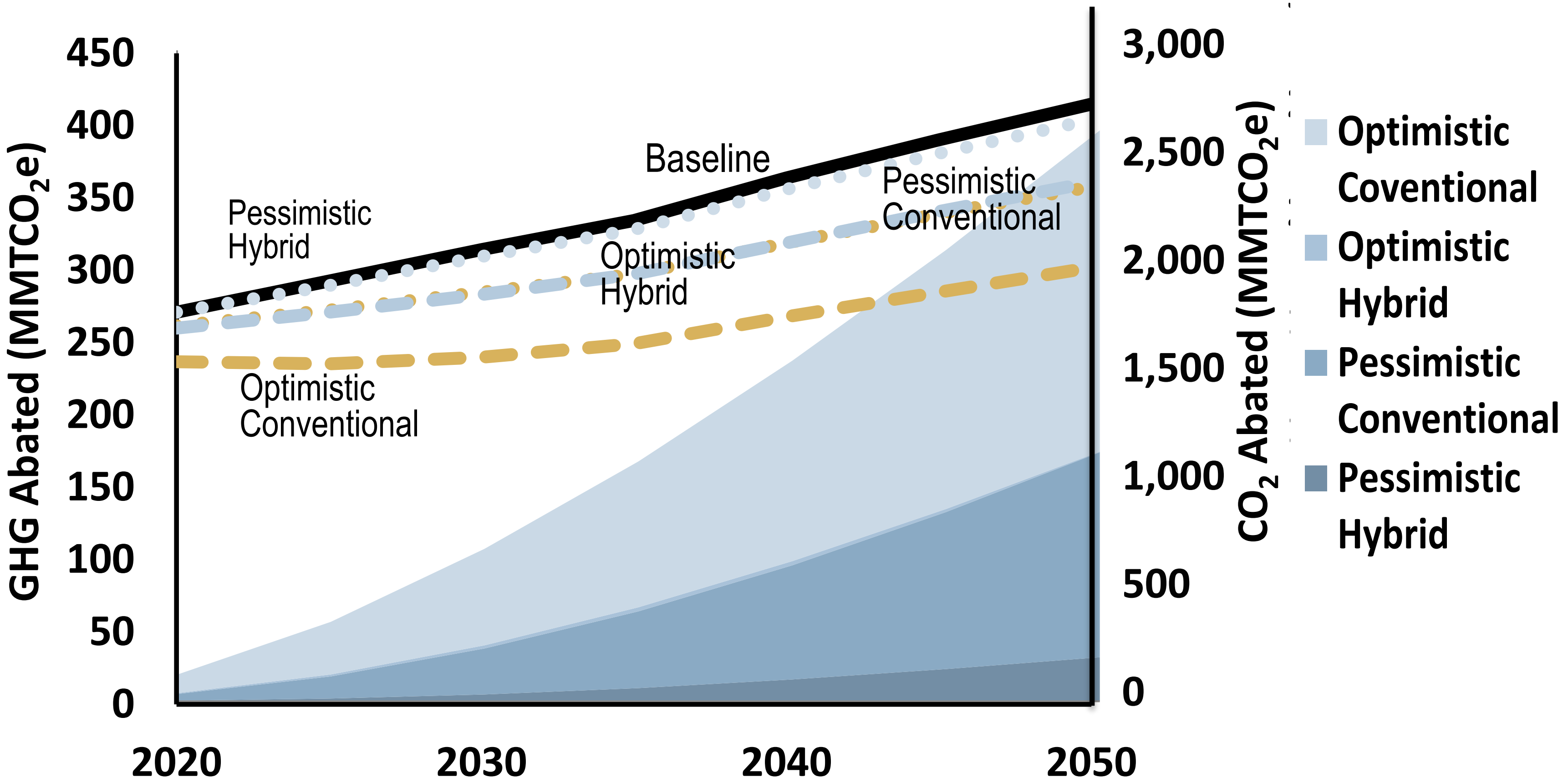
SuperTruck technologies projected to reduce fuel consumption nearly 30 percent and save 6 billion barrels of oil by 2050 (ROI of 500:1)



Source: *DOE [SuperTruck Program Benefits](http://www.transportation.anl.gov/pdfs/TA/903.PDF) Analysis Final Report (http://www.transportation.anl.gov/pdfs/TA/903.PDF)*

SuperTruck Technology Benefits Analysis

SuperTruck technologies projected reduce GHG emissions by 30 percent, averting 3 billion metric tonnes of CO_2e emissions of by 2050



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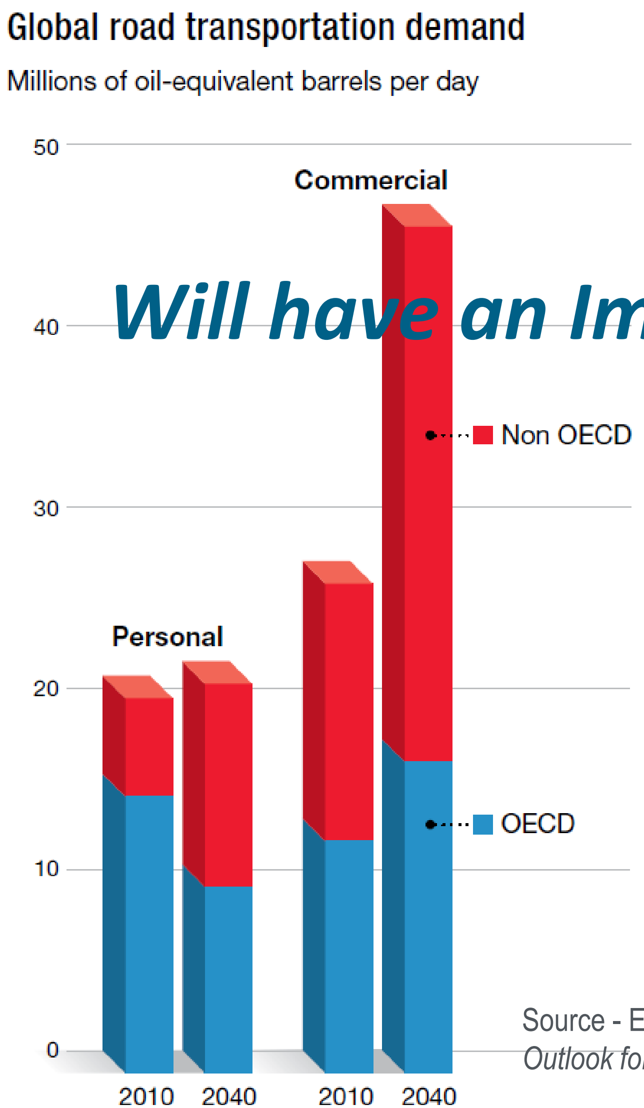

Will have an Impact!

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