Overview of the DOE High Efficiency Engine Technologies R&D

Roland Gravel
Advanced Combustion Engine R&D Subprogram
Vehicle Technologies Program

Vehicle Technologies Program Mission
To develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum.
The Federal Role

- Facilitate development of precompetitive technical knowledge base through investments in fundamental and applied R&D
- Undertake High-Risk Mid- to Long-Term Research
- Utilize Unique National Lab Expertise and Facilities
- Help Create a National Consensus
- Enable public-private partnerships to integrate R&D into industrially useful design tools
Strategic Goal: Reduce petroleum dependence by removing critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains in passenger and commercial vehicles.

Primary Directions:

- Improve ICE efficiency for cars, light- and heavy-duty trucks through advanced combustion and minimization of thermal and parasitic losses.
- Develop aftertreatment technologies integrated with combustion strategies for emissions compliance and minimization of efficiency penalty.
- Explore waste energy recovery with mechanical and advanced thermoelectrics devices.
- Coordinate with fuels R&D to enable clean, high-efficiency engines using hydrocarbon-based (petroleum and non-petroleum) fuels and hydrogen.
Research Approach

**Fundamental R&D**
- SNL – Low Temperature Combustion
- PNNL – Catalyst Characterization (NOx and PM Control)
- ANL – X-ray Visualization of fuel sprays
- LLNL – Chemical kinetics models (LTC and emissions)
- LANL – CFD modeling of combustion
- Universities – Complementary research

**Fundamental to Applied Bridging R&D**
- ORNL – Experiments and simulation of engines and emission control systems (bench-scale to fully integrated systems)
- ANL – H₂-fueled ICE; fuel injector design

**Competitively Awarded Cost-shared Industry R&D**
- Auto and engine companies – engine systems
- Suppliers – enabling technologies (sensors, VVA, WHR)

**Diagram:**
- Improved Understanding → Advanced Concepts → Commercial Product
- R&D Needs → Technical Barriers
Key Activities

- **Combustion and Emission Control R&D**
  - Fundamental Combustion Research
  - Emission Control R&D
  - High Efficiency Engine Technologies
    - Heavy Truck Engine and Enabling Technologies
    - Advanced Technology Powertrains for Light-Duty Vehicles
  - Health Impacts

- **Solid State Energy Conversion**
Goals

- **By 2015**, improve heavy truck engine efficiency to **50 percent** with demonstration in commercial vehicle platforms. This represents about a 20 percent improvement over current engine efficiency.
- **By 2018**, further increase the thermal efficiency of a heavy truck engine to **55 percent** which represents about a **30 percent** improvement over current engines.

<table>
<thead>
<tr>
<th></th>
<th>Light-Duty</th>
<th>Heavy-Duty</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
<td>2015</td>
</tr>
<tr>
<td>Engine brake thermal efficiency</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Powertrain cost</td>
<td>&lt; $30/kW</td>
<td></td>
</tr>
<tr>
<td>NOx &amp; PM emissions</td>
<td>Tier 2, Bin5</td>
<td>Tier 2, Bin2</td>
</tr>
<tr>
<td>Fuel economy improvement</td>
<td>25 – 40%</td>
<td></td>
</tr>
</tbody>
</table>
Challenges

- Increase Efficiency
- Reducing Emissions
- Ensuring Durability
- Maintaining or Reducing Cost
Systems Approach to Dramatically Improve Diesel Engine Efficiency and Reduce Emissions

- Partnerships with auto/truck manufacturing industry, energy companies, suppliers and national laboratories
- Improve fundamental understanding
- Use integrated systems approach
- Progress being made in all 3 areas
Focus Research, Development and Demonstration in Five Key Technology Areas

- **Engine Systems**
- Heavy-Duty Hybrid
- Parasitic Losses
- Idle Reduction
- Safety

**R&D Coordinated with 21st Century Truck Partnership**

**DOE/EERE**
FreedomCAR and Vehicle Technologies

**DOD/Army**
TACOM NAC Military Vehicle R&D

**DOT / RSPA**
Intelligent Vehicle and Highway Safety R&D

**EPA**
Vehicle Emissions Regulations

- Allison Transmission
- BAE Systems
- Caterpillar
- Mack
- NovaBus
- DaimlerChrysler
- Oshkosh
- PACCAR
- Eaton
- Freightliner
- Honeywell

**U.S. Department of Energy** | Energy Efficiency & Renewable Energy

Vehicle Technologies Program
Objectives are to develop and demonstrate advanced engine and vehicle technology as follows:

- **Heavy-Duty Class 8 Trucks**
  - 20% improvement in engine brake thermal efficiency (50% BTE)
  - 50% improvement in freight efficiency (ton-miles/gallon)
  - Modeling and analysis for pathway to 55% Brake Thermal Efficiency

- **Light-Duty Vehicles**
  - 25% fuel economy improvement over for gasoline engines baseline*
  - 40% fuel economy improvement over for diesel engines baseline*

**Funding:**
- $100M in ARRA Funding
- $87M in annual appropriations over six fiscal years

*Baseline is state-of-the-art port-fuel injected gasoline engine
SuperTruck Initiative

Demonstrate a **50% improvement** in freight efficiency by 2015

- **Trailer skirts**
- **Gap reduction**
- **Tractor/trailer integration (major redesign)**

**AERODYNAMICS**
- Highway: 21%
- Urban: 5%

**Combustion improvements**
- **Turbocompounding**
- **Waste heat recovery**

**ENGINE**
- Highway: 59%
- Urban: 58%

**ROLLING RESISTANCE**
- Highway: 16%
- Urban: 9%

**INERTIA/BRAKING**
- Highway: 0%
- Urban: 16%

**DRIVETRAIN**
- Highway: 2%
- Urban: 5%

**AUXILIARIES**
- Highway: 2%
- Urban: 7%

**Electric accessories**

**New generation wide base single tires**
- **Tire rubber compound**
- **Central tire inflation**

**Hybridization**

- **Reduced drivetrain friction**
- **Automated manual transmissions**

Heavy-duty trucks use 20% of the fuel consumed in the United States. Fuel economy improvements in these trucks directly and quickly reduces petroleum consumption.

Energy losses in Class 8 trucks and opportunities for efficiency improvements.
# Systems Level Technology Development, Integration, and Demonstration for Efficient Class 8 Trucks (SuperTruck)

<table>
<thead>
<tr>
<th>Awardees</th>
<th>Additional Team Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cummins, Inc.</td>
<td>Peterbilt, Eaton, Delphi, Bridgestone, Modine, U.S. Xpress, Purdue University, University of Wisconsin, and Oak Ridge National Laboratory</td>
</tr>
<tr>
<td>Daimler Trucks North America</td>
<td>Detroit Diesel, Oak Ridge National Laboratory, Massachusetts Institute of Technology, and University of Oregon</td>
</tr>
<tr>
<td>Navistar, Inc.</td>
<td>Arvin Meritor, ATDynamics, Bosch, FEV, Federal Mogul, Michelin, Modine Swift, Sheppard, Safeway, University of Illinois, Southwest Research Institute, Wabash National, University of Wisconsin, Argonne National Laboratory, and Lawrence Livermore National Laboratory</td>
</tr>
</tbody>
</table>
Funding Opportunity Announcement (FOA) - Multiple topic areas for near and mid-term projects in technology areas that support the vehicle technologies mission and goals.

Area of Interest 4 - Advanced Thermoelectrics and Enabling Technologies for Energy Efficient Powertrains (supplier base focused)
## Advanced Combustion Engine R&D Budget by Activities

<table>
<thead>
<tr>
<th>Major Activities</th>
<th>FY 2008 Appropriation</th>
<th>FY 2009 Appropriation</th>
<th>FY 2010 Appropriation</th>
<th>FY 2011 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Combustion Engine R&amp;D</td>
<td>$44,591K</td>
<td>$40,800K</td>
<td>$57,600K</td>
<td>$57,600K</td>
</tr>
<tr>
<td>Combustion and Emission Control *</td>
<td>38,815</td>
<td>35,089</td>
<td>47,239</td>
<td>47,239</td>
</tr>
<tr>
<td>Solid State Energy Conversion**</td>
<td>4,527</td>
<td>4,568</td>
<td>8,748</td>
<td>8,748</td>
</tr>
<tr>
<td>SBIR/STTR</td>
<td>1,248</td>
<td>1,143</td>
<td>1,613</td>
<td>1,613</td>
</tr>
</tbody>
</table>

*Includes Heavy Truck Engine and Health Impacts.

**Formerly Waste Heat Recovery