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

Overview of the Advanced Combustion Engine R&D

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Team Lead

Opportunity for Increased Internal Combustion Engine Efficiency

Increasing the efficiency of internal combustion engines (ICEs) is one of the most promising and cost-effective approaches to improving the fuel economy of the U.S. vehicle fleet.

- "…***The internal combustion engine will be the dominant prime mover for light-duty vehicles for many years, probably decades …"*** NRC Report[1]
- Advanced engines in conventional, hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) will maintain significant market share for several decades
- Medium-duty and heavy-duty commercial vehicles account for a quarter of the fuel used (mostly diesel fuel)
  - **No obvious alternative to ICE for over-the road trucks in the foreseeable future**

[1] *Review of the Research Program of the FreedomCAR and Fuel Partnership: Third Report,* NRC, 2010

Advanced Combustion Engine R&D

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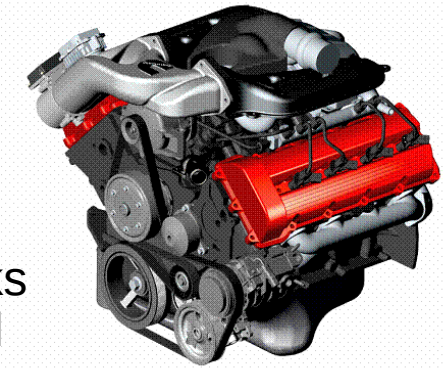
Strategic Goal: Reduce petroleum dependence by removing critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains in passenger and commercial vehicles



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

Performance Targets

	Light-Duty		Heavy-Duty	
	2010	2015	2015	2018
Engine brake thermal efficiency	45%		50%	55%
Powertrain cost	< $30/kW			
NOx & PM emissions	Tier 2, Bin5	Tier 2, Bin2	EPA Standards	EPA Standards
Fuel economy improvement		25 – 40%	20%	30%

Advanced Combustion Engine R&D: FY 2011

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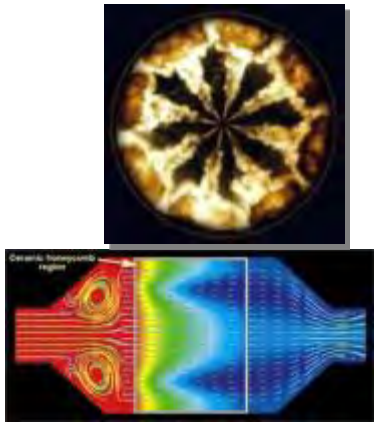
Increasing engine efficiency is one of the most cost-effective approaches to increasing fuel economy

Advanced Combustion Engine R&D
$57,600
(SBIR/STTR - $1,613)

Combustion and Emission Control R&D
$47,239

- TARGETS
- ACTIVITIES
- PROJECTS



Solid State Energy Conversion
$8,748

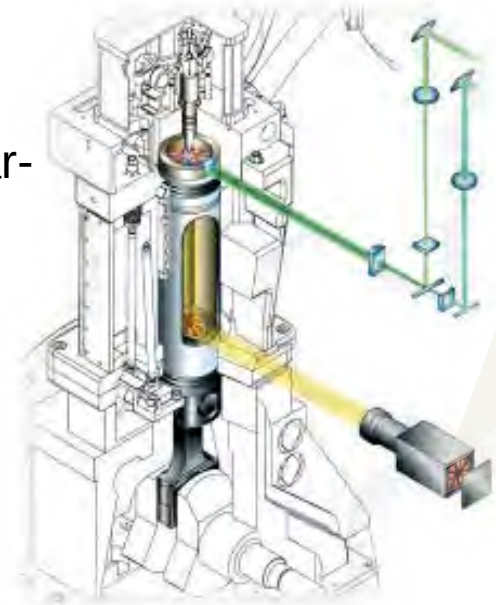
- TARGETS
- ACTIVITIES
- PROJECTS

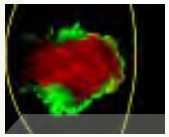
Combustion and Emission Control

Combustion and Emission Control
$47,239

- **Combustion Research ($19,032)**
- Emission Control and Aftertreatment ($8,200)
- High Efficiency Engine Technologies ($18,159)
- Health Impacts Research ($1,848)

- Explore low-temperature combustion strategies to achieve higher engine efficiencies with near-zero emissions of NOx and PM
- Develop greater understanding of engine combustion and in-cylinder emissions formation processes
- Develop science-based, truly predictive simulation tools for engine design





Soot (red) & OH (green)

Engine Simulation

3-Million Cell LES Grid

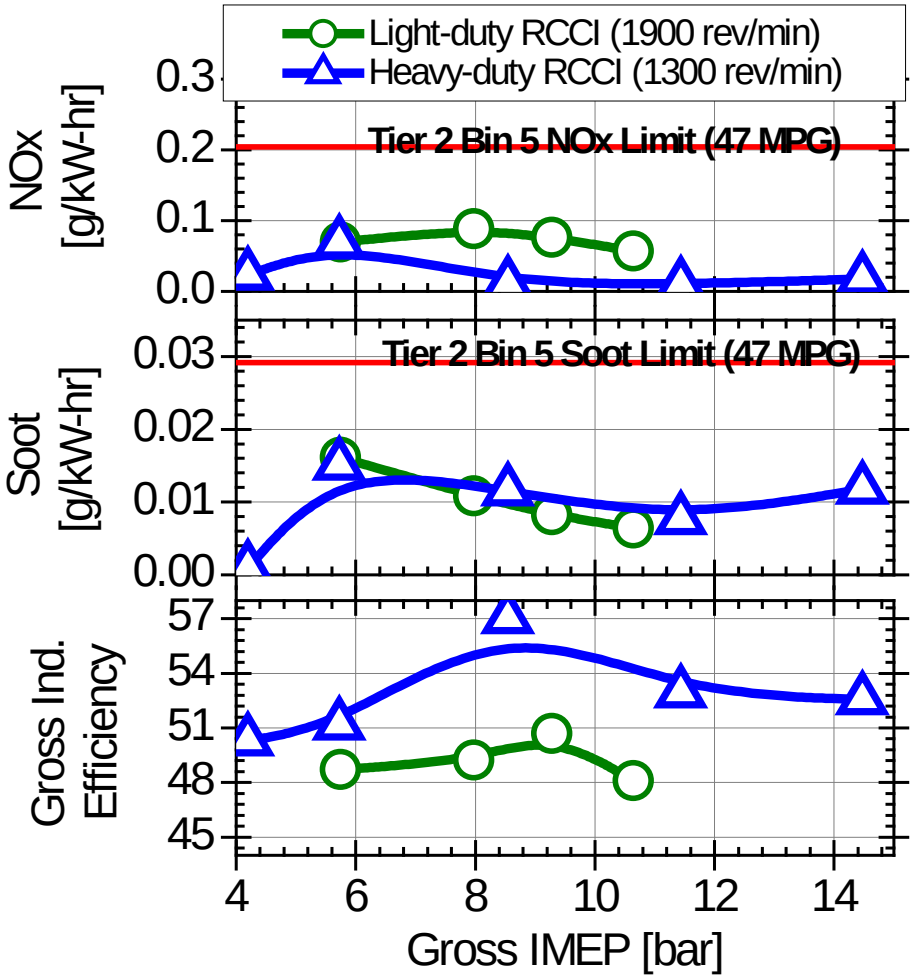
Research Supports DOE/Industry High-efficiency, Clean Engine Goals

- **GOAL**: **Develop knowledge base for low-temperature combustion strategies and carry research results to products**
  - Science-base for advanced combustion strategies
  - Computational tools for combustion system design and optimization
  - Identify potential pathways for efficiency improvement and emission compliance
- Close collaboration with industry through the **Advanced Engine Combustion MOU** led by Sandia National Labs carries research to products

- **Cross cuts light-duty and heavy-duty engine R&D**
- University research integrated with MOU (Wisconsin, Michigan, MIT, UC Berkeley, and Michigan State)

LTC in Heavy- and Light-Duty Engines (UW)

- Engine efficiency improvement could increase LD fuel economy by over 75 percent compared to current gasoline engine.
- Dual fueling (with gasoline and diesel fuel) has shown indicated efficiency between 50% and 59%.



Combustion and Emission Control R&D

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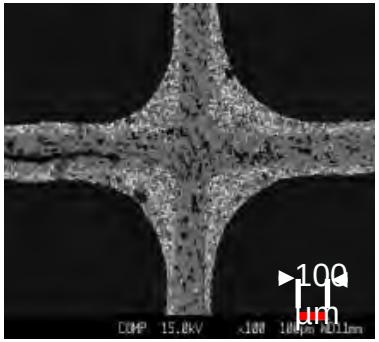
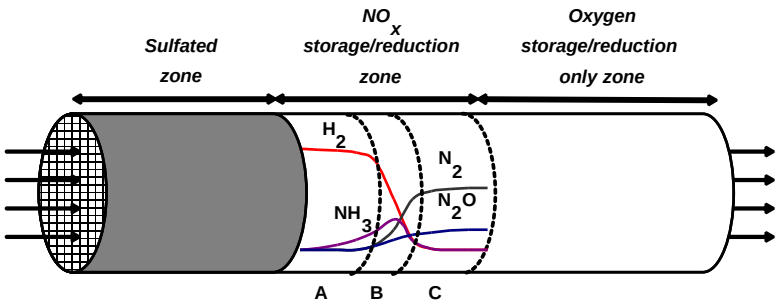
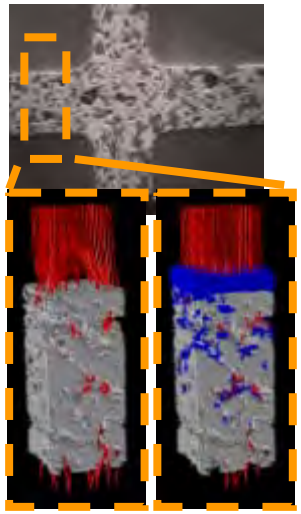
- Develop more efficient approaches for reducing NOx and PM in exhaust.
- Reduce energy penalty and cost of emission control systems





ORNL LNT Model

PNNL DPF Model



Red= streamlines
Blue= soot

Supports DOE Research on Engine Emission Control:

- Promotes development of improved computational tools for simulating realistic full-system performance of lean-burn diesel/gasoline engines and associated emissions control systems
  - Emphasis on engine-aftertreatment system efficiency
  - Integration with advanced combustion processes Identification of new catalyst materials to reduce need for precious metals (i.e., costs)
- Coordinated by subcommittee of industry, government, and academic representatives
  - Workshops and monthly focus groups discussions
  - Industry surveys provide recommendations for R&D directions
  - CLEERS website (www.cleers.org) includes data and forum for model and data exchange

13 Workshops held to date

Function Integration Is Next Major Hurdle for Aftertreatment Technology

Fundamental understanding of SCR & DPF behavior leads to better integration into a single monolithic device, which will help with efficiency, packaging, weight and cost.

On-going PNNL CRADA with PACCAR achieves:

- Better understanding of coupling SCR-DPF and trade-offs
- Determined requirements & limitations for on-board packaging and integration with engine management
- Proper thermal management of the system for regenerating the DPF without negative impacts on the SCR catalyst

PACCAR Inc

Combustion and Emission Control R&D

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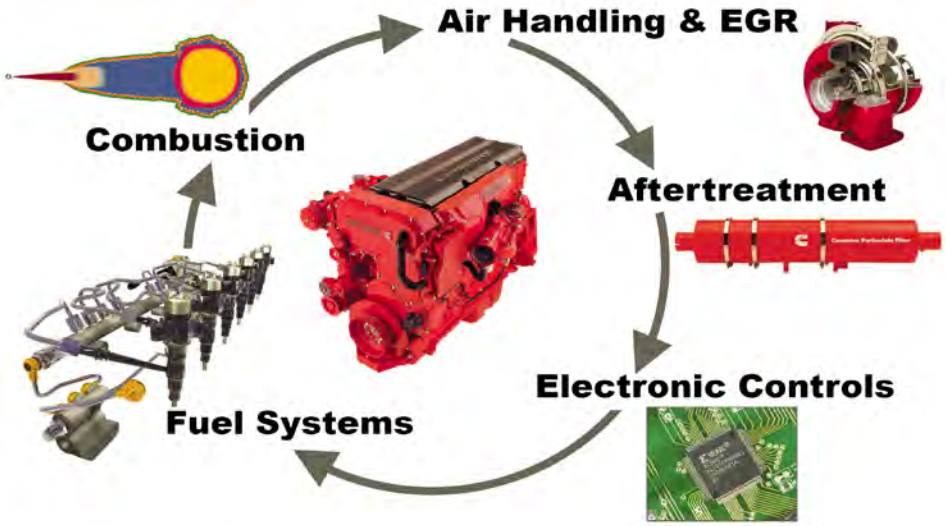
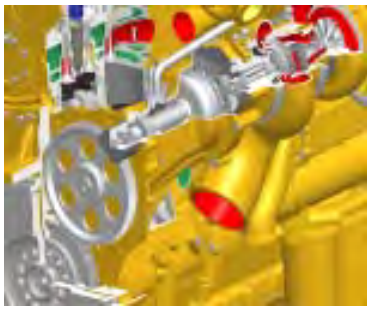
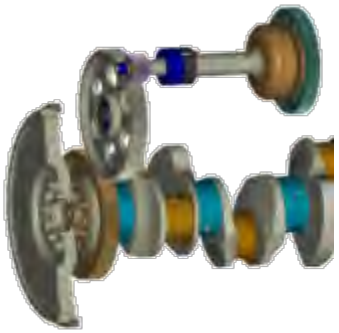


Integration of Component Technologies

Mechanical Turbocompound





SuperTruck and Advanced Technology Powertrain Projects

Develop and demonstrate systems level technologies for efficient Class 8 Trucks (SuperTruck) and Advanced Technology Powertrains for Light-Duty Vehicles

- 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 for gasoline engines over baseline*
  - 40% fuel economy improvement for diesel engines over baseline*

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

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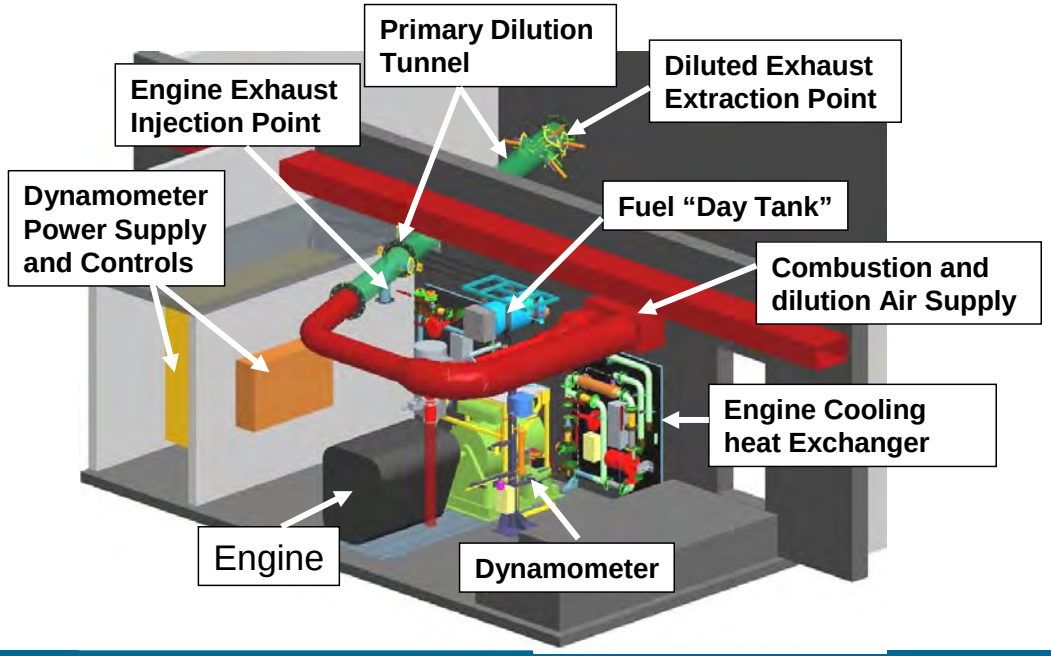

Ensure that technologies developed by VTP will not cause adverse impacts on human health through exposure to toxic particles and gases, emanation of electromagnetic fields, etc.

Solid State Energy Conversion

By 2015, **increase fuel economy** of passenger vehicles by at least 5% with thermoelectric generators that convert waste heat to electricity

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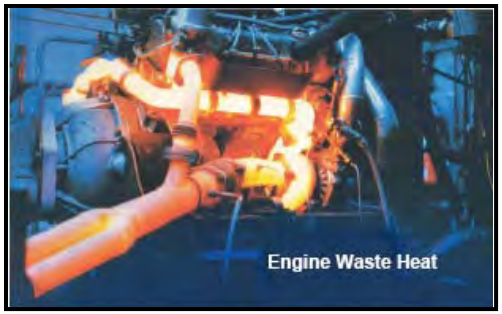

- Develop advanced thermoelectric systems that directly convert waste heat from engine exhaust to electricity for improved vehicle fuel economy.
- Develop advanced thermoelectric systems for energy efficient heating/cooling of vehicle occupants for improved vehicle fuel economy.

Contact Information

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www.vehicles.energy.gov