Energy Efficiency & Renewable Energy

Overview of the Advanced Combustion Engine R&D

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Plenary Session - *2012 Annual Merit Review and Peer Evaluation Meeting*
DOE Vehicle Technologies Program and Hydrogen and Fuel Cells Program
Washington, DC
May 14-18, 2012

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Opportunity for Increased Internal Combustion Engine Efficiency

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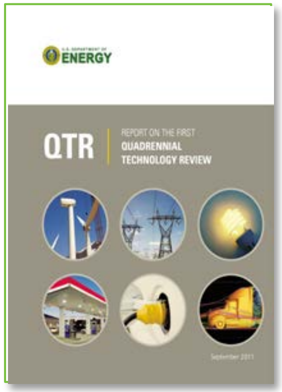
Increasing the efficiency of internal combustion engines (ICEs) is one of the most promising and cost-effective approaches to improving the fuel economy of the U.S. vehicle fleet in the near- to mid-term.

"The performance, low cost, and fuel flexibility of ICEs makes it likely that they will continue to dominate the vehicle fleet for at least the next several decades. ICE improvements can also be applied to both hybrid electric vehicles (HEVs) and vehicles that use alternative hydrocarbon fuels." DOE QTR 2011[1]



DOE 2011

"…The internal combustion engine will be the dominant prime mover for light-duty vehicles for many years, probably decades …" NRC Report 2010[2]

NRC 2010

"The EIA 2011 reference case scenario projects that even by 2035, ***99% of light-duty vehicles sold will have ICEs***; heavy trucks will be predominantly ICE-powered." EIA AEO 2011[3]

[1] Quadrennial Technology Review, DOE 2011
[2] *Review of the Research Program of the FreedomCAR and Fuel Partnership: 3rd Report,* NRC 2010
[3] Energy Information Agency, *Annual Energy Outlook 2011*

Advanced Combustion Engine R&D

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 through advanced combustion strategies
- Develop aftertreatment technologies
- Explore waste energy recovery with mechanical and advanced thermoelectric devices

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 2012

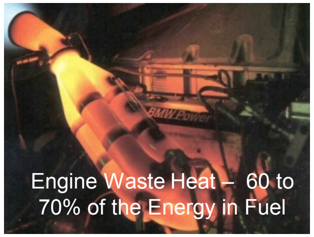
Increasing engine efficiency is one of the most cost-effective approaches to increasing fuel economy

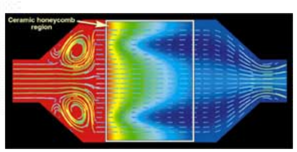
Strategic Goal: Remove critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains in passenger and commercial vehicles

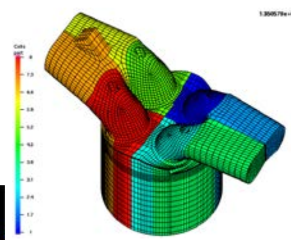
Advanced Combustion Engine R&D
$58,027

Combustion and Emission Control R&D
$49,320

Solid State Energy Conversion
$8,707





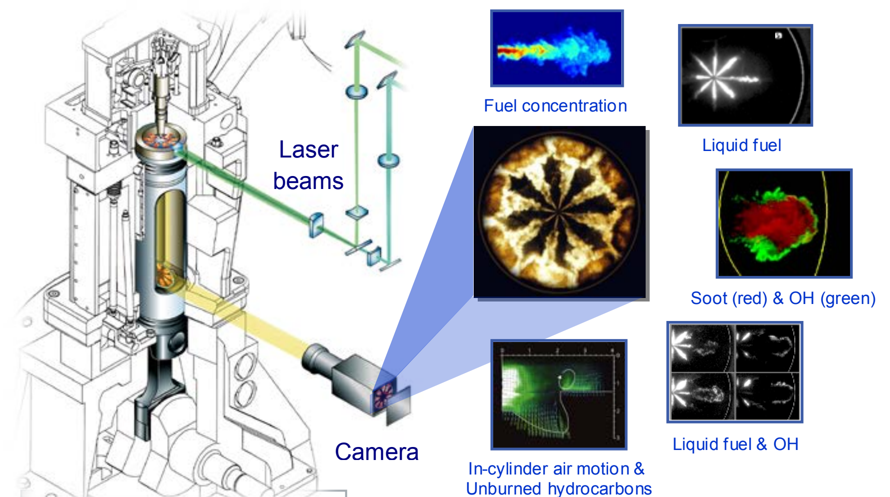


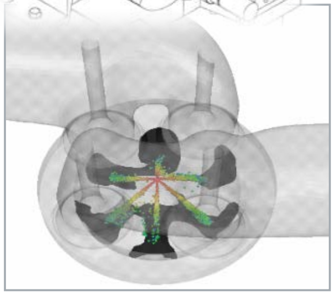
Combustion and Emission Control

- Combustion Research
- Emission Control and Aftertreatment
- High Efficiency Engine Technologies

Combustion Research

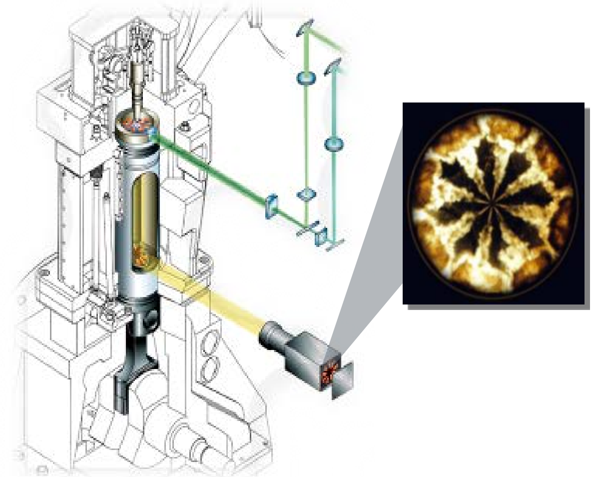
- Explore low-temperature combustion strategies to achieve higher engine efficiencies with near-zero emissions of NOx and PM.
- Develop greater understanding of engine combustion and in-cylinder emissions formation processes.
- Develop science-based, truly predictive simulation tools for engine design




Engine Simulation

Advanced Engine Combustion R&D Collaborations (MOUs and Working Groups)

- Advanced Engine Combustion Memorandum of Understanding (MOU), led by SNL, with 10 auto/engine and 5 energy companies, 6 natl. labs, and 5 universities ***carries fundamental combustion research (light- and heavy-duty engines) to products.***

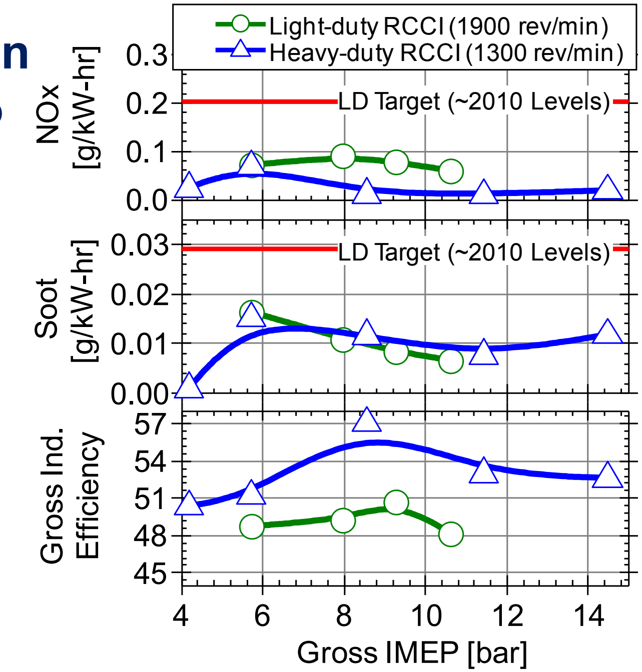


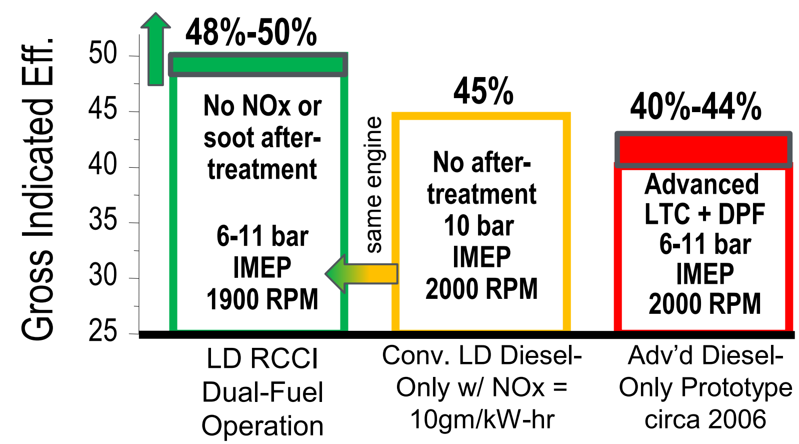
- **SC/BES and EERE/VTP have a long and productive history of collaboration on increasing engine efficiency.**
- Joint workshop on Predictive Simulation of Internal Combustion Engines (PreSICE) for improved fuel spray models and simulation of stochastic processes in engines.
- Co-funding Combustion Research Computational and Visualization facility at Sandia/Livermore

Combustion Research Computational and Visualization facility

Dual-fueling (with gasoline and diesel fuel) in laboratory engines demonstrate potential to increase efficiency with very low emissions

- Heavy-duty RCCI has potential for 20% efficiency improvement with low engine-out NOx and soot compared to conventional diesel with full aftertreatment.
- Light-duty RCCI can improve passenger vehicle fuel economy by 50 to 75 percent
  - indicated efficiencies of 48-50% are possible *over a wide load range*.
  - engine NOx and soot are very low, suggesting no after-treatment is needed. An oxidation catalyst may be required to control CO and HC.
  - peak pressure rise rates (ringing intensity) are easily controlled, even at the highest loads.



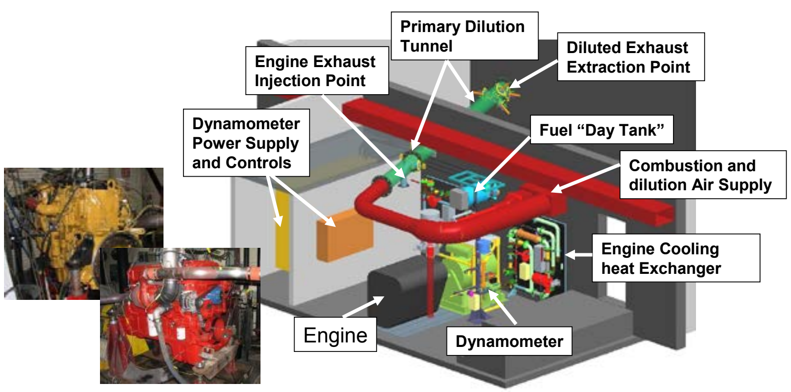


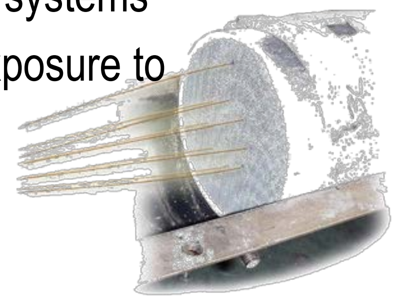
Combustion and Emission Control R&D

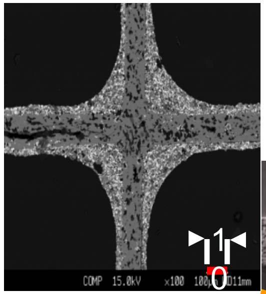
Combustion and Emission Control

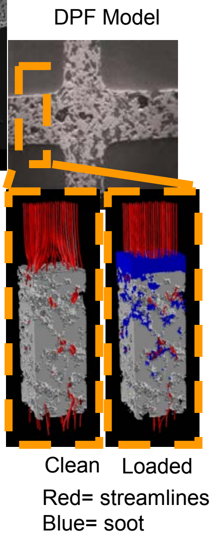
- Combustion Research
- **Emission Control and Aftertreatment**
- High Efficiency Engine Technologies

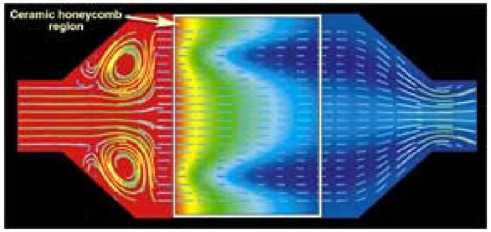
- Develop more efficient approaches for reducing NOx and PM in exhaust.
- Reduce energy penalty and cost of emission control systems
- Ensure no adverse impacts on human health from exposure to emissions from these new technologies







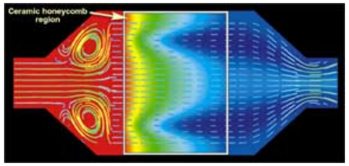




CLEERS* Working Group Supports DOE Advanced Engine Emission Control Research

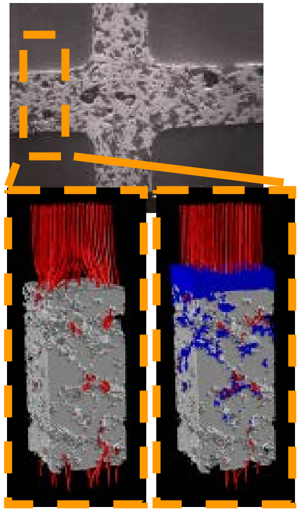
- Promotes development of improved computational tools for simulating realistic full-system performance of advanced engines and associated emissions control systems
  - Emphasis on engine-aftertreatment system efficiency.
  - Integration with advanced combustion processes.
  - **Identification of new catalyst materials to reduce need for precious metals (i.e., costs).**
- Coordinated by subcommittee of industry, government, and academic representatives.
  - Annual workshops and monthly focus group teleconferences.
  - CLEERS website (www.cleers.org) includes data and forum for model and data exchange.

*<u>C</u>rosscut <u>L</u>ean <u>E</u>xhaust <u>E</u>missions <u>R</u>eduction <u>S</u>imulation



Temperature gradient and flow through a catalyst

PNNL DPF Model



Clean Loaded

Red= streamlines
Blue= soot

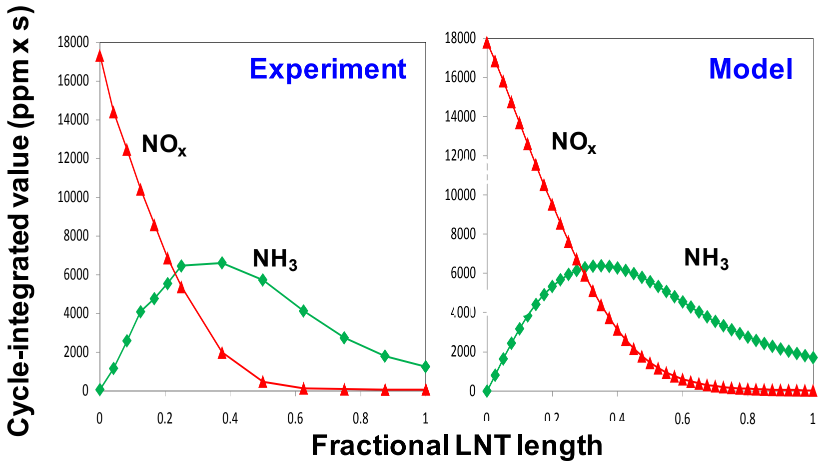
Improved Lean NO_x Trap Models Predict NH_3 Formation and Sulfur Impacts on Performance (SNL,ORNL)

Motivation:

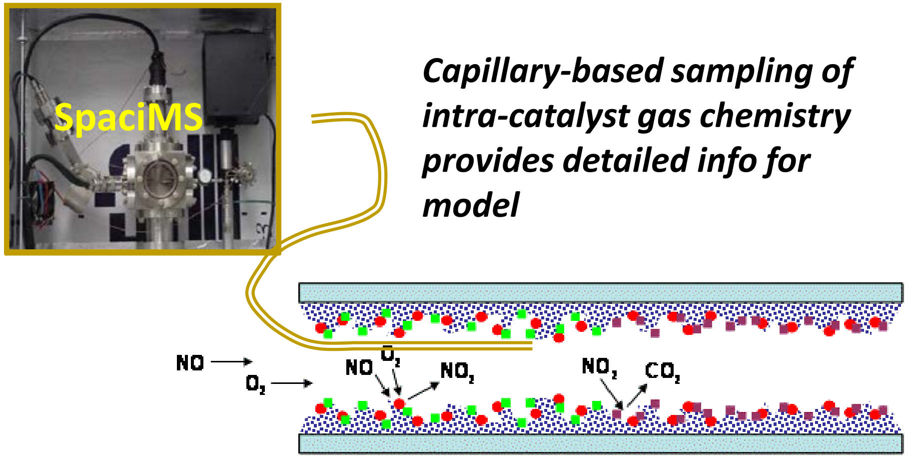
- Understanding lean-NOx Trap (LNT) chemistry at a fundamental level will help in optimizing catalyst formulation and usage, enabling lower cost of fuel-efficient lean-burn engines.

Results:

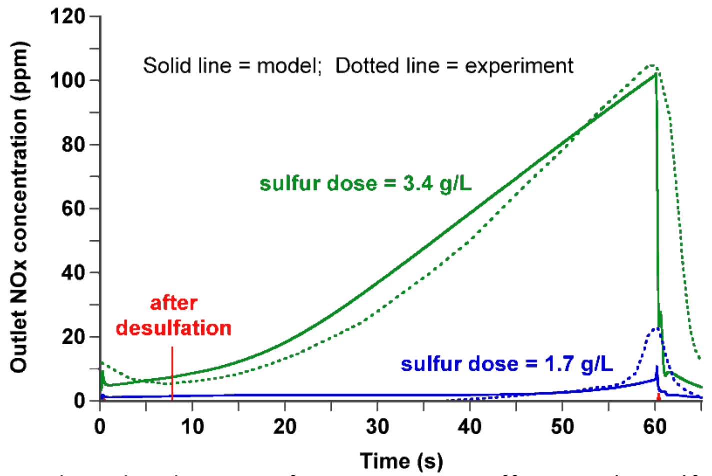
- Catalyst chemistry model improvements:
  - NH_3 formation in LNT (slip reduction, LNT+SCR)
  - Sulfation and deSulfation of LNT



Measured and predicted NH_3 formation inside LNT catalyst during regeneration. Needed for reduced NH_3 slip and NH_3 utilization in LNT+SCR strategy.



Capillary-based sampling of intra-catalyst gas chemistry provides detailed info for model



Predicted reduction of NOx trapping efficiency by sulfur poisoning and its reversal via high-temperature desulfation under rich conditions.

Combustion and Emission Control R&D

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Combustion and Emission Control

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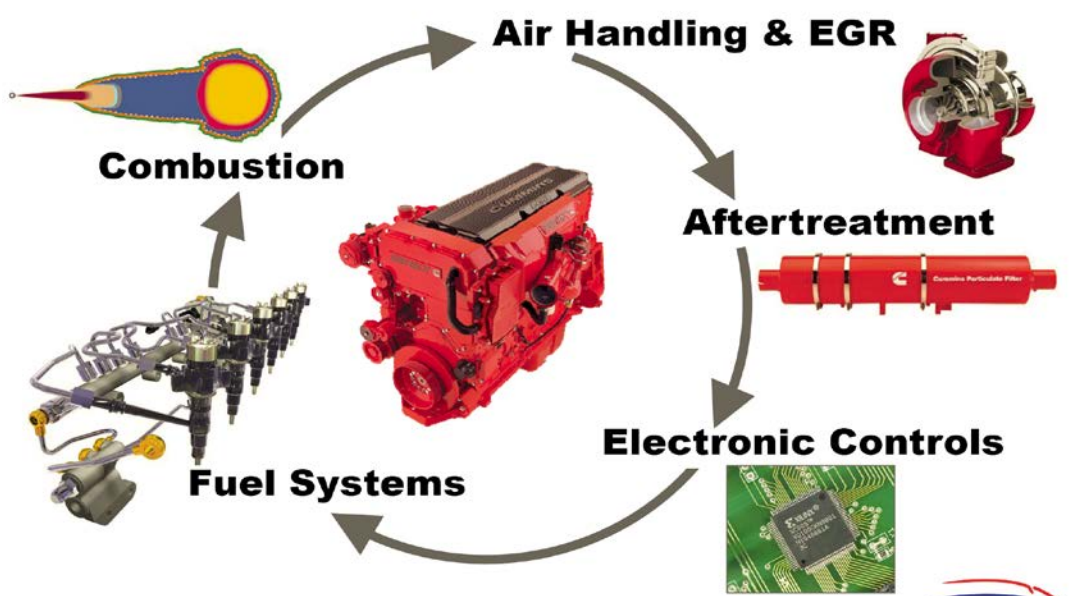
- Emission Control and Aftertreatment
- High Efficiency Engine Technologies



Integration of Component Technologies

Develop and Demonstrate System Level Technologies to Improve Fuel Economy

- **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

Solid State Energy Conversion

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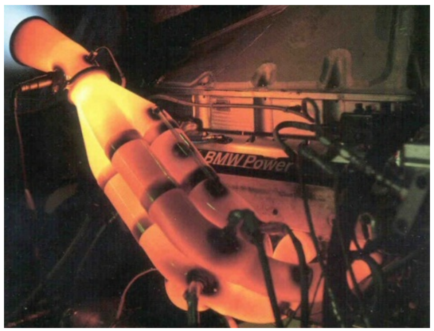
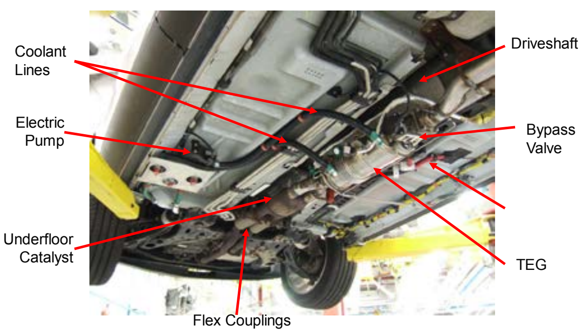
By 2015, **increase fuel economy** of passenger vehicles by at least 5% with thermoelectric generators that convert waste heat to electricity

Solid State Energy Conversion



Engine Waste Heat – 60 to 70% of the Energy in Fuel



TEG integrated into the Lincoln MKT

- Develop advanced thermoelectric systems that convert energy from the engine exhaust waste heat directly to electricity for improved vehicle fuel economy.

Competitively selected cost-shared 2nd Gen TEG projects:

- Amerigon
- General Motors
- GMZ Energy

National Science Foundation
Directorate for Engineering
Division of Chemical, Bioengineering, Environmental and Transport Systems

- NSF and DOE/VTP MOU on cost-competitive automotive thermoelectric materials development at universities (with industry and national lab partners) ($4.5M each for three years)

Contact Information

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