Overview of DOE Emission Control R&D

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Hydrogen and Fuel Cells Program
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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**: To provide the science base for combustion and emission formation needed to develop more efficient, cleaner engines for transportation.
  - Supports U.S.DRIVE mid-term program goal
    - Light-duty
      - improve fuel economy by 25 to 40% by 2015
  - Supports 21st Century Truck Program goal
    - Heavy-duty
      - engine efficiency of 50%, emission compliant, by 2015
      - engine efficiency of 55%, emission compliant, by 2018

- Key customers: the U.S. vehicle and engine industry.

- Strong interactions and collaborations between industry, suppliers, universities, and national labs.

Advanced Combustion Engine R&D

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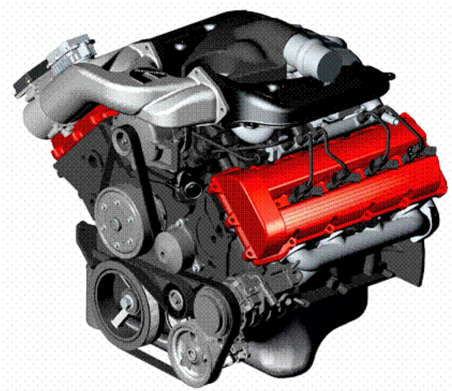
Strategic Goal: Reduce petroleum dependence by removing critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains in passenger and commercial vehicles



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%

ACEC Emissions Baseline and Goal

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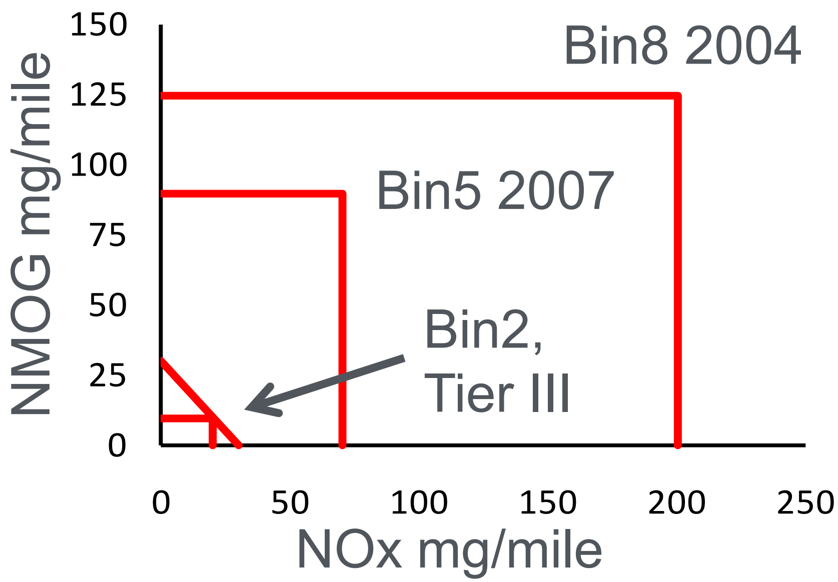
Baseline Emissions Today

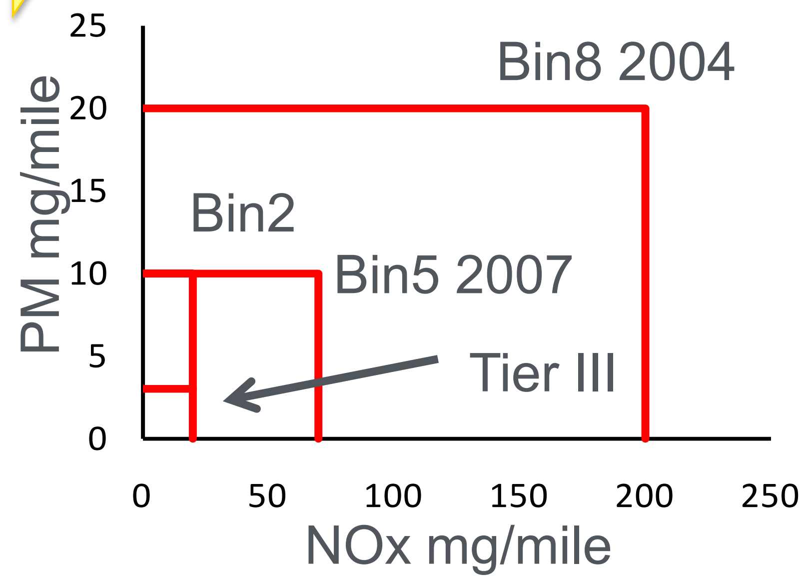
Emissions Goal Tomorrow Tier III

US EPA Tier II Bin 5

Reduction of 81% (NMOG + NOx) and 70% PM

SULEV30 **+** **Particulate Mass Regs**

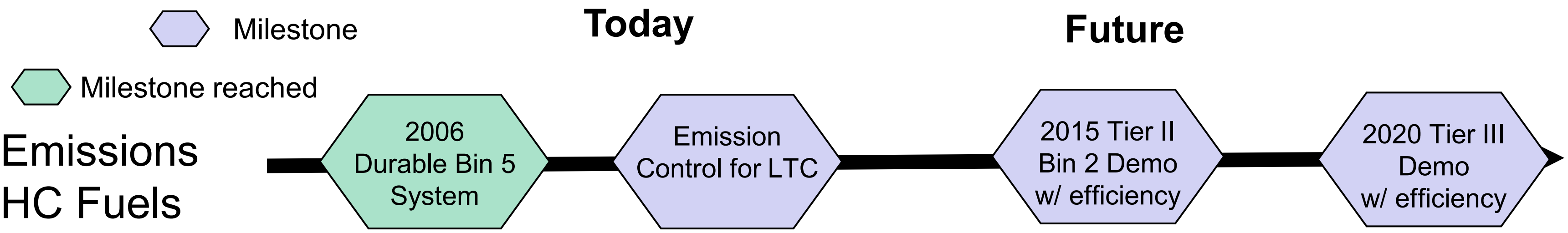




All light-duty US production gasoline and diesel vehicles meet Bin5 or lower emissions
Some light-duty US production gasoline vehicles meet Bin 2 emissions
No light-duty US production diesel vehicles meet Bin 2 emissions

Tier II Bin 5	= 90mg/mi NMOG, 70mg/mi NOx, 10mg/mi PM
Expected Tier III	= SULEV30 (30mg/mi NMOG + NOx, similar to Tier II Bin 2) and 3mg/mi PM
NMOG	= Non Methane Organic Gases
SULEV	= Super Ultra Low Emission Vehicle

Emission Control R&D



- Focus on improving understanding of aftertreatment systems for LTC and lean-burn gasoline.
  - Mechanisms of catalyst deactivation at high temperature and by sulfur
  - Computer models to predict aftertreatment performance
  - Control strategies to optimize efficiency
  - Discovery of new, lower cost catalyst materials
- Technology areas:
  - NOx adsorbers
  - Urea and HC SCR
  - Particulate filters

Emission Control Research Approach

Advanced Combustion Engine R&D → Industry

Fundamental Research → Applied Research → Technology Maturation & Deployment

Fundamental R&D

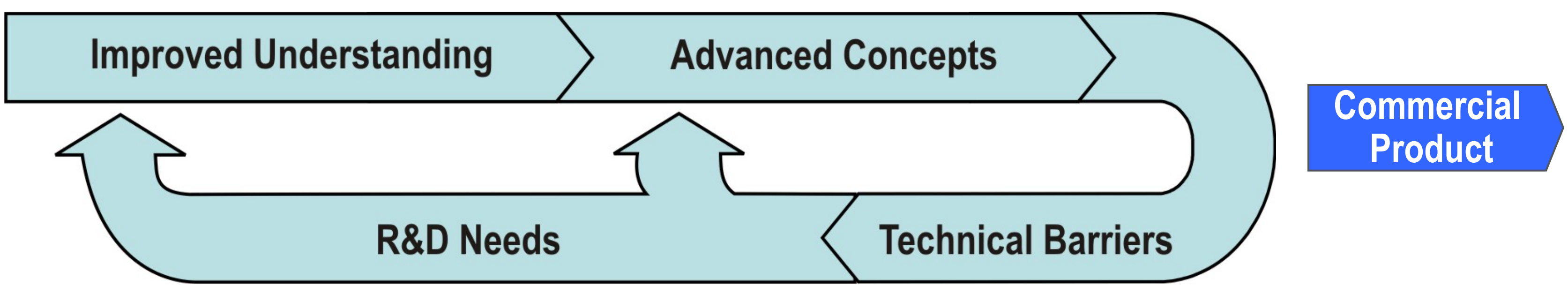
- SNL – Advanced Combustion Engine-Out Emissions
- PNNL – Catalyst and DPF Fundamentals
- ANL – Heavy Duty DPF CRADA
- LLNL – Chemical kinetics models (LTC and emissions)
- Universities – Houston, Connecticut, Michigan Tech

Fundamental to Applied Bridging R&D

- ORNL – Experiments and simulation of emission control systems (bench-scale to fully integrated systems)

Competitively Awarded Cost-shared Industry R&D

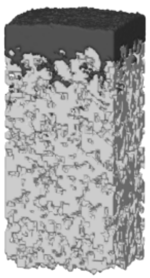
- Vehicle and engine companies – engine/emission control systems
- Suppliers – enabling technologies (Catalysts, Substrates, NOx/PM control devices, sensors)



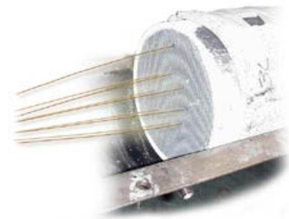
CLEERS* Working Group Supports DOE Advanced Engine Emission Control Research

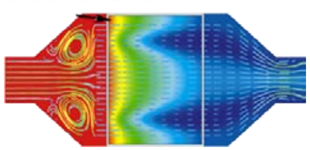
- Promotes development of improved computational tools for simulating realistic full-system performance of advanced engines and associated emissions control systems.
  - Emphasis on engine-aftertreatment system efficiency.
  - Integration with advanced combustion processes.
  - Identification of new 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.

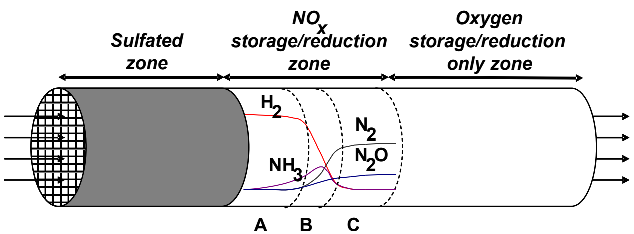
*<u>C</u>rosscut <u>L</u>ean <u>E</u>xhaust <u>E</u>missions <u>R</u>eduction <u>S</u>imulation



PNNL DPF Model







ORNL LNT Model

Emission Control Technical Barriers

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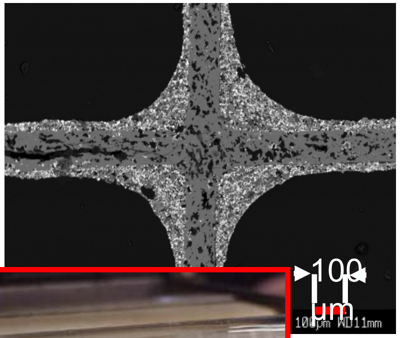
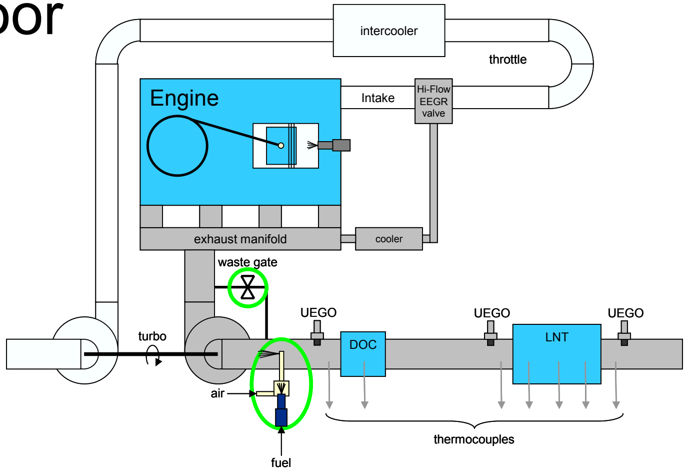
- ❑ Deficiencies in fundamental understanding and modeling capabilities
- ❑ Degradation from sulfur in fuels (even at 15 ppm) and lubricants and thermal processes
- ❑ High platinum group metal content, high cost
- ❑ Need high effectiveness over broader temperature range
- ❑ Inefficient engine management for regeneration and desulfation (LNT) and poor reductant utilization (LNC)
- ❑ Inadequate sensors for process control or diagnostics;
- ❑ Inadequate methods for rapid-aging
- ❑ Cost/Packaging constraints on the vehicle





Emission Control System Challenges

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- Achieving an efficient, durable, low-cost emission control system complementing new combustion strategies
  - Low NOx conversion at low temperatures (200-250C)
  - NOx adsorbers: fuel penalty, conversion efficiency versus temperature, platinum group metal content, sulfur poisoning
  - Urea Selective Catalytic Reduction (SCR): catalyst deactivation, incomplete reaction products
  - Hydrocarbon SCR: conversion efficiency temperature window, early development stage
  - PM: regeneration strategy, DI gasoline, future regulation of particle number and size distribution
  - Oxidation catalysts: high temperature durability, HC, CO, and NO oxidation efficiency
- Focus on lower emissions (SULEV30 and Tier III)
  - Study systems with 90% conversion of all emissions below 200C
  - Study PM from lean DI gasoline due to new regulations, different size and morphology vs diesel

Advanced Combustion Engine R&D Budget by Activities

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Major Activities	FY 2010	FY 2011	FY 2012	FY 2013 Request
Advanced Combustion Engine R&D	**$57,600K**	**$57,600K**	**$58,027K**	**$55,261K**
Combustion and Emission Control	47,239	47,239	49,320	47,505
Solid State Energy Conversion	8,748	8,748	8,707	7,756
SBIR/STTR	1,613	1,613	--	--

NRC Question: What technologies are in production?

Knowledge from DOE-Funded Work Used in Vehicle Aftertreatment Systems

- 2007 Dodge Ram 2500 and 3500 vehicles with Cummins 6.7L turbo diesel:
  - DOE funding improved understanding of lean NOx trap aftertreatment in the areas of chemical reaction mechanisms for NOx uptake and release, mechanisms for catalyst deactivation by temperature and sulfur to improve failure analysis, and measurements of spatially resolved gas composition inside the catalyst.

- 2010 Ford Super Duty with 6.7L turbo diesel:
  - DOE funding improved understanding of diesel aftertreatment system integration in the areas of diesel oxidation catalyst, urea-based selective catalytic reduction technology for NOx aftertreatment, and diesel particulate filter. Benefits from the DOE program are catalyst type, urea injection concept, and filter regeneration strategies. The DOE program provided data that showed this system to be durable for extended test periods.

Thank You!

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Web site:
http://www.eere.energy.gov/vehiclesandfuels