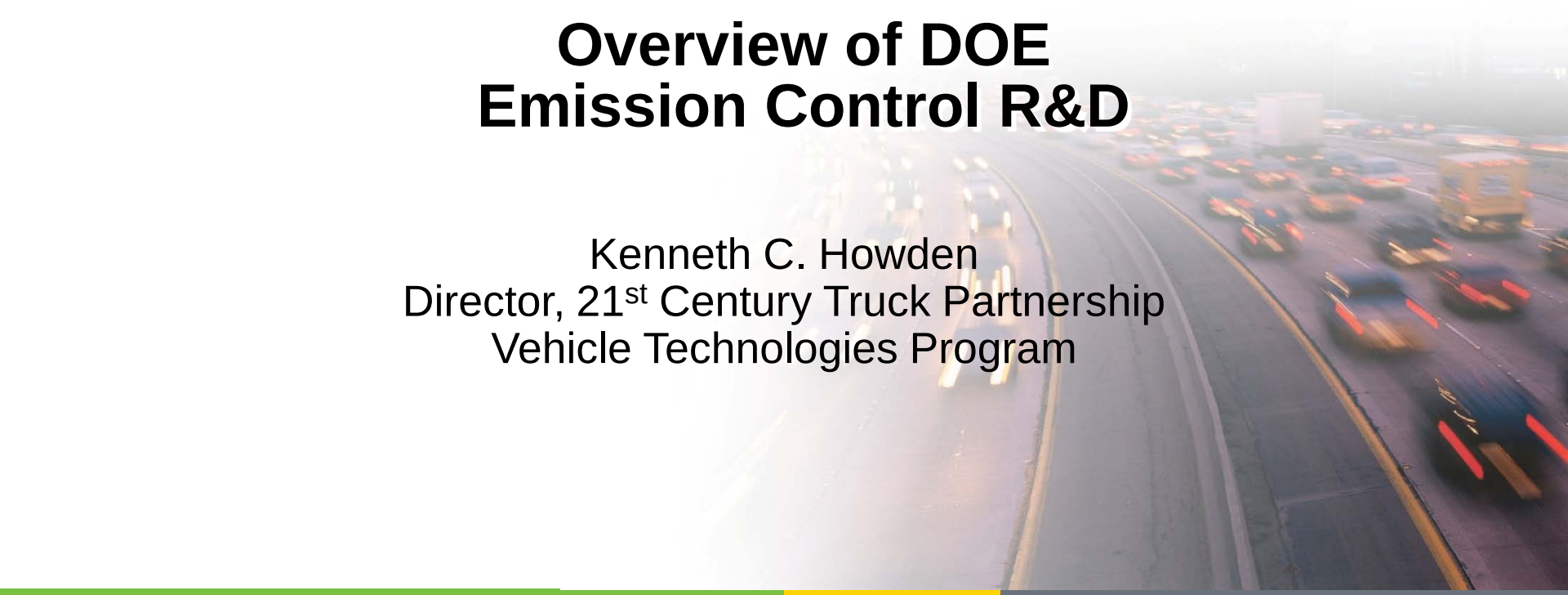
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of DOE Emission Control R&D



Kenneth C. Howden
Director, 21st Century Truck Partnership
Vehicle Technologies Program

Presented at the
2011 DOE Annual Merit Review
Hydrogen and Fuel Cells Program
and Vehicle Technologies Program
Washington, DC
May 9-13, 2010

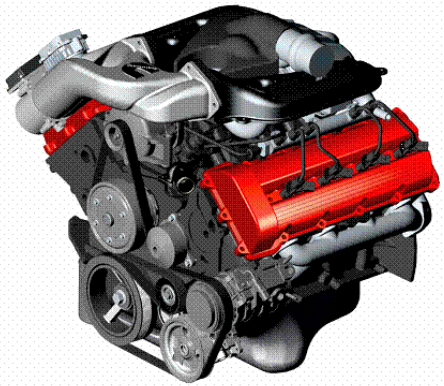
Vehicle Technologies Program Mission
To develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum.

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

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



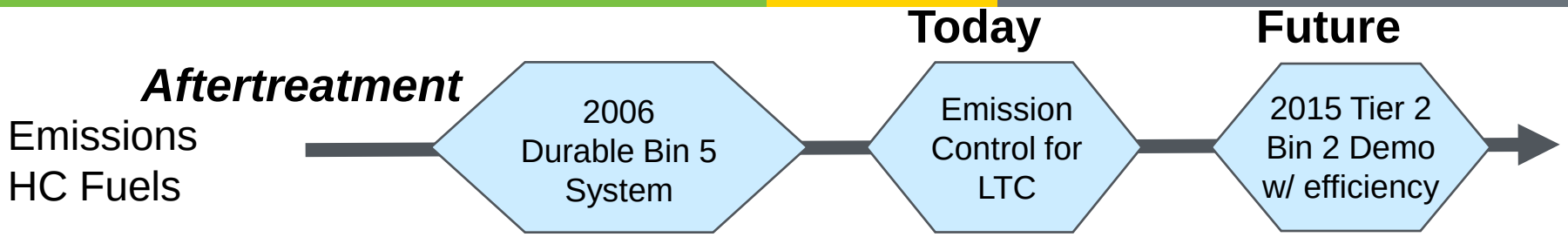
Primary Directions

- Improve ICE efficiency 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%

Emission Control R&D

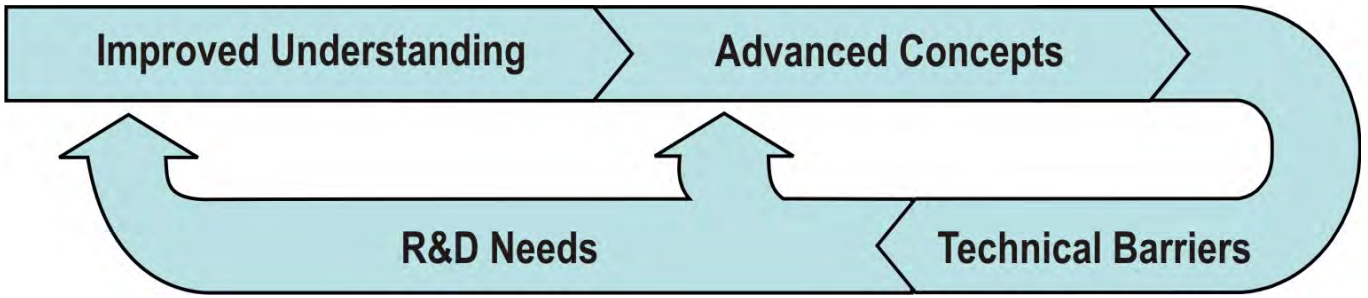


- Focus on improving understanding of aftertreatment systems for LTC and lean-burn gasoline.
  - Computer models to predict aftertreatment performance
  - Mechanisms of catalyst deactivation at high temperature and by sulfur
  - Increase efficiency of NOx, PM, and HC emission control systems
  - Develop low-cost base metal catalysts to replace expensive platinum group metals
  - Develop lighter and more compact mutifunctional components and new control strategies
- Technology areas:
  - NOx adsorbers
  - Urea and HC SCR
  - Particulate filters
  - Oxidation catalysts

Emission Control Research Approach

Advanced Combustion Engine R&D → **Industry**

Fundamental Research	Applied Research	Technology Maturation & Deployment
Fundamental R&D	Fundamental to Applied Bridging R&D	Competitively Awarded Cost-shared Industry 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	▪ ORNL – Experiments and simulation of emission control systems (bench-scale to fully integrated systems)	▪ Vehicle and engine companies – engine/emission control systems ▪ Suppliers – enabling technologies (Catalysts, Substrates, NOx/PM control devices, sensors)



Commercial Product

CLEERS* Working Group Supports DOE Advanced Engine Emission Control Research

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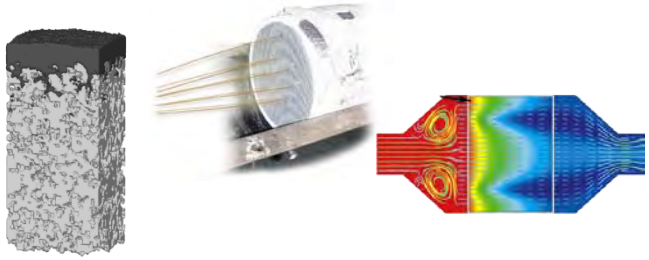
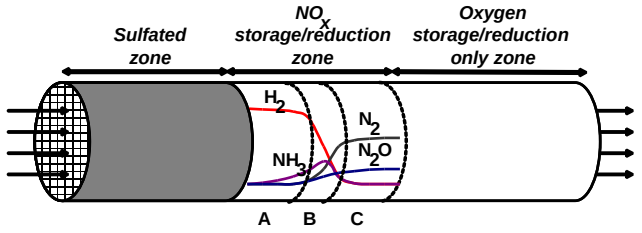
- Promotes development of improved computational tools for simulating realistic full-system performance of lean-burn diesel/gasoline engines and associated emissions control systems.
  - Emphasis on engine-aftertreatment system efficiency.
  - Integration with advanced combustion processes.
  - Identification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

Annual CLEERS Workshop



PNNL DPF Model

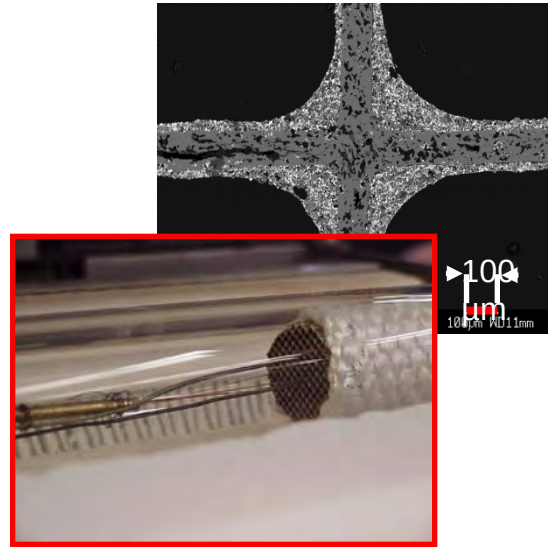


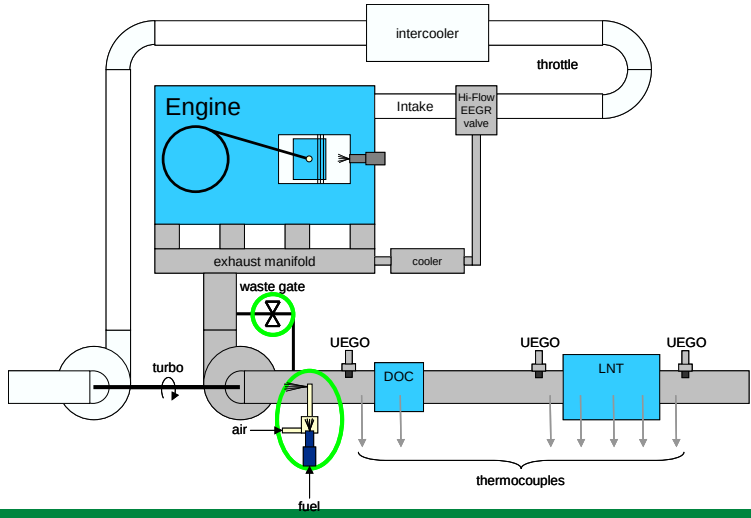
ORNL LNT Model

*Crosscut Lean Exhaust Emissions Reduction Simulation

Emission Control Technical Barriers

- 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 Challenges

- 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

Advanced Combustion Engine R&D Budget by Activities

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Major Activities	FY 2009 Appropriation	FY 2010 Appropriation	FY 2011 Request	FY 2012 Request
Advanced Combustion Engine R&D	**$40,800K**	**$57,600K**	**$57,600K**	**49,000K**
Combustion and Emission Control *	35,089	47,239	47,239	40,824
Solid State Energy Conversion**	4,568	8,748	8,748	6,804
SBIR/STTR	1,143	1,613	1,613	1,372

**Includes Heavy Truck Engine and Health Impacts.*
***Formerly Waste Heat Recovery*