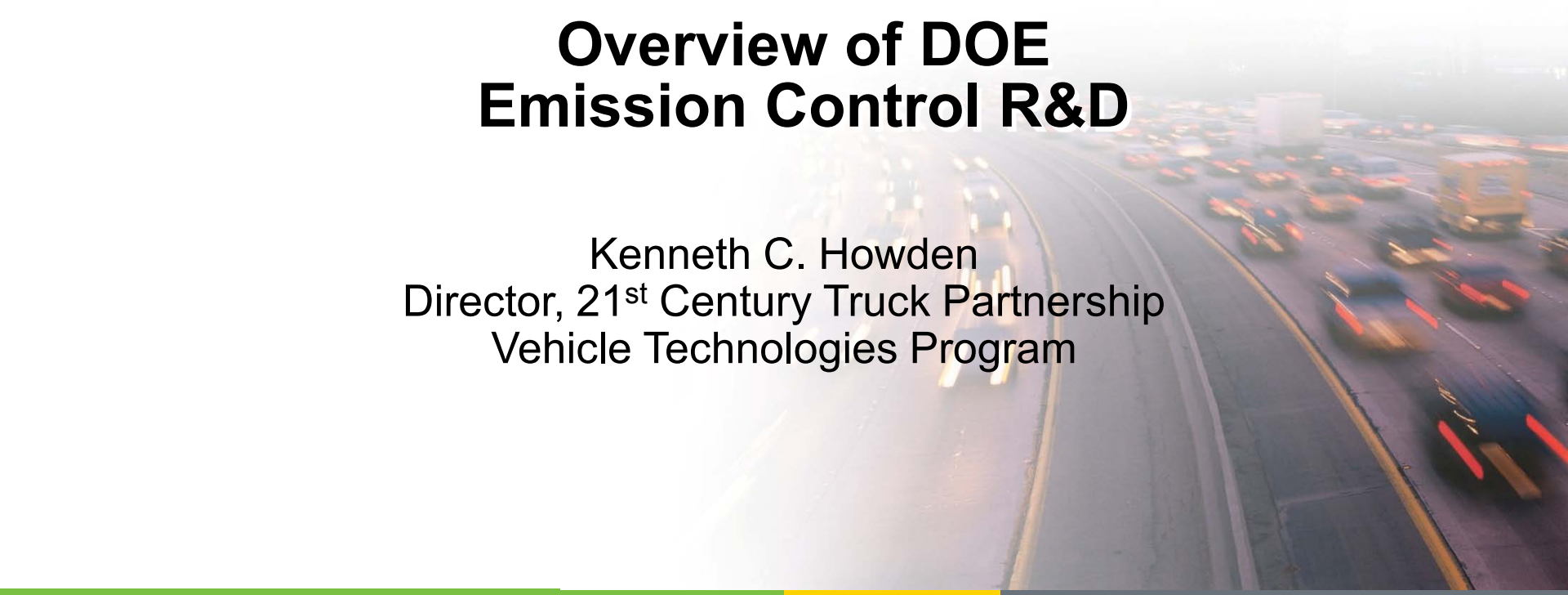
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of DOE Emission Control R&D



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

Presented at the
2010 DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review
Washington, DC
June 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

- Undertake High-Risk Mid- to Long-Term Research
- Utilize Unique National Lab Expertise and Facilities
- Help Create a National Consensus
- Work Cooperatively with Industry

DOE Advanced Combustion and Emission Control 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

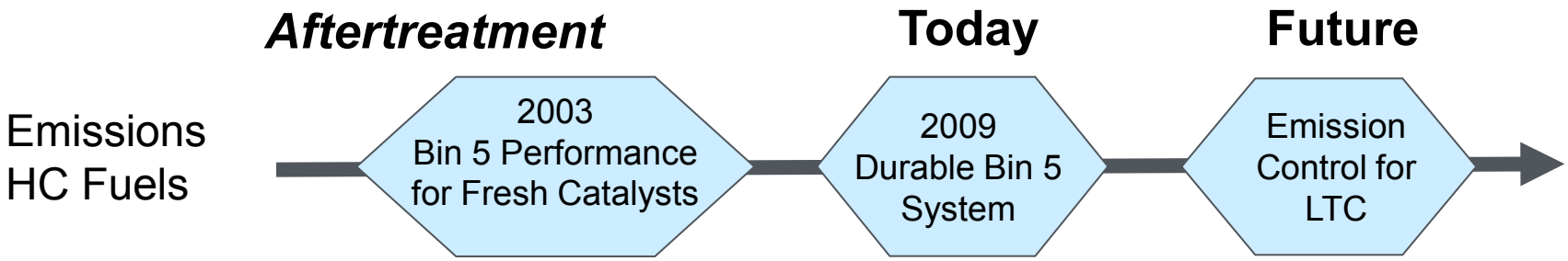
Primary Directions

- 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.
  - 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
  - Oxidation Catalysts
  - Particulate filters

Emission Control Research Approach

Advanced Combustion Engine R&D → Industry

Fundamental Research → Applied Research → Technology Maturation & Deployment

Fundamental R&D

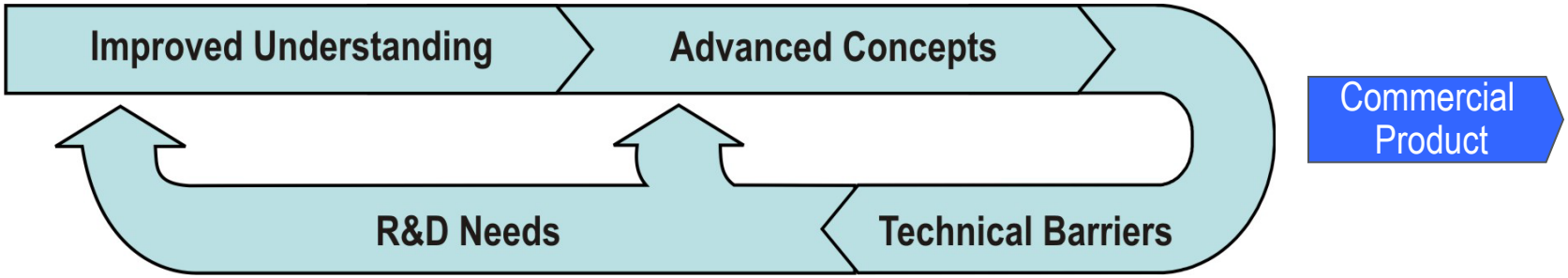
- SNL – Advanced Combustion Engine-Out Emissions
- PNNL – Catalyst and DPF Fundamentals
- ANL – Heavy Duty DPF CRADA
- LLNL – Chemical kinetics models (LTC and emissions)
- Universities – Connecticut, Houston, Michigan Tech

Fundamental to Applied Bridging R&D

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

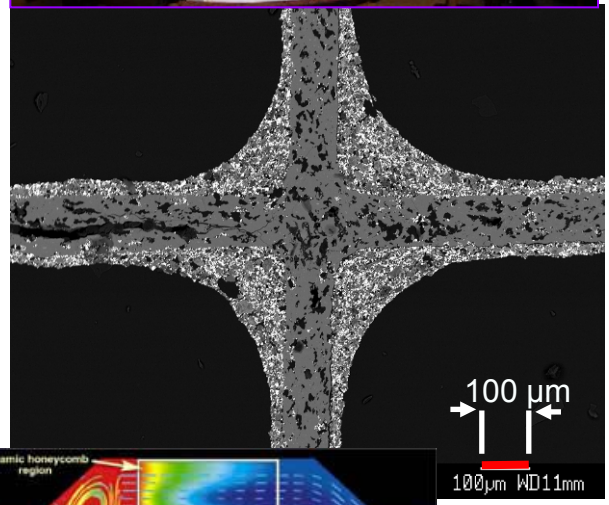
Competitively Awarded Cost-shared Industry R&D

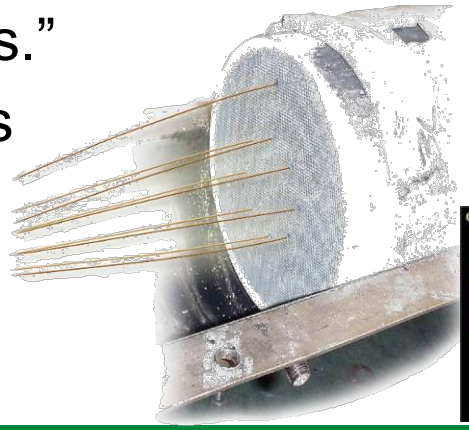
- Vehicle and engine companies – engine/emission control systems
- Suppliers – enabling technologies (Catalysts, Substrates, NOx/PM control devices, sensors)

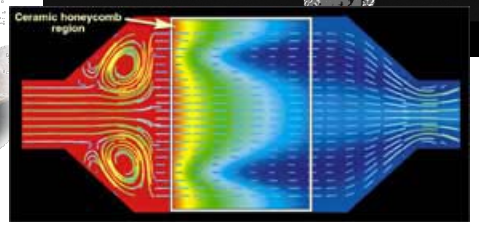


Emission Control R&D

- CLEERS* started in 2001, encompasses DPF, LNT, SCR (Urea and HC)
  - Govt/Industry/University research coordination www.cleers.org
- Thousands of NOx catalyst formulations studied
- Emphasis on minimizing “fuel penalty” while achieving emissions levels
- Integration of advanced combustion regimes with aftertreatment
- Creation of “kinetics maps.”
- Reduce need for precious metals



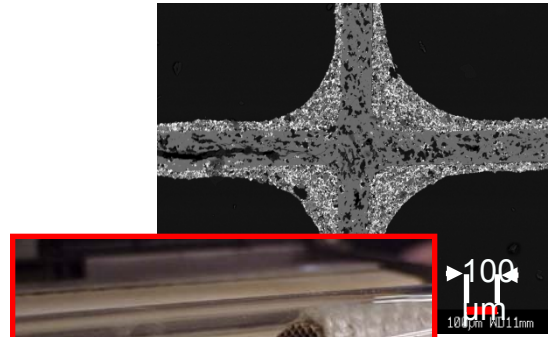


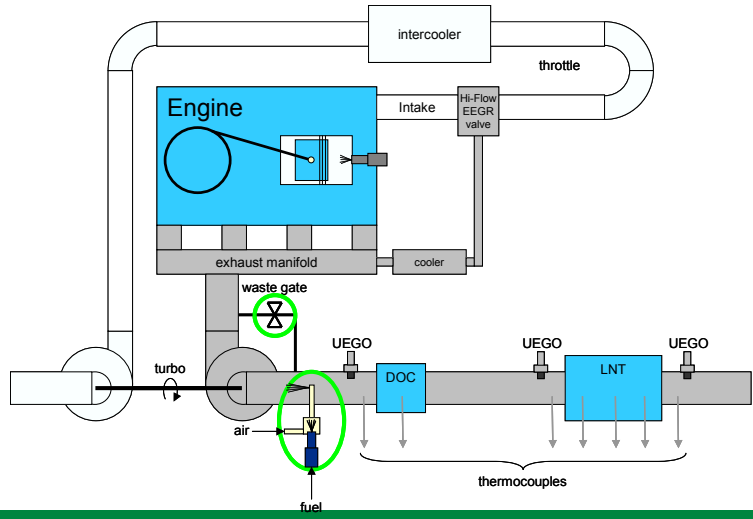


*Crosscut Lean Exhaust Emissions Reduction Simulation

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
  - Oxidation catalysts and NOx adsorbers: fuel penalty, 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

Advanced Combustion Engine R&D Budget by Activities

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

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

Future Awards

Funding Opportunity Announcement (FOA) - 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

Advanced Combustion Engine R&D

- **Strategic Goal**: To provide the science base for combustion and emission formation needed to develop more efficient, cleaner engines for transportation.
  - Supports FreedomCAR mid-term program goals
    - Light-duty
      - peak efficiency of 45%, emissions compliant, by 2010
      - 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.