The Advanced Collaborative Emissions Study

Moving Forward with Assessing the Emissions and Health Effects of New Diesel Technology

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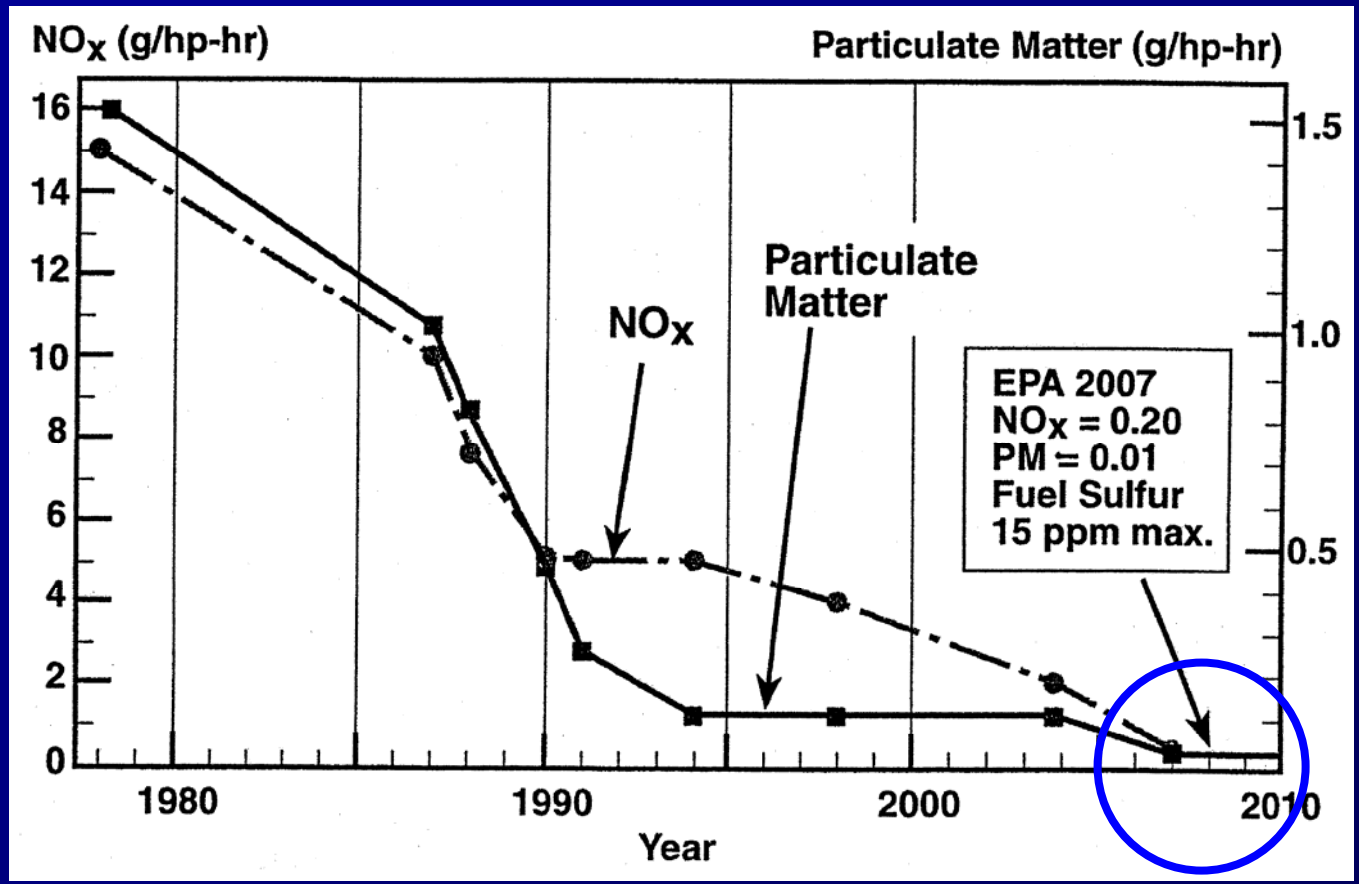
ACES

Overview

- Emerging cleaner diesel technology
  - Opportunities and challenges
- The Advanced Collaborative Emissions Study (ACES)
  - Emissions Characterization
  - Health Effects Studies
  - Next Steps to Implement ACES

Improvements in PM and NOx Diesel Emission Standards



Source: G Andrews, U Leeds

What Technologies Will Be Used in 2007 and 2010 Heavy-Duty Diesel Engines?

2007

- 15 ppm sulfur diesel fuel
- PM control (catalyst, trap)
- Some NOx control (primarily exhaust gas recirculation)

2010

- 15 ppm sulfur diesel fuel
- PM control (catalyst, trap)
- NOx control (possible options NOx adsorbers or selective catalytic reduction)

Diesel Health Issues

Historically

- Lung cancer –primary driver of diesel debate
- Contribution to PM exposures, effects
- Asthma and allergies –emerging issues

New (2007-2010) Diesel

- Most diesel health assessments based on 1980s, earlier technology.
  - "**As cleaner engines replace older engines.. general conclusions will need to be reevaluated" (EPA 2002)**
- Most pollutants will decrease substantially, but *new species may be formed*.
  - **Effects expected to be reduced, but new technologies should be evaluated before widespread introduction**

Advanced Collaborative Emission Study

- A partnership of HEI and CRC
  - supported by a wide range of key government, industry and environmental groups
- Designed to:
  - Produce health-relevant characterization of emissions from 2007- and 2010- compliant heavy-duty diesel engines/control systems (CRC)
  - Assess possible health effects in animals exposed to whole exhaust from one of these systems (HEI)
  - Provide a report of the results and a commentary (HEI)

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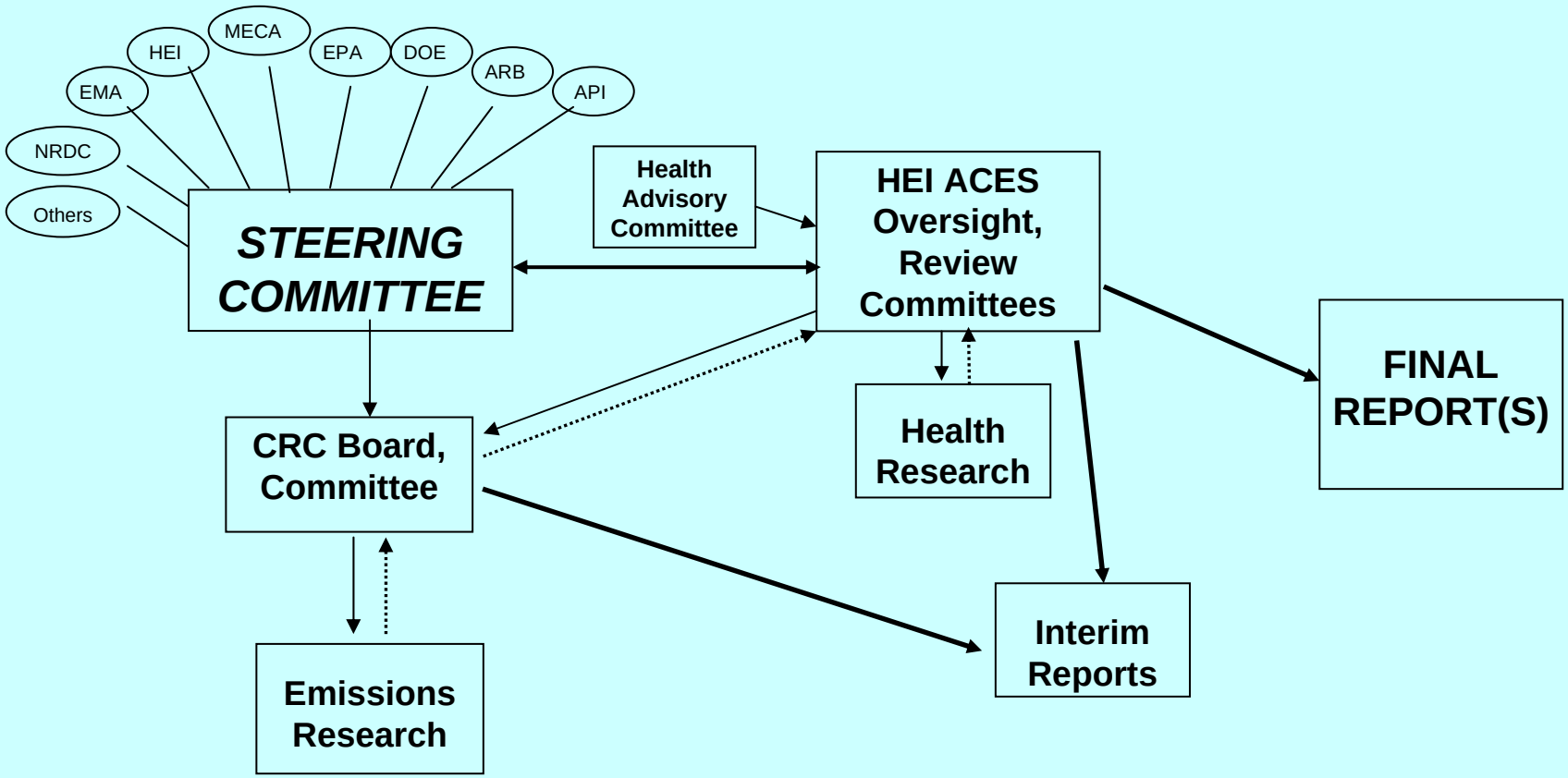
Main Hypotheses

Emissions from combined new heavy-duty diesel engines, aftertreatment, lubrication, and fuel technologies designed to meet the 2010 NOx and PM emission standards will have very low pollutant levels.

They will not cause an increase in tumor formation or substantial toxicity to any organ or other serious health effects in rats and mice at the dilution ratios used compared to animals exposed to filtered air, although some biologic effects may occur.

ACES Organization



ACES Leadership

- *Steering Committee* **-** Provides guidance and overall direction during the planning stages and all phases of the project
  - *Members*: DOE, EPA, CARB, NRDC, EMA, API, Control manufacturers, HEI, CRC,
- *HEI ACES Oversight Committee* – Oversees all aspects of ACES health testing
  - Chaired by Dr. Mark Utell, University of Rochester
- *CRC ACES Committee* – Oversees all aspects of ACES Emissions Characterization

Overview of ACES

- Detailed characterization of exhaust from 2007- and 2010-compliant heavy-duty diesel engines
  - Possible biological screening
- Health effects testing of 2010-compliant engine
  - Chronic bioassay in rats and mice measuring cancer and non-cancer endpoints
  - Studies of short-term effects
    - Unassigned animals in the chronic bioassay
    - Selected animal models exposed after end of bioassay

ACES KEY COMPONENTS

Phase	New 2007 engines	New 2010 engines
1	Emission characterization (at dynamometer facility); possible biological screening	
2		Emission characterization (at dynamometer facility); possible biological screening
3A		Emission characterization (at health testing facility)
3B		Chronic bioassay and associated studies - in vivo genotoxicity - respiratory function - inflammation, immune changes - resistance to infections
3C		Short-term non-cancer studies using selected animal models - allergic response - resistance to infections - cardiovascular changes?

ACES Emissions Characterization

Phase 1. 2007 Heavy-Duty Diesel Engines

- Catalyzed particulate trap
- 4 prototypes to be tested
- EMA now working with companies
  - To identify which companies and engine/control systems will be used
  - To plan of early 2006 delivery to an emissions testing facility

Phase 2. 2010 Heavy-Duty Diesel Engines

- Again, 4 engines with particulate traps
- Manufacturers have not selected final NOx control system for production
  - NOx adsorber
  - Selective catalytic reduction (SCR) – urea
  - Engine modifications
- Different manufacturers may use different approaches

Phase 2. Selection of 2010 Heavy-Duty Diesel Engines for Health Testing

- Single engine of four to be selected for detailed health testing
  - Rigorous selection criteria to be developed
  - Potential role of biological screening being considered
    - To augment emissions data
  - May be hard to select single engine if different NOx control approaches used or if each engine has different emissions

Phase 3A. 2010 Heavy-Duty Diesel Engines

- Emissions characterization and validation study to be done at health lab
  - To ensure sampling is properly done
- During health testing
  - Routine emissions monitored continuously
  - Detailed emissions characterization in middle and at end

Emissions to be Characterized

- Regulated emissions
  - HC, CO, NOx, PM
  - Size distribution of PM
- Unregulated emissions
  - List of 800 compounds
  - 3 categories by importance
    - Must be measured – about 190 compounds
    - Should be measured if reasonable to do so
    - Measured if it done concurrently with higher priority compounds or at little additional cost

Unregulated Emissions – Categories of Compounds

- Metals/elements
- Inorganics
- Gas/particle hydrocarbons
- Branched alkanes
- Cycloalkanes/cycloalkenes
- Alkenes/alkynes
- Aromatics
- Halogenated compounds
- PAH compounds
- Nitro-PAH/oxygenated PAH
- Aldehydes/ketones
- Urea and other nitrogen compounds

Possible Biological Screening

- Possible short term *in vitro* bioassays being considered
  - to supplement emissions characterization
  - mutagenicity, oxidative damage, inflammation
- Issues
  - Would results be useful in engine selection for health testing? How would they be used?
  - Can results be used to select or tailor long term health tests?
  - Are results affected by artifacts?
- Detailed review of options underway
  - Any screening would require field testing in Phase 1 before application in Phase 2

Measurement Issues

- Artifact loss/formation for PM collection may be a serious problem in characterizing emissions from 2007 and later diesel engines
- Nitro-PAH compounds being formed?
- CRC E-66 project examining improved methods of PM collection
- National Renewable Energy Laboratory funding work to investigate nitro-PAH artifact formation during sampling of 2007-like diesel emissions

ACES Health Effects Studies

ACES Health Effects Studies

- Phase 3B: Chronic Bioassay in Mice and Rats
  - Cancer and noncancer effect measurements
    - Both long and short term
  - Core health effects study

- Phase 3C: Additional studies of noncancer effects in animal models that cannot be accommodated within the chronic bioassay

ACES Project Plan
Chronic Bioassay in Rats and Mice (Phase 3B)

- Similar to National Toxicology Program (NTP) bioassay
- Duration: likely 24 months
- Species: one species each of rats and mice (to be selected)
- 288 rats, 360 mice for each exposure (half male, half female)
  - 180 rats, 180 mice used for full duration
  - 108 rats, 180 mice for intermediate timepoints and additional effect measurements
- 4 exposure levels
  - 10:1, 30:1, 100:1 dilution of whole diesel exhaust (tentative)
  - Clean air exposure
  - Highest dilution may be similar to clean air exposure

Endpoints in Chronic Bioassay (Phase 3B)

- Standard NTP effect measurements at full duration:
  - Histopathology, tumor incidence, weight for major organs
- Standard NTP endpoints at intermediate timepoints
  - Hematology and clinical chemistry, histopathology in key organs
- Additional endpoints in animals allocated to intermediate timepoints and unassigned animals
  - Pulmonary function and histology (airway remodeling)
  - Inflammation; blood coagulation factors
  - Genotoxicity
  - Immunotoxicity
  - Resistance to respiratory infection

Additional Health Effects Testing (Phase 3C)

Short-Term Studies Using Special Animal Models and Experimental Procedures

Examples

- Resistance to respiratory infection (with different infectious agents)
- Effects on allergic response in sensitized animals
- Cardiovascular effects
  - if there are adequate markers of animal changes in ECG, coagulation factors, other effects
- Others to be determined

ACES Time Line

Timing	Emissions Characterization	Health
2005-2007	- Finalization of plans and funding - Solicitation of facilities and investigators: **Phase 1 RFP Fall 2005** **Phase 3 RFP Spring 2006**	
	- 2007 emission characterization and potential bio-screening field test **(1)** *- Interim reports*	- Final plan of health effects measures
2007-2009	- 2010 emission characterization and potential bio-screening (**2**) - Construction and evaluation of exposure set up at health facility - 2010 engine selection **(3A)** *Interim reports*	- Solicitation and selection of additional investigators to implement health measures. - Health protocols finalized
2009-2012		- 24-month bioassay **(3B)** - Short-term health effects studies**(3C)** *- Final Reports*

Costs and Funding

- ACES is a major undertaking
  - Approximately $20 million over 7 years
- Funding Commitments are in place or underway from:
  - US DOE
  - US EPA
  - CARB
  - Engine Manufacturers Association
  - Petroleum Industry
  - Emission Control Manufacturers

Progress and Remaining Decisions

- Steering Committee has agreed on major elements
- Some Technical Decisions still to be made in course of project:
  - Whether to add biological screening to phases 1 and 2
    - In latter stages of considering options
  - How to proceed with health testing if substantially different emissions are found from different 2010 technologies
  - What will the PM levels be in the animal chambers after exhaust dilution to reduce temperature and CO levels
- **Initial RFP issuance expected Fall 2005**

Summary

- ACES offers an unprecedented opportunity to obtain timely data on new diesel technologies
  - Detailed and health relevant emission characterization
  - Data on effects of chronic and short term exposures
    - cancer and non-cancer
- Progress has been made on
  - project funding
  - a joint project plan (CRC and HEI)
- Although there are still important technical questions to address in the coming years
  - *ACES is about to take off!*

Thank You!

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HEI ACES Oversight Committee

- **Mark Utell, Chair**, Professor of Medicine and Environmental Medicine, University of Rochester;
- **Richard Albertini**; Professor, Department of Medicine, University of Vermont School of Medicine;
- **Melvyn Branch**, Joseph Negler Professor of Engineering, University of Colorado;
- **Paul Catalano**, Lecturer on Biostatistics, Department of Biostatistics, Harvard School of Public Health;
- **Kenneth Demerjian**, Professor and Director, Atmospheric Sciences Research Center, SUNY, Albany;
- **Helmut Greim**, Professor of Toxicology and Environmental Hygiene, Technical University of Munich;
- **Thomas Kensler**, Professor, Division of Toxicological Sciences, Johns Hopkins University;
- **David Kittelson**, Professor, Department of Mechanical Engineering, University of Minnesota;
- **Eugene McConnell**, former Director of Toxicological Research and Testing, National Toxicology Program
- **Günter Oberdörster**, Professor, Department of Environmental Medicine, University of Rochester;
- **Charles Plopper**, Professor and Chair, Department of Anatomy, Physiology, and Cell Biology, UC - Davis;
- **Howard Rockette**, Professor and Chair, Department of Biostatistics, University of Pittsburgh;

Additional Detailed Information on Emissions Characterization

Emission Test Cycles

- EPA heavy-duty driving cycle
- Engine (not vehicle) testing
- Possibly some CARB driving cycles
  - Developed as part of CRC E-55/E-59 program
  - 4 modes
  - Idle
  - Creep (very low speed, lots of idle time)
  - Transient (typical urban)
  - Cruise (on-highway with some acceleration/deceleration from idle)

Fuel Specifications

- Low sulfur diesel fuel
- Typical of fuel to be in-use in 2007-2010 time frame
- Specifications for
  - Cetane 40-45
  - Aromatics 35-45%
  - Polycyclic aromatic hydrocarbons 8-10%
  - Distillation range (initial, 10%, 50%, 90%, end points)
  - Sulfur 12-15- ppm
- Use single batch of fuel for all testing if possible

Oil Specifications

- Oil typical of those to be used in 2007-2010 engines
- Specifications
  - Sulfated ash 0.8-1.0%
  - Phosphorus 0.08-0.1%
  - Sulfur 0.25-0.50%

Emissions Characterization

- Emissions to be characterized during normal operation (engine properly tuned etc.)
- Engine to be operated as in-use and meeting manufacturers' specifications
- Malfunction conditions not included
- Emission testing to be done at standard temperatures
- Low and high temperature conditions not included

Sources of Compounds to be considered for Emissions Characterization

- CARB diesel air toxics list
- EPA mobile source air toxics list
- EPA list of 16 key POM compounds
- Compounds listed in EPA Diesel Health Assessment Document
- South Coast Air Quality Management District list of toxics
- National Renewable Energy Laboratory Gasoline/Diesel PM Split Study
- Various nitrogenous species

CRC ACES Committee

- Alberto Ayala, California Air Resources Board
- James Ball, Ford Motor Company
- Nick Barsic, John Deere & Company
- Mike Bogdanoff, South Coast Air Quality Management District
- Steven Cadle, General Motors Company
- Jeanette Clute, Ford Motor Company
- Wayne Daughtrey, Exxon Mobil
- James Eberhardt, U.S. Dept. of Energy
- King Eng, Shell Oil Company
- Timothy French, Engine Manufacturers Association
- Thomas Hesterberg, NAV International
- Albert Hochhauser, ExxonMobil Research and Engineering Company
- Paul Hodgins, Caterpillar, Inc.
- Bruce Jarnot, American Petroleum Institute
- Douglas Lawson, NREL
- David Lax, American Petroleum Institute
- Hector Maldonado, California Air Resources Board
- Mani Natarajan, Marathon-Ashland Petroleum
- Kathy Nauss, Consultant
- Richard Phillips, ExxonMobil
- Michael Reale, Daimler Chrysler
- Helen Shapiro, Alliance of Automobile Manufacturers
- Shirish Shimpi, Cummins Engine Company
- Joseph Somers, U.S. Environmental Protection Agency
- Neville Thompson, CONCAWE
- Matthew Thornton, NREL
- Steve Welstand, Chevron
- Shawn Whitacre, NREL
- Ben Wright, ConocoPhillips