

**Advanced Collaborative Emission Study (ACES) -
Characterization of new-technology diesel engine
emissions and their effects
in a lifetime rat inhalation study**

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**Northeast Diesel Collaborative 2015 Partners Meeting
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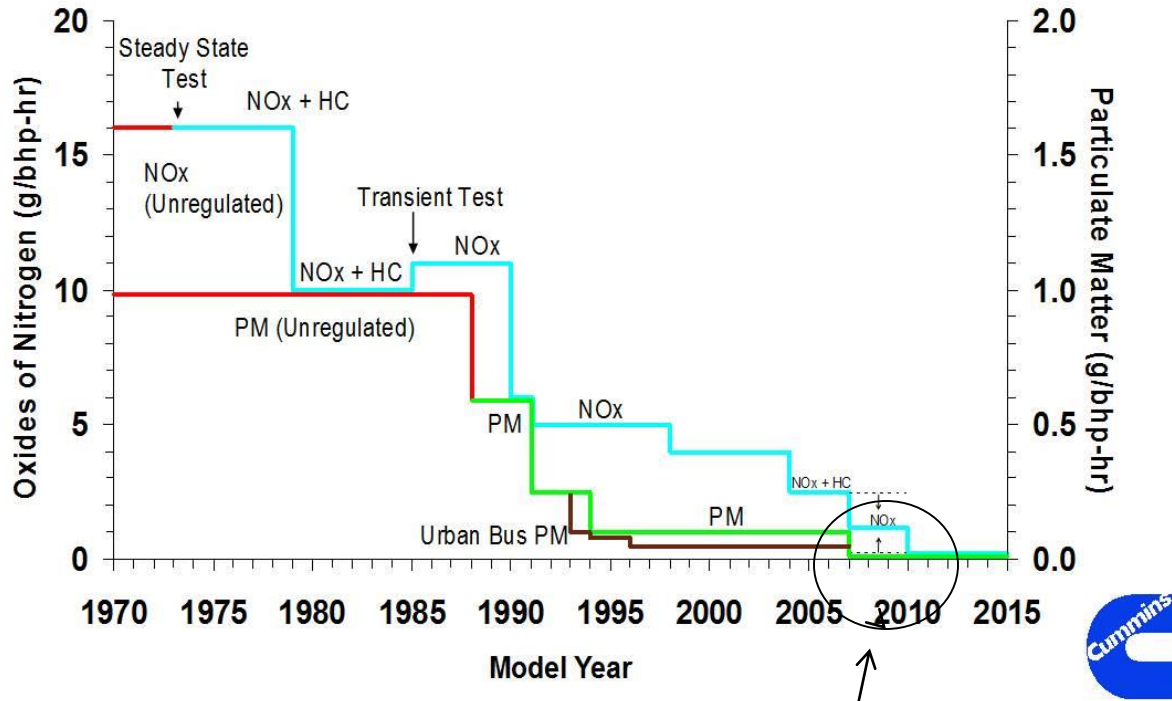
The Health Effects Institute (HEI)

- **Original Idea** - 1977 Clean Air Act §202(a)(4): Car manufacturers required to test health effects of emissions.
- Health Effects Institute - created by EPA + Industry (1980): credible science for decision making
- **HEI KEY FEATURES**
 - **Balanced core government and industry funding (EPA, motor vehicle industry, and other government and private groups).**
 - **Independent Board of Directors and separate expert Science Committees to select and review funded studies**
 - **Fund research worldwide on health effects of mobile-source air pollution**
 - **Issue reports and reviews of funded studies (2015 – ACES)**
 - **Issue reviews of major topics**
(2015, in press – Evaluation of recent diesel epidemiology studies).



Regulation of Diesel Emissions

EPA Heavy-Duty Engine Emission Standards

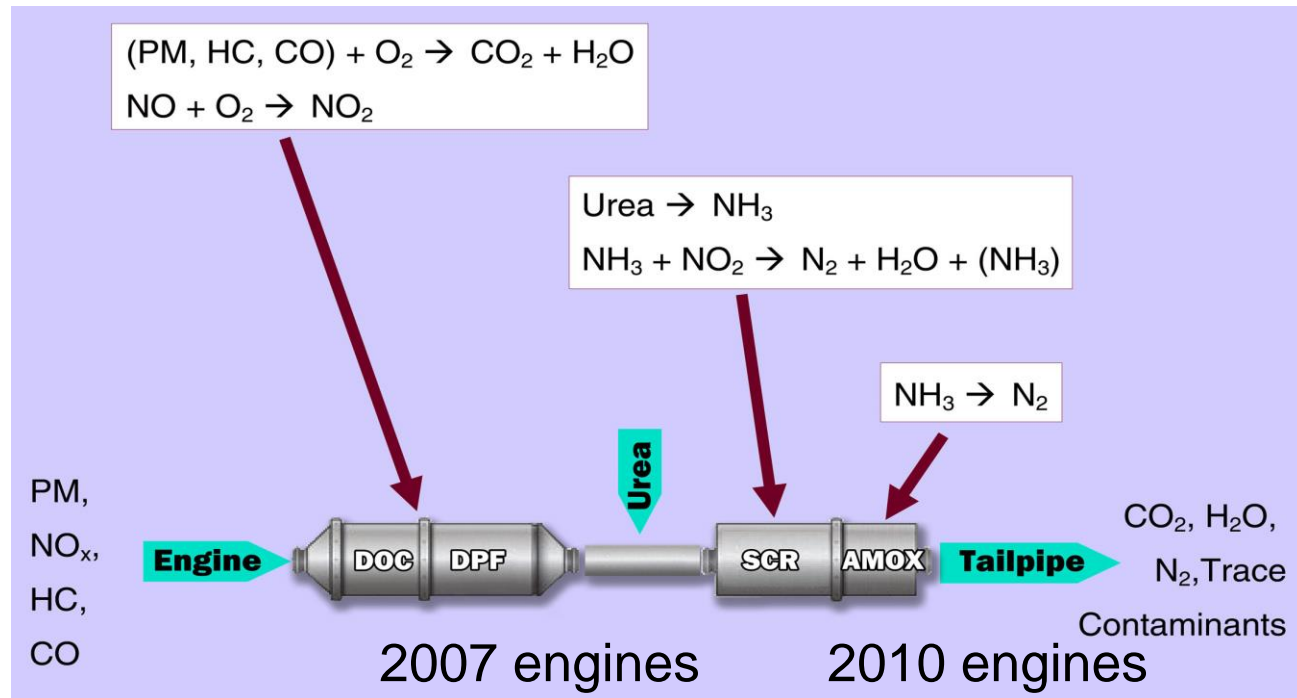


Similar patterns
in Europe

ACES engines



Advances in technologies in 2007 and 2010 diesel engines



Rationale for ACES:

Evaluate the 2007 and 2010 technologies to assess any changes in the emissions and possible reductions in health effects



ACES – Emissions characterization

- **Phase 1: Test 4 new HHDE built to meet 2007 PM standards**
- **Phase 2: Test 3 new HHDE built to meet 2010 NOx standards**
- Measured > 700 species pollutants, both regulated and unregulated
- Engines tested over different cycles (FTP and a 16-hour cycle)

Overseen by the Coordinated Research Council (CRC) and conducted by Imad Khalek (Southwest Research Institute, San Antonio, TX)



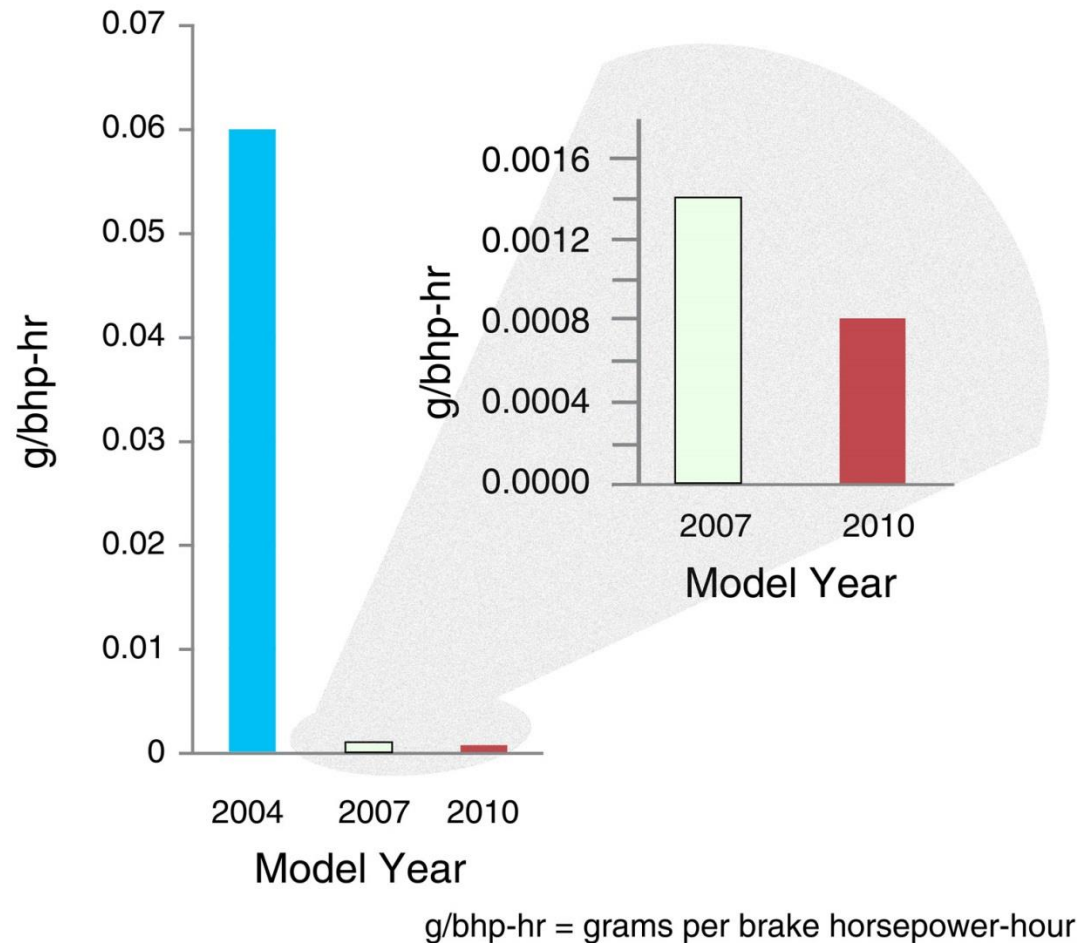
ACES results - Key emissions measured compared with EPA standards (g/hp-bhr)

	MY 1998	MY 2004	MY 2007 Measured Phase 1	MY 2010 Measured Phase 2
PM	0.1	0.1	0.01 0.0014	0.01 0.0008
NOx	4.0	2.0	1.2 1.09	0.2 0.08

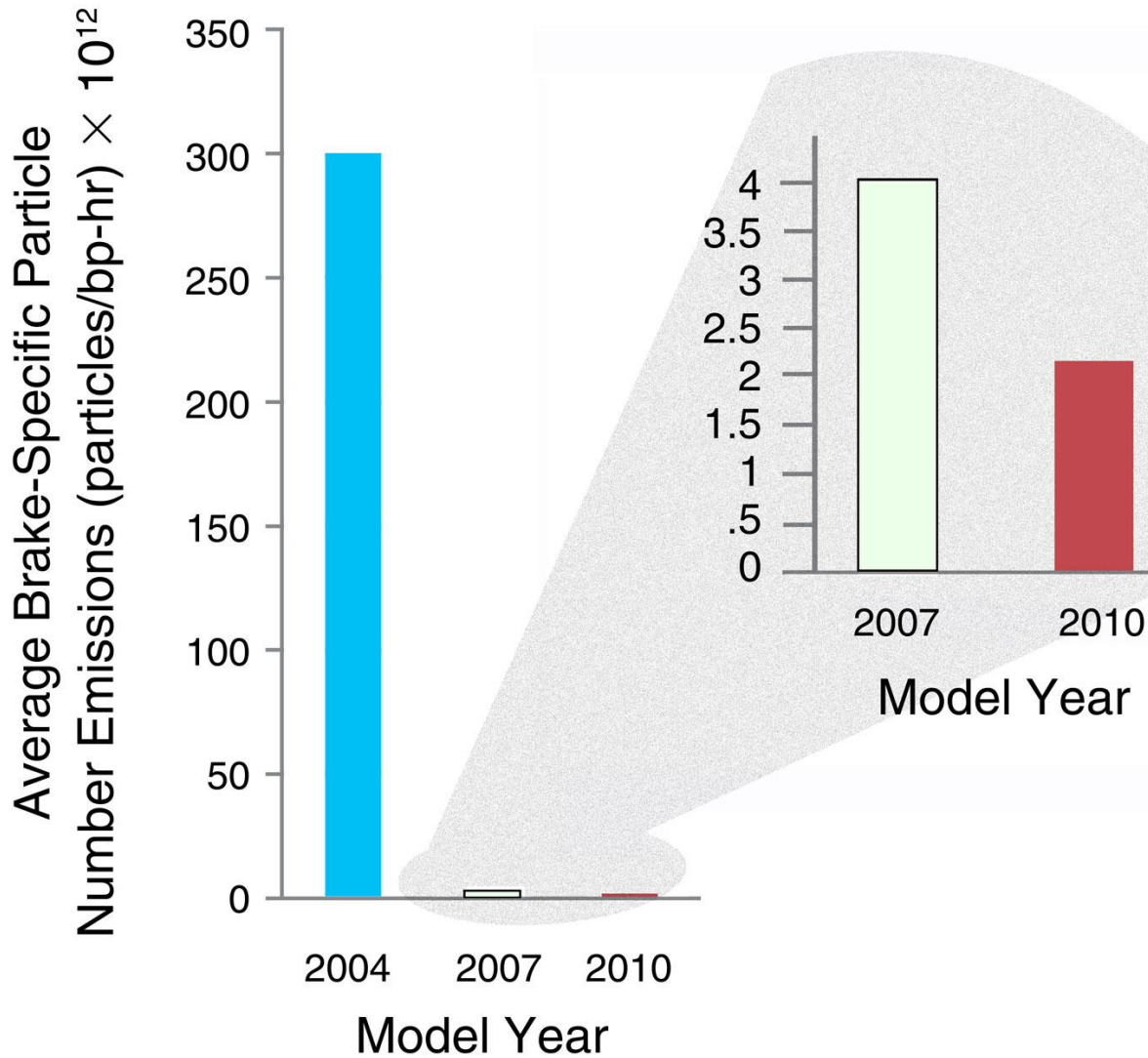


Results of Phases 1 and 2 – Total mass emissions from 2007 and 2010 engines much lower than from 2004 engine

Mass Emissions



Number Emissions

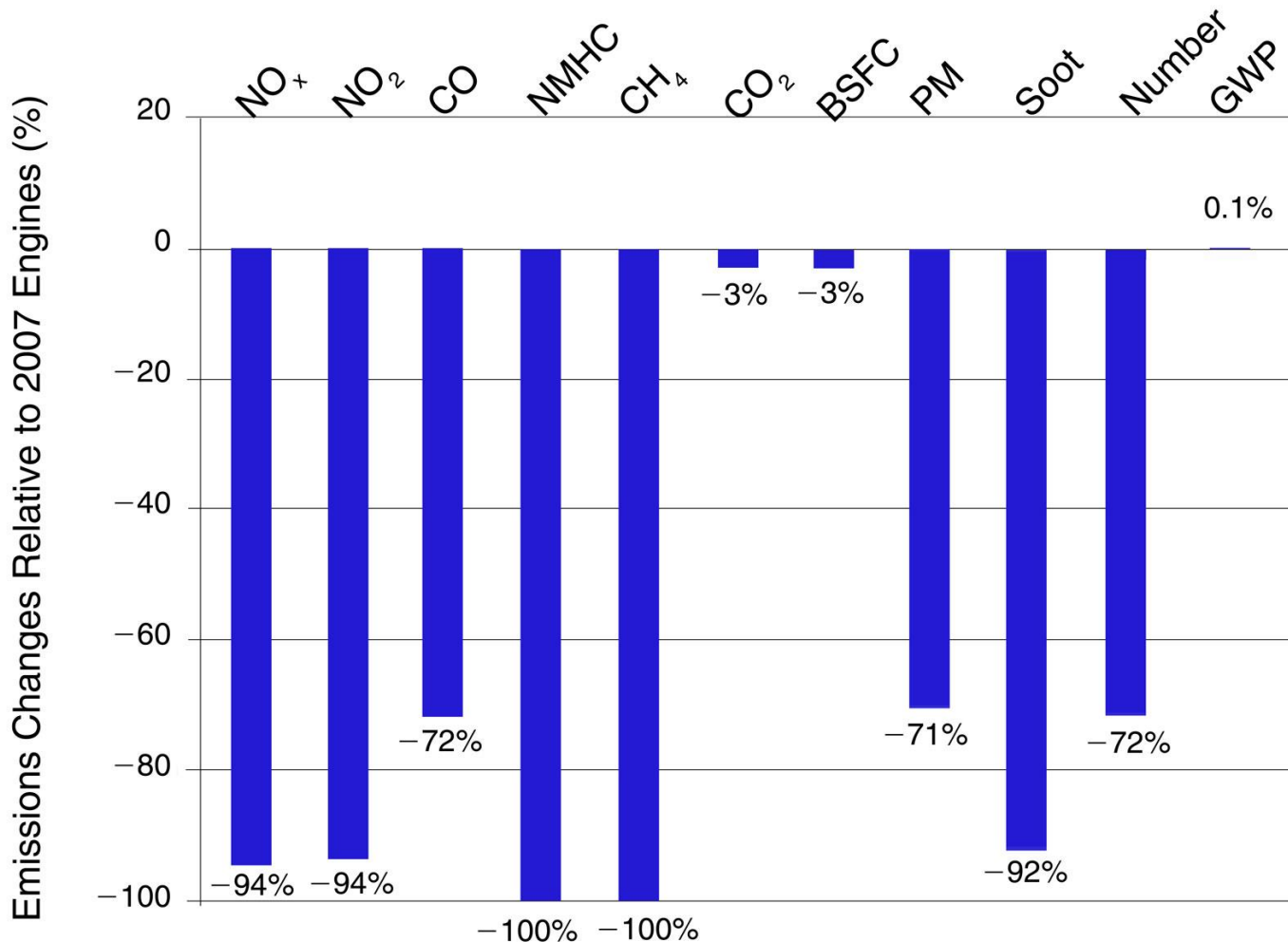


Particle numbers from 2007 and 2010 engines 100x lower than from 2004 engines

g/bhp-hr = grams per brake horsepower-hour



Most emissions from 2010 engines are lower than emissions from 2007 engines

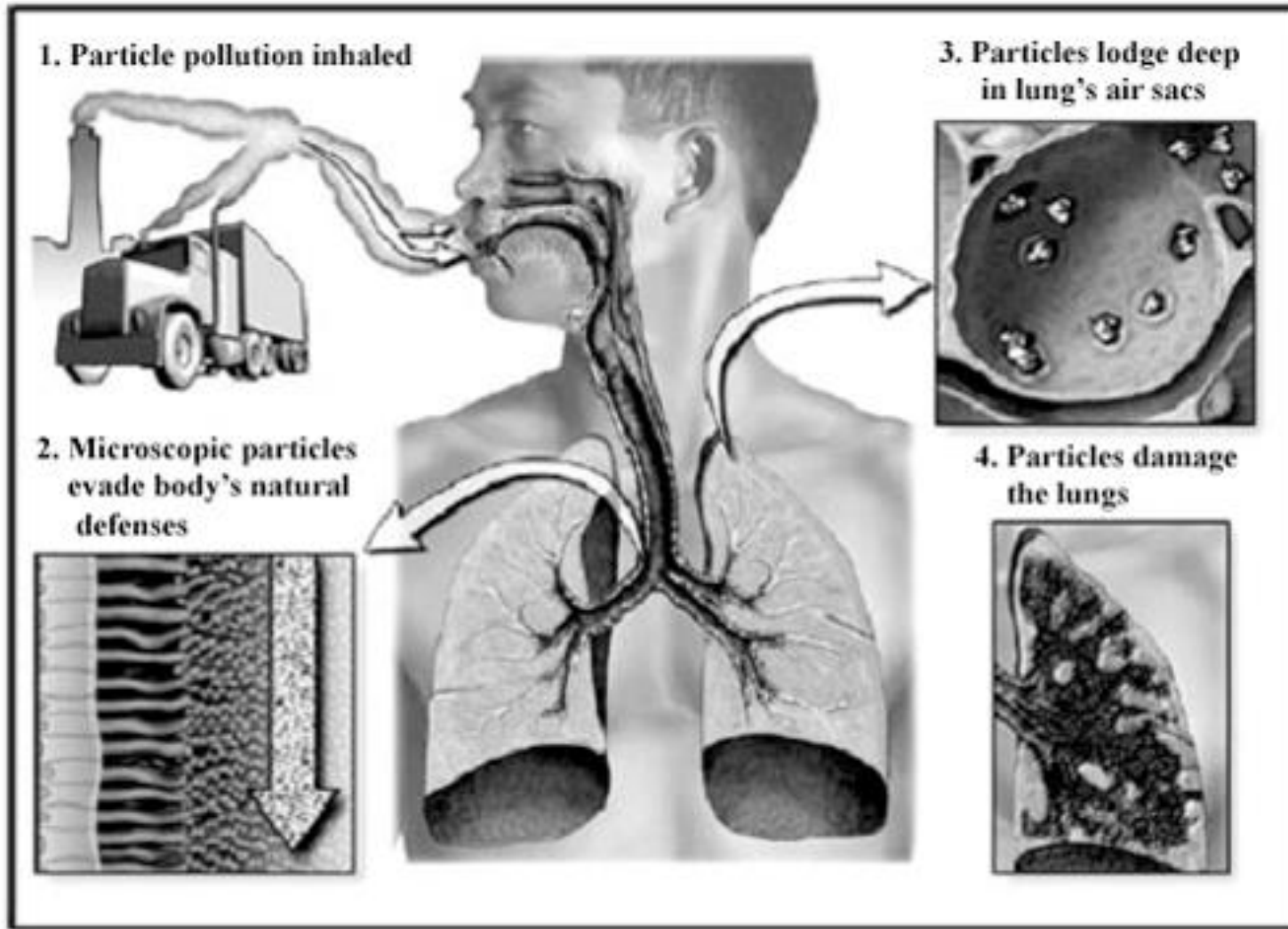


ACES Phase 3 - Goals

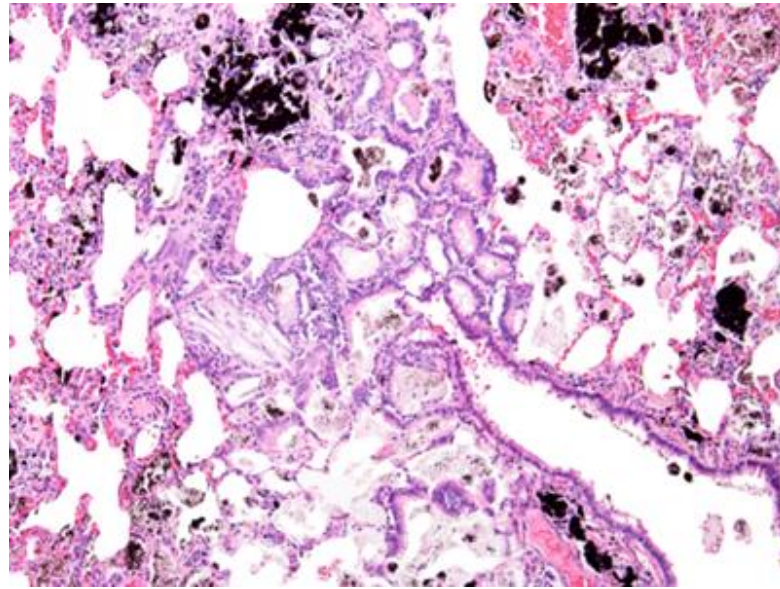
- **Assess health effects of lifetime exposure of rats to 3 dilutions of emissions from a 2007-compliant diesel engine = **New Technology Diesel Exhaust (NTDE)** (+ clean air control)**
 - >200 male and female rats (Wistar Han strain) exposed for lifetime, for 16 hr/day, 5 days/wk.
 - Concentrations:
 - **High = 4.2 ppm NO₂ (PM at chamber inlet = 12.3 µg/m³)**
 - **Medium = 0.8 ppm NO₂ (PM = 1.07 µg/m³)**
 - **Low = 0.1 ppm NO₂ (PM = 0.3 µg/m³)**
- **Biological measurements at 1, 3, 12 and 24 months + terminal sacrifice (= 28 months for males, or 30 months for females)**



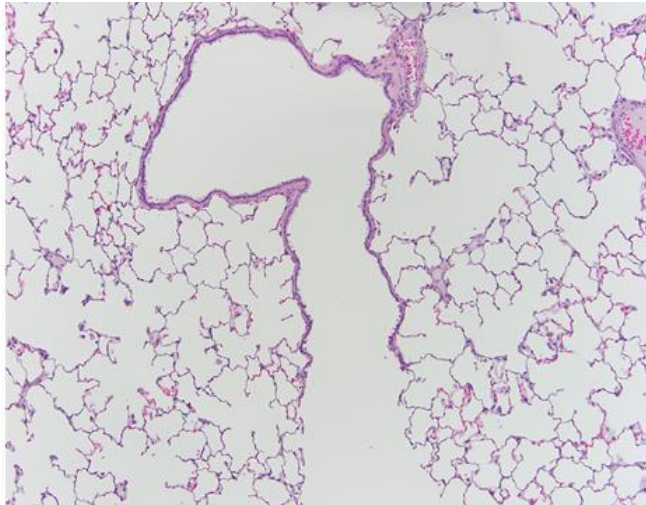
Health effects of inhaled particles



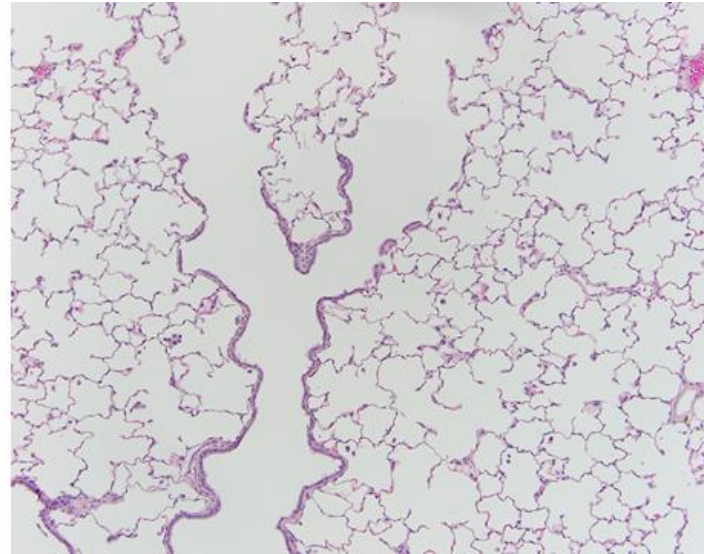
**Rat lungs exposed
to diesel exhaust
for 30 months**



**High dose
traditional
diesel**



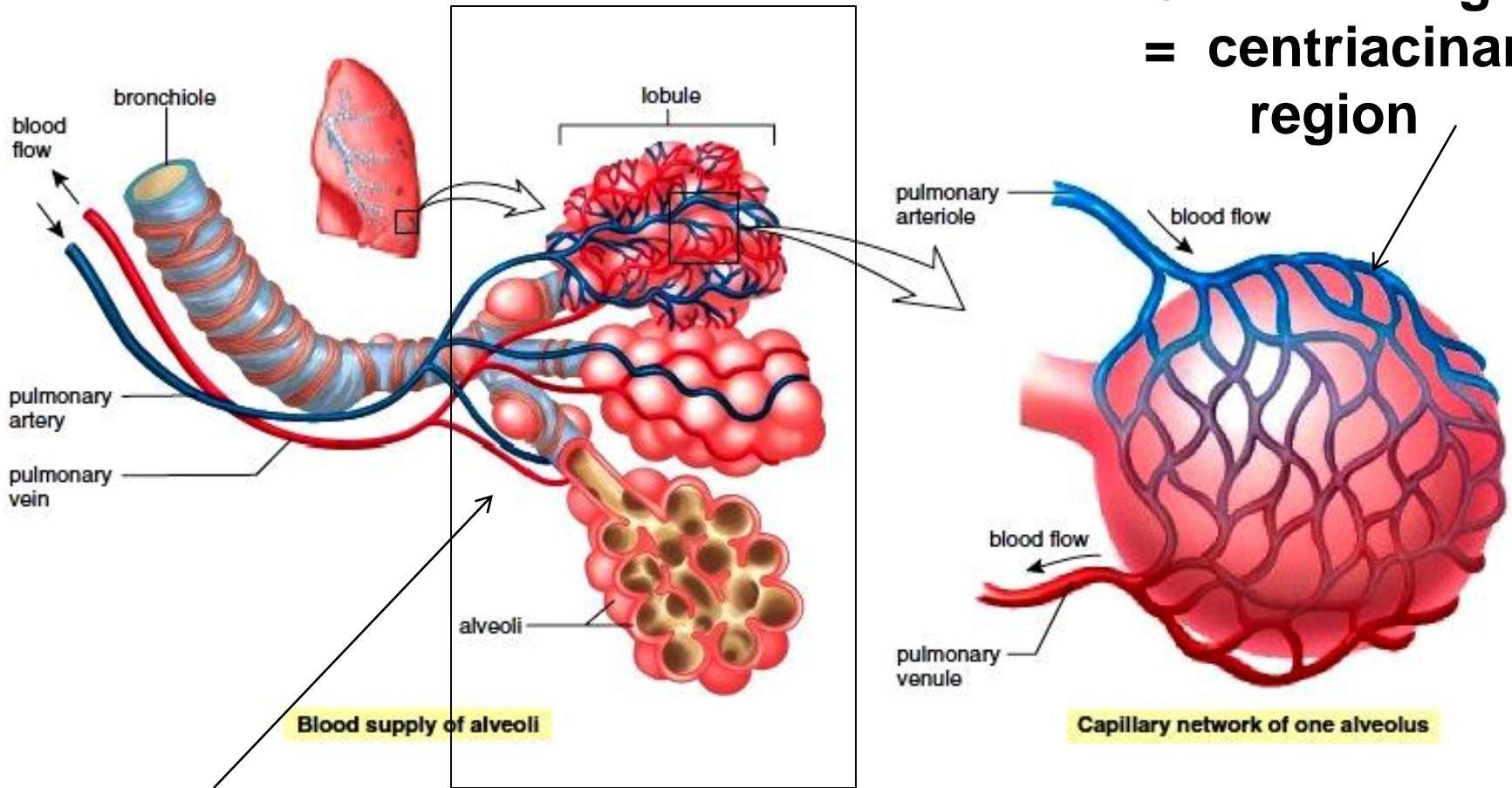
Control = filtered air



**High dose
2007
diesel**

The Gas Exchange - Centriacinar - Region of the Lung

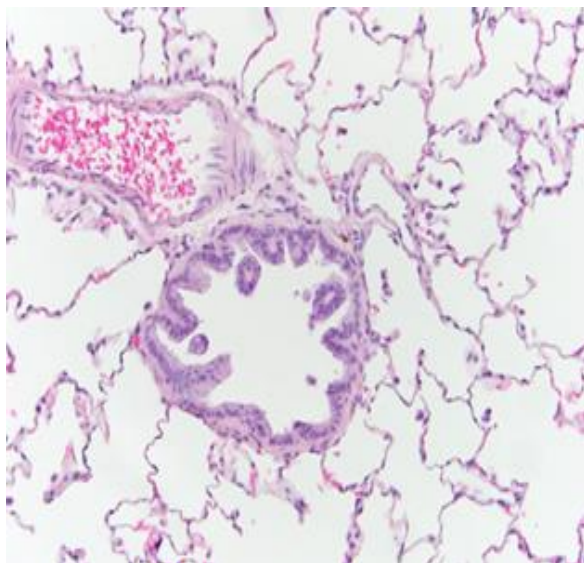
**Gas exchange
= centriacinar
region**



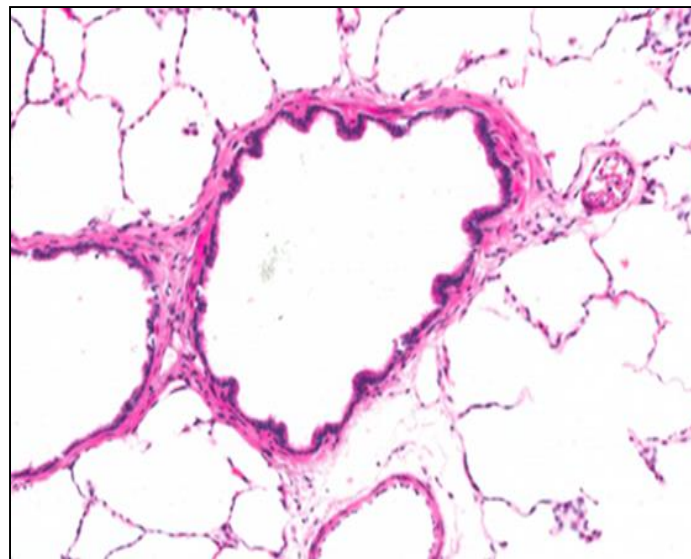
**Histopathology area of
interest**



Lung effects of new diesel are similar to those of NO₂



ACES – 4,2 ppm NTDE
Male 28 months



9.5 ppm NO₂ for 24 months
F344 rats, 1989 study

ACES Phase 3

- **Key findings:**

- No increase in tumor formation over background in the lung or any other organ of rats
- Subtle changes in the centriacinar region of the lung, resembling changes after long-term exposure to NO₂

= Major differences compared to long-term exposures to “traditional” diesel exhaust

- Small decreases in respiratory flow and reduced diffusion capacity of carbon monoxide (= DL_{CO})
- Few changes in markers of inflammation or thrombosis in lung tissue, bronchoalveolar lavage fluid or blood
- No consistent changes in many biochemical markers
- No exposure-related changes in genotoxic endpoints



ACES - Conclusions

ACES demonstrates the effectiveness of the emissions controls in greatly reducing both PM and NOx and suggests a similar reduction in the toxicity of new- technology diesel (NTDE).

CAUTIONS

- **Emissions Characterization**
 - Engines tested on a dynamometer
 - SCR does not work perfectly in stop-and-go and cold driving
- **Health Effects**
- **Rats - extrapolation to humans?**



Acknowledgments

- Imad Khalek, Southwest Research Institute, ACES Phase 1 and 2 Principal Investigator
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- Jacob MacDonald, Lovelace Respiratory Research Institute, ACES Phase 3, Principal Investigators
- Annemoon van Erp and Maria Costantini, HEI - ACES oversight

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- ACES Reports can be downloaded from
 - Health Effects Institute www.pubs.healtheffects.org
 - Coordinating Research Council
<http://crcao.org/publication/index.html>

