The Advanced Collaborative Emissions Study "ACES"

Next Generation Diesel What is Possible….

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Vehicular Pollution and its Impact on Human Health
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Next Generation Diesel: What is possible

- Why Diesel?
- What do we know about health effects?
- How are fuels and technology changing?
- Benefits of Emission reduction
- ACES Emissions Characterization and Health Assessment
- Way Forward: *Enabling the future*

What has driven increasing use of diesel?

- Diesel Engines have substantial advantages:
  - Higher fuel efficiency
  - Lower CO and CO2 emissions
  - Heavy duty hauling capacity
  - Durability
  - Existing fuel and maintenance infrastructure

Major Diesel Emissions

- Carbon Monoxide
- Carbon Dioxide (Climate Change)
- **Particulate Matter (PM)**
- Lead
- **Nitrogen Oxides (NOx) and Hydrocarbons (HC)**
  - ***Precursors to Ozone and PM***
- **Nitrogen Dioxide**
- **Air Toxics**
  - Polycyclic organic matter (e.g. PAHs
  - Aldehydes
  - Metals
  - others

Diesel Exhaust Progression

Exhaust from engines using older technologies:

- **Pre-1988** diesel in use *prior to the US EPA diesel particulate standards* can have high emissions
- **"Transitional" 1988-2006** diesel engines show some improvement
  - Progressive improvements in engine design, but
  - Prior to the full-scale implementation of multi-component after-treatment systems
- Substantial contributors to PM NOx emissions, mortality and respiratory health effects
- ***Diesel longevity mean many of these engines still on the road, especially in developing countries***

Older Smoking Engines have Highest Toxicity

- Despite improvements in many areas, especially older engines or in areas with high sulfur fuels also emit high levels of PM, NOx, and chemicals attached to the particles (e.g. PAHs)
- *Seagrave (2002)* Assessed PM and semi volatile exhaust from normal and high emitting diesel
  - Subjected to a host of a laboratory tests of inflammation, mutagenicity, toxicity
- *Results*:
  - High-Emitting Diesel (and Gasoline) showed substantially greater health effects effect

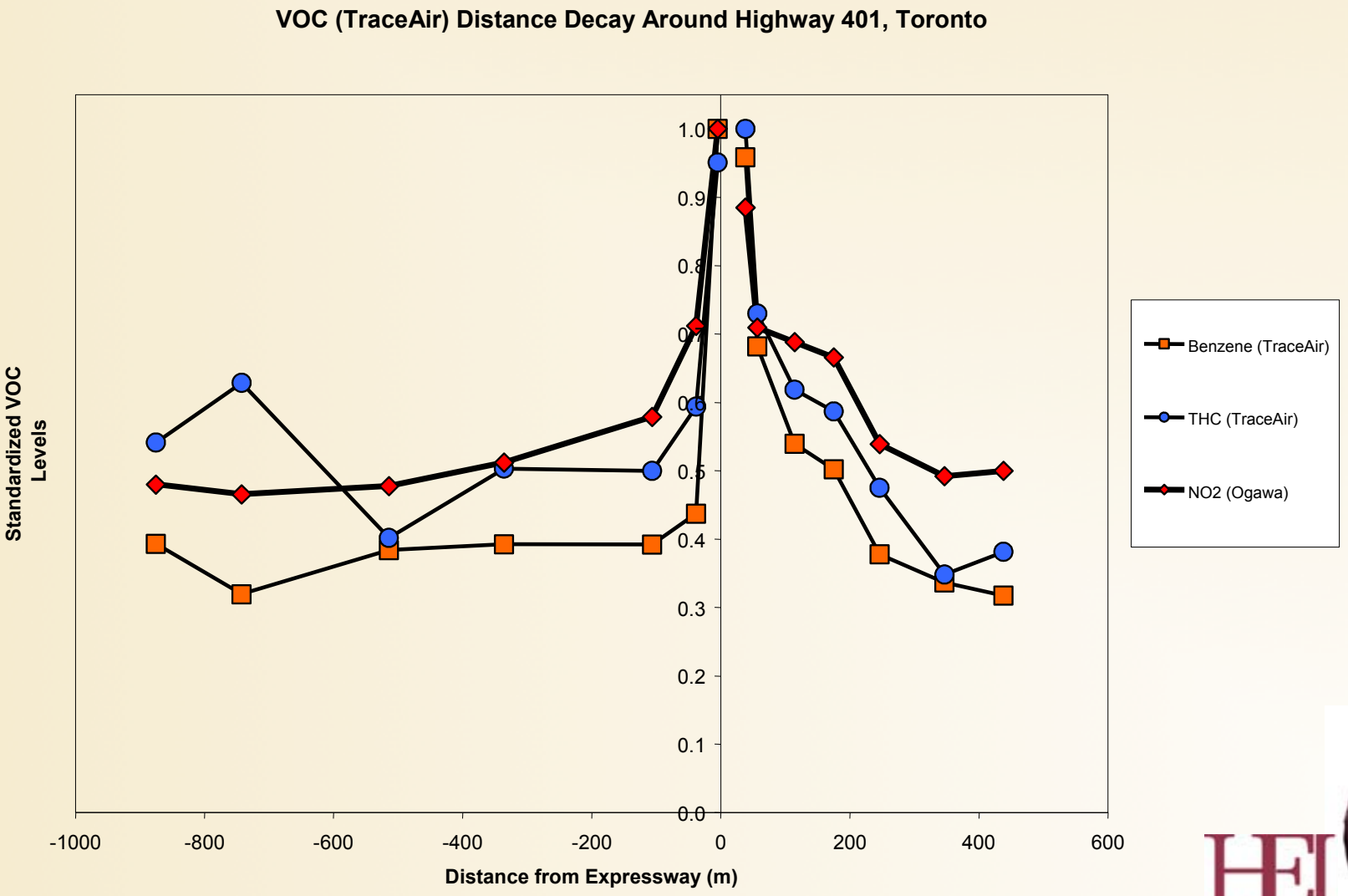
Diesel Risk Assessment: Cancer

- Reviews by International, National, State Agencies
  - IARC (WHO,1989)
  - International Programme on Chemical Safety (WHO,1996)
  - U.S. EPA (2002)
  - California OEHHA (1998)
  - NIEHS/NTP (1999)
- Most have called diesel a probable human carcinogen
  - Difficult to quantify precise risk
  - California has found it a known carcinogen
    - estimated 3 excess cancers in 10,000
- New IARC Review of diesel carcinogenicity in June 2012

Who is Likely to be Exposed?

Highest levels within 300 – 500 meters of a major road

(HEI Review of Health Effects of exposure to Traffic)



Toronto, Beckerman et al. (2008)

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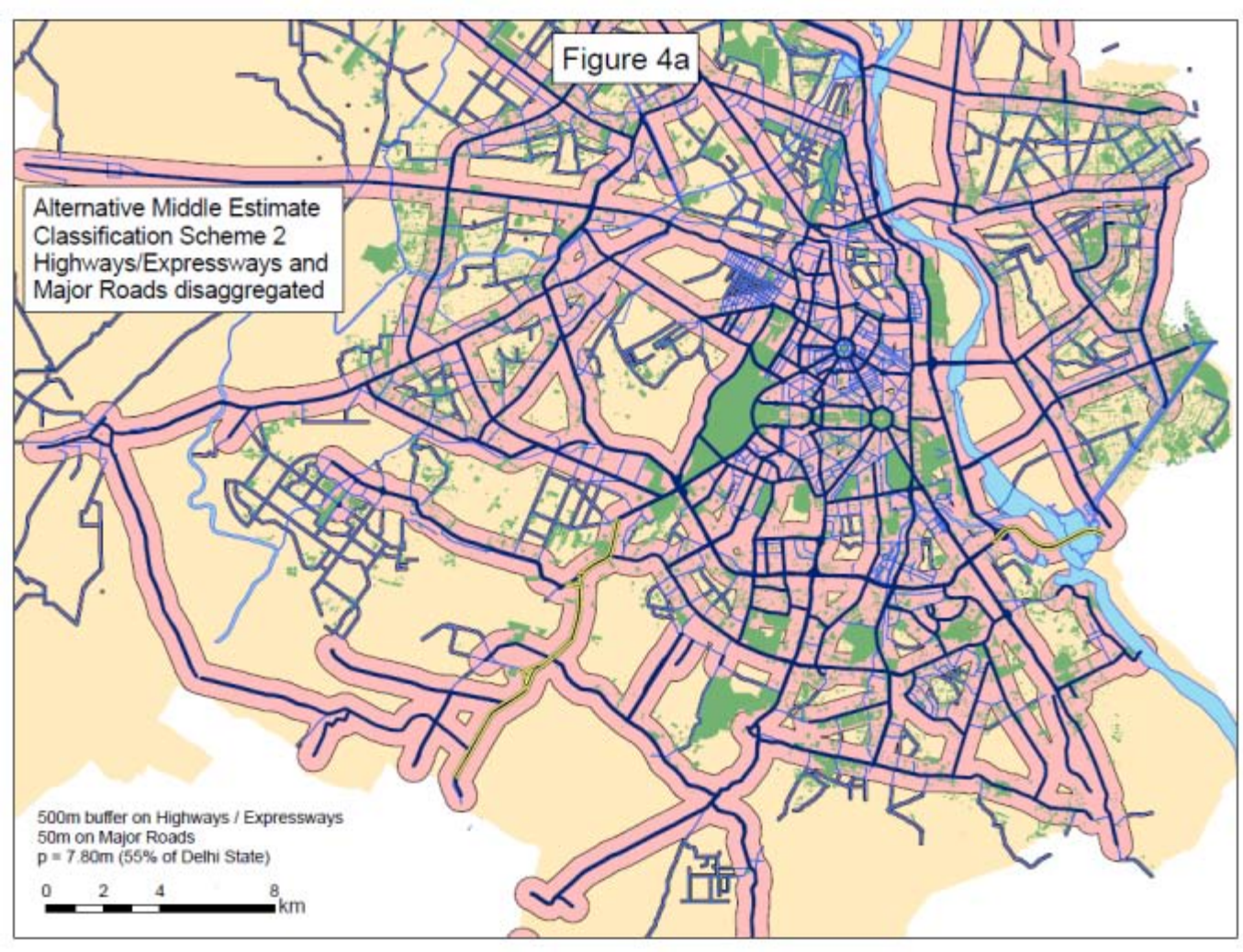
The Traffic Impact Area in Delhi:

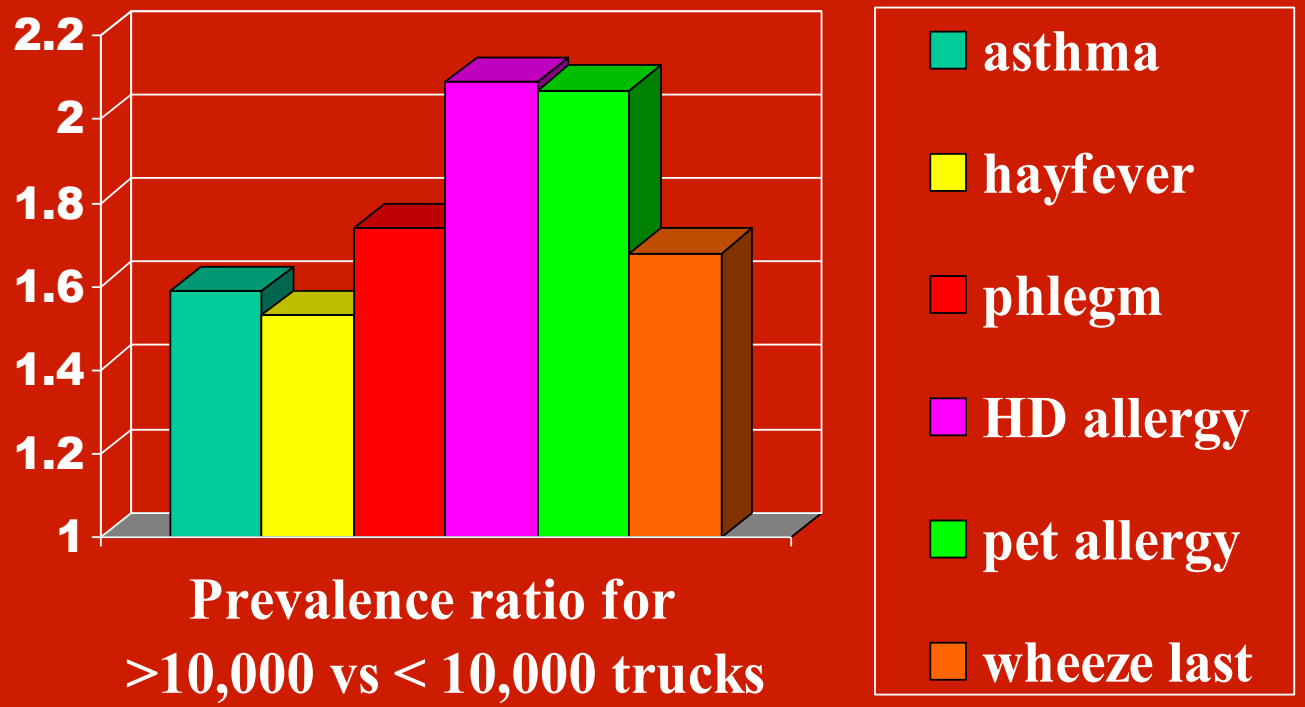
New HEI Analysis: 55% of the Population within 500 meters of a Freeway; 50 meters of a Major Road



Association between truck traffic and symptoms

(Brunekreef 1999)

- 2500 Children in 24 schools, located near freeways with varying traffic density (i.e truck vs. car)



How are Technologies and Fuels Changing?

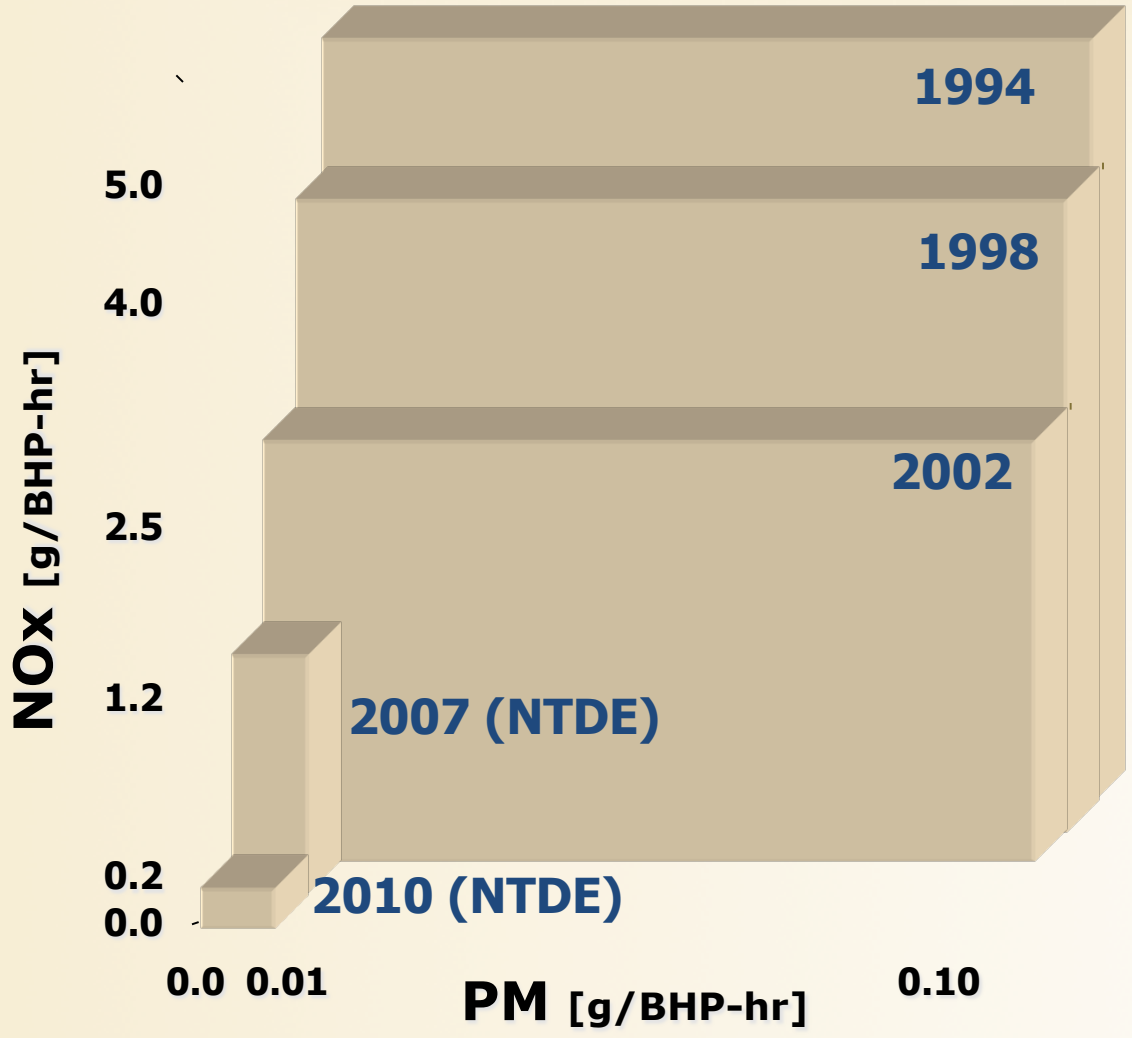
HD Truck and Bus Engines

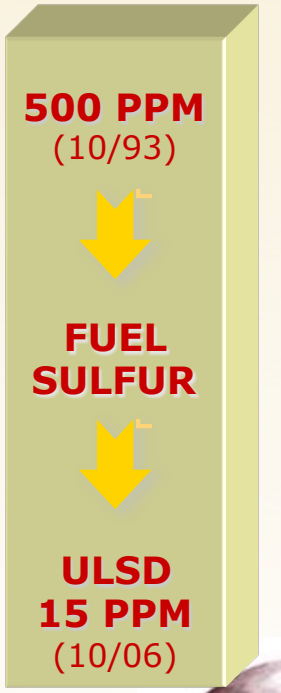
In US
2007
- 15 ppm sulfur diesel fuel
- PM control (filter)
- Some NOx control (primarily exhaust gas recirculation)

2010
- 15 ppm sulfur diesel fuel
- PM control (filter)
- NOx control (likely option: selective catalytic reduction and/or Advanced Exhaust Gas Recirculation (EGR))

Progress in India
2010
50 ppm sulfur diesel in 13 cities
350 ppm in balance of country
PM filters not required
Advanced NOx control not required

Evolution of US Heavy Duty Diesel On-Road Emission Standards





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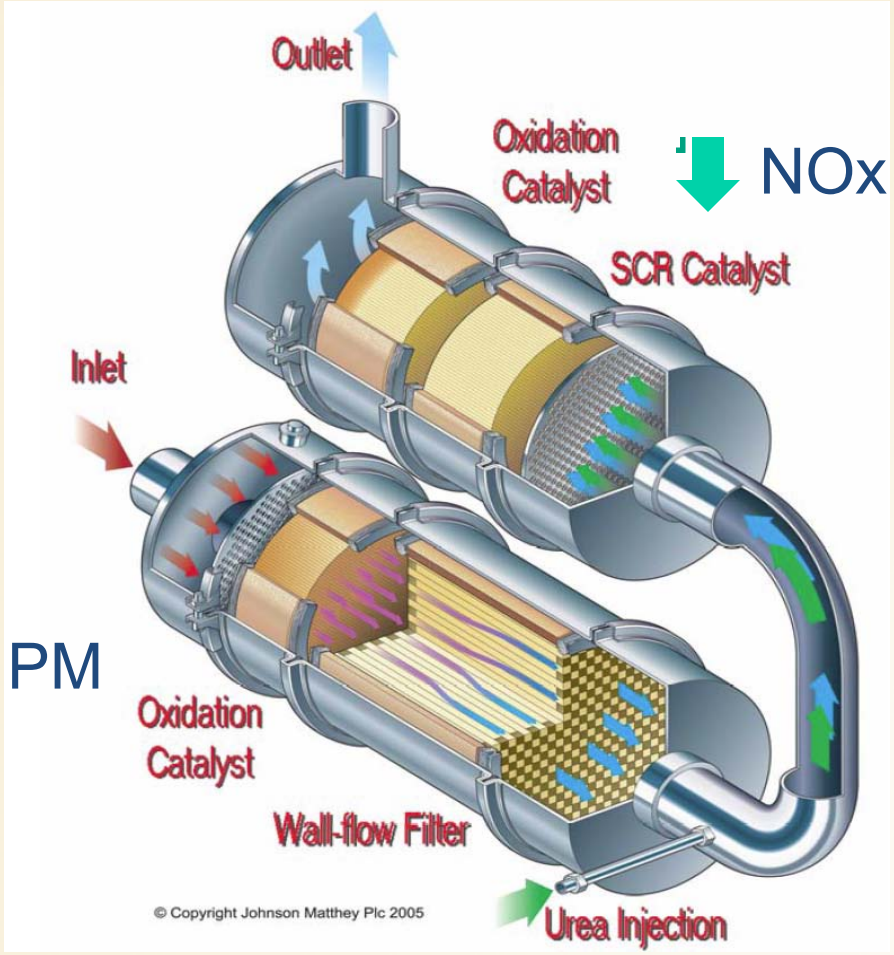
Key Need: Ultra Low Sulfur Diesel

- Clean fuel essential to enhanced control technology
  - Excess Sulfur can
    - Block particle filters
    - Coat NOx controls and cause reduce effectiveness
  - De facto world standard moving to 15 ppm or lower
    - Already in place in Europe, US

Key Need: Exhaust Treatment Systems

—Particle Removal and NOx Elimination



DOC+DPF+SCR

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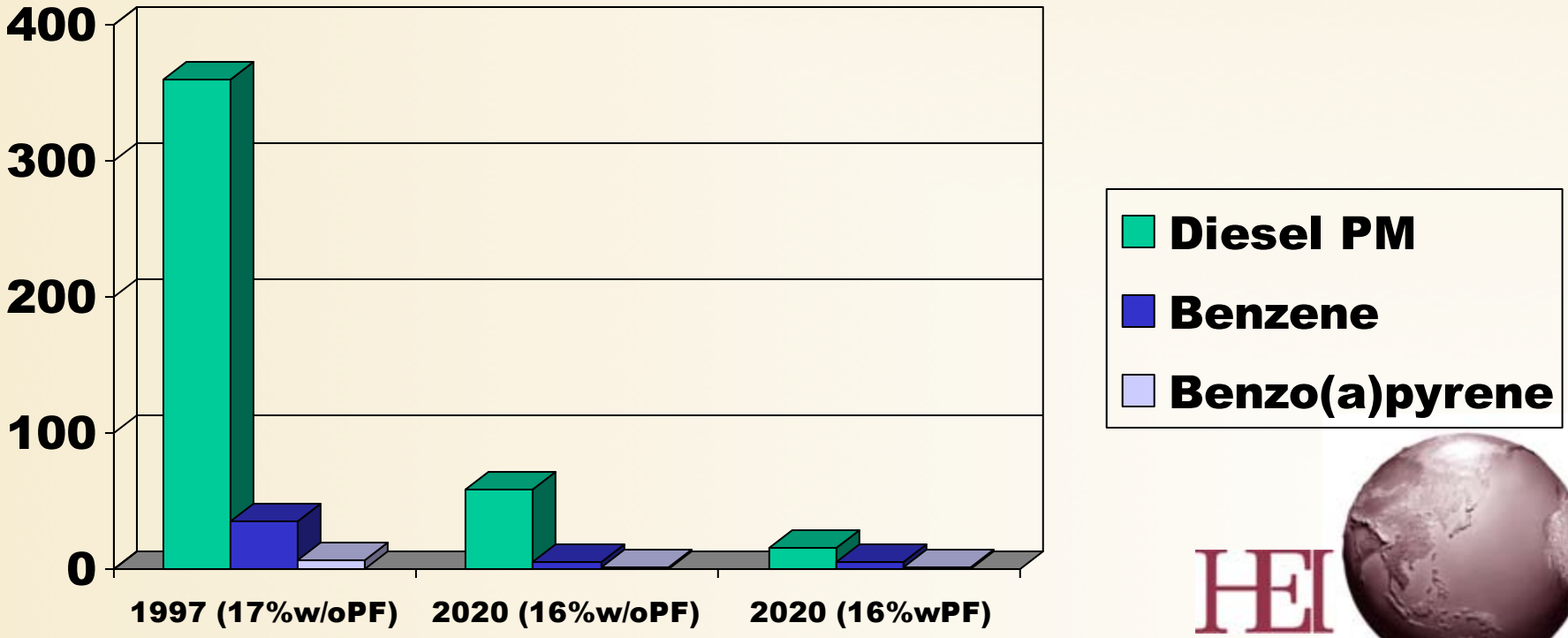
With Controls, Cancer Risk Estimates Drop Dramatically

(Source: Fraunhofer Institute 12/99)

Estimated Lifetime Cancer Risk in a German City (per million people)



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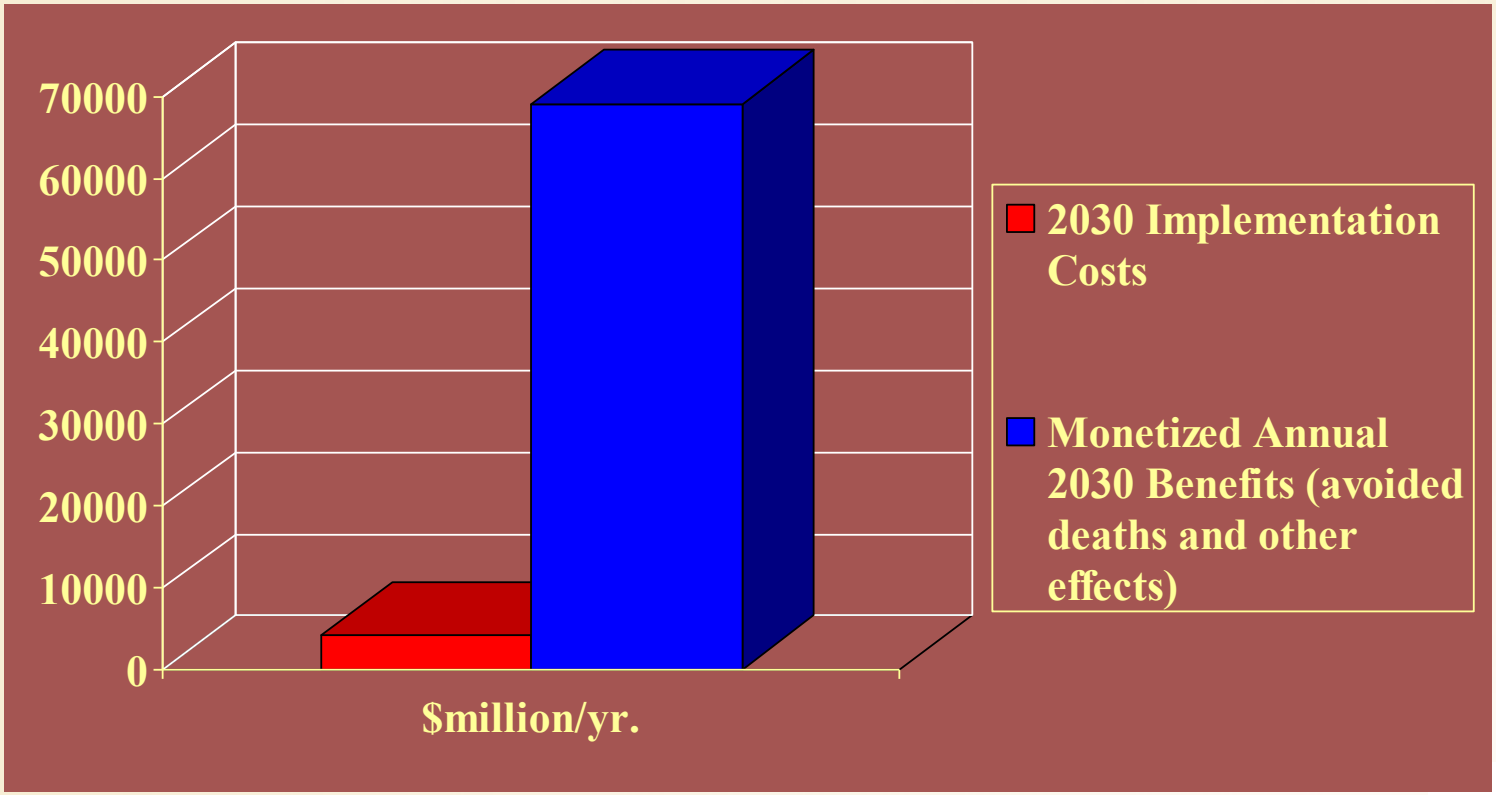
Comparing Costs and Benefits US Highway Diesel Rule

(Source US EPA 2000)



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New Technology Diesel in US

Exhaust from engines utilizing new technologies:

- Meets EPA 2007 on-road PM and NOx standards
- Fully integrated electronic control systems
- Ultra low sulfur diesel fuel (< 15 ppm)
- Oxidation catalysts
- Wall-flow diesel particulate filters (DPFs)
- Applies to both new and retrofitted engines

Are new diesels meeting the challenge?

Advanced Collaborative Emissions Study (ACES)

Cooperative multi-party effort to characterize emissions and possible health effects of new advanced heavy duty engine and control systems and fuels in the market 2007 – 2010.




PROJECT SPONSORS

US Department of Energy (DOE) OVT and NETL
Engine Manufacturers Association (EMA)
US Environmental Protection Agency (EPA)
California Air Resources Board (ARB)
American Petroleum Institute (API)
Aftertreatment Manufacturers
Coordinating Research Council (CRC)

Evaluating Emissions of Advanced Technology Diesels

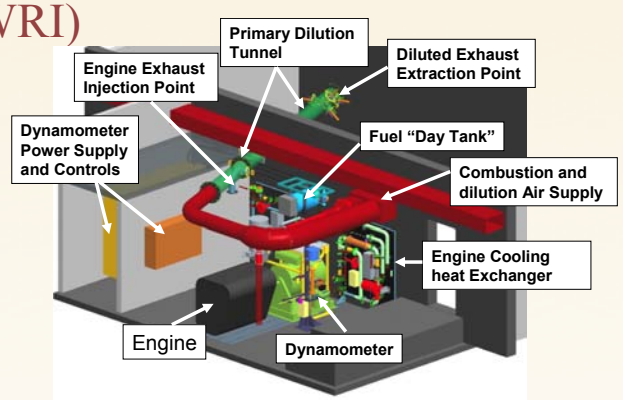
- New 2007/2010 engine/control systems and fuels designed to result in substantially reduced emissions.
- Substantial public health benefits are expected from these reductions.
- *But, w*ith any new technology it is prudent to ensure there are no adverse impacts to public health and welfare.

ACES is moving to *answer these important questions*:

Phase 1: 2007 Engine Emissions Characterization (CRC and SWRI)

Report Complete (www.crcao.org)

Dramatic reductions!



Phase 2: 2010 Engine Emissions Characterization

Planning Underway – to start Fall 2011

Phase 3: 2007/2010 Engine Health Effects Testing (Lovelace Respiratory Research Institute (LRRI)

(Short Term biological screening and Long-Term Health Effects Test on 2007 Engines)

Health testing complete through 1 year

First results (1 – 3 months) entering HEI Review Now

Published in time for IARC April 2012

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PHASE 1 Results:

Substantial Reductions below standards (except for NOx which will be regulated in 2010)

Regulated Emissions Relative to EPA 2007 Standard Based on FTP Transient Cycle

	2007 EPA Standard (g/hp-hr)	Average ACES Engine Emissions (g/hp-hr)	ACES Emissions % Reduction Relative to the 2007 Certification Standard
CO	15.5	0.33	98
NMHC	0.14	0.0064	95
PM	0.01	0.0011	89
NO_X	1.2 [a]	1.075	10

[a] Average value between 2007 and 2009, with full enforcement in 2010 at 0.20 g/hp-hr

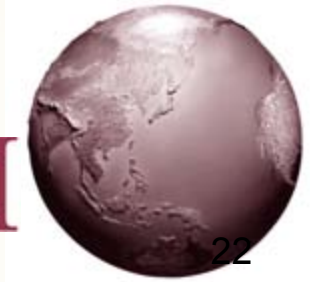
Unregulated Emissions

On a g/hr emission rate basis, all unregulated emission species listed below were below the level observed with 2004 engine technology used in CRC E55/59.

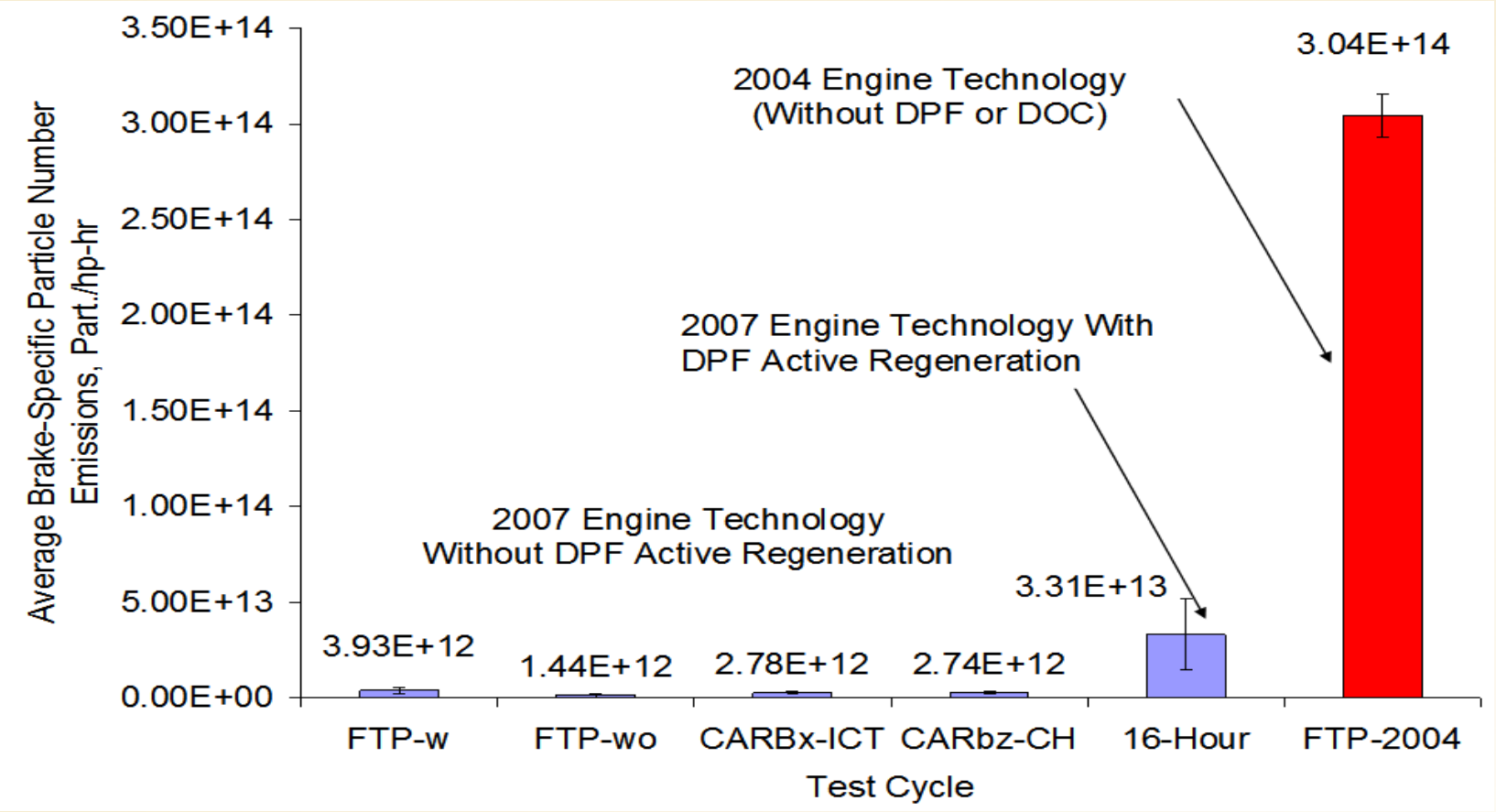
Compounds	% Lower Than 2004 Engine Technology	
	16-Hour Cycle	CARBx-ICT
Single Ring Aromatics	82%	69%
PAH	79%	26%
Nitro-PAH	81%	49%
Alkanes	85%	84%
Polar	81%	12%
Hopanes/Steranes	99%	99%
Carbonyls	98%	78%
Inorganic Ions	38%	100%
Metals and Elements	98%	90%
Organic Carbon	96%	78%
Elemental Carbon	99%	100%
Dioxins/Furans[a]	99%	N/A

[a] Relative to 1998 Engine Technology

In general, the low exhaust temperature cycle CARBx-ICT showed less reduction for the hydrocarbon-based compounds, compared to the 16-Hour Cycle



Average Total Particle Number Emissions Reduced



- With regeneration, the particle number emissions average was approximately 90 percent lower than the level emitted by a 2004 engine technology, and without regeneration it was approximately 99 percent lower
- Average particle number with regeneration was more than a factor of 10 higher than that without regeneration (Note that there was no difference in PM mass emissions)

Concluding Thoughts

-Older technology diesel currently on the road in US, India associated with emissions of PM, NOx, other toxic air pollutants

-Significant mortality, morbidity impacts from exposure to diesel PM

-IARC, others identified diesel exhaust from many current and older engines as likely human carcinogen

-ACES confirms new diesel technology (EPA 2007-10 compliant) using ultra low sulfur fuel (15 PPB), and particle filters result in dramatic reductions in emissions

-Way forward for much cleaner diesel, improved health is clear

Thank You

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