

Diesel — What the Future Holds

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Panel Discussion on

*Will the Real “Clean Fuel” Please Stand Up: Sorting
Fact From Fiction About Heavy-Duty Engines*



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Background and Issues

2

Heavy-Duty On Road Standards

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2007-2010 Heavy-Duty Diesel Engines

4

Summary Comments

- 1** Background and Issues
- 2 Heavy-Duty On Road Standards
- 3 2007-2010 Heavy-Duty Diesel Engines
- 4 Summary Comments

Emissions that result in largest societal damages are PM and NOx

Direct Particulate Emissions
PM_{<2.5} μ

Oxides of Nitrogen
NO_x

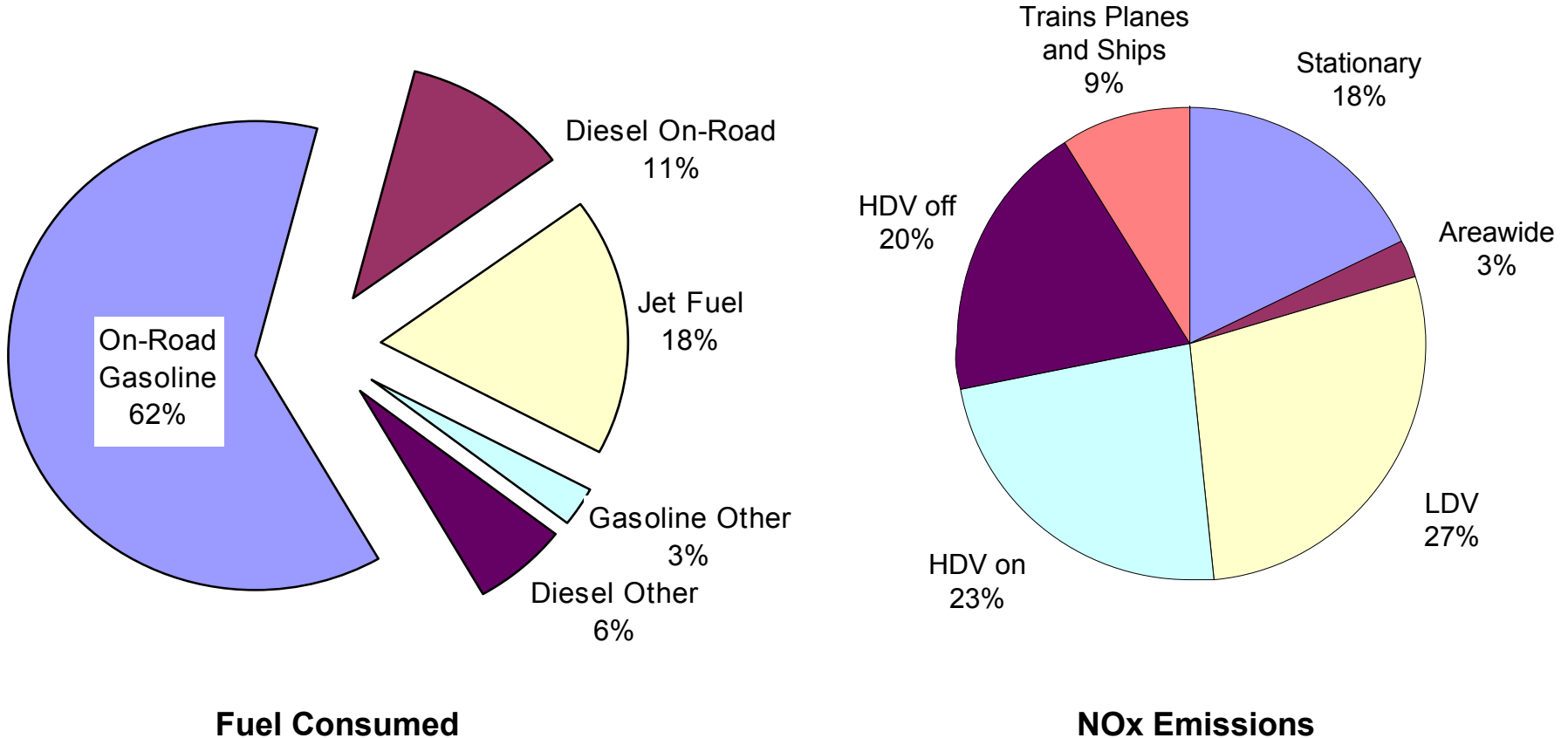
Ozone O₃
Secondary Particulate

Hydrocarbons
HC
Toxics

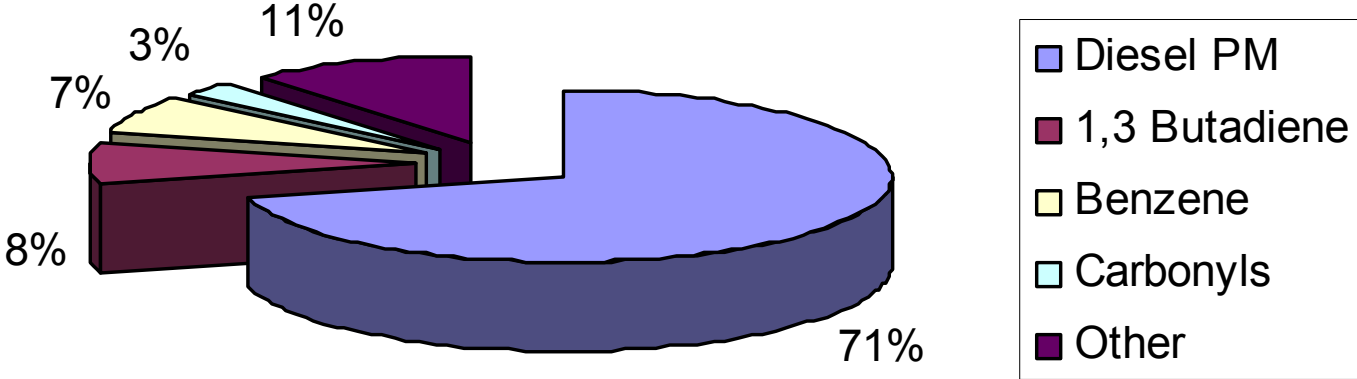
Carbon Monoxide
CO



Diesel Emissions Much Greater than Gasoline Emissions



Diesel Particulate from mobile sources dominate the cancer risk in the South Coast Air Basin

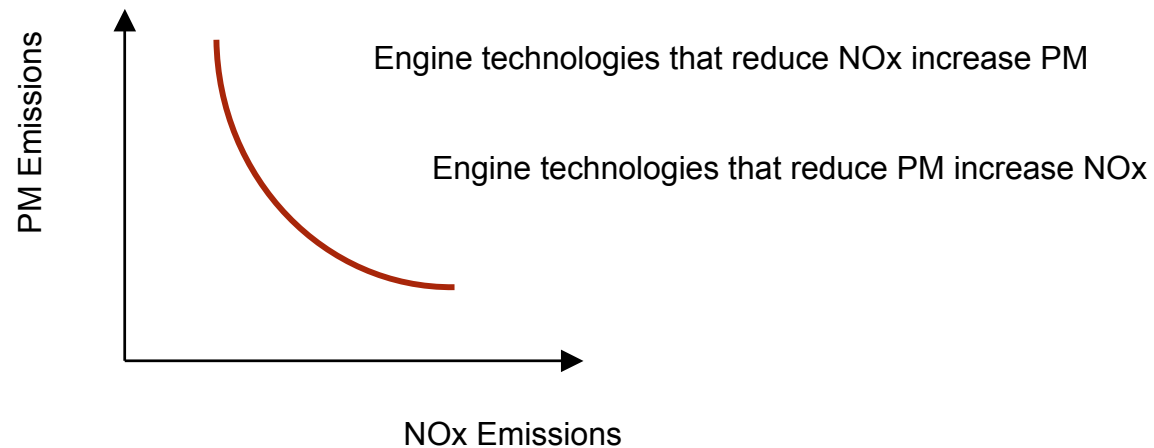


Basinwide Cancer Risks about 1400 in one million

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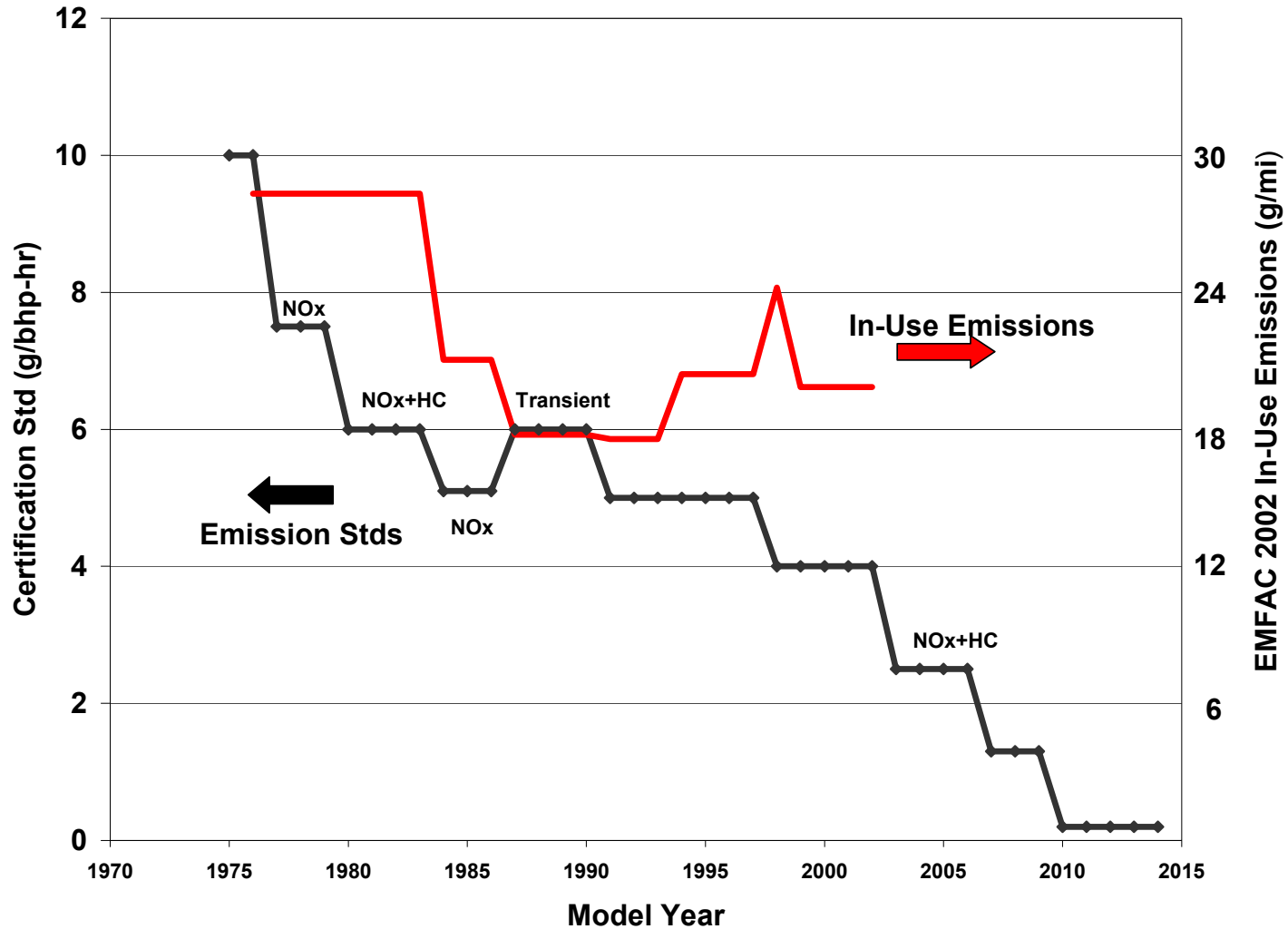
Diesel Engines emit higher emissions of NOx and PM than other engines

- NOx–PM tradeoff for Diesel Engines

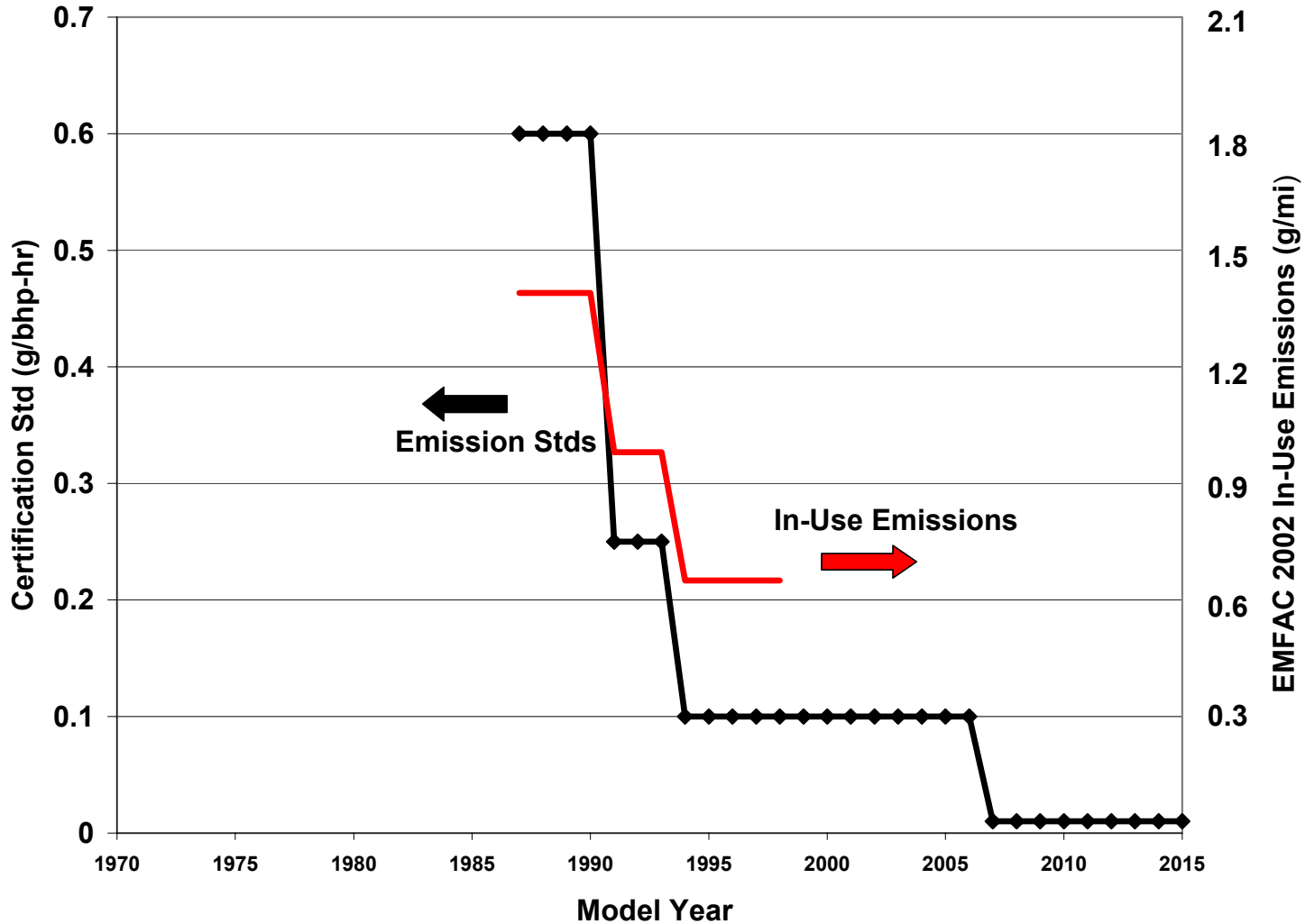


- Heavy Duty Diesel engine standards
 - NOx started in mid 1970's
 - PM started in mid 1980's
 - Standards on Diesel fuel also started in the mid 1980's (for emission control)

NOx Engine Standards and In-Use Emissions



PM Standards and In-use Emissions



Annual Benefits of On-Road 2007/2010 Heavy-Duty Standards

- 2.6 million tons of NOx, 110,000 tons of diesel PM, and 17,000 tons of toxic pollutants reduced
- Emission reductions decrease exposures to ozone and direct and indirect fine particulate (PM_{2.5}) resulting in following health benefits
- EPA estimate of avoided cases per year in 2030
 - 8,300 premature deaths
 - 5,500 chronic bronchitis
 - 9,500 hospital admissions
 - 1,539,400 lost work days
- EPA estimates the value of these avoided cases at \$70 Billion in 2030

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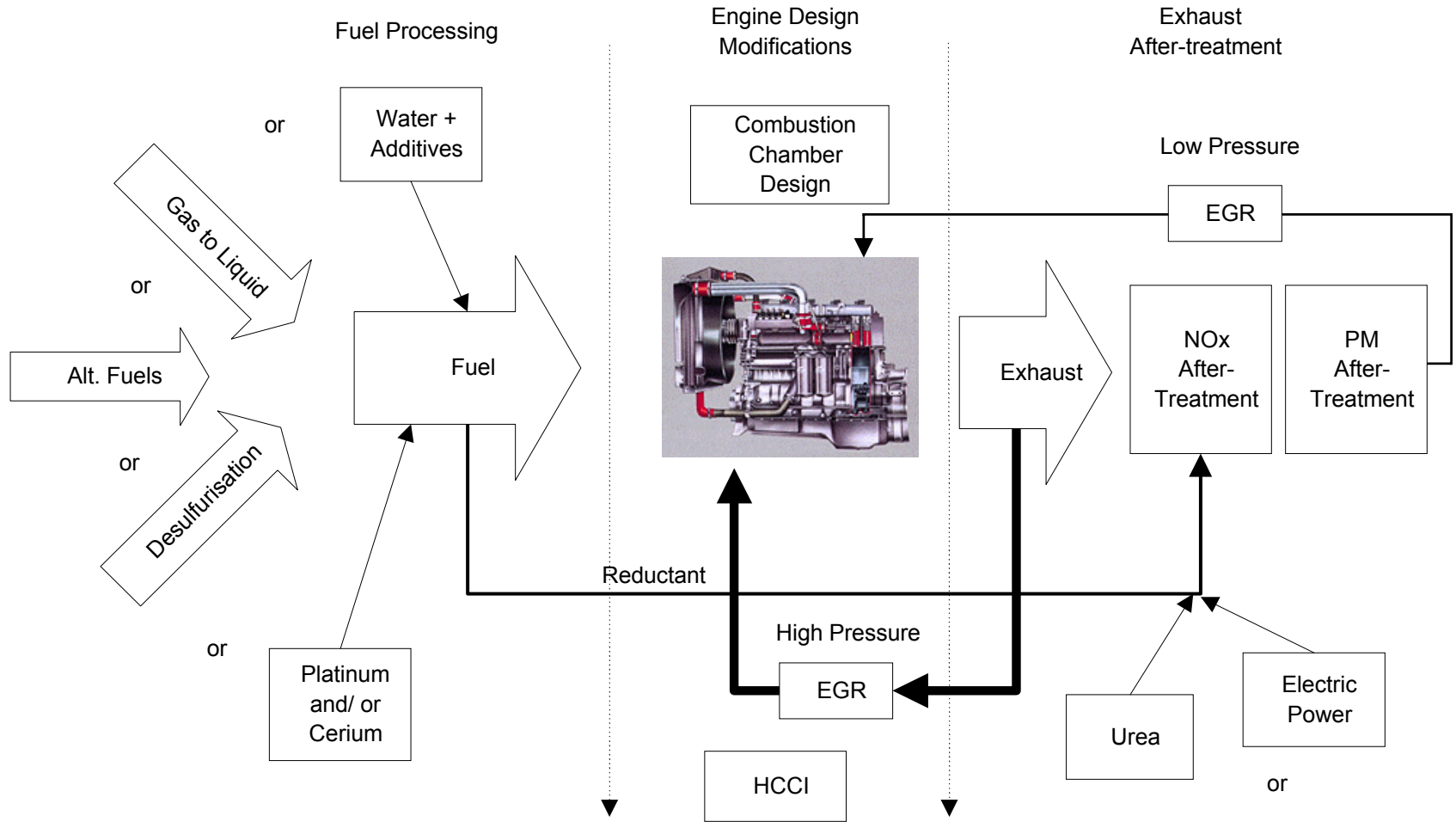
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2007-2010 Heavy-Duty Diesel Engines

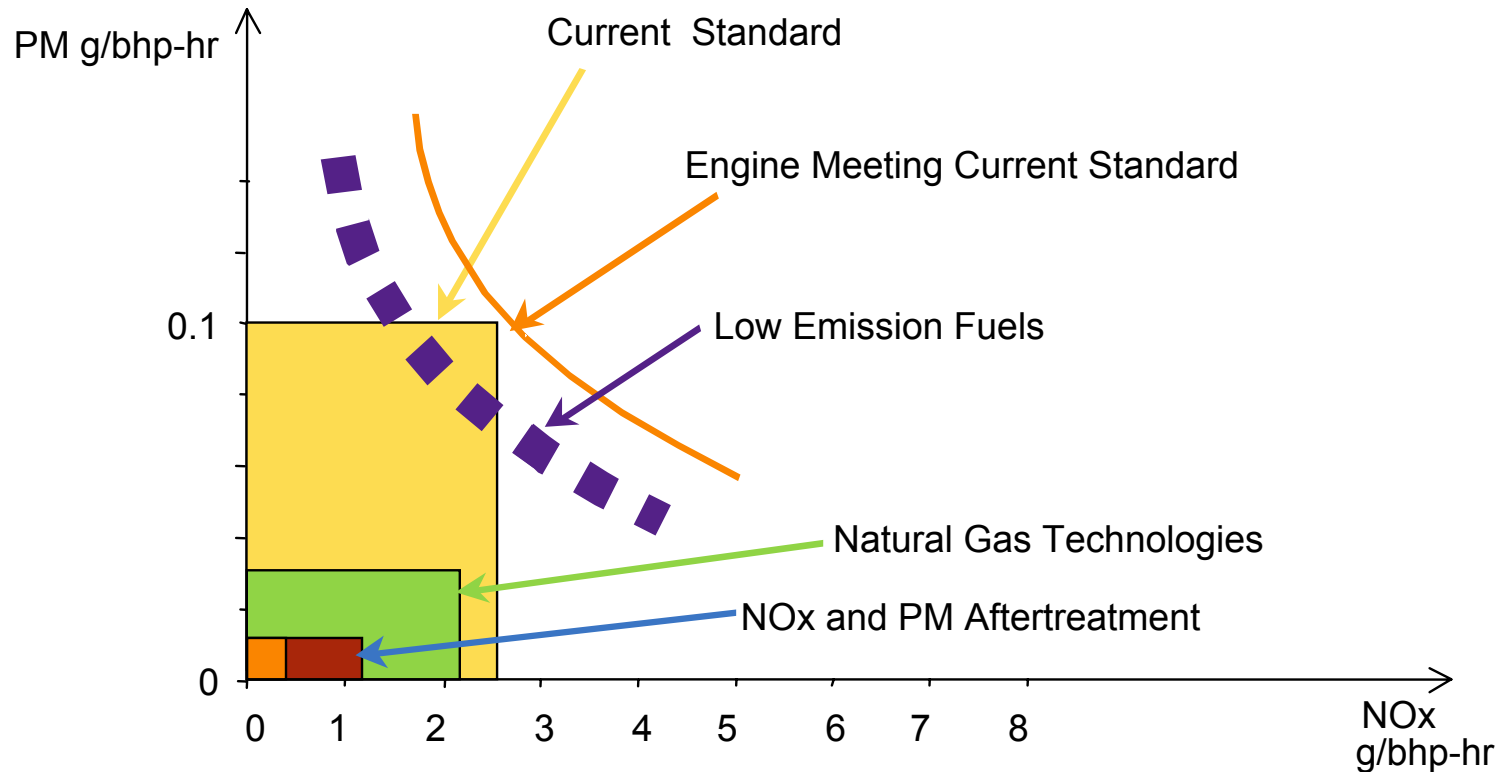
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Summary Comments

Future emission control strategies will be much more integrated



Potential emission reductions vary depending on the chosen approach and level of integration



To protect public health, EPA promulgated new on-road engine, vehicle, and fuel standards

	2006	2007	2008	2009	2010	2011	2012
PM		100% at 0.01 g/hp-hr					
NOx		50% at 0.20 g/hp-hr			100% at 0.20 g/hp-hr		
Fuel		80% at 15 ppm maximum sulfur (under temporary compliance option)			100% at 15 ppm		



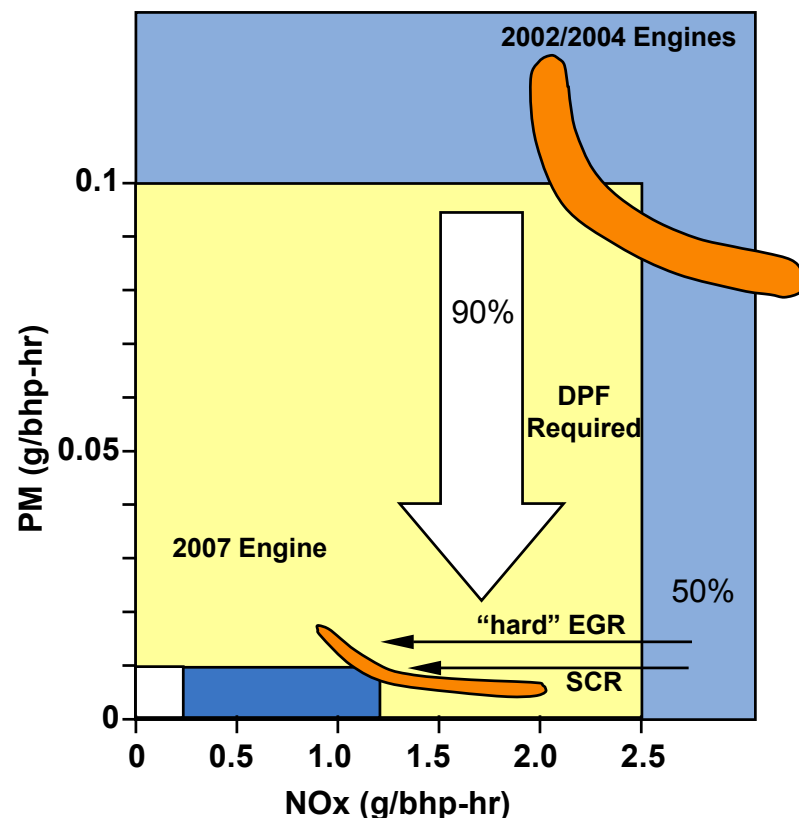
Ultra Low Diesel Fuel

- Ultra low sulfur (S <15 ppm) will be required in 2006 timeframe
- Small PM reduction (15%)
- Technology enabler for DPFs and NOx aftertreatment like lean NOx catalysts or NOx adsorbers
- California also requires low aromatics to get NOx reduction in existing fleet
 - equivalent fuel formulations also acceptable
- Other diesel fuel formulations are also being introduced
 - emulsified fuels like PuriNOx
 - ethanol blends with diesel called E-Diesel
 - biodiesel either as blend or use neat



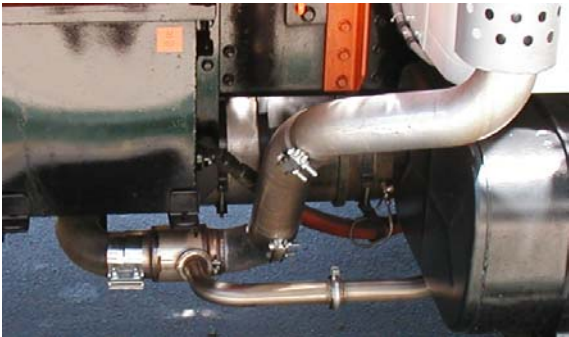
Diesel Engines Meeting 2007 Standards

- Ultra low sulfur (S <15 ppm) will be required in 2006 timeframe
- Active regeneration diesel particulate filters will be needed
- Two NO_x control options were considered
 - “Hard” Exhaust Gas Recirculation (EGR)
 - Selective Catalytic Reduction (SCR) using urea as reductant
- Engine Manufacturers will predominately use EGR in 2007 engines



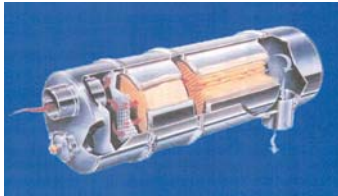
Tradeoffs of NOx control for 2007

High Pressure EGR Engine



Low Pressure EGR

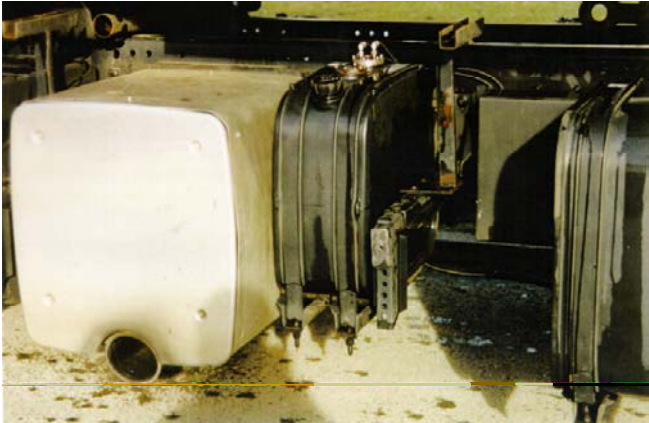
Diesel Particulate Filters



Johnson Matthey CRT



Engelhard DPX

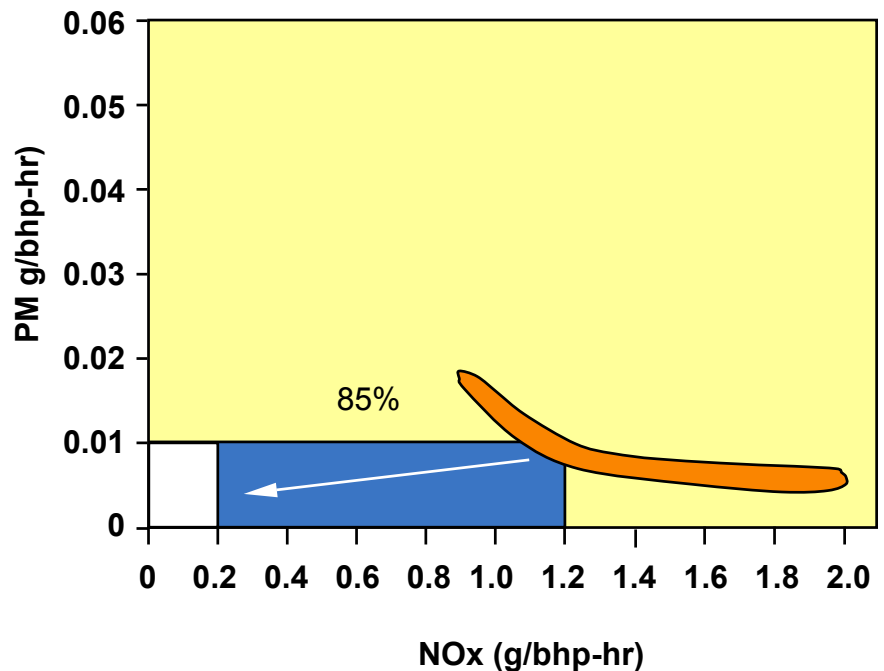


SCR Catalyst and Urea Storage Tank



Diesel engine meeting 2010 standards

- ULSD fuel
- Active DFP
- Integrated engine, DFP, NOx Control System
 - SCR
 - Lean NOx catalyst
 - NOx adsorbers
- HCCI with variable valve timing and integrated aftertreatment



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Comparison of 2007/2010 engine technologies to diesel engine meeting 1998 standards of 4 g/bhp-hr NOx and 0.1 g/bhp-hr PM

Effects on Fuel Consumption

- Diesel Engines
 - DPF Small reductions
 - EGR 6 to 10% reduction
 - SCR* 2 to 3% reduction
 - Lean NOx Catalyst, NOx Adsorber 2 to 6% reduction
- Natural Gas Engines
 - Spark ignited LB Oxidation Catalyst 20% reduction
 - SCR 2-3% reduction
 - HPDI 0%
 - DFP Small reduction
 - SCR 2-3% reduction

Effects on Costs

- Diesel Engines
 - ULSD \$0.05/gallon increase
 - Lower mpg
 - Increased first cost for integrated engine and emission controls
- Natural Gas Engines
 - No added cost of fuel
 - Lower mpg but depends on fuel cost price differences
 - Increased first costs for integrated engine and emission controls

*Assumes Urea price comparable to diesel

Evaluating technologies over vehicle life will be even more important in making buying decisions

- Life cycle costs of competing technologies
 - First costs
 - Fuel costs
 - Other O&M costs
 - Infrastructure costs (if not included in fuel costs)
- Other considerations
 - Upstream emission benefits of natural gas
 - Greenhouse gas emissions benefits
 - Ground and water pollution benefits
 - Petroleum reduction benefits

Thank You For Your Attention



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