

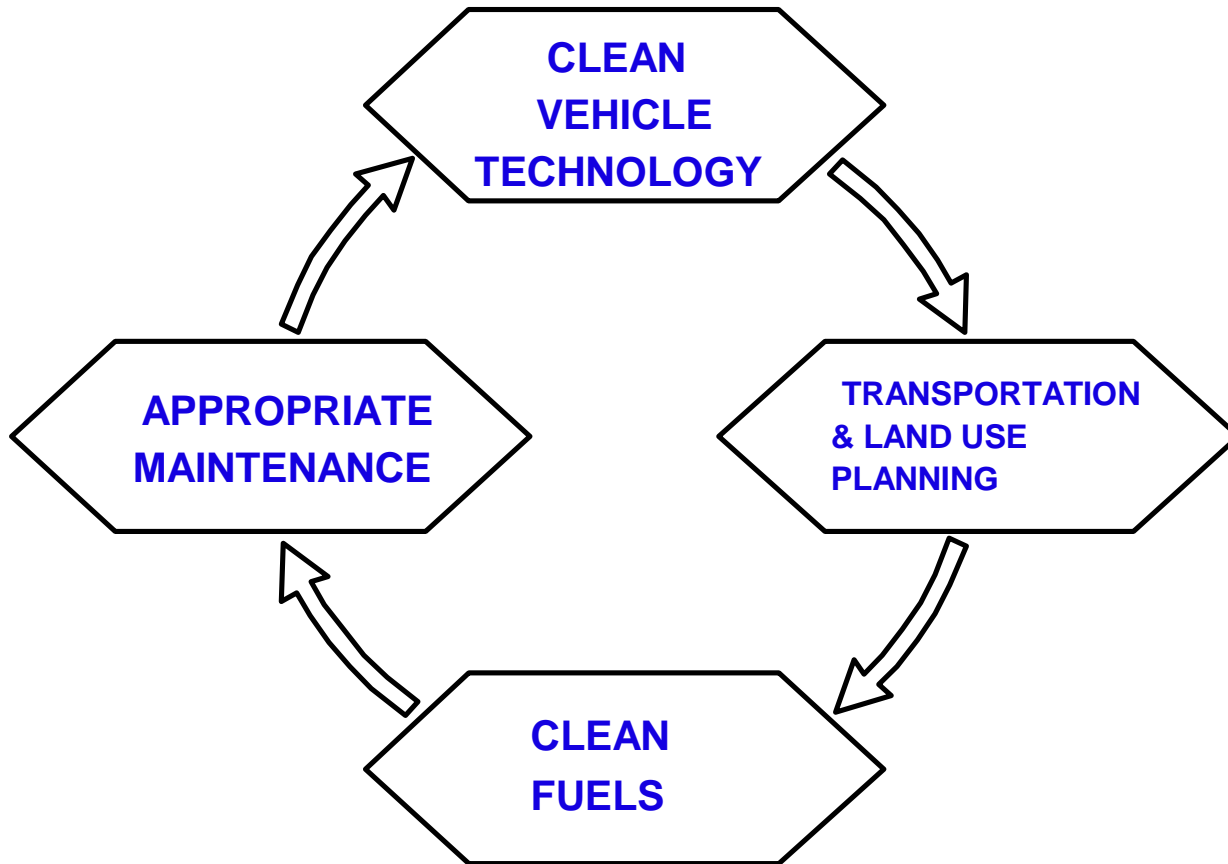
Clean Fuels - A Critical Role in Clean Air

Understanding Urban Air Pollution
and the Role of Diesel Exhaust

Delhi, India - November 6-11 2000



ELEMENTS OF A COMPREHENSIVE VEHICLE POLLUTION CONTROL STRATEGY

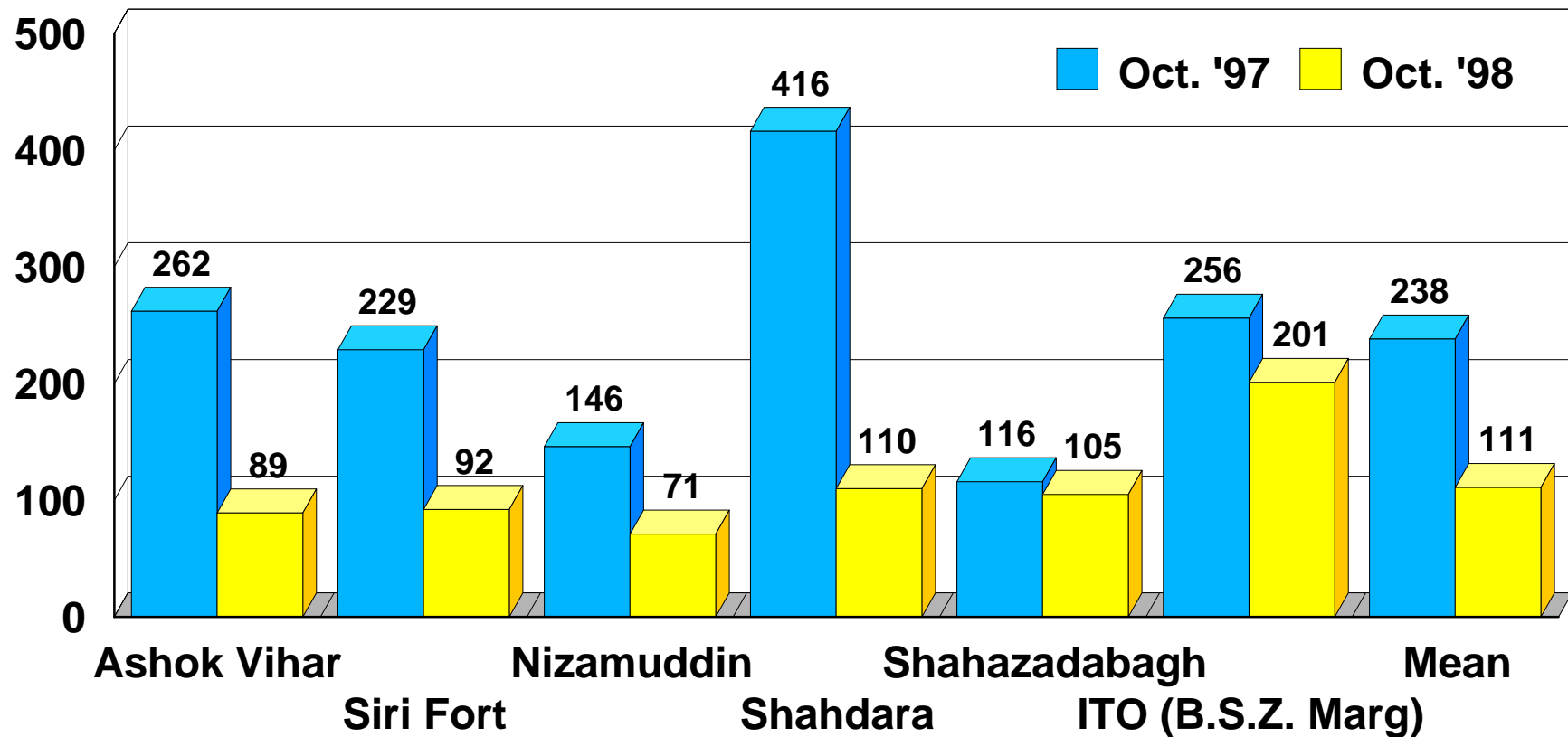


Why Are Fuels Important?

- Fuel Constituents Directly Affect Emissions
- Fuel Changes Can Immediately Impact on Emissions/Air Quality
- Fuel Composition Can Enable/Disable Pollution Control Technology

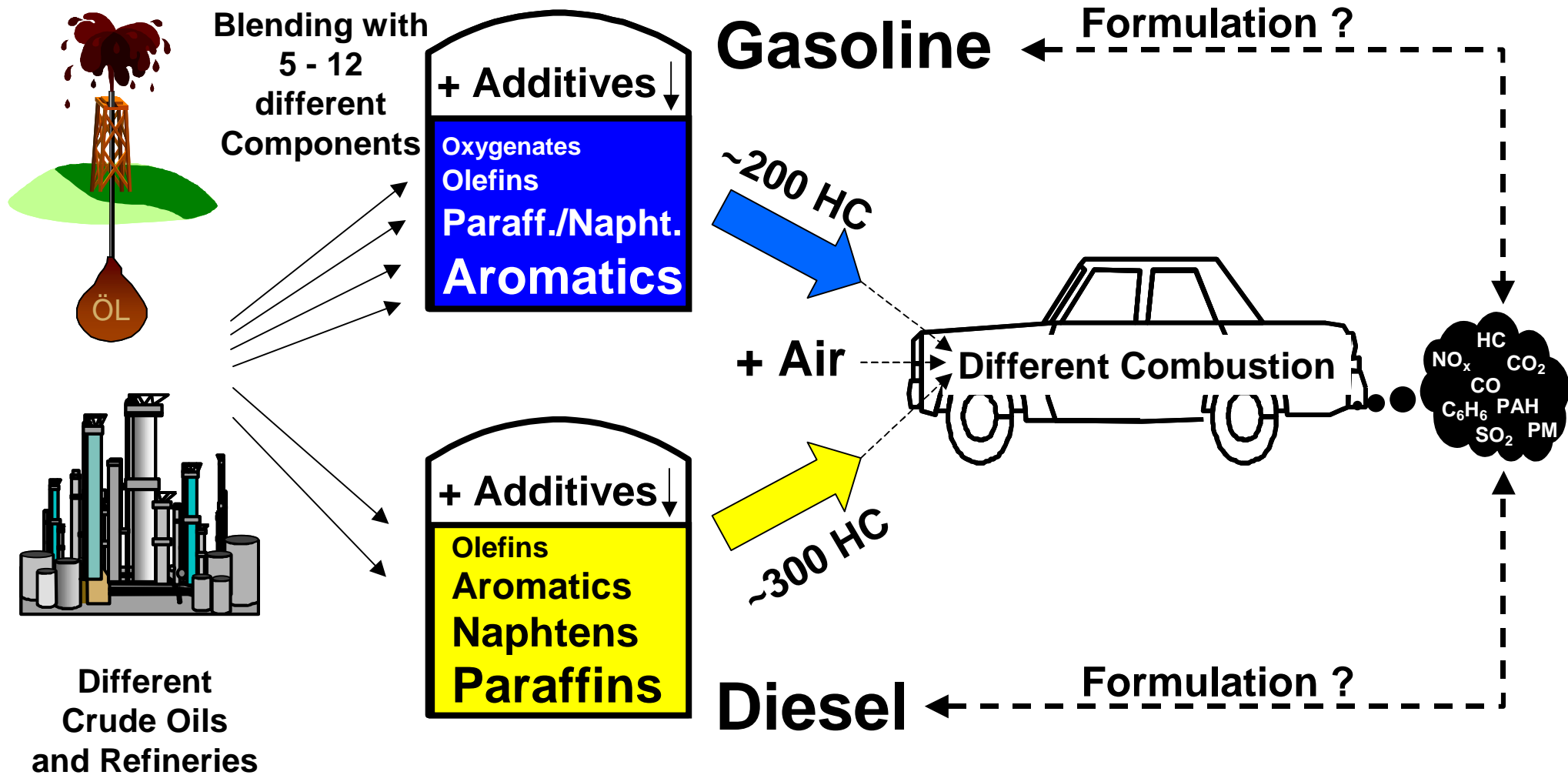
Ambient Particulate Lead in Delhi (Pre and Post Unleaded Petrol)

Nanogram per cubic Meter

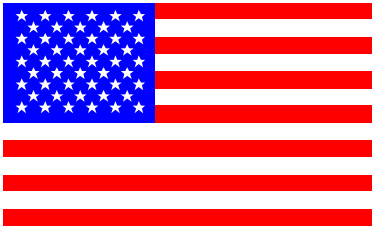


Avg. Reduction 53%
Source: CPCB

Different Automotive Fuels = Different Exhaust Emissions



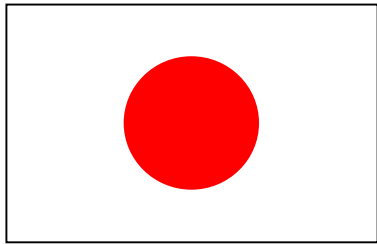
World-wide Specifications for Cleaner Burning Fuels



USA

US-Federal ➤ RFG Phase 1 / 2 / 3

California ➤ Ca RFG Phase 1 / 2 / 3



Japan

Quality Assurance Law

➤ JSI-Standards Gasoline / Gasoil



Europe

➤ EU-Directive 1998 / 70 EG (fuels 2000/2005)



World-wide Automobile Manufacturers


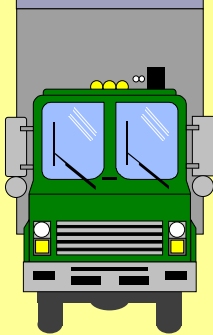
Requirements on Fuel Quality after Year 2000 (Extract)

Requirement	EU-Fuel-Directive		WW FC Categorie 4
	2000 (Euro 3)	2005 (Euro 4)	
Gasoline			
Vapour Pressure (Summer) max kPa	60	60 (?)	60
Benzene max Vol.%	1	1	1
Aromatics max Vol.%	42	35	35
Sulphur max ppm	150 (50/10)*	50	10
Diesel Fuel			
Cetan Number min	51	51 (?)	55
Density max kg/m ³	845	845 (?)	820 - 840
Aromatics max Vol.%	-	-	15
Sulphur max ppm	350	50	10

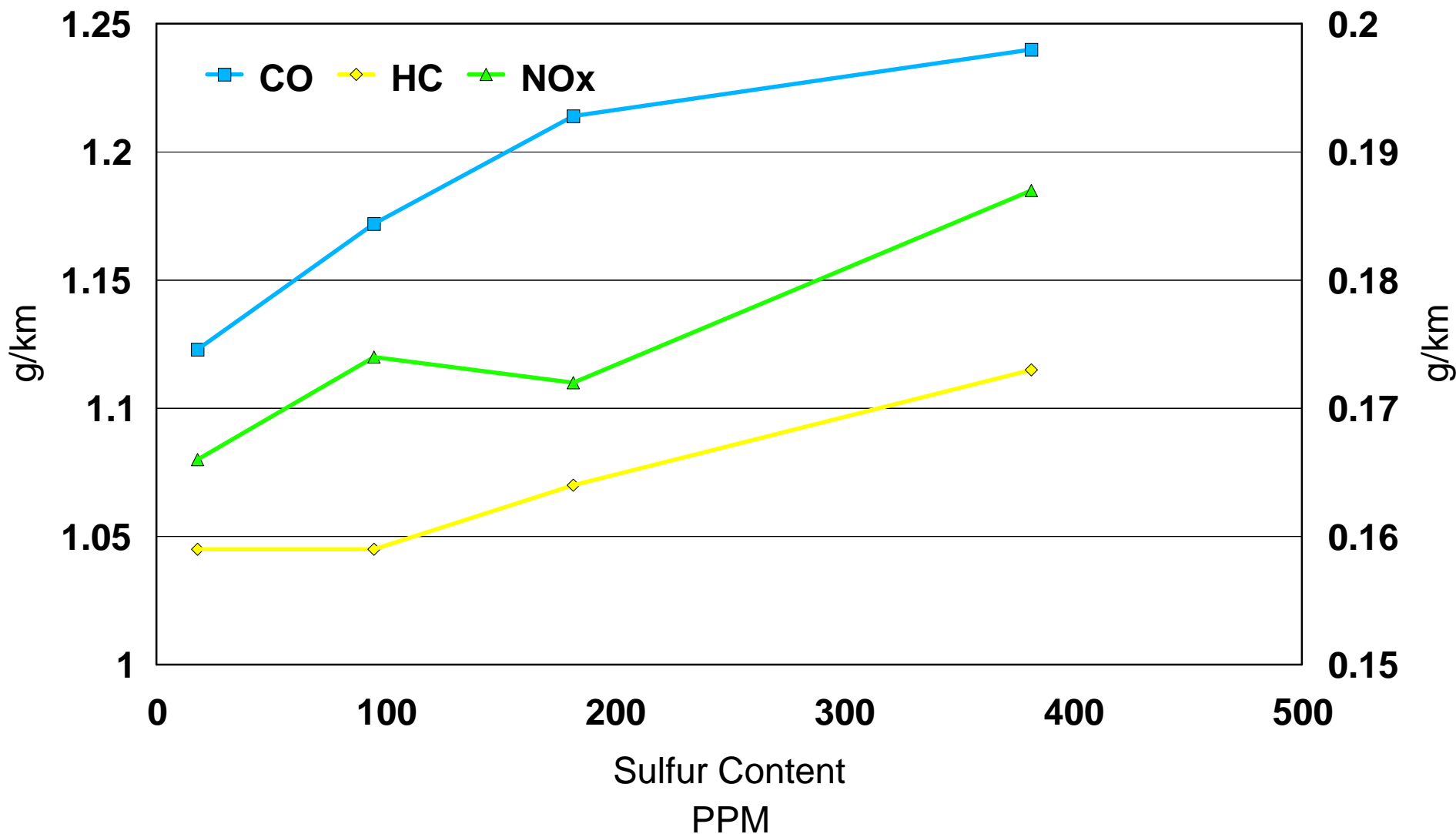
 Demand for new engine- or exhaust-after-treatment

*) In Germany voluntary for SuperPlus

EPEFE - Test - Program

Fuels		Vehicles		
12 Test Gasolines	11 Diesel Fuels	Gasoline LDV	Diesel LDV	HDV
Sulphur 370 → 17 ppm	Density 857 → 827 kg/m ³	16 New European Test Cycle 	19 	5 Test Cycle ECE R 49 (88/77/EWG) 
Aromatics 52 → 13 Vol.%	Poly-Aromatics 7,8 → 1,0 Gew.%			
Mid-Range Distillation (E100) 36 → 65 Vol.%	Cetan Number 49,5 → 59,1			
	Back End Distillation (T95) 372 → 328 °C			
More influences fixed with available results				

Impact of Gasoline Sulfur Levels on Emissions



Changes in Gasoline Qualities Have Effects on Emissions

Fuel-change \ Emissions	Regulated			Unregulated		
	CO	HC	NOx	Benzene	Butadiene	Aldehyde
Reduction of ...						
Benzene	o	o	o	++	o	o
Aromatics	++	++	-	+++	---	---
Olefins	o	o	o	o	++	o
Sulphur	+	+	+	o	o	o
Vapour pressure	o	o/+	o	o	o	o
Adjustment Volatility	+	+++	-	++	?	?
Addition Oxygenates	++	+	o	o	o	--

Effect

+	-	} 2-10 % } 10-20 % } > 20 %	Improvement or Deterioration	o	} ± 2 %
++	--				
+++	---				

Changes in Diesel Fuel Have Effects on Emissions

Diesel fuel-change	Vehicle - Emissions LDV / HDV			
	CO	HC	NOx	Particulates
Reduction of ... Sulphur	o	o	? / o	+ / +++
Density	+++ / -	+++ / --	o / +	+++ / o
Poly-Aromatics	- / o	- / +	+ / o	+
Back End Distillation (T95)	o / -	- / ---	- / o	+ / o
Increase of ... Cetan Number	+++ / +++	+++ / +	o	- / o

Effect

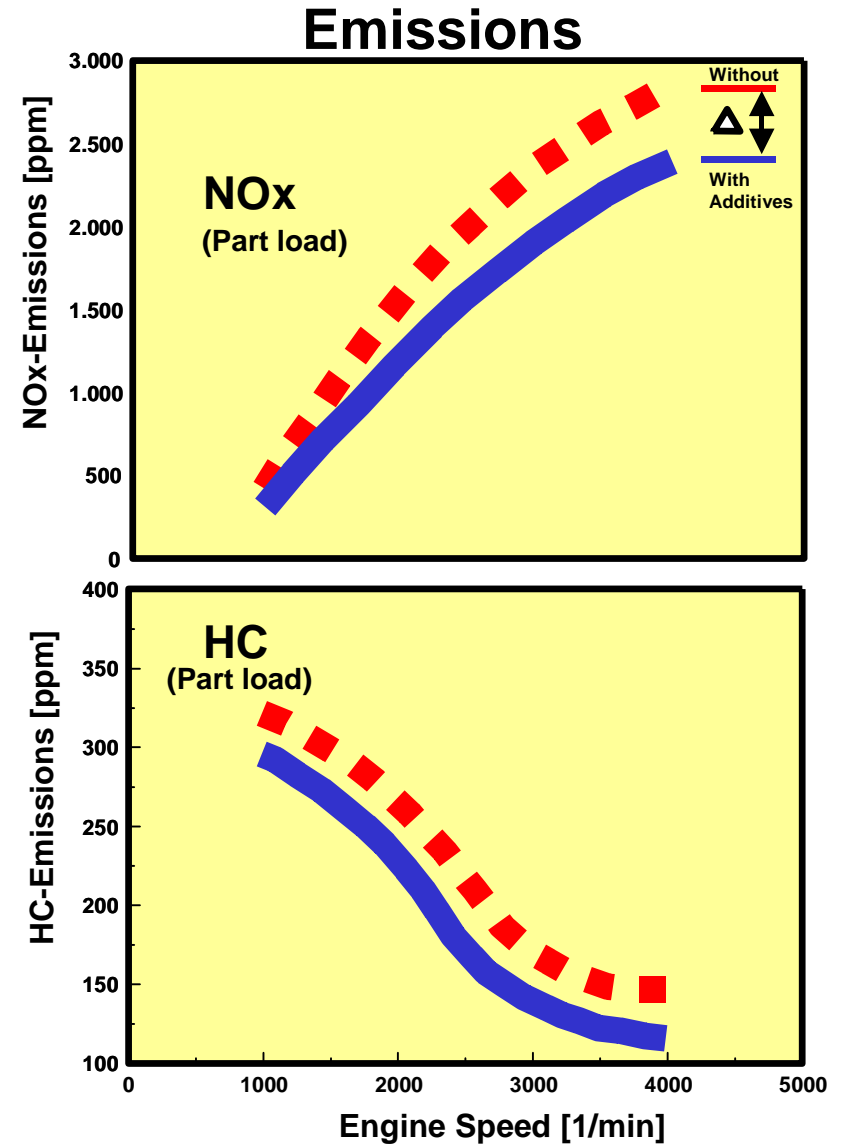
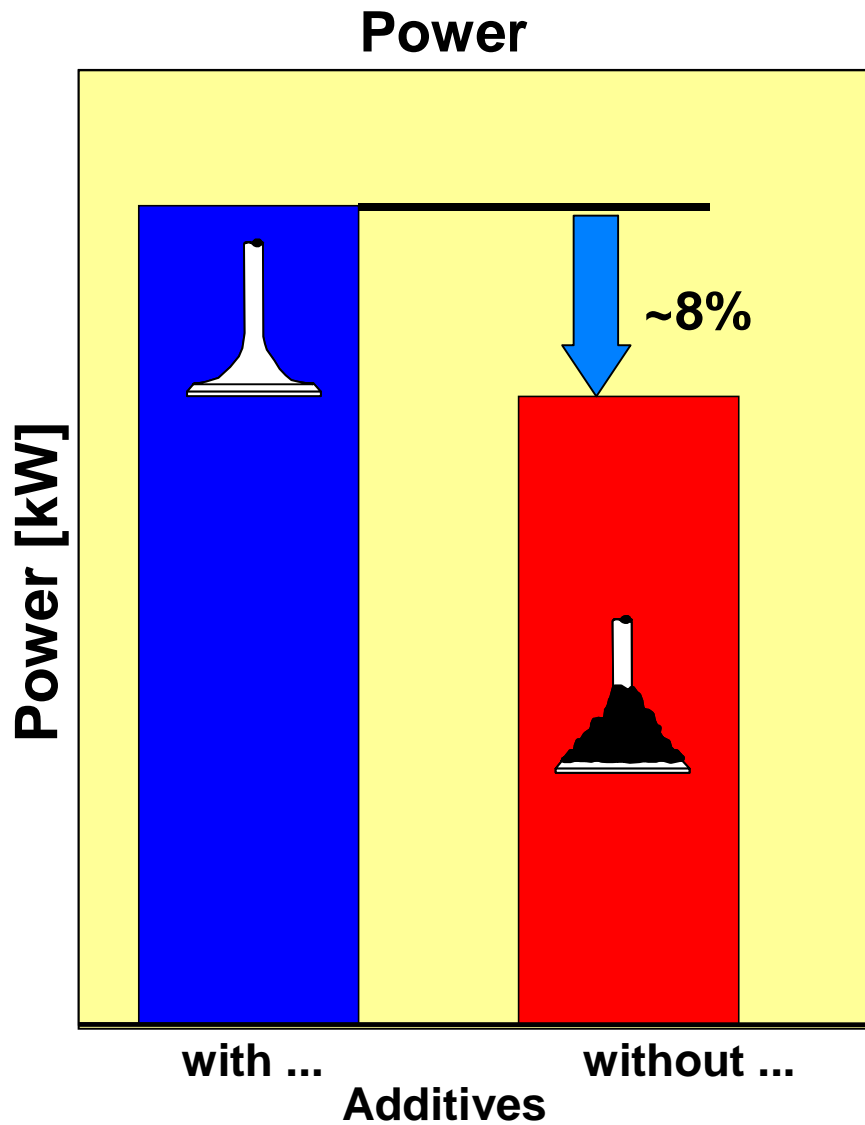
+	-	}
++	--	
+++	---	

2-10 %
10-20 %
> 20 %

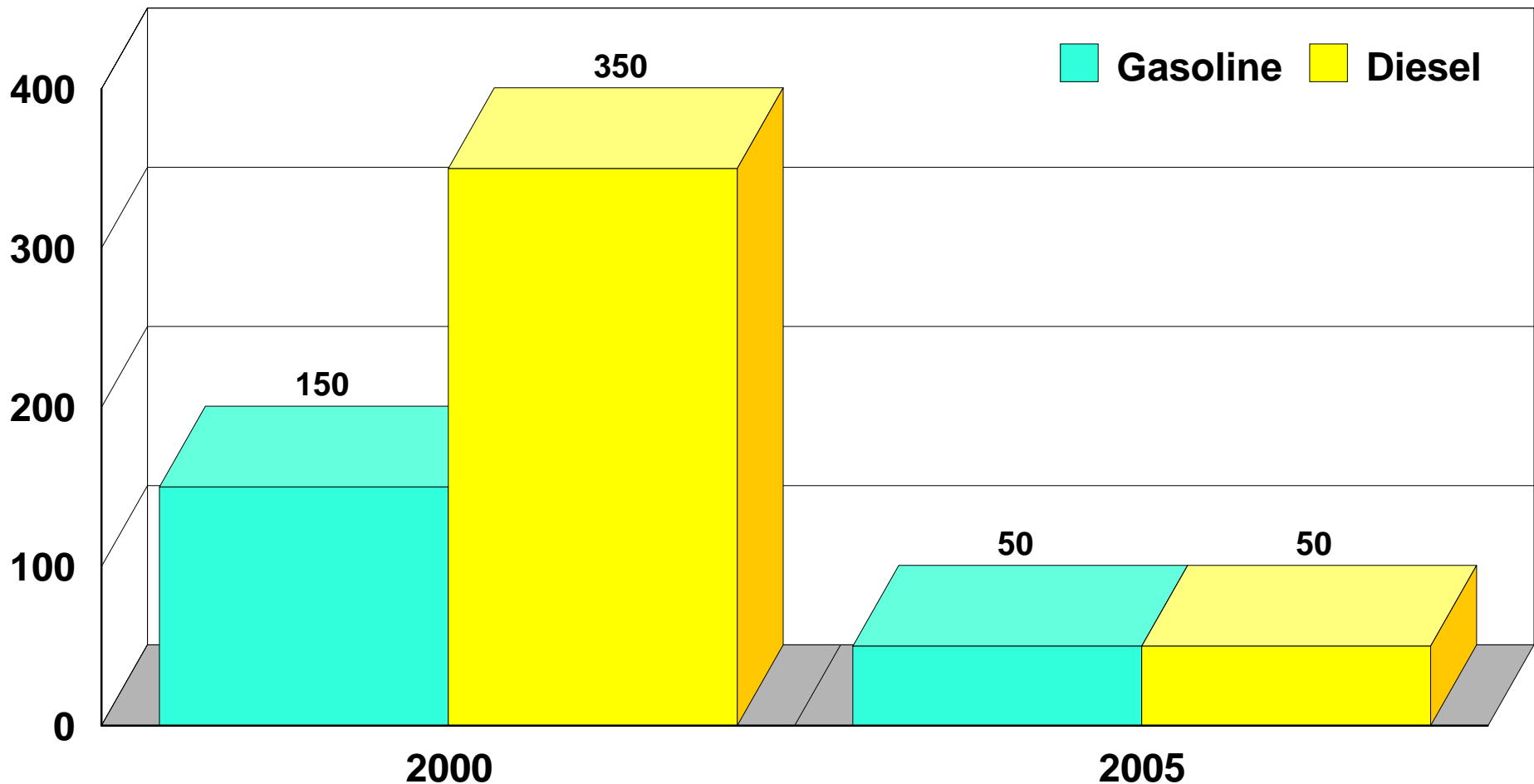
Improvement
or
Deterioration

o ± 2 %

Influence of Inlet Valve Deposits on Engine Power and Emissions



Maximum Fuel Sulfur Limits Adopted For Europe (PPM)



2005 Limits Can Be Encouraged From 2000 With With Fiscal Incentives

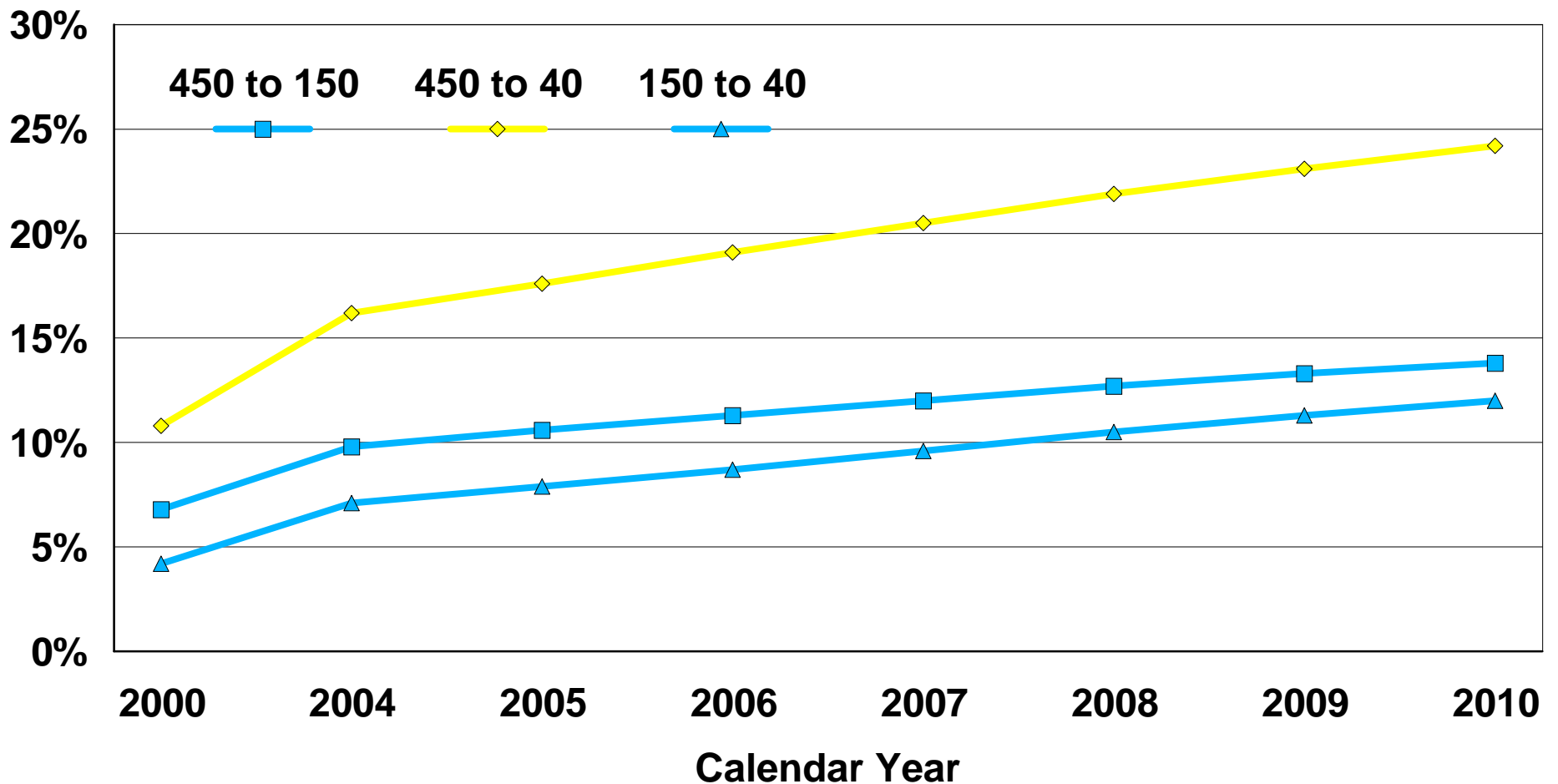
Low Sulfur Gasoline

- Sulfur Poisons The Catalyst
- Impact is Irreversible
- Future Low Emissions Technologies Even More Sensitive
- CO, HC & NO_x Emissions All Improve With Low Sulfur Gasoline

Impact of Low Sulfur Gasoline on Emissions

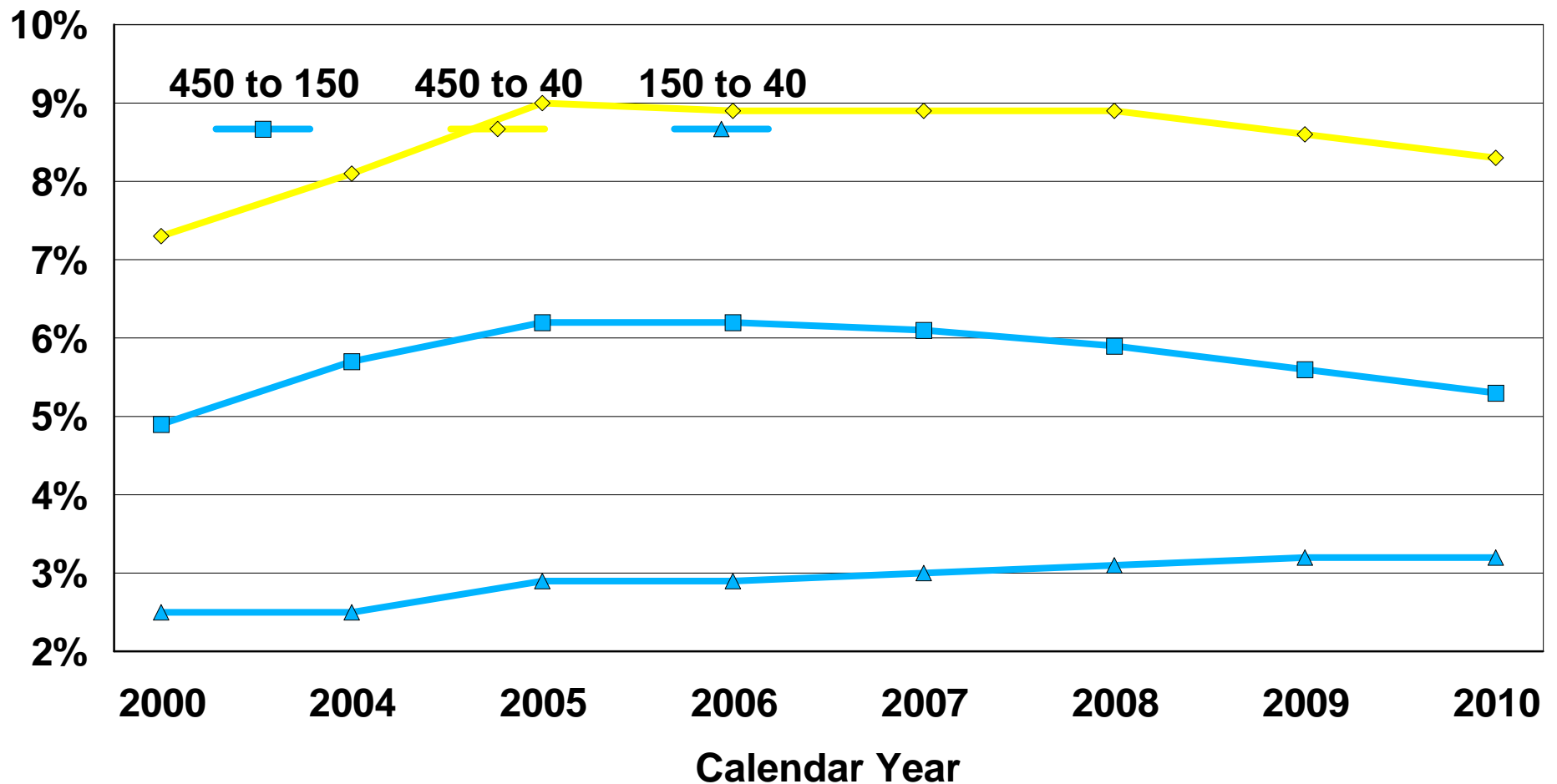
Percent Reduction in Light Duty Vehicle Emissions

NOx



Impact of Low Sulfur Gasoline on Emissions

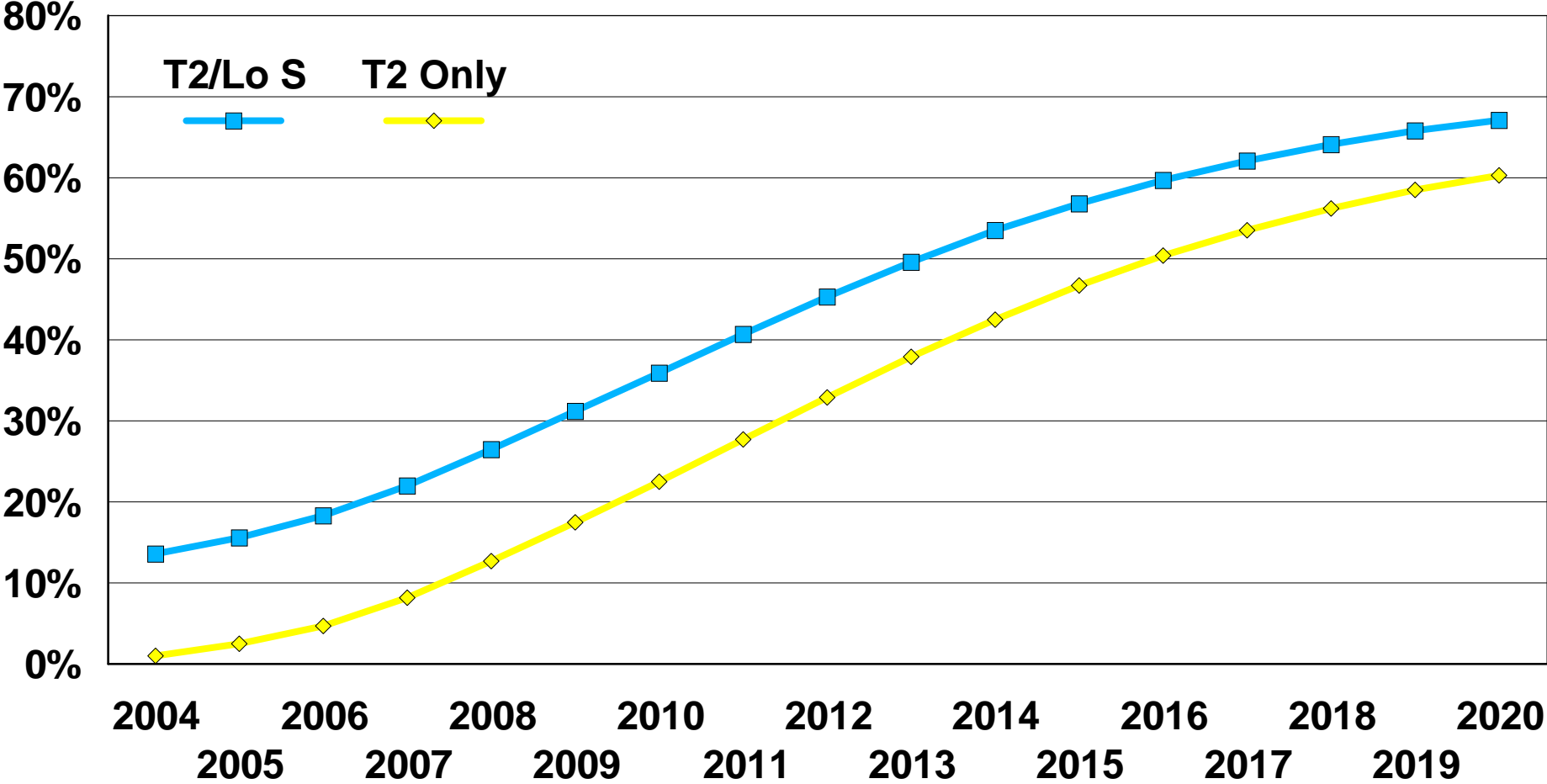
Percent Reduction in Light Duty Vehicle Emissions
NMHC



Impact of Sulfur on Vehicle Emissions

Percent Reduction in Light Duty Vehicle Emissions

NOx

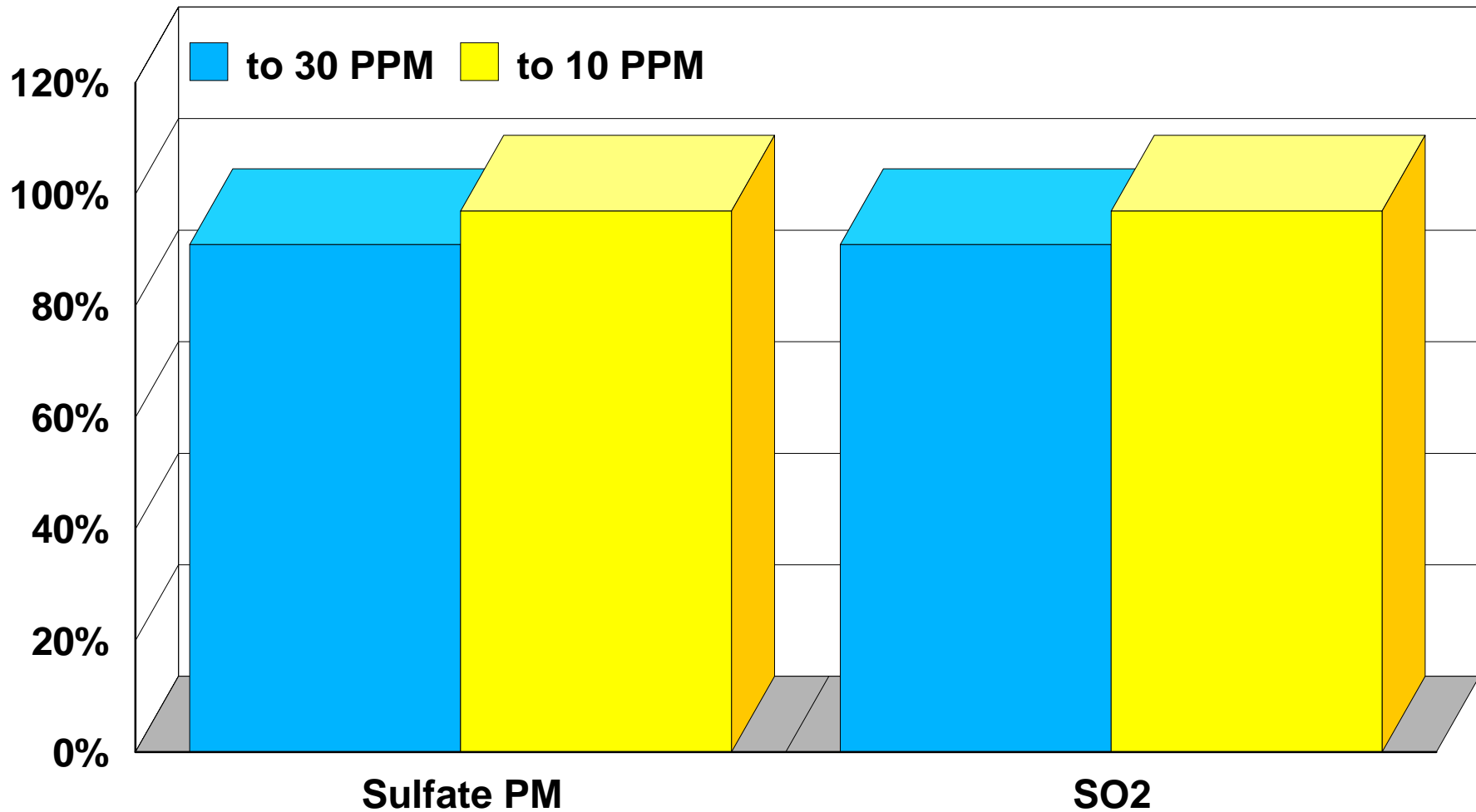


Need For Low Sulfur Diesel Fuel

- Lower Sulfur Lowers Direct PM Emissions and SO₂
- Lower Sulfur Allows the Use of Some Advanced Diesel NO_x/PM Control Technologies
- Lower Sulfur Improves Performance of Other Advanced Technologies

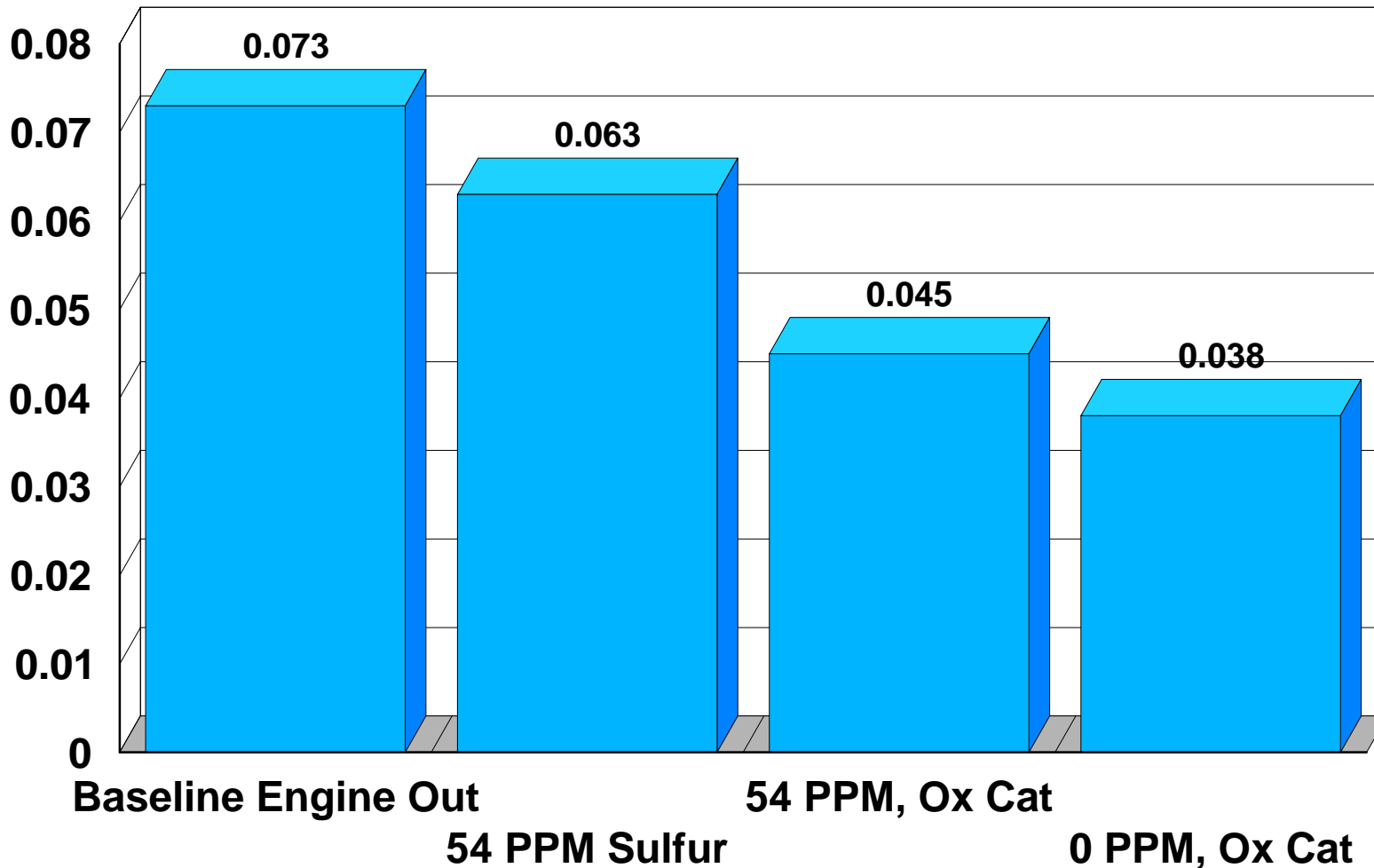
Impact of Lower Sulfur Fuel on Sulfate & Sulfur Dioxide Emissions

Percent Reduction in Emissions

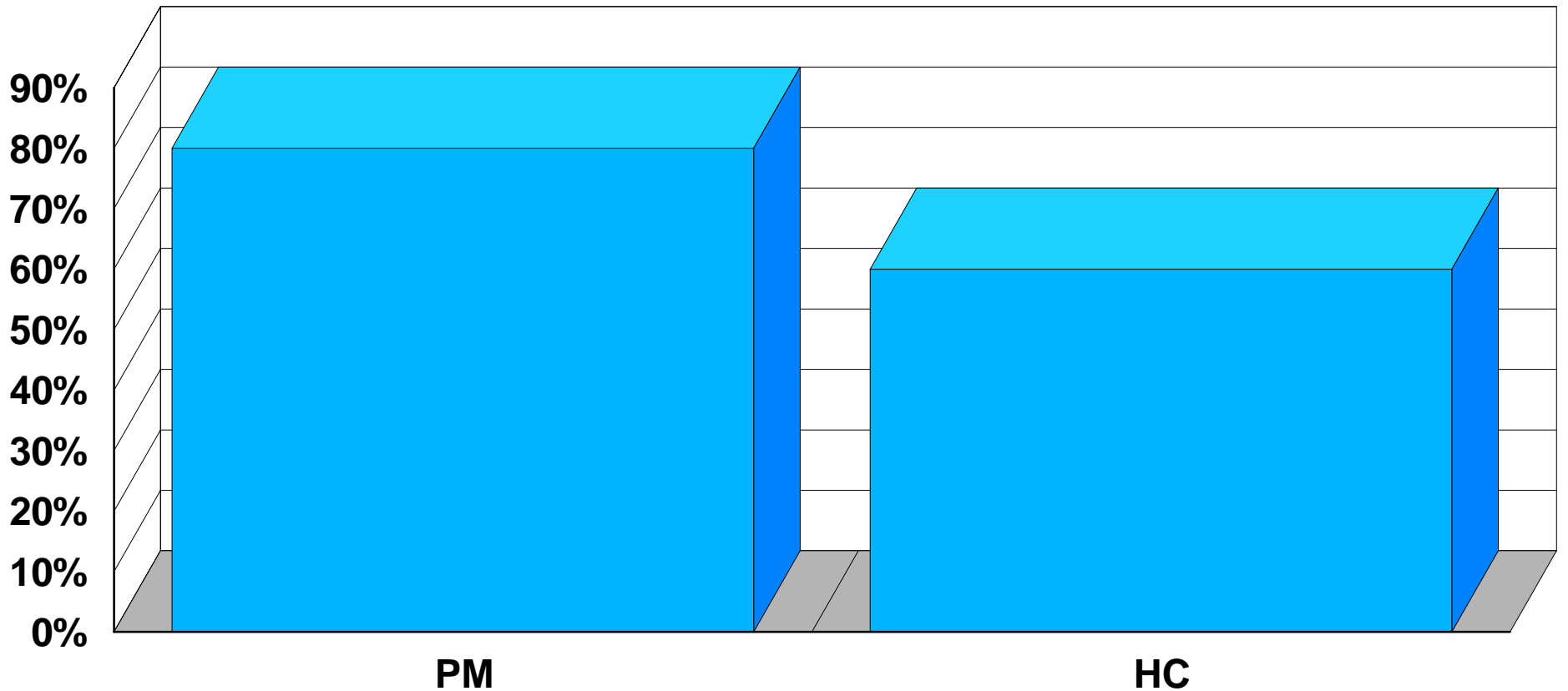


Impact of Low Sulfur Fuel on PM Emissions

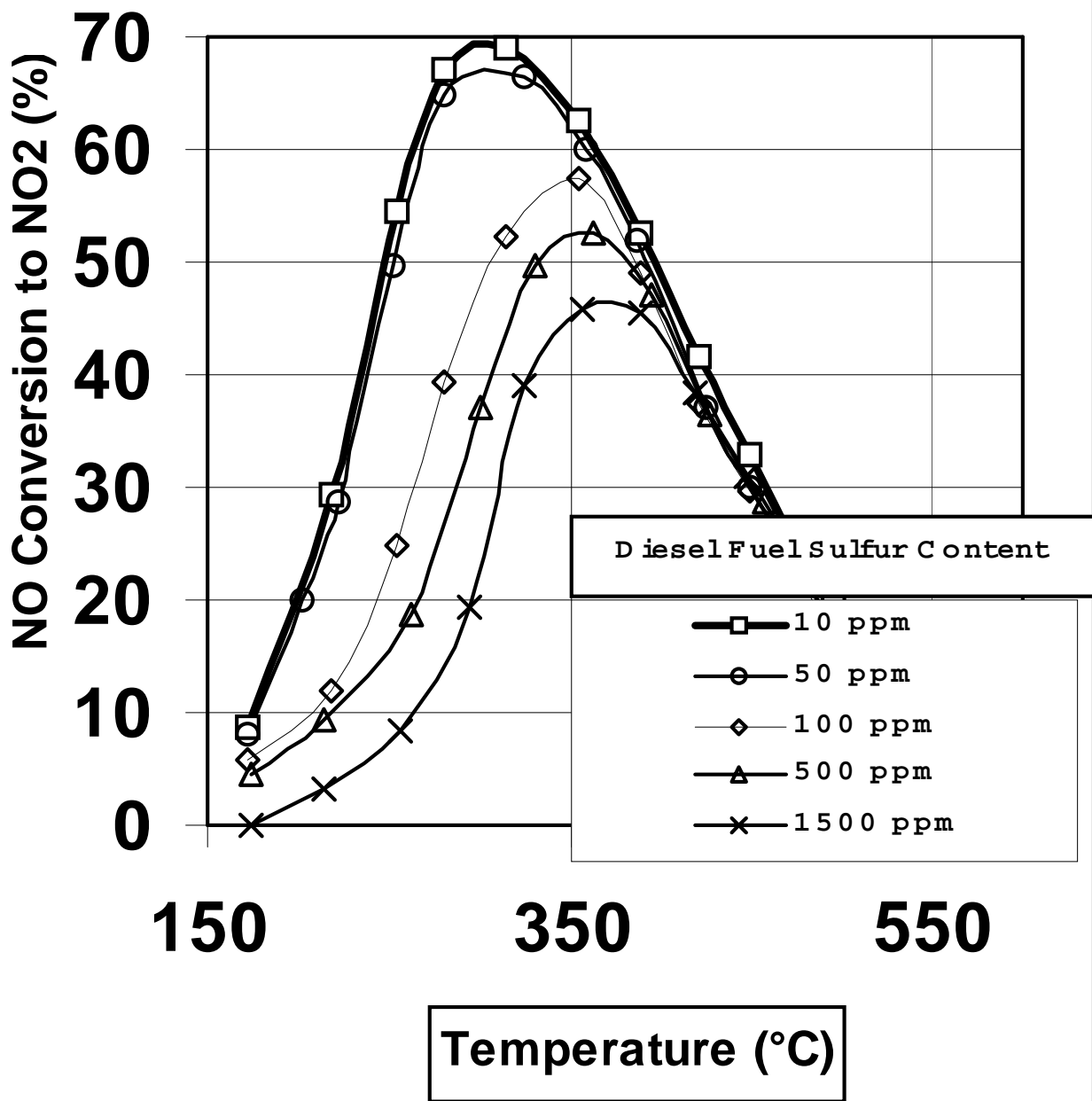
PM Emissions (g/bhp-hr)



Swedish Retrofit Requirements Stockholm, Goteborg & Malmo

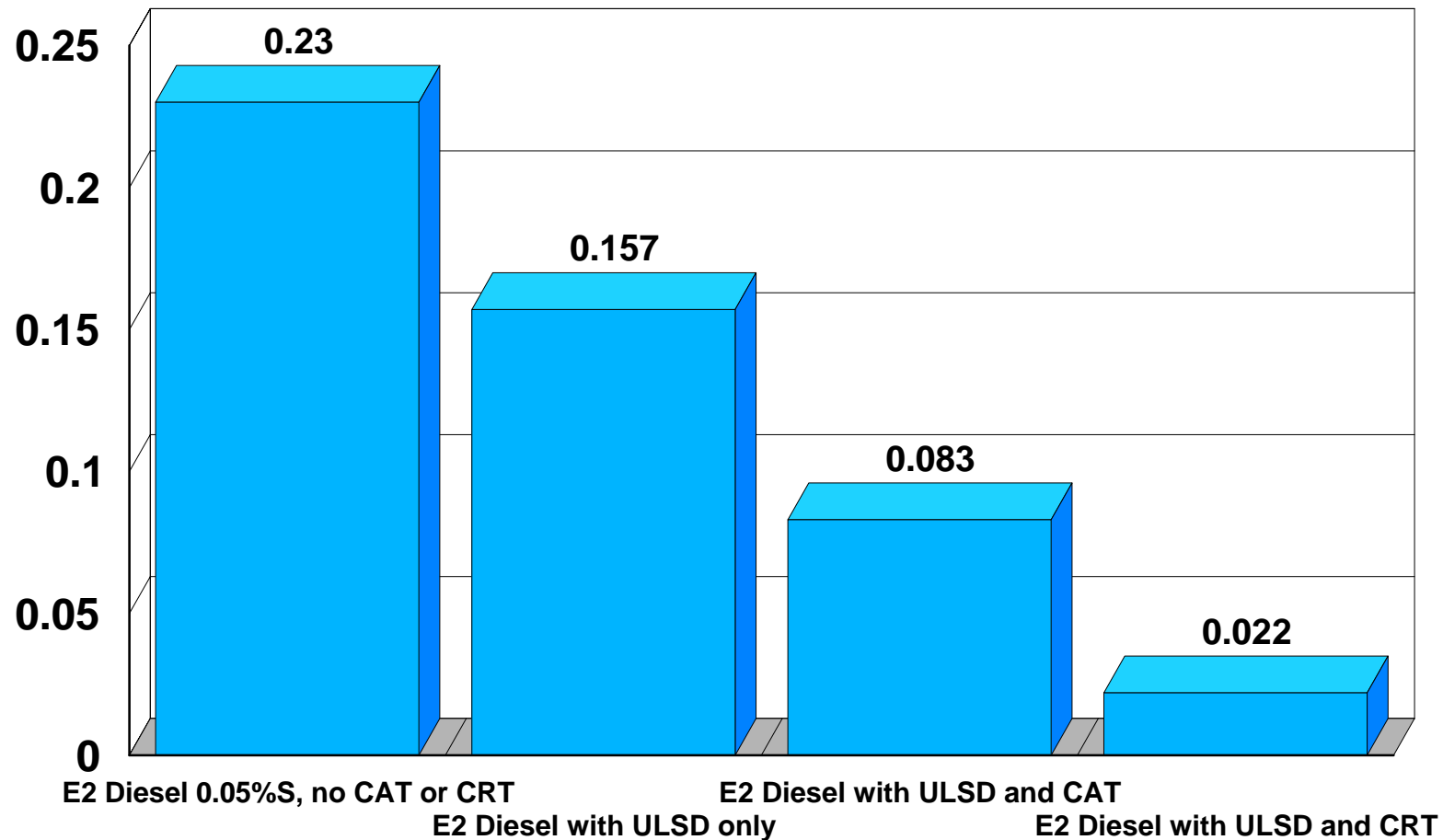


**No Increase in NOx, Noise
Over 10 Years Old
Requires Ultra Low S Fuel**



Impact of Different Treatments on London Bus Emissions

PM-10
Grams/Kilometer



Sensitivity of Diesel NOx Control Technologies

Technology	Sulfur Sensitivity
Cooled EGR	Durability Questions
NOx Storage Catalyst	Intolerant
Lean NOx Catalyst	Very Sensitive
SCR	Sulfur Tolerant

Conclusions - Why Lower Sulfur in Gasoline?

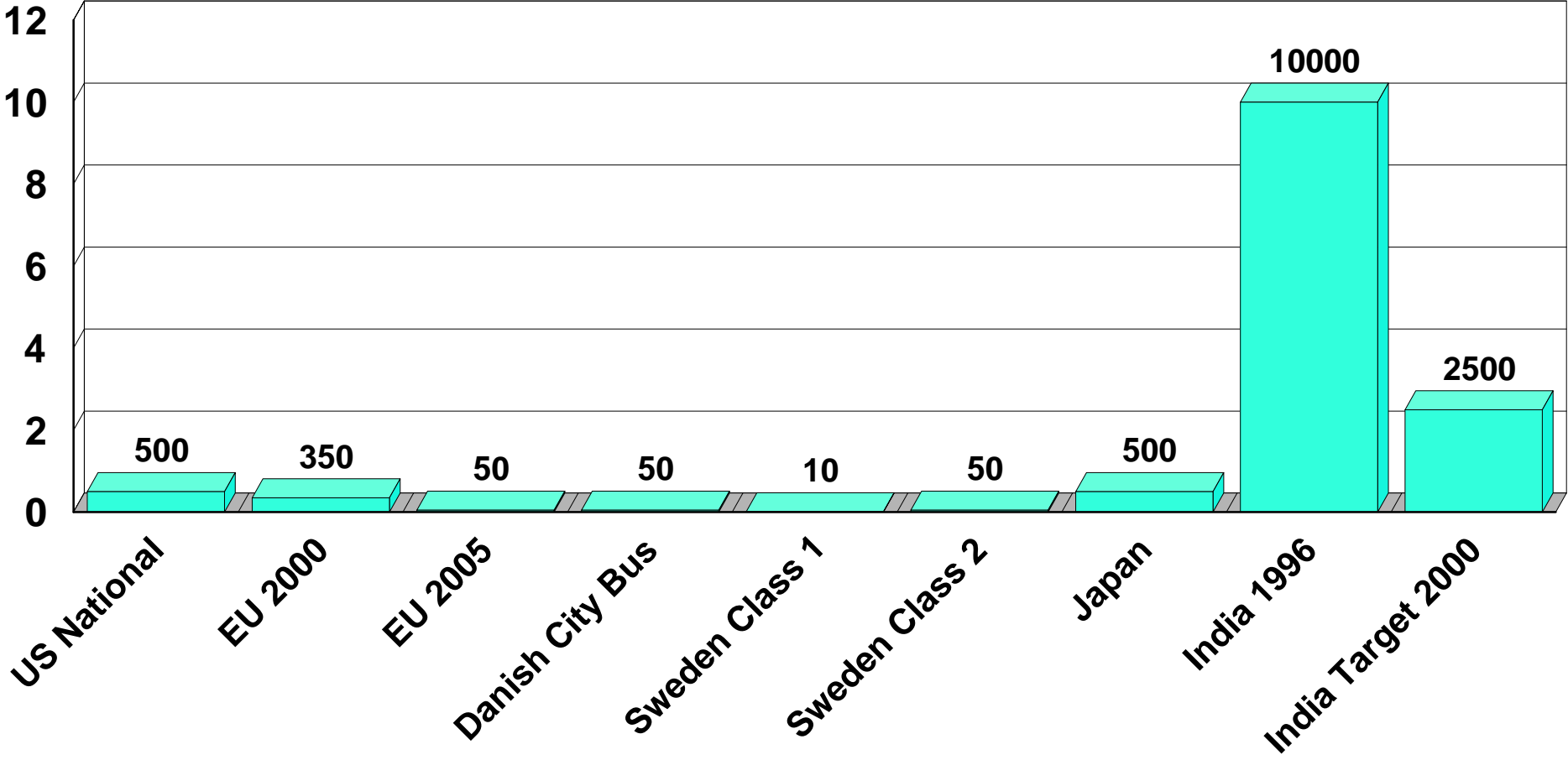
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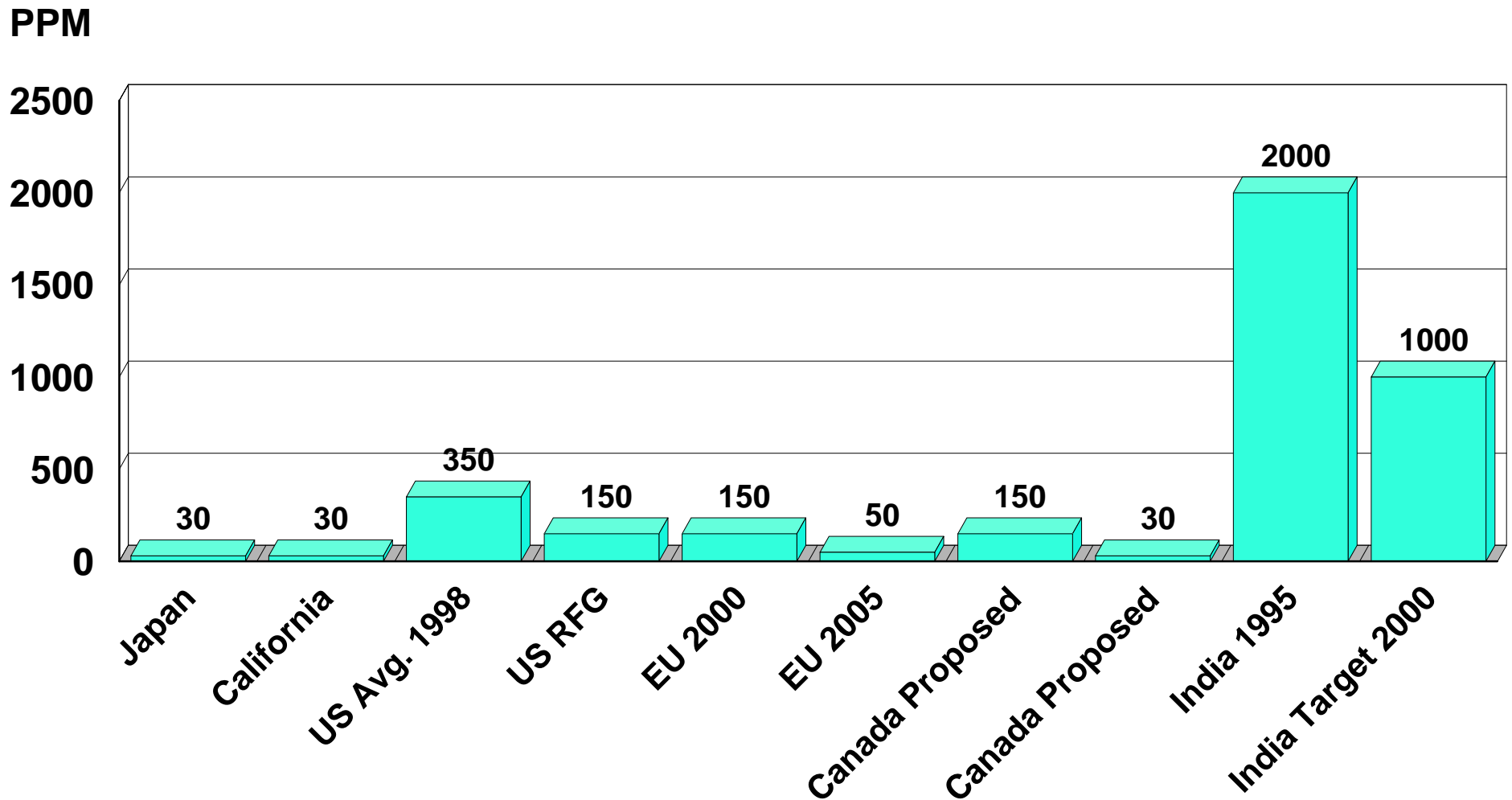
- Lower Direct Emissions of PM
- Lower Sulfur Dioxide
- More Technological Options to Lower Diesel PM & NOx
- Greater Potential to Lower:
 - ▶ PM Mass
 - ▶ PM Number
 - ▶ PM Toxicity

Diesel Fuel Sulfur Specifications

PPM



Sulfur Levels in Gasoline



Benzene in Gasoline

- US Federal - 1.0%
- California - 1.0%
- Japan - 1.0% (1999)
- EU - 1.0%
- India Target 2000 - 5.0%

Fuels & Lubricants Challenges For India

- Ban Leaded Gasoline - Done
- Lower Sulfur in Diesel & Gasoline - Started
- Maximum Benzene at 1%
- PreMixed Fuel & Lube for Two Strokes
- Fuel Characteristics Posted & Enforced (No Adulteration Tolerated)

Conclusions

- Serious Pollution Control Programs Must Adopt A Comprehensive, Holistic Approach
- Fuels Should Be Improved (Incremental Progress)
 - ▶ Ban Leaded Gasoline
 - ▶ Lower Sulfur in Diesel & Gasoline
 - ▶ Maximum Benzene at 1%
 - ▶ Fuel Characteristics Should be Posted & Enforced (No Adulteration)

Conclusions (*continued*)

- Effective Enforcement is Critical
- A Strong Public Awareness Program should be Introduced

Conclusions

- Why Can't India Have EU Quality Fuel by 2005?