How To Reduce Air Pollution With Cleaner Fuels and Cleaner Vehicles

Michael P. Walsh

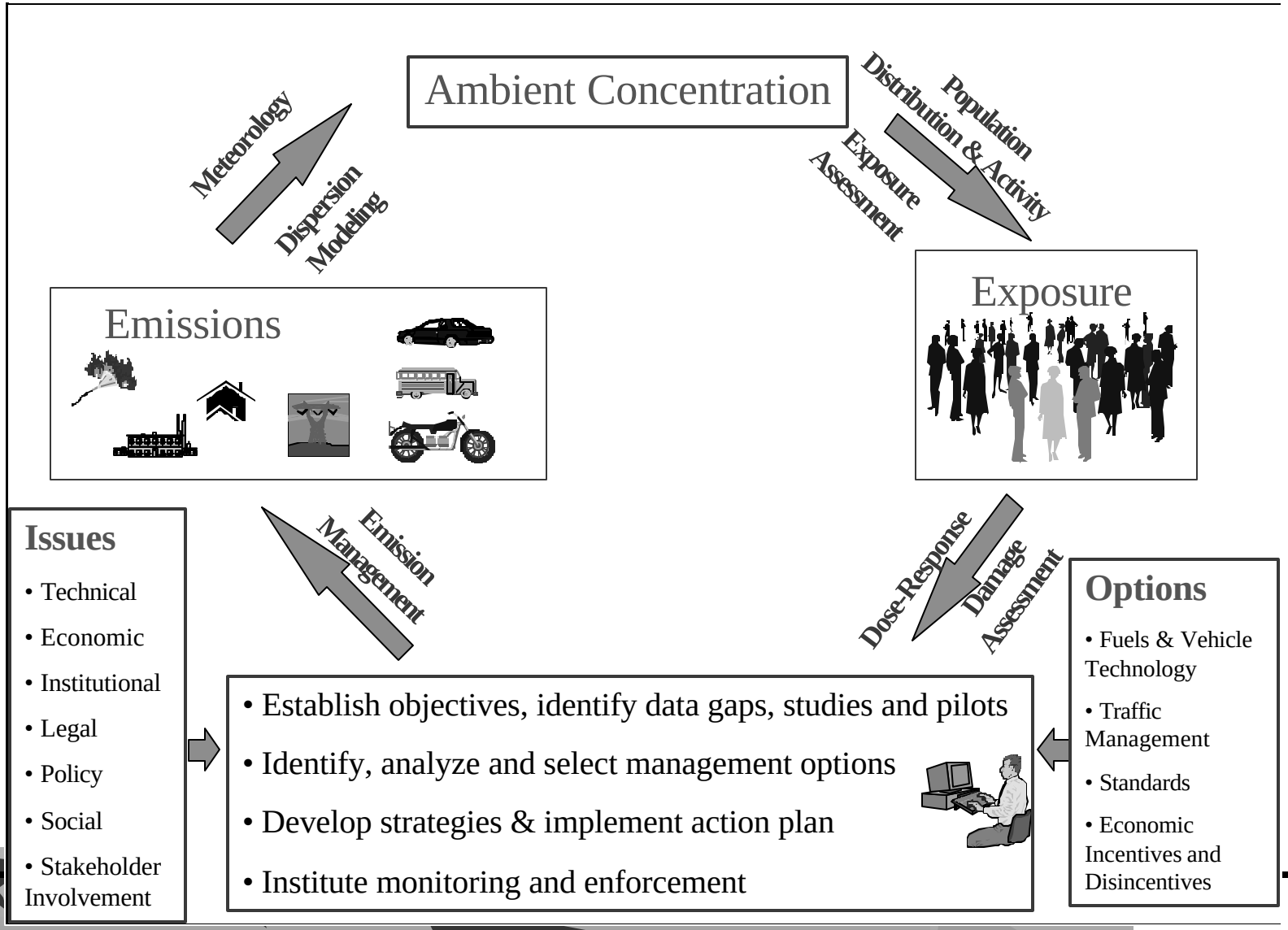
May 2006

United Nations Commission For Sustainable Development

Overview

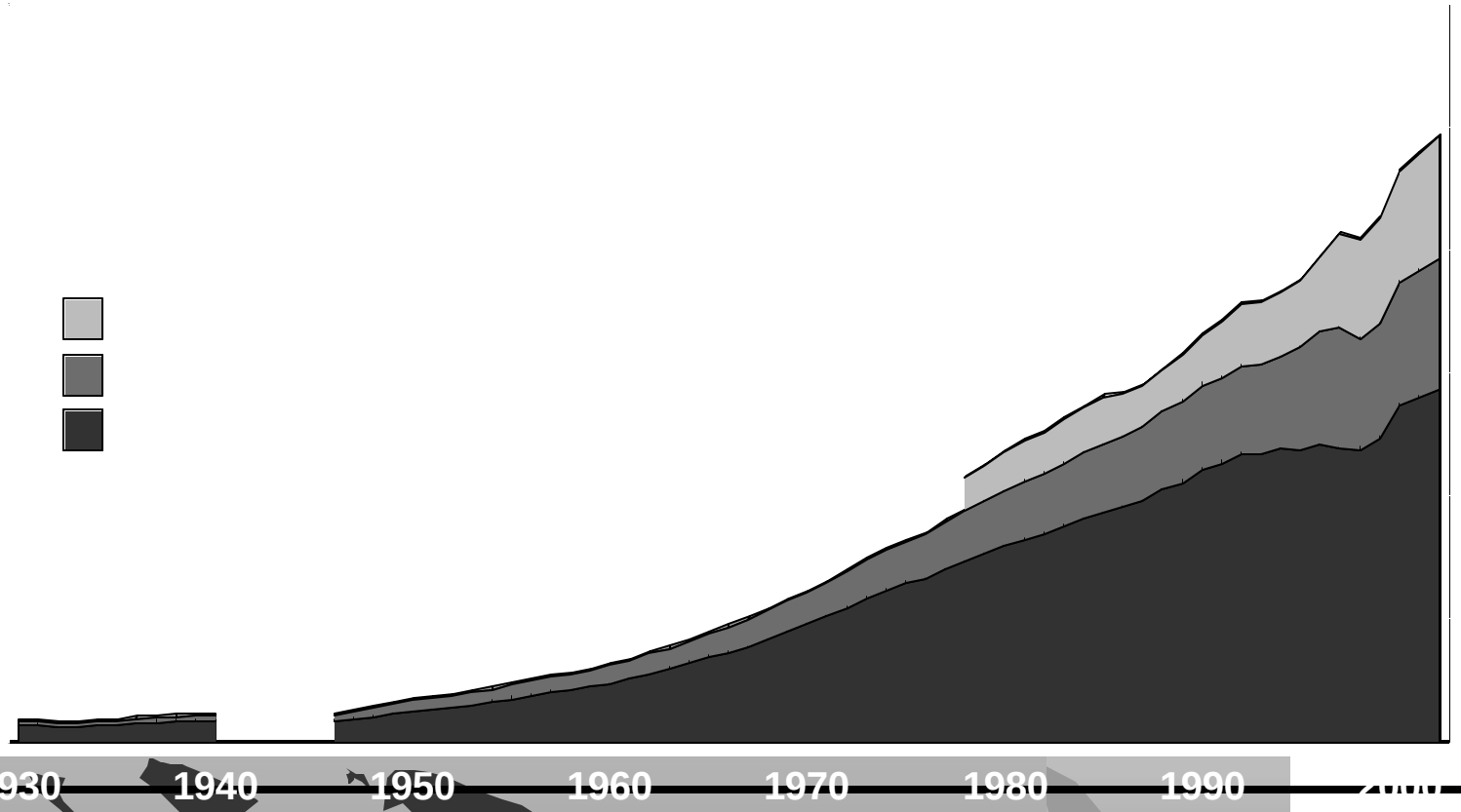
- Why We Are Concerned About Vehicle Emissions
- Clean Fuels-Clean Vehicles – A Systems Approach
- Clean Cars: New and Existing
- Clean Buses: New and Existing
- Clean Off Road Technology
- Economic Instruments
- Traffic Control

Integrated Air Quality Management Framework

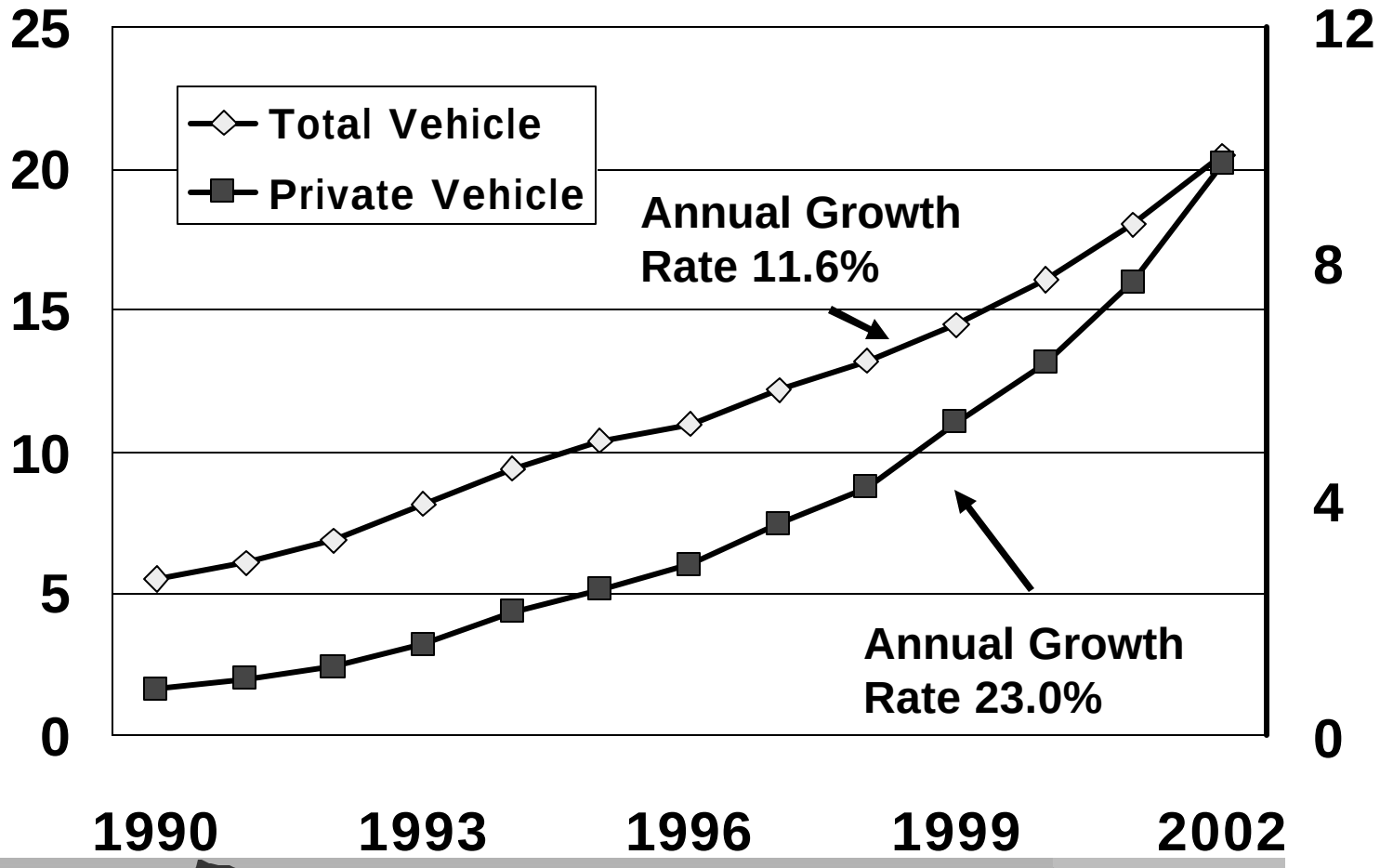


Huainan

World Motor Vehicle Population

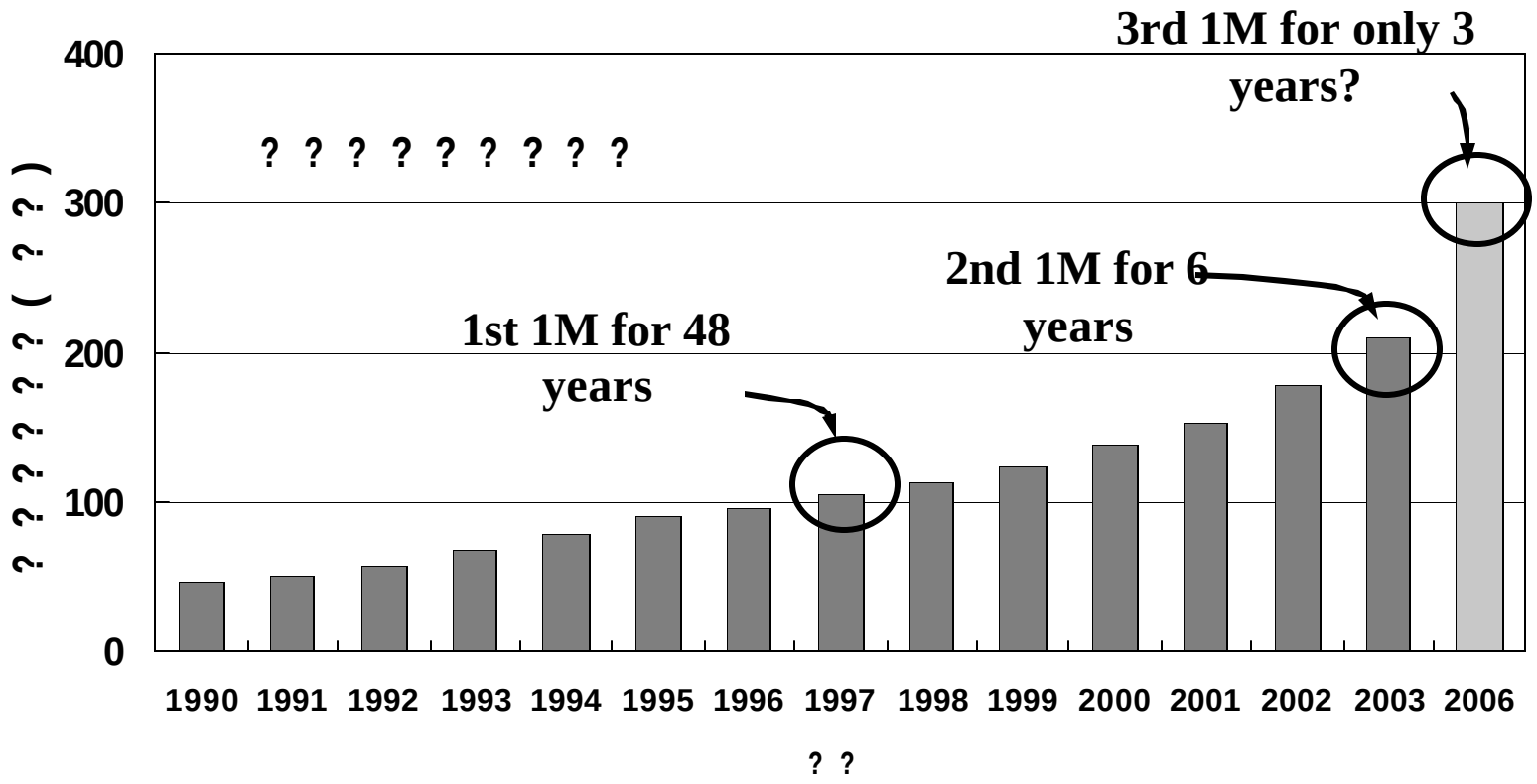


Chinese Vehicle Population Has Been Exploding (million)

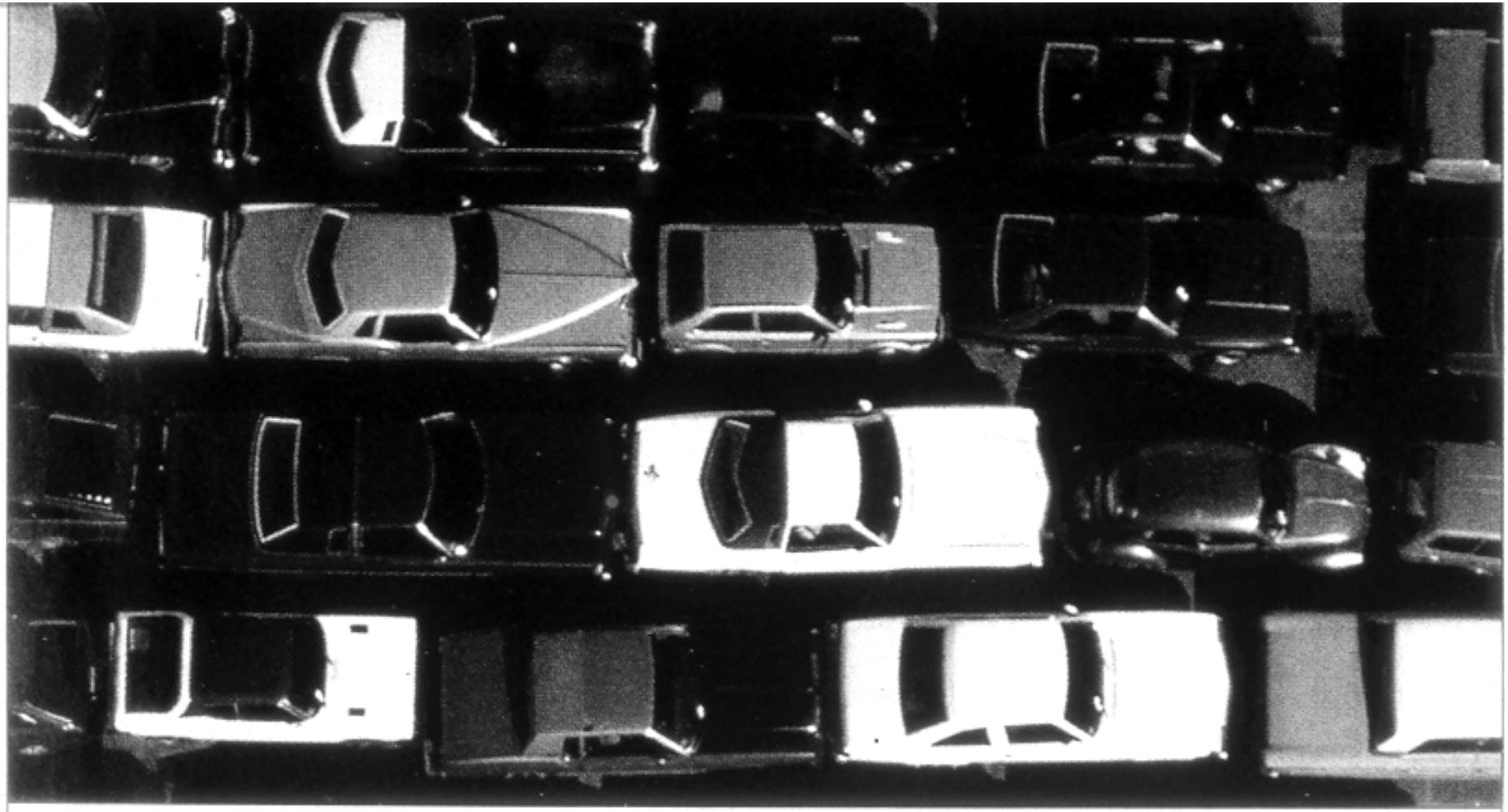


Plus Approximately 50 Million Motorcycles And Over 20 Million Agricultural Vehicles

Vehicle Growth in Beijing is Exploding



Source: He Kebin



LA: Once you're here, you'll never move.

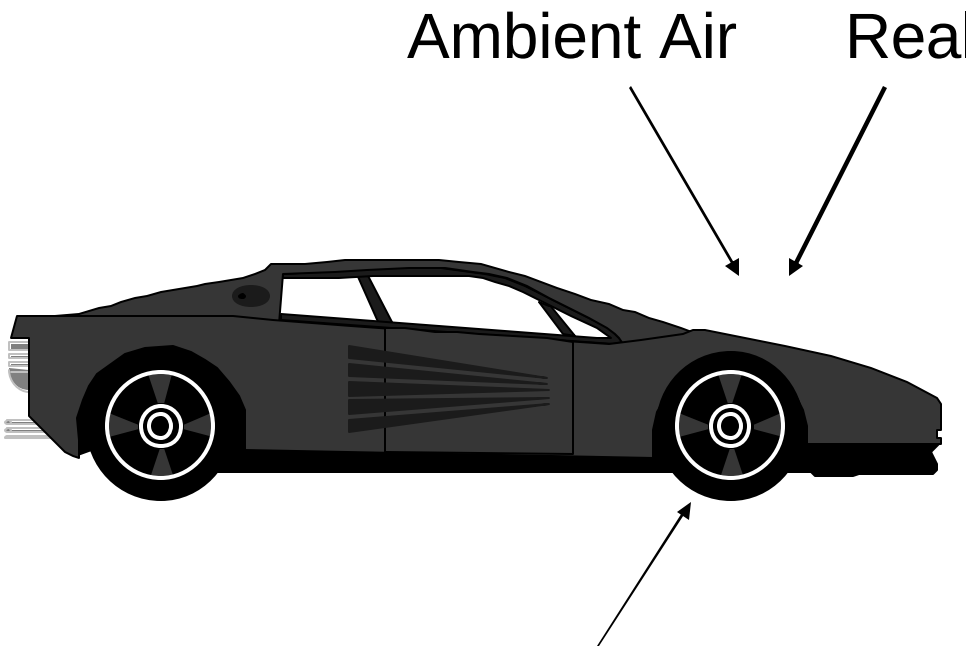
Pollution Shifting From Coal Based To Vehicle Based

Beijing November 2004

Shanghai November 2004

Products of Combustion

- Lead
- Hydrocarbons
- Carbon Monoxide
- Oxides of Nitrogen
- Carbon Dioxide
- Particulates
- Other pollutants
- Water Vapor



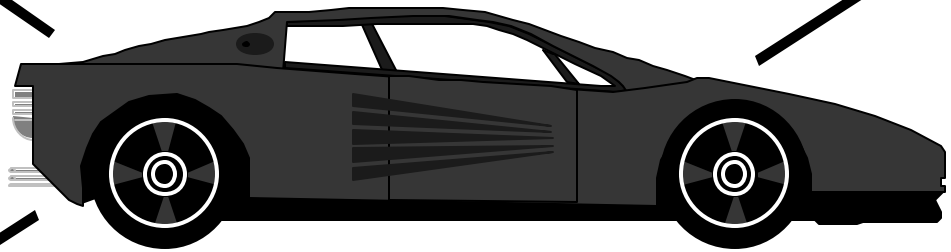
Other Emissions From Vehicles

Refueling Losses

displaced vapors

Evaporative Emissions

diurnal, running losses, hot soak

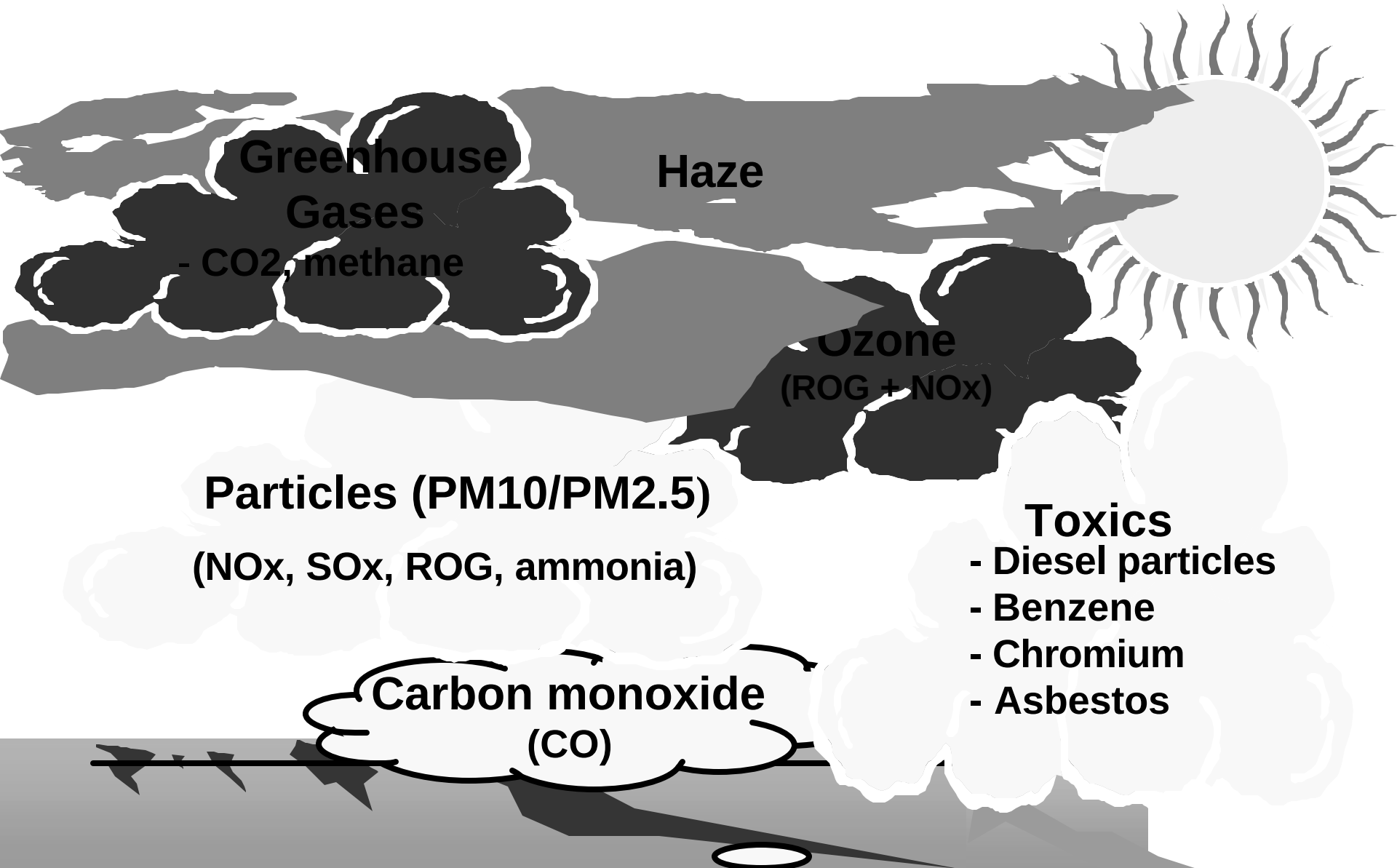


- Other Emissions
  - brake linings, tire wear, fluid leaks

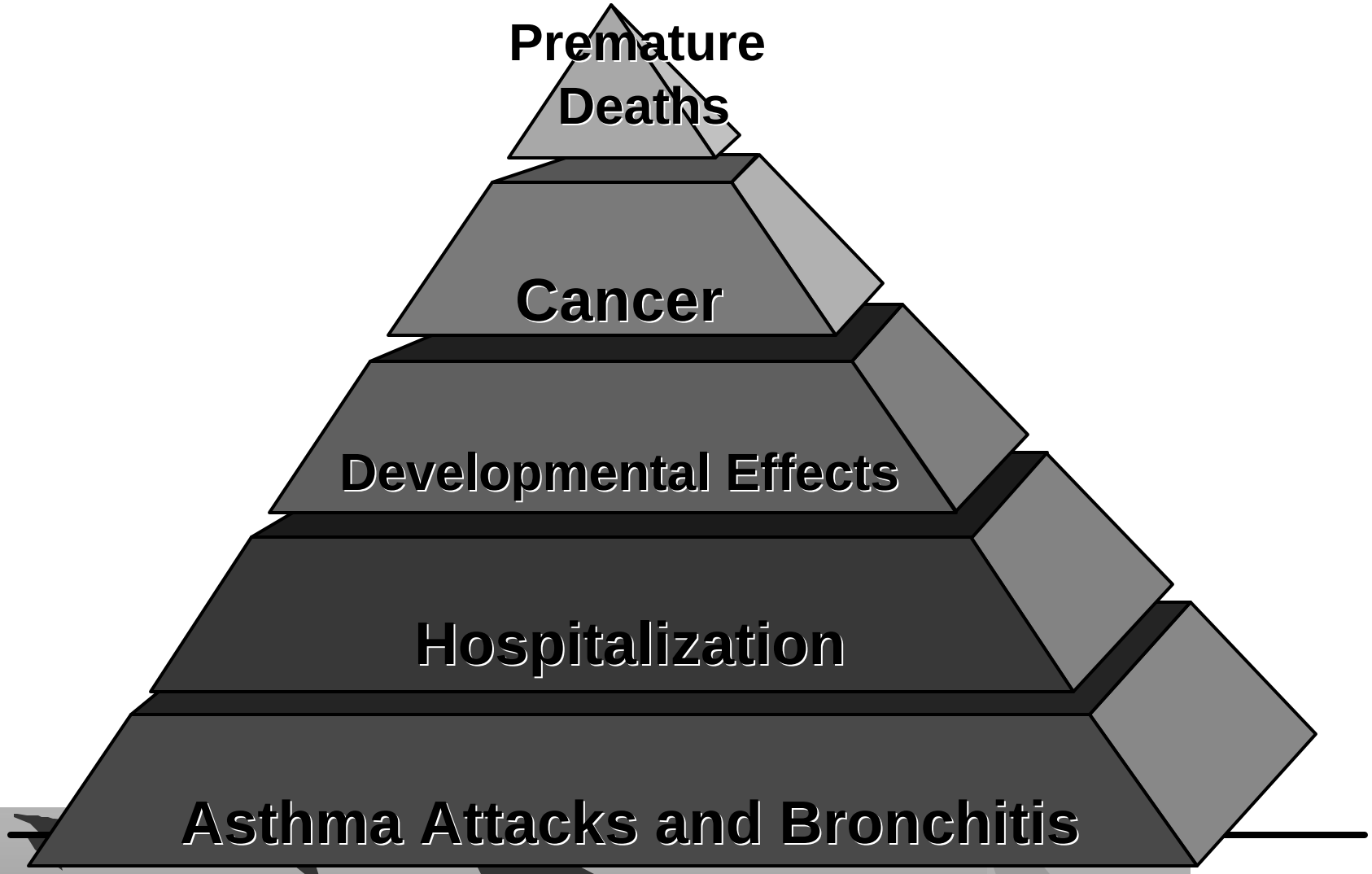
Crankcase Losses

due to "blow-by"

What pollutants are of concern?



Health Impacts of Air Pollution



Adverse Health Effects From Air Pollution Beyond Dispute

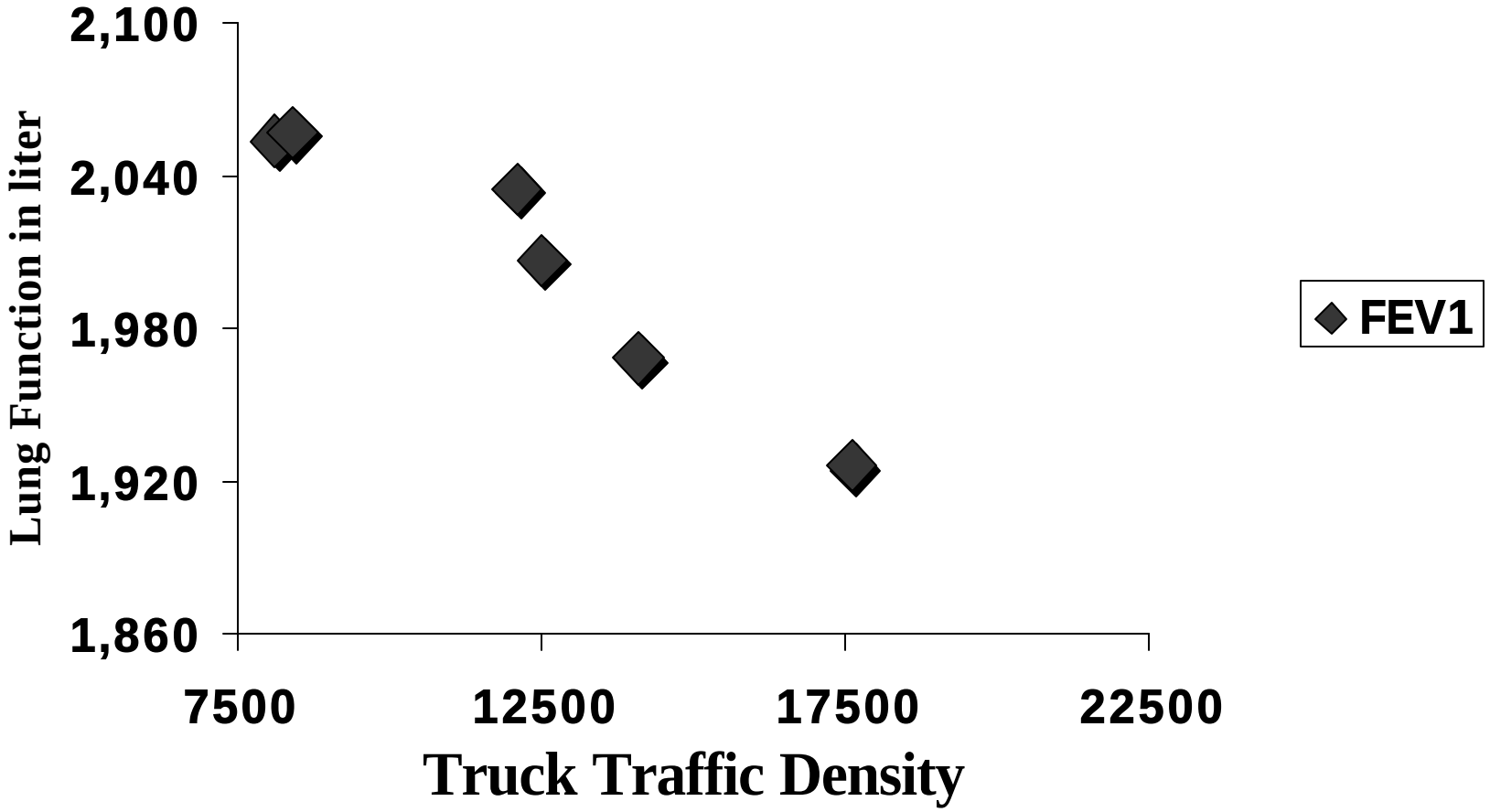
- WHO Concludes ~ 800,000 Premature Deaths Each Year From Urban PM
- Numerous Studies in Europe & US Consistently Link PM With Premature Deaths, Hospital Admissions, Asthma Attacks, Etc.
- No Evidence of a Threshold
- Ozone Also A Serious Health Concern
- NO_2, Various Toxics Also Problematic

HEALTH IMPACTS OF VEHICLE EXHAUST

- Over the past decade, dozens of studies from all over the world have shown that spending time in close proximity to heavy traffic, especially diesel truck traffic, is associated with a wide range of morbidity effects, as well as increased mortality

- Diesel exhaust particulate (DEP) declared a toxic air contaminant by ARB in 1998

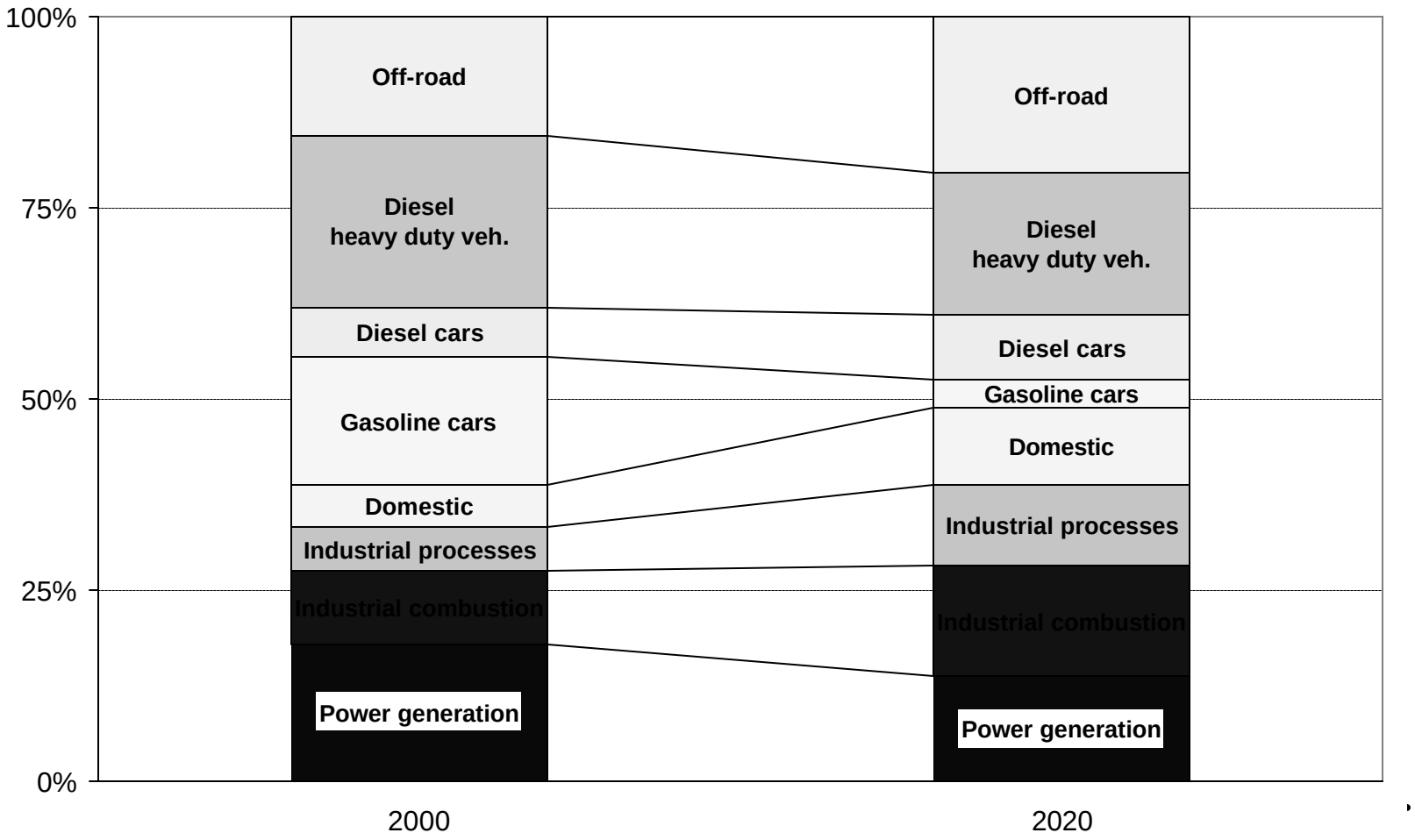
Proximity To Truck Traffic Linked To Lung Function in Children



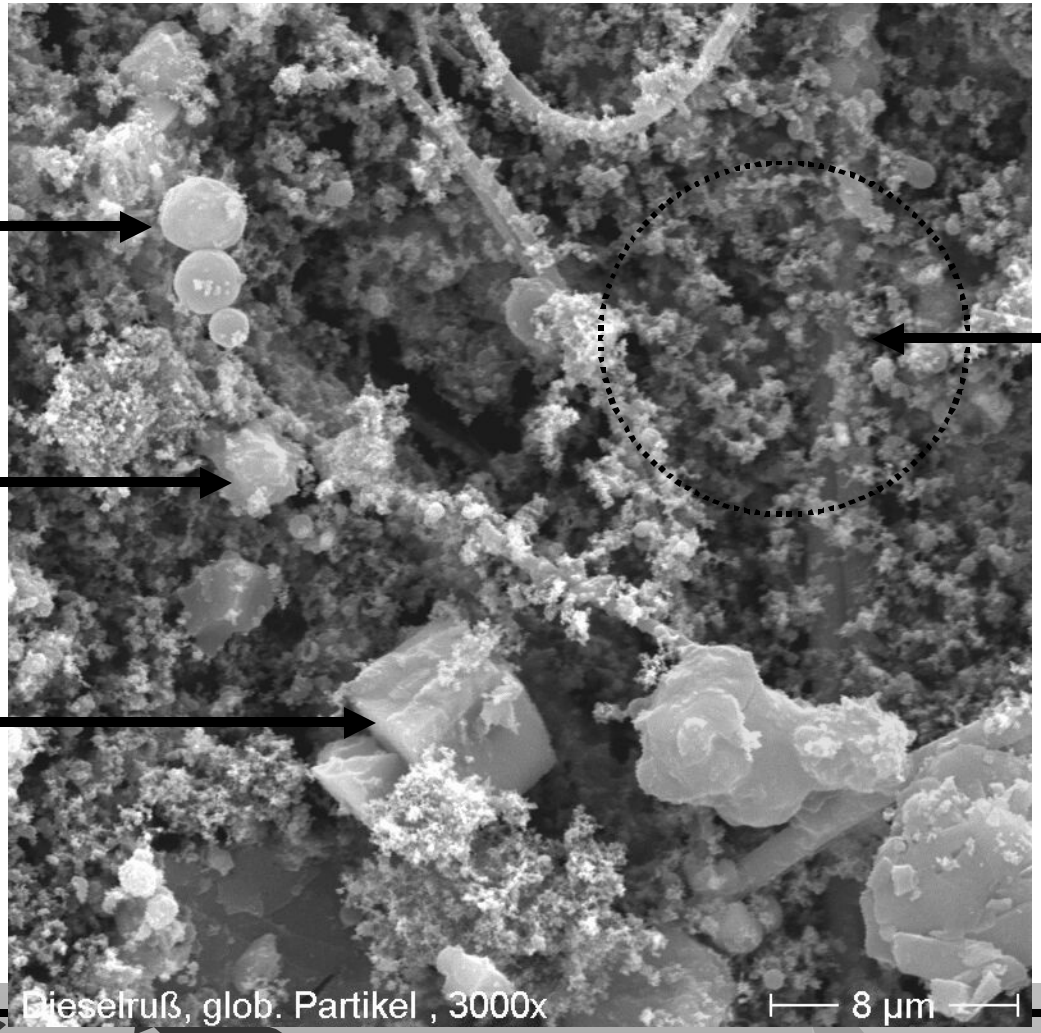
Brunekreef, Epidemiology; 8: 298-303

NO_x emissions

EU-25



PM10 sample taken near a street in Vienna



Combustion products

Minerals

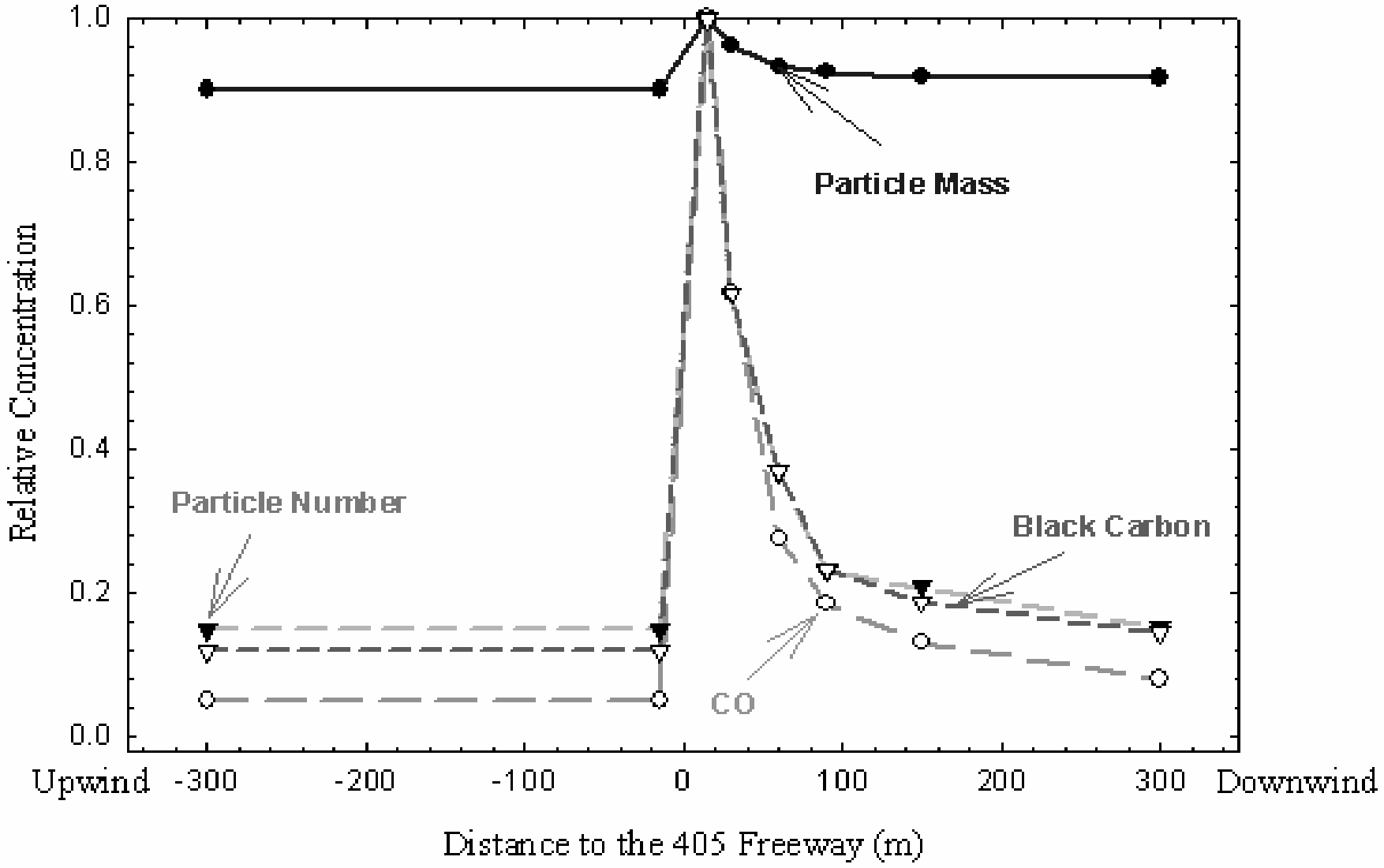
Salt

Diesel soot

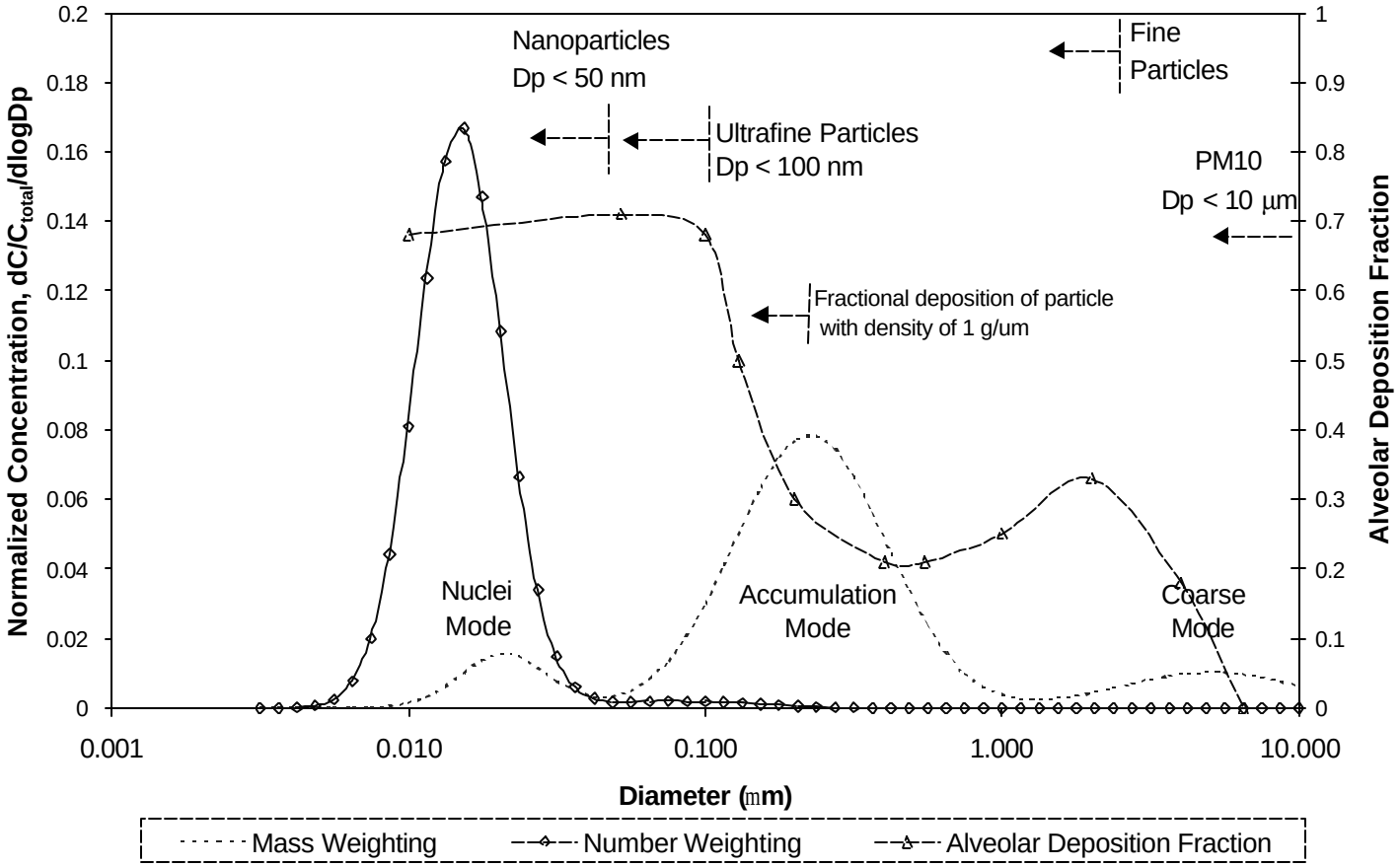
Source: Umweltbundesamt, Wien

RELATIVE POLLUTANT CONCENTRATIONS vs DISTANCE FROM I-405 FREEWAY

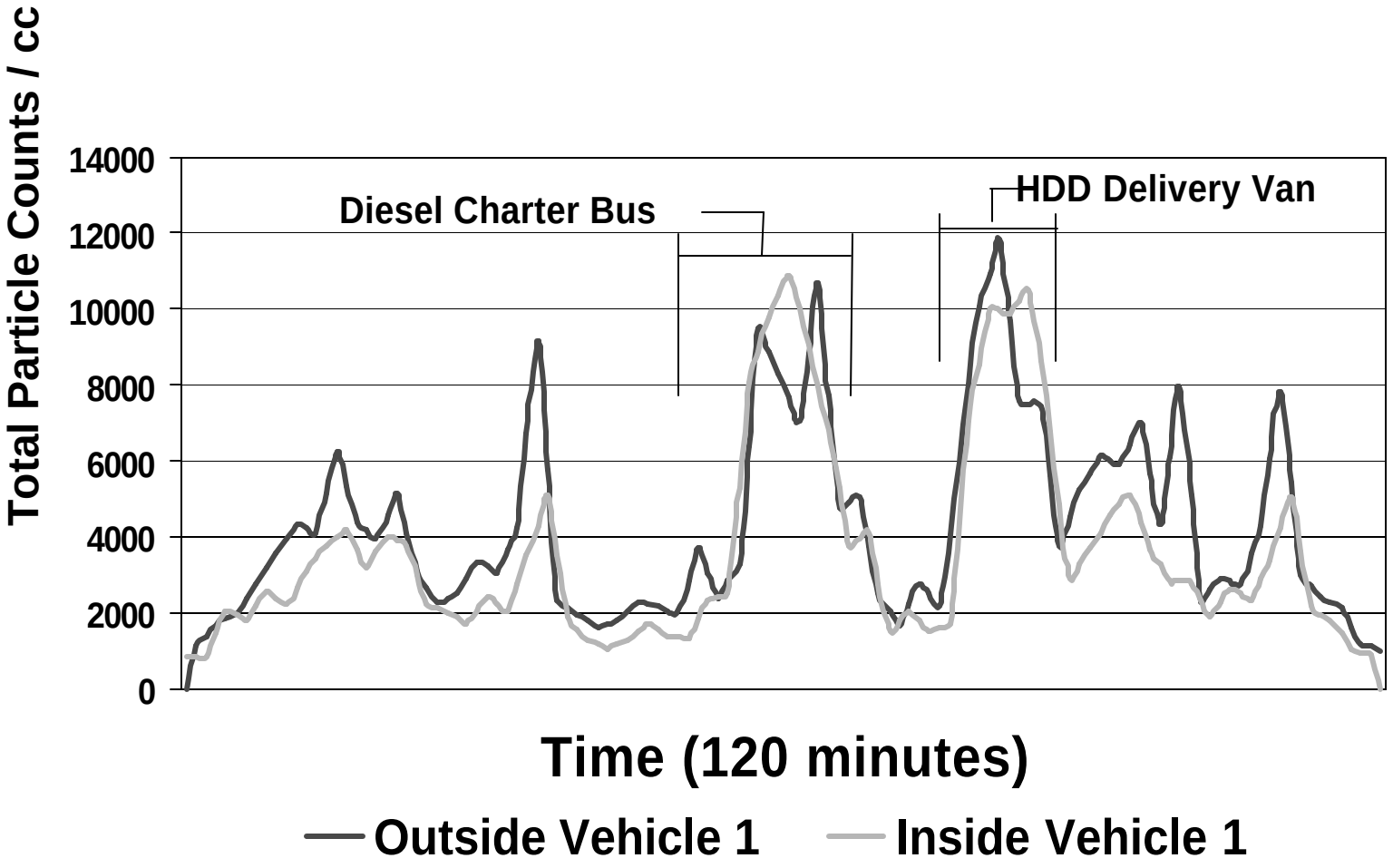
(Zhu et al., 2002a)

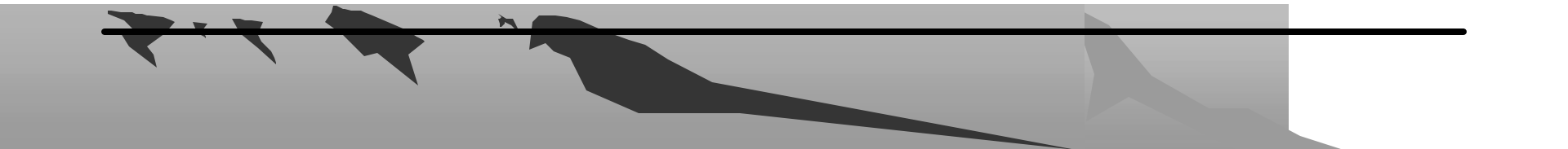


Typical engine exhaust mass and number weighted size distributions shown with alveolar deposition



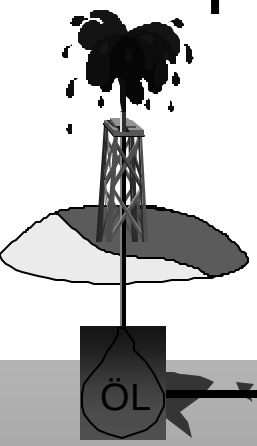
ARB In-Vehicle Study
Real-Time Fine Particle Counts
(L.A. Freeway, AM Rush Hour, Vent Open)

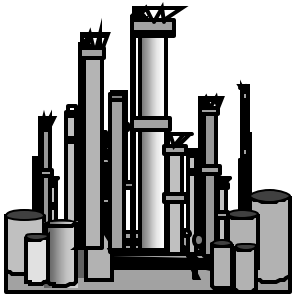




Why Are Fuels Important?

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





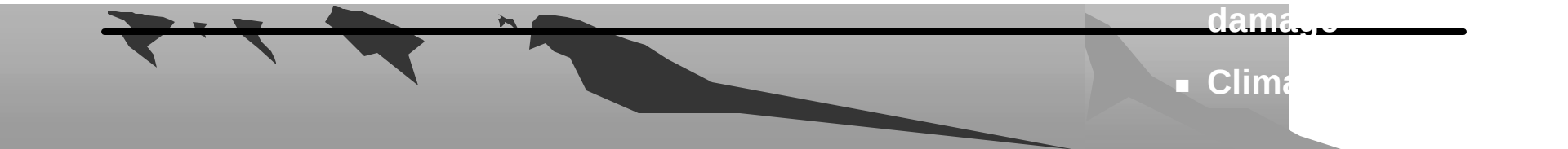
Motivation For Improved Fuels Qualities

Improved fuel qualities → **Reduced emissions** → **Improved air quality** → **Environmental benefits**

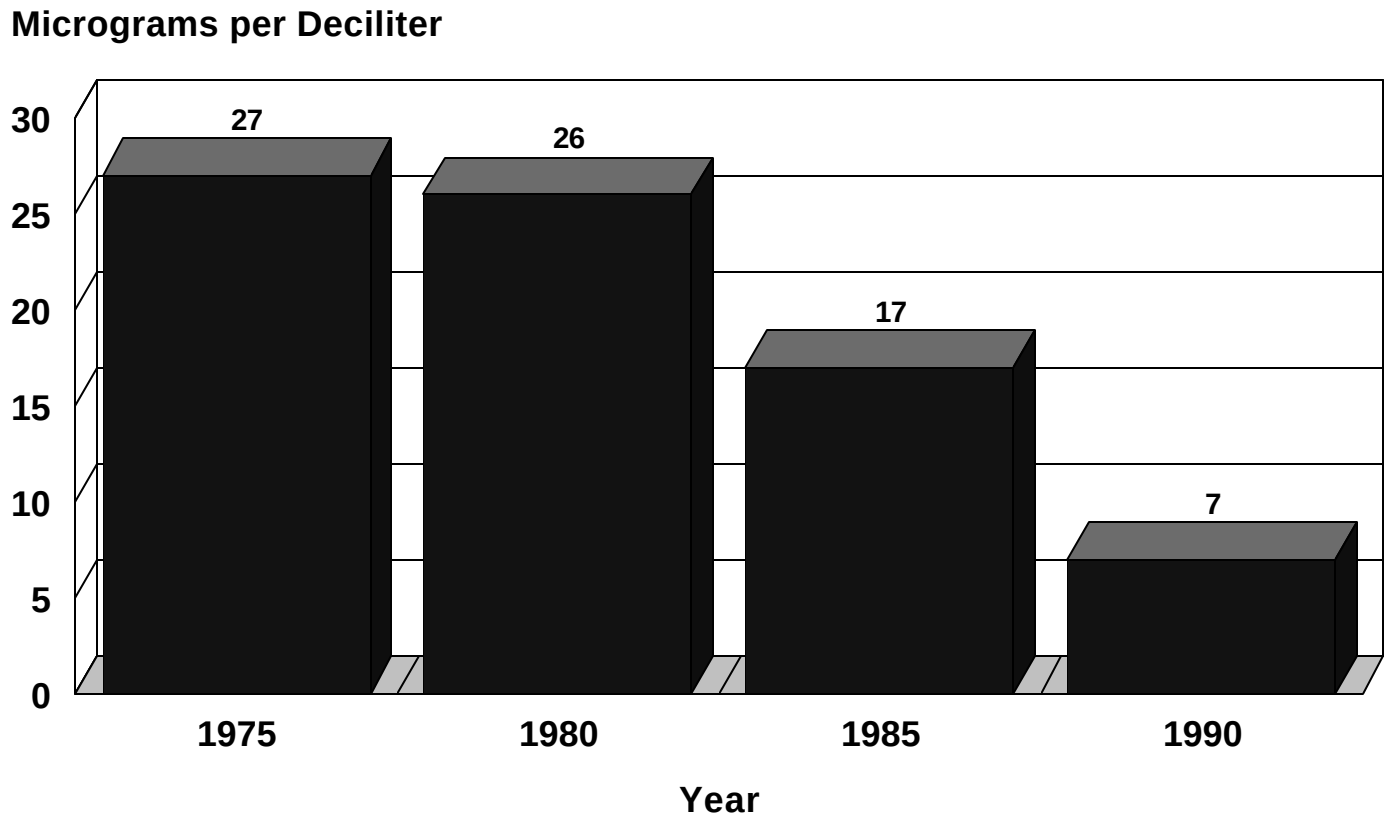
- **Gasoline – Lead/Sulfur**
- **Diesel –Sulfur**
- **Other Parameters**

- **Carbon monoxide (CO)**
- **Hydrocarbons (HC)**
- **Nitrogen oxides (NO_X)**
- **Particulate matter (PM)**
- **Sulfur (SO_2)**
- **Polyaromatic**

- **Improved human health**
- **Reduced corrosion**
- **Improved crop yield**
- **Less**
- **Clima**



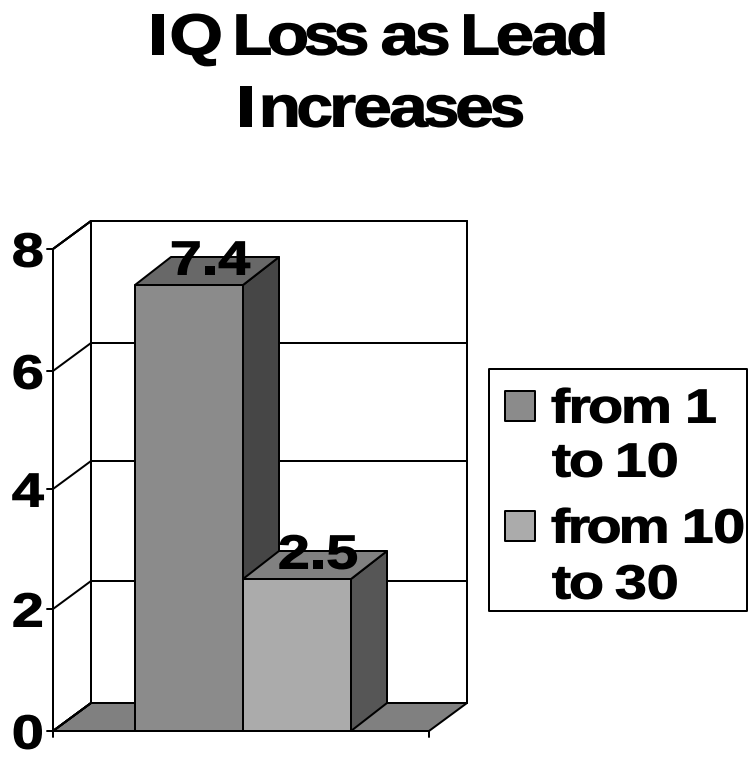
Blood Lead Levels Considered Elevated



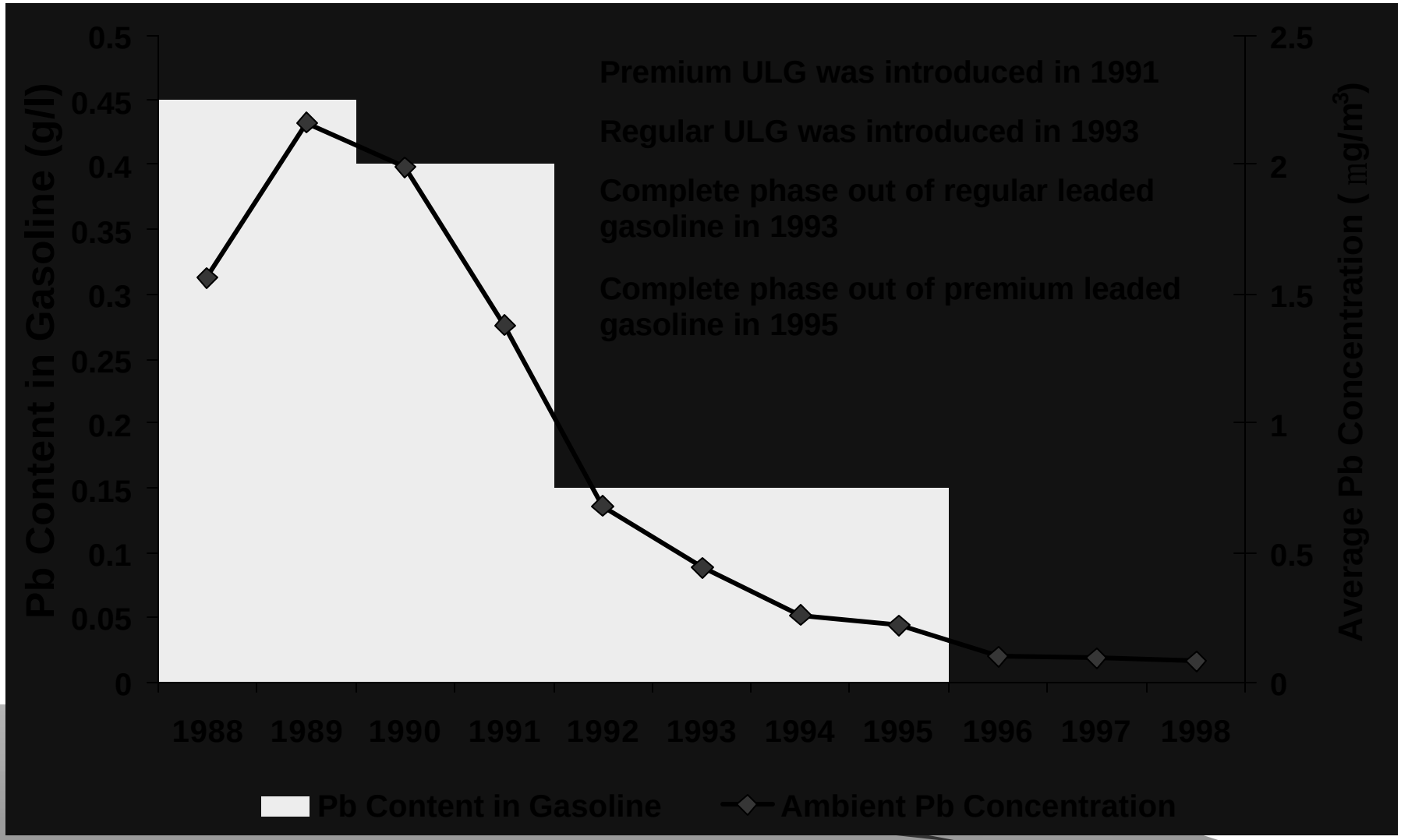
Is Any Lead Acceptable From A Health Standpoint?

Study Indicates Largest Impact at Very Low Lead Levels

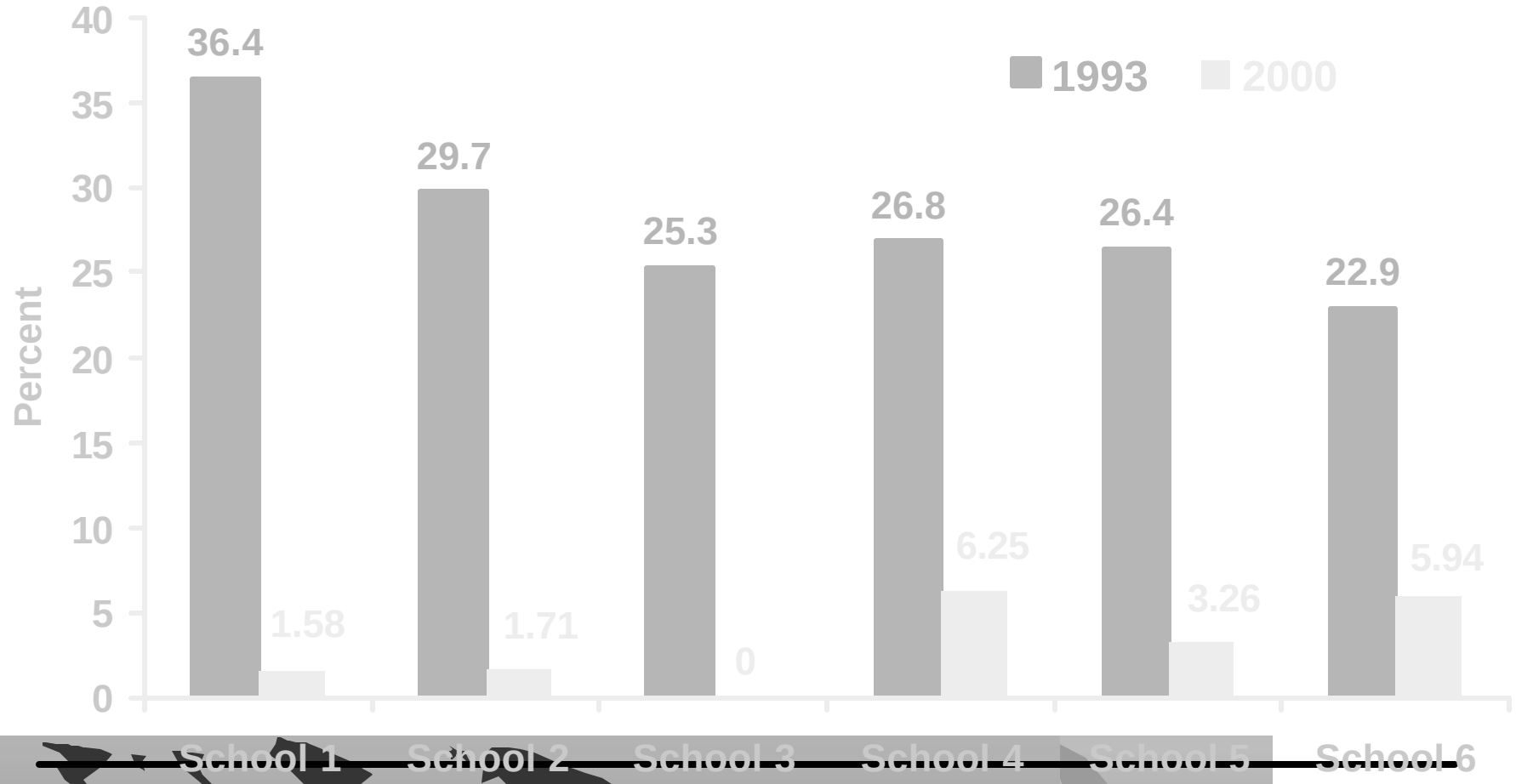
- New England Journal of Medicine (4/17/2003)
- 172 children tested at 6, 12, 18, 24, 36, 48, 60 months
- Corrected for confounding variables
- 101 children never above 10µg/dl
- Blood lead significantly associated with I/Q



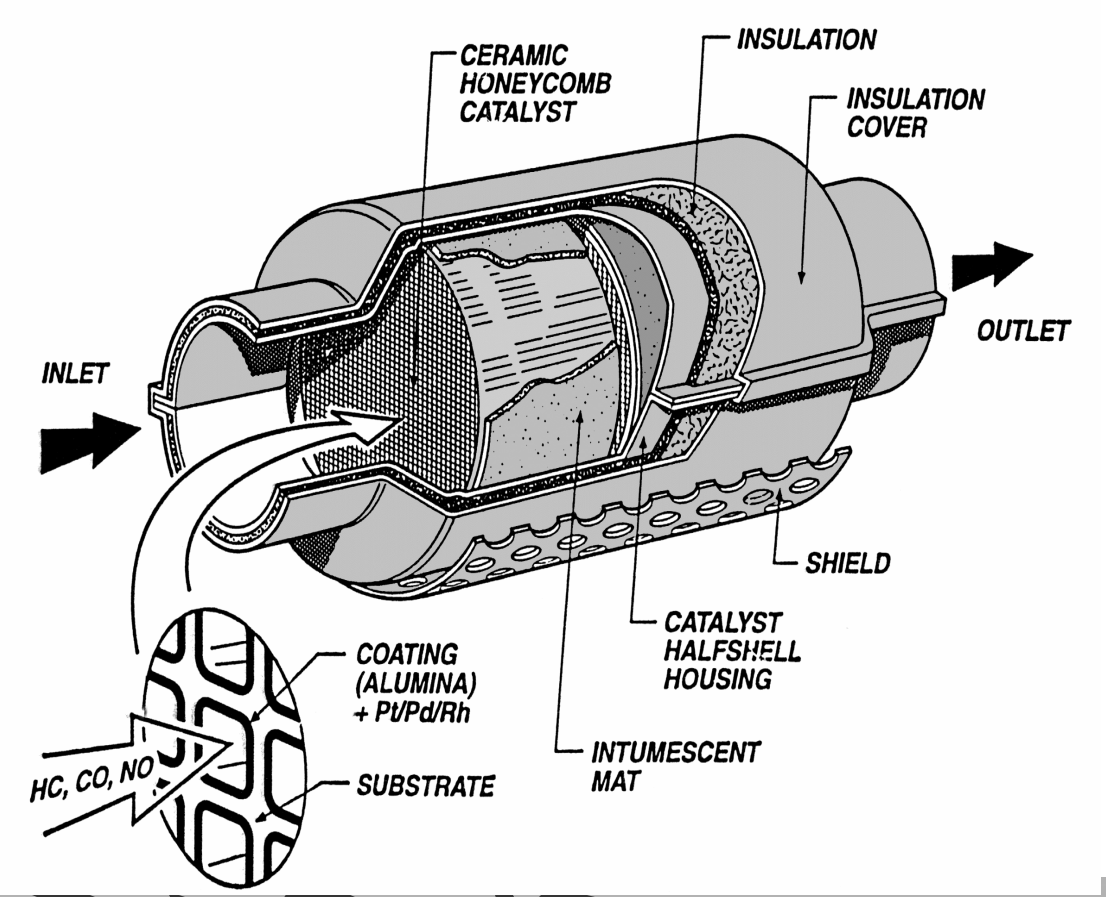
Ambient Pb Concentrations in Bangkok and Pb in Gasoline from 1988 - 1998



Percentage of School Children with Blood Pb Levels = 10 mg/dl



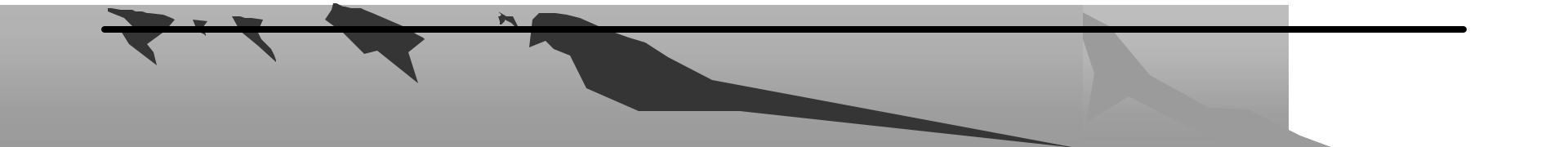
The Three-way Catalytic Converter: A Familiar Technology Re-Engineered for High Performance in Close-coupled and Underfloor Applications



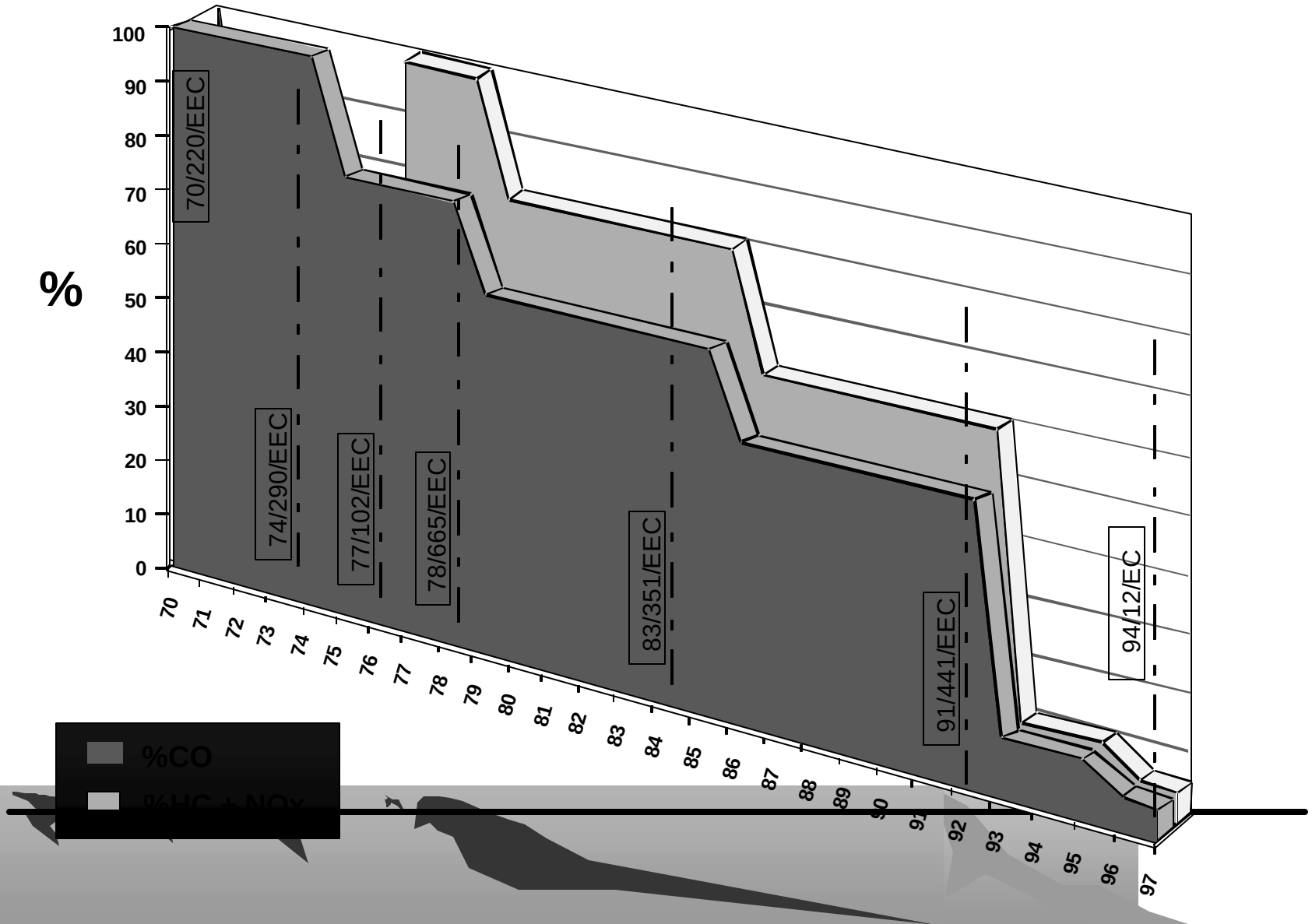
- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management

Can Only Be Used With Lead Free Fuel

The “Technology Enabling” Fuels Story in Europe



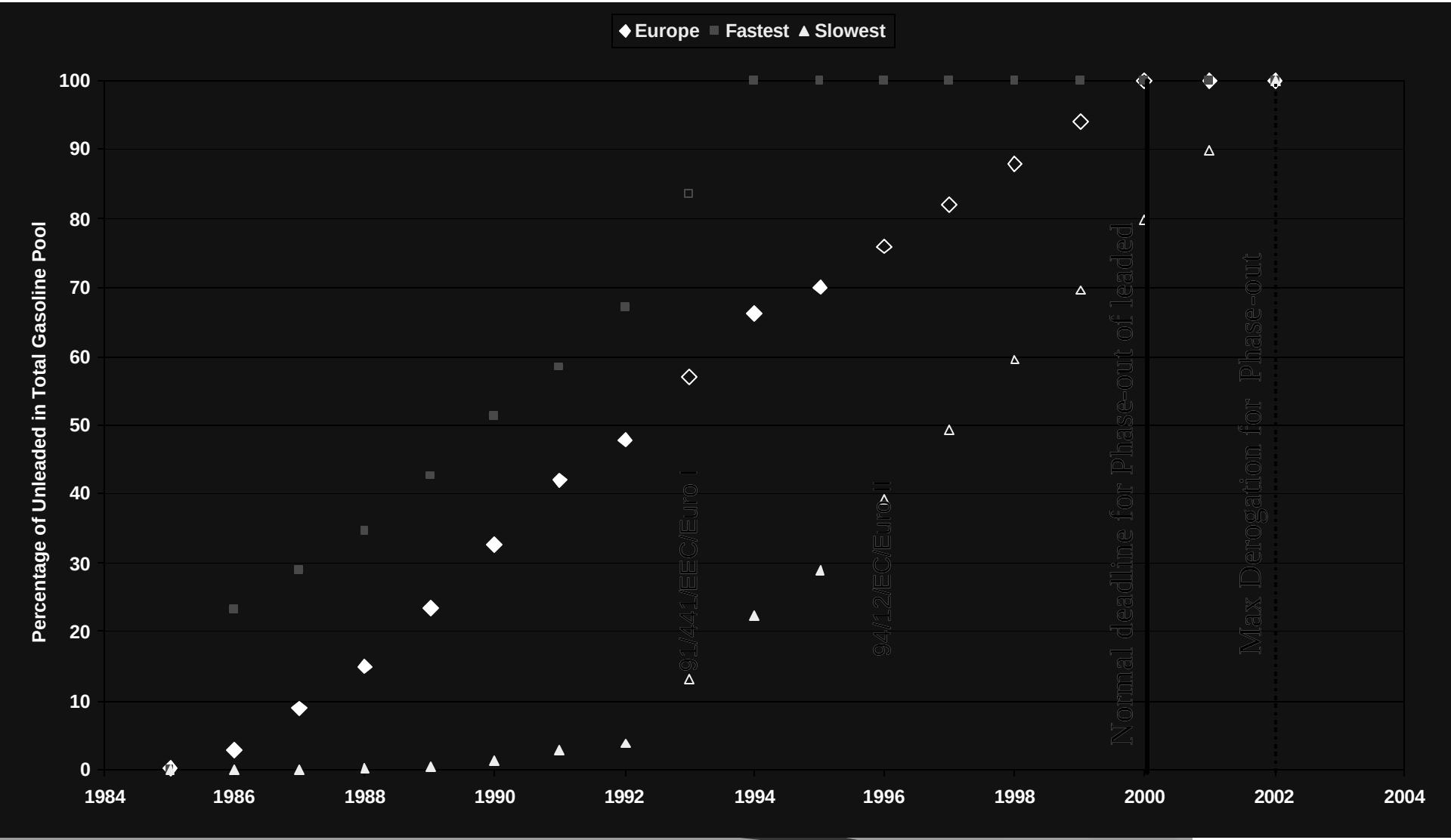
EVOLUTION OF THE REGULATORY EXHAUST EMISSION STANDARDS FOR PASSENGER CARS IN THE EU



The “Technology Enabling” Fuels Story in Europe -Introduction of unleaded Gasoline -

- Until early 80’s “lead reduction/phase out” initiative in Europe, transport fuel specifications largely determined by performance concerns rather than environmental concerns
- Introduction of unleaded gasoline provided the “enabling fuel” for introduction of catalyst technology-rate of introduction largely determined by tax incentive of unleaded vs leaded
- Availability of unleaded gasoline in Europe, for all countries, has led the demand from catalyst equipped vehicles
- EU Directive 98/70/EC required complete phase out of leaded gasoline by Jan 1, 2000
- Derogation for maximum of two years (Jan 1, 2002) granted for countries (southern Europe) with slower fleet turnovers

Relationship Between Vehicle Technology and Introduction of Unleaded Gasoline in Europe



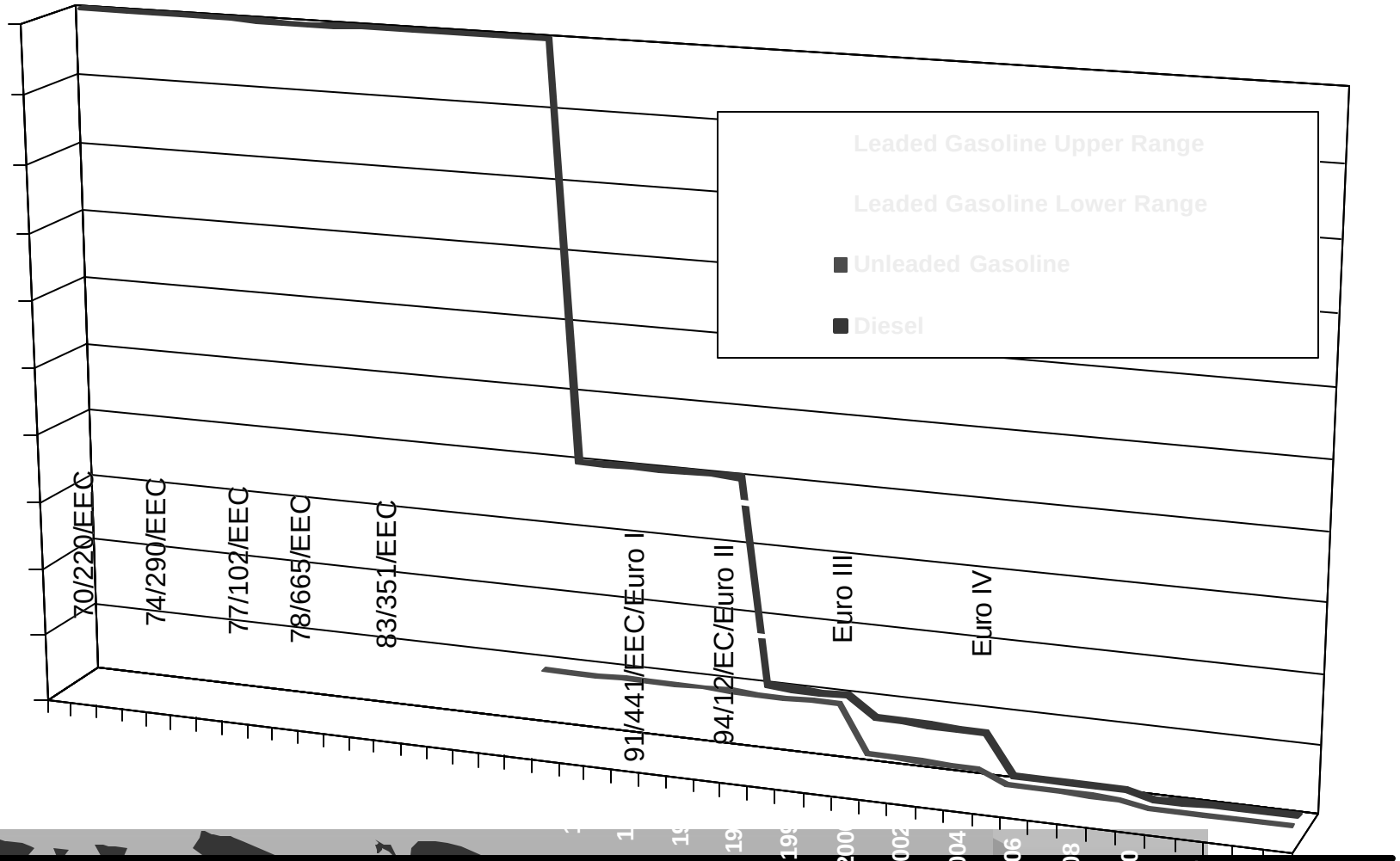
Why Low Sulfur Fuel?

- Lowers Emissions From Existing Vehicles
  - SO_2 From All Vehicles
  - PM From Diesel Vehicles
  - CO, HC, NOx, Toxics From All Catalyst Vehicles
- Enables Advanced Technologies & Tight Standards For New Vehicles
- Enables Retrofit Technologies To Clean Up Existing Vehicles

The “Technology Enabling” Fuels Story in Europe -Introduction of Lower Sulphur Fuels -

- Lowering of sulphur levels on both Diesel (to 2000ppm) and Gasoline (unleaded to 500 ppm) in late 80’s largely driven by direct concerns over urban air quality (SO_2)
- Further move on Transport Diesel in early 90’s (2000➔ 500 ppm largely seen as “enabling” step for oxidation catalyst on LD Diesel required to meet 1996 emission standards
- First European Auto Oil programme (93-96) indicates lower sulphur gasoline enhances catalyst performance: 2000 limit: 150ppm and 2005 limit at 50ppm
- Same programme indicated lower sulphur diesel contributes to lower particulates both directly and through enabling higher performance technology: 2000 limit: 350ppm and 2005 limit at 50ppm
- More recent concerns over growing CO_2 contribution from road transport has driven move to “Ultra Low” sulphur gasoline and diesel to facilitate “high fuel efficiency”/“high environmental performance” transport :

Relationship Between Vehicle Technology and Sulphur in Gasoline & Diesel Fuel



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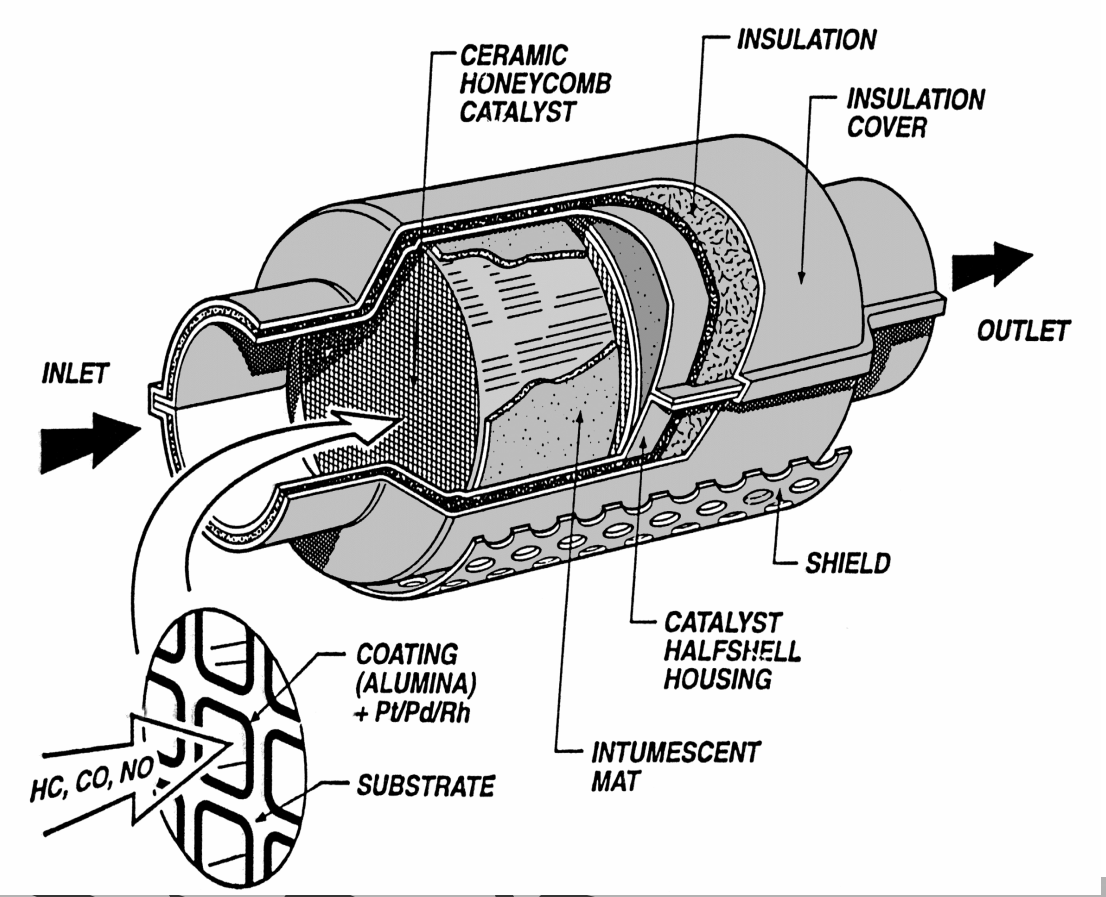
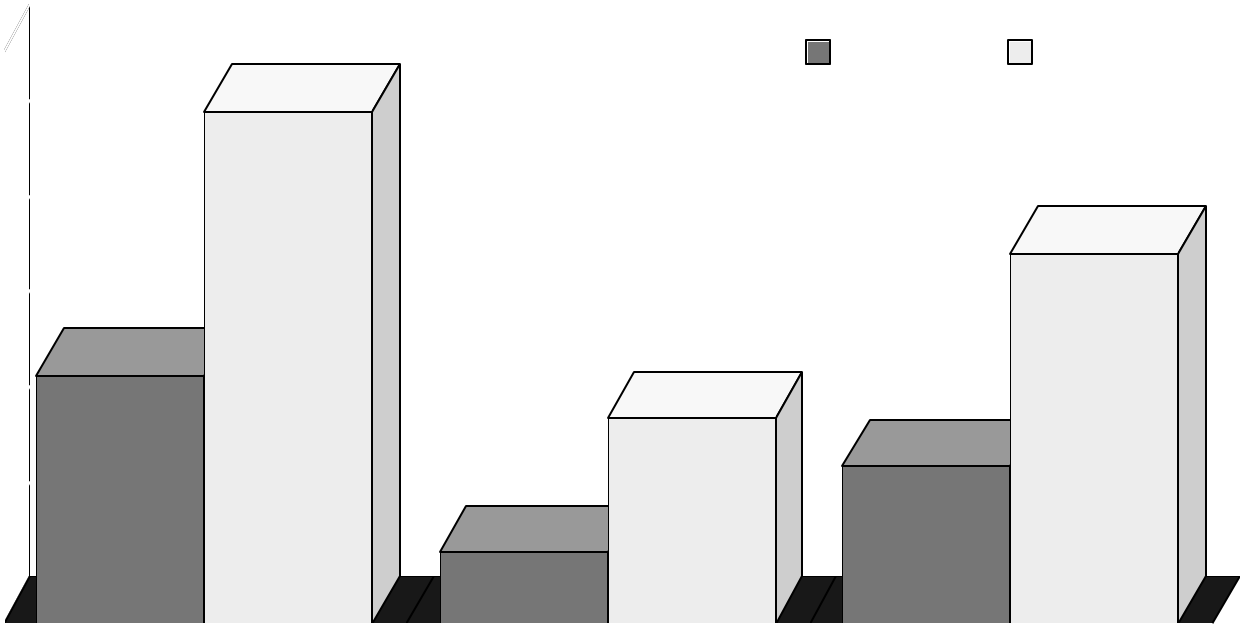


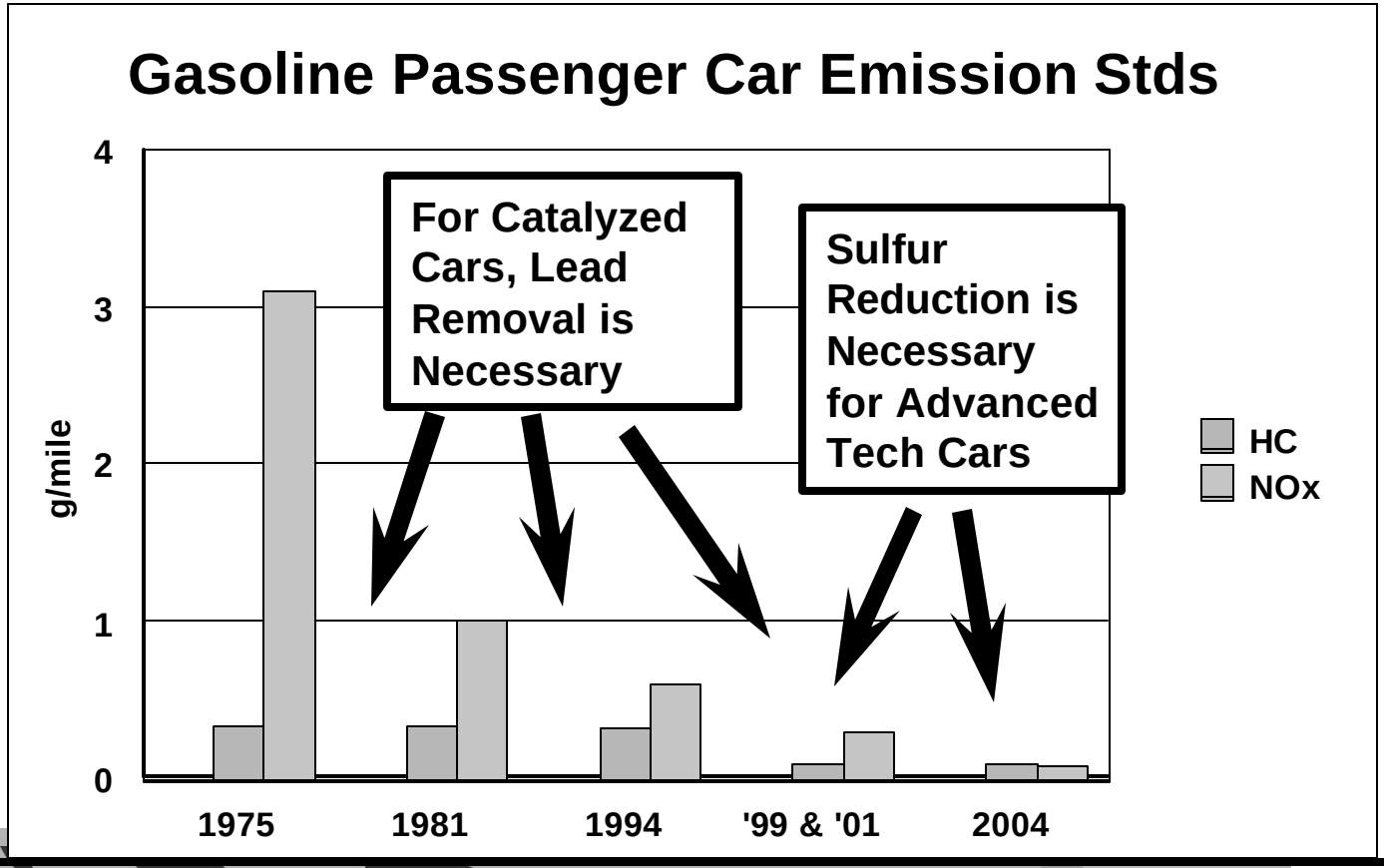
- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management

Maximum Emissions Performance Is Only Achieved With Near Zero Sulfur Fuel

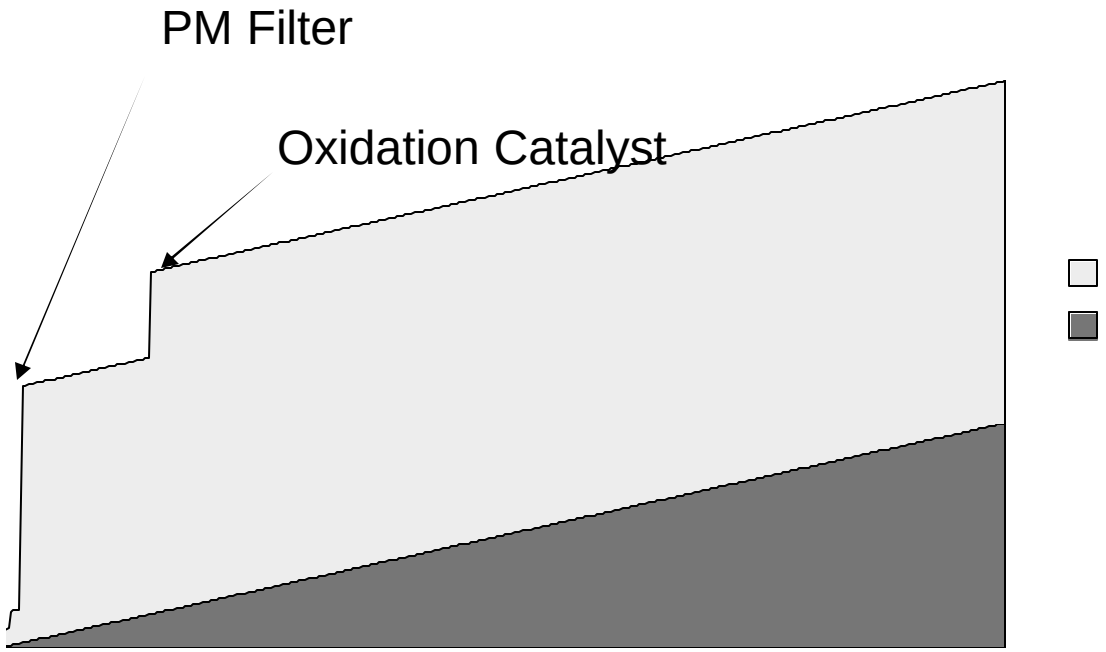
Increase in In-Use Vehicle Emissions in Bangkok Due To Sulfur in Fuel (Gasoline)



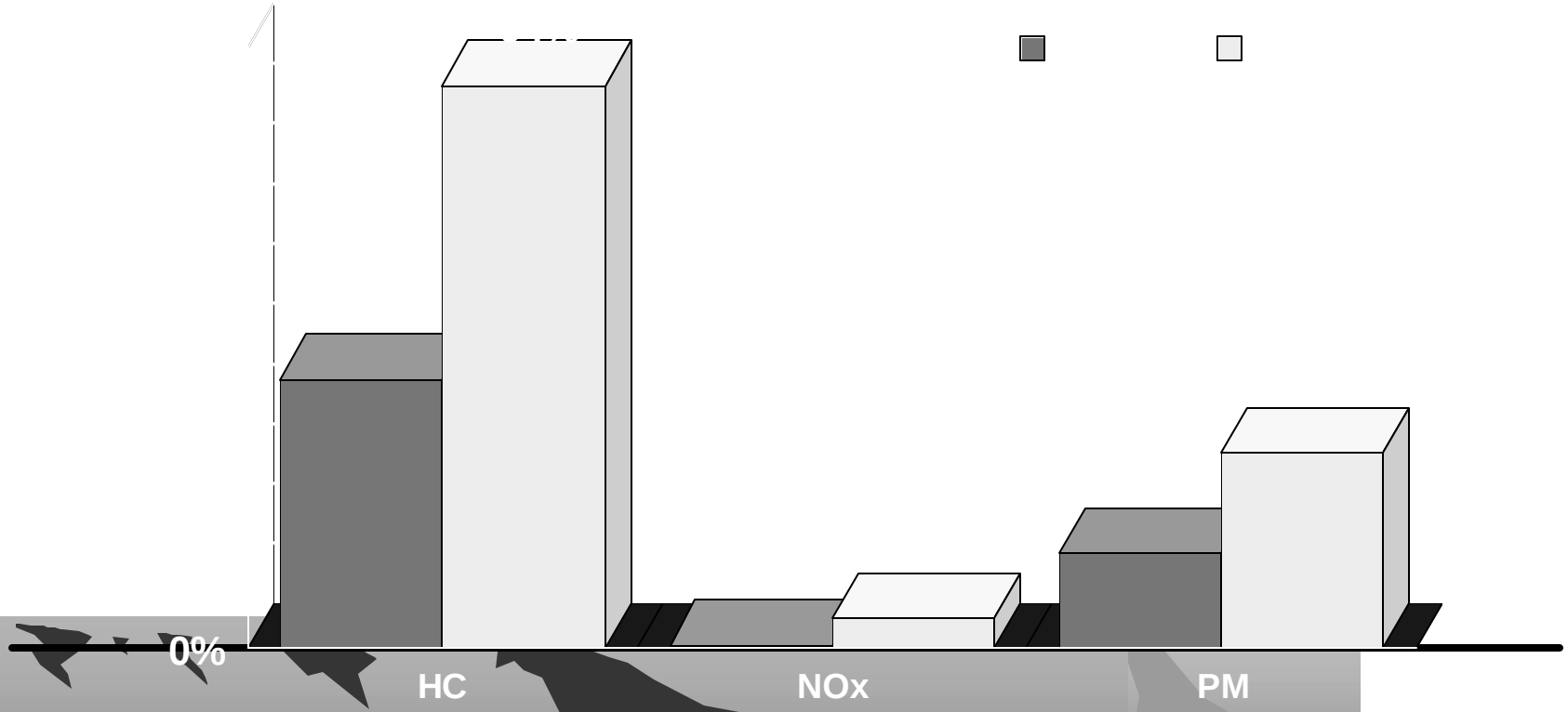
Enabling Emissions Control
Sulfur Is The Lead of the New Century
Gasoline Cars and Trucks



Linkage Between Fuel Sulfur and PM Emissions

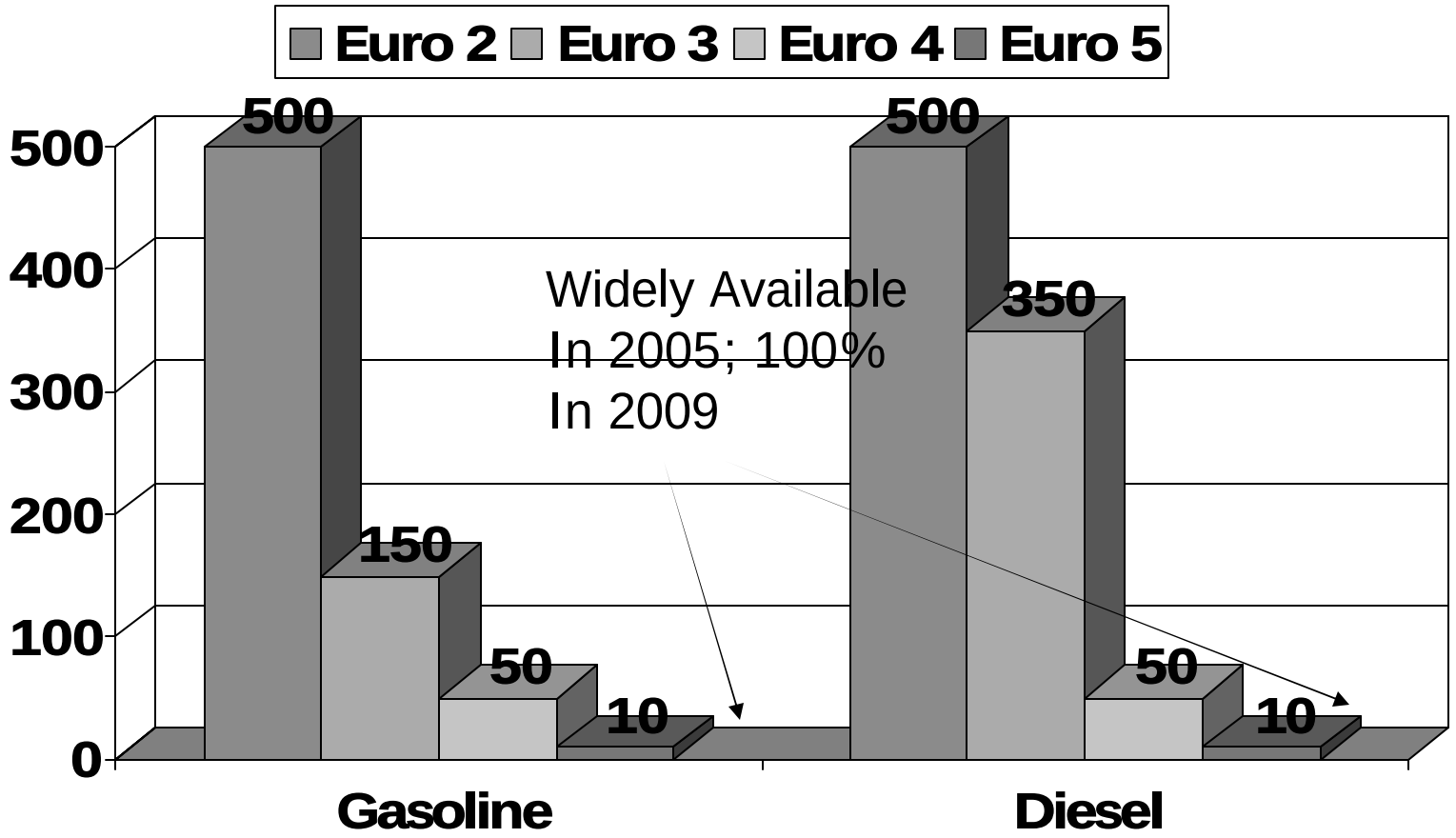


Increase in In-Use Vehicle Emissions in Bangkok Due To Sulfur in Fuel (Diesel)



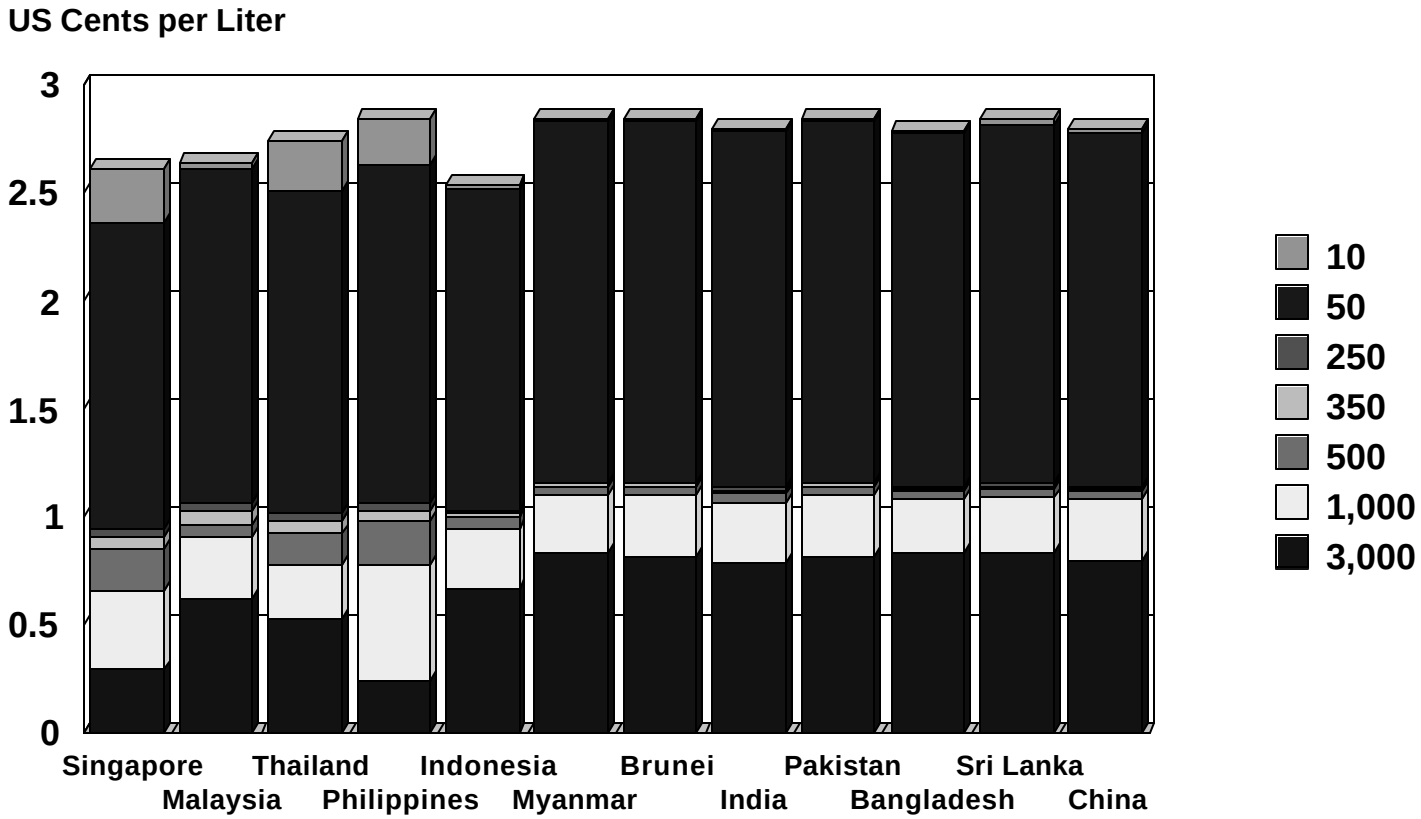
Impact on Vehicles Meeting EURO 3 Standards

European Fuel Sulfur Levels (PPM)



Cost of Reducing Sulfur in Diesel Fuel in Asia

(High Sulfur Crude)



Selective EU Fuel Quality Requirements

Requirement	1996 (Euro 2)	2000 (Euro 3)	2005 (Euro 4)	2009 (Euro 5)
Gasoline				
Vapour Pressure (Summer) max kPa		60	60	?
Benzene max Vol %		1	1	?
Aromatics max Vol %		42	35	?
Sulphur max ppm	500	150	50/10	10
Diesel				
Cetane Number min	48	51	51	?
Density max kg/m3		845	845	?
Polycyclic Aromatics max Mass %		11	11	?
Sulphur max ppm	500	350	50/10	10

Gasoline Effects on Emissions

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

0	+ / – 2 %	+ ++ +++	- -- ---	2-10 % 10-20 % > 20 %	} Improvement or Deterioration

Diesel-Fuel 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 ...				
Cetane Number	+++/++	+++/+	o	-/o

Effect

+	-	2-10 %
++	--	10-20 %
+++	---	> 20 %

Improvement or Deterioration

o ± 2 %

00_2137

MMT is An Emerging Fuels Problem

- Fuel octane under pressure due to elimination of lead
- Organo-metallic additives are a cheap way to increase octane
- Experience with these additives shows that they can cause
  - Health problems
  - Technical problems

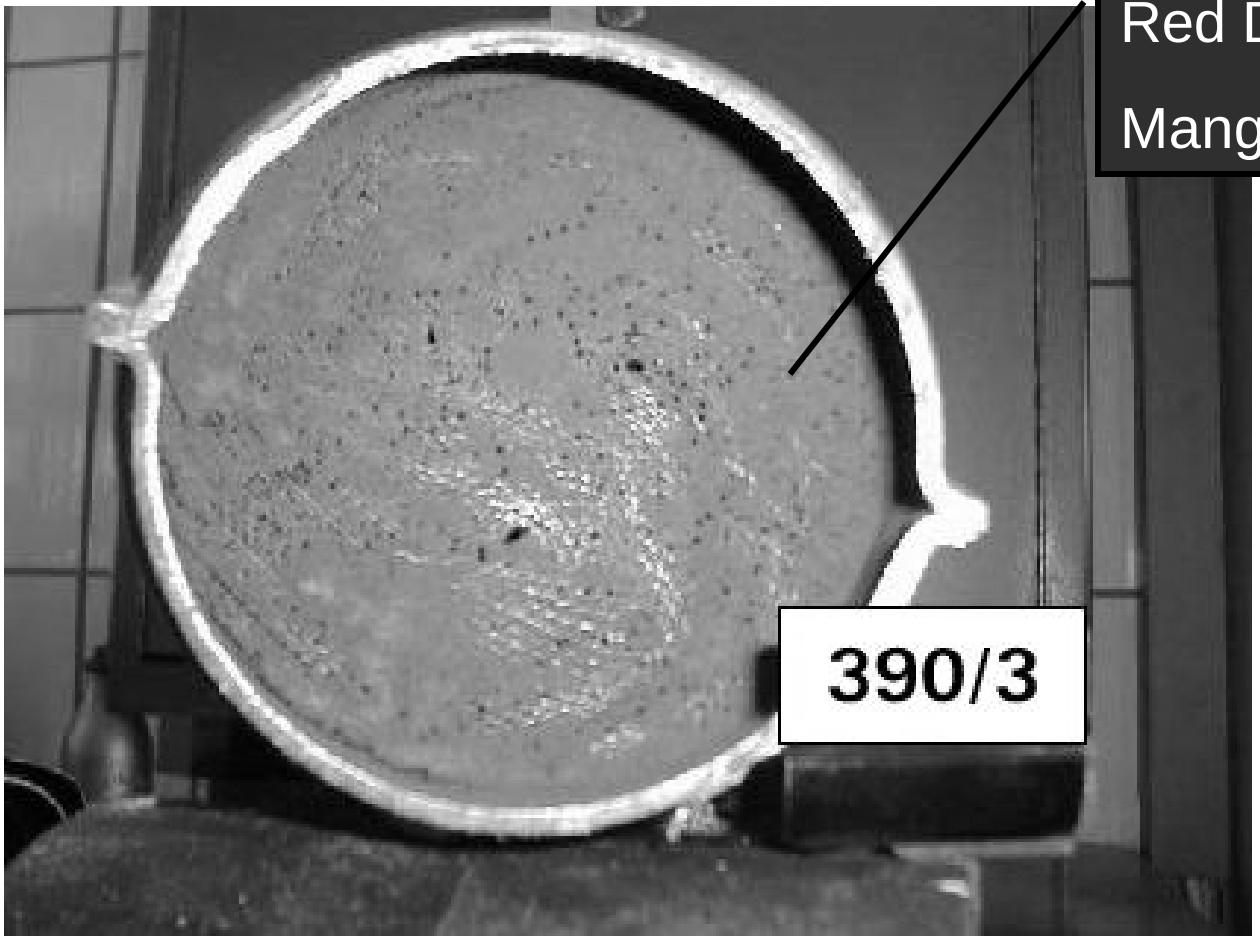
Implications of Recent Study

HEALTH EFFECTS INSTITUTE

"The finding that manganese transport out of the brain occurs via the slow process of diffusion, rather than via carrier-mediated transport, is important: **it suggests that no mechanism exists to protect the brain from accumulating manganese**. **This finding has important implications for neurotoxicity resulting from chronic manganese exposure**."

Experience with MMT

China: Blocked catalytic converter



After

33.000 km

Source: Schindler, VW

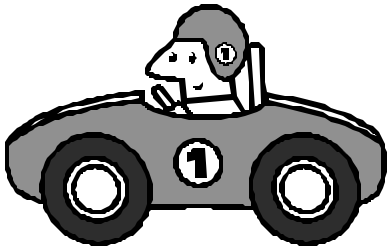
ICCT Conclusions Regarding MMT

Considering the available information, the International Council on Clean Transportation (ICCT) is unable to conclude that the use of MMT will not result in direct adverse health impacts nor that emissions of CO, HC and NOx from catalyst equipped cars will not increase. Based upon the precautionary principle, the California Air Resources Board banned the use of MMT in unleaded gasoline in 1976. In 1996, the Administrator of the EPA stated, “the American public should not be used as a laboratory to test the safety of MMT” (Browner 1996). The ICCT believes this statement to be true for the citizens of every country. Consistent with the precautionary principle, the ICCT recommends that countries delay any use of MMT in gasoline at this time, pending the outcome of ongoing health-based studies and further review of the vehicle impacts.

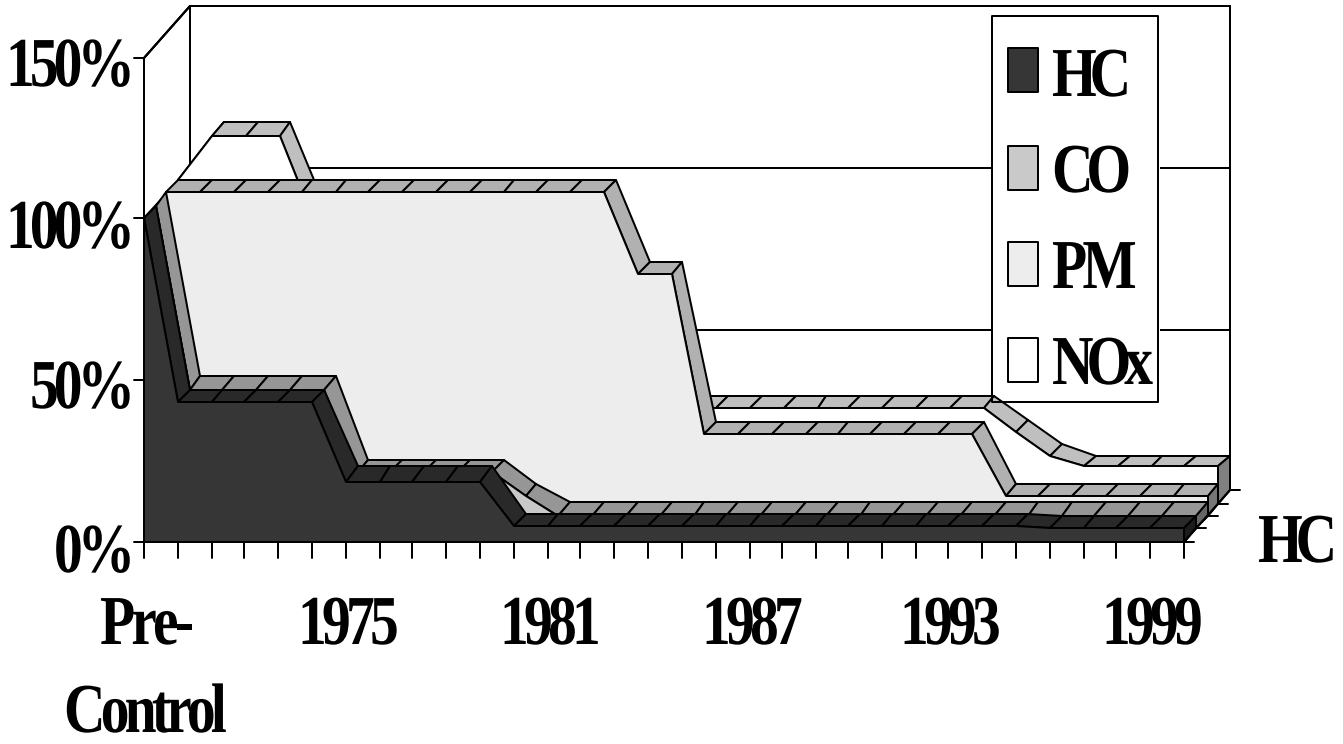
Copies of the ICCT Report Available at
http://www.cleantransportcouncil.org/index.php

The Path To Cleaner Cars

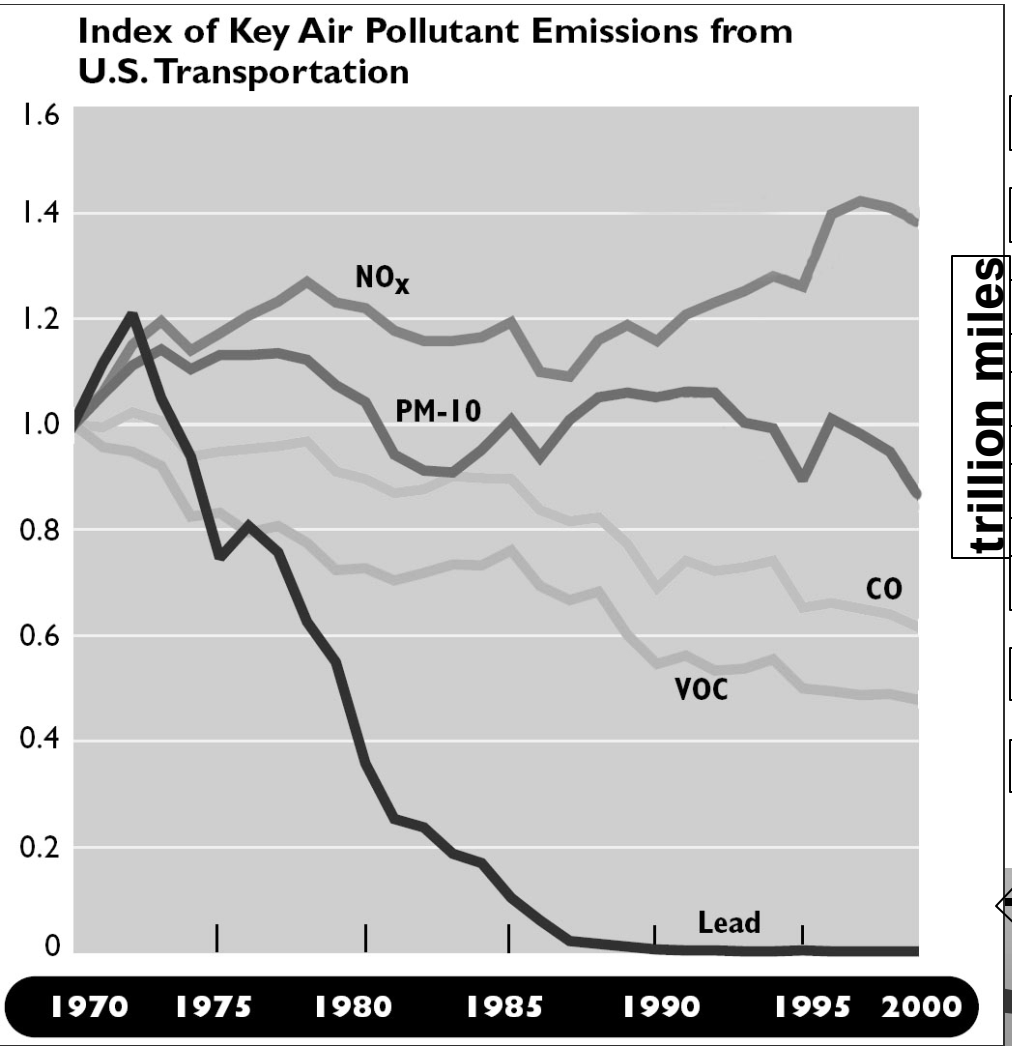
- Cleaner Fuels
- Tighter New Vehicle Standards
- Inspection and Maintenance
- Other
  - Scrappage
  - Retrofit

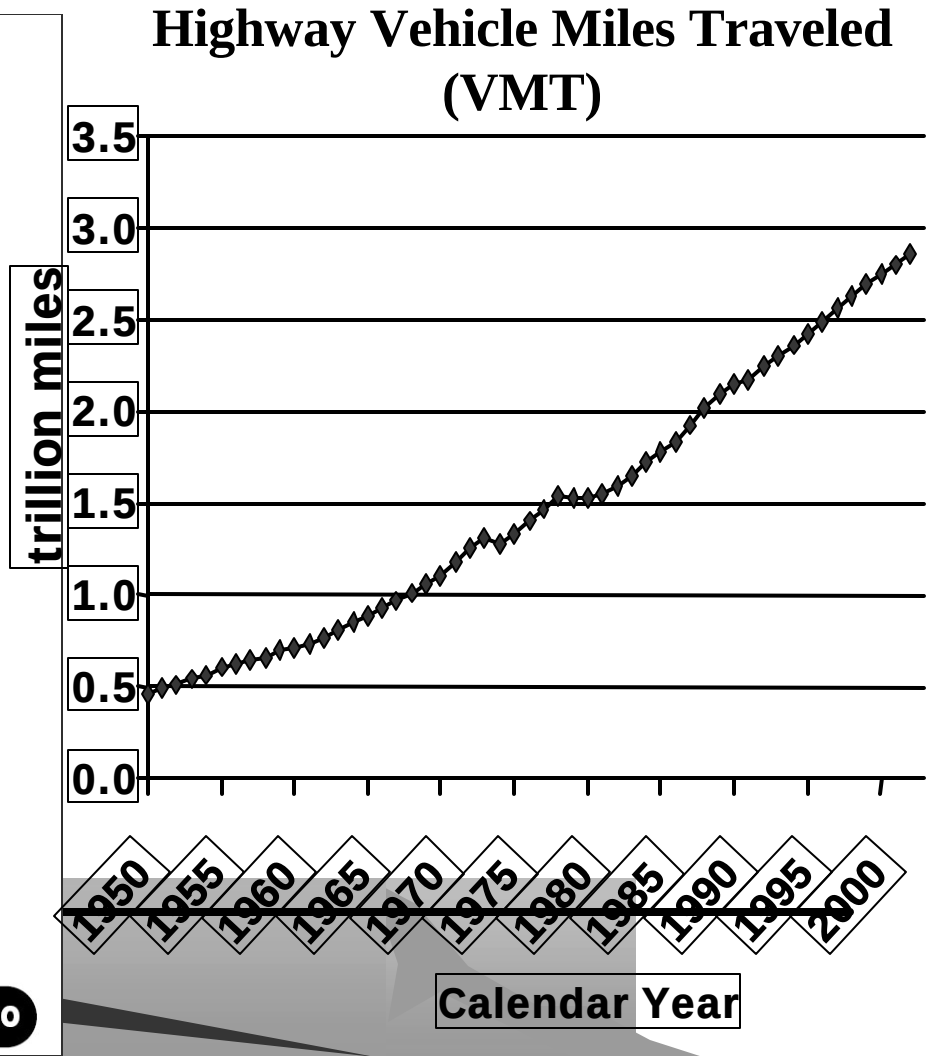


New Car Emissions Standards in the US

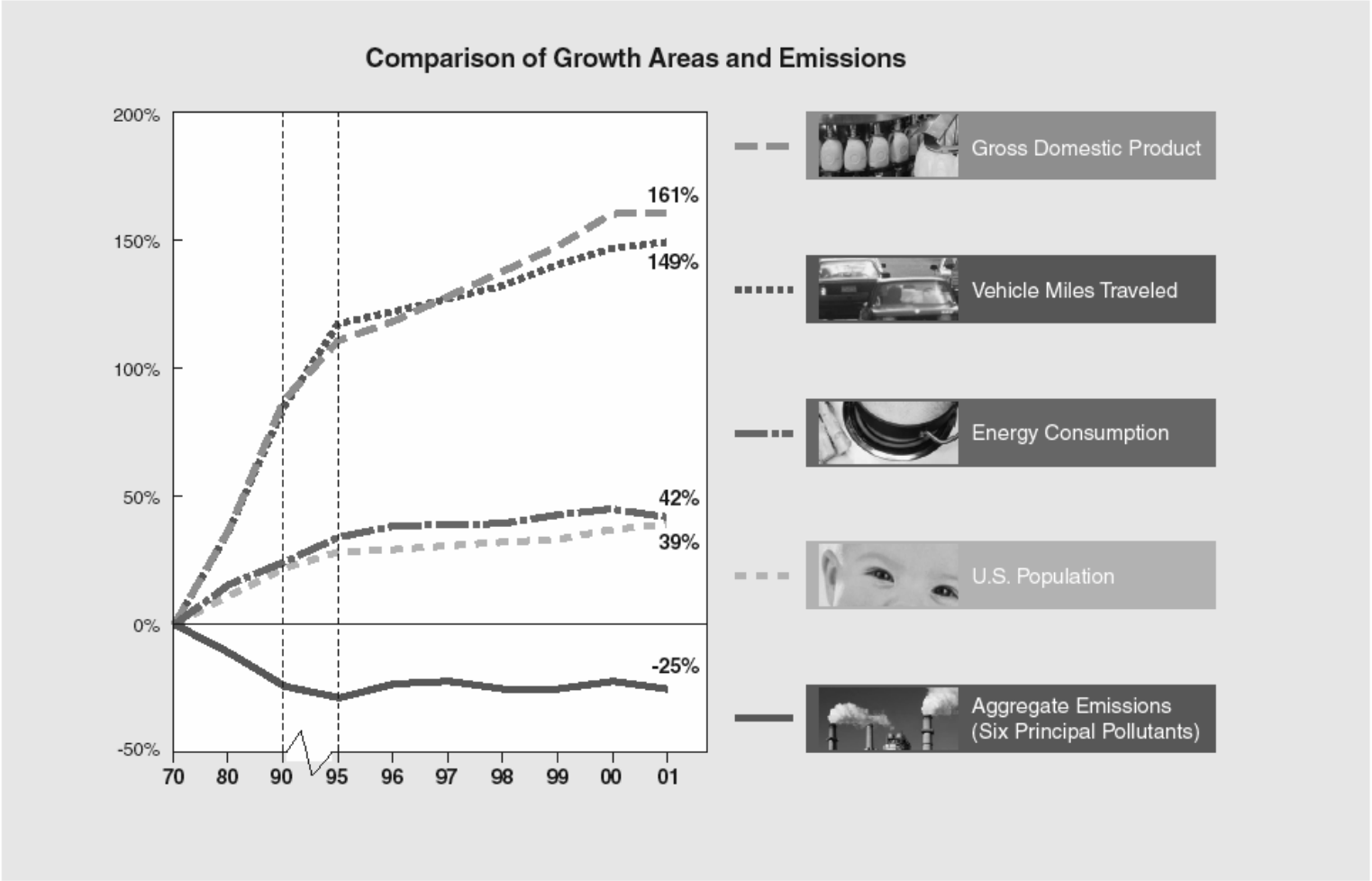


U.S. Progress towards Clean Fuels and Vehicles



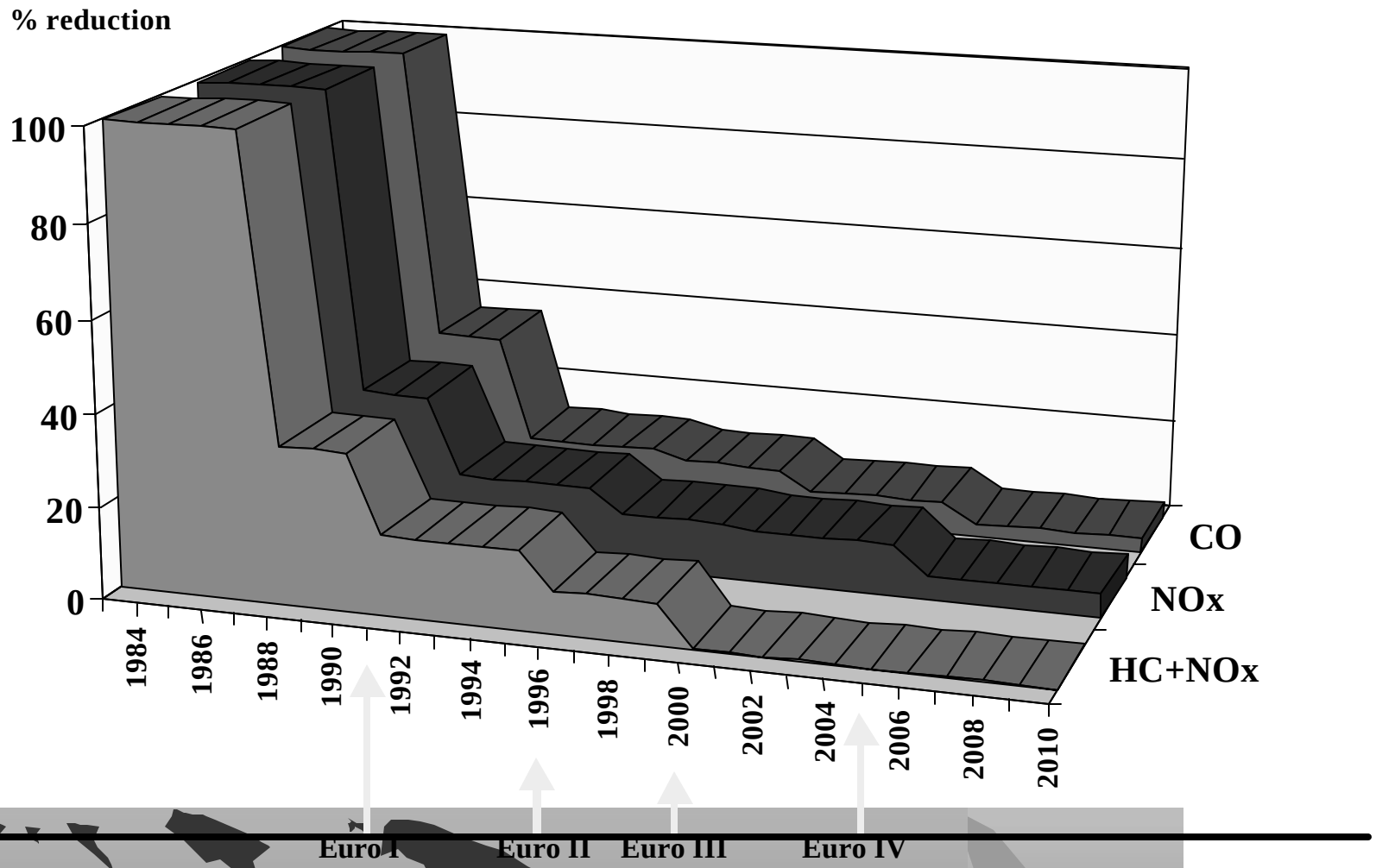


Economic Growth Can Coexist with Clean Air and Low Energy Consumption

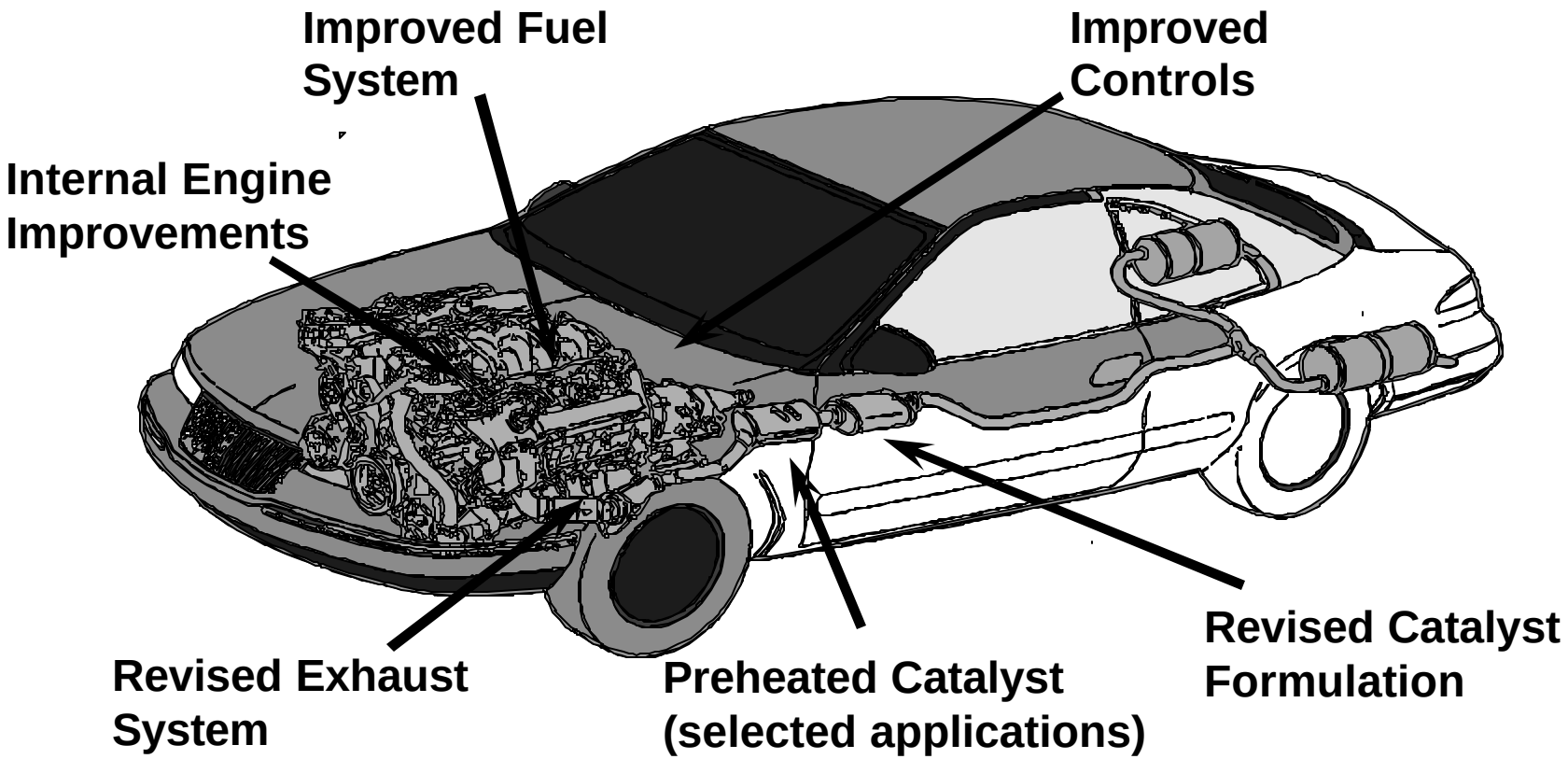


Between 1970 and 2001, gross domestic product increased 161 percent, vehicle miles traveled increased 149 percent, energy consumption increased 42 percent, and U.S. population increased 39 percent. At the same time, total emissions of the six principal air pollutants decreased 25 percent.

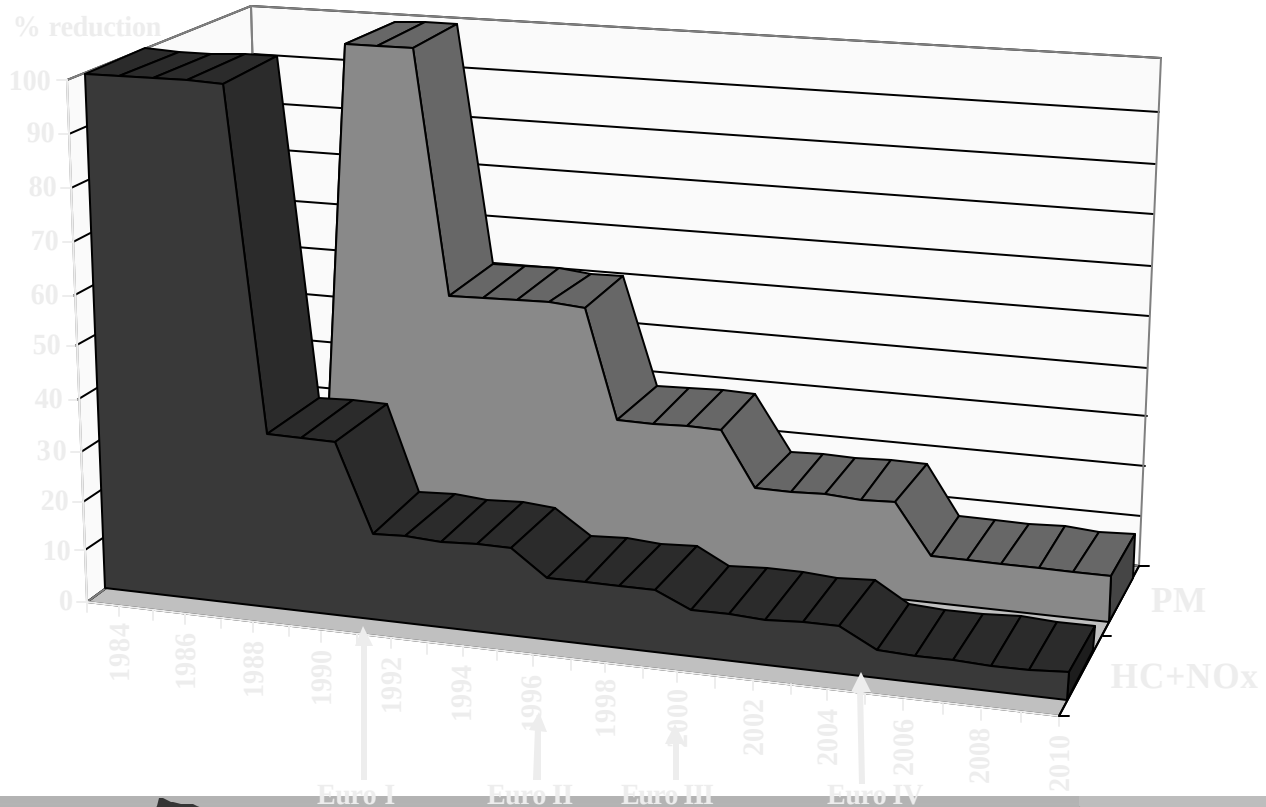
EU Emissions Standards For Petrol Fueled Cars



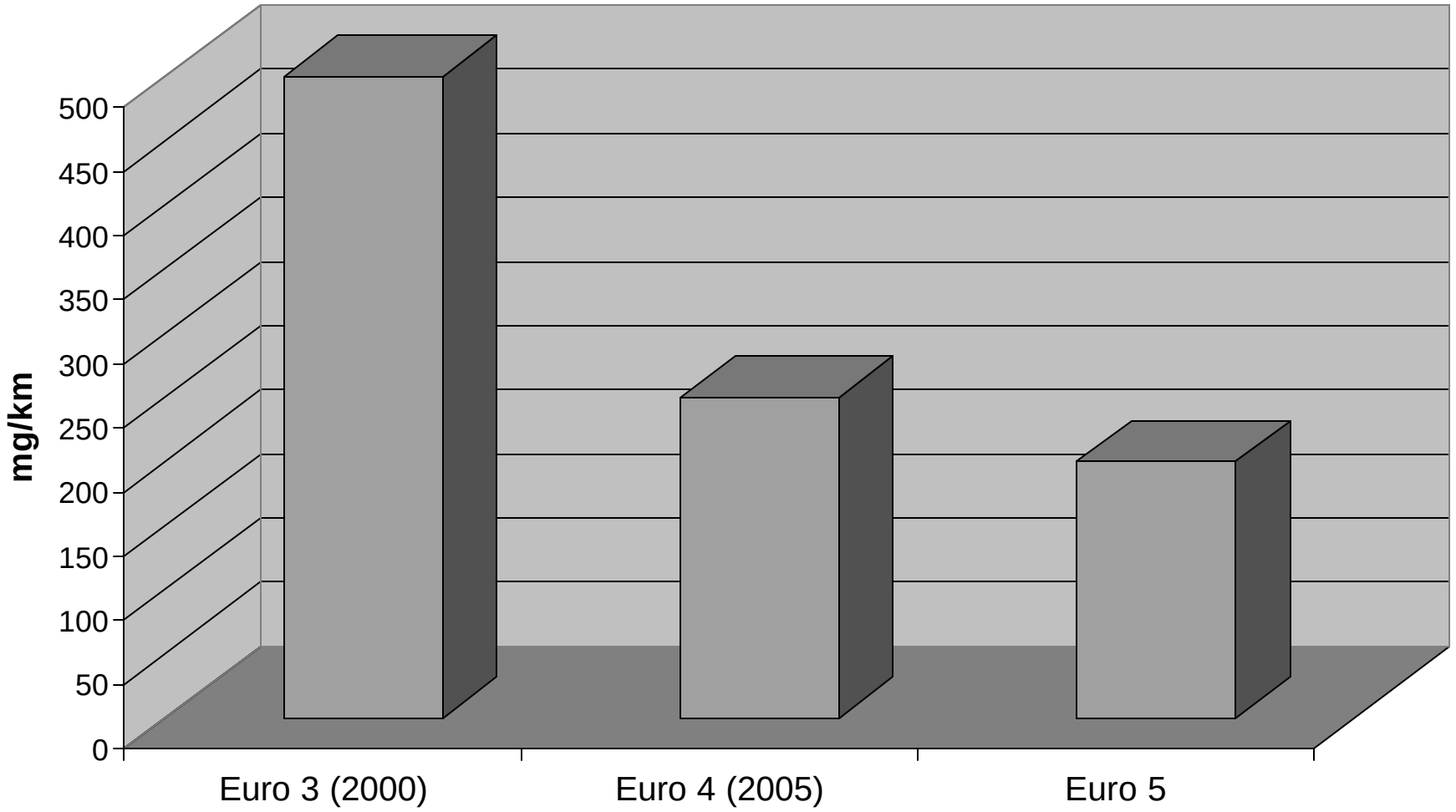
Best Practice Pollution Control System



Emissions From Diesel Cars In Europe

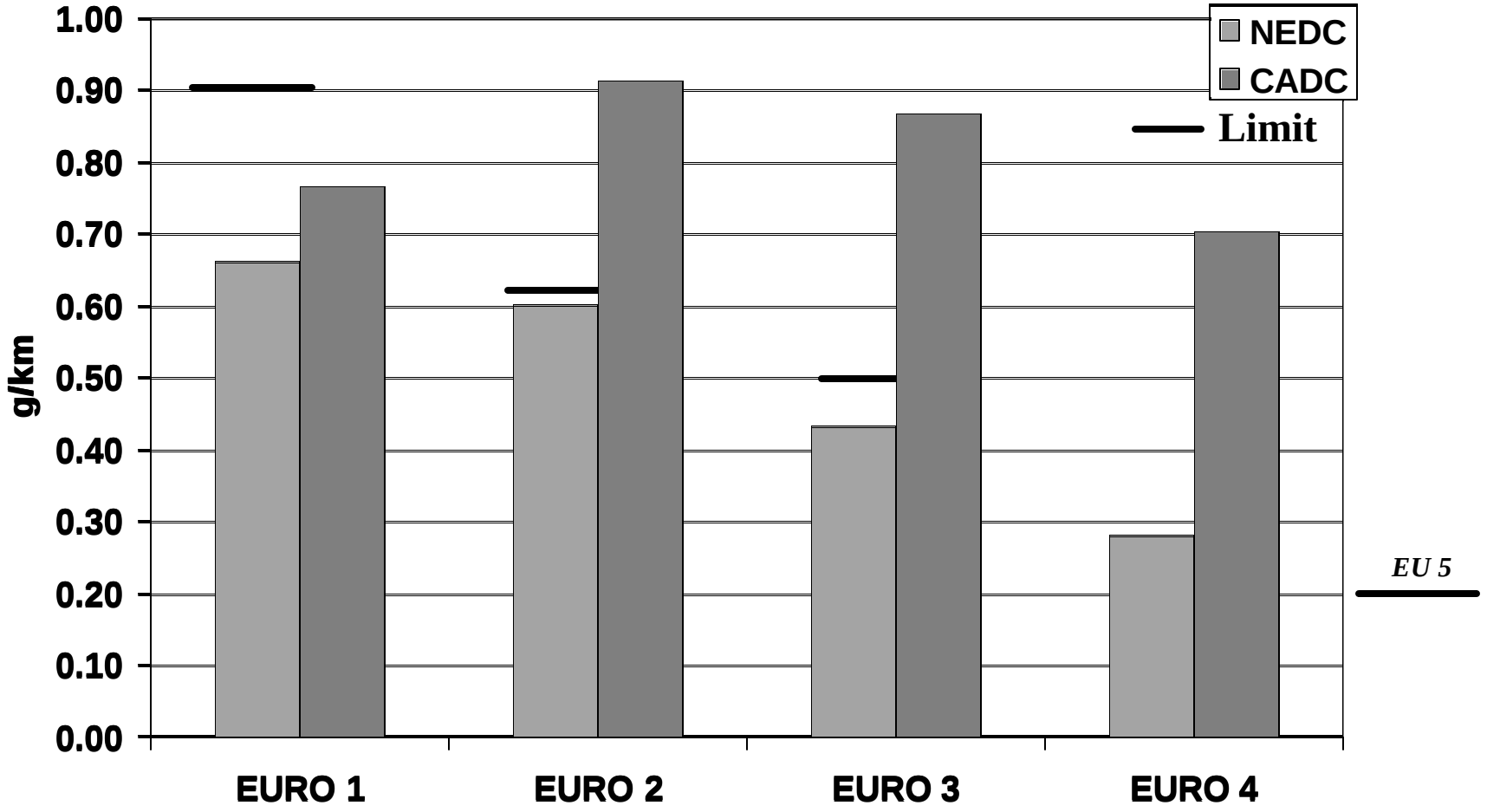


Diesel NOx emission limits

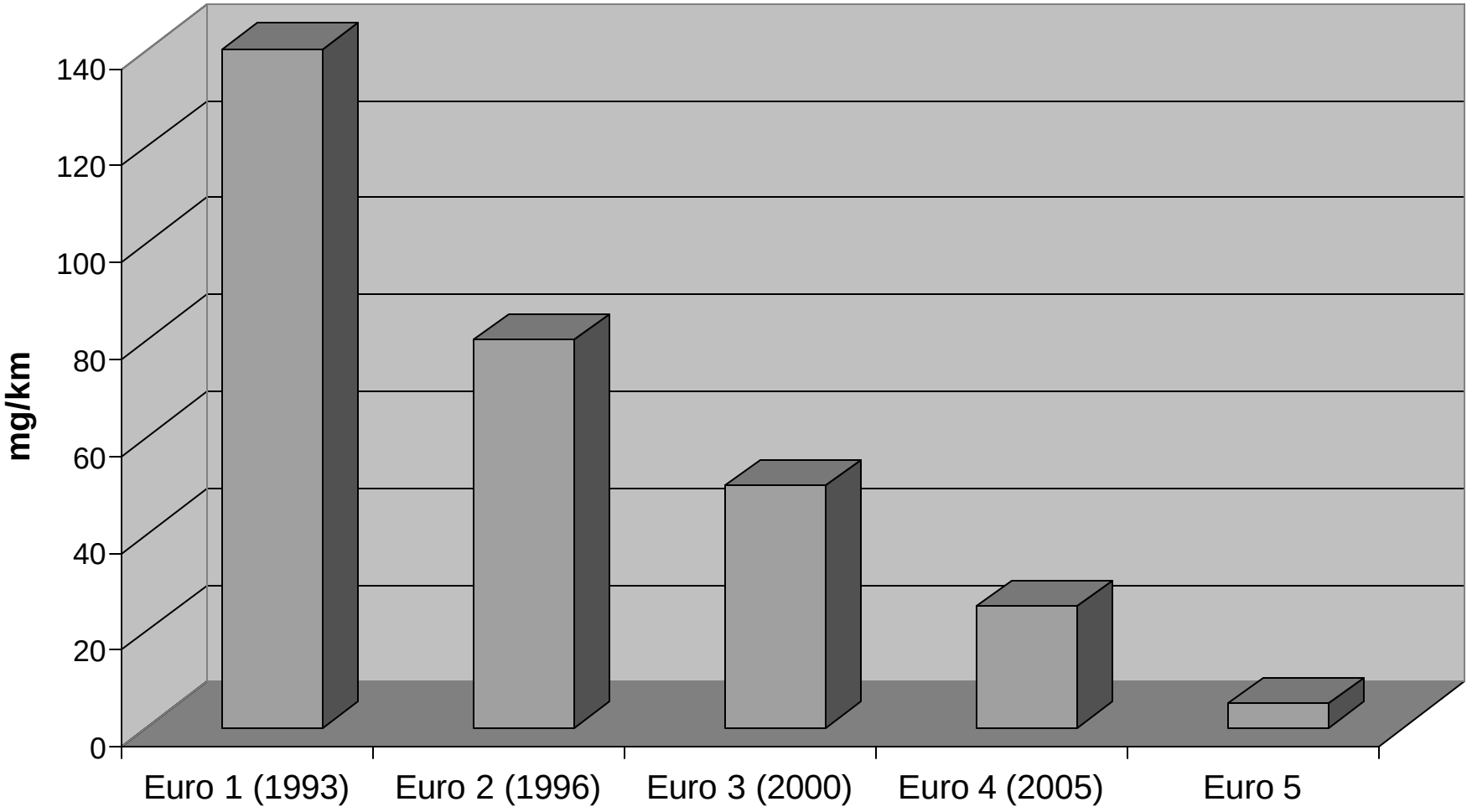


Question 1.2

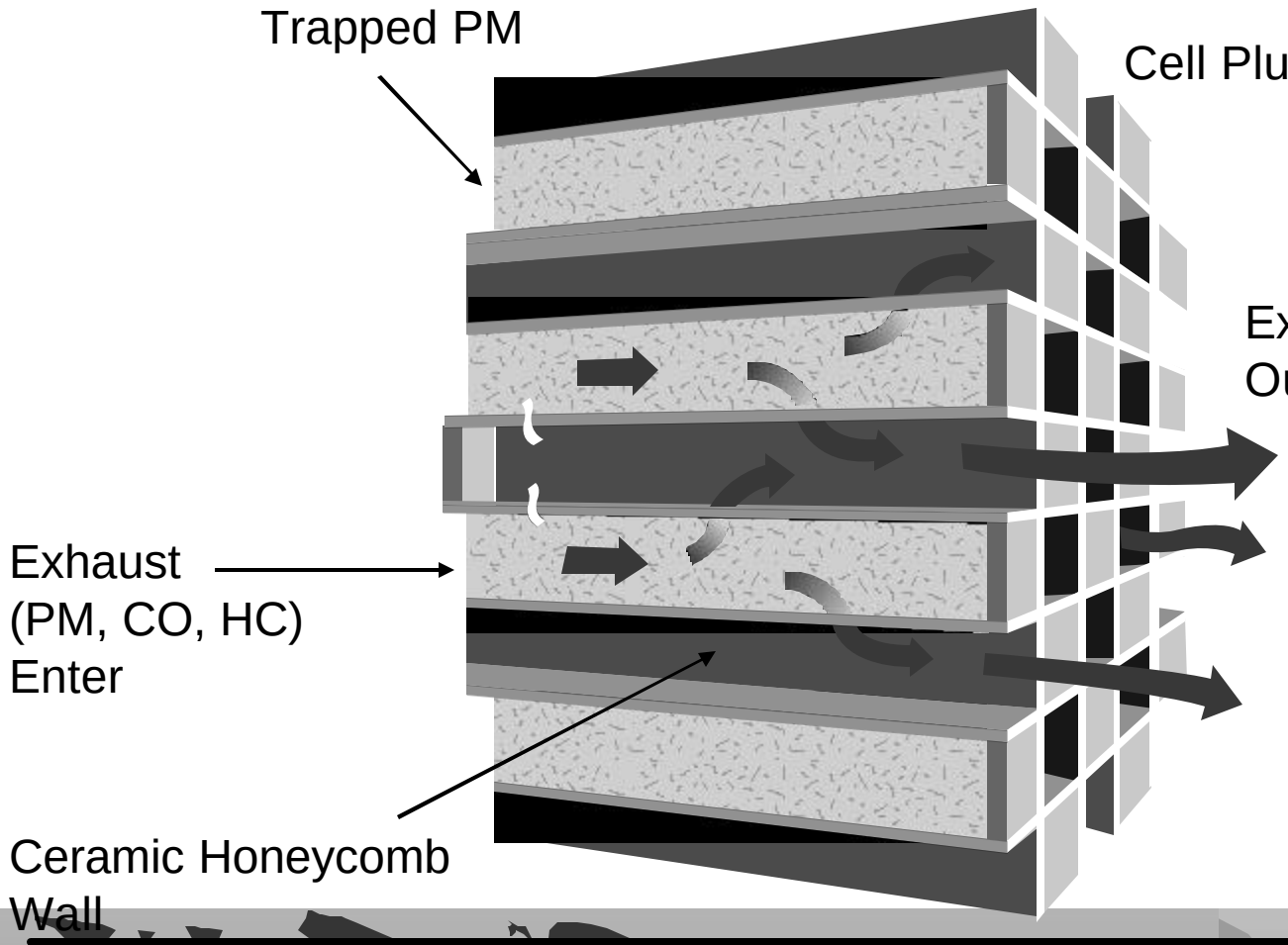
How have specific NOx emissions of diesel passenger cars evolved in the past?



Evolution of PM emission limits



Diesel Particulate Filters



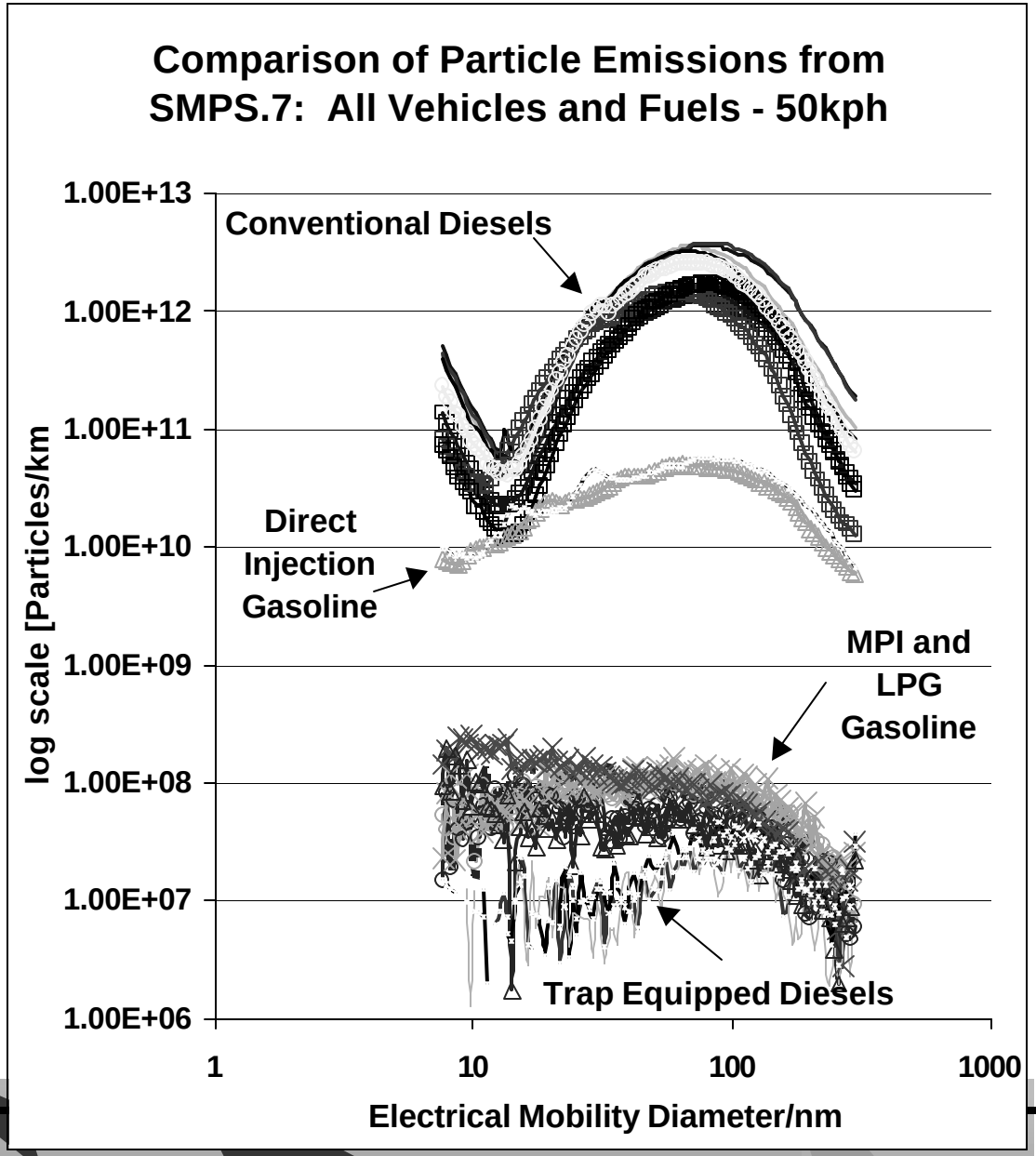
Reductions:

- **-80 to 95% PM**
- **-80-100% HC, CO**
- **-80%+ toxins**

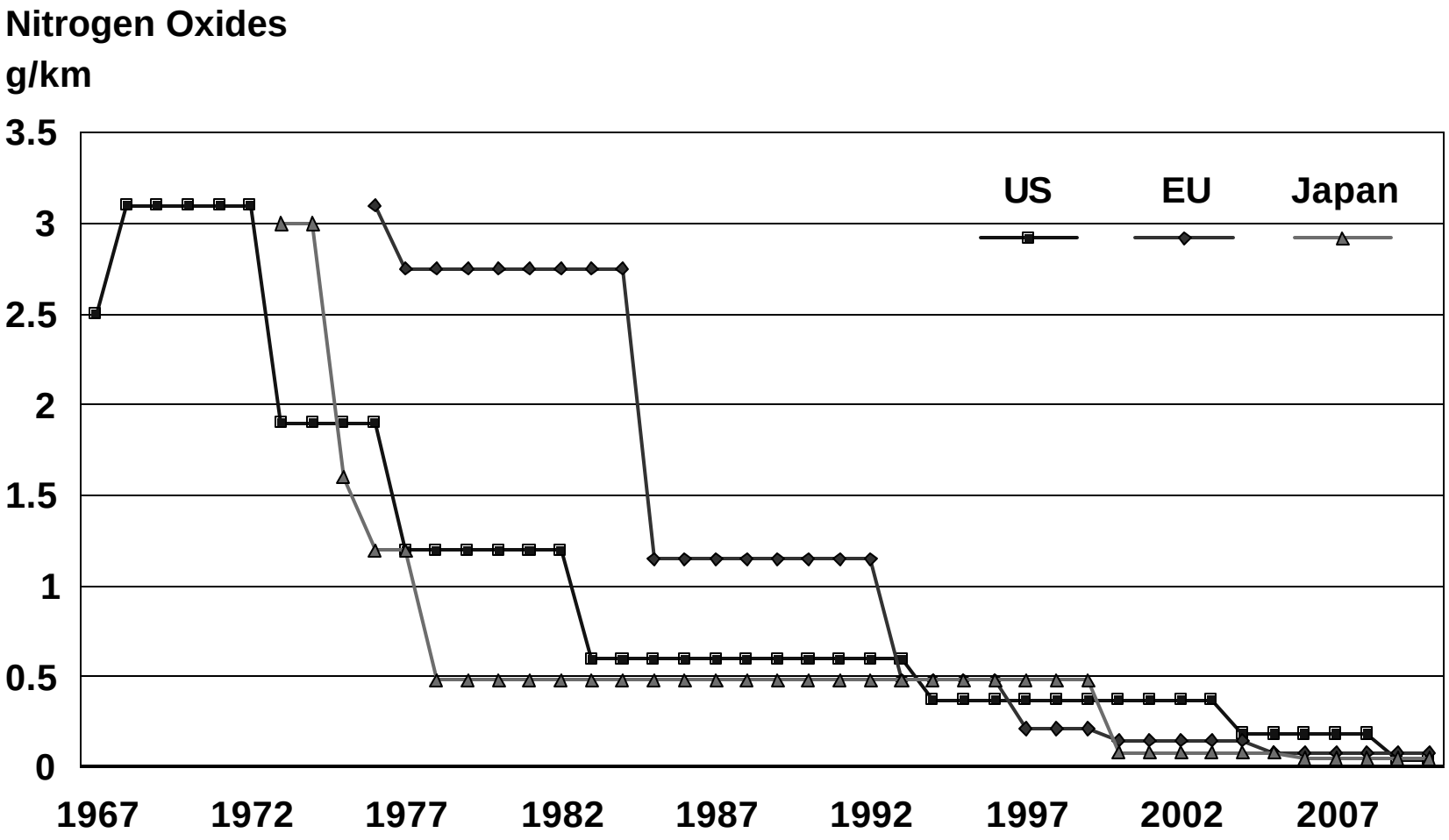
Issues to balance:

- sulfate formation
- regeneration and back pressure
- Fuel Economy

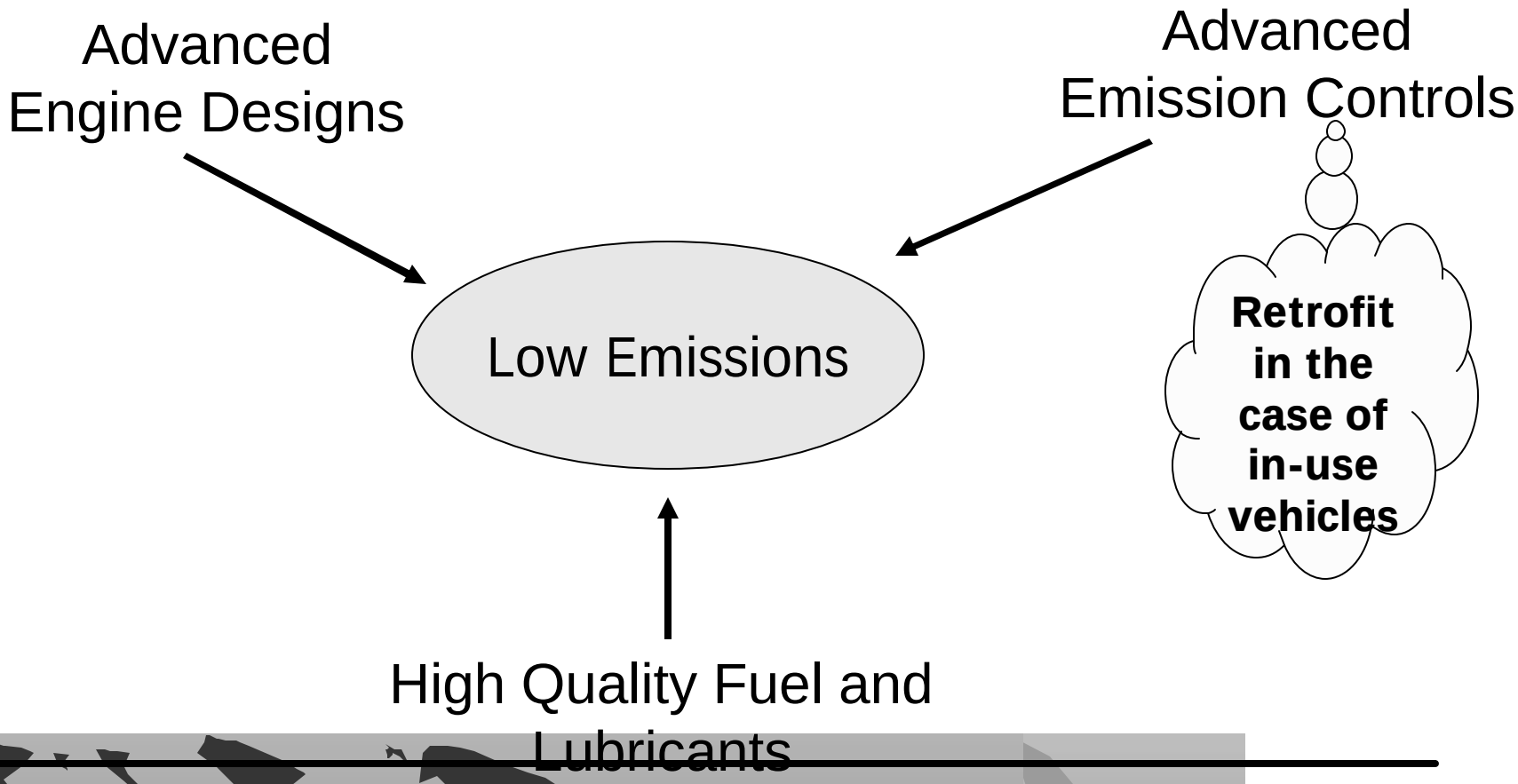
Higher Sulfur Reduces Efficiency, Potential Durability, Fuel Economy


Comparison of Particle Emissions from SMPS.7: All Vehicles and Fuels - 50kph
1.00E+13
1.00E+12
1.00E+11
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
log scale [Particles/km
Conventional Diesels
Direct Injection Gasoline
MPI and LPG Gasoline
Trap Equipped Diesels
1
10
100
1000
Electrical Mobility Diameter/nm

Emissions Standards Trends For Gasoline Cars



Meaningful Emission Control Reductions in New Vehicles Requires a Systems Approach



ZEV Regulation Restructured in 2003 for More Flexibility

10 % Mandate

6 %

Near-Zero Conventional Vehicles (Path 1)

>0 - 2 %

Battery Electric
H2 Fuel Cell
(Path 3)

2 - 4 %

Clean Hybrids
(Path 2)

I/M Plays A Critical Role

- Improved Vehicle Maintenance
- Deterrent To Tampering
- Deterrent To Misfueling
- Primary Enforcement Mechanism For Other Strategies
  - Alternative Fuel Retrofit
  - Other Retrofit

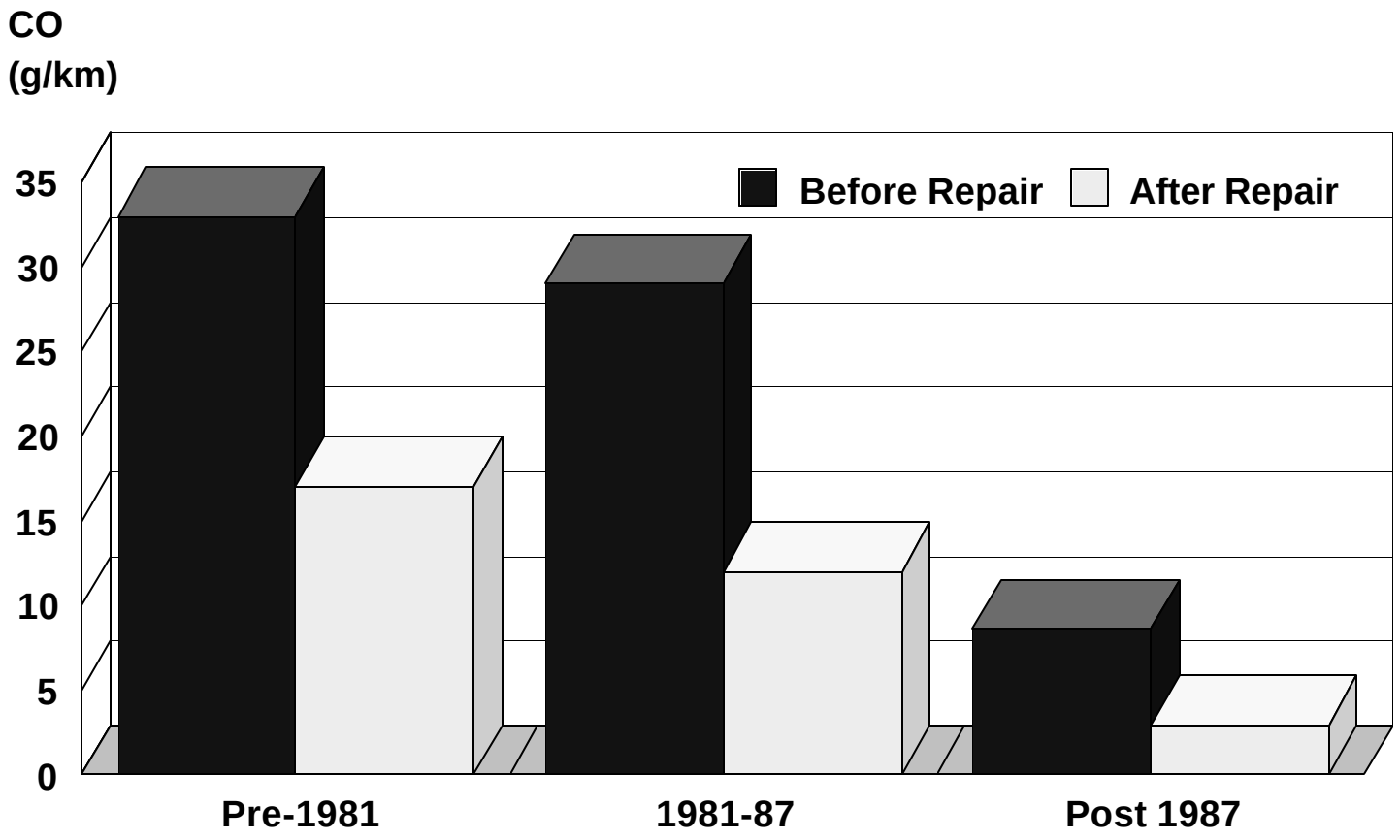
Vehicle Inspection and Maintenance (I/M) Program

- Purpose:
  - To Assure that vehicle is properly maintained and used
  - Identify Dirtiest Vehicles & Get Them Repaired
  - Identify Unsafe vehicles & Get them Repaired
- General Attributes:
  - Relatively short
  - Relatively simple
- Test Types
  - Idle
  - 2-Stage Idle
  - Steady Speed Loaded
  - Transient Loaded
- Variety of Safety Tests

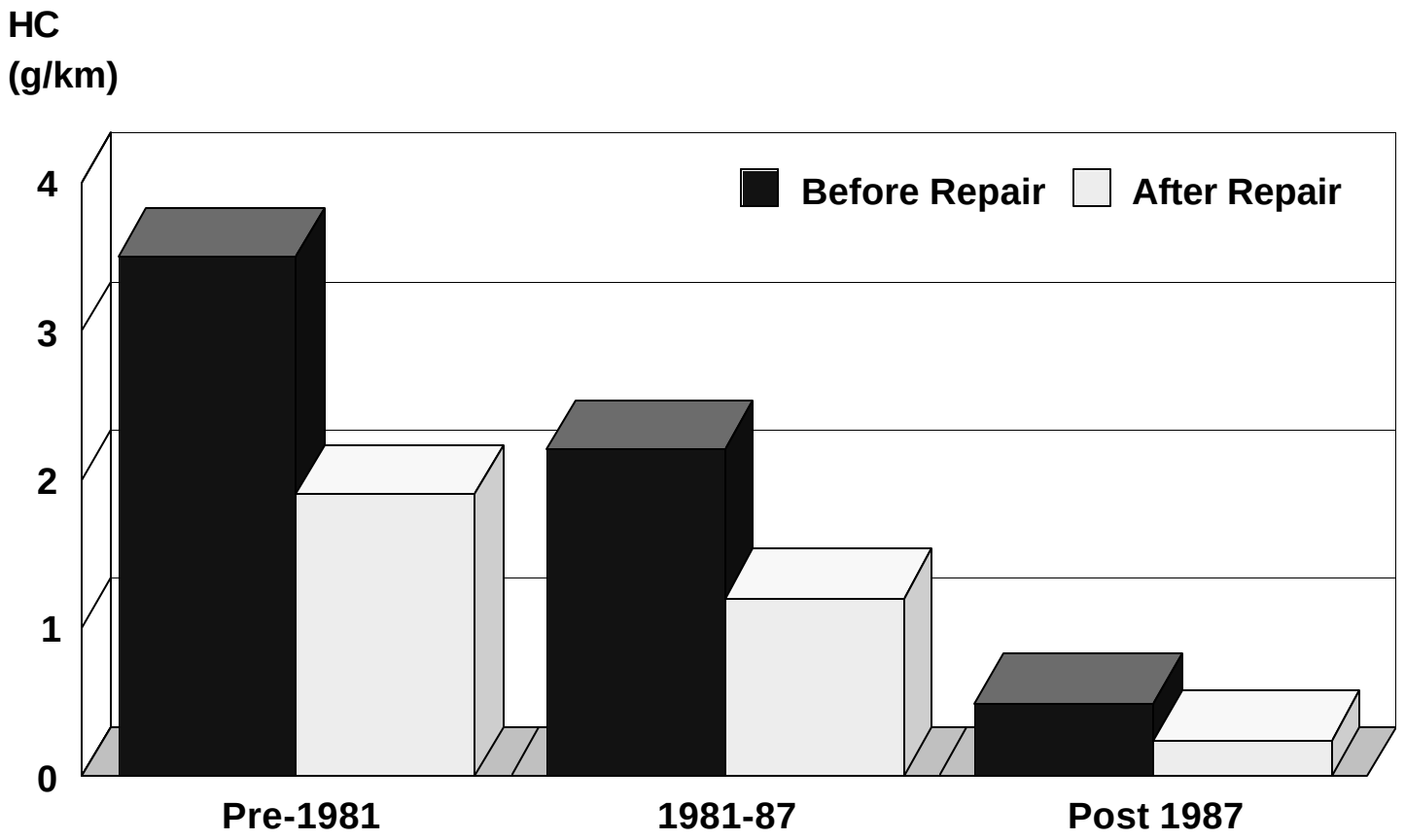
Inspection/Maintenance
Considerations

- Program Type
- Effectiveness
  - Enforcement
  - Test types
  - Network design
  - Frequency
  - Quality of repairs
- Cost
  - Economies of scale
  - Sophistication
  - Capital
  - Operations
- Economic Impact
  - Ability to pay for repairs
  - Waivers
  - Scrappage
  - Alternatives
- Institutional Support
  - Audits
  - Oversight
  - Training

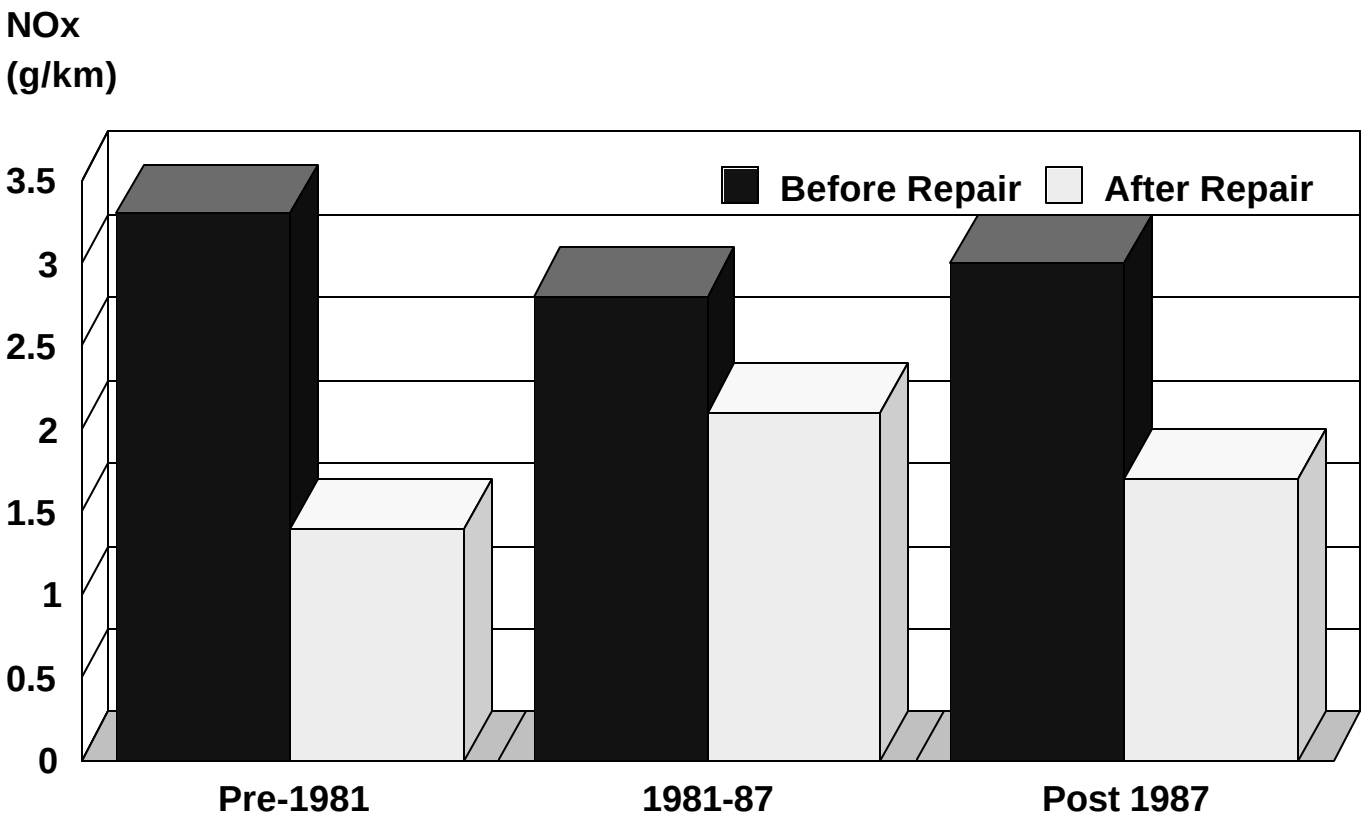
Results of the British Columbia I/M Program Audit



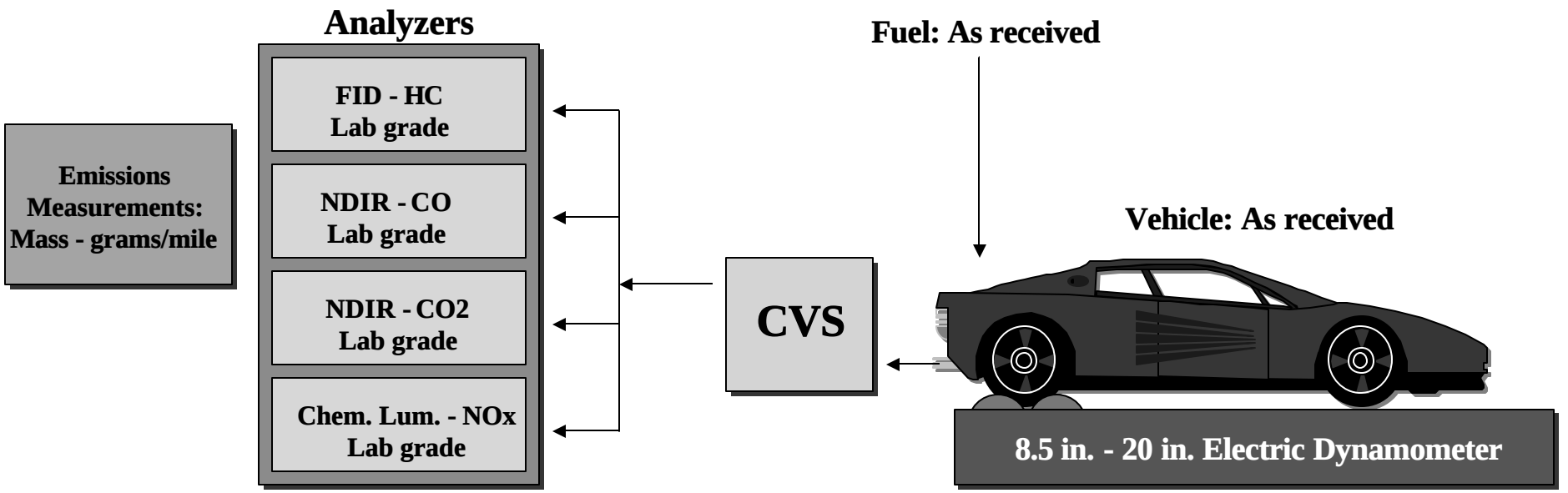
Results of the British Columbia I/M Program Audit



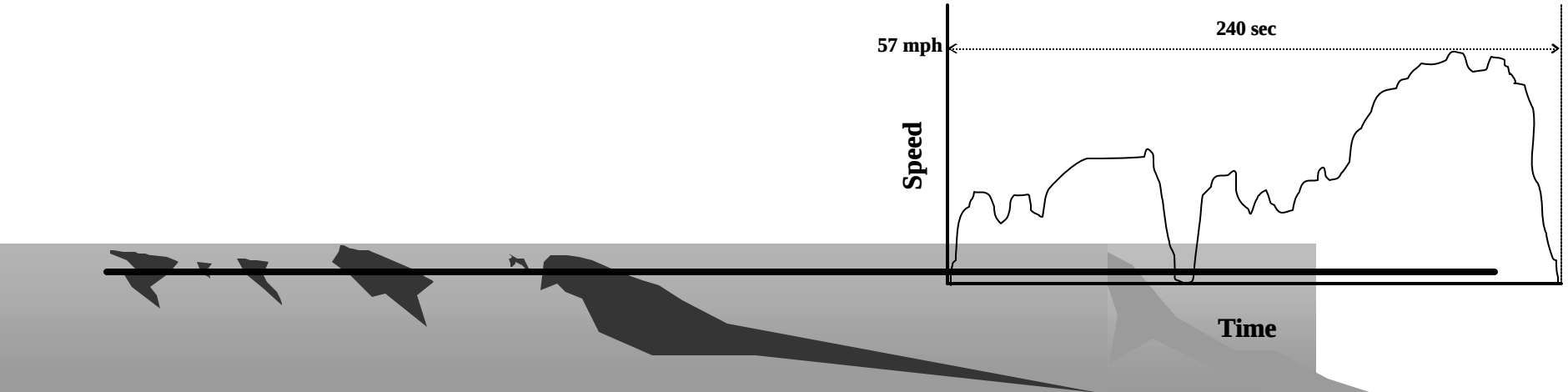
Results of the British Columbia I/M Program Audit



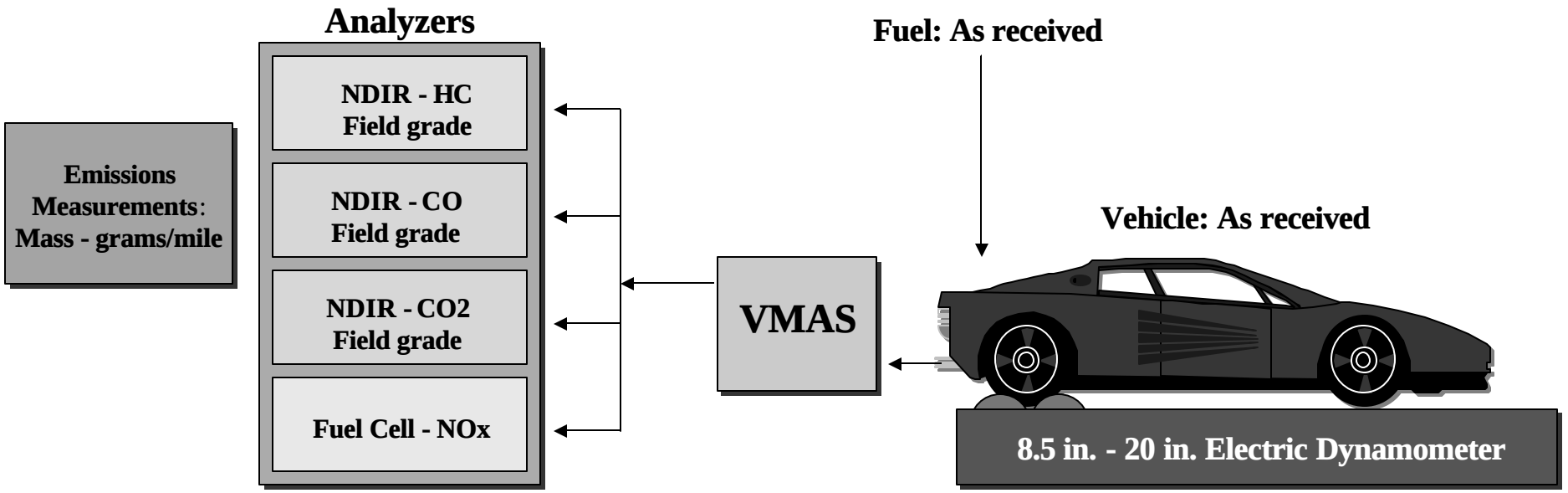
Test Type: IM240



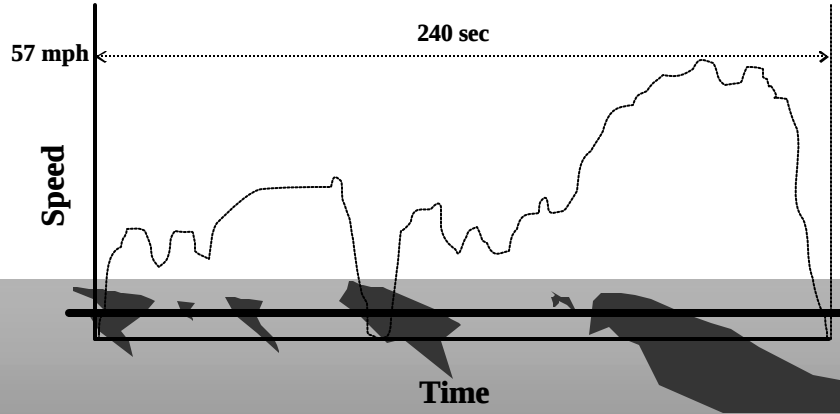
IM240 Test Cycle: Transient, loaded mode



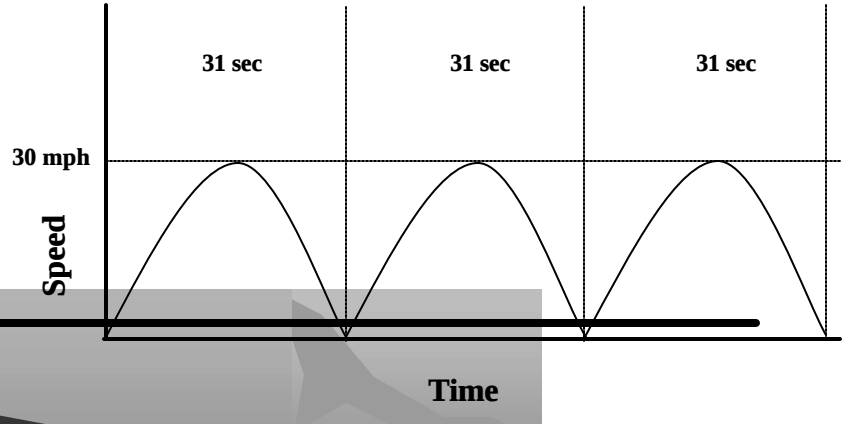
Test Type: Mass 31 or IM240 or Other

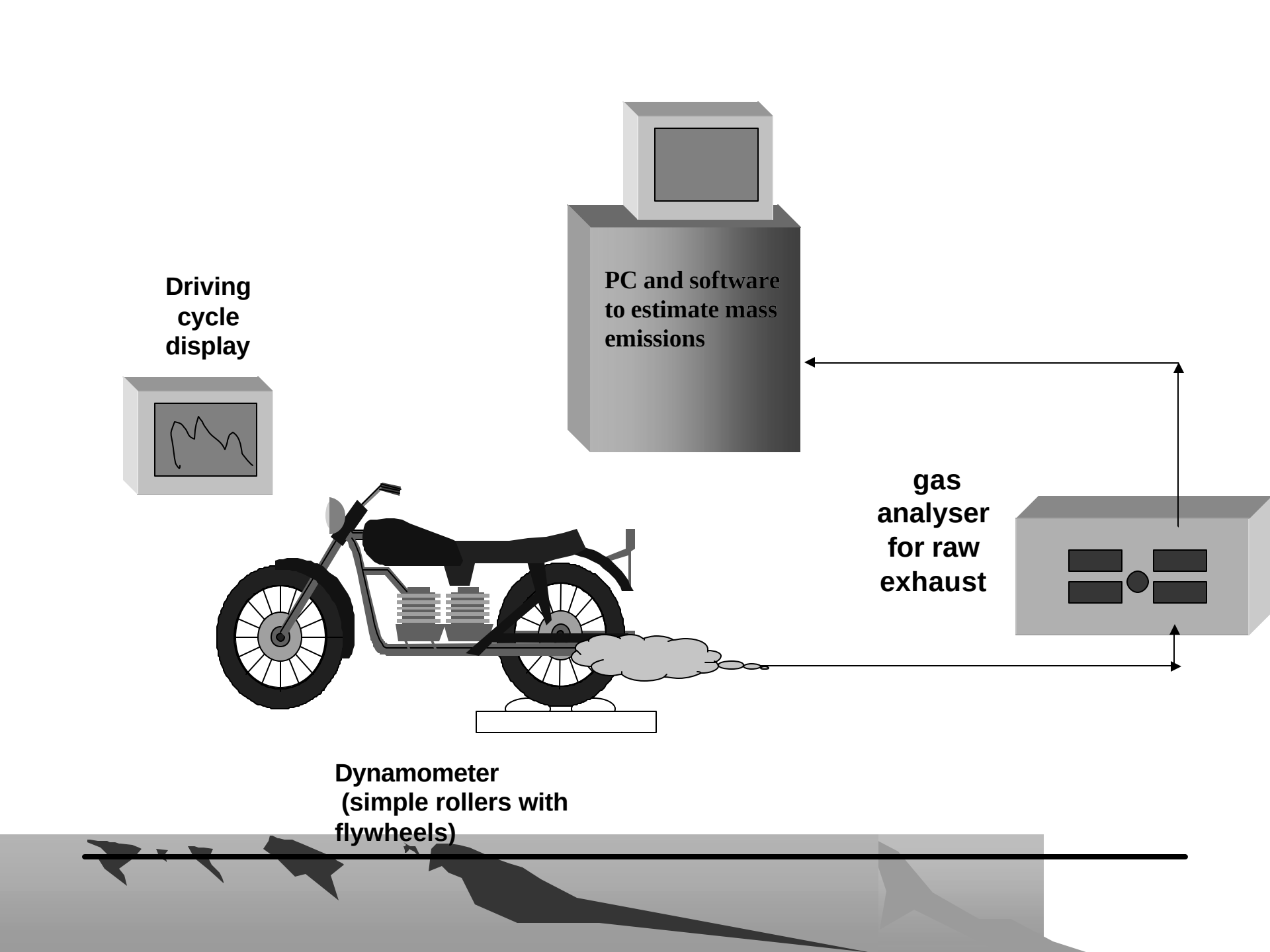


IM240 Test Cycle: Transient, loaded mode



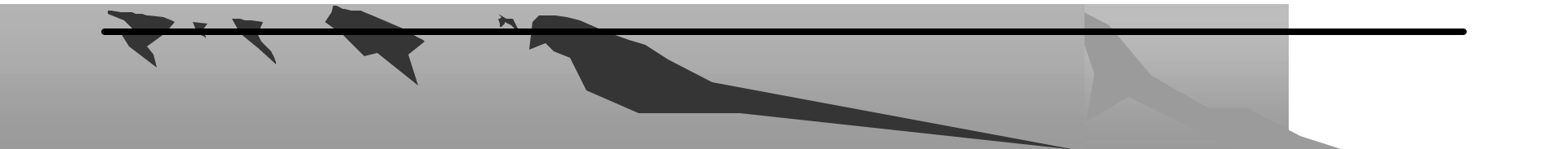
MASS 31 Test Cycle: Transient, loaded mode

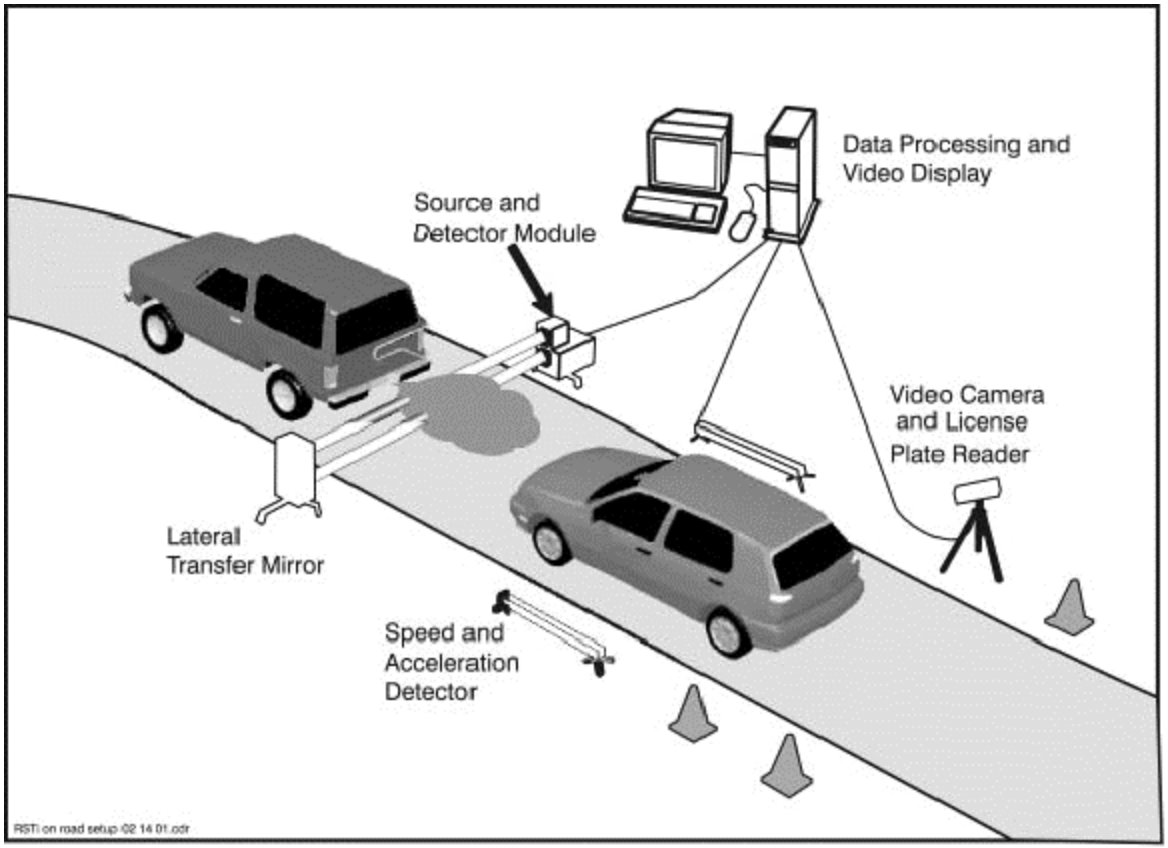



Driving cycle display
PC and software to estimate mass emissions
gas analyser for raw exhaust
Dynamometer (simple rollers with flywheels)

Remote Sensing

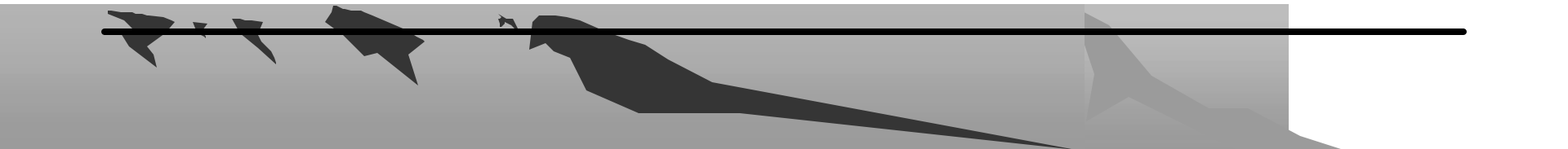
- Definition
  - Measure emissions while vehicle drives on road
- Features
  - Measures HC, CO, NOx
  - May measure speed or acceleration. etc.
  - Uses lasers or NDIR
  - Tests many cars per hour
  - Set up on roadways
  - Takes picture of license plate
- Advantages
  - Very cheap tests
  - Complements I/M
    - Prevent readjustment
    - Screen Uninspected Vehicles
- Challenges
  - Comprehensiveness
  - Selecting Appropriate Locations
    - Single Lanes
    - Slight Acceleration



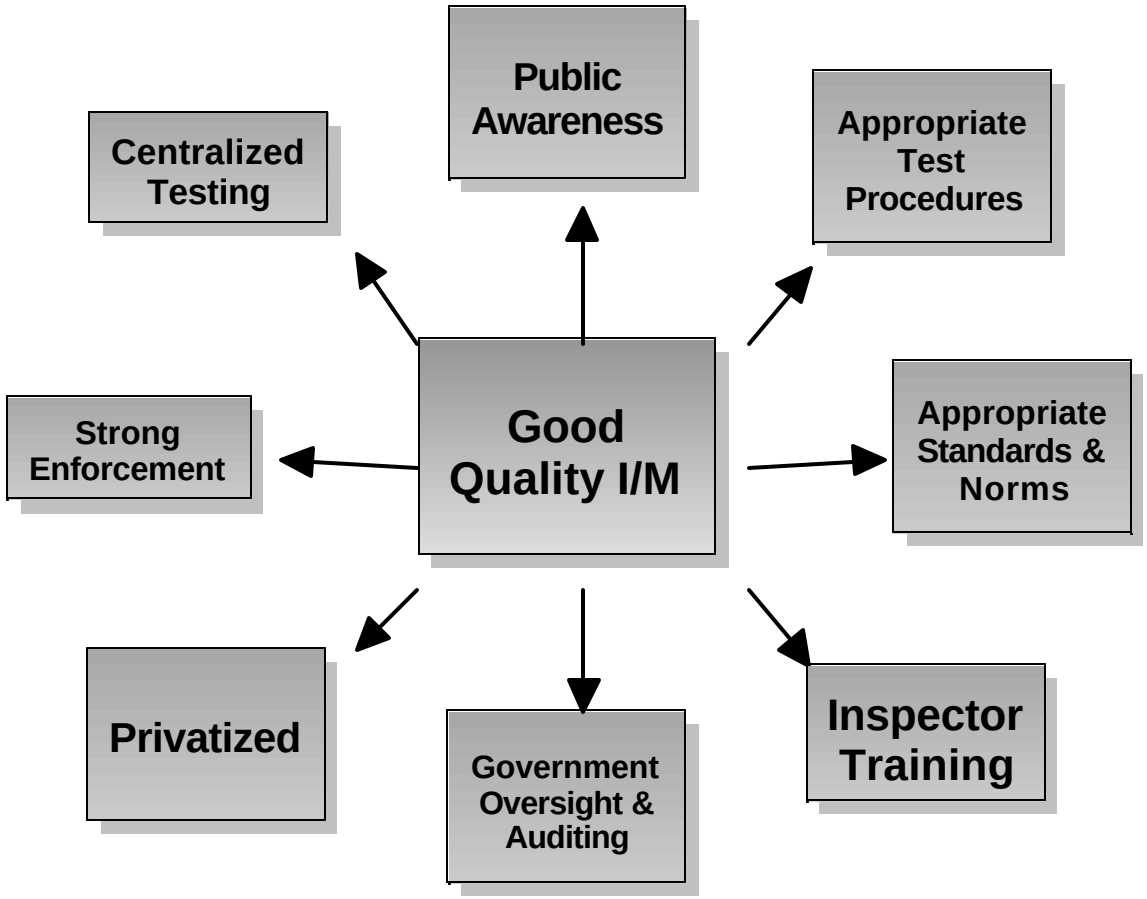

Data Processing and
Video Display
Source and
Detector Module
Video Camera
and License
Plate Reader
Lateral
Transfer Mirror
Speed and
Acceleration
Detector
RSTI on road setup 02 14 01.cdr

Applications

- Auditing
  - Over 1 million vehicles tested worldwide
  - Very Good For Seeing Trends
- Clean Screening
  - Useful Complement To High Quality Comprehensive I/M Program
  - Colorado's RapidScreen
- Dirty Screening
  - Useful In Areas With Limited or Weak I/M Programs
  - California/Swedish Studies Show Very Good Results
  - Requires Good Registration Data
  - Good Also For Central Fleets

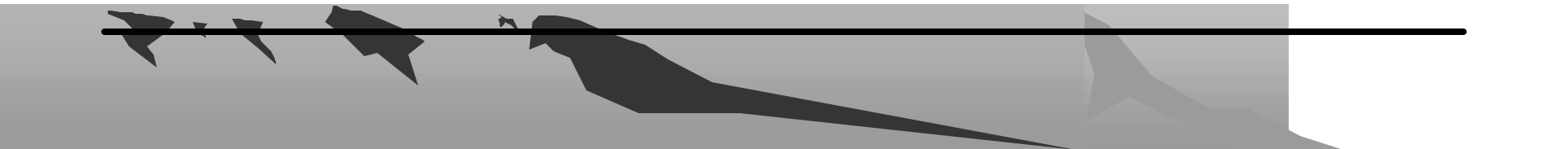


Elements of A Successful I/M Program



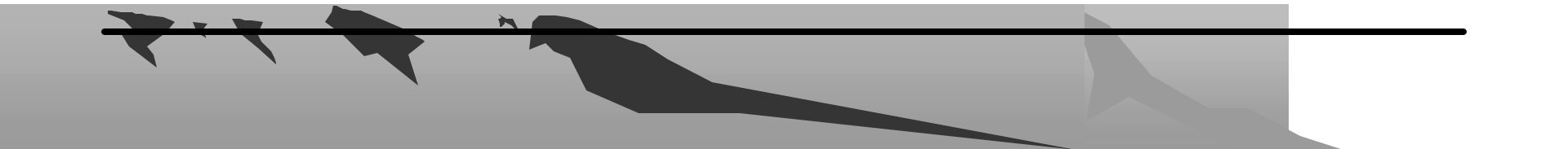
Other

- Scrappage
- Retrofit
- Alternative Fuels



Why Use Alternative Fuels?

- Petroleum Displacement
- Energy Diversity
- Air Quality Improvement
- Greenhouse Gas Emission Reductions
- Domestic Economic Development

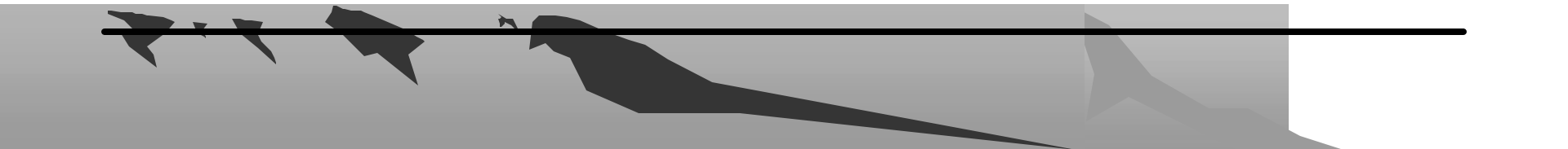


Alternative Transportation Fuels

- Electricity
- Ethanol
- Hydrogen
- Methanol
- Natural Gas
  - Compressed
  - Liquefied
- Propane (LPG)
- 100% Biodiesel

Alternative Fuel Vehicles Available Now

- Ethanol
- Natural Gas
- Propane (LPG)



Ford Crown Victoria

Ford F-150

Natural Gas Vehicles

- Very Low Emissions
- Good Performance
- Lower Cost Fuel

- Limited Range, but Adequate for Most Applications
- Few Refueling Stations
- Higher Cost Vehicle

Honda Civic

New Flyer D40 LF Bus

Propane Vehicles

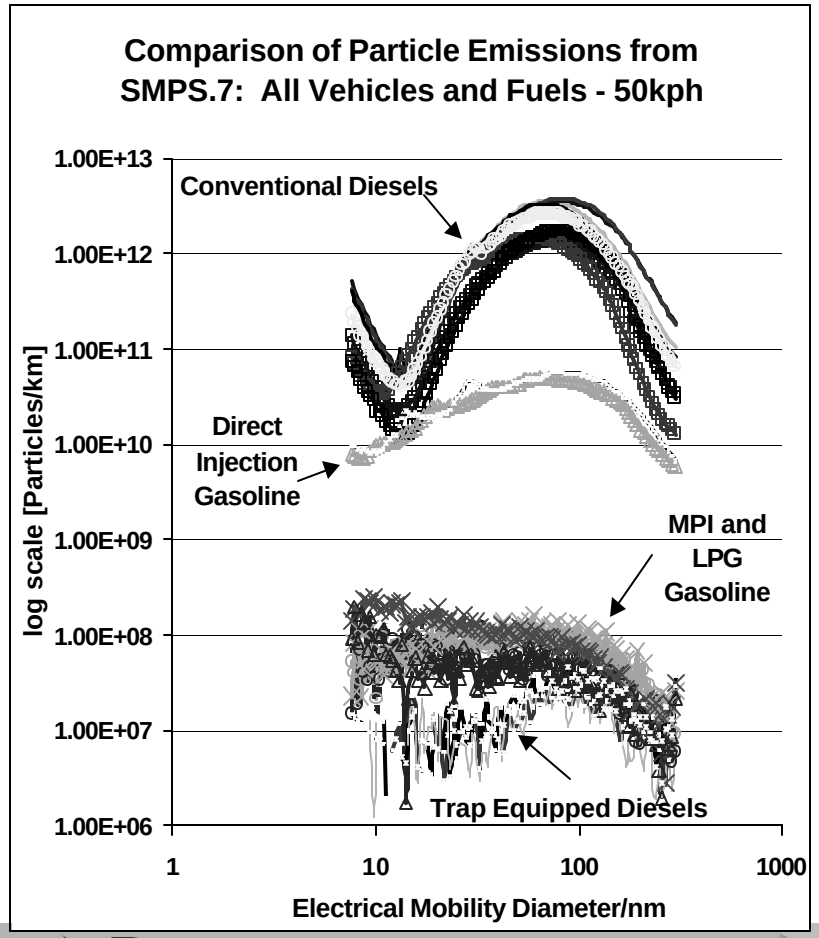
- Low Emissions
- Good Performance
- Cost Similar to Gasoline

Ford F-150

- Few Typical Refueling Stations, Many Potential Places to Refuel
- Higher Vehicle Cost

Ford Club Wagon

Ultrafine Particles Vary For Different Fuels



Ethanol Vehicles

- Low GHGs
- Less Reactive

- Subsidy Required to be Cost Competitive

Ford Taurus

Ford Ranger

Chrysler Minivan

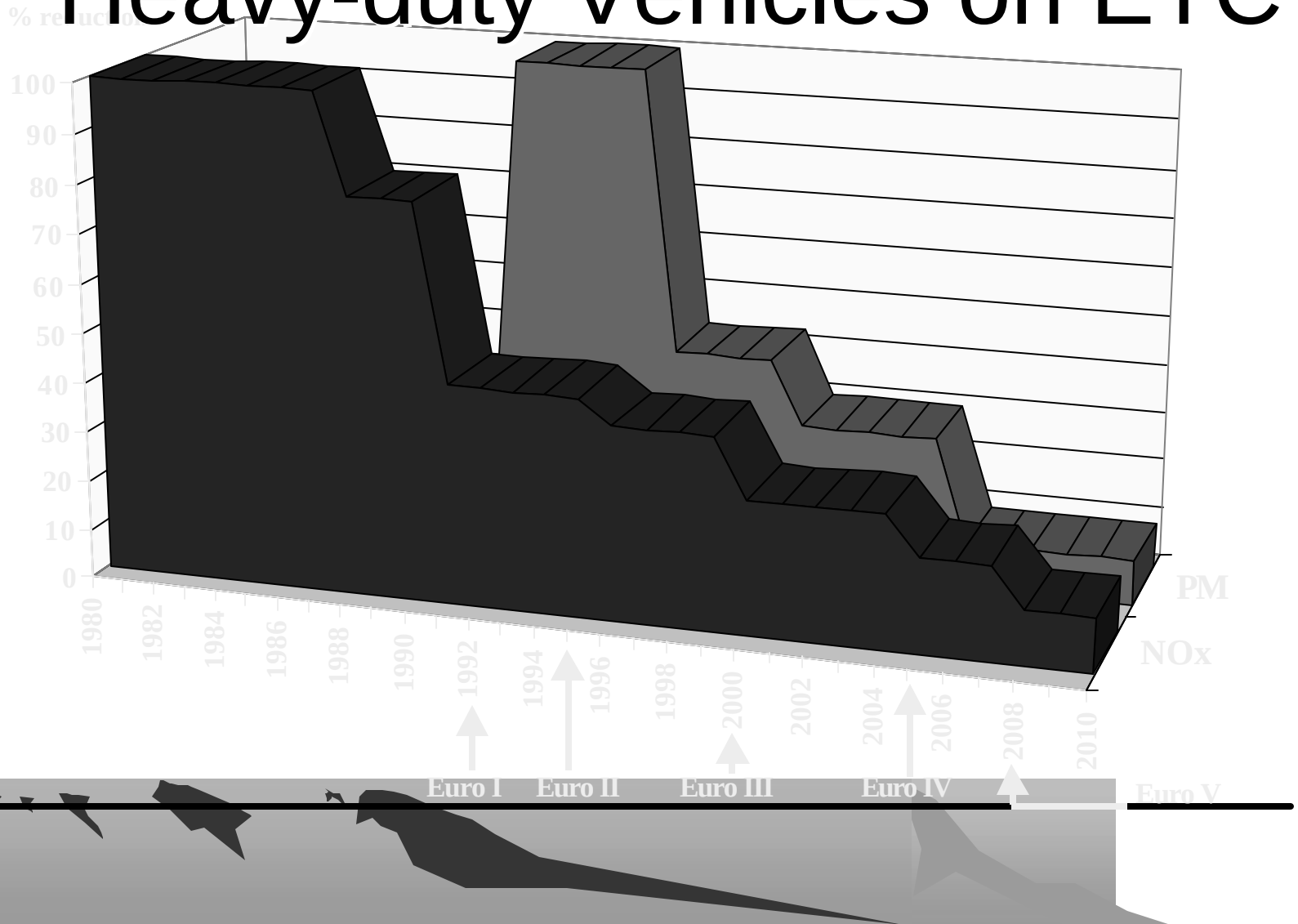
Long-term Outcomes With Alternative Fuels

- Billions of gallons of oil displaced or reduced
- Thousands of tons of emission reductions
- Enhanced energy security and improved transportation sustainability

The Path To Cleaner Buses & Trucks

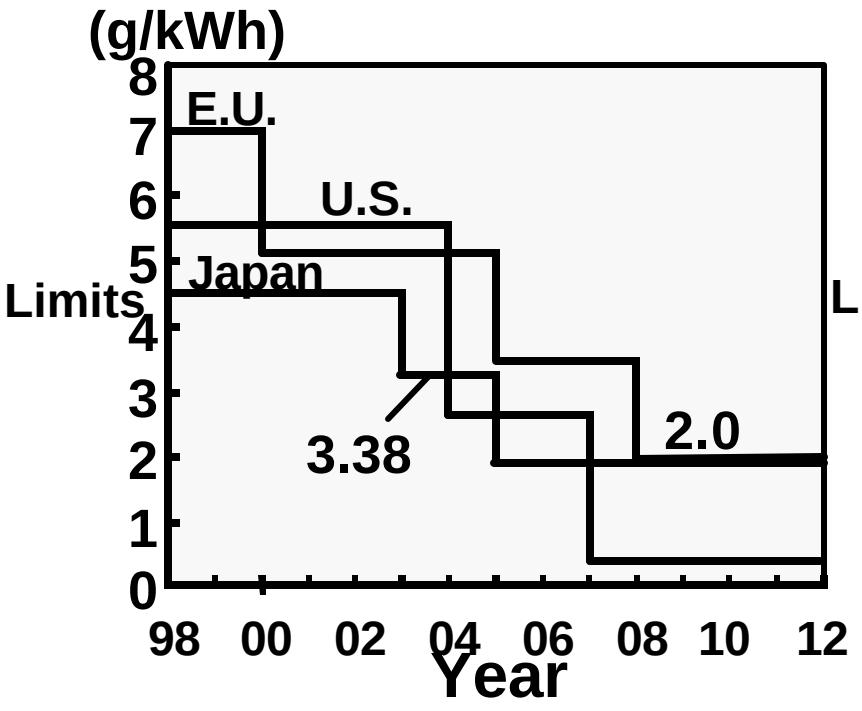
- Cleaner Fuels
- Tighter New Vehicle Standards
- Inspection and Maintenance
- Other
  - Scrappage
  - Retrofit
  - Alternative Fuels

EU Emissions Standards For Heavy-duty Vehicles on ETC

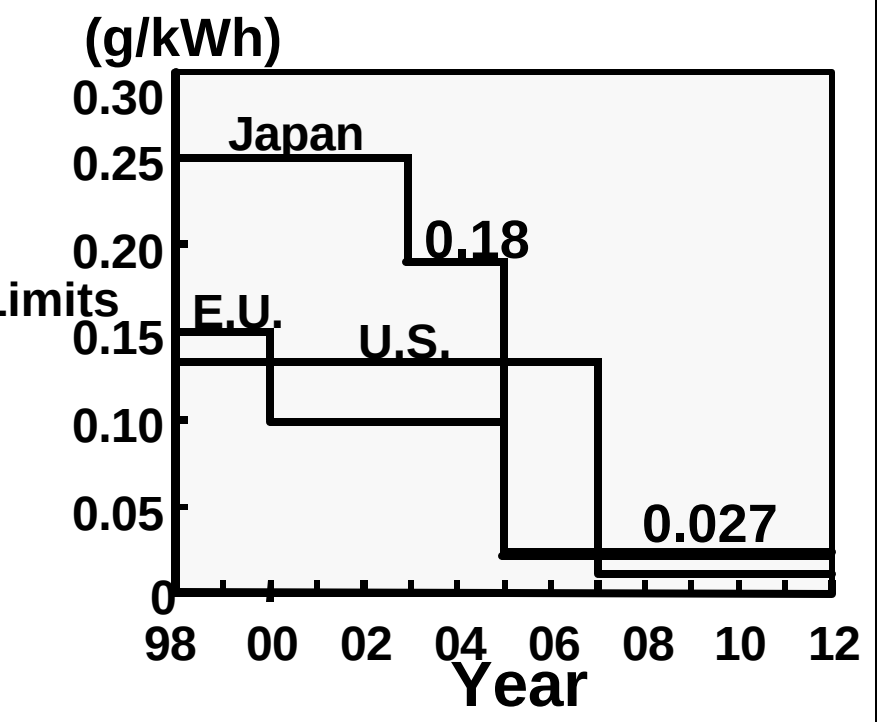


International Emission Regulations:
- Heavy-duty vehicles (GVW>3.5t) -

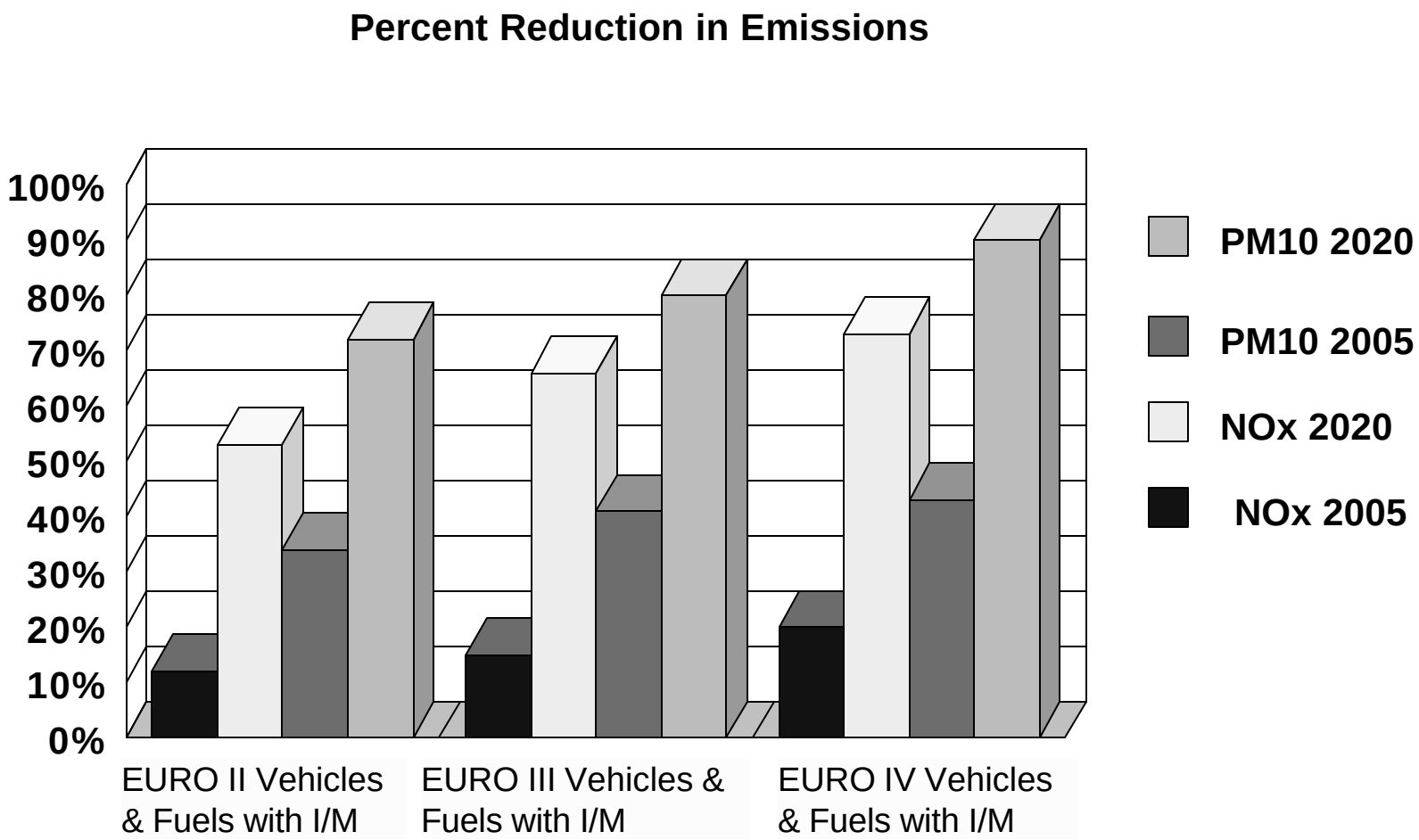
? Nitrogen oxides (NOx)



? Particulate matter (PM)

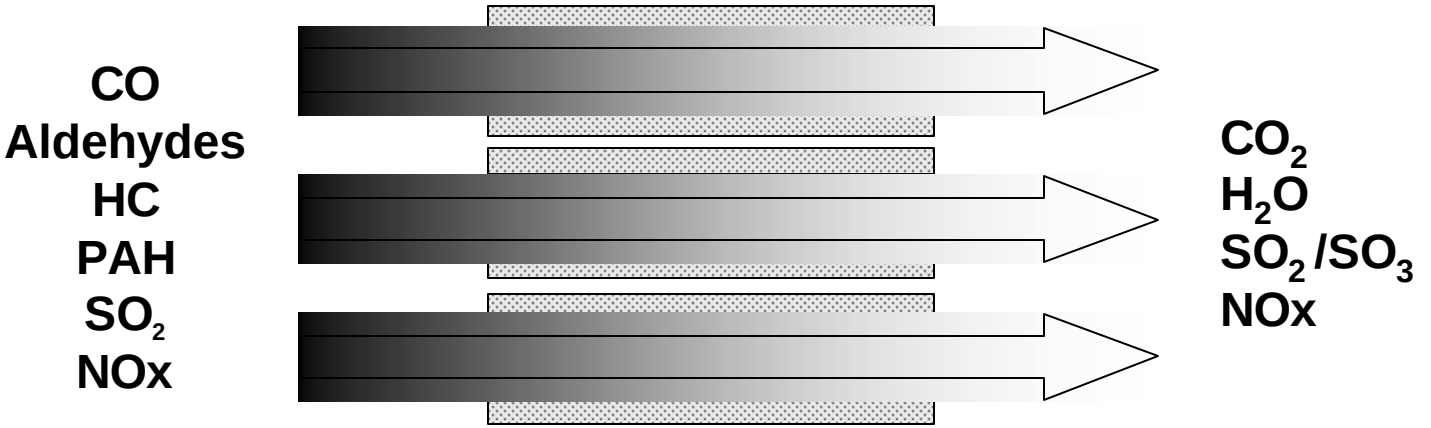


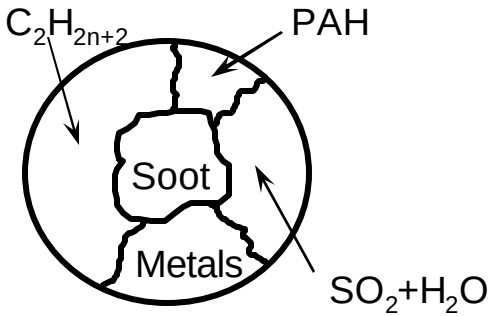
Impact of Clean Vehicles and Fuels On Diesel Vehicle Emissions



Source: Camarsa, BAQ 2003

Diesel Oxidation Catalyst





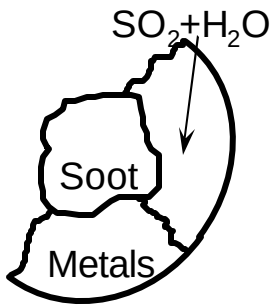
Flow through monolith with catalytic coating

$CO + 1/2\ O_2 \rightarrow CO_2$

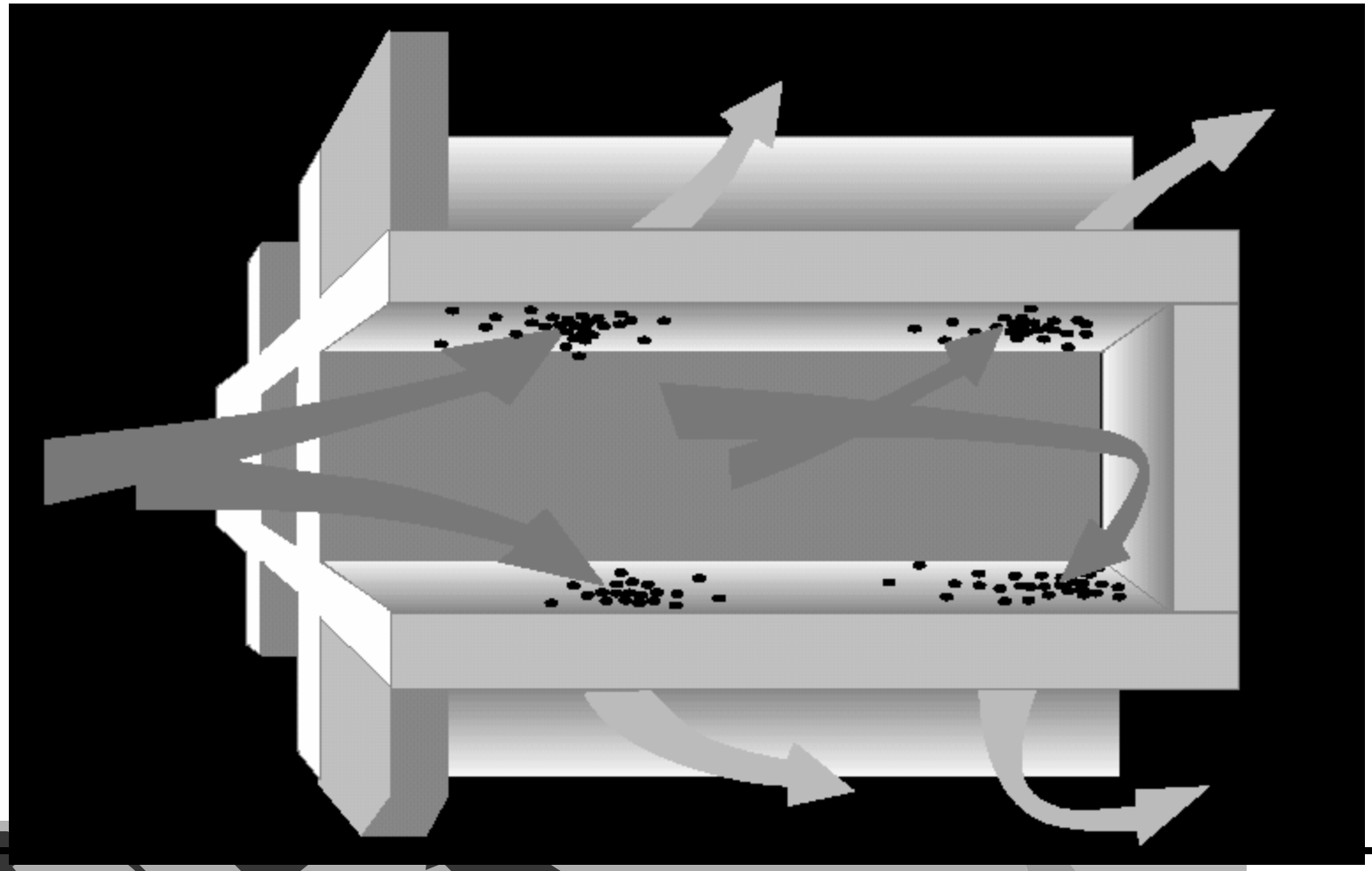
$HC + O_2 \rightarrow CO_2 + H_2O$

$PAH + O_2 \rightarrow CO_2 + H_2O$

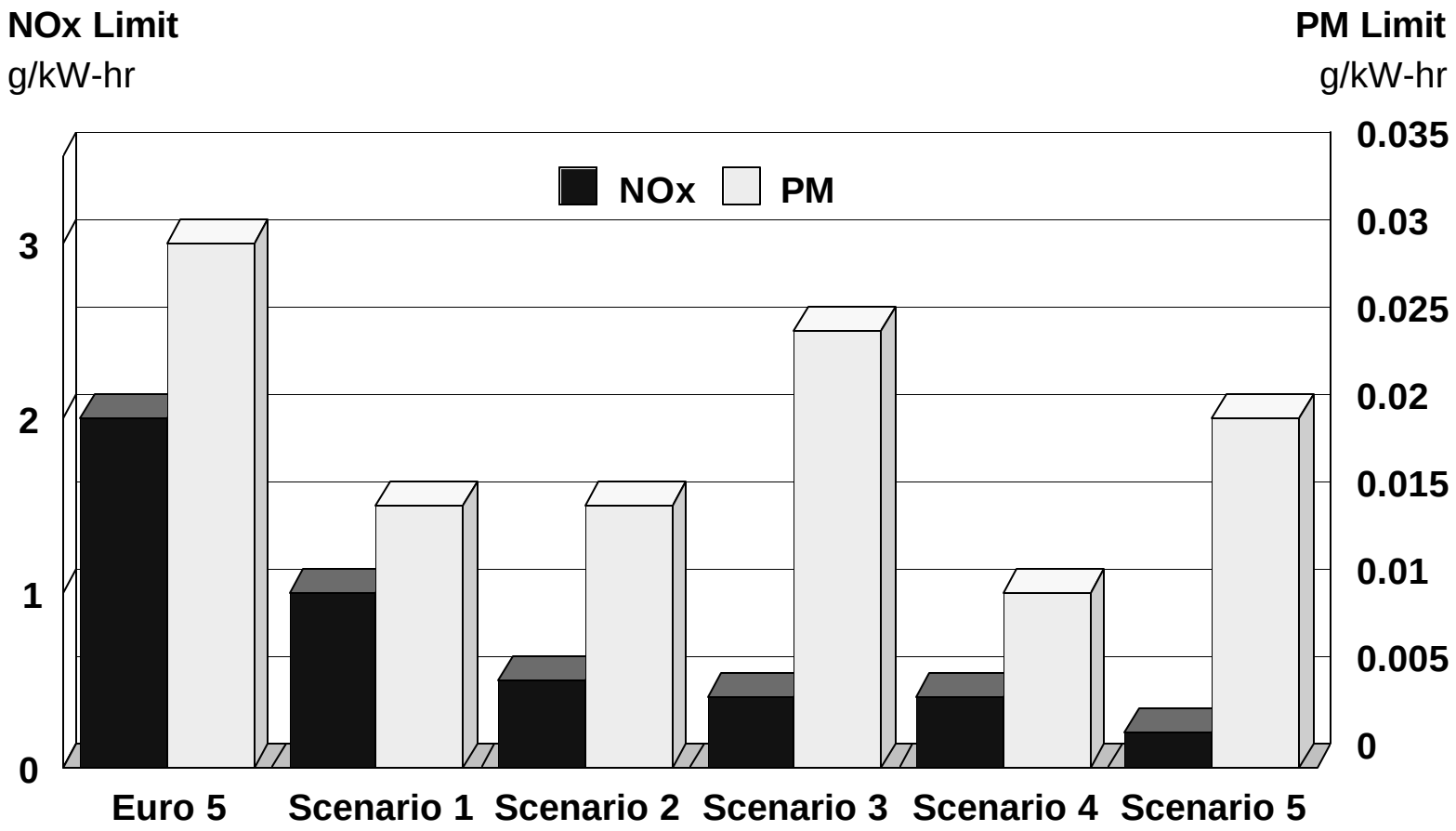
$Aldehydes + O_2 \rightarrow CO_2 + H_2O$



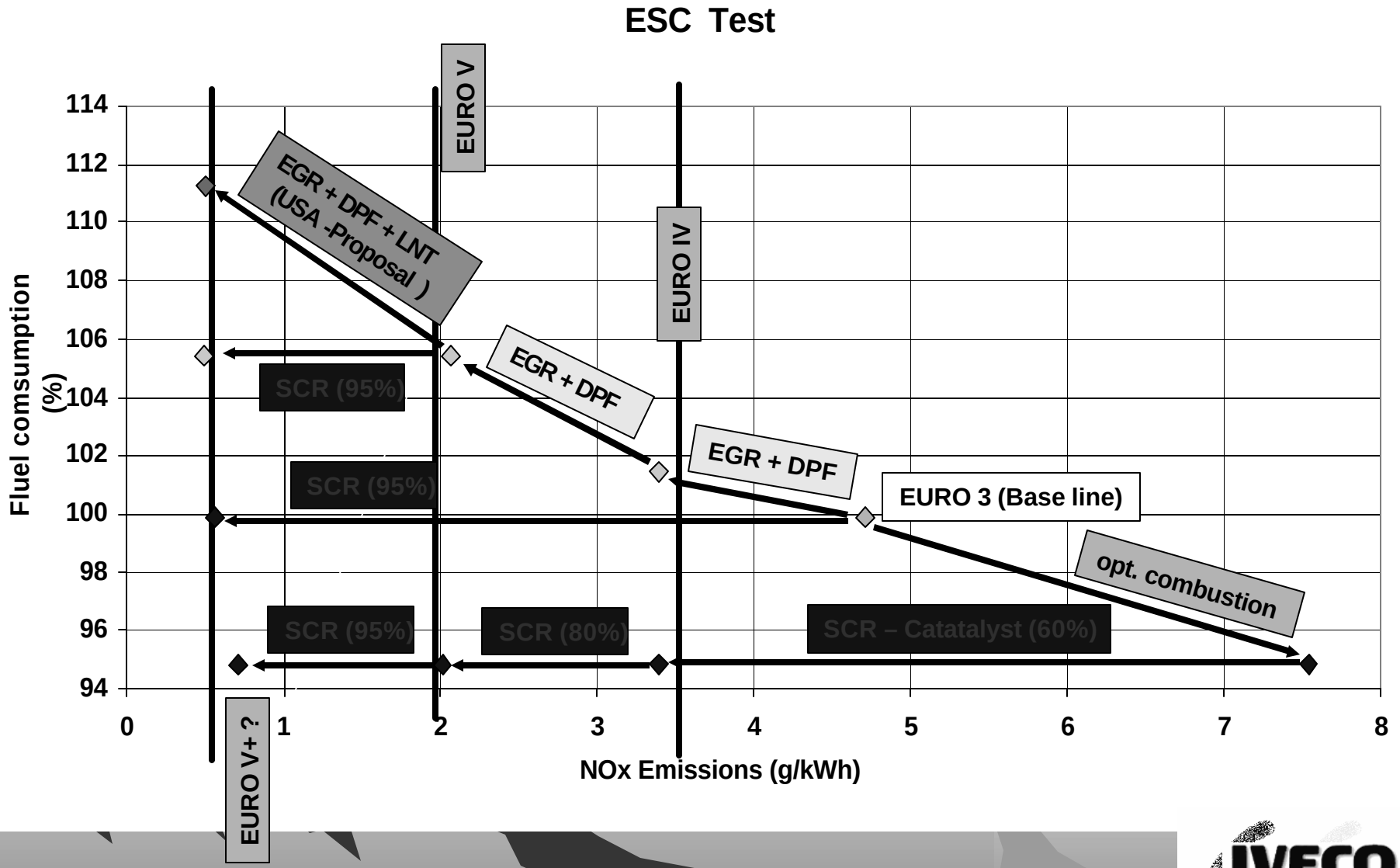
Diesel Particulate Filter



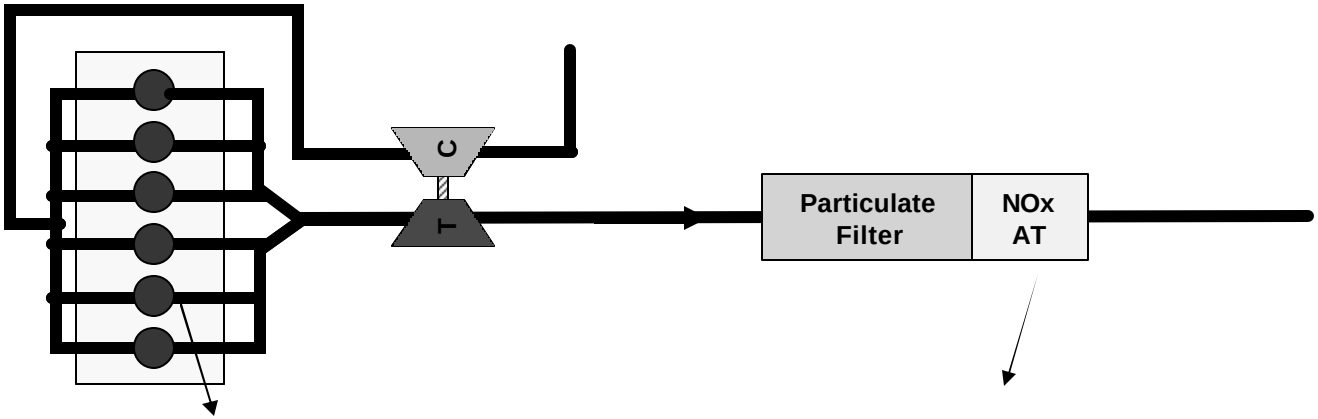
Scenarios Under Consideration For Euro 6



Strategies for Euro 5+(?) with After Treatment



NOx Reduction Options



Engine NOx Technology

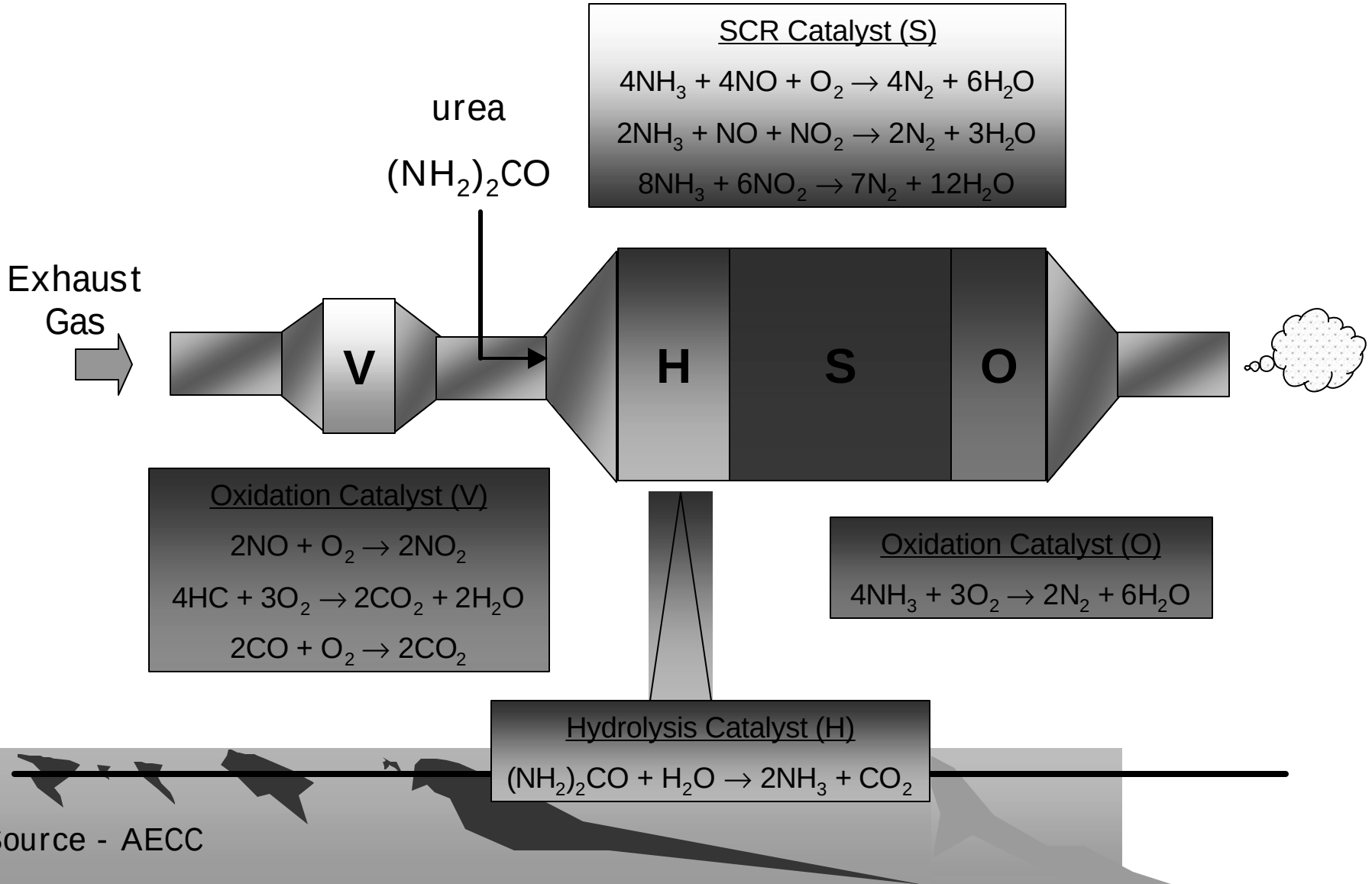
- Advanced Diesel Combustion

Aftertreatment NOx Technology Options

- DeNOx Catalyst
- NOx Adsorber
- Urea SCR

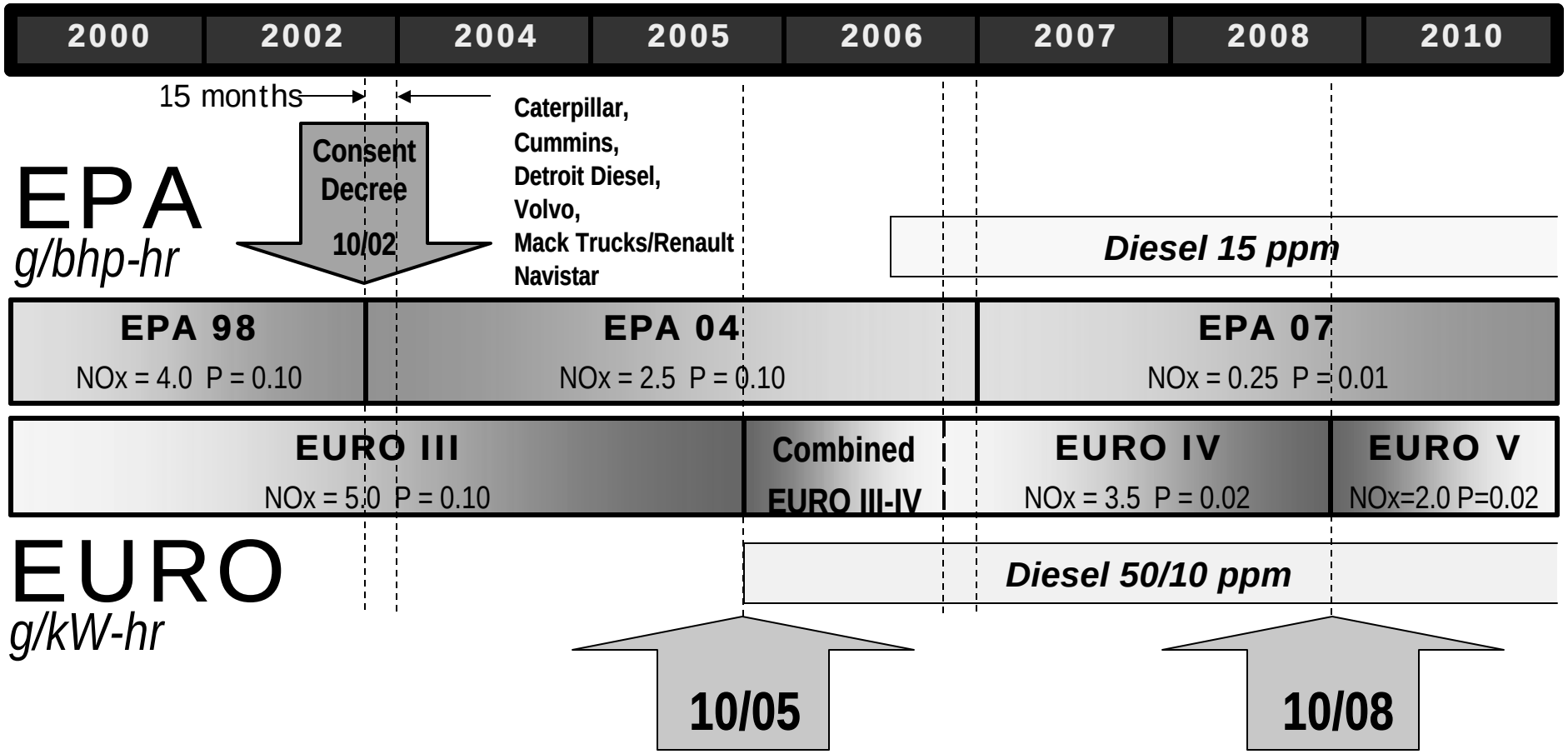
- Engine-Out NOx Measures Reduce Size / Cost of Aftertreatment
- Aftertreatment Options Need to be Evaluated for Maturity and Cost
- Combination of Engine Out and Aftertreatment may Provide Best NOx Reduction Value Path

Urea-Selective Catalytic Reduction



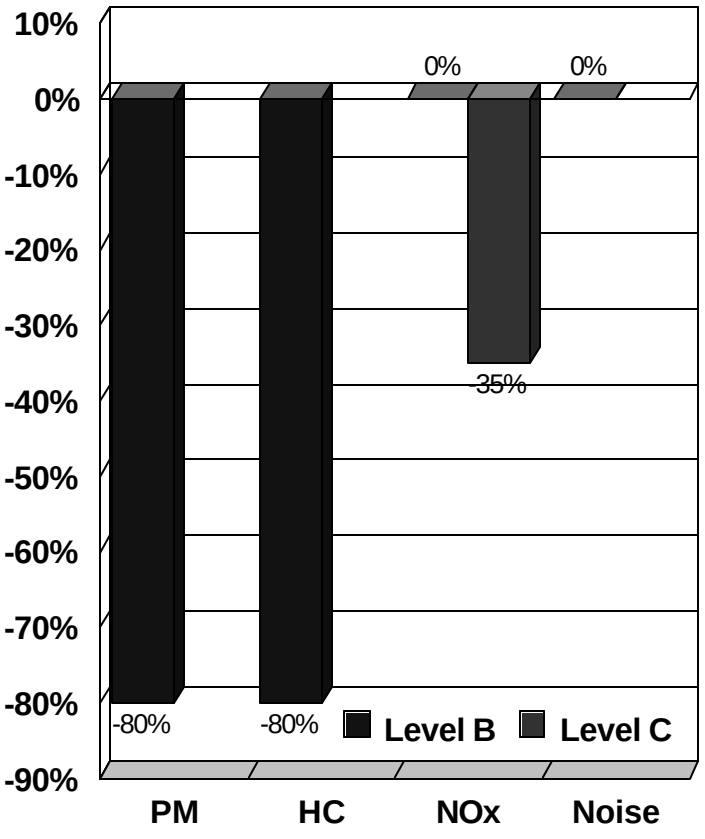
Source - AECC

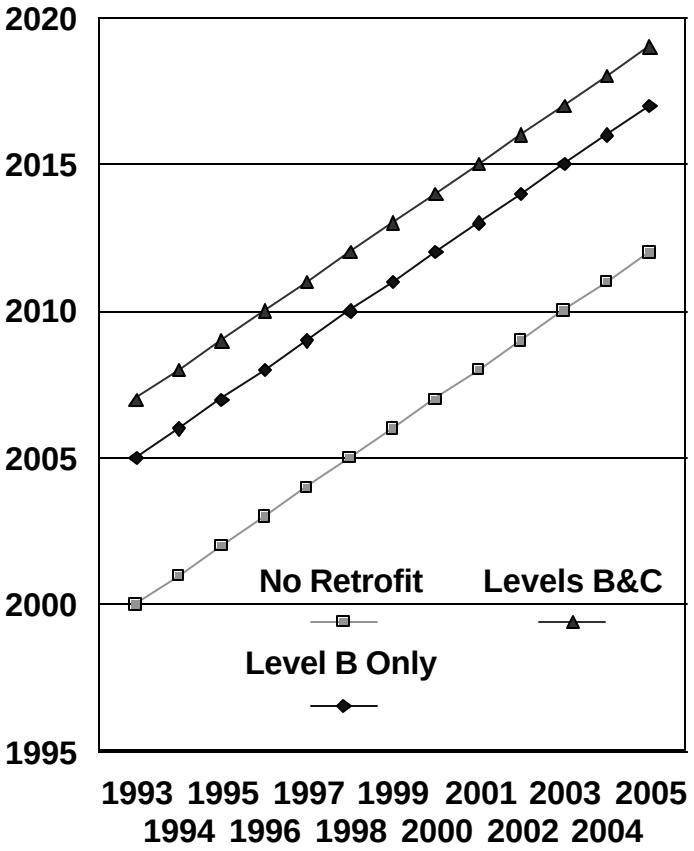
Close Linkage Between Vehicle Emissions Standards and Fuel Sulfur Levels



What To Do About Existing Vehicles?

Swedish Retrofit Program
All Trucks Above 3.5 Tons





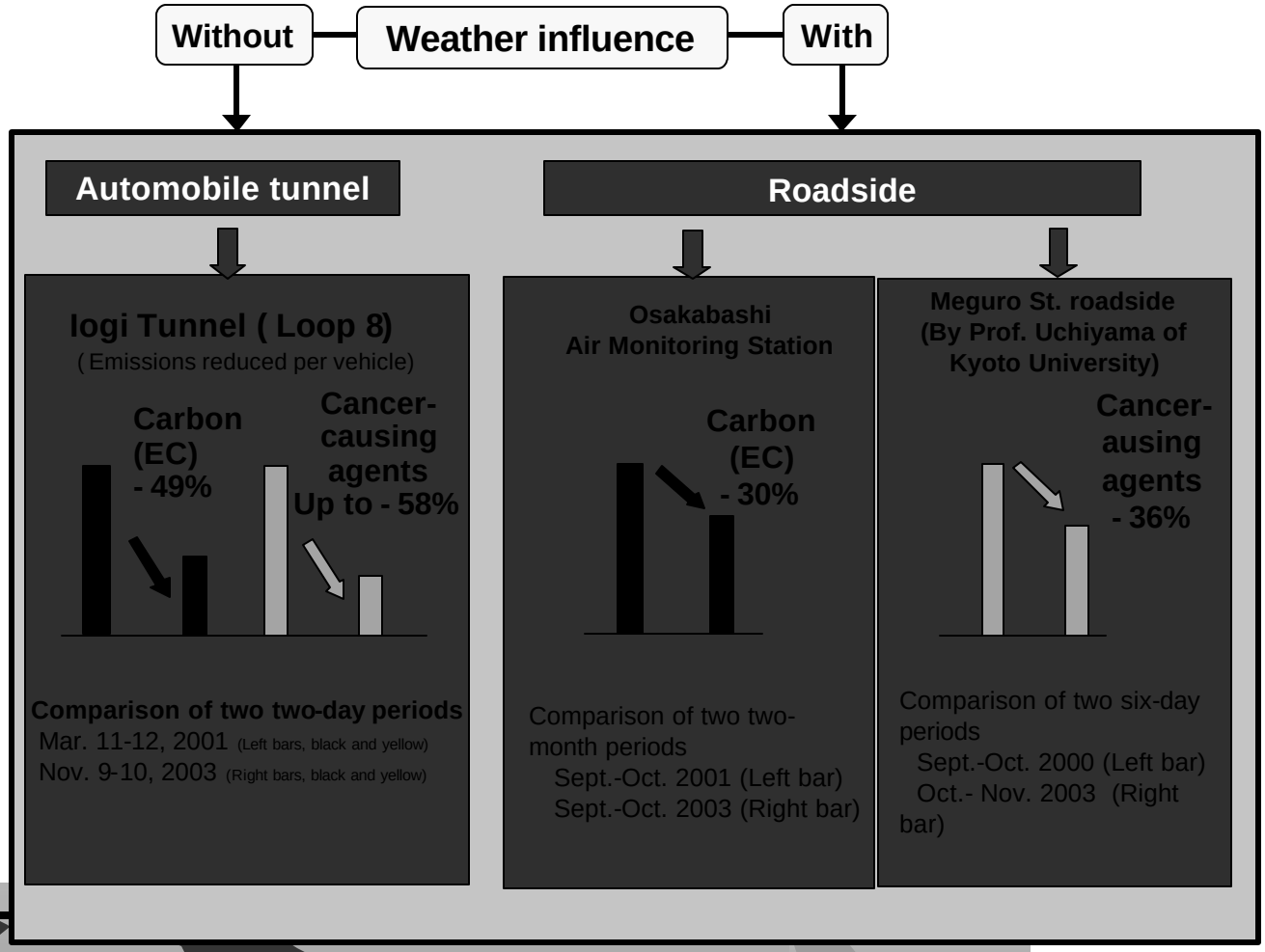
Very Low Sulfur Fuel Dominates The Market

Metropolitan in-Use Diesel Program

Tokyo Metropolitan Research Institute for Environmental Protection

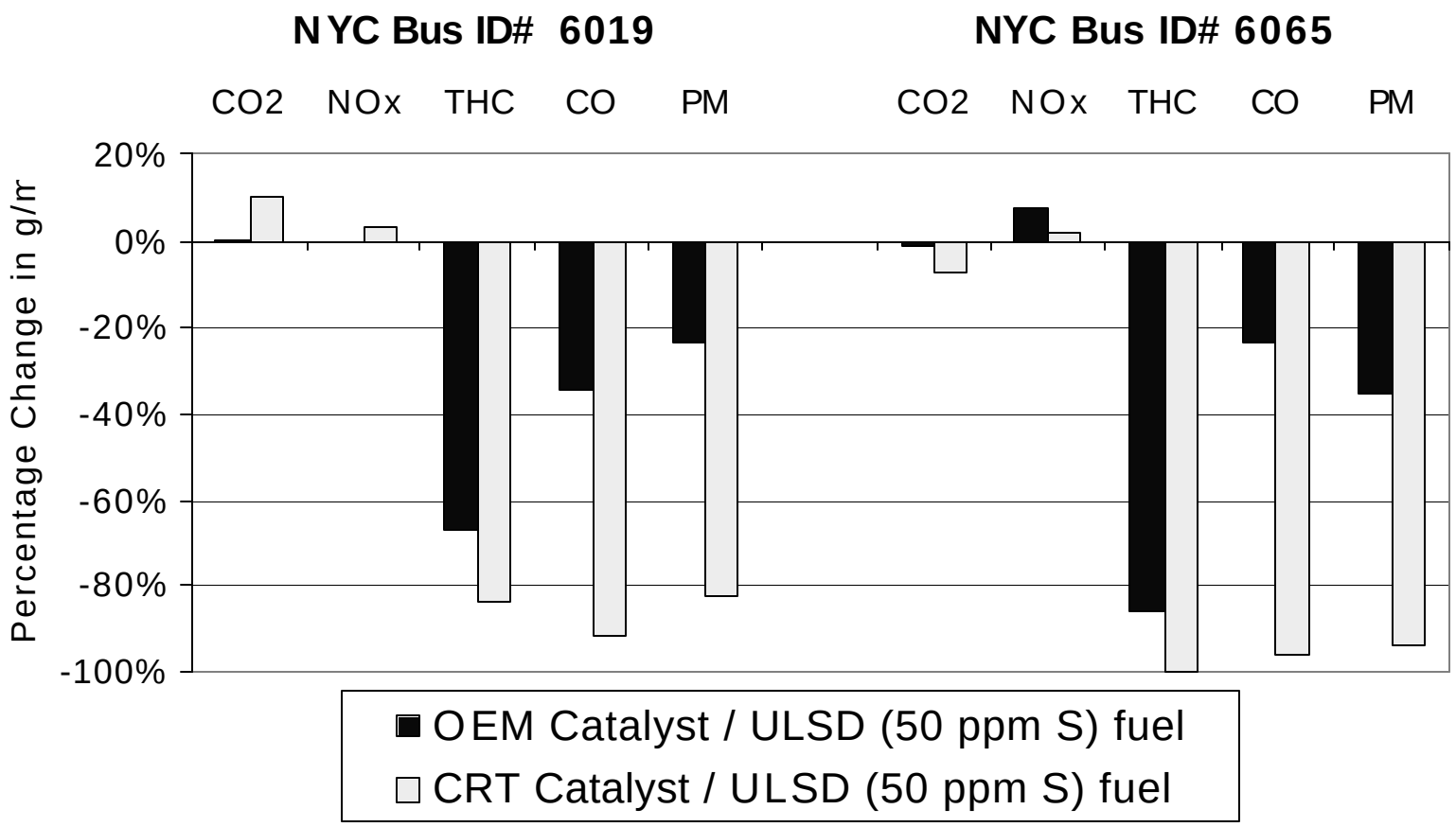
Measurement results indicate that Diesel PM levels have been significantly reduced.

(By the Research Institute for Environmental Protection)



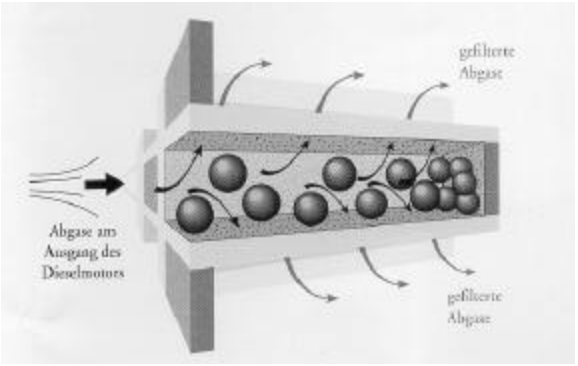
(With cooperation from the Bureau of Construction)

New York City Retrofit Experience



General Regulatory Approach

- Retrofit mid-aged engines
  - Filters 85% PM ↓
  - Catalysts 25% PM ↓
  - Other 50% PM ↓ typica
- Replace older engines
  - Re-power
  - New vehicle



Verified Devices and Applications

Type	#[1]	PM↓	NOx ↓	Years[1]	On/off
Filter	5	85		1994-2004	On
Filter	3	85	25-40	1993-2003	On
Filter	1	50		1991-1993	On
Fuel	2	50	15	1996-2002	On
Ox catalyst	2	25		1973-2003	On
Ox catalyst	2	25	25-80	1991-1998	On
Filter	1	85		1996-2004	Off
Fuel+ox cat.	1	50	20	1996-2002	Off
Ox catalyst	1	25		1994-2002	Off

[1] Individual devices may have a more limited model year application

Cost of Retrofits in California

- Passive filter $8500
- Flow through filter $5000
- Catalyst $2000

- Cost benefit ratio[1] > 4:1

[1] Based on trash truck rule

Experience With Retrofits

	# of Retrofits
Transit bus	**~1000**
Trash truck	**>1000**
School bus	**>2000**

EPA Funded Retrofit Projects

Cost Estimates for Retrofit Technologies

Technology	Cost per Device/System ($)
Diesel Oxidation Catalysts (DOC)	500 to 2,000
Diesel Particulate Filters (DPF)	3,000 to 5,500
Combined Lean NOx Catalyst/DPF Systems	5,000 to 10,000
EGR Systems	13,000 to 15,000
SCR Systems	10,500 to 50,000

Note: DPF costs are higher for active systems and systems that include backpressure monitoring.

Retrofit Technology Verification Program

- **Memorandum of Agreement between EPA and CARB**
  - EPA recognizes and accepts those retrofit hardware strategies or device-based systems that have been verified by the California Air Resources Board (CARB).

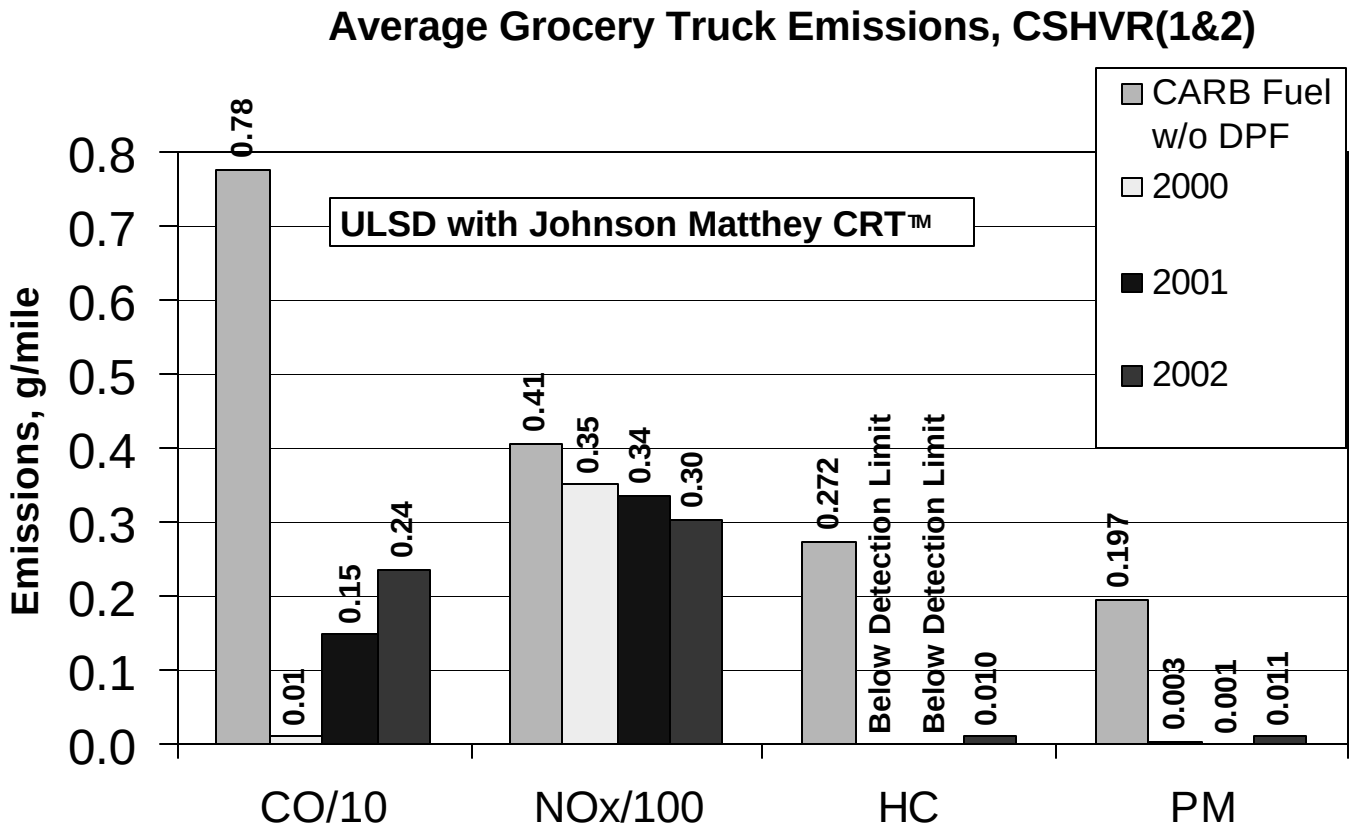
- **Retrofit technologies to reduce PM and NOx emissions currently verified by EPA & CARB:**
  - DPFs, DOCs, Crankcase Filtration, Emulsified Fuel, Biodiesel, EGR and SCR systems.

- **Information about EPA's Verification program: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm**

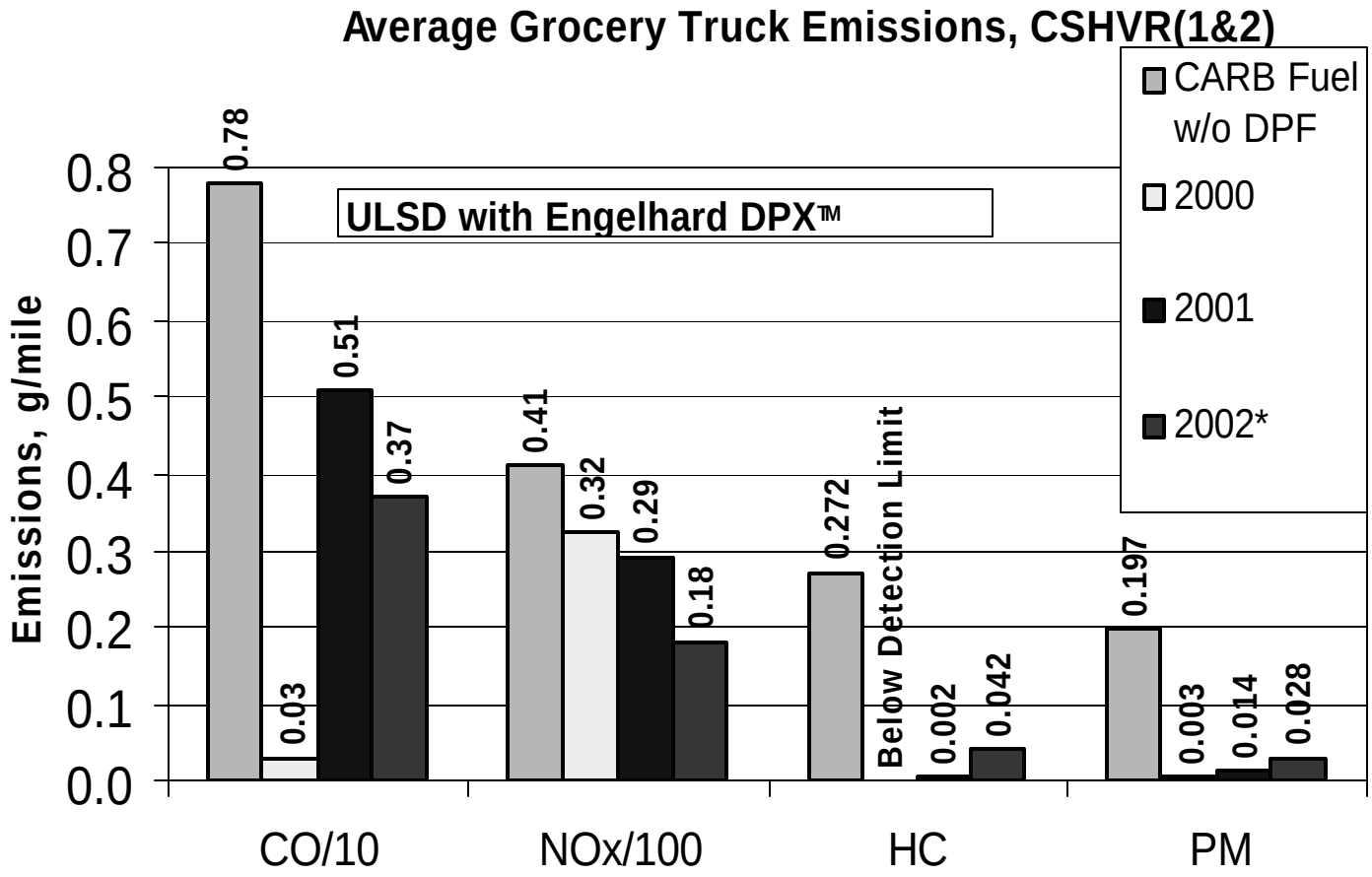
Conclusions Regarding Retrofits

- **A wide variety of retrofit options are available for all types of diesel engines to reduce HC, CO, PM and toxic emissions**
- **NOx retrofit controls are emerging- Technology development continues to expand the range of applications available for retrofit**
- **A successful retrofit program must be properly designed and implemented**
- **States as well as the Federal government are responsible for making diesel emission reductions possible**

Retrofit Durability & Reliability



Retrofit Durability & Reliability



Ford Crown Victoria

Ford F-150

Natural Gas Vehicles

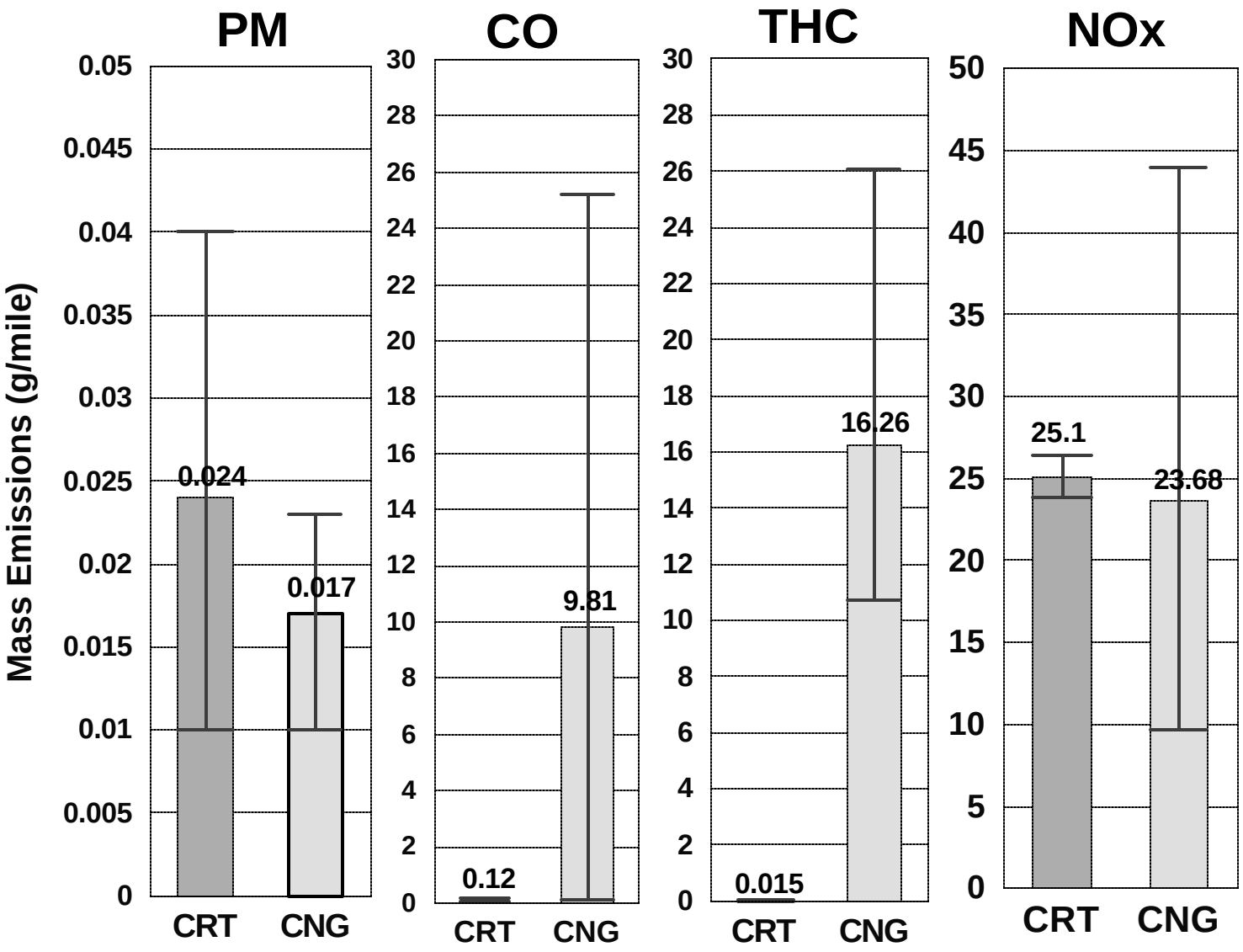
- Very Low Emissions
- Good Performance
- Lower Cost Fuel

- Limited Range, but Adequate for Most Applications
- Few Refueling Stations
- Higher Cost Vehicle

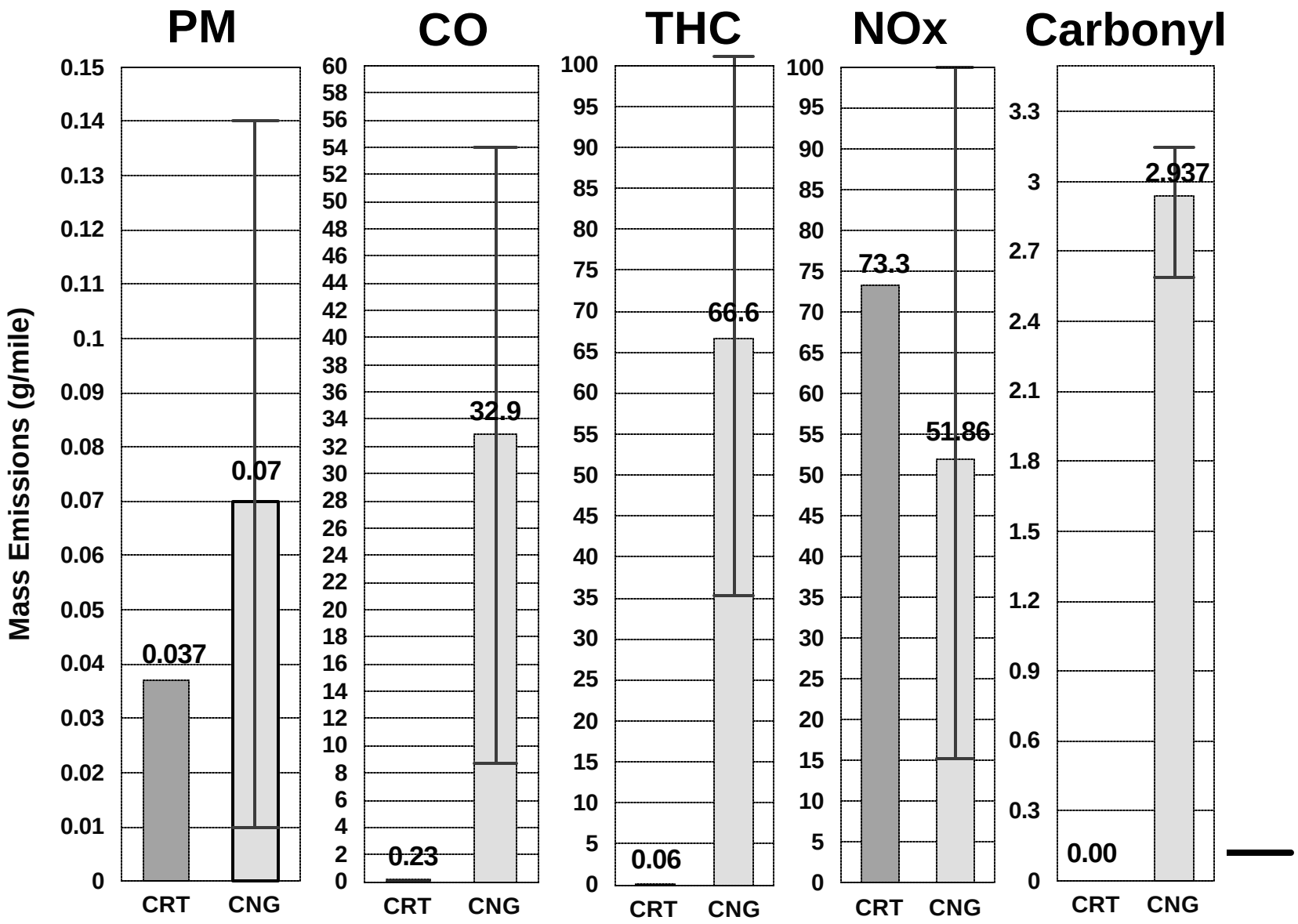
Honda Civic

New Flyer D40 LF Bus

Emissions Test Results - CRT vs. CNG
CBD Cycle



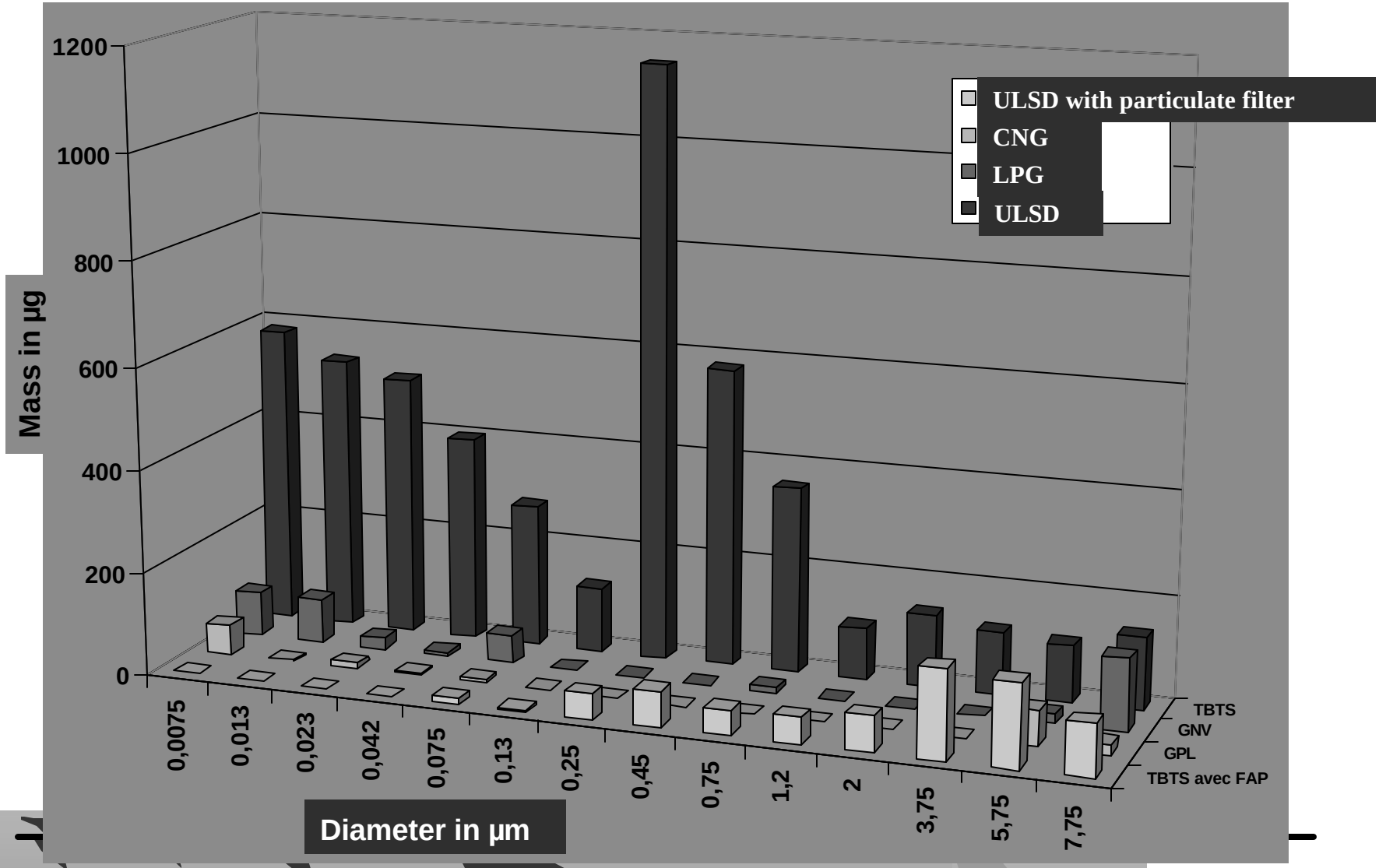
Emissions Test Results - CRT vs. CNG
NY Bus Cycle



NYC Conclusions
Clean Diesel vs. CNG

- **PM emissions from CRT-equipped buses appear to be about equivalent to those from CNG buses**
  - **Average PM emissions with CNG is lower on CBD cycle, but higher on NY Bus cycle**
  - **Much wider range of values with CNG, especially on NY Bus cycle**
- **CO and HC emissions from CRT-equipped buses are much lower than those from CNG buses**
- **NOx emissions are generally lower from CNG buses than from CRT-equipped buses, but show a wider range of variability**
- **Carbonyl emissions from CNG buses are much higher than from CRT-equipped buses.**

RATP Emissions Tests: Distribution of Particulate Size



Fuel Diversity

- **Increase alternative fuel use in urban fleets.**
- **Use gas-to-liquids.**
- **Develop hydrogen infrastructure to support fuel cell commercialization.**

SmartWay Transport (Freight Sector)

- **Objective:**
  - Eliminate unnecessary idling from trucks and locomotives
  - Target federal and state fleets for major PM reductions
  - Create diesel emission reduction projects at borders
  - Create demand for lower emission freight services
- **Freight traffic exists on highways, at ports and on construction sites**
- **SmartWay Transport challenges trucking companies to improve the environmental performance of their fleets**
  - Emphasis on saving fuel and greenhouse gas emission reductions as well as PM, NOx, and toxics
  - New SmartWay Ad Campaign launched
  - FY05 $5 million anti-idling grant competition

Inspection and Maintenance Programme for Diesel Vehicles

❖ **Annual Roadworthiness Inspection**

- ✓ **Transport Department Program**
- ✓ **Smoke check by**
- ✓ **Free Acceleration Smoke Test (FAS)**
- ✓ **Random testing using dyno (10%)**

Smoky Vehicle Control Programme

- **Implement by Environmental Protection Department to Control Vehicle Emissions**

  - ✓ **Started at 1988**
  - ✓ **Accredited spotters to report smoky vehicles**
  - ✓ **Summons vehicles concerned to undergo smoke compliance check**
  - ✓ **Designated Vehicle Emission Testing Centres conduct smoke test**
  - ✓ **Failure to comply may face license cancellation**

Road Side Enforcement by the Police on Diesel Smoke

- ✓ **Not to exceed 60 HSU measured by smoke meter using free acceleration smoke test method**
- ✓ **Issue fixed penalty tickets to excessive smoky vehicles**
- ✓ **Report these smoky vehicles to EPD for follow-up action**

Enforcement against Smoky Vehicles

- **These enforcements have alleviated the smoky vehicle problem but the improvement was not sufficient.**

- **Many spotted smoky vehicles are repeaters.**

  The Reasons：

  - ✓ **Tampering with the engine fuel pump can easily cheat the free acceleration smoke test.**
  - ✓ **Even checking engine speed as part of the free acceleration smoke test cannot stamp out this malpractice.**

Enforcement against Smoky Vehicles

- The Solution:
  - ✓A smoke test that is more effective in screening out vehicles with tampered engines should replace with the free acceleration smoke test.

Test Methods for Checking Compliance

A. Dynamometer Smoke Test

- ✓ Check rated rpm ± 5% manufacturer spec
- ✓ Check road power to at least 50% of manufacturer spec
- ✓ Smoke limit 50 HSU

B. Free Acceleration Smoke Test

- ✓ Check rated rpm ± 5% manufacturer spec
- ✓ Can not check road power
- ✓ Smoke limit:-

Pre- 90	60 HSU
Post 90	50 HSU

The Path To Cleaner Off Road Vehicles

- Cleaner Fuels
- Tighter New Vehicle Standards
- Inspection and Maintenance
- Other
  - Scrappage
  - Retrofit

2WD tractor
130 hp

combine
300 hp

4WD tractor
250 hp

square
baler
60 hp

square
bale
wagon
150 hp

Nonroad Diesels

- **Construction**
  - excavators, bulldozers, ...

- **Industrial**
  - portable generators, forklifts, airport service equipment...

- **Agricultural**
  - tractors, combines, irrigation pumps, ...

US EPA Non-Road Diesel Emission Limits

ISO 8178 Test Cycles

kW<8

8<kW<19

19<kW<37

37<kW<75

75<kW<130

130<kW<225

225<kW<450

US EPA Non-Road Diesel Emission Limits

ISO 8178 Test Cycles

kW<8

8<kW<19

19<kW<37

37<kW<75

75<kW<130

130<kW<225

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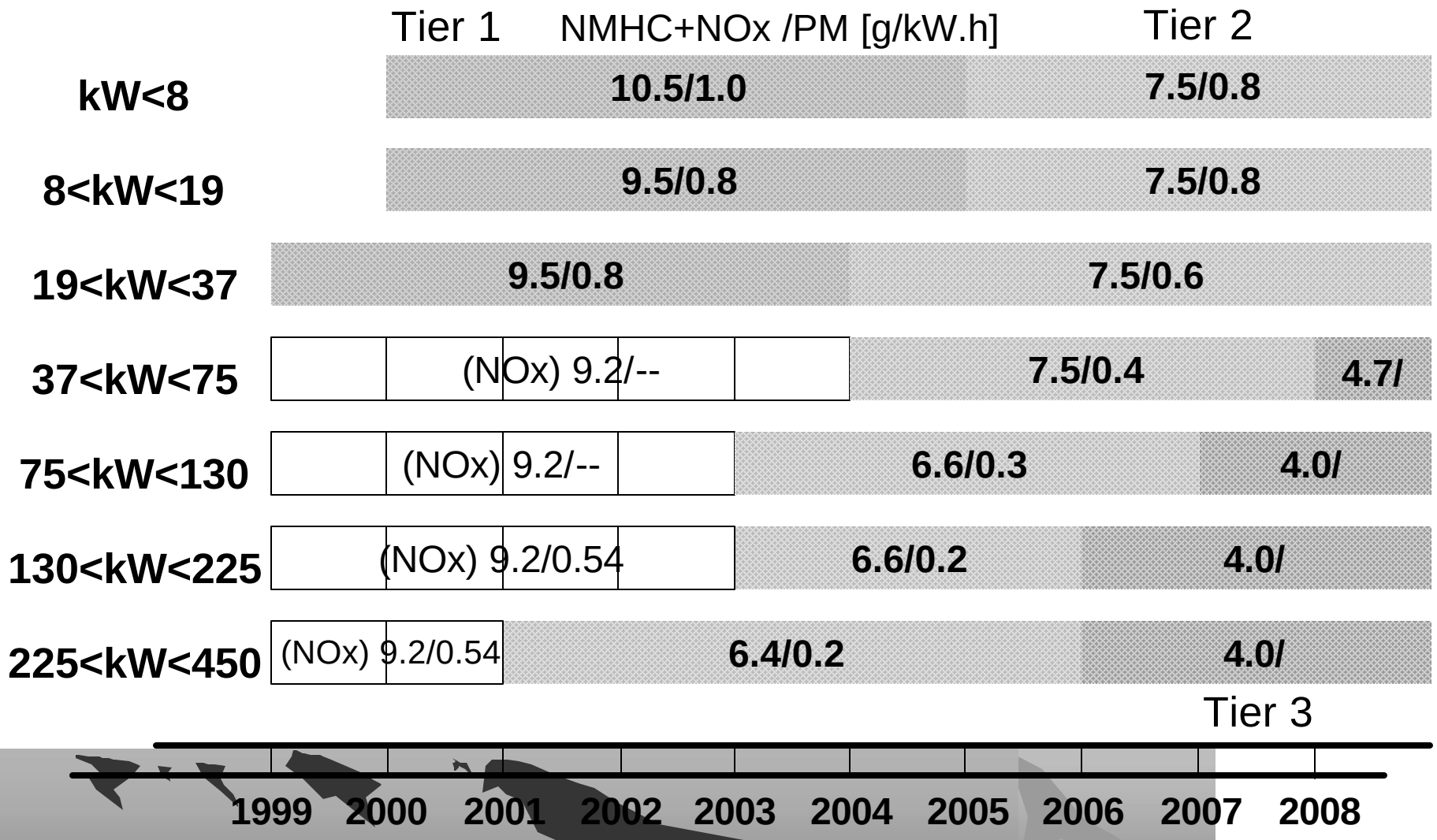
US EPA Non-Road Diesel Emission Limits



US Final Engine Standards Program

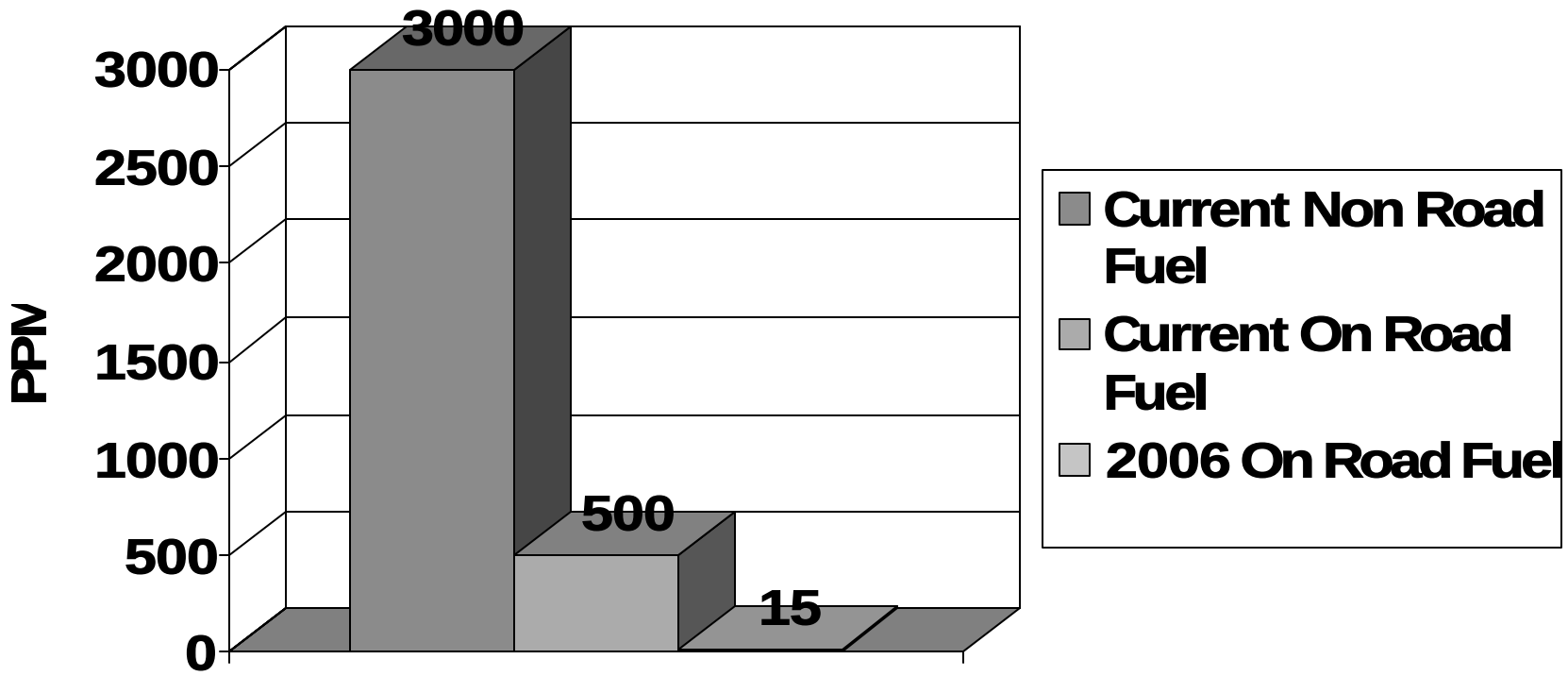
500 ppm NR fuel \ 15 ppm NR fuel \

hp	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
<25	Tier 1				PM *(reductions w/oxidation catalysts or engine-based control)*							
25-75					PM *(reduction w/oxidation catalysts or engine-based control)*					**PM: 100%** NOx		
75-175	existing Tier 2								**PM:100%** **NOx: 50%**	**50%**	**100%**	
				existing Tier 3								
175-750								**PM: 100%** **NOx: 50%**	**50%**	**50%**	**100%**	

Percentages indicate portion of sales required to meet advanced emission control technology standards

For Engines>750 HP, EPA Will Require PM Filters But NOx Controls For Some Categories Still Under Review

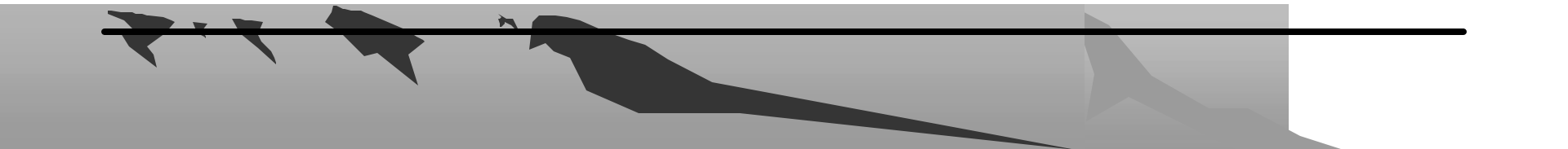
Diesel Fuel Sulfur Levels



Advanced Emission Controls Have Demonstrated Dramatic Reductions on Existing Diesel Engines

The Important Role of Economic Instruments

- Taxes
  - Vehicles
  - Fuels
- Incentives



Control Measures promoted by:

- Limit values set by law
- In Use Compliance Testing
- Inspection and Maintenance
- Financial incentives, promoting earlier introduction of cleaner vehicles and retrofiting
- Public awareness e.g. German Blue Angel

Economic Instruments

- Increasingly Important As Market Based System Introduced
- Short Term Opportunities
  - Fuel Quality
  - Encourage Tighter Standards (if Fuel is Available)
  - Other…

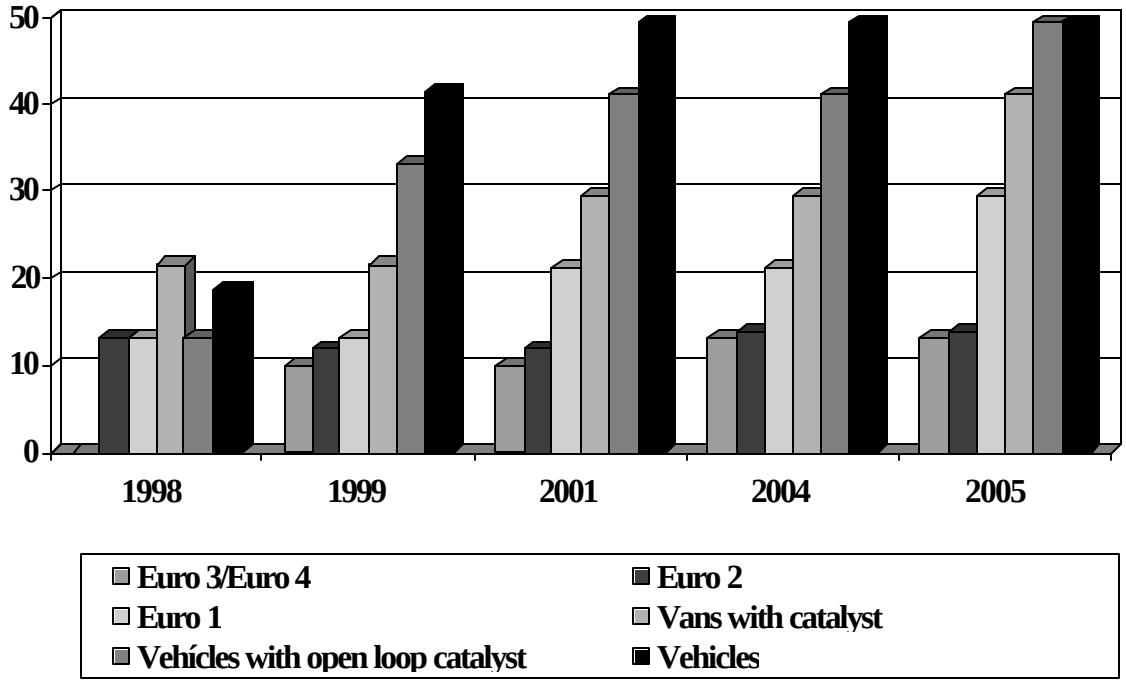
Leaded Gasoline

Leaded gasoline was phased out in Germany only by tax incentives making leaded gasoline more expensive than unleaded much earlier than EU required by directive

Cleaner Vehicles

Cleaner vehicles were and are promoted in Germany by tax incentives making making high polluting vehicles more expensive and cleaner vehicles less expensive.

Annual Emission Related Vehicle Tax in Germany (in DEM/100 ccm per ano)



It was possible to qualify to the tax reduction by retrofit to the same emission standards as for new cars

About 1 million cars are retrofitted with closed loop catalyst up to now

Example:

Gasoline car with a engine volume of 2000 ccm

1. meet Euro IV: Annual tax in 2002 : exempted up to 250 €, afterwards 100 € per year until 2003; from 2004 135 €
2. Without catalyst:

   Annual tax: 500 € per year

Difference in 5 years: about **2500 €**

Example 2

Diesel car with a engine volume of 2000 ccm

1. Meet Euro IV: Annual tax in 2000: Exempted up to 600 €. Afterwards annual tax: 280 € until 2003, from 1.1.2004 310 € per year;
2. Not meeting Euro I: in 2000 570 €, from 2001 until 2004 670 €, from 2005 **740** €.

Difference in 5 years: **2640** €

Fuel Quality is Critical

- Very Low Sulfur Levels
  - Enhances All Catalyst Technology Performance
  - Necessary To Use Advanced Technologies
  - Other Benefits
- Other Fuel Properties Also Important
  - Detergents
  - MMT
  - Etc.

Fuel Taxation in Germany

- Higher fuel tax (+ 1.5 €ct/Litre)
  for low sulphur gasoline and diesel fuel with more than **50 ppm Sulphur from the** 1.1.2001

- Higher fuel tax (+ 1,5 € ct/Litre)
  for gasoline and diesel with more than **10 ppm Sulphur from the** 1.1.2003
  (< 10ppm = sulphur free)

- additionally the so called Eco tax reform from 1999 to 2003 was imposed. Every year the fuel tax was raised by 1.5 €ct/litre

Sulphur “Free” Fuel

From 1st of January 2003 1.5 €ct per litre tax incentive for sulphur content less than 10 ppm for both gasoline and diesel fuel (**Onroad and offroad !**).
Market changed completely within weeks.

Today the average sulphur content is about 3-5 ppm!!!

Heavy Duty Road Tax in Germany

From the 1st of January 2005 a heavy duty road tax is imposed. Heavy duty trucks with a gross weight of more than ten tons have to pay 12 € cts/ km on German autobahns.
Trucks meeting EURO III, EURO IV or EURO V norms have to pay less, trucks meeting only EURO I or less have to pay more!
Due to the recent introduction the effects cannot estimated.

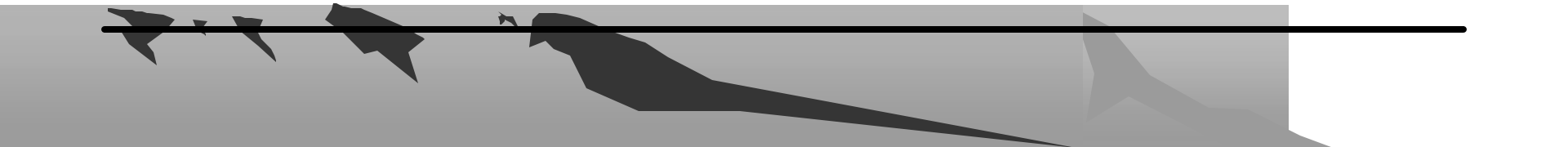
Heavy Duty Road Fee in Switzerland

The fee depends on three factors:

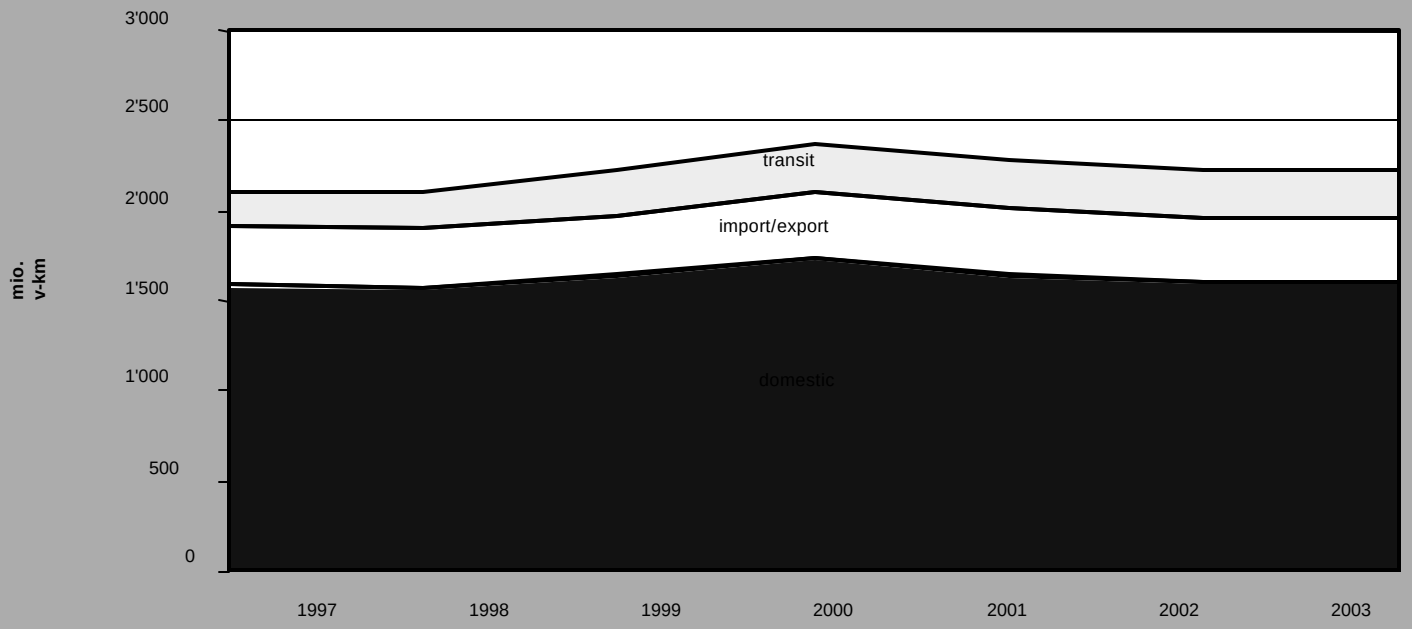
- the distance driven on the Swiss road network (all roads)
- the laden weight of vehicle and trailer
- the emissions of the vehicle (there are three emission classes)

The fee was introduced on 1 January 2001 at a rate of 1.0 Ct/tkm. In parallel, the weight limit was raised from 28 to 34 tonnes.

From January 1st 2005 the rate was increased to 1.6 ct/tkm and the weight limit to 40 tonnes.

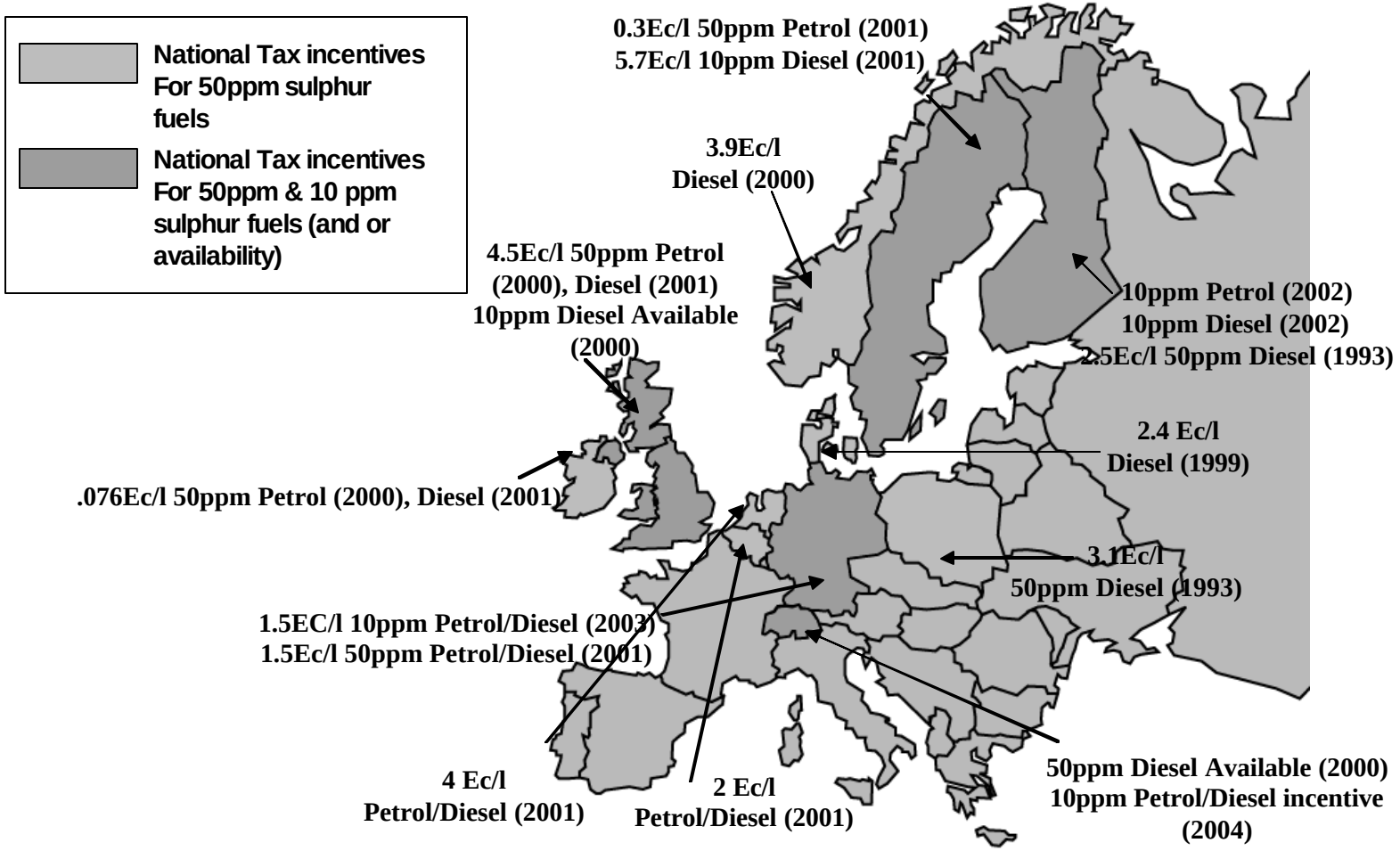


Change in mileage 1997 – 2003

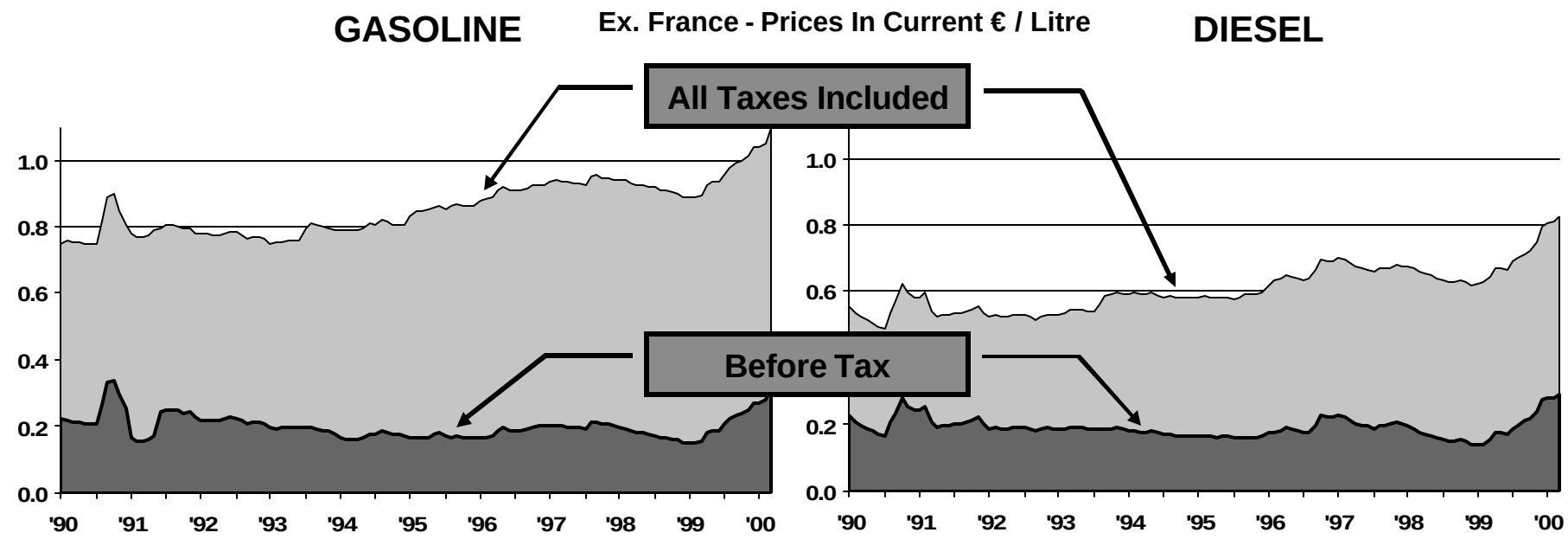


After a strong increase between 1997 and 2000, mileage in freight transport (measured in vehicle-km) was reduced remarkably in the years after the introduction of the fee.

European Tax Incentives Schemes To Encourage Low Sulfur Fuels

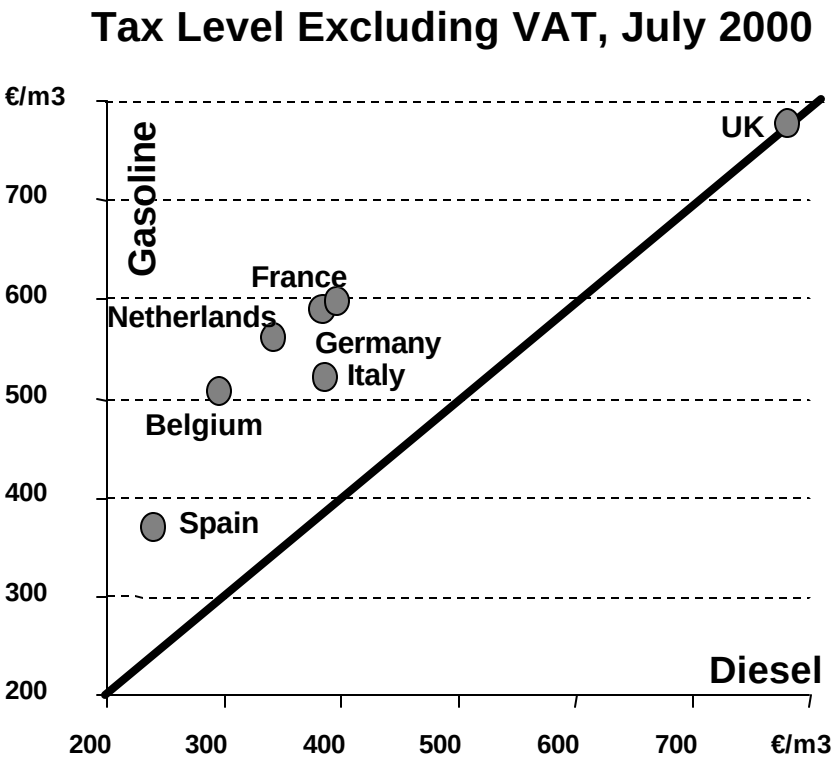


Source: IFQC



Significant Amount Of Transport Fuel Taxes - More Than 170 G€ / Year - Charged To The Consumers At The EU Level

Differential Tax Levels Have A Strong Impact On Engine Choice & Fuel Demand Patterns :



- **Less Than 10% Of Vehicles With A Diesel Engine In 1985 In France, Spain, Italy & UK**
- **In 2000, Proportion Of Diesel Engines (New Cars) Is :**
  - **50% In Spain,**
  - **45% In France,**
  - **30% In Italy**
  - **Merely 15% In UK**

Tax Incentives for Low Emission Vehicles and High Fuel Economy Vehicles (2004-2005)

Emissions+ / Fuel economy	？？？：50% lower emission vehicles	？？？？：75% lower emission vehicles
Vehicles: achieving fuel economy standard in 2010	No incentives	*25% annual tax reduction *200,000 yen purchase tax deduction
Vehicles: 5% higher fuel economy than the standard in 2010	*25% annual tax reduction *200,000 yen purchase tax deduction	*50% annual tax reduction *300,000 yen purchase tax deduction

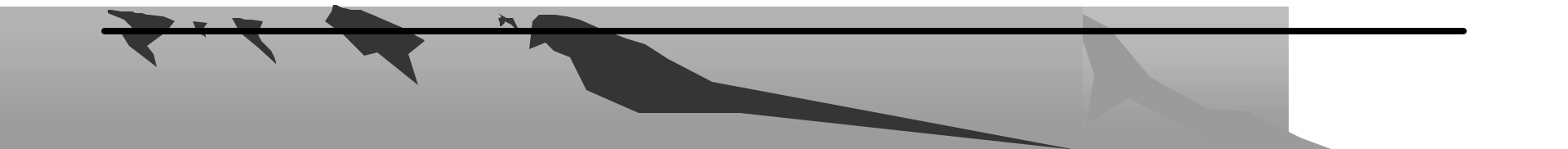
+: compared to the new long-term standard in 2005

Summary

- Design taxes that are easy to understand
- Simple to administer
- Minimum record keeping
- Minimum reporting
- Allowing compliance checks
- Maintain tax yield
- Give environmental message

Urban Transport Programs

Ingredients for Success



Bogotá

Population:	7.0m
Area:	492sq. km
Total vehicles:	800,000
Public Transport	56%
Cars/M cycles	21%
Other (NMT)	23%

Bogotá

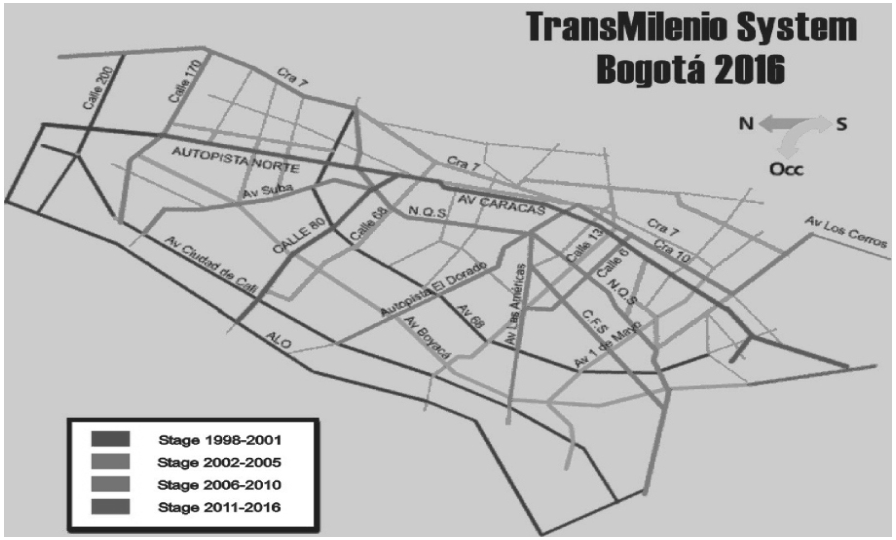
Introduction of Bus Rapid Transit (BRT): "Transmilenio"

- Construction of almost 200 kilometers of bike paths

  City administration of Bogotá is succeeding in dissuading citizens from using their cars by promoting commuting by bus and/or bicycle and using car pools.

- The key ingredient - the city Mayor, Enrique Peñalosa
  - deeply involved in the city's urban transport issues
  - understood the city and its people
  - had the courage to take risks

Bogotá: Transmilenio Bus Rapid Transit



"Mayor Peñalosa decided in 1998 to reject a Master Plan that proposed to solve Bogotá's traffic jams with a metro system and elevated highways because it was unaffordable, promising mobility for the few, not mobility for all. The cost of one subway lane, could provide quality bus rapid transport to the whole city and have money left for sewage, schools and parks."

Bogotá: Transmilenio Results

- Within three years (by December 18, 2000)
  - the system was operational.
- Within ten months (by October 2001)
  - 540,000 trips per weekday
  - 23 miles of exclusive lanes
  - 54 stations
  - 364 articulated buses
  - 110 feeder buses
- Within 15 months (by March 2002)
  - 800,000 trips per weekday
  - 26 miles of exclusive lanes
  - 62 stations (including four terminals
  - Peak direction passenger volumes have been reported at 45,000 with system speeds averaging 26 kilometers per hour overall.

Bogotá: Transmilenio Management

Infrastructure provided by the State
Stations
Yards and workshops
Complementary infrastructure
Control center

TRANSMILENIO S.A.

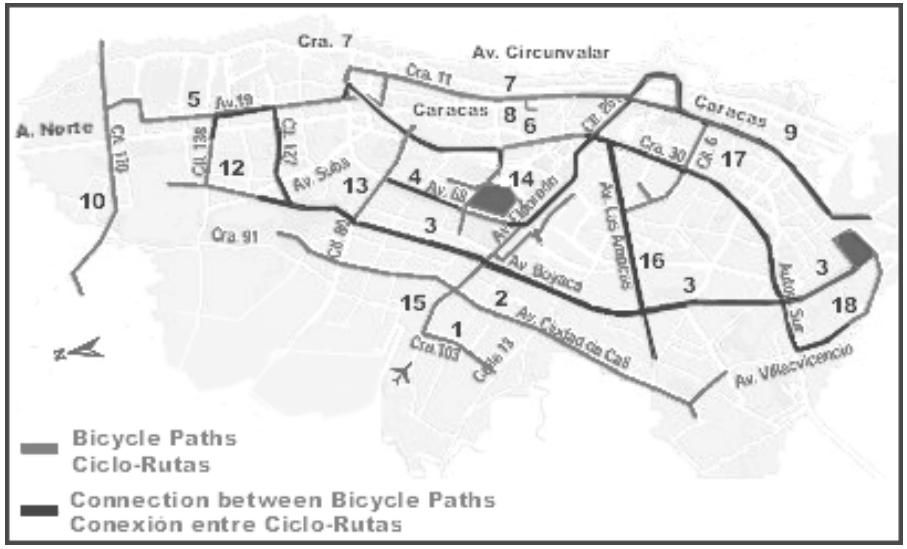
Planning, management and control

Collecting system provided by the Private sector
Equipment
Cards
Trust handling

Operation provided by the Private sector
Massive transportation buses
Companies
Employees
Services

Bogotá: Transmilenio Public Relations

Bogotá: 200 km bike path network



"With the money that Bogotá would have paid in one year of interest for a loan to build the metro, Mayor Peñalosa built 155 miles of bicycle paths that now move 5% of the population, up 10 times from bike ridership in 1998."

Bogotá

Key ingredients for success

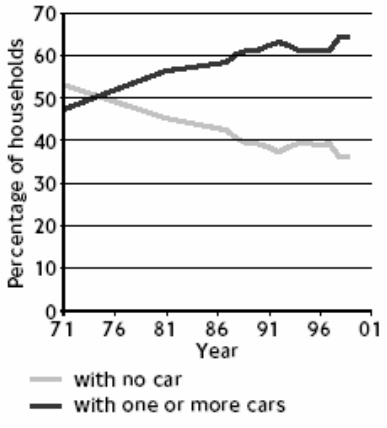
- *Leadership:* Strong leadership, popular support and political commitment;
- *Management:* The creation of a single agency (Transmilenio SA) with powers to plan, design, implement and regulate the new bus system
- *Speed:* It is possible to develop a bus based, high capacity, and high quality mass transit system in a very short time.

London

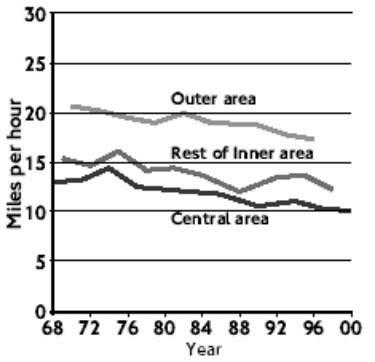
Population:	7.1m	
Area:	1,579sq. km	
Average daily trips:	29.3m	
Public Transport	29%	(86%)
Cars/M’cycles	38%	(6%)
Other	33%	(8%)

London 2002: Problems

– Car ownership increases by 15%



- Average morning peak hour traffic speeds drop to below 10 mph (16 kph) for the first time since records began.



Source: TfL

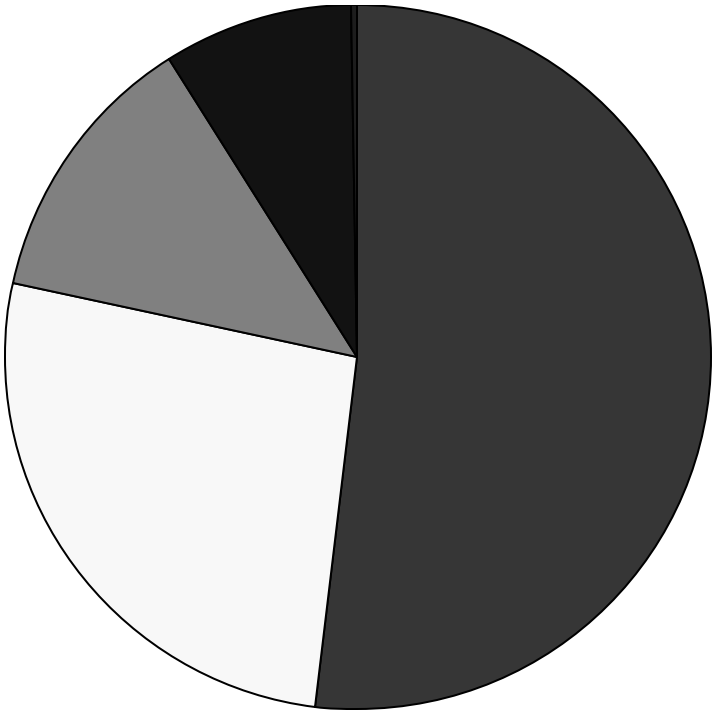
London 2001: Problems and Priorities

- "…the value of wasted time and increased vehicle operating costs imposed on individuals and businesses by traffic congestion in London total £2 billion (US$3.2 billion) per year…."
    - The Mayor's Transport Strategy, Greater London Authority

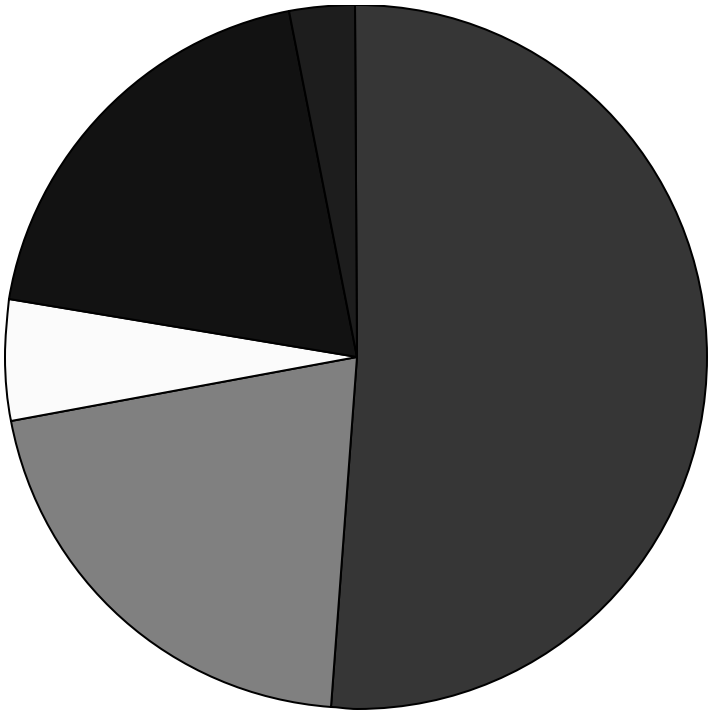
- In a poll conducted in 2001, Londoners say:
- "…the two top transport priorities for the Mayor to tackle are reducing traffic congestion and improving the reliability of bus services…"

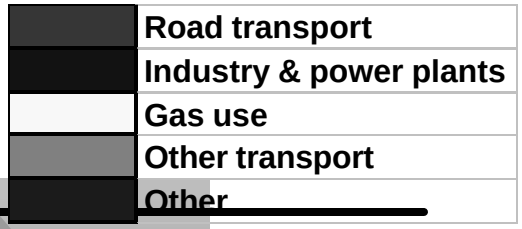
Emissions within London 2002

NO_x (NO_2)



PM_{10}





Main local source: Road Transport

The Mayor’s Plan…

- Support sustainable economic growth by:
  - tackling congestion and unreliability
  - providing improved access by public transport, walking and cycling
  - provide adequate capacity for future growth
  - support and encourage balanced spatial growth
  - make it easier for people to access their workplaces and for businesses to move goods and provide services.

London's Air Quality Strategy

Leading by Example

- **Buses** (~7,000)**,** Tendered
  - All at least Euro II + particulate trap by end 2005
- **Taxis** (~20,000)**,** Regulated through licences
  - All at least Euro III equivalent by mid-2008
- **Road Maintenance Vehicles**
  - **Under contract**, all at least Euro III
- **Buildings** and **Tube**
  - Using Renewable Electricity
- **Contracts / Purchasing**
  - Requires Environmental Policy as a purchasing consideration

Traffic Reduction Measures

- Improved Public Transport - esp. buses
- Improving walking & cycling, including maps, highway alterations
- Travel Plans
- Parking Control
- Co-ordination of road maintenance
- Congestion Charging in Central London
- Guidance for appropriately located developments
- Refusing inappropriate developments

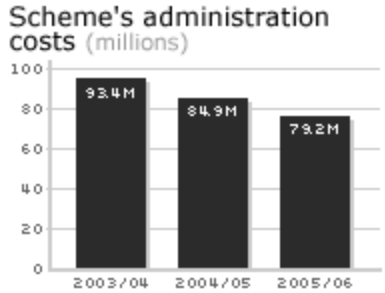
$\Rightarrow$These implemented through Transport & Planning Strategies

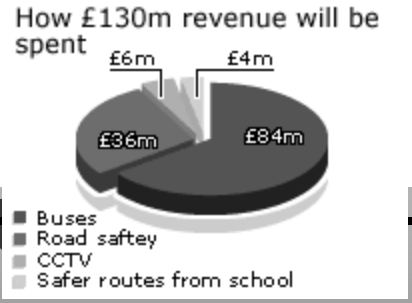
Congestion Charge

- Zone ~22km^2 $\Rightarrow$ 15% traffic reduction in zone
- Limited impact on Air Quality, more on emissions
  - purpose is Congestion reduction
  - only in operation 07:00-18:30, Mon-Fri
  - only 1% of London area
  - traffic reduction mainly on cars, not heavy duty
  - NO_2 impact limited due to ozone and NO issue
- 100% reduction for cleanest alternatively fuelled vehicles

Congestion Charge

- reduce traffic congestion by 15%
- reduce time spent in delays by 30%
- Increase traffic speeds 10 - 15%.
- improve safety and the environment





Annual Costs

- £70m (US$110m) by 2005

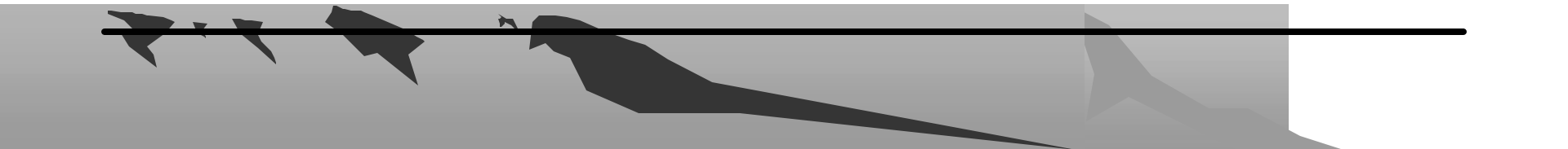
Annual Revenues

- £200m (US$320m) of which £130m (US$206) for transport improvements

Congestion Charge

- Introduced on February 17, 2003
  - *"This is an historic day for London. Everyone knows that tough decisions have to be made to tackle the congestion which cripples this capital city of ours. From today something is being done. If we want London to continue to be a success story for business and jobs, then we must enable people to move around the heart of London more efficiently. Congestion charging is the only option available - there is no practical alternative."*

    Ken Livingston

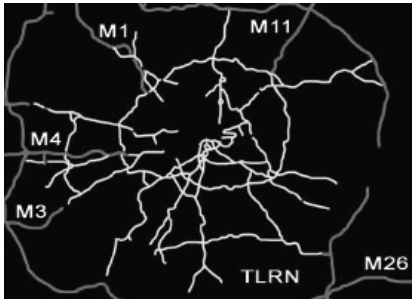


Congestion Charge

- Results (August 2003)
  - Traffic was reduced by 20% (cars by 30%);
  - Delays were reduced by 32% – 40%;
  - Speeds increased by 30%;
  - Journey times to central London were reduced by 14%;
  - Bus patronage increased during the morning peak hour by 14%;
  - Buses in the zone increased by 19%; and
  - Excess waiting time at bus stops fell by one-third within the zone.

London: Management

- Transport for London (TfL)
  - Responsible for Transport System
    - Implement transport strategy
    - Manage transport services
    - Integrated approaches to traffic management and transport
  - Strategic Road Network
    - 550 km (5% of total roads)
    - carries 33% of London's traffic
  - Traffic Signals and ATC
    - all of London's 4,600 traffic lights
  - Public Transport
    - Manages buses and LRT
    - Runs Underground



London

- Key ingredients for success
  - *Leadership:* Strong leadership, popular support and political commitment;
  - *Management:* Careful planning and the creation of TfL to take a truly integrated approach to how people, goods and services move around London.
  - *Strategic Policies:* The establishment of a clear and comprehensive strategy and making it available to everyone on-line.

London LEZ would:

- Cover all Greater London (2,466km^2)
- Cover lorries (HGV), buses & coaches
- Euro 3 emissions standard for PM_{10} in mid-2008
- Tighten in 2010 to Euro 4 for PM_{10}
  - If Government supports certification for NOx retrofit, include Euro 4 for NO_x in 2010
  - Potentially extend to vans (LGVs) in 2010, with 10 year age limit
- Be enforced by cameras, & charging system

Estimated LEZ Air Quality Impact

	Reduction in Emissions (relative to baseline)			Reduction in Area Exceeding Targets (relative to baseline)		
Pollutant	**2007**	**2010 A)**	**2010 B)**	**2007**	**2010 A)**	**2010 B)**
NO_x (NO_2)	**1.5%**	**2.7%**	**3.8%**	**4.7%**	**12%**	**18.9%**
PM_{10}	**9.0%**	**19%**	**23%**	**0%**	**32.6%** an.ave.	**42.9%** an.ave

- Assumes E2+p.t. for 2007, E3+p.t. for 2010, A)= no vans, B)= with vans

Singapore

Population:	3.6m
Area:	647.5 sq. km
Total vehicles:	707,000
Public Transport	53%
Cars/M’cycles	25%
Other	22%

Singapore

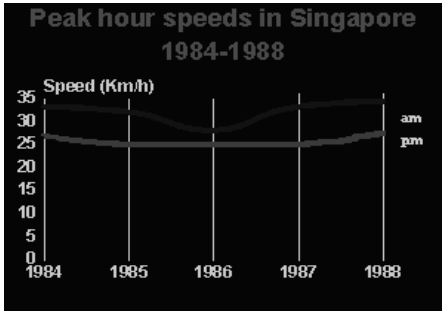
- Comprehensive Approach
  - Road Infrastructure Investment
  - Public Transport Investment
  - Traffic Management Actions
  - Road User Charges
  - Car Ownership Fiscal Measures
  - Integrated Land Use Planning
  - Education / Public Relations

Singapore: Key ingredients for success

- Effective Government and Comprehensive Management
  - A stable Government
    - with the power, institutional capacity and mandate to regulate and enforce urban transport measures
  - A comprehensive transport planning and management system - the Land Transport Authority (LTA)
    - plans, develops, implements and manages transport infrastructure and policies including the regulation of public transport services (both bus and rail)
  - Singapore gets top ratings
    - for bus, MRT, LRT and taxi services in “convenience, accessibility, savings in travel time, reliability and comfort”.

Singapore: Key ingredients for success

- Demand Management
  - Area Licensing (1972)
    - Reduced congestion
    - Increased public transit ridership
    - Reduced pollution
    - Reduced energy consumption
  - Electronic Road Pricing (1998)
    - 15% reduction in traffic
    - 22% increase in speed
    - Variable charges possible



Singapore: Key ingredients for success

- Adequate and Sustained Investment
  - Additional road infrastructure
  - Good maintenance of roads
  - Improving coordinated traffic lighting systems
  - Rail based MRT.

  - The taxes and fees imposed on vehicles generated huge financial resources
  - Annual revenue from road transportation is estimated to be at least 3-4 times road expenditure.

Singapore: Key ingredients for success

- Technology and Innovation
  - The ERP depends on sophisticated technology that allows time of day pricing reflecting traffic conditions.
  - Computerized traffic control systems were already in place by 1986 in the CBD.
  - Replaced with a traffic adaptive signal control system monitored centrally to adjust to changing traffic conditions.
  - Efforts are now being made to create a GPS public taxi system to dispatch taxies automatically.

Conclusions

- Leadership and Integrated Management
- Image, Adequate Investment and Speed of Implementation
- Demand Management and BRT
- Strategic Policies and Land Use Transport Coordination
- Technology and Innovation
- Cycling and Walking
- Key Ingredients Ratings
- Knowledge Sharing

Postscript

1. Car ownership is unavoidable but excessive car use is a problem not a solution to urban mobility.
2. Road space will always be limited, so priority must be given to moving people and goods not vehicles.
3. Public Transport is the best solution for the person trips.
4. Bus Rapid Transit is a quick solution to improving public transport and reducing congestion.
5. Travel Demand Management is an essential measure for reducing traffic congestion and improving the environment.
6. Non-motorized transportation must be enhanced and protected to achieve environmental sustainability within city neighborhoods and communities.
7. Developing a viable public transport system should not require sacrificing the time and accumulated wealth of an entire generation.
8. It is not necessary to destroy the city s identity in order to reduce traffic congestion.
9. All transportation solutions must be equitable to the city's residents.
10. Sustainable transportation development is always better than the vicious circle taken by many cities of trying to accommodate the private car by building more and more increasingly costly road space.

Thank You Very Much!

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