Diesel – What The Future Holds: An International Perspective

California Air Pollution Control Officers Association

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Michael P. Walsh

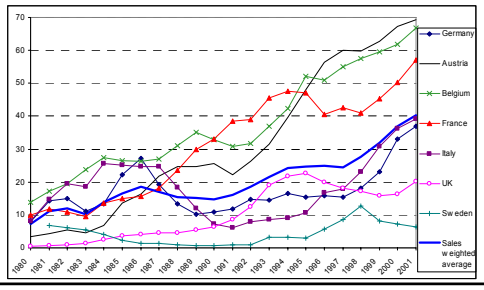
International Consultant

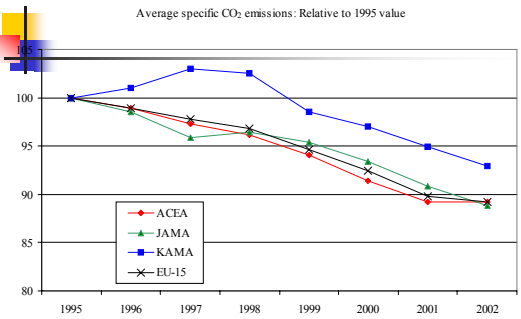
Europe

Major Issues:

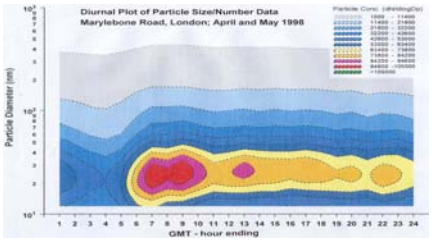
- **High PM**
- **High PM Number**
- **Record Ozone**
- **Roadside NO2**
- **NOx NEC**
- **CO2 Targets**

Penetration of Diesel Cars in Europe (% of New Sales)





Vehicles Are A Major Source of Ultrafine Particles

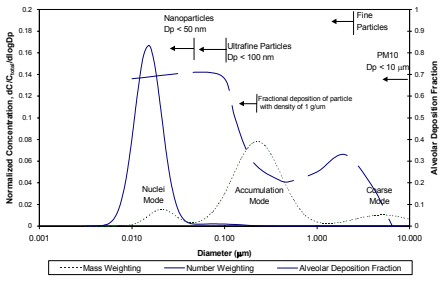


Concern Over Ultrafine PM Reinforced

- Daily Mortality in Erfurt Germany
  - Health Effects of Ultrafine & Fine PM Comparable
  - Effects of Ultrafines Depend on Number and Surface Area
  - Since 91/92 PM Mass Has Declined
  - Since 91/92 very small particles (.01-.03) increased

HEI Research Report 98, November 2000

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



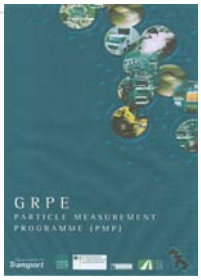
Instruments: Number Measurement

- Laser-light scattering
- Differential mobility spectrometer (number & size distribution)
- Electrical mobility (CPC)
- Electrical mobility/optical counter (number & size distribution)
- Electrical Low Pressure Impactor (ELPI) (number & size distribution)

Recommendations

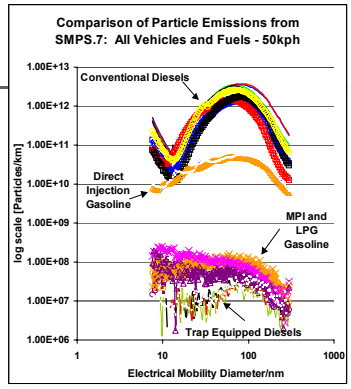
Mass measurement

- Modified US 2007 - offers significant improvements in COV compared to European filter method.

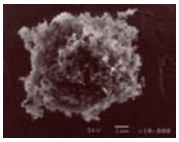


Number Measurement

- CPC - good overall robustness & good repeatability (COV) when operated with appropriate sample pre-treatment; very linear in experiments using the CAST system



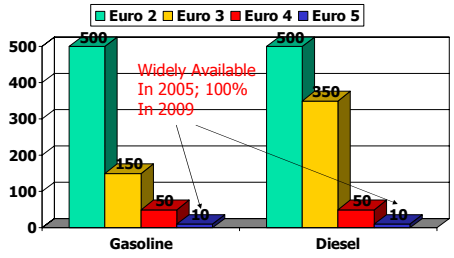
Concerns Continue To Be Raised Regarding Impact of Soot On Climate

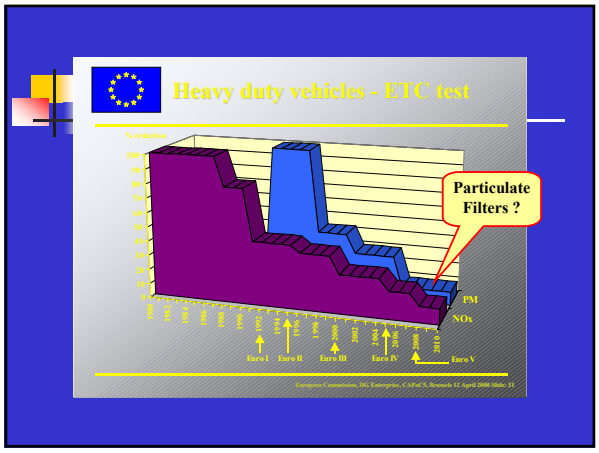


- Soot Deposited On Snow Reduces Its Ability To Reflect Sunlight
- Soot May be Twice as Effective as Carbon Dioxide in Forcing Global Warming

James Hansen and Larissa Nazarenko

European Fuel Sulfur Levels (PPM)





Would You Rather Put A Filter on Your Kid Or Your Car?

UBA- Proposal for Amendment of EURO 5 Limits for HDV

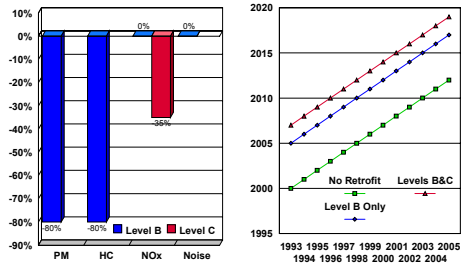
	EURO 3		EURO 4/5	
	1999/96/EG			
	ab2000		ab 2005/2006 bzw. 2008/2009*)	
	ESC- und ELR-Test [1]	ETC-Test [2] [3]	ESC- und ELR-Test [1]	ETC-Test [2] [3]
	g / kWh	g / kWh	g / kWh	g / kWh
CO	2,1	5,45	1,5	4,0
HC	0,66		0,46	—
NMHC	—	0,78		0,55
Methane	—	1,6 [4]		1,1 [4]
NO_x	5,0	5,0	3,5 / **1,0**	3,5 / **1,0**
PM	0,1	0,16 [5]	0,02 / **0,002**	0,03 / **0,003**
Rauch	0,8 m^{-1}	—	0,5 m^{-1} / ?	—

[1] new test procedure for all diesel engines
[2] additional transient test cycle for diesel engines with aftertreatment systems
[3] for gas engines only transient test
[4] for CNG engines only
[5] for diesel engines only
*) for EURO 5 (from 2008/09) originally only the NOx standard was reduced from 3,5 to 2,0 g/kWh

NOx-limit of less than 1,0 g/kWh is nessessary to fullfill NEC requirements (2001/81/EC)

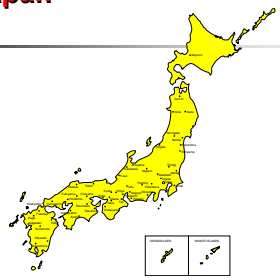
Quelle: UBA, Nov. 2002

Swedish Retrofit Program All Trucks Above 3.5 Tons

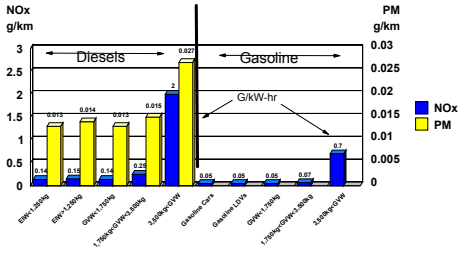


Very Low Sulfur Fuel Dominates The Market

Japan



New Standards For Japanese Vehicles (October 2005)



Reduction of Sulfur in Diesel Fuel in Japan

Year	Sulfur Content
~1992	5000 ppm
1993	2000 ppm
1997	500 ppm
2003/4	50 ppm
2005/7	10-15 ppm

New Long-Term Passenger Car Emission Standards In Japan

* Sulfur content will be lower than 10 ppm by 2008.
* Compensating CO_2 emission due to refinery desulfurization will greatly depend on the share of fuel-efficient PCs sold.
* Combustion technology is being improved.
* Cold start emission regulations are supposed to be more stringent.
* When? 2010? [NOx]: 0.05 g/km → ? g/km
  [HC] : 0.05 g/km → ? g/km

Next Generation EFVs to be Developed by 2010

Heavy-Duty Vehicles

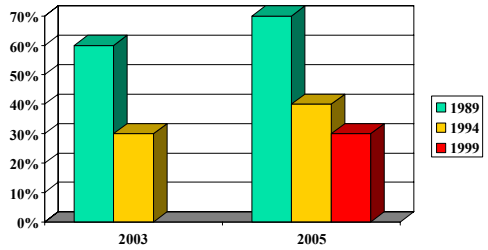
Technical Targets

- *1/10 of 2005 Diesel NOx Std. (0.02 g/kWh)
- *Nearly Zero PM
- *Diesel-Like Efficiency

Vehicle Types

- *Hybrid Vehicles
- *CNG & DME Vehicles
- *Super Clean Diesels
- *FC Buses

Retrofit PM Reduction Required For Device Consideration in Tokyo



China: Home of the Megacity

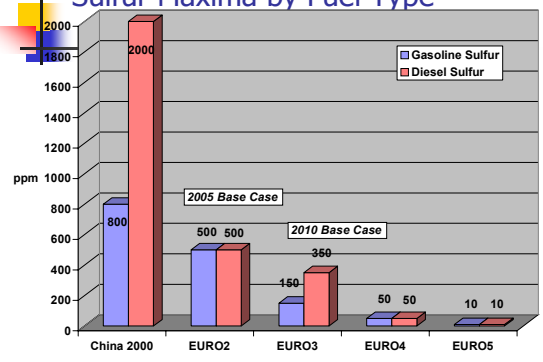
Control Measures on Motor Vehicle Pollution in China

Emission Standards For New Vehicles

Time / Category	Before 2000	2000	2001	2002	2003	2004	2005
PC	ECE 1503	EURO I	←	←	←	EURO II	←
LDV& LDT	ECE 1503	←	EURO I	←	←	←	EURO II
HDDV	None	←	EURO I	←	←	EURO II	←
Motorcycle	ECE R 40	←	EURO I	←	←	←	EURO II

Beijing, Shanghai already Introduced Euro 2 in 2003

Sulfur Maxima by Fuel Type



South Korea

- Vehicle Standards
  - Gasoline Vehicles – ULEV by 2006
  - Diesel Vehicles – Euro 4 by 2006
  - 50% Tighter by 2010
- Fuels
  - Diesel S from 430 to 30 by 2006
  - Gasoline S from 130 to 50 by 2006
- "Clean" Vehicle Incentives – (50-75% Lower)
  - Mandatory For Public Agencies
  - Economic Incentives For Others

Taiwan

- From July 1999, US 94 Heavy Truck & Diesel Light Truck Standards Were in Effect
- Starting January 2004, EU Diesel Car Standards Will Be Deemed Equivalent To Taiwan Light Duty Standards
- On January 2007, US 2004 HD & US Tier 2 Light Duty Standards Apply; EU Heavy Duty Standards Deemed Equivalent
- Gasoline S From 180 to 50 & Diesel S from 350 to 50 From January 1, 2007

South America

Brazil

- Passenger Cars & Light Commercial Vehicles
  - US EPA 1983 Standards Since 1997
  - Tier 1 Phased in 2005-2007 (40/70/100%)
  - Tier 2 in 2009
  - No Diesel Cars Allowed
- Heavy Duty Trucks & Buses
  - Euro 3 Phased in 2004-2006
  - Euro 4 in 2009
- Fuels
  - Diesel Fuel S in City from 2000 to 500 in 2005 & to 50 in 2009; on rural areas from 3500 to 2000 in 2005 & to 500 in 2009
  - Gasoline S from 1000 to 400 in 2004 & to 80 in 2008

18 measures of High Impact (2001-2005) in Chile

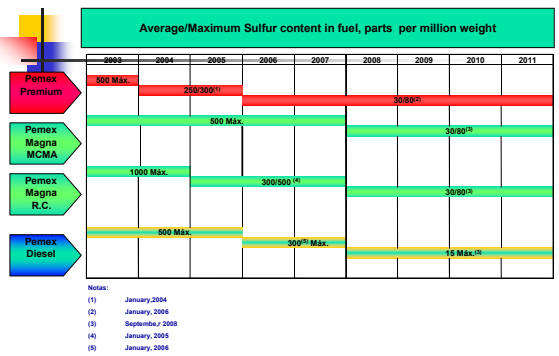
- Renovation of buses:
  - Reduction of 75%PM10 and 40% NOx with the Urban transport plan
  - Retirement of 2,700 pre-EPA buses
  - Incorporation of low emission's buses and **post treatment systems starting year 2004**
- Renovation of trucks:
  - EURO III and EPA98 Standards
  - **Incorporation of post combustion treatment systems**.
- New standards for light vehicles.
  - Tier1 and EURO III Standards
- Dust Control:
  - Street dust control
  - Street pavement programs
- Fuel Improvement:
  - **Diesel Quality from 300 to 50 ppm by 2004**
  - Gasoline Quality improvement by 2003
  - Gasoline Quality improvement by 2005
  - Progressive regulations on firewood burning
- New industry standards:
  - CO emission standards
  - SOx emission standards
  - Reduction program of SOx in major industrial processes
- Integrated System of Compensations and Tradable Emission Permits
  - Emission shares of NOx in the industry
  - Emission shares of PM10 in industrial processes
  - A 150% emissions compensation for all new activities (industry and transport)

Mobile Sources Program In Mexico

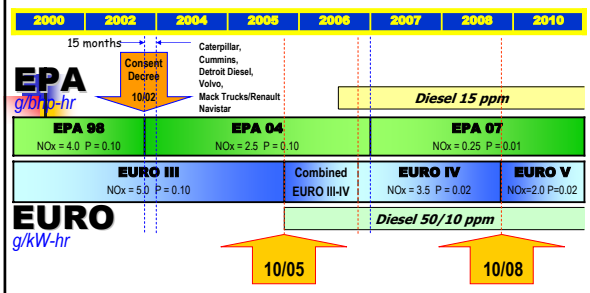
Tighten emission limits for new gasoline and diesel vehicles.

- Gasoline:
  - Tier I first introduced in 1999 (US-EPA-94).
  - Tier II to be introduced in 2006, under discussion.
- Diesel:
  - EPA-98 currently in place.
  - Standards for new diesel vehicles under discussion.
- Key Issue Is Fuel Quality

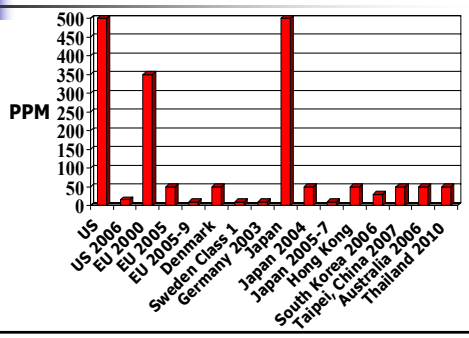
ULSF introduction agreement:
SEMARNAT-SENER-PEMEX REFINACIÓN



Close Linkage Between Vehicle Emissions Standards and Fuel Sulfur Levels



Ultra Low Sulfur Diesel Fuel Is Spreading



Consensus: Diesel PM Filters Technology of Choice

- Over 500,000 New Cars in Europe
- Retrofitted on Thousands of Vehicles Worldwide (e.g., Sweden since '96)
- Will Be Most New Diesel Vehicles in Japan by 2005
- In US, International Already Certified & Cummins & Caterpillar On Track For 2007

Europe & US Diverging On NOx Control

- DeNox Catalysts
  - Seems To Be EPA's First Choice in US
  - Are Where They Need To Be At This Point According To Independent Diesel Review Panel – No Show Stoppers!
  - Will Likely Not Be Needed in the US Before 2010
- SCR
  - Is First Choice in Europe
  - Fuel Economy Benefits Attractive
  - Infrastructure Remains A Concern To US EPA But Significant Efforts Are Underway
  - Also Concern Over Placing Refueling Responsibility on Truckers

Conclusions

- Diesel PM & NOx Remain Major Concerns
  - PM_{10} & $PM_{2.5}$ & Ultrafines
  - Ozone
  - NO_2
- Special Concerns With Diesel PM
  - Small Size
  - Toxicity
- Stringent New Diesel Standards and Low Sulfur Fuel Requirements Spreading
- PM Filters Seen As Key To Control; Different NOx Controls
- Europe Considering Additional Heavy Duty Truck Standards
- Non Road & Retrofit – Unfinished Agenda