

18.ETH-Conference on Combustion Generated Nanoparticles
Zürich June 2014

Best Available Technology for all Engines in Use !

*Urgent Need for a Fleet Turn-Around
Challenge for the OEM*

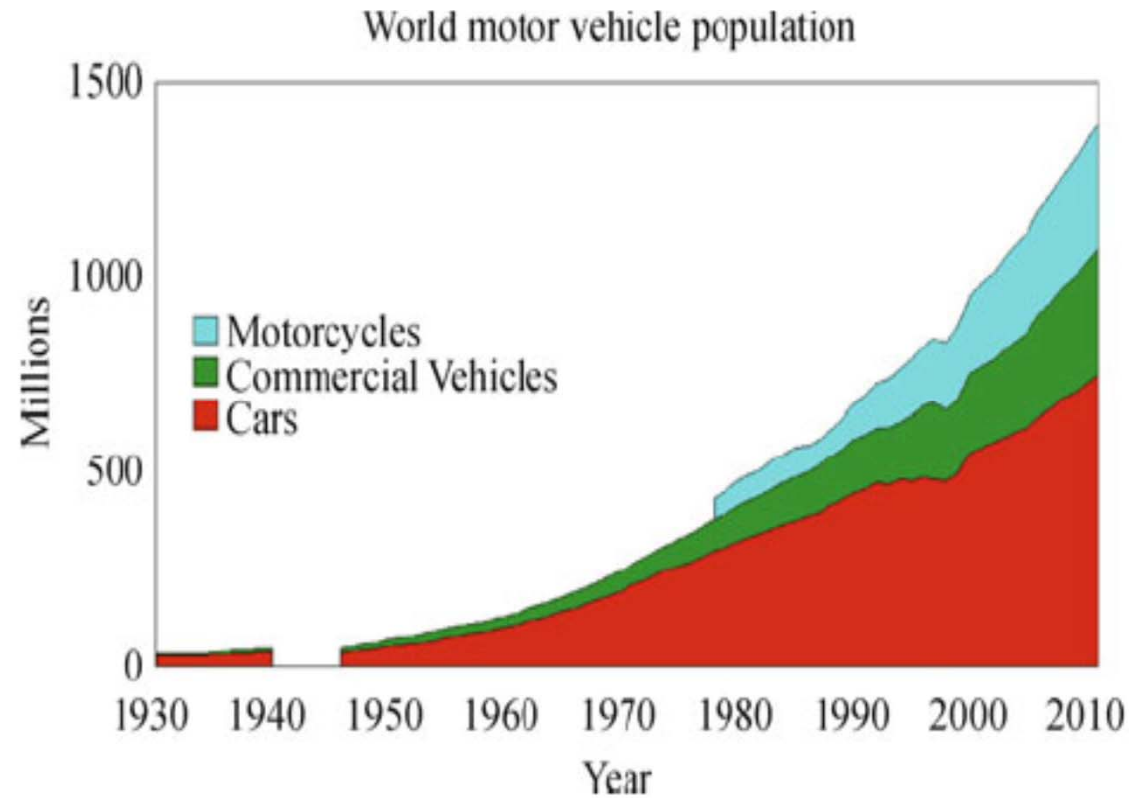
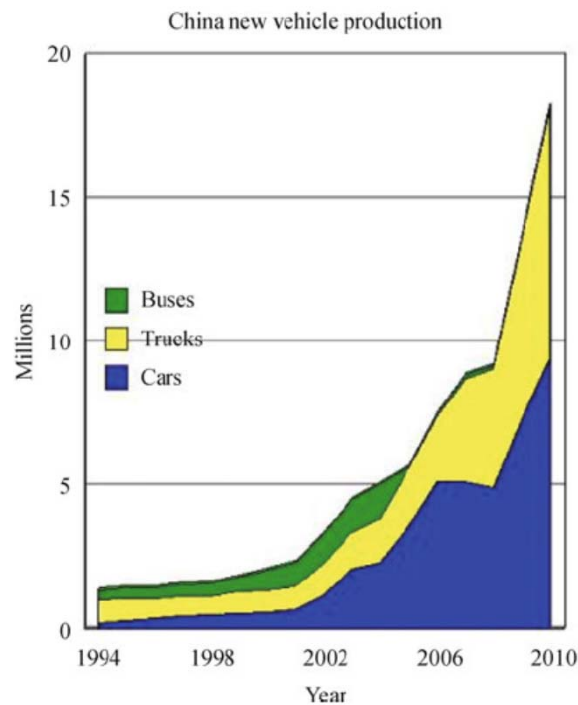
Andreas Mayer

F.Legerer, John J.Mooney

Contents

- Mobility at any price ?
- Loosing the battle at the hotspots
- Progress with new engines too slow
- Upgrade tools for in-use engines
- Upgrade in use engines permitted ?
- Upgrade in-use engines feasible ?
- Upgrade in-use engines cost-effective ?
- Retrofit or OE-upgrade
- Introduction of upgrade engines
- Who to start ?
- win-win-win

Society needs Mobility

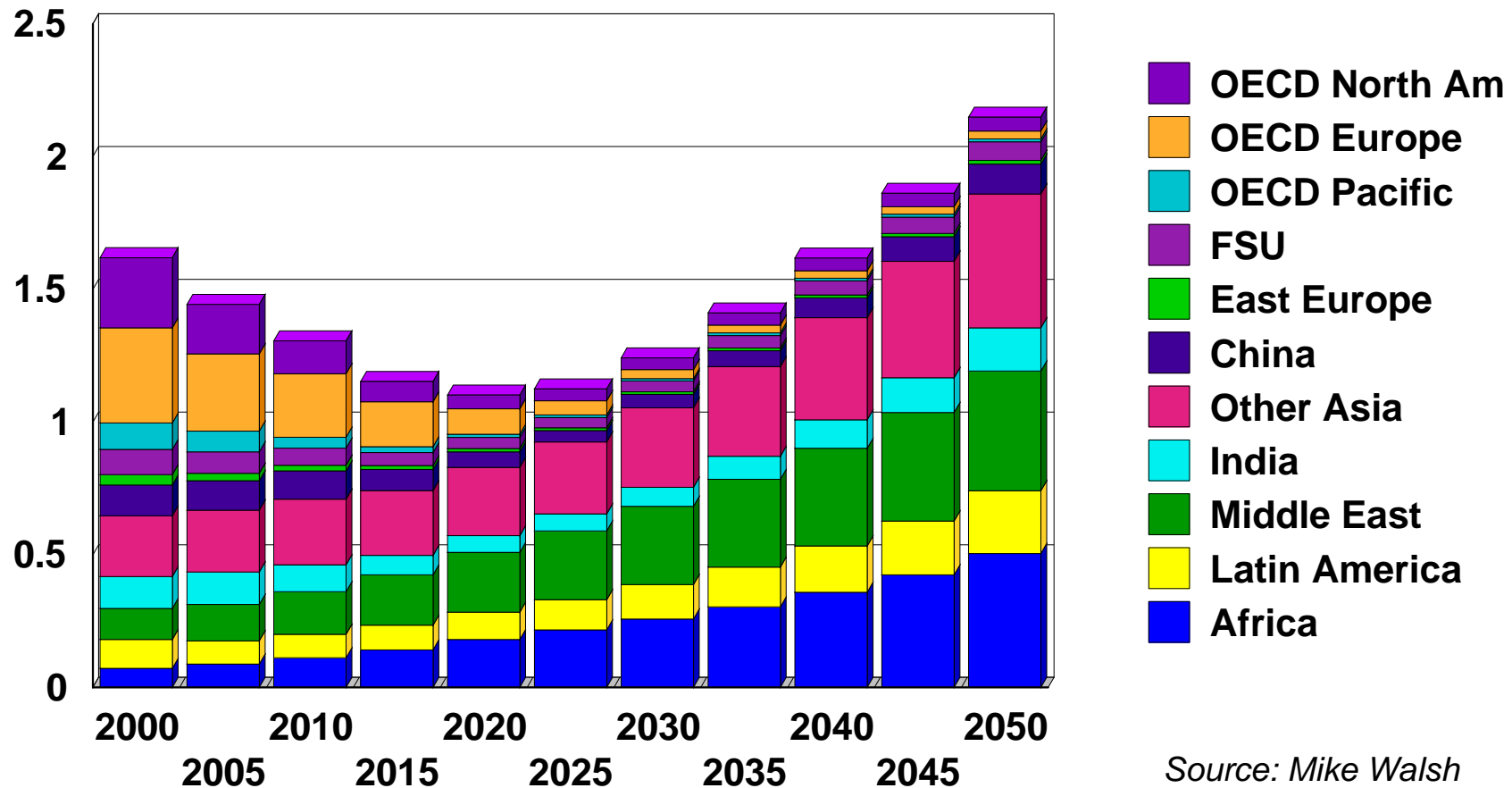


Road Vehicle Emissions By Country

Particulate Matter

Base Case

Million Metric Tons

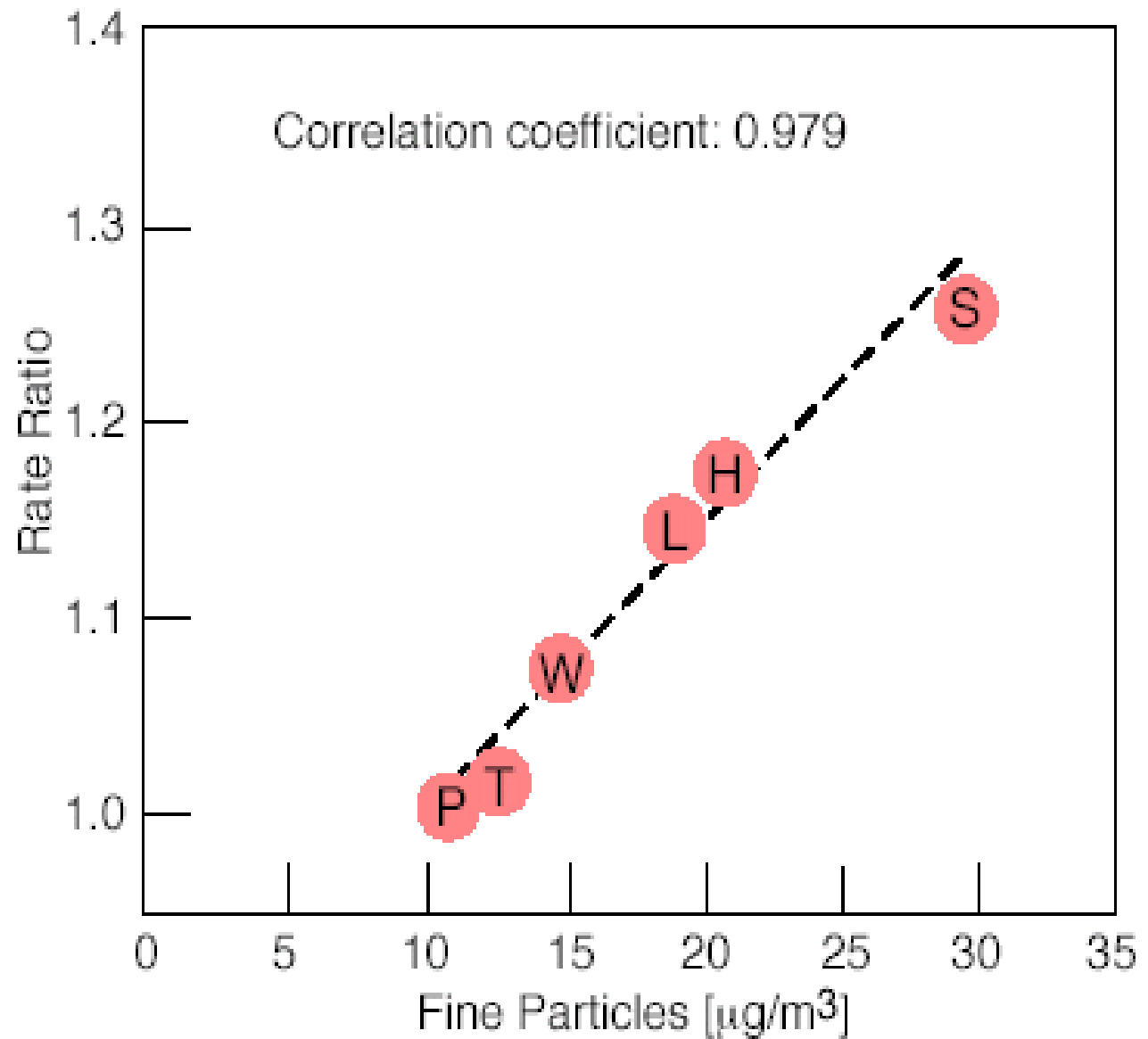


Source: Mike Walsh

Mortality correlates with PM2.5

6-Cities-Study
USA 1978-93
15'000 cases

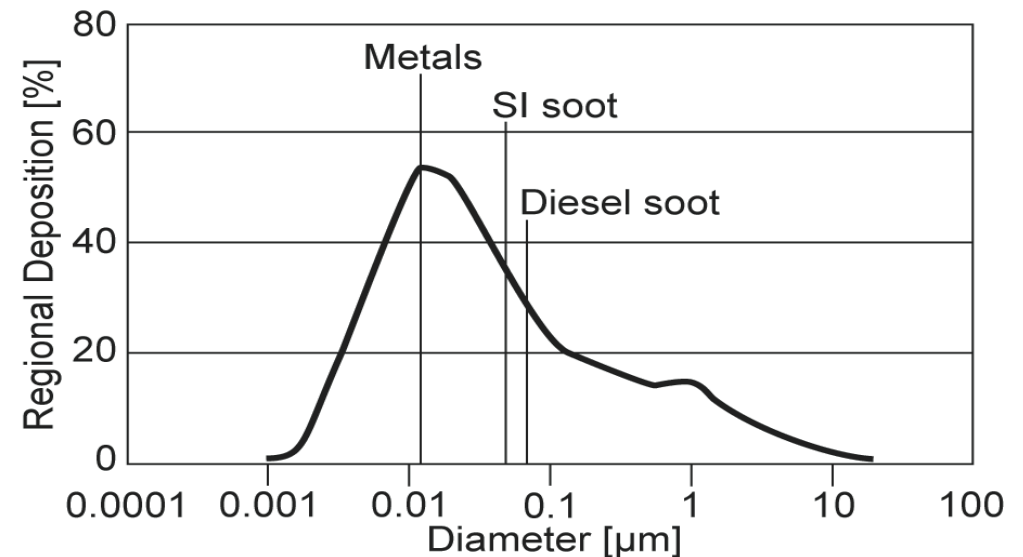
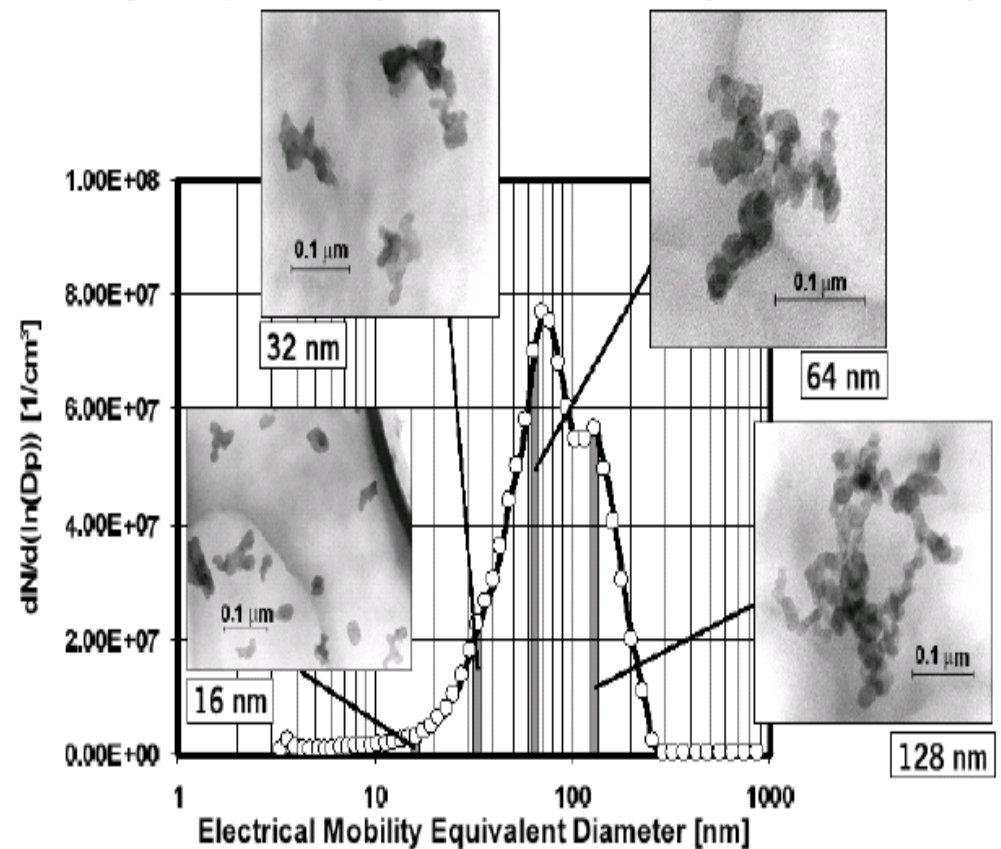
Correlation with
fine particles only



Source: D.Dockery NEJM 1993

The weakest size range
of the Lungs
is the strongest emission
range of the Engines
and the weakest size
range of Filters

*The Lung is an open
door for engine emitted
particles*



WHO 12.Juni 2012

„Diesel Exhaust Carcinogen Class 1“

237 years after P.Pott

International Agency for Research on Cancer



PRESS RELEASE
N° 213

12 June 2012

IARC: DIESEL ENGINE EXHAUST CARCINOGENIC

Lyon, France, June 12, 2012 -- After a week-long meeting of international experts, the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), today classified diesel engine exhaust as **carcinogenic to humans (Group 1)**, based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

Mortality and Health Cost global 2012

due to Traffic Emissions [per year]

	Inhabitants Mio	Mortality x1000	Cost Mia €	Mortality per 1 Mio	Cost €/Pers
USA	313	200	?	638	?
Kalif.	38	9	?	236	?
London	8.1	4	23.4	493	2800
Schweiz	7.8	4.5	6.5	576	833
EU28	505	480	650	960	1390
World	7000	7000 <small>Like world war II</small>	3'500	1000 <small>12% of all death</small>	500

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- **Loosing the battle at the hotspots**
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Claude Monet

1901

fascinated
„London-Smog“



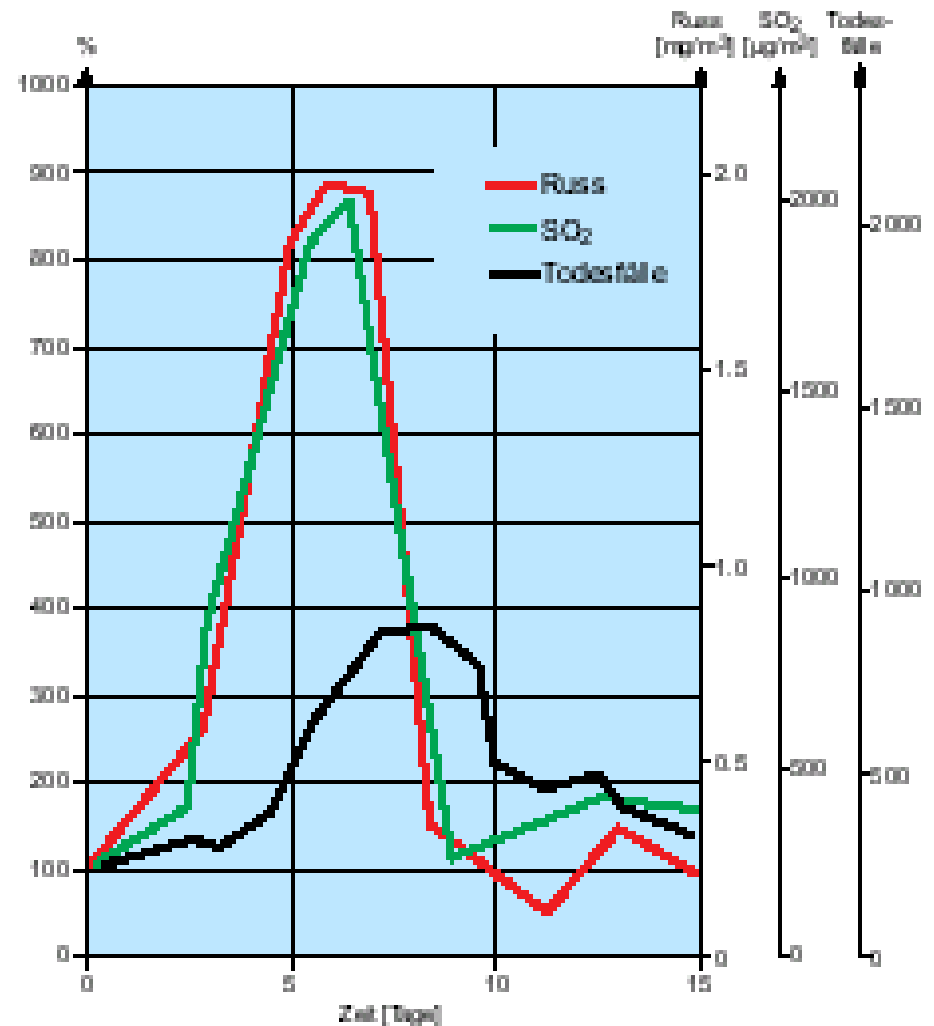
Short Term Effects

London Smog 1952

6000 died within one week

6000 more within one month

8 month after replacing electric tram by Diesel buses



Histological Research

of lungs compartments from 50 yeary old autopsies

Electron microscopic analyses revealed the dominance of retained soot and a surfeit of other particle types. A variety of metal-bearing particle types were found in all compartments, but Pb, Zn, and SnZn types appeared the least biopersistent. The results support the acute toxicologic importance of ultrafine carbonaceous and metal PM. *Key words:* 1952 London smog, autopsy, lung

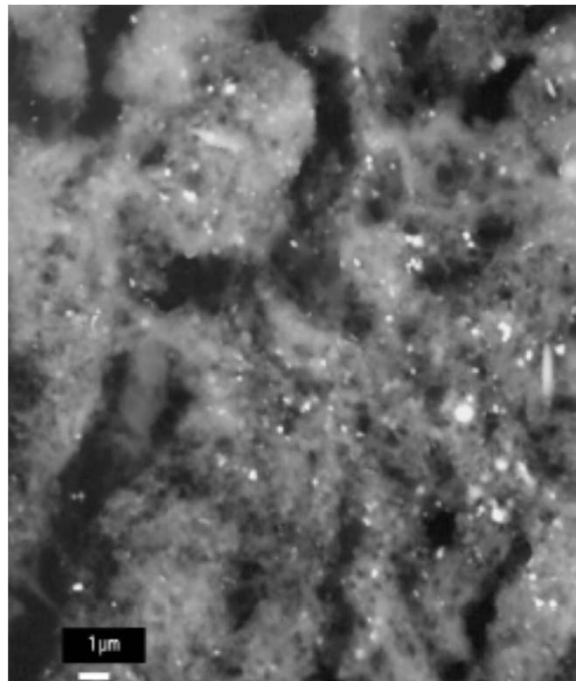


Figure 2. BE micrograph of section of airway aggregate from case 2 revealing abundant submicrometer inorganic (bright) particles.

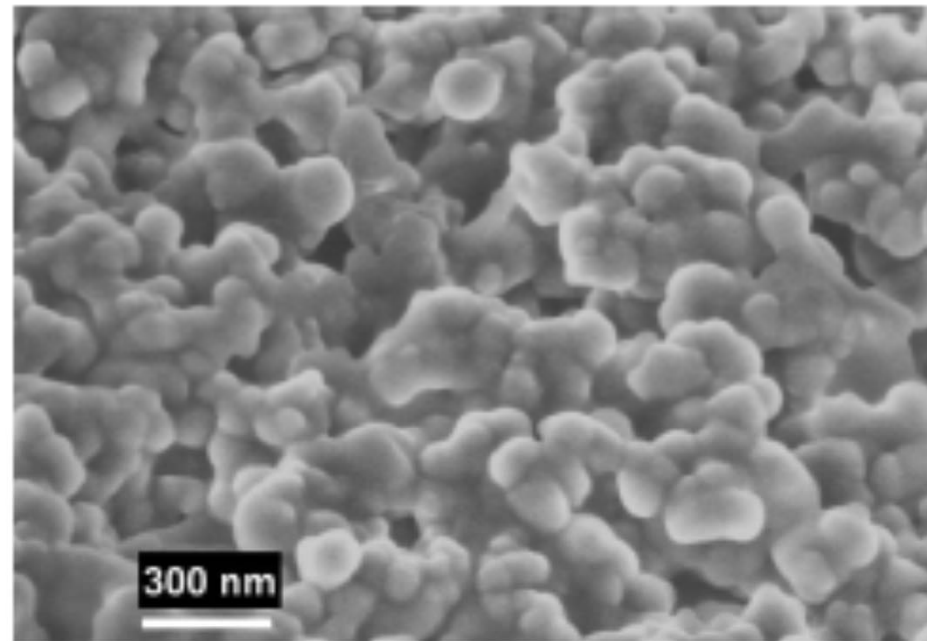


Figure 3. High-magnification field emission scanning electron micrograph of airway aggregate from case 2 showing ultrafine PM structure.

Beijing December 2012

VERT -Retrofit Bus + Construction Machines



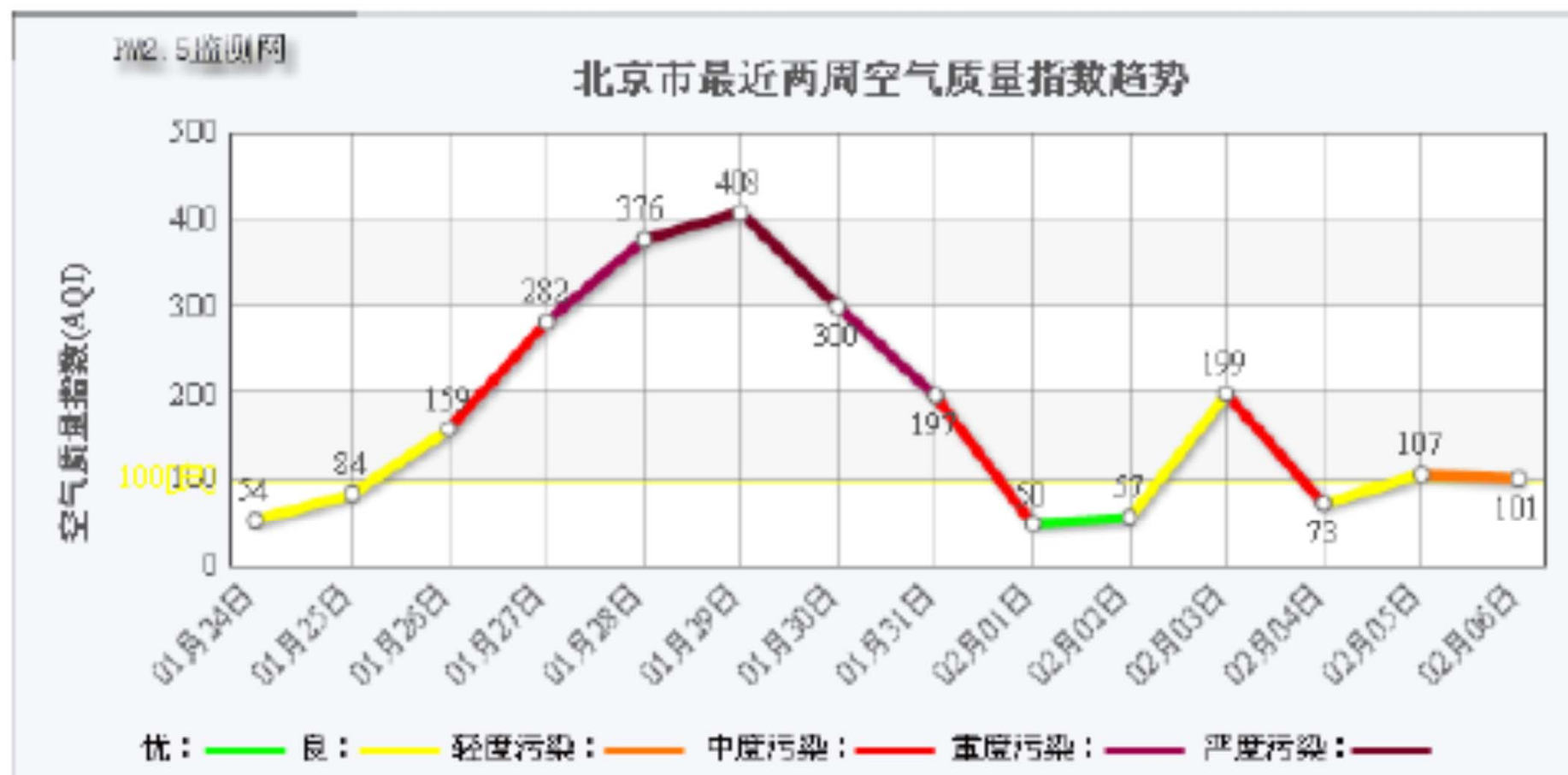
Beijing 20.12.2012 9:00
day before predicted apocalypse

DiSCmini: 90'000 P/cm³
(60 nm → 20 µg/m³ BC)

PM2.5 official: 182 µg/m³

PM2.5 US: 320 µg/m³
(24h-mean value)

PM2.5 official



Bogotá 2013 VERT-Retrofit 12'000 buses



Foto tomada el 20 de abril de 2006 a las 8:30 a.m. (smog fotoquímico)

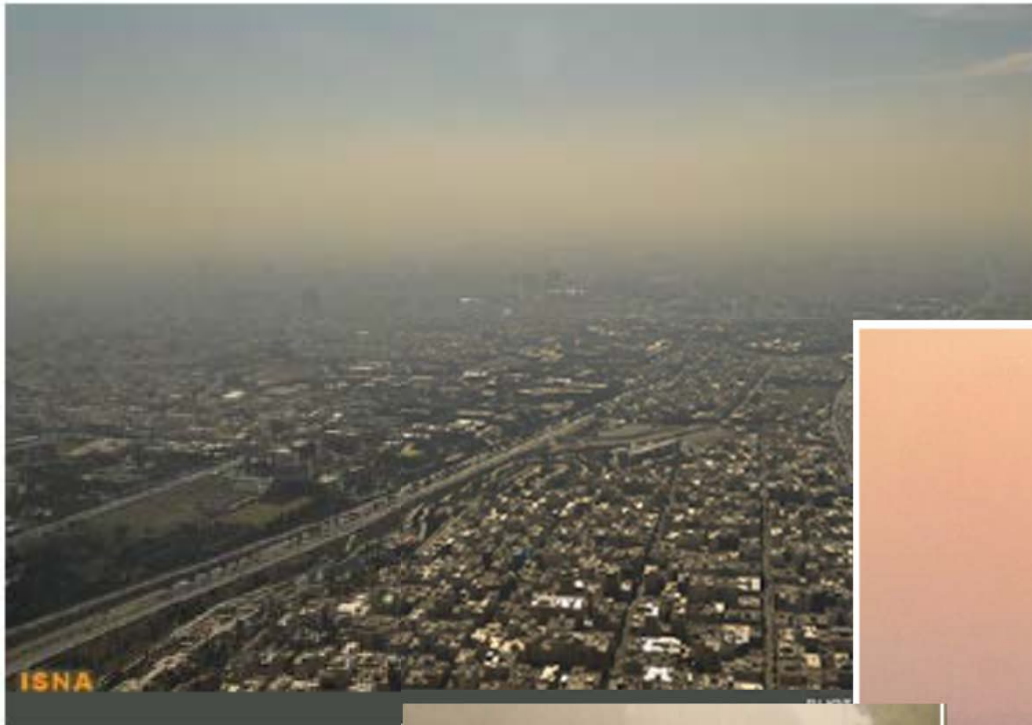
Foto: Juan Felipe Franco



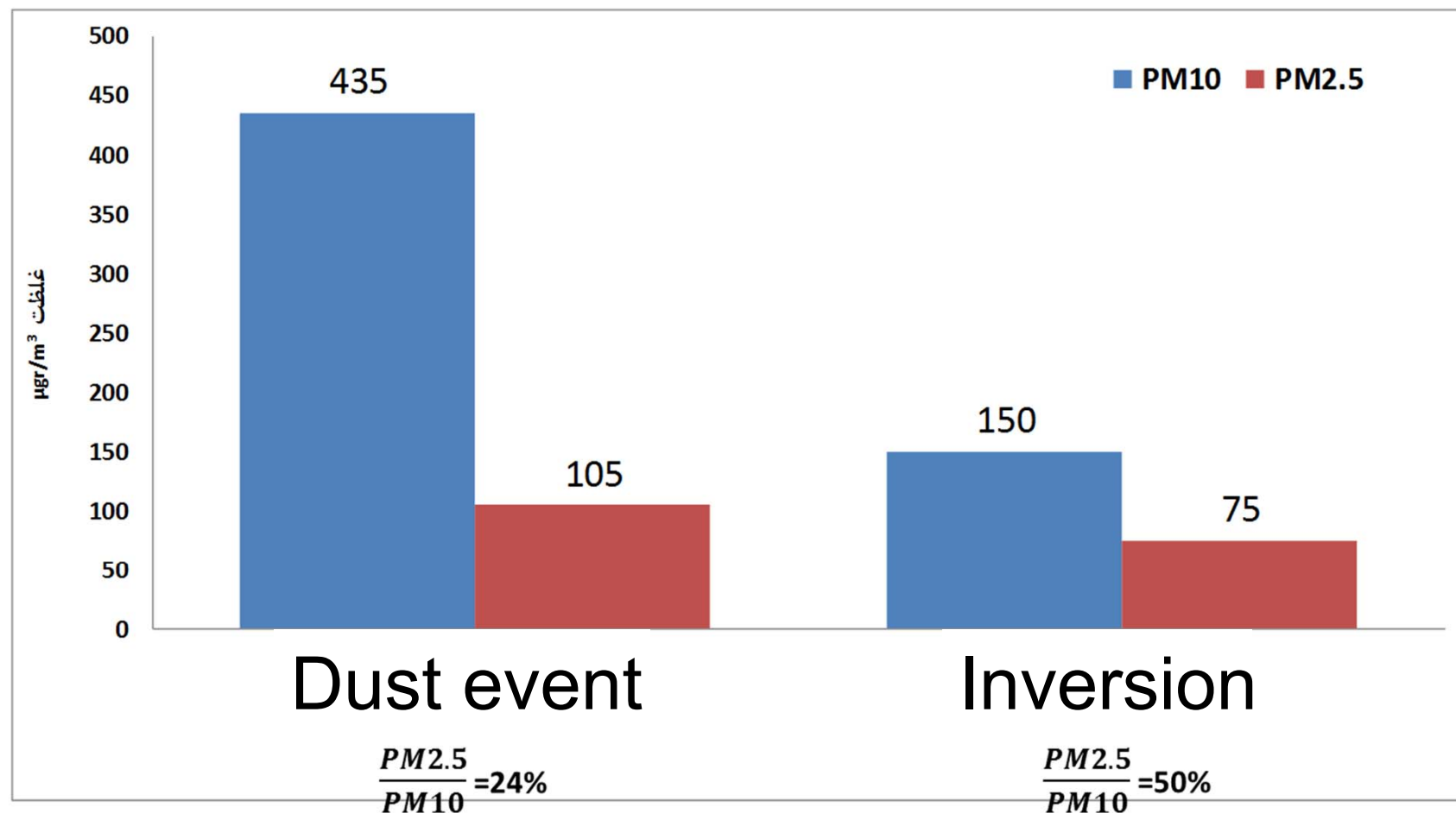
Foto tomada el 3 de mayo de 2006 (segundo día para de transporte). 8:30 a.m.

Foto: Juan Felipe Franco

Tehran 2013 VERT-Retrofit 7'000 Buses



PM10 versus PM2.5 at inversion and dust event

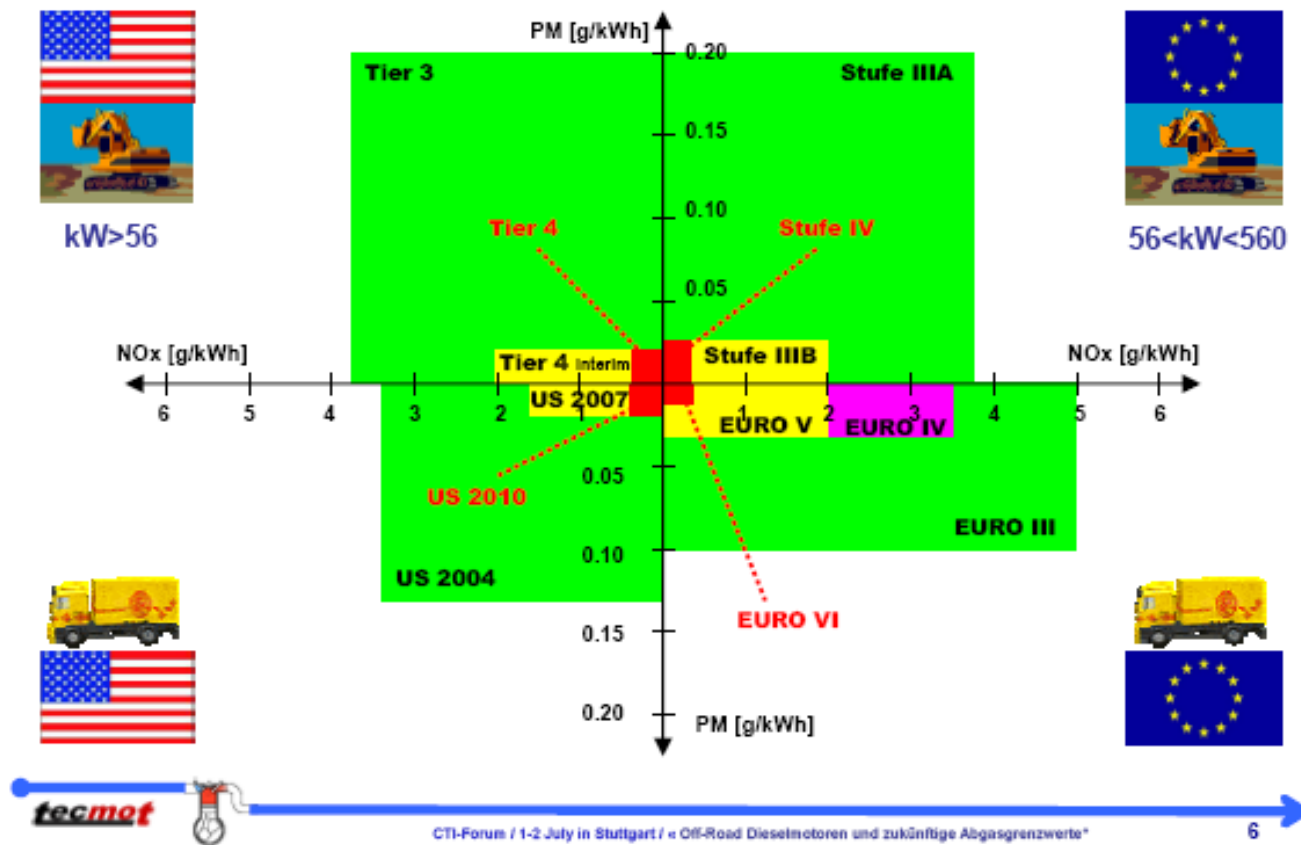


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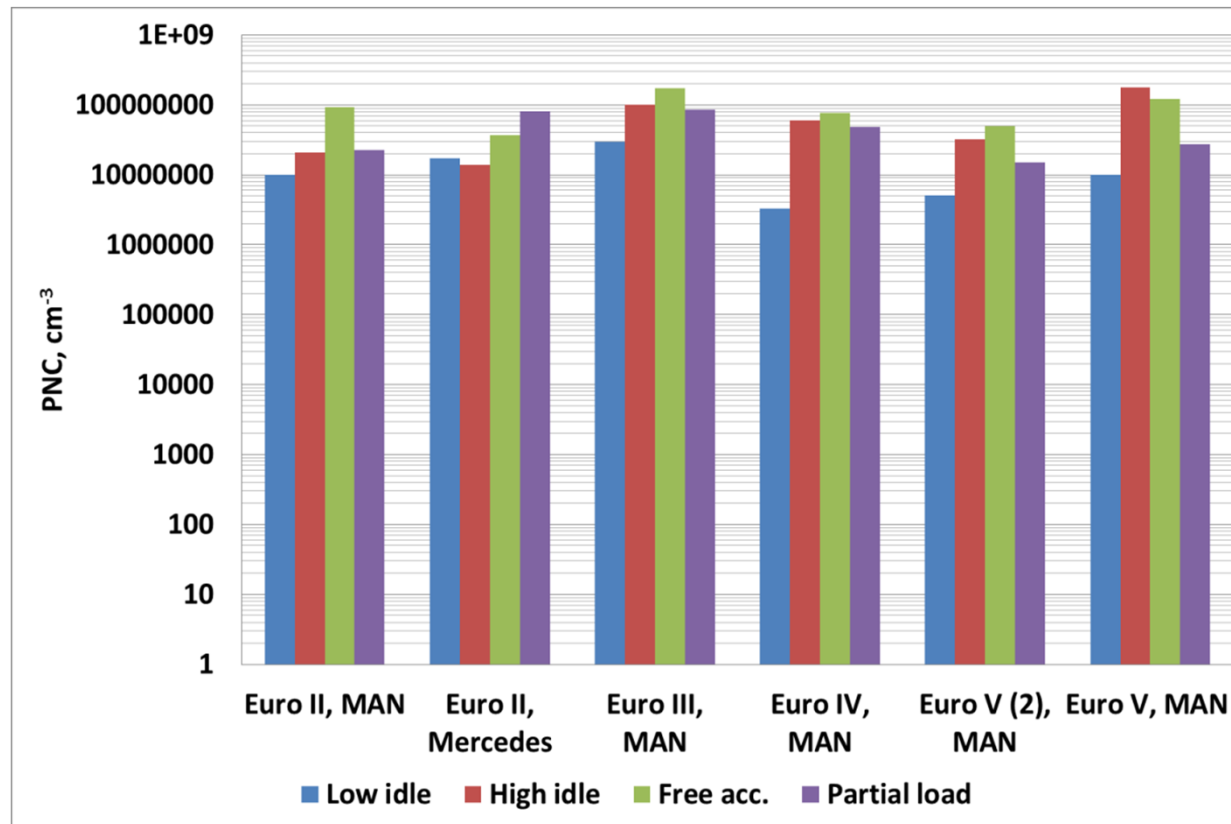
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Emission Regulation PM

Übersicht der HD-Abgasgesetzgebung (USA & EU)



What happened to PNC while PM was reduced



Recent Test in Tel-Aviv – see paper in session 5

Coagulation

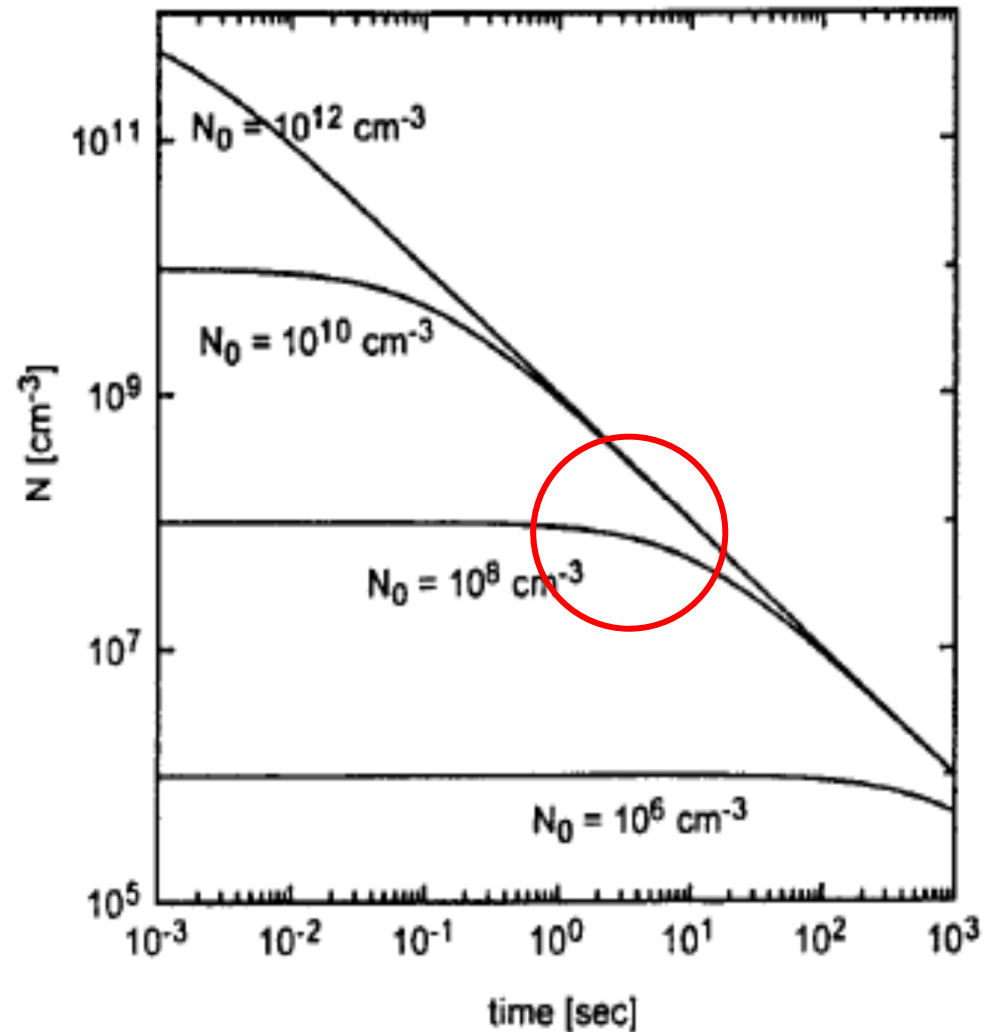
Brings PNC quickly to a saturation point while particle size is growing

Paper on Scavenging
Session 4B

$$N(t) = N_0 / (1 + N_0 K_0 \times t)$$

$$D(t) = D_0 \times (1 + N_0 K_0 \times t)^{1/df}$$

Source W.C.Hinds



Particle Emission of ICE

Diesel

Sootpeak: 80 nm; 10^6

Ashpeak: 10 nm; 10^7

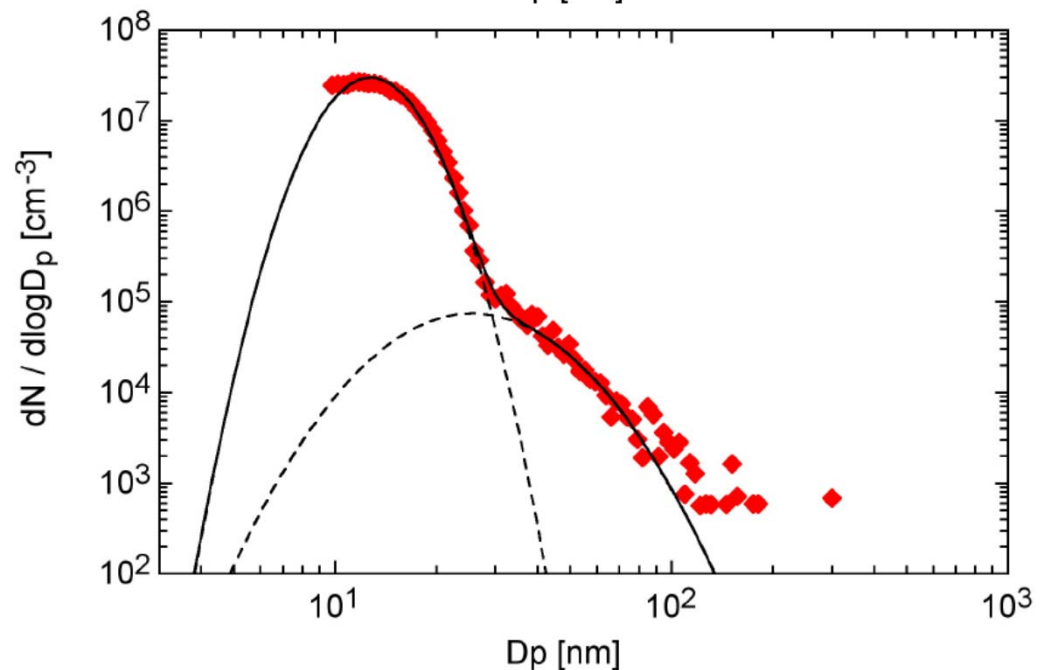
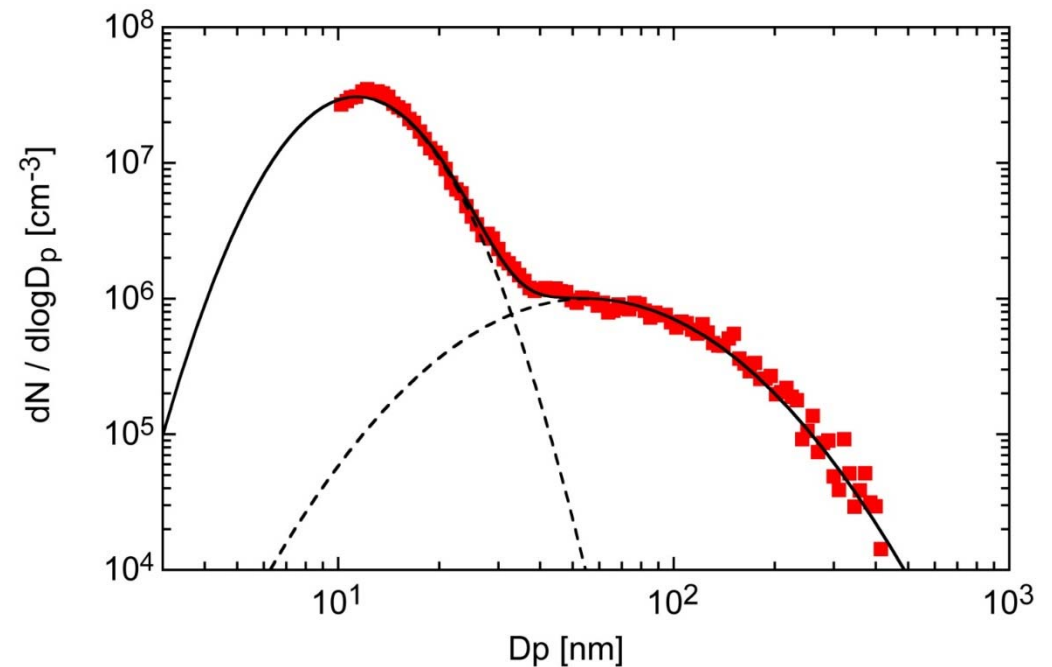
Petrol

Sootpeak: 30 nm; 10^5

Ashpeak: 10 nm; 10^7

Soot and Ash Peaks

Source: M.Kasper



EU Strategy with Filters Euro-VI

EU Co-Decision (Art.12, Rec.15 - 2008)

- In order to achieve these environmental objectives it is appropriate to indicate that **particle number limits** are likely to reflect the **highest level of performance with particle filters** using **best available technology**
- .. the commission shall introduce **particle number based limit values** at a level appropriate to the technologies actually being used.

EU PNC-Regulation enforced the DPF but Only 2 % of the Population

- In Europe **only onroad** and **only new, only Diesel**
- US has no regulations which requires filters
- Asia and Latin America target Euro IV
- All activities are limited to new engines only
- **We need a *turn-around* of the whole fleet**

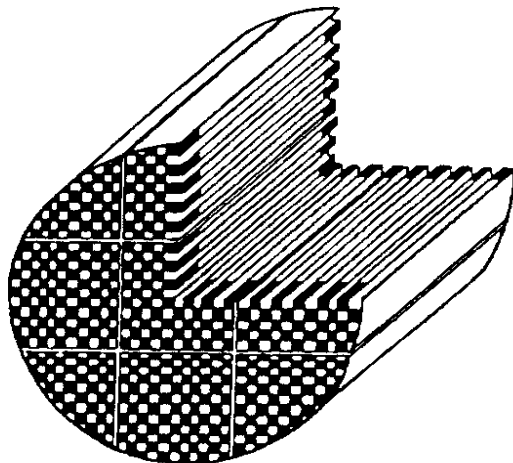
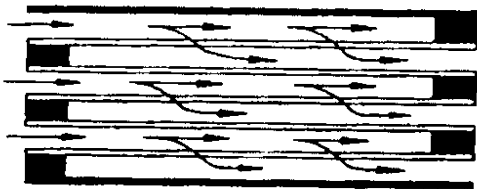
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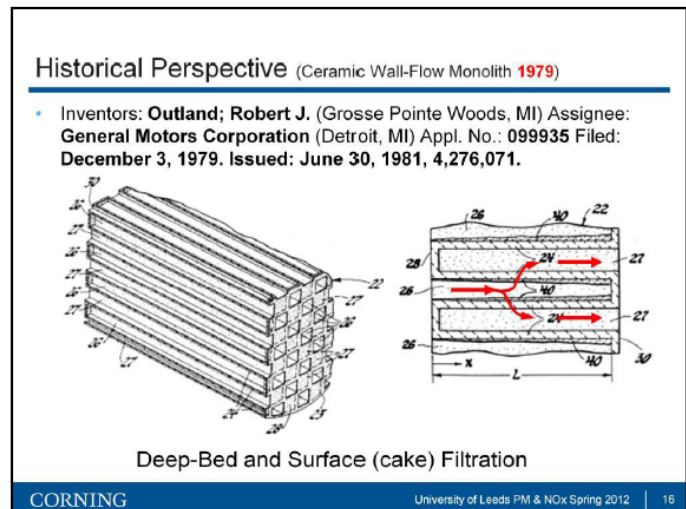
Particle Filter für Diesel-Exhaust 1982

now over 40 Mio successful on the road

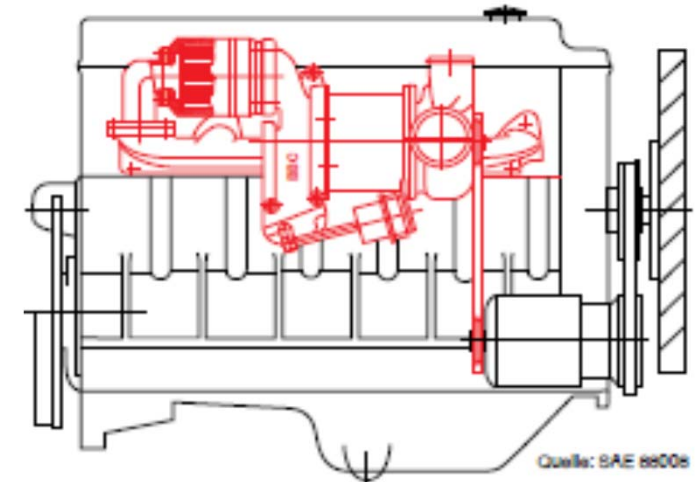
1982
Corning



1979
GM

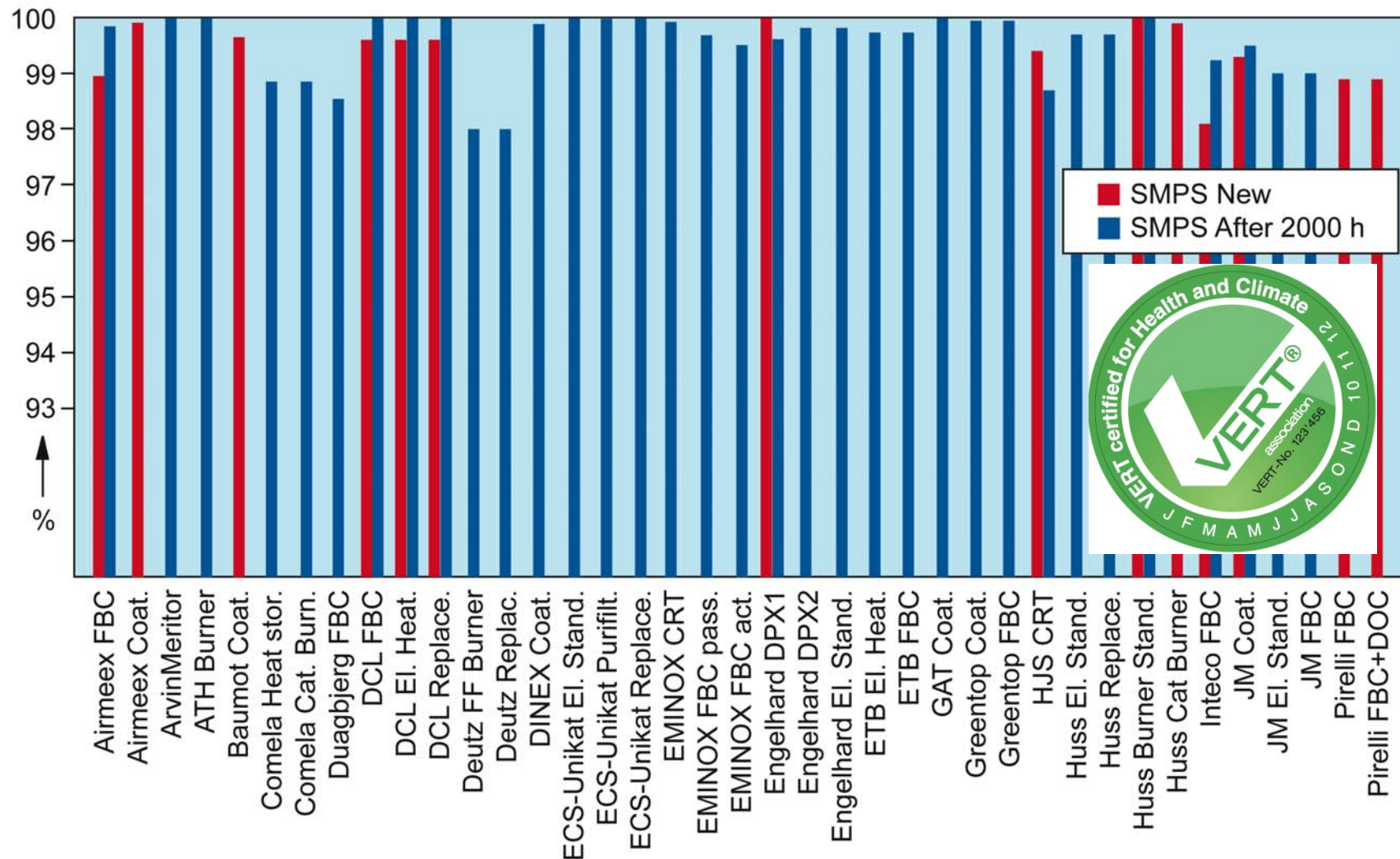


1985
BBC
DB



65 Filter-Families VERT certified

Average 98.4 %, 25 % pass 99.8 %



Upgrade Tools

- **High Efficiency Particle Filters for CI and SI**
- Catalysis for Reduction of CO, HC, PAH, Soot
- DeNOx – however with a much lower priority
- Closed Crankcase to avoid Blow By HC-Emission
- Clean Fuels
- Low Ash Lubrication Oils (no regulation so far !)
- Nanoparticle Cabin Filters
- Engine Management upgrade Kits

and we must intensify inspection and maintenance

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Upgrade legally permitted ?

- **Polluter Pays – Principle**

The operator of a technical system is the polluter. He is legally responsible for all damages inclusive health effects due to operation. He may voluntarily upgrade his system to reduce cost and he can be forced to upgrade any time if upgrade is available.

Is a vehicle such a system ? Of course.

- **Road Vehicles lose Operation Permission if modified**

by retrofitting you not only lose the permission to use a vehicle on public roads but you also lose the manufacturer guarantee

- **Governments can permit and require Retrofit (CH 1990)**

you do not lose the permission to use a vehicle on public roads but you may lose the manufacturer guarantee

- **OEM can not upgrade a homologated Vehicle, unless**

there is a regulation which permits or requires upgrade

Contents

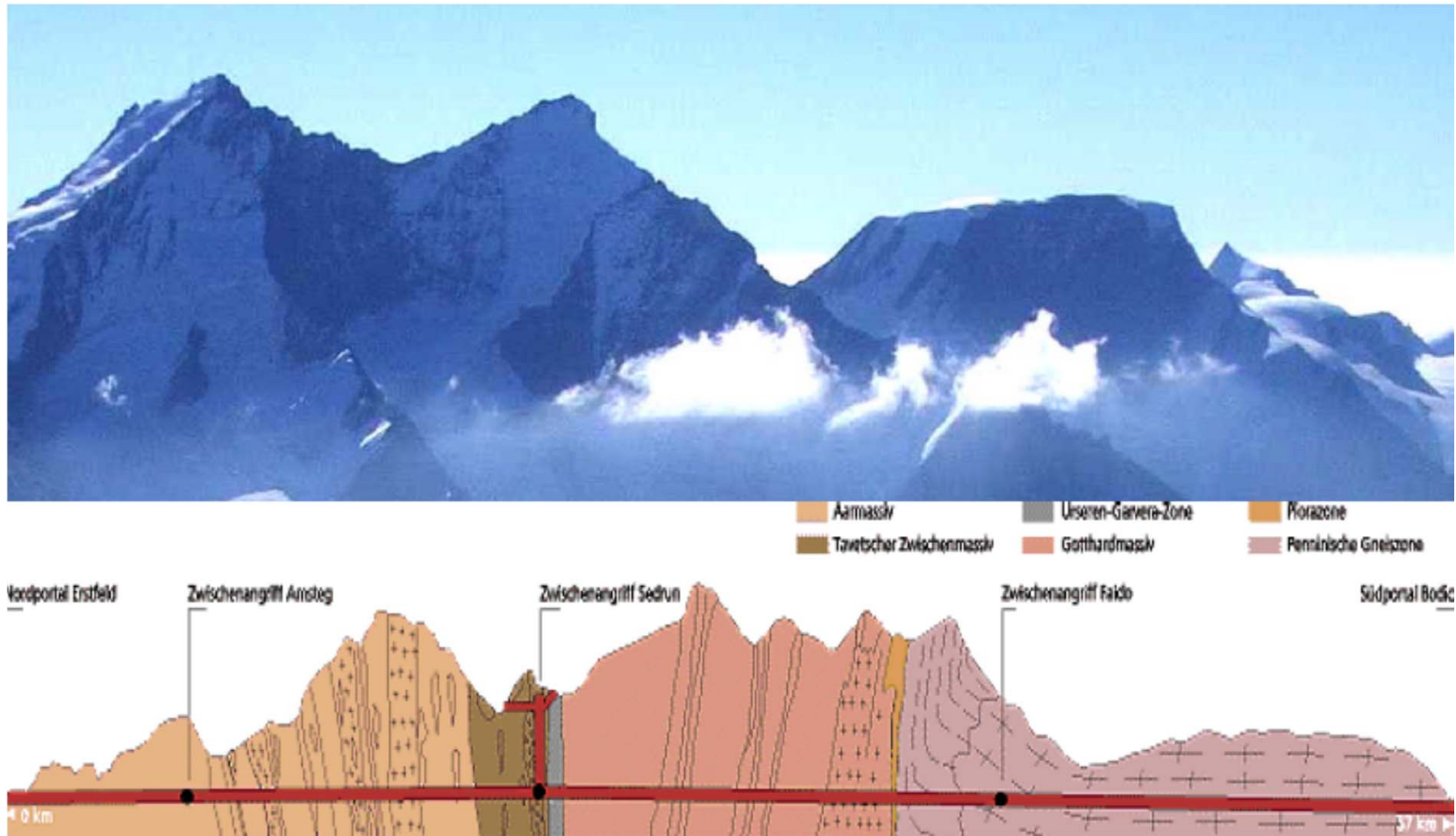
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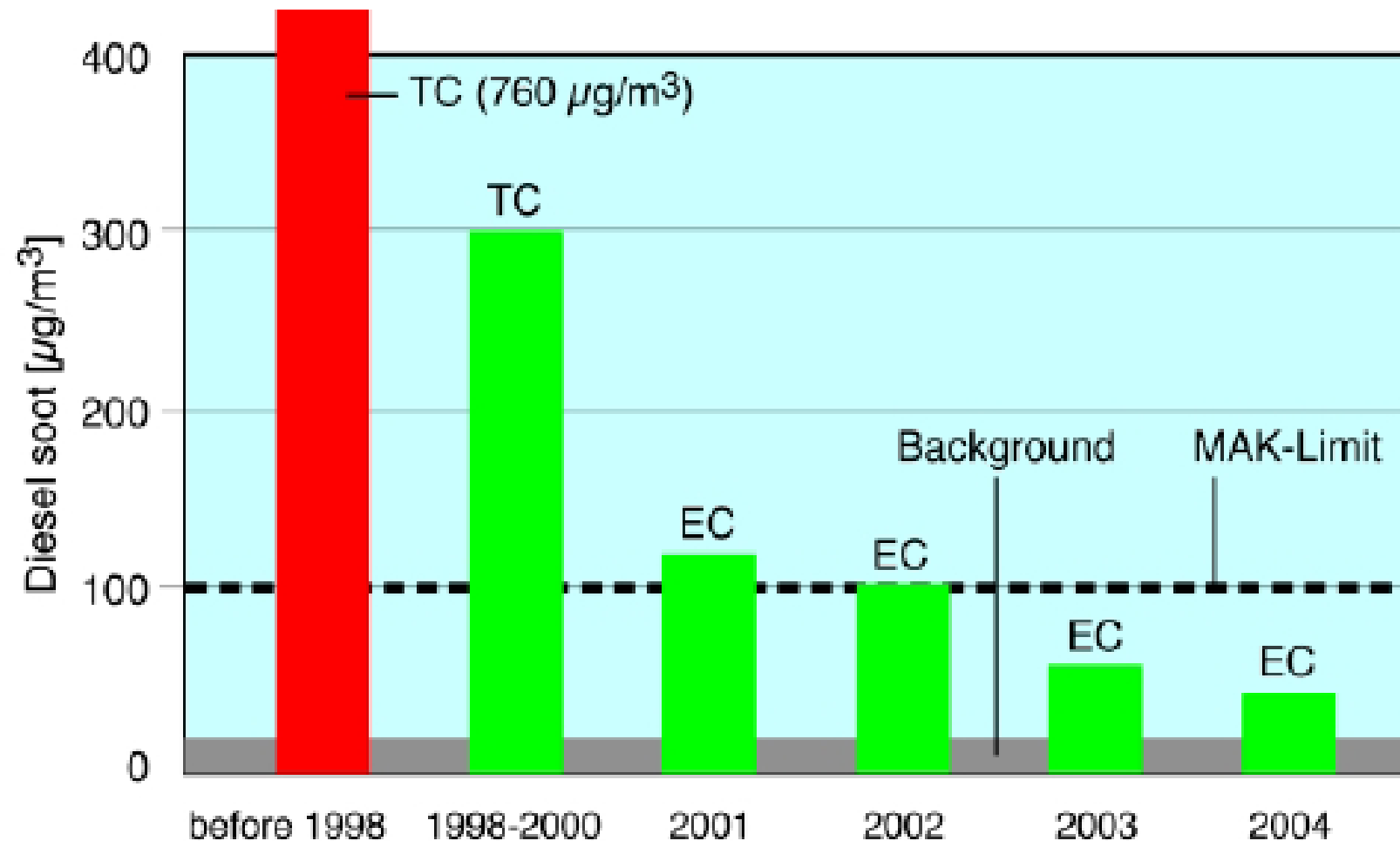
VERT 1993 -1998

Construction of the NEAT tunneling system

AQ-limit value $100 \mu\text{g}/\text{m}^3$ and carcinogenicity declared

PM defined by «solid particles 20-500 nm»





Air Quality in Swiss Tunnelling Sites
Filters obligatory for every Diesel Engine SUVA/H.Egli

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Table 1 Air pollution cost factors in EUR/ton of pollutant (€₂₀₀₈ values)

Pollutant	PM _{2.5} (exhaust)			PM ₁₀ (non-exhaust)			NO _x	NMVOC	SO ₂
Region type	Metropolitan	Urban	Non-urban	Metropolitan	Urban	Non-urban			
Source	HEATCO	*UBA/ HEATCO	HEATCO	*UBA/ HEATCO	*UBA/ HEATCO	*UBA/ HEATCO	NEEDS	NEEDS	NEEDS
Country									
Austria	482,200	155,900	80,700	192,900	62,400	32,300	13'600	1'600	10'000
Belgium	483,400	156,000	104,400	193,400	62,400	41,700	8'700	2'600	10'900
Bulgaria	70,500	22,700	18,100	28,200	9,100	7,200	7'100	400	6'200
Czech Republic	355,400	114,500	88,200	142,200	45,800	35,300	10'600	1'100	9'500
Denmark	436,400	140,700	51,300	174,500	56,300	20,500	5'300	1'200	5'700
Estonia	261,700	85,000	44,200	104,700	34,000	17,700	2'800	600	4'500
Finland	432,600	139,400	36,100	173,000	55,800	14,400	2'600	600	3'500
France	438,600	141,200	87,700	175,500	56,500	35,100	10'500	1'400	9'900
Germany	420,200	128,800	82,900	172,100	55,500	22,600	12'700	1'400	10'900
Greece	Switzerland			498,700			160,500		
Hungary									
Ireland	537,200	173,400	56,200	214,900	69,300	22,500	4'400	1'100	5'400
Italy	397,400	128,400	72,300	159,000	51,400	28,900	9'500	1'100	8'700
Latvia	245,300	78,900	45,600	98,100	31,500	18,200	4'000	700	5'000
Lithuania	266,300	86,500	53,300	106,500	34,600	21,300	5'600	800	5'700
Luxembourg	877,100	282,400	125,000	350,800	112,900	50,000	12'700	2'400	10'300

Switzerland	498,700	160,500	82,400
Poland	248,900	79,900	74,700

Value chosen: 460 CHF/kg PM₁₀

Monetary Health Benefit

DPF-Application on a Heavy Duty Truck

	HDV+FFF	
PM-Emission (Euro III / 3)	0.1 g/kWh	
Mileage	1000 hrs/yr	
Average Performance [kW]	100	
PM Emission [kg/year]	10	
Overall vehicle life [year]	15	
Emission [kg/vehicle life]	150	
Filter type	wall flow	
Filter efficiency [%]	99.9	
Health Cost [€/kg PM10]	460	
Total prevented soot [kg/life]	150	
Health Benefit [€]	69'000	37

Retrofit or OE-Upgrade ?



- Retrofitters were the pioneers and continue to be the true pioneers in many areas but 50 small companies can not solve this giant worldwide problem against the OE since retrofit is limited in volume and cost – strong limiting factors and here is the problem

we must involve the Engine OEM by Directives

- OEM know best how they can upgrade their own older generation engines at low cost and guaranteed quality. They know the clientele and applications, can use their sales and maintenance network and have the capacity
- and some have started to do so – some in cooperation with retrofitters (German Maut, Tunneling, LEZ)

Who to Start ?

- **EU must start and is best prepared: legally and technically**
- BAT is required because of carcinogenicity
- Retrofit regulations are in place with UN-ECE-REC
- BAT catalysed filter aftertreatment is available in large volume for CI and SI
- Cost Effectiveness is proven
- EU-Incentive regulations are in place
- LEZ-regulations are in place
- Retrofit has demonstrated feasibility during 20 years
- Polluter Pays principle is valid
- ***Regulation must require OEM to provide BAT emission upgrade for their older generations – faced-in gradually***

WIN - WIN - WIN

- Fleet-wide Application of catalysed UFP-filters will eliminate health effects by vehicle emissions
- A large new Market created for 15-25 years
- OEM can solve this with available, proven and cost effective technologies
- Health cost will be much reduced and will cover all investment with a 10:1 benefit/cost ratio
- Upgrading becomes excellent new business for OEM
- **This can start immediately**
or who will take the responsibility to delay it ?

