VERT-Workshop within AQM2016-Conference Tehran January 2016

Benefit/Cost-Analysis and Cost-Effectiveness

when using Emission Control Devices like DPF for IC Engines

Mortality and Health Cost global 2012/15

due to traffic [per year]

	Inhabitants Mio	*Mortality Traffic x1000*	Related Health Cost Mia€	Mortality per 1 Mio and year	Cost €/Pers
USA	313	200	?	638	?
California	38	9	?	236	?
London	8.1	4	24	493	2800
Schweiz	7.8	5.5	18	705	2’300
EU28	508	430	1100 ?	798	2’100
World	7000	4500	?	642	2?

Resulting Questions

- can we define a monetary value for health impacts by vehicle exhaust emissions?
- can we thus define a **monetary benefit** for measures like DPF to avoid this health impact?
- are these benefits higher or lower than the cost? In other words: is Benefit/Cost >1
- how compare DPF/GPF/DOC/SCR/SDPF/PFF
- who pays for cost and who receives benefits ?

DEFINITIONS used here

Specific Cost [€/kW]

Permits to compare cost for different size engines, different applications, influence of production volume an design but does not mirror the effectiveness nor benefits

Cost-Effectiveness [€/kg soot]

Permits to compare entirely different measures (open/closed filters) with respect to cost required to reach a certain physical effect – permits to predict how much money will be required to reach for a certain target but does not tell whether the society is gaining or losing money.

Benefit/Cost-Ratio [€/€]

Now also benefits are expressed in monetary units, which allows to clearly show whether the society is gaining or losing money when introducing a certain measure to improve public health environment conditions – the only valid final argument

Different social «Stakeholders» have different viewpoints

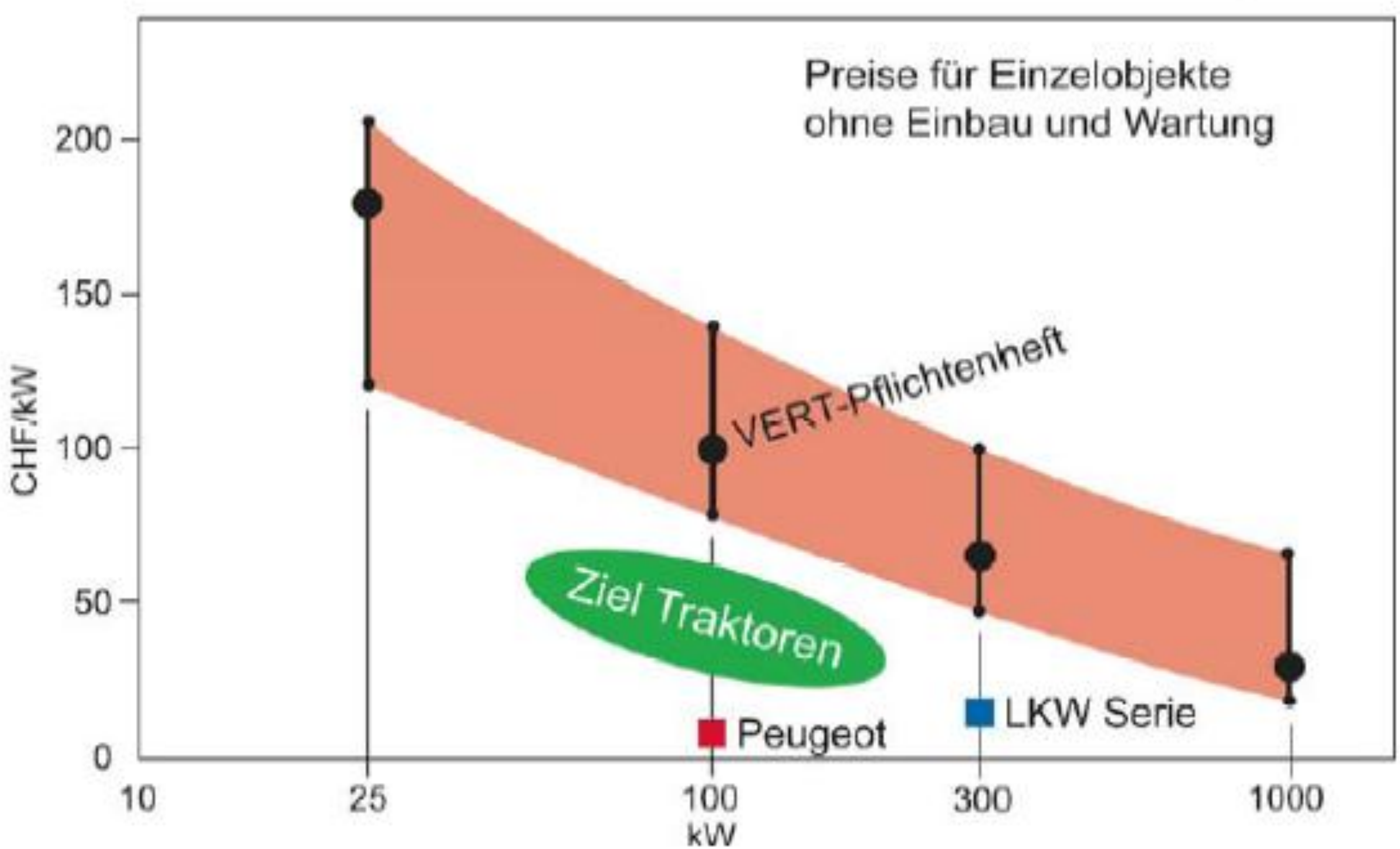
- The vehicle owner
- People getting sick from high air pollution
- Children suffering already unborn
- The Government
- The Global Climate
- Nature – flora and fauna
- The Society of a State and of the Globe

FOR THE OWNER of a vehicle the implementation of a DPF has no direct commercial advantage *„nothing but a Cost Factor“*

- Purchase price
- Installation cost
- Maintenance involved
- Backpressure may reduce fuel economy
- Warranty for the engine may be refused
- Additional safety and dependebility aspects ?

Specific Cost €/kW

Sales Price Statistics for Retrofit in Switzerland 2005

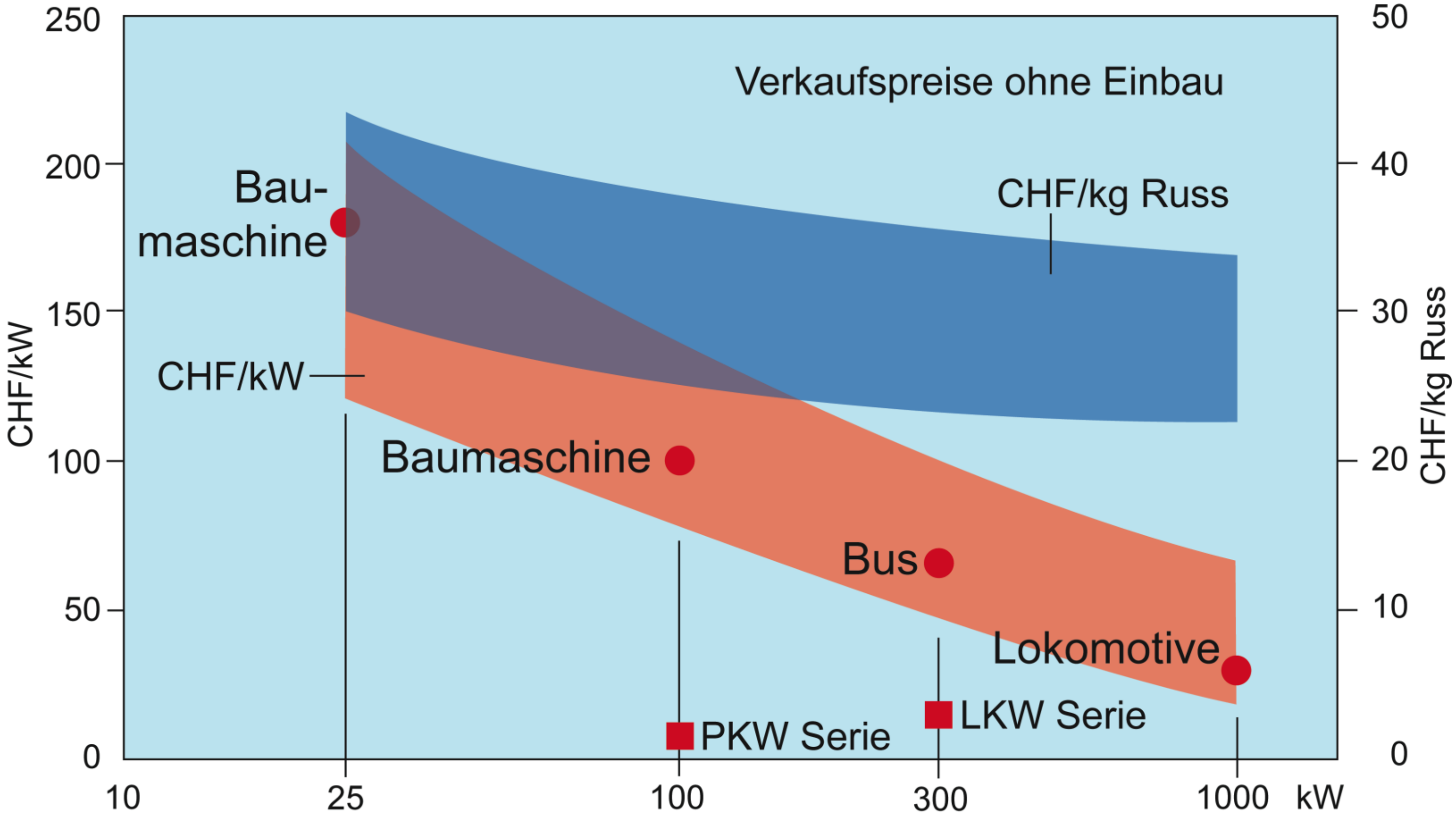


Cost - Effectiveness

is overall Cost of a Retrofit Measure compared to the Effect – which is the Mass of not-emitted Soot due to the application of this Measure

[€] / kg Soot

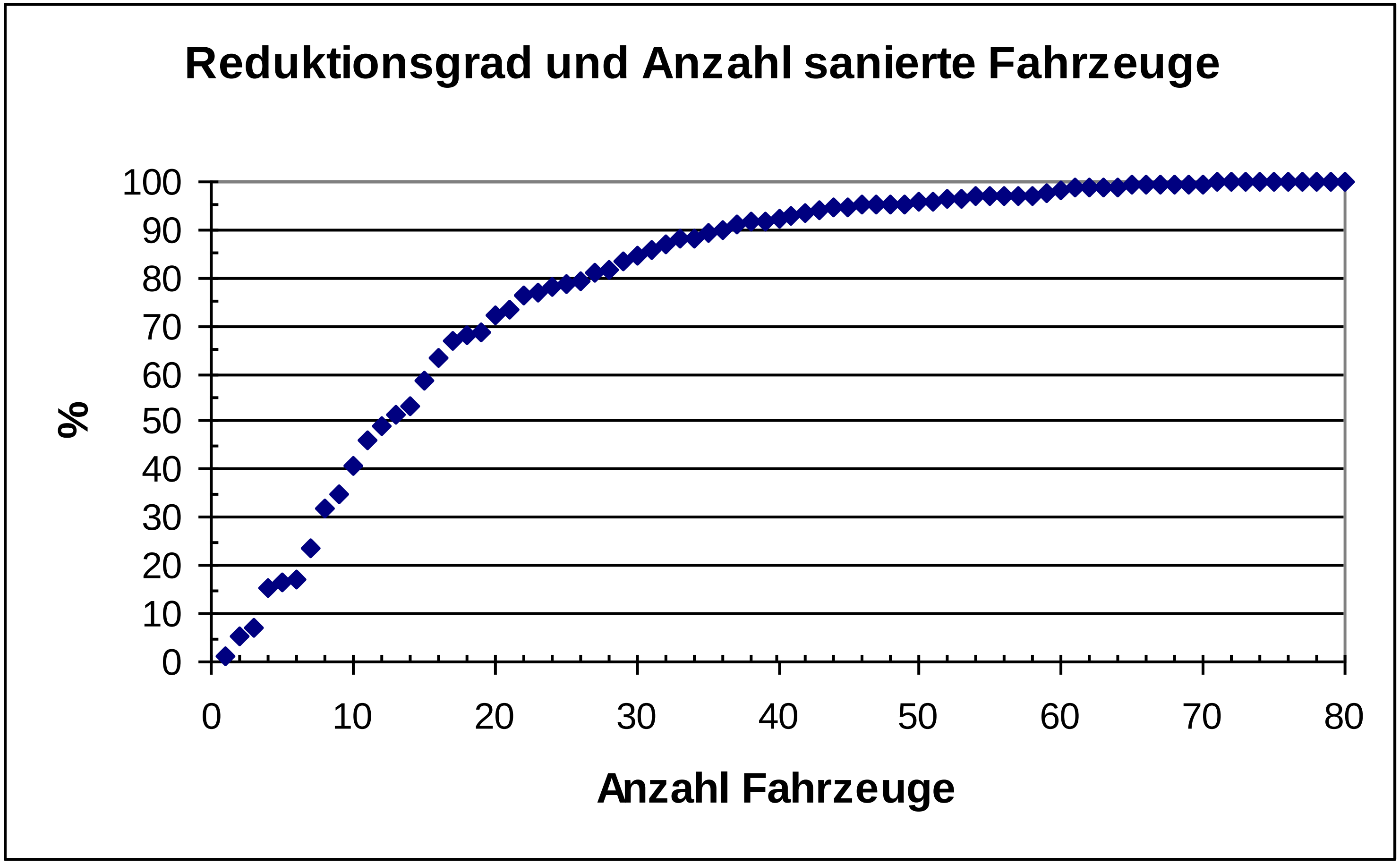
Cost-Effectiveness €/kg soot
for VERT-certified full flow filters at the same operation conditions



Calculate Cost Effectiveness €/kg soot for a whole Vehicle Fleet

Fahrzeug-, Geräteart	Motor-leistung	Euro-Norm	Jg.	Rest-Lebensdauer	Ersatz gemäss Mehr-jahres-planung	Betriebsstunden oder km jährlich	Emissions-Faktor	Russ-Menge gesamt	Kosten/ Nutzen	Kosten
	KW						g/kWh	kg	Fr/kg	Fr
Kehrmaschine	100	D 00	2001	6	2012	1'617.00	0.70	339.57	20.32	6900
Schwemmwagen	63	D 00	2002	9	2015	1'292.75	0.80	293.20	23.53	6900
Kleintraktor	25	D02	2006	13	2019	1'221.00	0.80	158.73	23.94	3800
Kleintraktor	18	D 00	2002	7	2013	780.45	2.50	122.92	30.91	3800
Kleintraktor	22.2	F 01	2005	11	2017	1'149.00	0.80	112.23	33.86	3800
Transporter	45	1	1993	1	**2007**	455.00	0.40	4.10	927.96	3800
Transporter	34	1	1994	2	**2008**	291.25	0.40	3.96	959.35	3800
Walze	18	D 00	1998	8	2014	25.00	2.50	4.50	1'133.33	5100
Kompressor	32.5		1992	2	**2008**	47.00	2.10	3.21	1'184.63	3800
Lieferwagen	66	3	2002	9	2015	107.00	0.10	3.18	1'604.83	5100
Walze	**10**	D 00	1985	6	2012	30.75	3.00	2.77	1'770.55	4900
Walze	**10**	D 00	1984	6	2012	19.00	3.00	1.71	2'865.50	4900
Raupenbagger	**13.3**		2005	12	2018	6.50	2.50	1.30	2'930.40	3800
Walze	**3.6**	D 00	1997	7	2013	45.25	3.00	1.71	3'975.56	6800

Soot Reduction by Selection of Vehicles according to Cost-Effectiveness



FOR PEOPLE in Street Canyons and drivers – exposed to exhaust gas DPF/GPF provides a Health Benefit

Switzerland, year 2000: Health Effects are very large:

• **Mortality due to traffic related air pollutions**	**3’700**
• Mortality due to traffic accidents	600
• Mortality due to smoking	4’000
• **Hospitalization days**	**15’700**
• **Asthma attacks**	**41’100**
• **Bronchitis in children**	**39’000**
• **Days with restricted activity**	**1'773’800**

In 2015: Mortality increased to 5’500 per year (EU agency)

Respective Health Cost 18 Mia – 25% of federal budget

THE Government:

1. **Emission is a health concern and we must protect our citizen**
2. **Emission creates high health cost which we should avoid**
3. **Diesel Particle Emission is carcinogenic , (WHO 2012) and has no “no-effect” level**

→ Health impact must therefore be minimized

→ Best Available Technology BAT required

→ **But Cost must be lower than Benefit**

Cost of DPF must be lower than Monetary Health Benefit due to use of DPF

Benefit / Cost

For the Society Benefits must be quantified in Monetary Terms and compared to Cost in order to decide whether a Measure is economic and therefore justified or not

Benefit / Cost – Factor

[€] / [€]

a dimensionless factor → comparing apples to apples

To calculate the monetary value of the health benefit needs a *Multi-Discipline Approach*

(Prof.Amir Hakami, Tehran AQM 2016)

1. **Epidemiology must provide the information on mortality/morbidity**

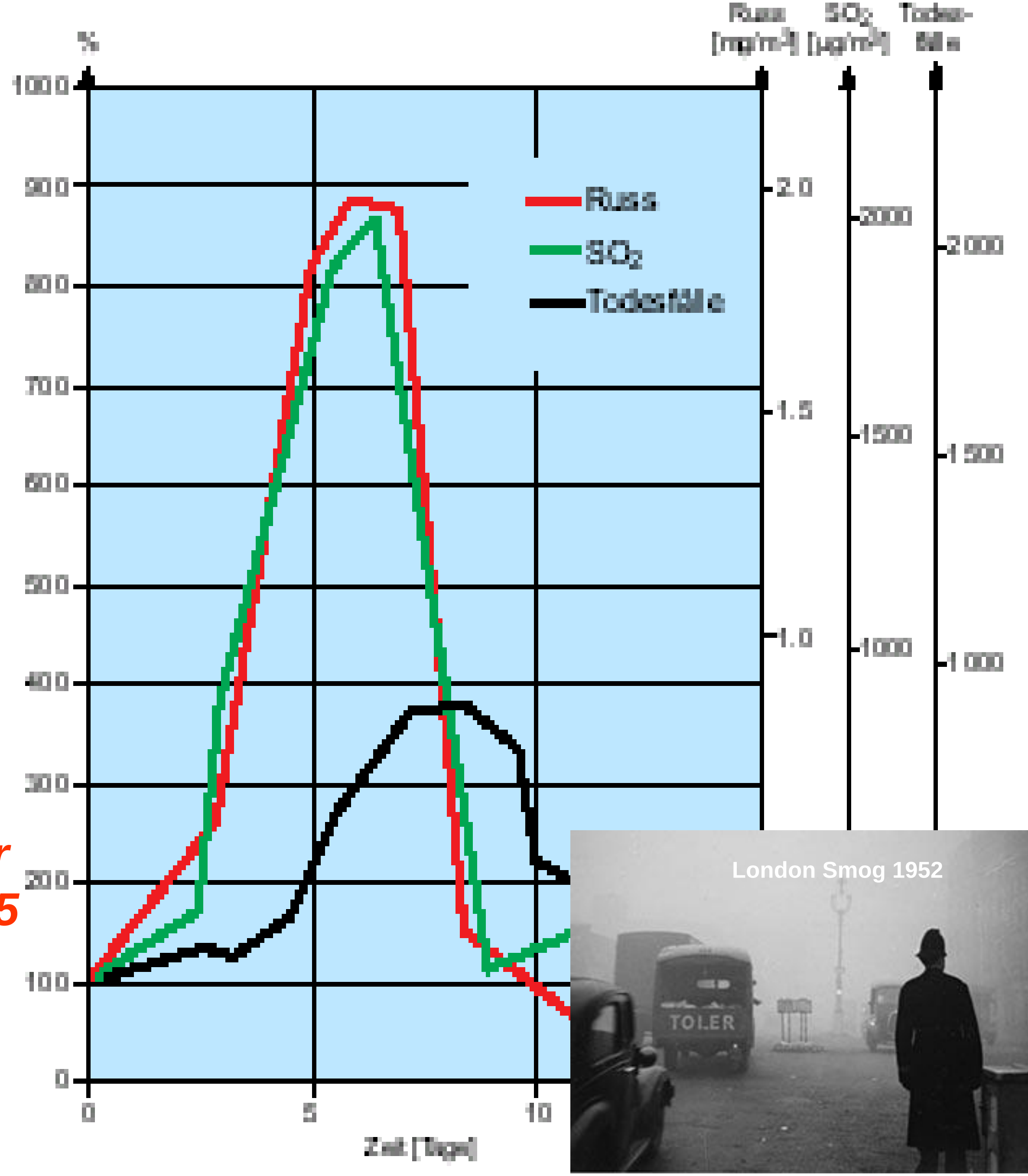
2. **Economy must calculate the associated cost for the society**

London Smog 1952

during one week died
6'000 persons
6'000 more next month

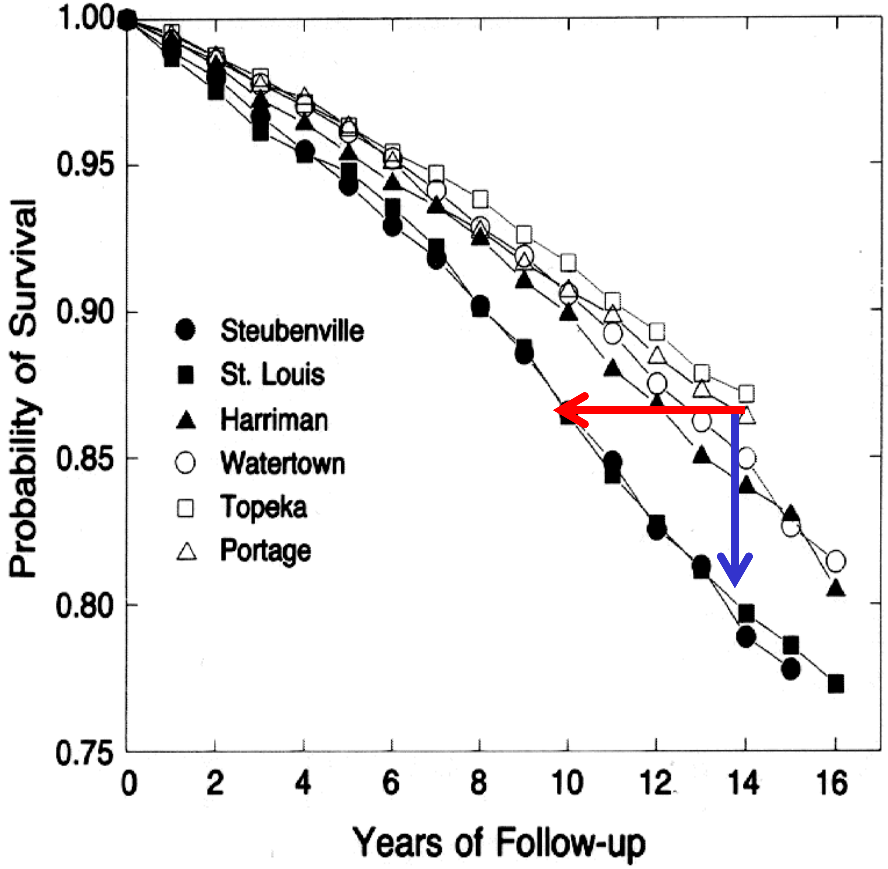
London had replaced the electric tram by Diesel buses 6 month before

The famous medical doctor Sir Percival Pott found 1775 that soot is the reason for carcinoms in chimney sweeps



1973/93 Six Cities Mortality Study

- Random sample of 8411 adults in six cities
  - Dirty: *Steubenville, OH & St. Louis, MI*
  - Moderate: *Watertown, MA & Harriman, TN*
  - Clean: *Topeka, KS & Portage, WI*
- Enrolled 1974-77
- 14-16 years of mortality follow-up



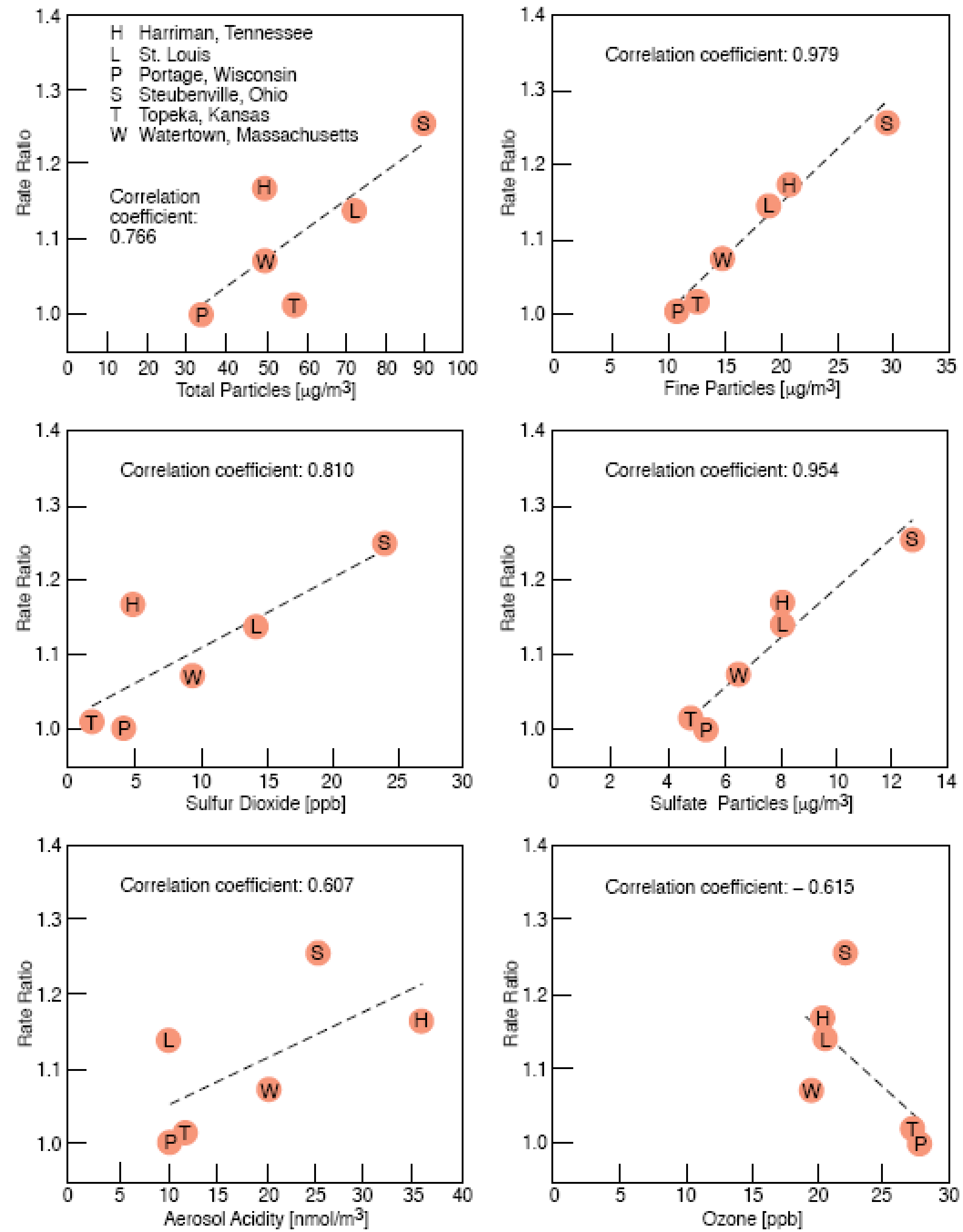
Dockery et al, NEJM 1993;329:1753

Mortality due to Particles

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

Correlation with fine particles only

(Quelle: Dockery
NEJM 1993)



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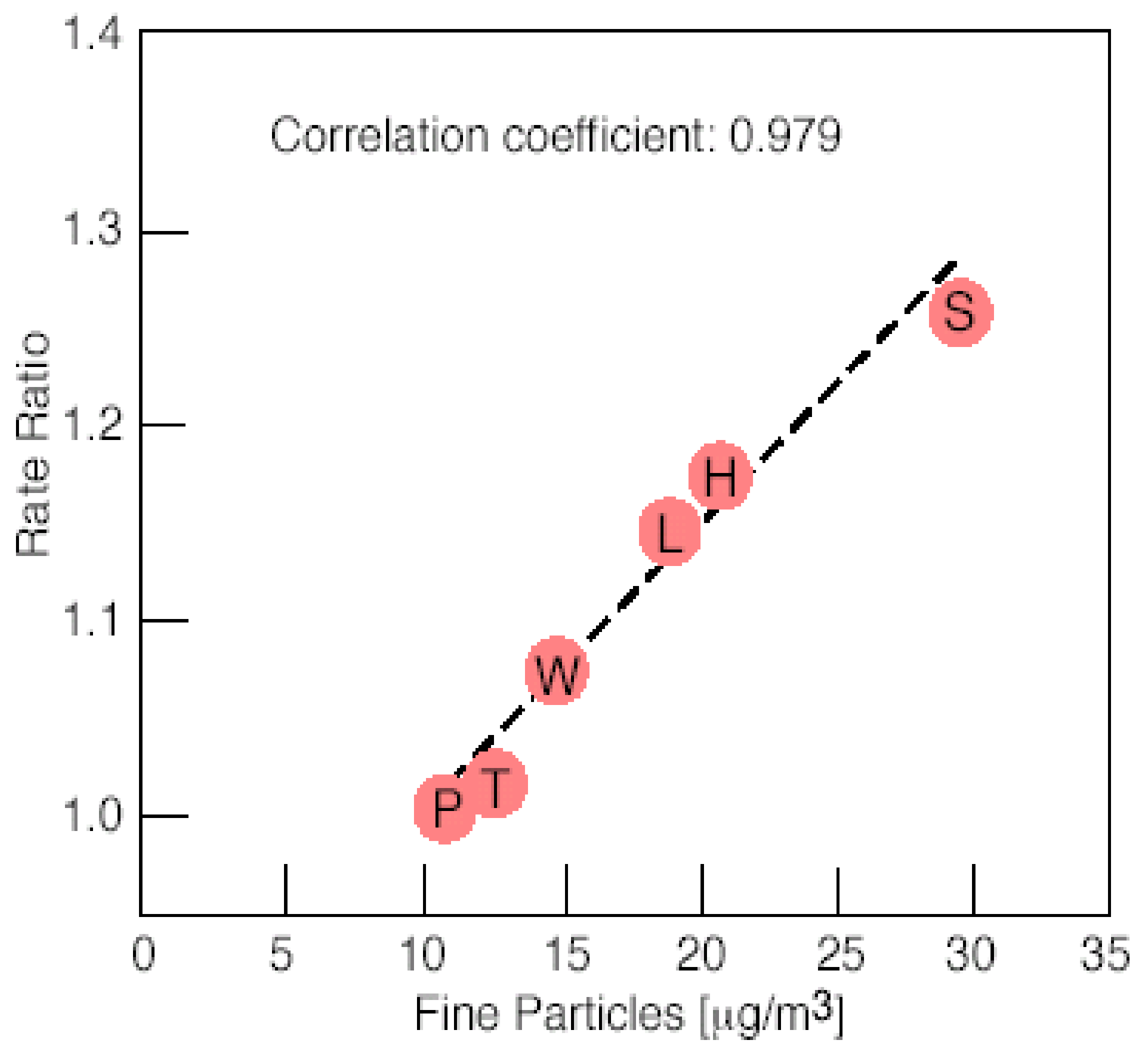
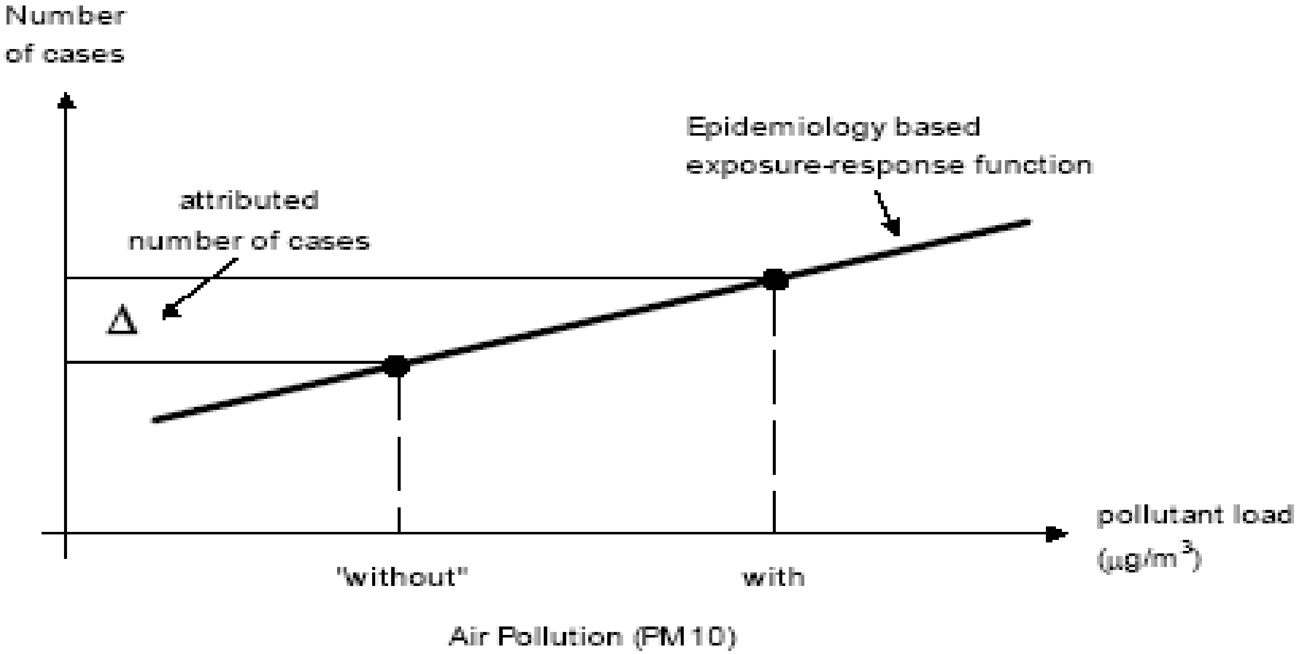


Risk for premature death is proportinal to concentration increase of UFP → **the linear dose-effect relationship**

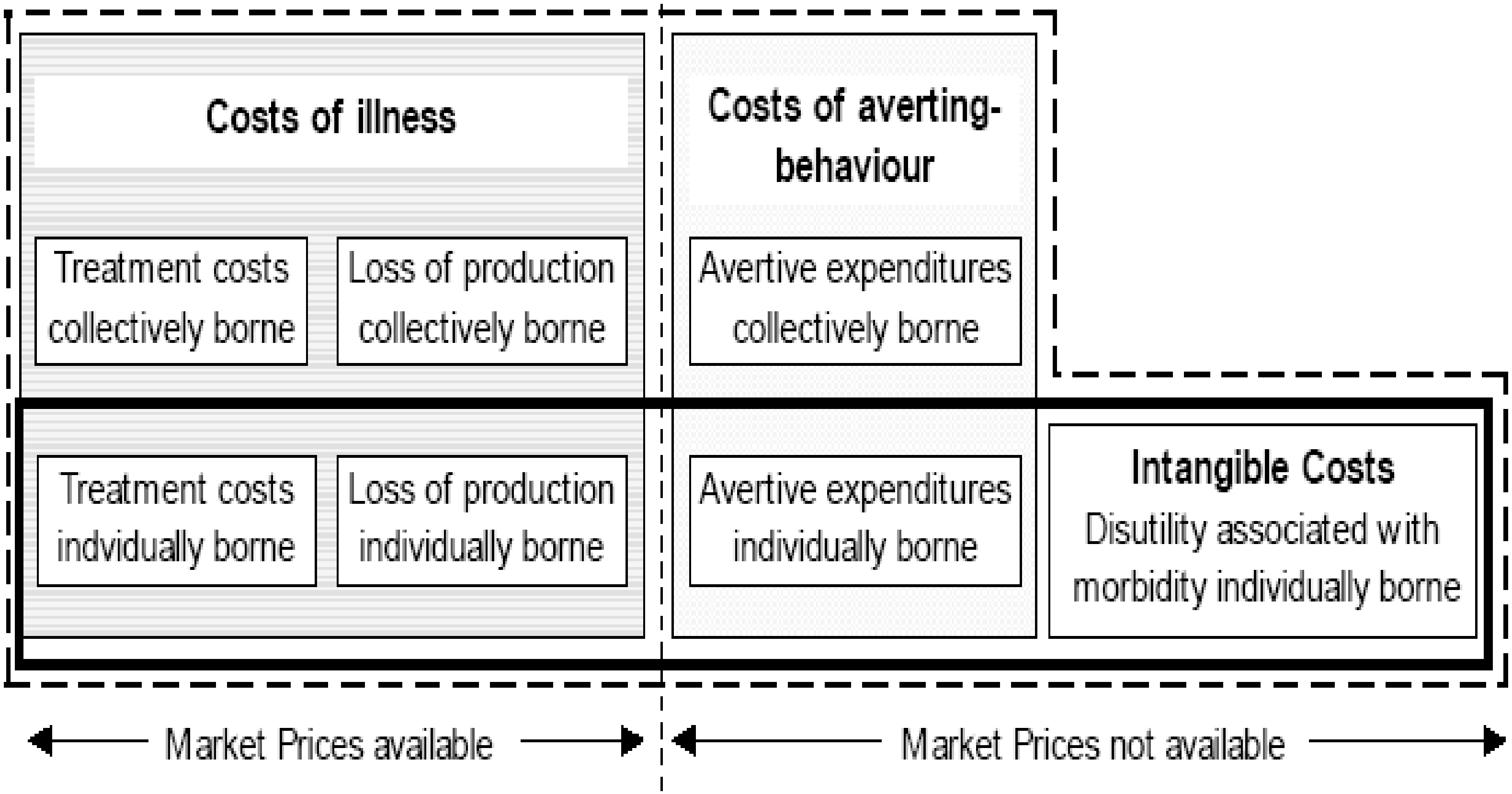
Epidemiologic Model for Health Cost „Dose/Effect Proportionality“

„Dose“ is PM10 – Concentration

„Effect“ can be mortality, mobidity, hospital accesses etc.



Health Cost Elements



How to convert Public Health Effects into Monetary Terms ?

WHO and many National Health Institutions have investigated the multitude of so-called “external cost elements” like hospital cost, medication, lost working time, lateral cost, tax loss etc. in function of ambient air pollution and established dose-effect relationships.

They have statistically linked these cost to ambient air pollution to individual pollution parameters like Ozon, CO or PM10 and evaluated the integrated monetary effects on population living in megacities, cities or countryside.

2015 OECD Ecomonic Cost of health Impact

Table 1.3. Premature deaths from air pollution (APMP, HAP, and APMP + HAP) per country in the WHO European Region, 2005 and 2010

	APMP		HAP		APMP + HAP	
	2005	2010	2005	2010	2005	2010
Albania	1 643	1 512	2 740	2 620	4 382	4 132
Andorra	29	31	–	–	29	31
Armenia	2 590	2 607	[illegible]	[illegible]	[illegible]	[illegible]
Austria	3 642	3 122	[illegible]	[illegible]	[illegible]	[illegible]
Azerbaijan	5 146	5 131	[illegible]	[illegible]	[illegible]	[illegible]
Belarus	8 400	8 236	[illegible]	[illegible]	[illegible]	[illegible]
Belgium	6 169	5 663	[illegible]	[illegible]	[illegible]	[illegible]
Bosnia and Herzegovina	2 171	2 016	[illegible]	[illegible]	[illegible]	[illegible]
Bulgaria	11 269	9 492	[illegible]	[illegible]	[illegible]	[illegible]
Croatia	3 692	3 057	[illegible]	[illegible]	[illegible]	[illegible]
Cyprus	323	299	[illegible]	[illegible]	[illegible]	[illegible]
Czech Republic	8 731	7 028	[illegible]	[illegible]	[illegible]	[illegible]
Denmark	1 833	1 818	[illegible]	[illegible]	[illegible]	[illegible]

Table 2.4. Economic cost of premature deaths from air pollution (APMP and APMP + HAP) per country in the WHO European Region, 2005 and 2010

	Economic cost of premature deaths from APMP US$ (millions)		Economic cost of premature deaths from APMP + HAP US$ (millions)	
	2005[1]	2010[2]	2005[1]	2010[2]
Albania	1 358	1 673	3 622	4 572
Armenia	1 599	2 160	3 398	3 690
Austria	11 957	11 457	11 957	11 457
Azerbaijan	3 377	7 415	5 893	10 042
Belarus	9 296	16 534	12 900	19 865
Belgium	19 559	19 842	19 559	19 842
Bosnia and Herzegovina	1 838	2 146	5 920	7 228
Bulgaria	13 803	16 788	2 182	32 091
Croatia	6 465	6 316	9 844	9 035
Cyprus	819	857	819	857
Czech Republic	19 862	19 321	22 834	20 901
Denmark	5 955	6 283	5 955	6 283

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	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4'500
Finland	432,600	139,400	36,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3'500
France	438,600	141,200	87,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9'900
Germany	430,300	138,800	83,900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10'900
Greece	338,600	109,100	47,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5'800
Hungary	288,900	93,000	74,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9'100
Ireland	537,200	173,400	56,200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5'400
Italy	397,400	128,400	72,300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8'700
Latvia	245,300	78,900	45,600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5'000
Lithuania	266,300	86,500	53,300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5'700
Luxembourg	877,100	282,400	125,000	350,800	112,900	50,000	12'700	2'400	10'300

Switzerland 2002
500 €/kg PM2.5

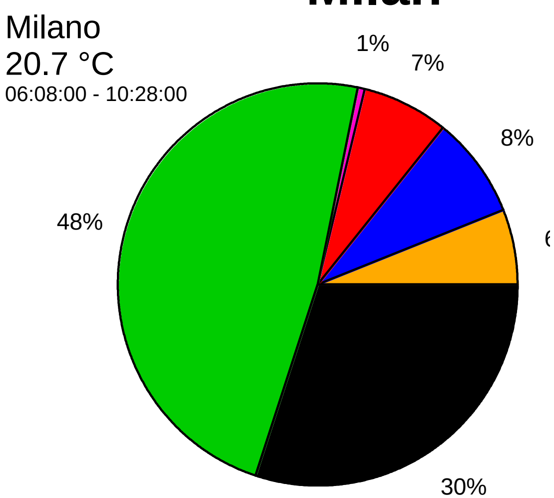
Switzerland	498,700	160,500	82,400
Poland	248,900	79,900	74,700

What is PM2.5 - Mass [mg/m3] of what ?

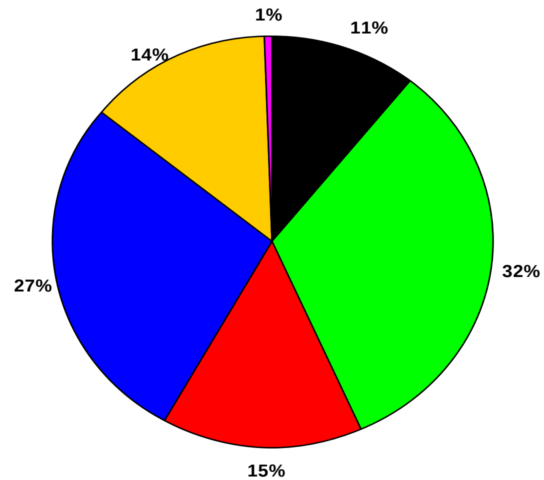
mix of unspecified substances – which is the toxic one ?

what represents the engine emission ?

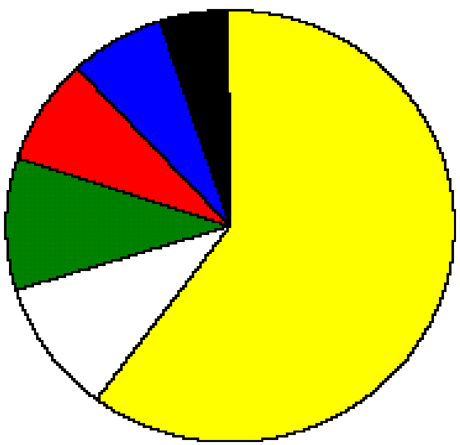
Milan



Zuerich



Hawai (?)



PM2.5 [µg/m^3] identical Mass

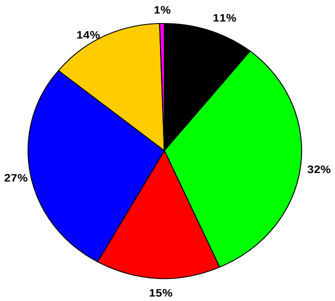
But these 3 situations can definitely not represent same air pollution = toxicity

Black Carbon
Organic mass
Nitrate
Sulfate
Ammonium
Chloride

Health Effect for PNC/PM 2.5

Short Term Cardiovacular Mortality (CVD)

comparing mass (PNC) to mass (PM2.5)



Study	City, Year		CVD -PNC per **10 µg/m3**	CVD - PM 2.5 **per 10 µg/m3**
Atkinson	London 2010		6.8 %	0 - 0.5 %
Stolzel	Erfurt 2007		9.9 %	0 - 1.5 %
Breitner	Beijing 2011		36.5 %	NA
Branis	Prag 2010		34.1 %	0 - 0.4
Forastiere	Rom, 2006		8.4 %	0.1- 3.1 %
Kettunen	Helsinki 2012		52.7 %	2.1 - 23 %
Average			24.7 %	3.1 %

Assumption: Particles 70 nm, Density:1, mass 3.2 x 10^{-16} g/P / 10'000 P/cm3 = 3.2 µg/m3

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Pollutant	$PM_{2.5}$ (exhaust)			PM_{10} (non-exhaust)			NO_x	NMVOC	SO_2
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Source	HEATCO	*UBA/ HEATCO	HEATCO	*UBA/ HEATCO	*UBA/ HEATCO	*UBA/ HEATCO	NEEDS	NEEDS	NEEDS
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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
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Estonia	261,700	85,000	44,200	[illegible]	[illegible]	[illegible]	[illegible]	600	4'500
Finland	432,600	139,400	36,100	[illegible]	[illegible]	[illegible]	[illegible]	600	3'500
France	438,600	141,200	87,700	[illegible]	[illegible]	[illegible]	[illegible]	1'400	9'900
Germany	430,300	138,800	83,900	[illegible]	[illegible]	[illegible]	[illegible]	1'400	10'900
Greece	338,600	109,100	47,700	[illegible]	[illegible]	[illegible]	[illegible]	600	5'800
Hungary	288,900	93,000	74,100	[illegible]	[illegible]	[illegible]	[illegible]	1'000	9'100
Ireland	537,200	173,400	56,200	[illegible]	[illegible]	[illegible]	[illegible]	1'100	5'400
Italy	397,400	128,400	72,300	[illegible]	[illegible]	[illegible]	[illegible]	1'100	8'700
Latvia	245,300	78,900	45,600	[illegible]	[illegible]	[illegible]	[illegible]	700	5'000
Lithuania	266,300	86,500	53,300	[illegible]	[illegible]	[illegible]	[illegible]	800	5'700
Luxembourg	877,100	282,400	125,000	350,800	112,900	50,000	12'700	2'400	10'300

Switzerland
1200-
2500 €/kg Soot

Switzerland	498,700	160,500	82,400
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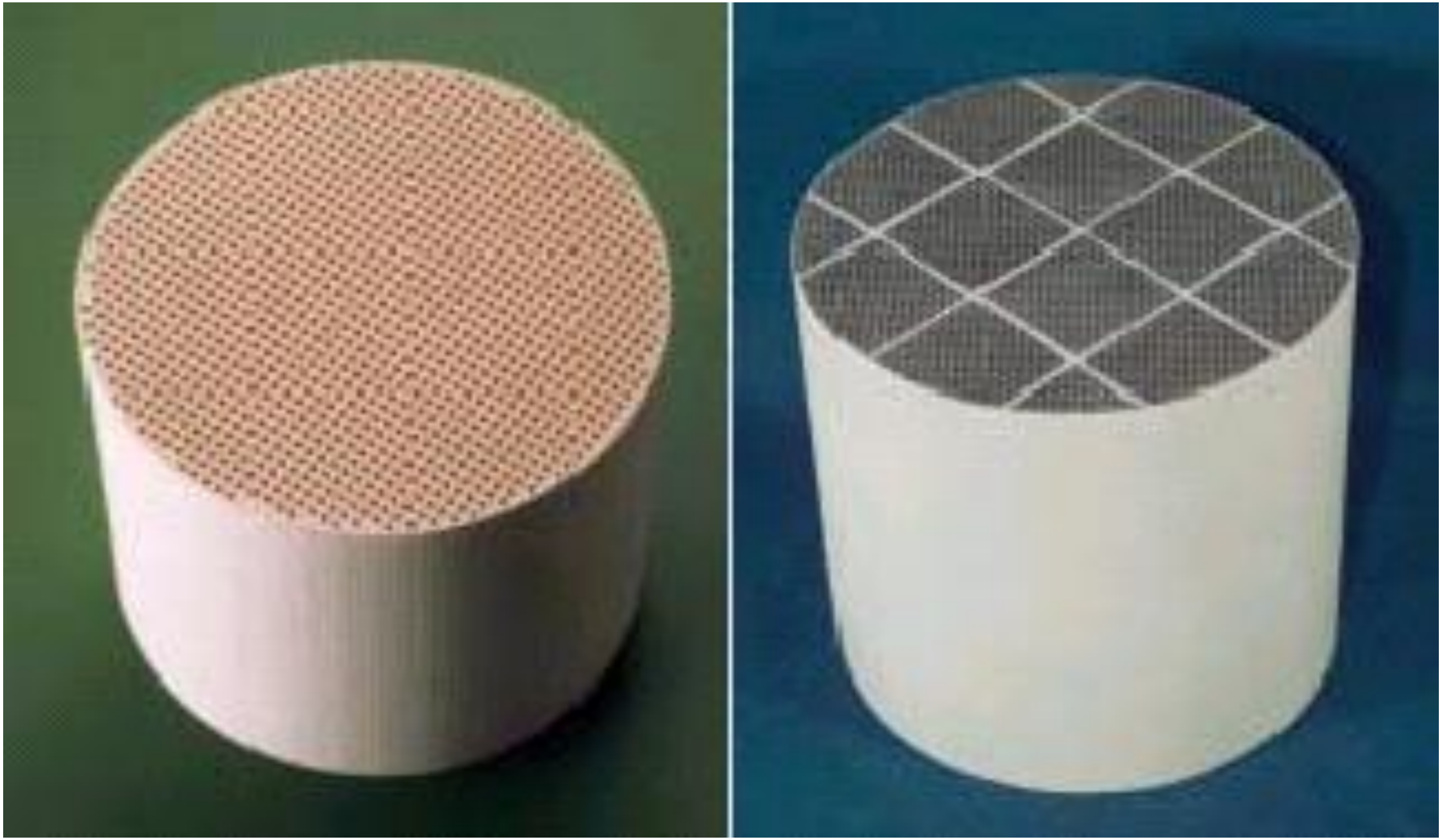
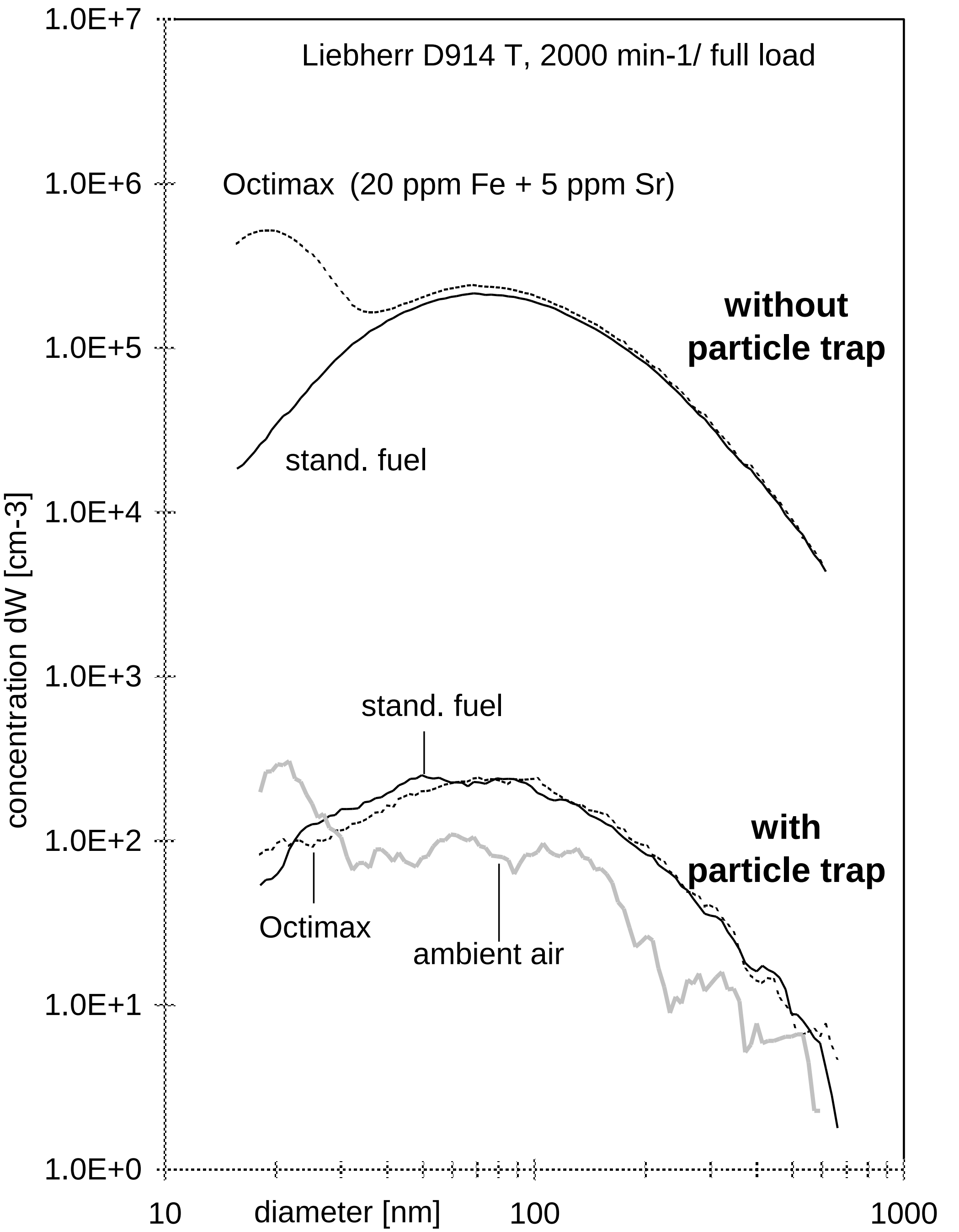
Reliable Solutions are available

in > 100 millions are today in use



Particle Elimination

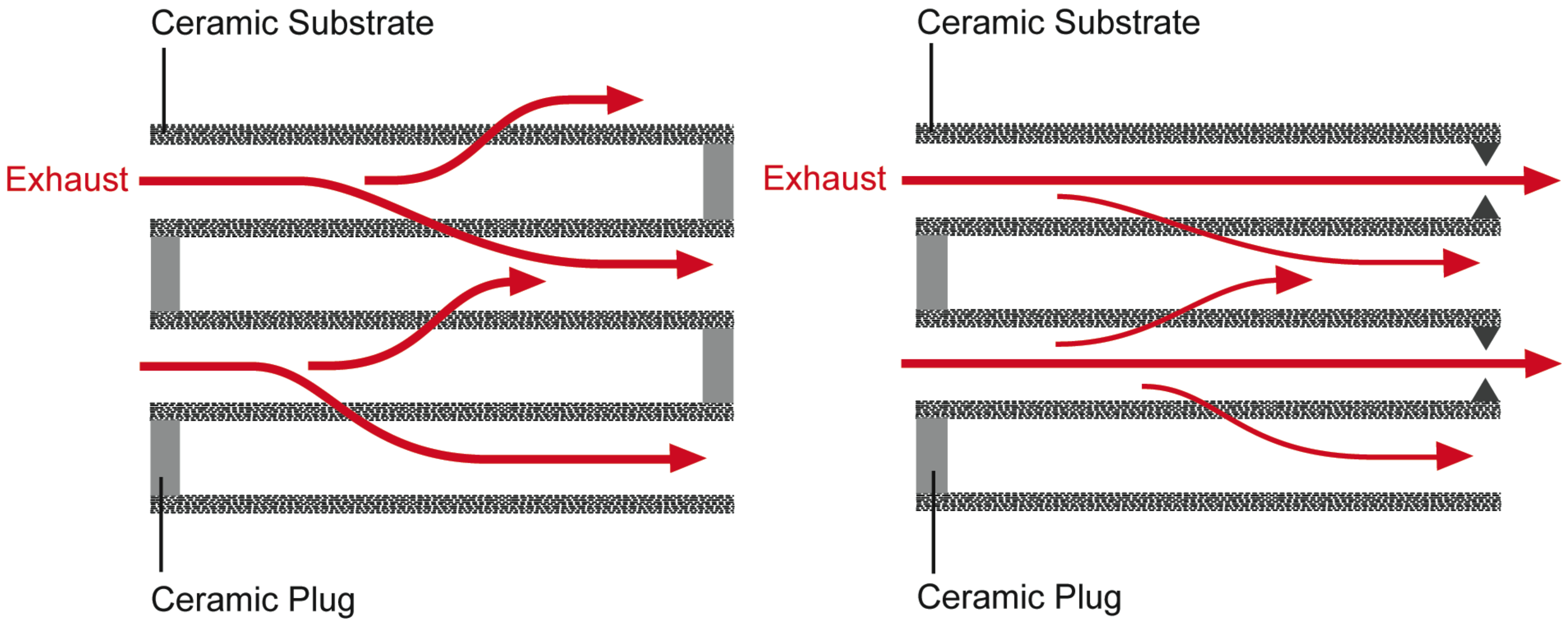
with CORNING-Filter and FBC



Are Alternatives available ?

Full Flow versus Partial Flow Filters

(„*closed*“ versus „*open*“)



Full Flow Filter and Partial Flow „Filter" comp. by Cost-Effectiveness €/kg Soot

	HDV+FFF	LDV+PFF
PM-Emission EURO III/3	0.1 g/kWh	0.05 g/km
Mileage	1000 hrs/y	10'000 km/y
Average Performance [kW]	100	10
PM Emission [kg/year]	10	0.5
Overall vehicle life [year]	15	10
Emission [kg/vehicle life]	150	5
Filter type	wall flow	partial flow
Filter efficiency [%]	99.9	20
Filter Cost [€]	8'000	750
Total prevented soot [kg/life]	150	1.0
Cost-Effectiveness [€/kg soot]	**53.3** [1)]	**750** [2)]

1) USA-EPA: 40-50 $/kg for offroad applications

2) UBA Wien (2009): Offroad 50-90 €/kg; LKW 90 €/kg; PKW offene Filter 200-643 €/kg

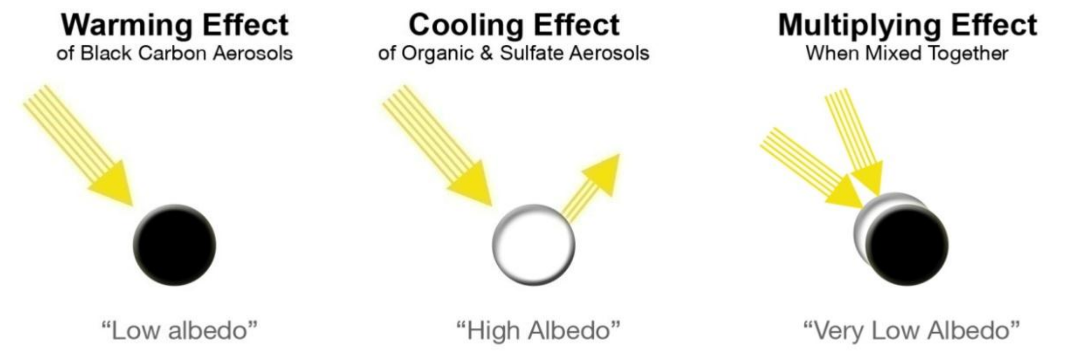
Diesel: Health Benefit for two typical retrofit DPF-Applications: *HDV+FFF versus LDV+PFF*

	HDV+FFF	**LDV+PFF**
PM-Emission (Euro III / 3)	0.1 g/kWh	0.05 g/km
Mileage	1000 hrs/yr	10'000 km/yr
Average Performance [kW]	100	10
PM Emission [kg/year]	10	0.5
Overall vehicle life [year]	15	10
Emission [kg/vehicle life]	150	5
Filter type	wall flow	partial flow
Filter efficiency [%]	99.9	20
Health Cost [€/kg Soot]	1’200	1’200.-
Total prevented soot [kg/life]	150	1.0
Health Benefit [€]	**180’000**	**1’200**

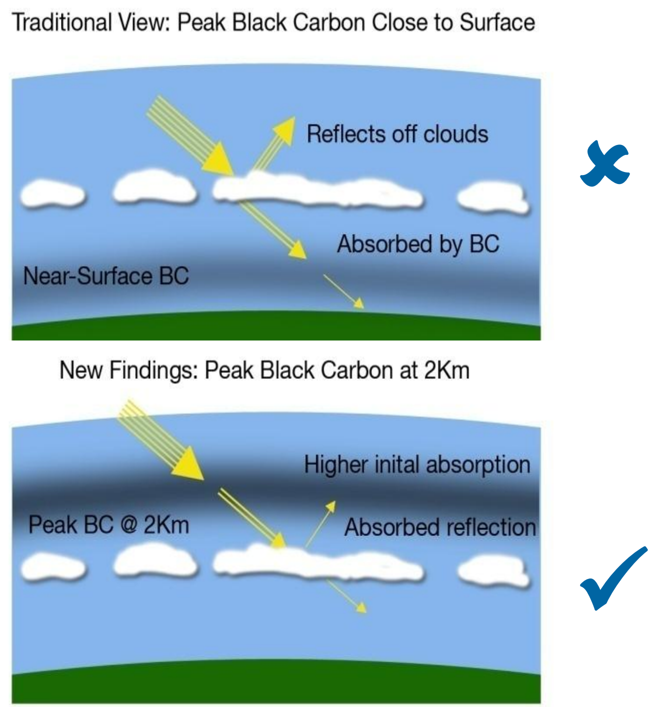
Health Benefit of DPF is about the investment for a vehicle

and we have a co-benefit
FOR GLOBAL SURVIVAL

since DPF can contribute to lower global warming by eliminating Black Carbon Particles

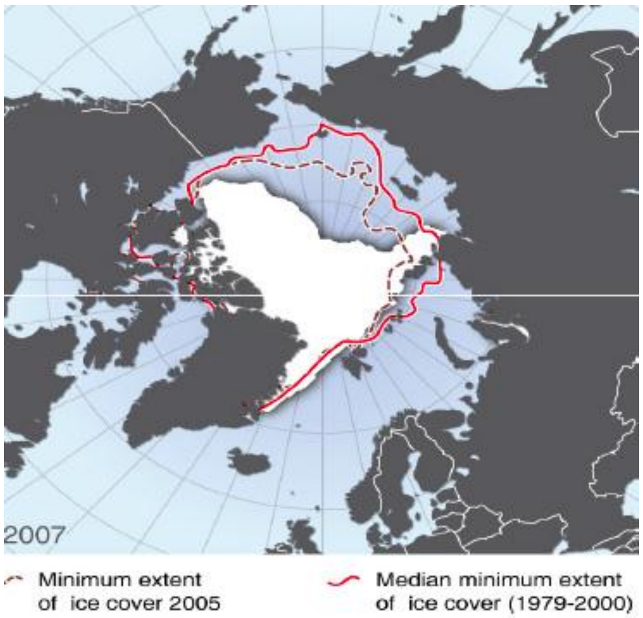


Higher in atmosphere



Science Daily, United Nations Environment Program Nov 2008

BC on snow decreases albedo, turning to water.. further lowering albedo



Source: UNEP/GRID Arendal & EPA

Journal of Geophysics Res.2007

Global Warming by BC-Particles

Jacobson 2002

360,000-840,000 : 1

Is the atmospheric warming effect

by 1 kg of BC particles compared to 1 kg of CO_2

120,000-280,000:1 for BC+OC to that of CO_2

→ However different residence times must be respected: 20 years for CO_2 and 1-2 month for BC which brings equivalence to about 1:2000

January and June 2009 M.Walsh

Table 1. Global Warming Potentials (GWP) drawn from the IPCC 4th Assessment Report

	GWP20	GWP100	GWP500
Black carbon	**1600**	**460**	**140**
Methane	72	25	7.6
Nitrous oxide	289	298	153
Sulfur oxides	-140	-40	-12
Organic carbon	-240	-69	-21
Carbon dioxide	1	1	1

Note: The methodology used for black carbon was also used for organic carbon and sulfur oxides. Values for black carbon, organic carbon and sulfur oxides were not published by the IPCC and are not official estimates.

Which €-Benefit associates the Society with Global Warming Reduction ?

Value of CO_2

- Trading CO_2 -Emissions (myclimate, atmosfair) costs 37-185 CHF per ton CO_2
- CO_2 –Tax today is 24-45 CHF per ton CO_2

→ Let's say: Value of CO_2–Reduction is 50 € per ton

BC / CO_2-GWP-Equivalent (BC = ultrafine black carbon particles)

- GWP of BC is 1'600 x higher than GWP of CO_2 for the same mass (kg)

→ Resulting Value of 1 kg BC-Reduction is 80 € (80'000 €/ton)

GW-Benefit [€] for the Society
2 typical Retrofit Applications

	HDV+FFF	LDV+PFF
PM-Emission (Euro III / 3)	0.1 g/kWh	0.05 g/km
Mileage	1000 hrs/y	10'000 km/y
Average Performance [kW]	100	10
PM Emission [kg/year]	10	0.5
Overall vehicle life [year]	15	10
Emission [kg/vehicle life]	150	5
Filter type	wall flow	partial flow
Filter efficiency [%]	99.9	20
BC GW benefit [€/kg soot]	80	80
Total prevented soot [kg/life]	150	1.0
Global Warming Benefit [EUR]	**12’000**	**80**

3 Petrol Engines tested with GPF

Fahrzeug	**Aprilia Leonardo 125**	**Audi A3 2.0 TFSI**	**Renault 18 TX**
Baujahr	2004	2007	1985
Motor	Viertaktmotor, Wassergekühlt	Viertaktmotor, Wassergekühlt	Viertaktmotor, Wassergekühlt
Hubraum	125 ccm	1984 ccm	2164 ccm
Zylinder	1	4	4
Gemischaufbereitung	Vergaser	Direkteinspritzung	Saugrohreinspritzung
Kraftstoff	Benzin bleifrei	Benzin bleifrei	Benzin bleifrei



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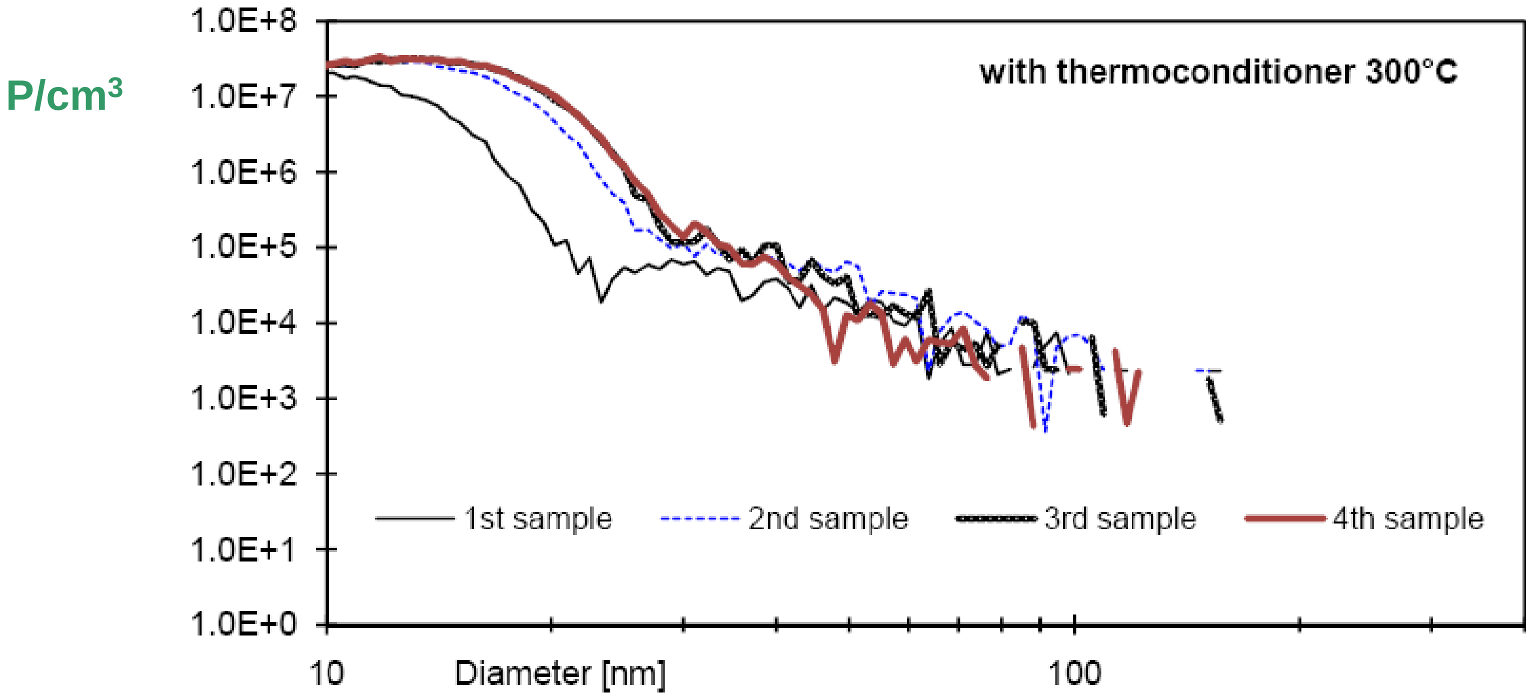
Health Benefit of Diesel LDV versus Gasoline based on soot particle mass PM

	Diesel+FFF	Gasoline+FFF
PM-Emission (Euro 3 or in use)	100 mg/km	10 mg/km
Mileage per anno	10'000 km pa	10'000 km pa
Average Performance [kW]	10	10
PM Emission [kg/year]	1.0	0.1
Overall vehicle life [year]	10	10
Emission [kg/vehicle life]	10	1
Filter type	wall flow	wall flow
Filter efficiency [%]	99.9	99.9
Health Cost [€/kg soot]	1’200	1’200
Total prevented soot [kg/life]	10	1.0
Health Benefit [€]	**12’000**	**1’200**

Honda 450 Motorbike (10'000 km)

Size Distribution at Idle (upper) and 50 km/h (lower)

as many as Diesel but smaller



Particle Emission of ICE

Diesel

Sootpeak: 80 nm; 10^6

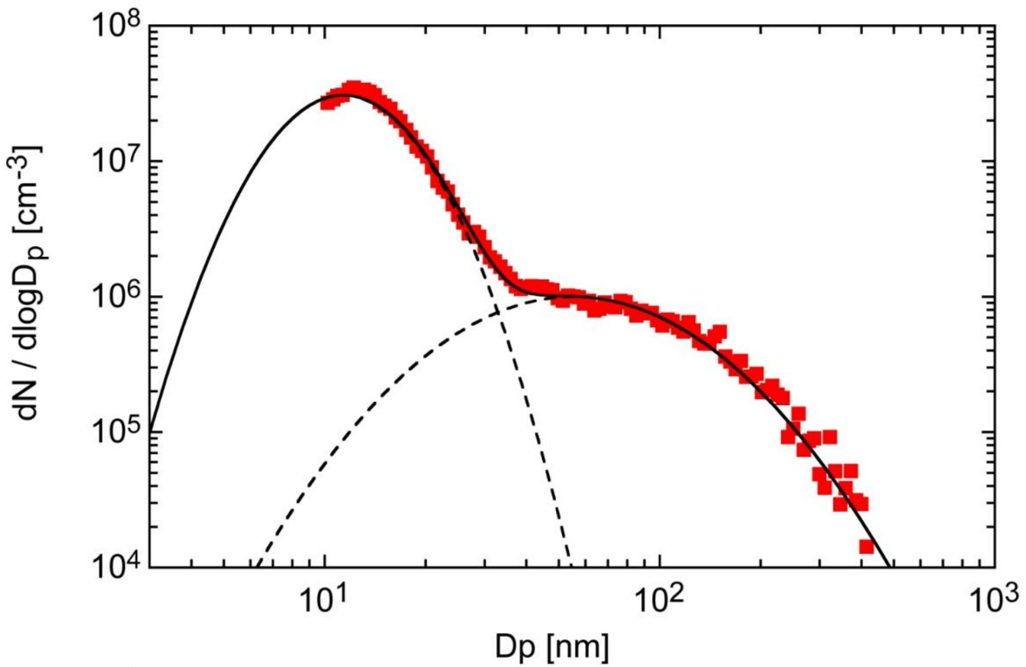
Ashpeak: 10 nm; 10^7

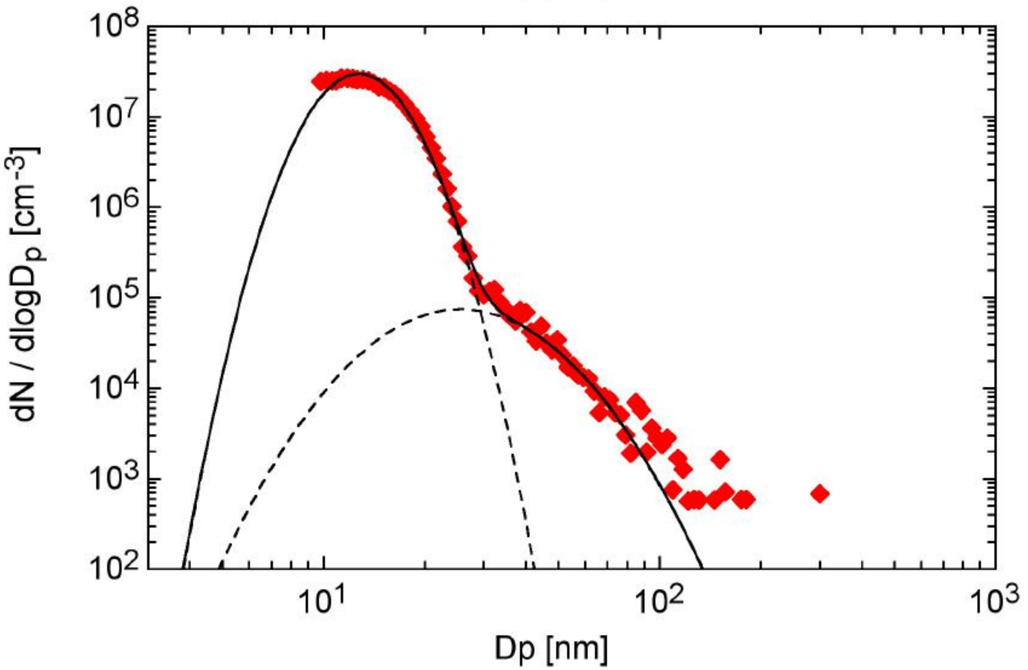
Petrol

Sootpeak: 40 nm; 10^5

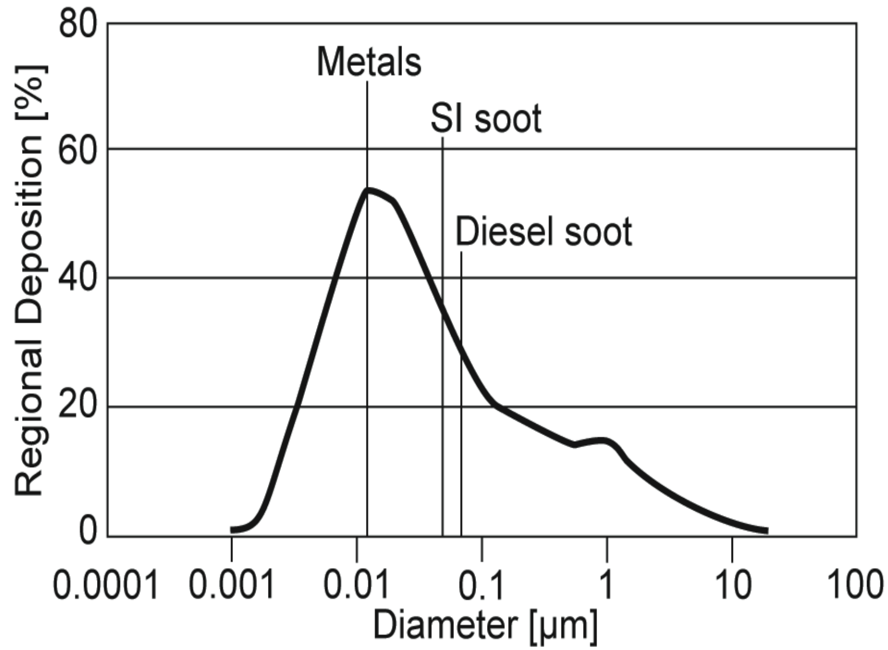
Ashpeak: 10 nm; 10^7

Soot and Ash Peaks

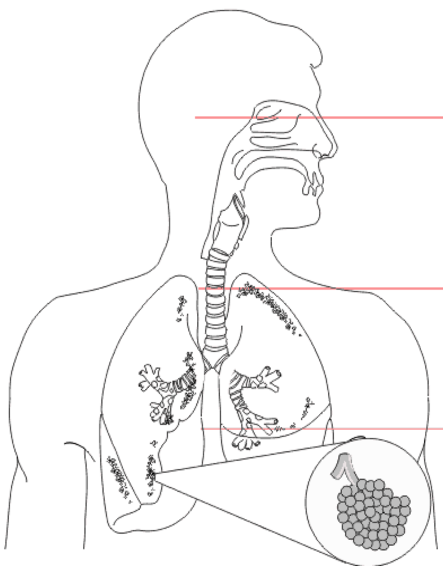




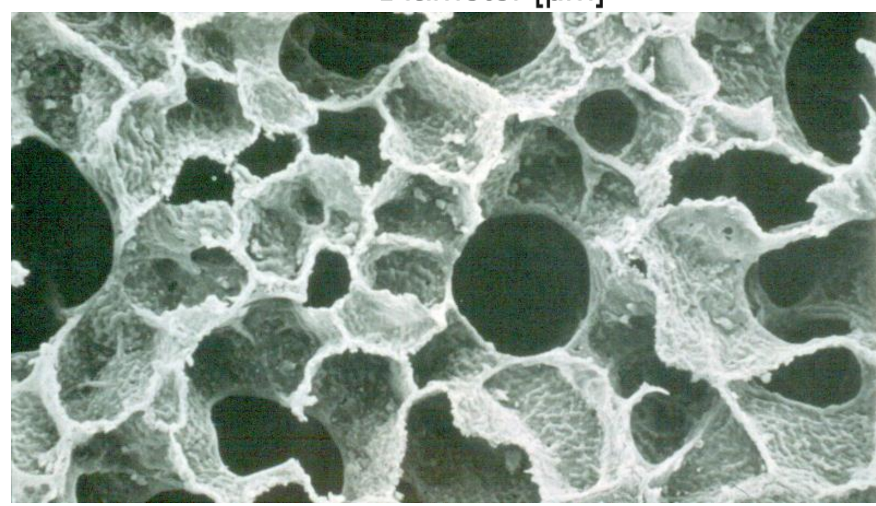
Why is particle size decisive for health risk considerations



Ablagerungen von Feinpartikeln im menschlichen Atemtrakt



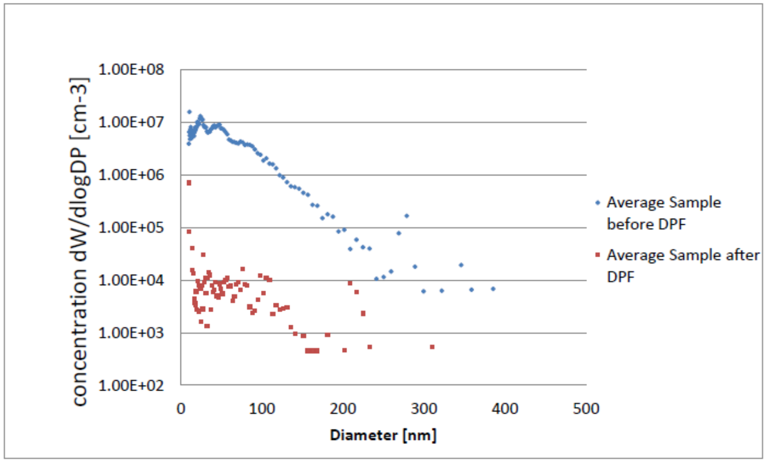
Angriffsorte	Luftschadstoffe
Nasen-Rachenraum	5-10 µm
Luftröhre	3-5 µm
Bronchien	2-3 µm
Bronchiolen	1-2 µm
Alveolen (Lungen-bläschen)	0.1-1 µm

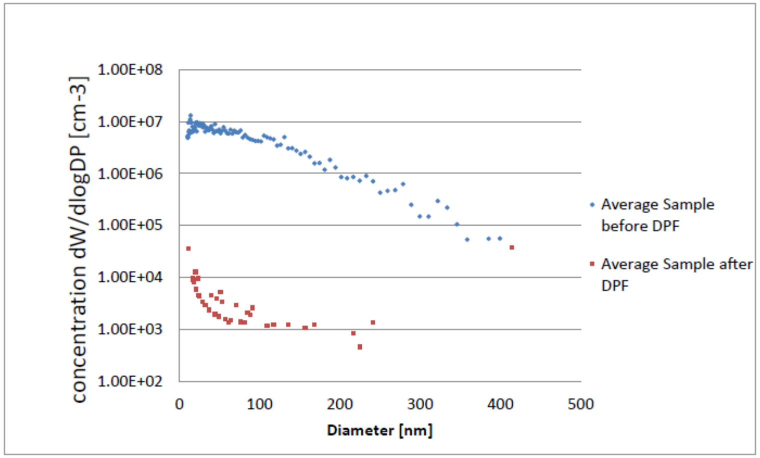


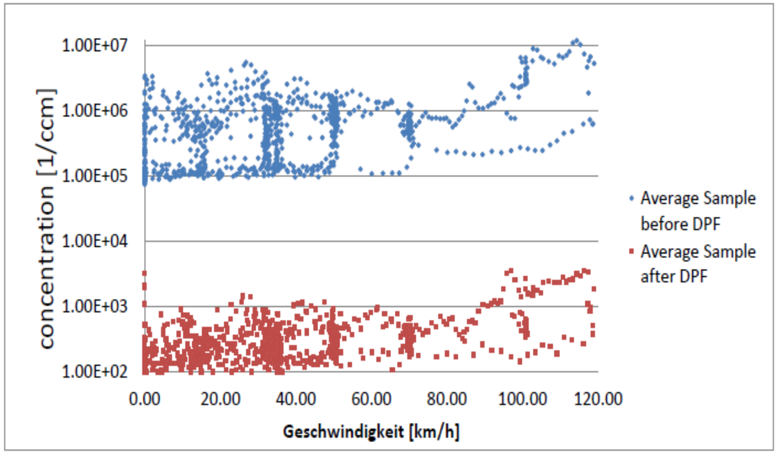
Ultrathin alveoli tissue permits penetration of gases and UFP into blood vessels

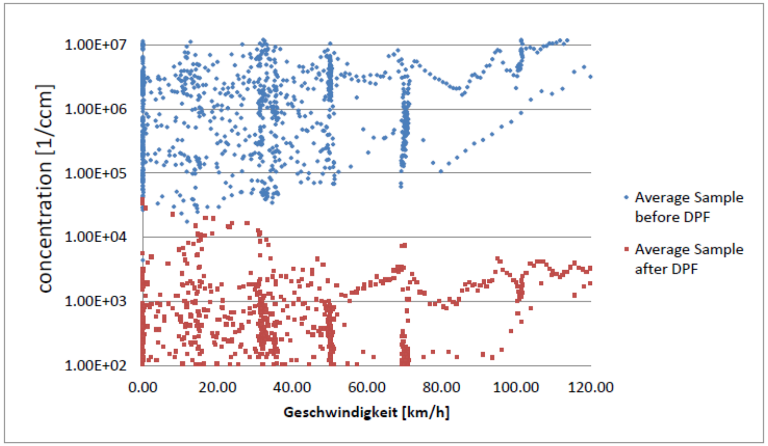
PN-Emission Petrol and GPF-Effects

Renault 18 PI (left) and Audi A3 DI (right) with GPF (red) and without GPF (blue)









Health Benefit of Diesel versus Gasoline based on Particle Number PN

	Diesel+FFF	Gasoline+FFF
PN-Emission	0.1g →10^{14} P/km	0.01g→10^{14} P/km
Mileage per year	10'000 km pa	10'000 km pa
Particle size	100 nm	50 nm
PM Emission [P/year]	10^{18}	10^{18}
Overall vehicle life [year]	10	10
Emission [P/vehicle life]	10^{19}	10^{19}
Filter type	wall flow	wall flow
Filter efficiency [%]	99.9	99.9
Health Cost [€/kg = /10^{18} P]	1’200	1’600
Total prevented soot [kg/life]	10^{19}@100 nm	10^{19} @ 50 nm
Health Benefit [€]	**12’000**	**16’000**

Mass of a 100 nm cube with unit density is 1 Femtogramm = 10^{-15} g

Health Benefit / Cost

- HD Diesel Euro3 Retrofit FFF: 180'000 / 8000 = 22.5
- HD-Diesel Euro5 OEM FFF: 36'000 / 4000 = 9
- LD Diesel Euro3 OEM FFF: 12'000 / 500 = 24
- LD Petrol based on PM 1'200 / 100 = 12
  based on PN 16'000/ 100 = 160

Cost of HD DPF Retrofit – PFF Retrofit – DPF OEM – PFF OEM
8'000.- 5000.- 4000.- 3000.-

Cost of LDV DPF: 500.-

Cost fo LDV GPF: 100.-

Health Benefit / Cost

even for Chinese assumptions 4:1

Beijing 6/VI standards are extremely cost-effective. A conservative estimate of the benefits of the Beijing 6/VI standards indicates that, in 2040, they would outweigh the costs by a factor of 4 to 1, with most of the benefit coming from better public health.

The ICCT report is at http://theicct.org/sites/default/files/publications/Beijing_Emission_Control_Programs_201511%20.pdf.

Summary

Overall Monetary Assessment of PM-Emission-Reduction by BAT Particle Filters has a double benefit for the Society reducing health risk and global warming.

Benefit for the Society is ***> 10 x higher*** *than actual Filter Cost*

Conclusion

Swiss Council 2002:

„Introduction of Particle Filters is a large benefit for public health and an economic requirement"