Highly Efficient Nanofilter System for Large Scale Petrol Engine Retrofit - Core Part of the EU Horizon Project AeroSolfd

Dr. Lauretta Rubino – VERT Association

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2) AURIGNA,
3) Mann + Hummel GmbH,
4) CORNING GmbH
5) University of Applied Sciences, Biel

Co-funded by the European Union

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AGENDA

- Introduction
- Motivation
- Emissions of Petrol Engines – high PN and PAH
- Need for a GPF with high FE
- EU HORIZON AeroSolfd Project
- Summary

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What is VERT?

- **VERT** is a Non-Profit Association (based in CH) of filter, catalyst manufacturers, instrument and engine manufacturers and research associates, founded in 1993
- **VERT** stands for Verification of Emission Reduction Technologies
- **VERT** is a Particle Filter Testing, Certification & Quality Control System
- **VERT®** is a Trade Mark for Particle Filters of **Best Available Technology (BAT)**

VERT scientific network

- 1997 first international ETH-NP workshop - 40 participants
- Today ETH-NPC is the annual event of UFP experts from science to technology
- 26th conference in June 20-22, 2023
- VERT Forum every year – 13th VERT Forum on 21st march 2023
- www.vert-dpf.eu/
- www.nanoparticles-ethz.ch

VERT and the Diesel Particle Filter

Research, Implementation and Quality Control
the interdisciplinary VERT Research Network

1994 developed for tunneling NEAT
2000 some hundred DPF in tunneling
2002-10 Swiss Construction 25‘000

2011 EU for Diesel, 2017 for Petrol DI
2018 China, 2020 India
today > 200 Milion worldwide

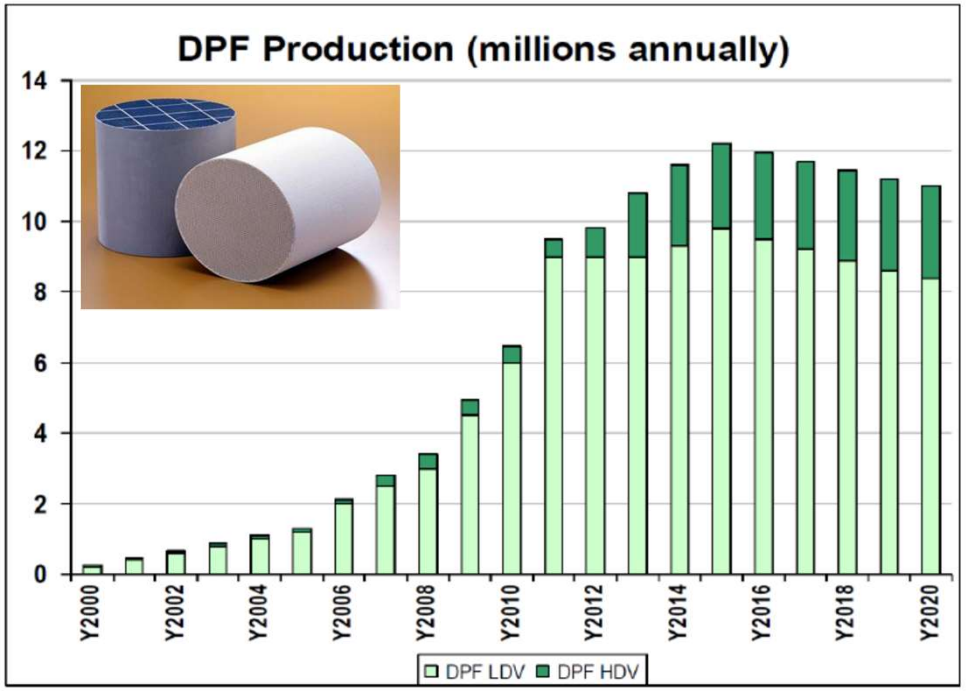


Fig. 6 DPF-Production annually for LDV and HDV – USA and Europe

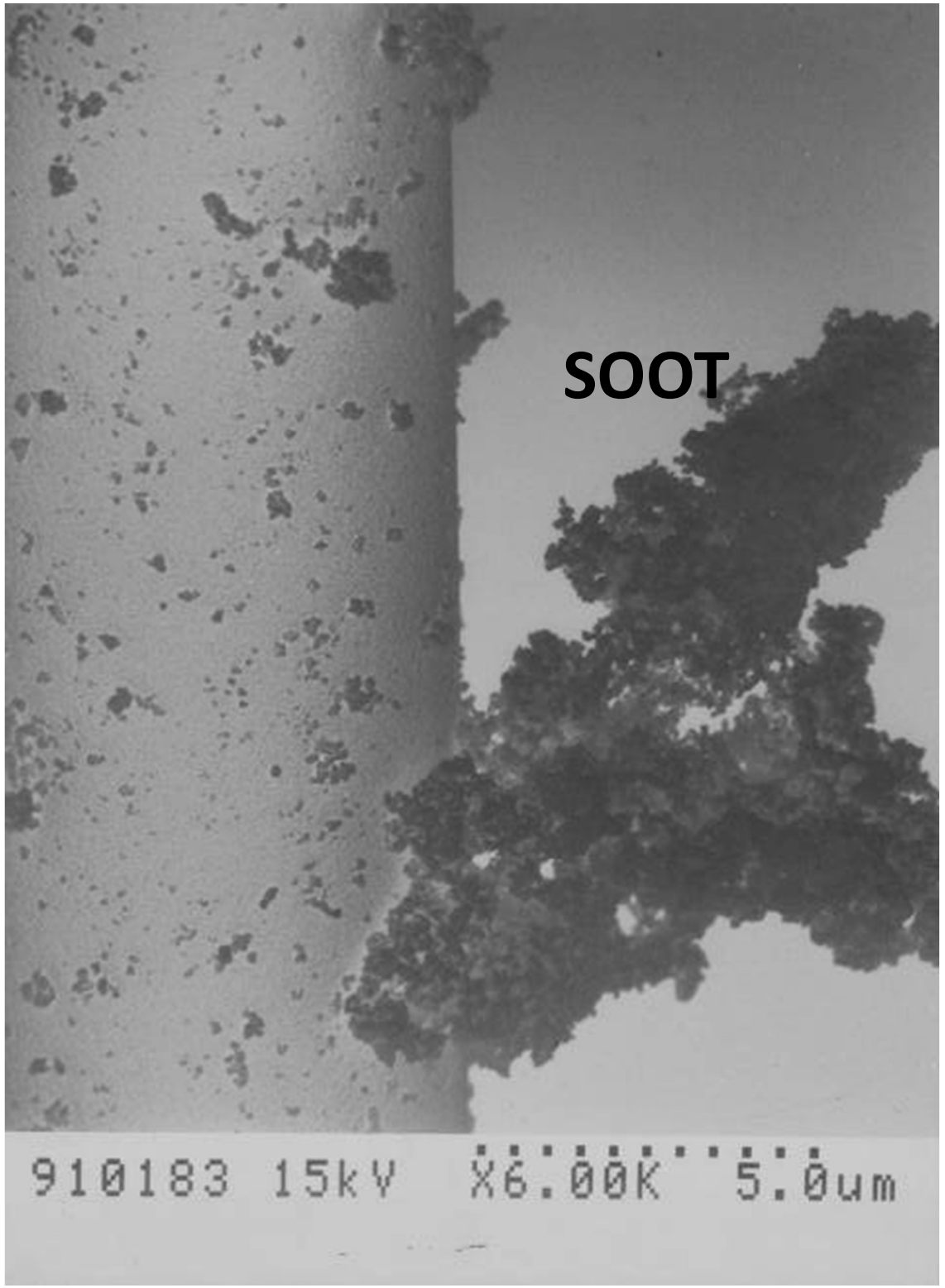
Thanks to Particle Filters > > 3.5 Mio premature death less

Soot Particles (UFP) a double Risk because of

- **size <100 nm**
- surface **> 100 m^2/g**
- carrying toxics
- persistent in organism
- carcinogenic

→long life toxic aerosol

weeks to months in air,
years in the organism

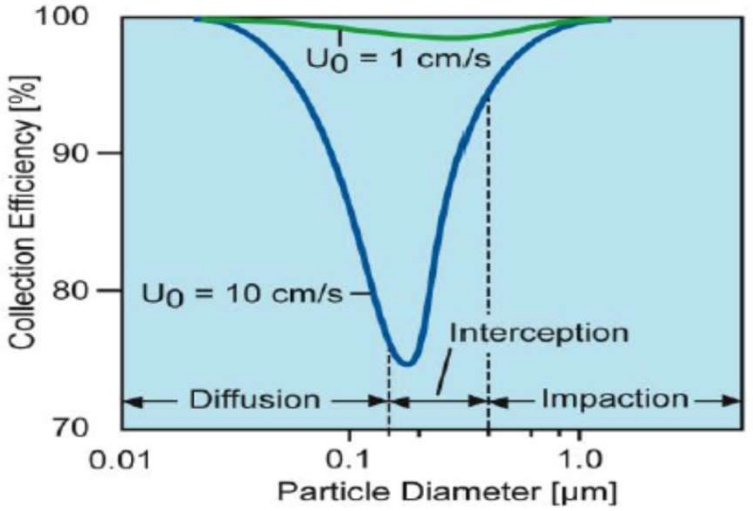


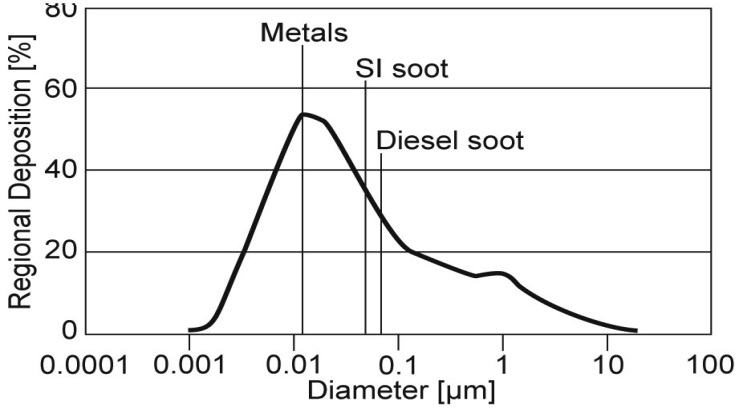
Size matters

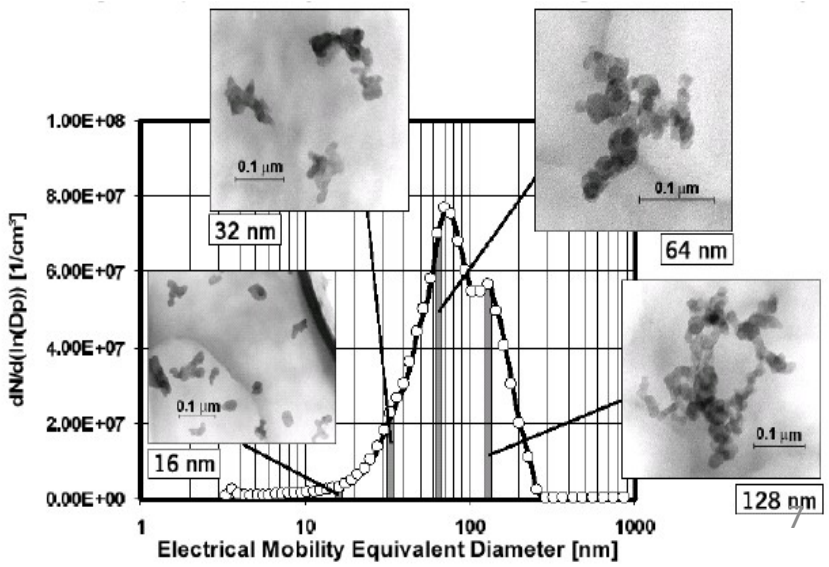
the weakest size range of filtration, the gap between diffusion and impaction

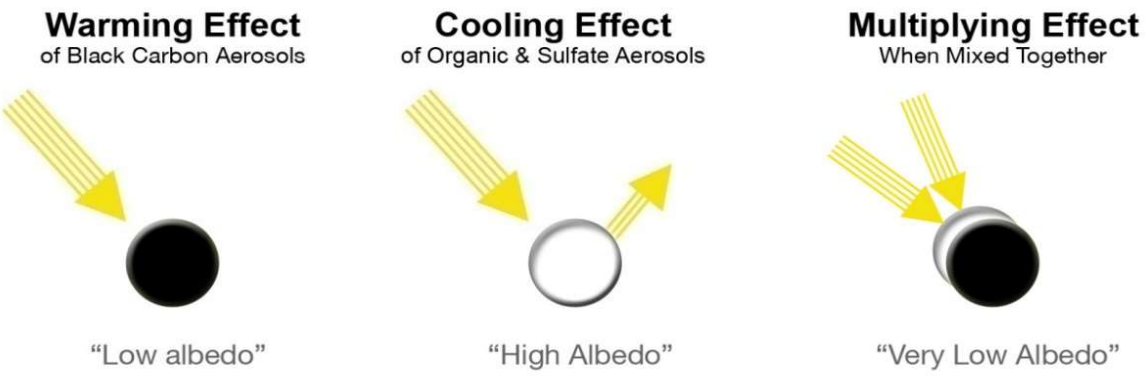
is the most sensitive size range of the lungs

the most intensive emission range of engines and the typical size range of viruses

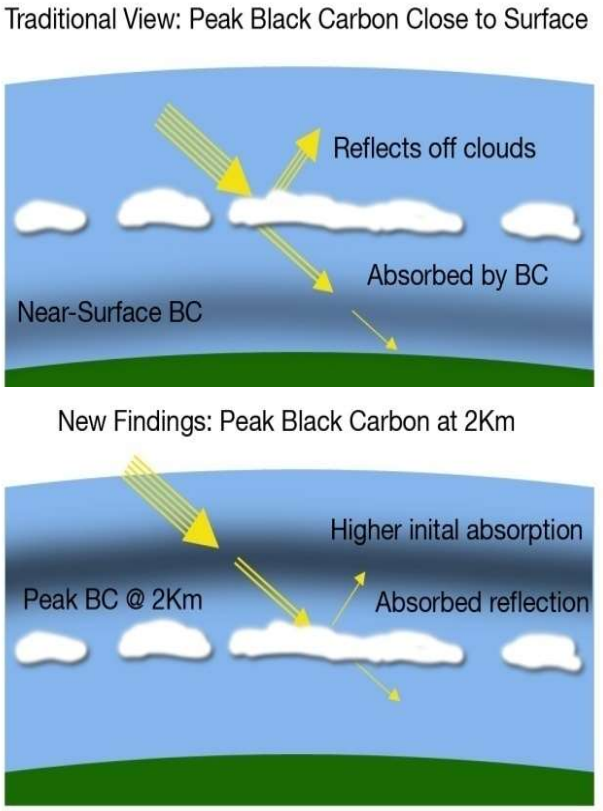






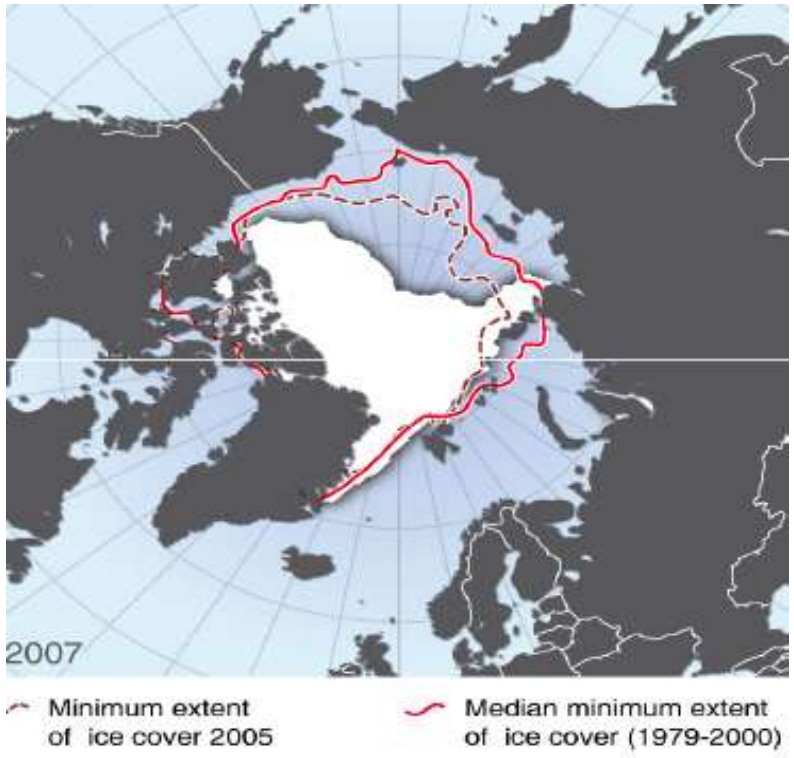


Higher in atmosphere



Science Daily, United Nations Environment Program Nov 2008

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

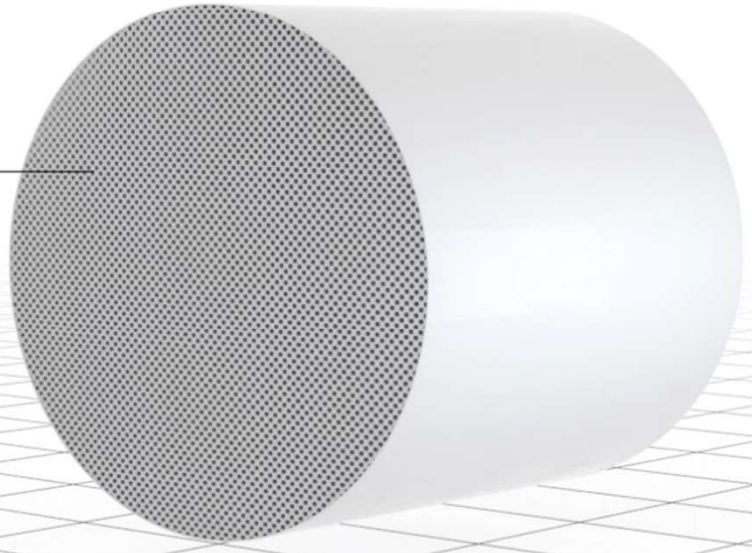


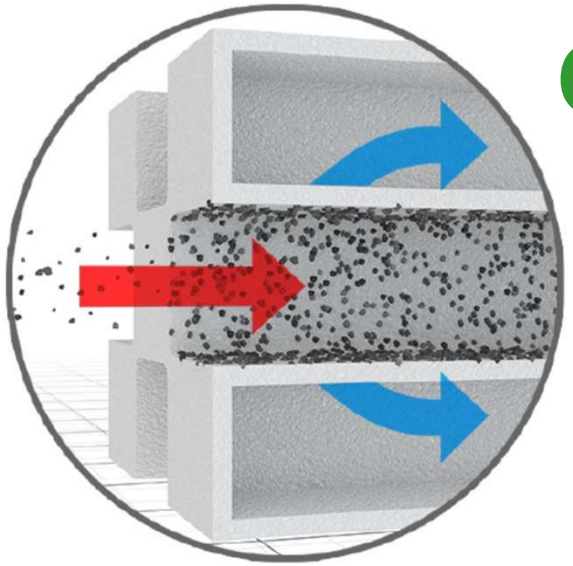
Journal of Geophysics Res.2007

Global Warming by BC-Particles

Corning® DuraTrap® GC

Gasoline Particulate Filter





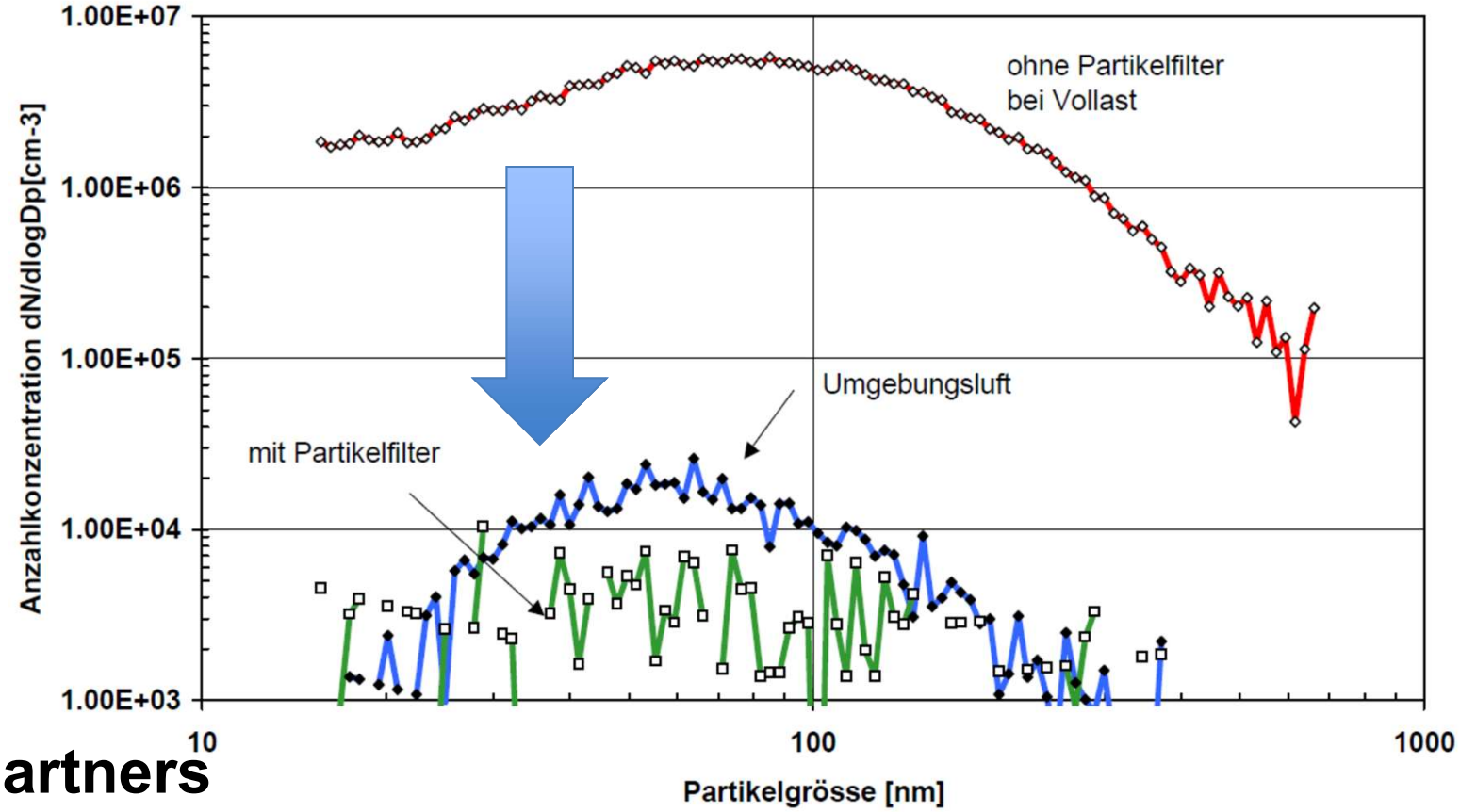
Ceramic wall flow multicell filter

invented 1979, now > 200 Mio in Diesel cars

- pore size 10-20 µm
- porosity 45-65%
- 200 cpsi
- >1 m^2 per 1 ltr bulk volume
- High in-flow speed but low face velocity some cm/s
- filtration efficiency >99%
- particle size 10 – 500 nm
- soot storage 10 g/ltr
- any shape and size
- temperature > 1000° C
- no aging over vehicle life
- no vibration problem
- easy to clean

Diesel particles are in the diffusion range

that makes them
so dangerous

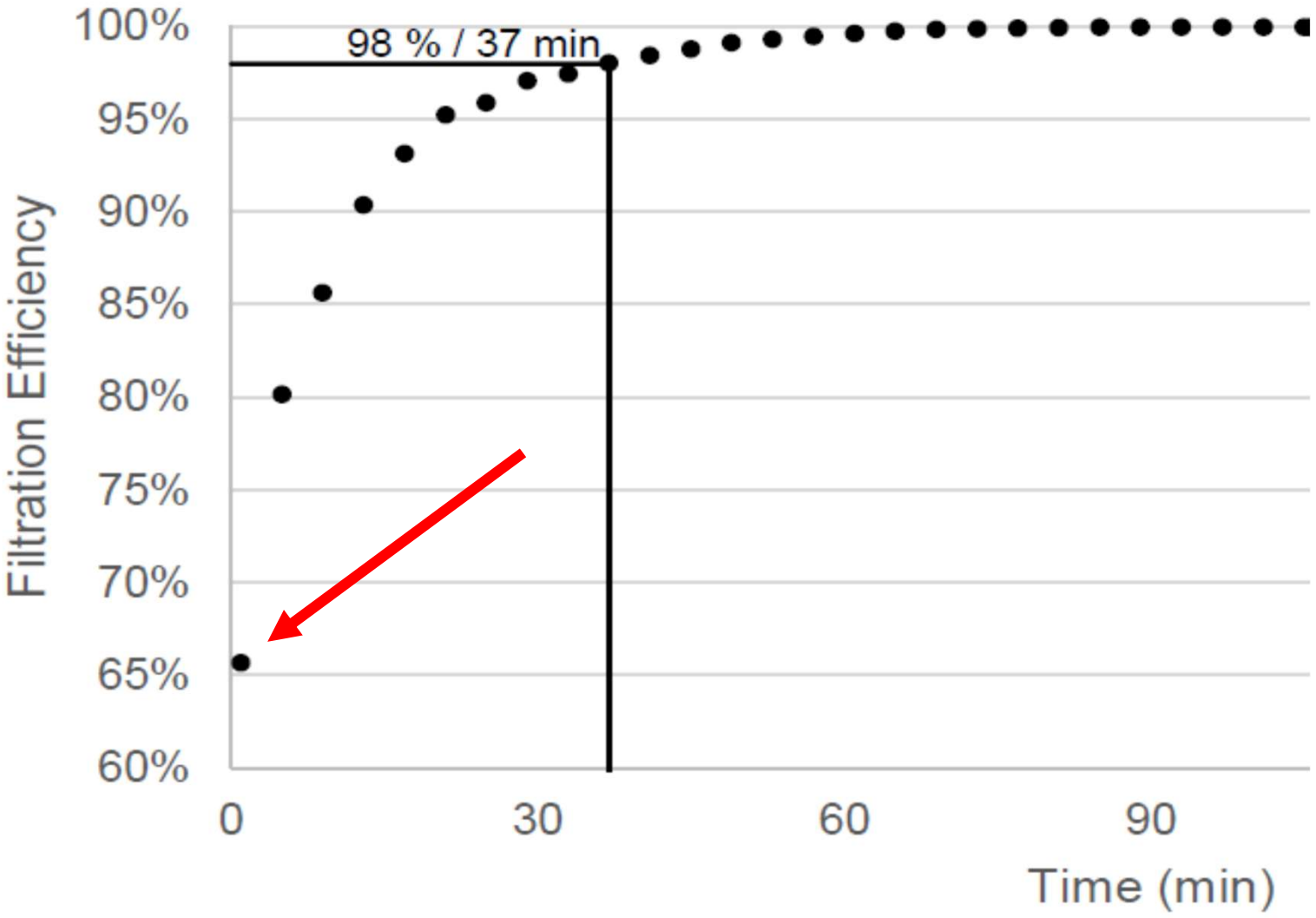


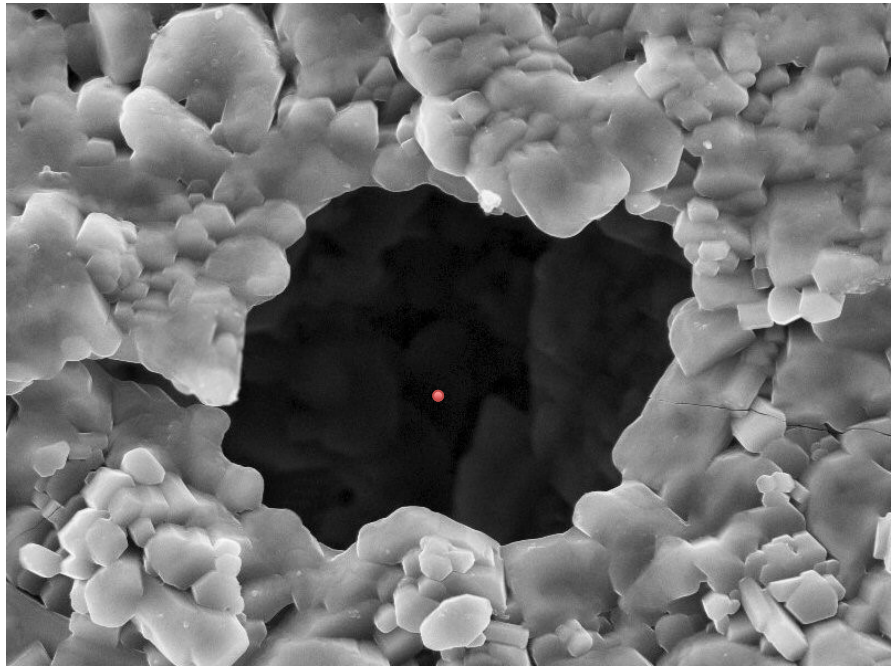
VERT Research Partners

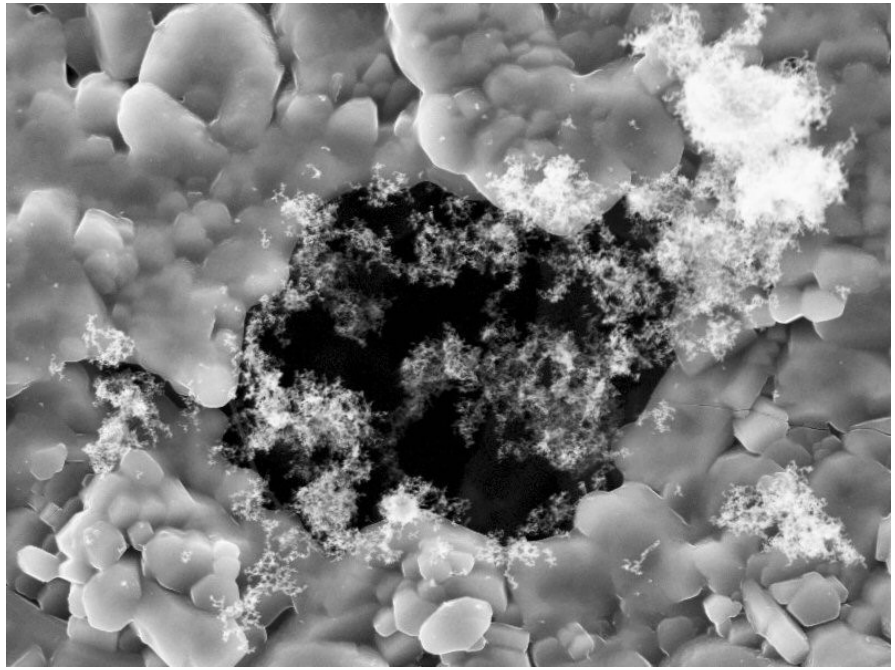
- Engine Emission Laboratory at Uni Biel AFHB
- Aerosol Laboratory at Uni FHNW
- Toxicology Laboratory Uni Bern –Fribourg
- Bioerosol (Virus) Laboratory AMI Uni Fribourg

But these filters have a big problem if not soot loaded

and… with petrol engines they remain clean







Particles 10-100 nm
are 100 - 1000 x
smaller than
filter pores 10-20 µm

With ultrafine particle
structures we can
stepwise build a
“membrane” covering
the pore

Payne S. /Uni. of Cambridge; Study of diesel particulate bridging behaviour with SEM; ETH-NPC 2012

Particle Emissions of Internal Combustion Engines

Diesel

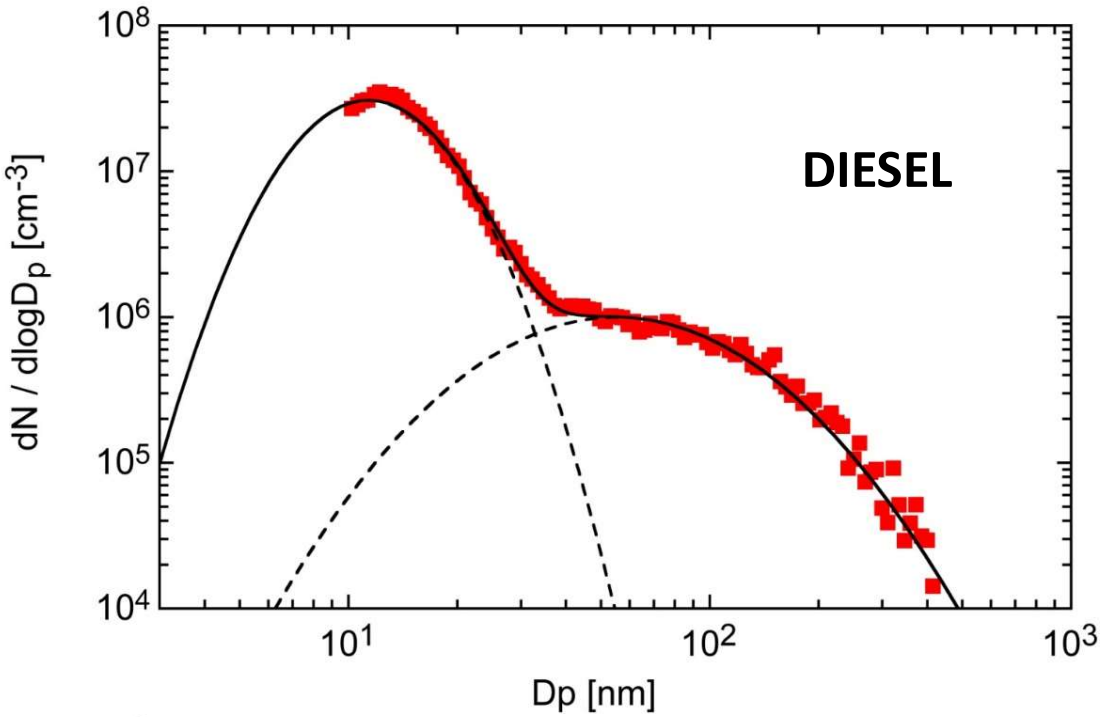
Soot peak: **80 nm**; 10^6 - 10^7

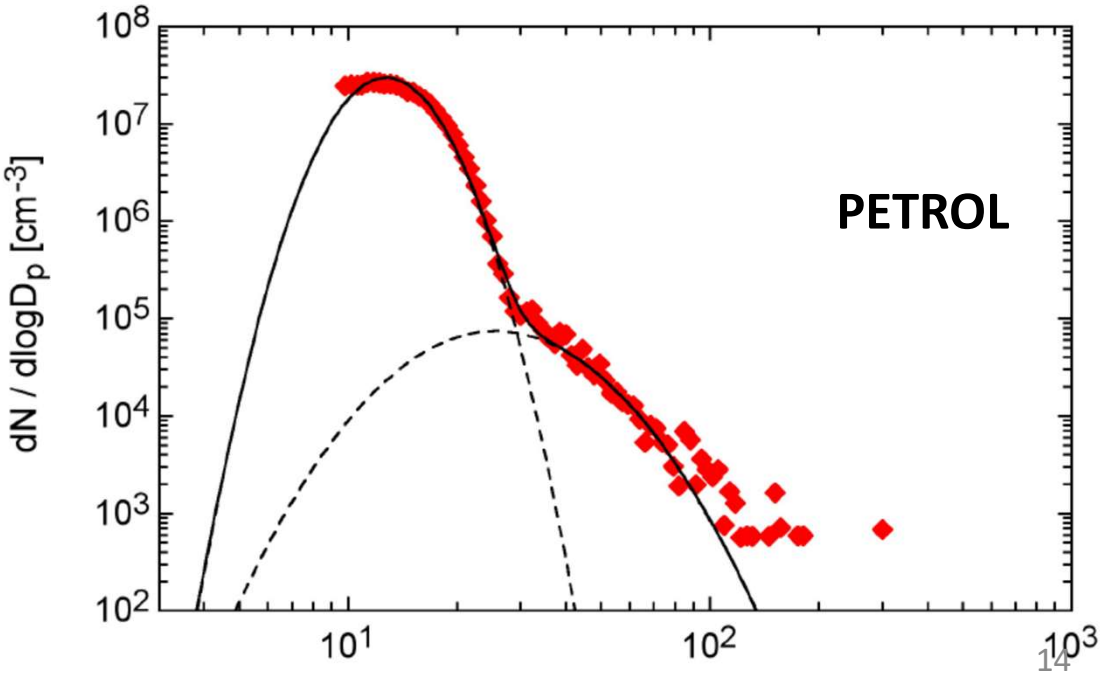
Ash peak: 10 nm;

Petrol

Soot peak: **40 nm**; 10^5- 10^8

Ash peak: 10 nm;





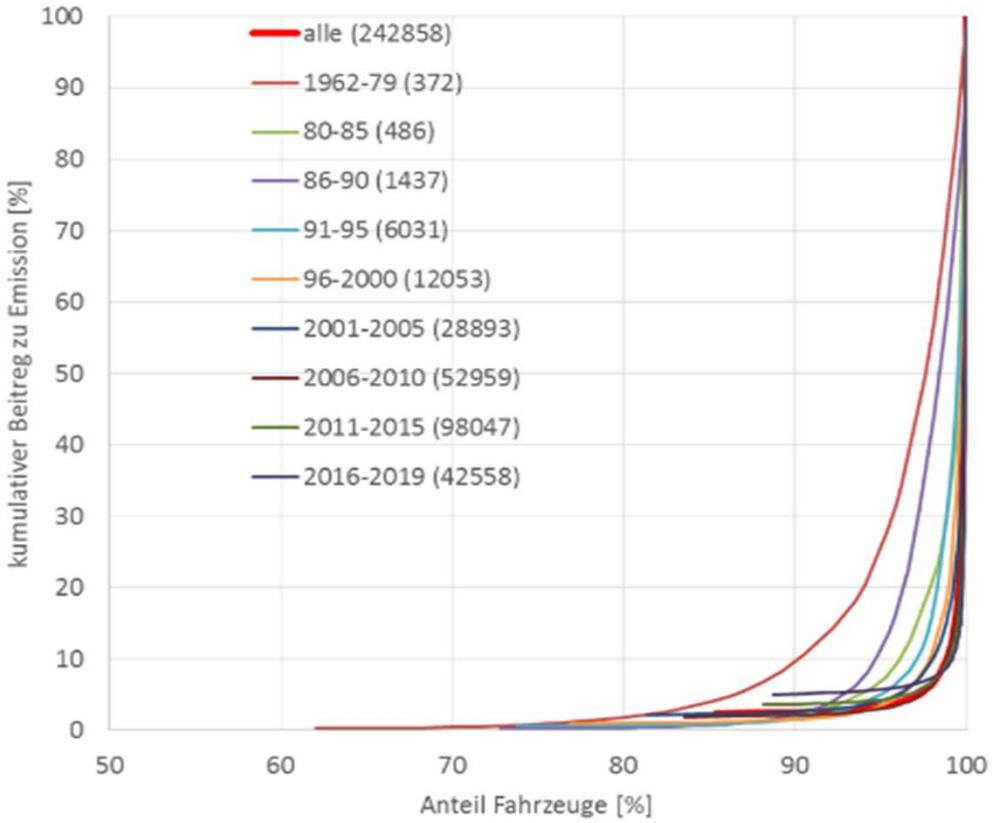
Source SAE 2012-01-841 Mayer et al

These cities have no Diesel LDV fleet
Emission is high because of Petrol Engine

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

All Megacities have the same pollution problem due to growing size and traffic
VERT is everywhere active to transfer Best Available Tehnology for Health and Global Warming Mitigation

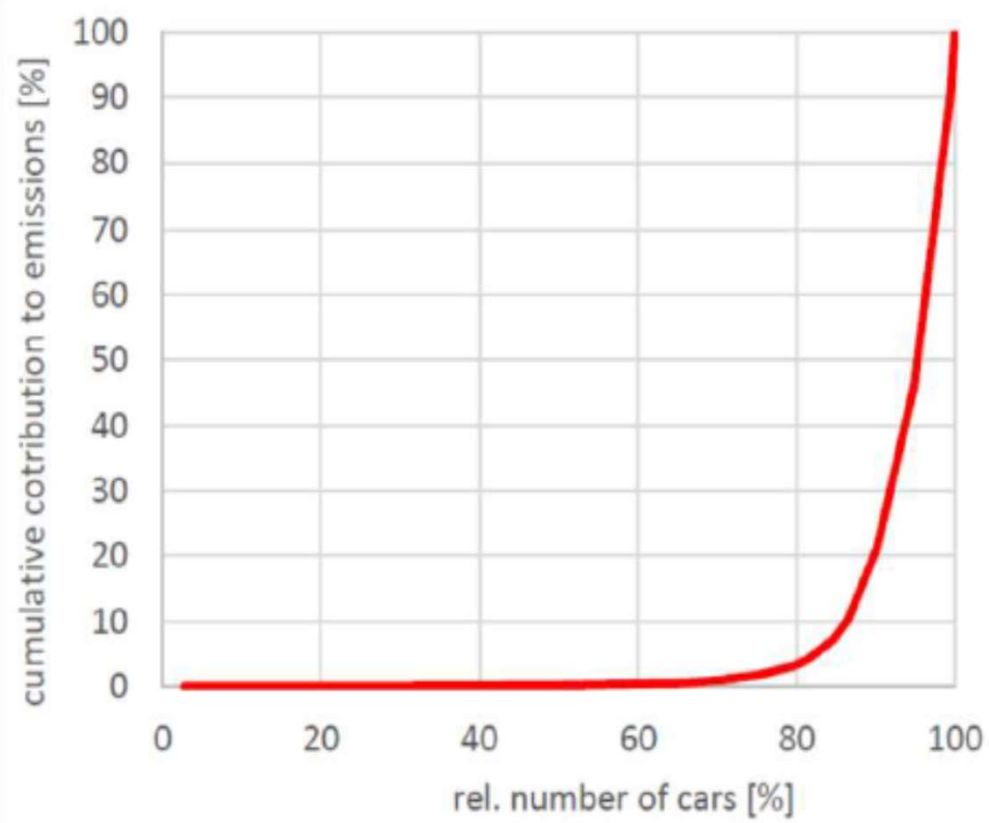
5% of the vehicles may produce >90 % of the overall emission of the fleet



The «dirty tail» phenomenon with Petrol Engines

PN-Emission of 400'000 cars in Mexico City

(VERT+Sedema 2017/18)

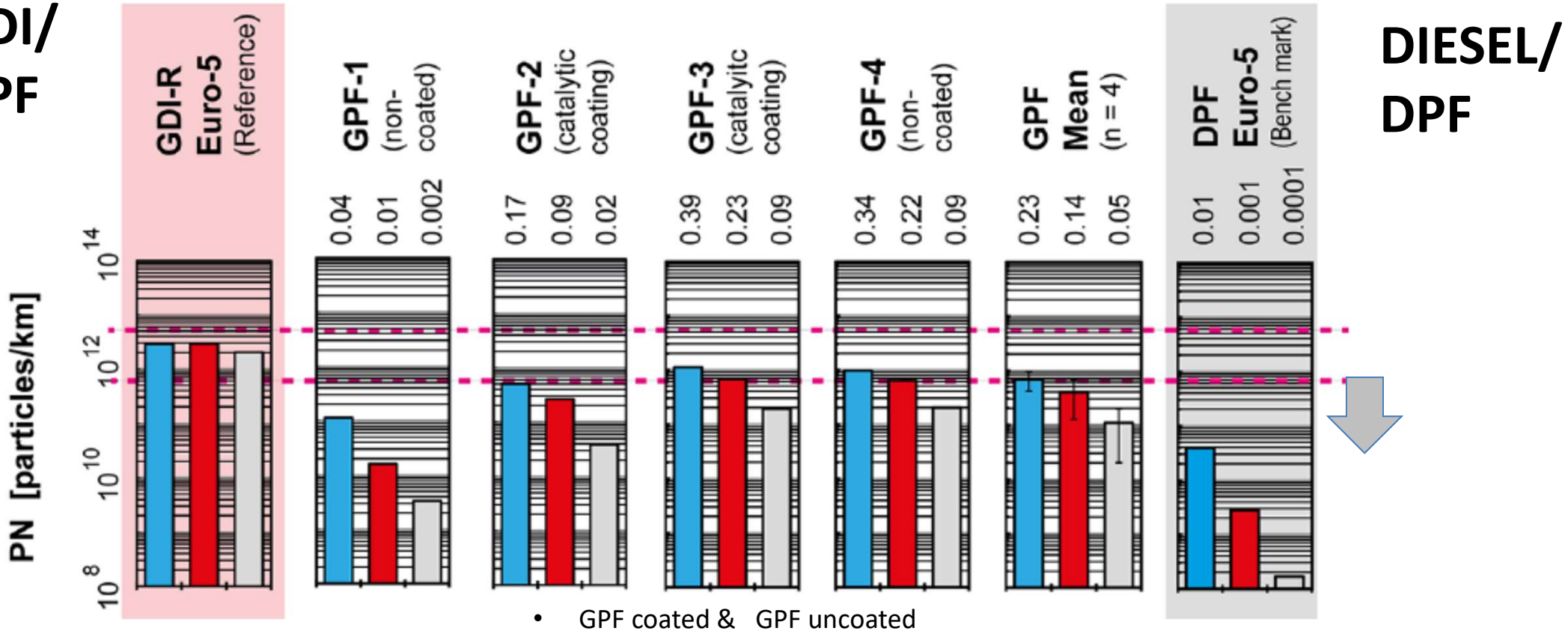


The «dirty tail» phenomenon with Diesels with particle filters

Cumulative contribution of High Emitters to Zürich fleet emission

(Gloor VERT Forum 2018)

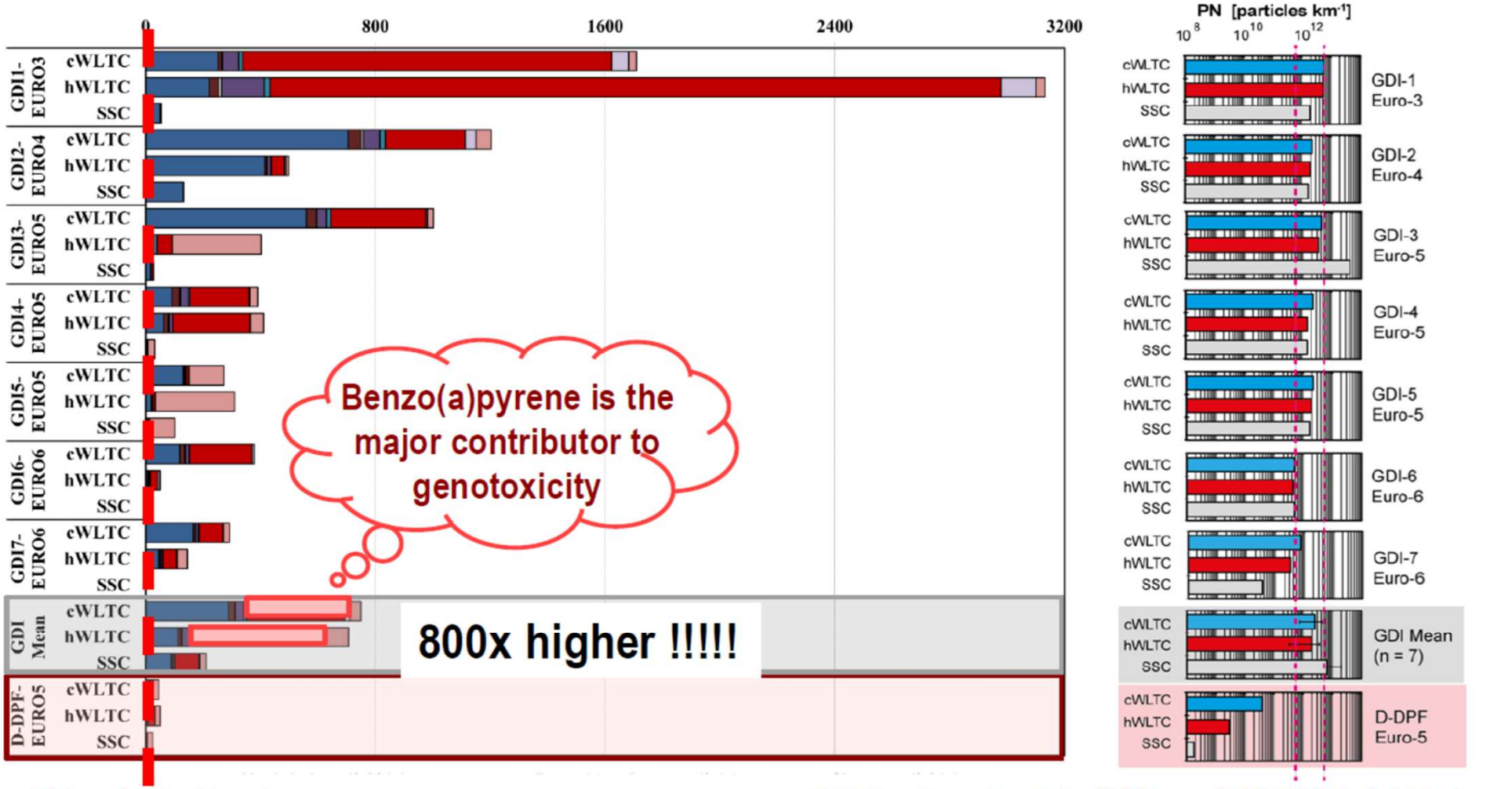
DI Petrol engines with/without GPF compared to Diesel with DPF – by far not good enough



Different colours refer to different driving cycles:
WLTP, RTS95 & stationary

DI Petrol Engine – High PAH Emissions

Empa
Materials Science and Technology

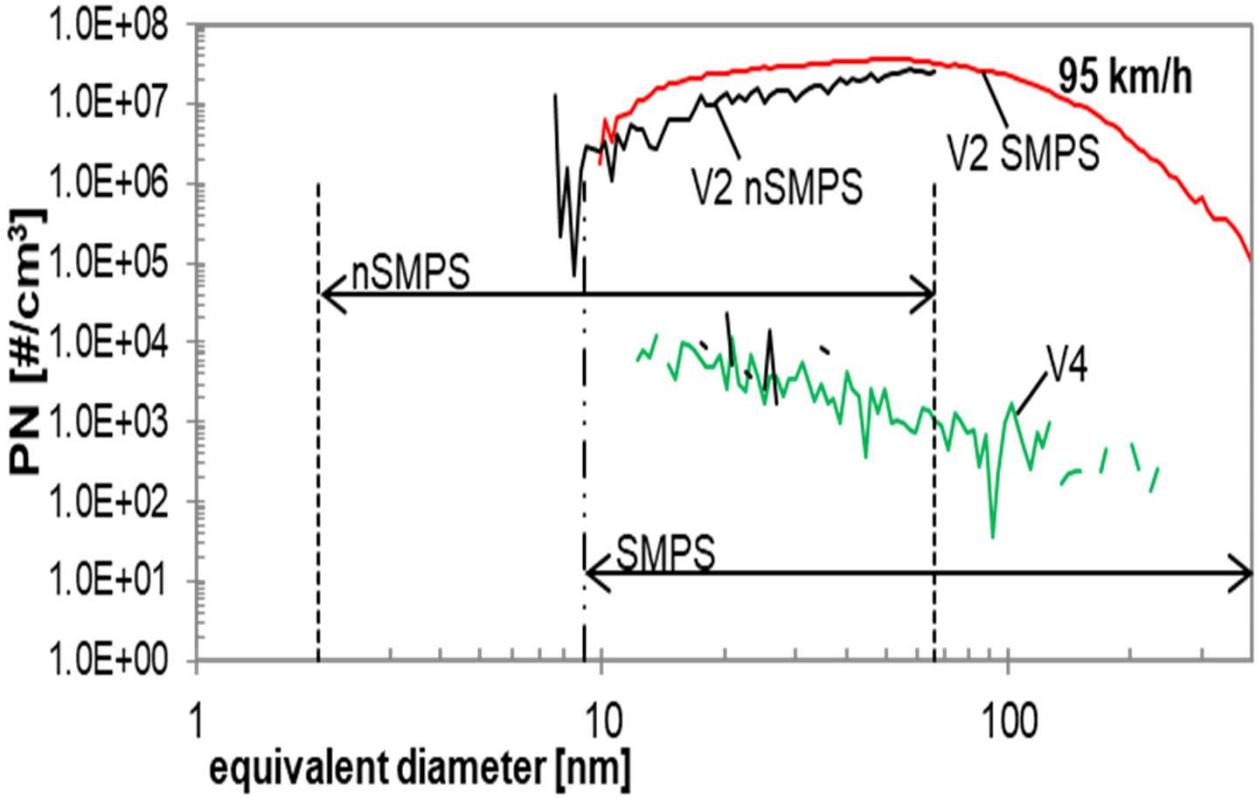


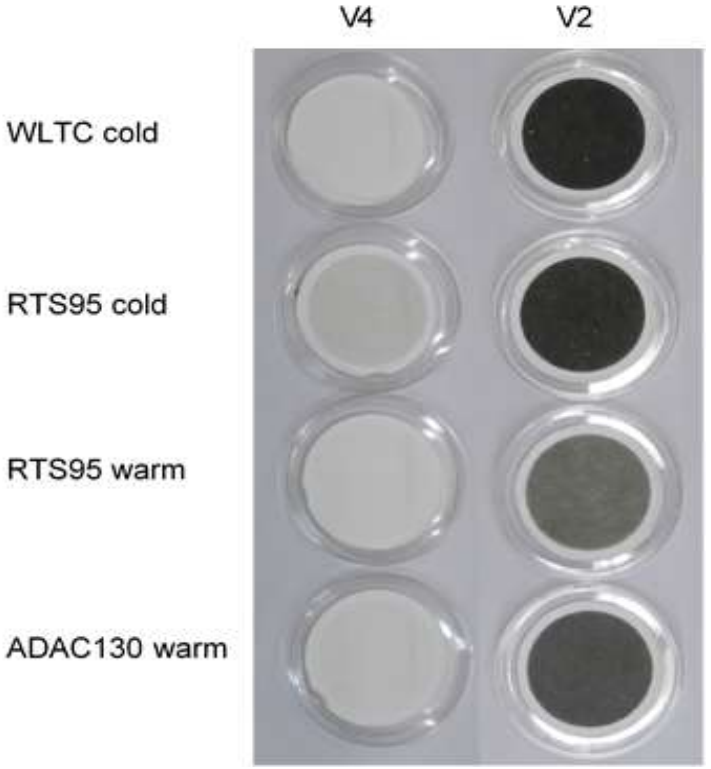
EU - air limit value:
1 ng/m^3 benzo(a)pyrene (2014/107/EC Directive)

GDI fleet emits 64-, 700- and 39000-fold higher PN emissions than the Euro-5 diesel vehicle

PFI engine may be even dirtier

the cleanest and the dirtiest of the test fleet by PN and by opacity in different test cycles



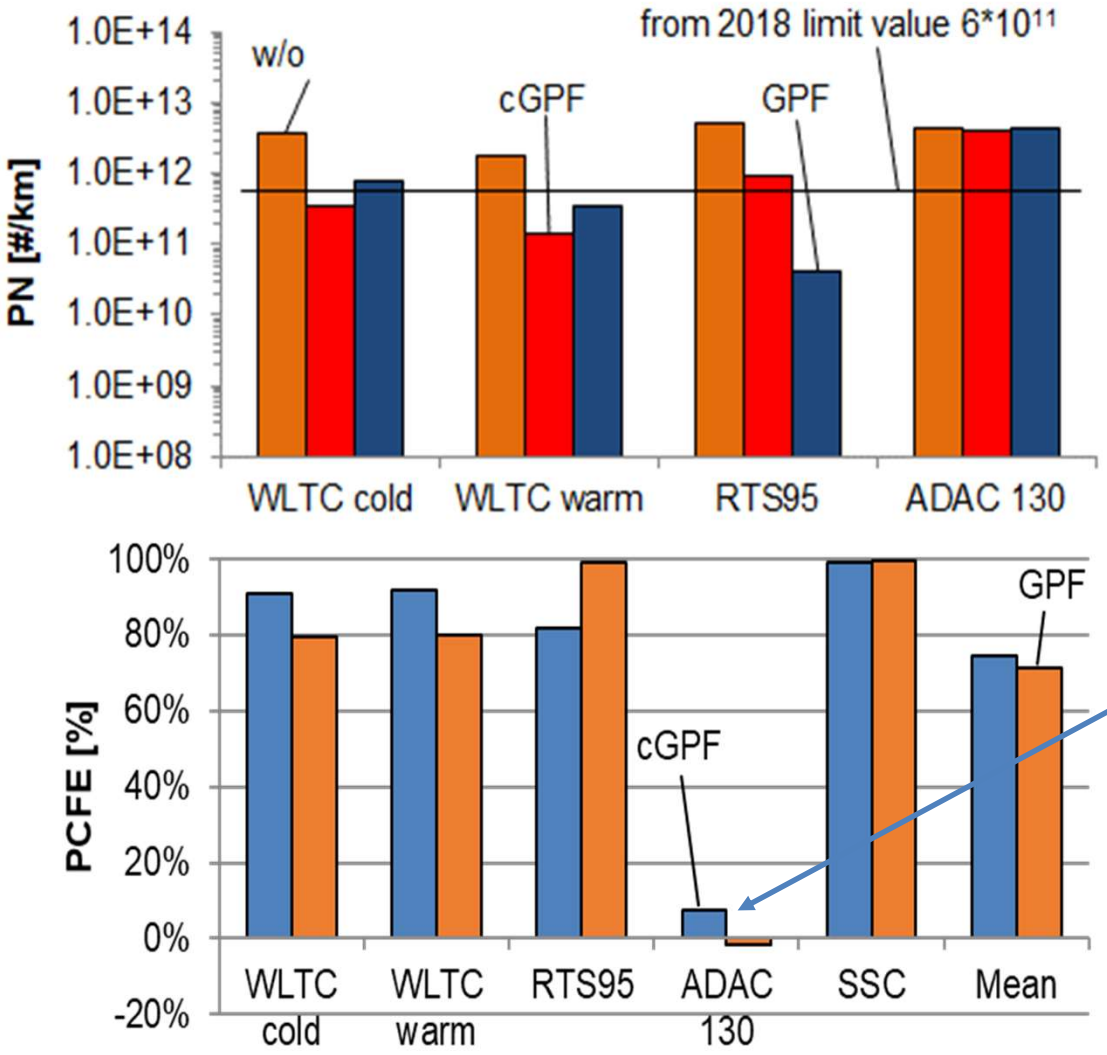


V2 vehicle

*source SAE 2018-01-0363

- **PFI engines do not have to comply with EU-PN limit values**, i.e. as a rule they do not have particulate filters

Commercial GPF do not provide sufficient filtration and may breakdown at high space velocity



ADAC German Motorway Test
Speeds up to 130 km/h


AeroSolfd
filtration devices
Fast Track to Cleaner Urban Air

WHAT IS AEROSOLFD?

Fast track to cleaner, healthier urban **Aerosols** by market ready **Solutions** for:

- **tailpipe**
- **brake systems**
- **(semi-)closed environments**

of retrofit **Filtration Devices**

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RETROFIT FILTRATION DEVICES

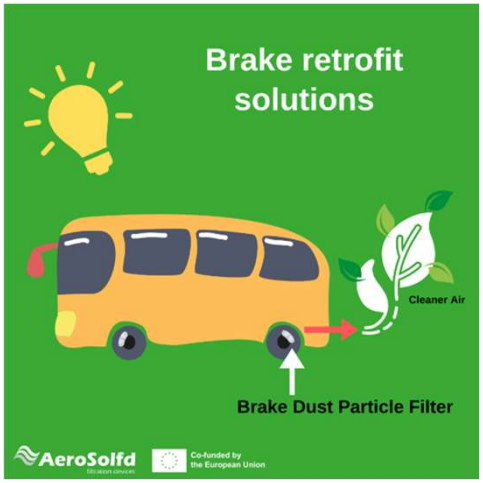
- AeroSolfd Solutions:

MANN + HUMMEL

Reducing tailpipe emissions

G15

Reducing brake emissions



G14

Reducing pollution
in (semi-)closed environments

G14

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APPROACH & TEAM

AeroSolfd
filtration devices

Development	Demonstration	Exploitation
• Specifications, design and integration • Testing, process validation	• Onsite measurements • Assessment	• Demo Sites • Infrastructure	• Sustainability aspects	• Business plan • IPR Strategy

16 Partners

8 Countries

Mann + Hummel

Co-funded by the European Union

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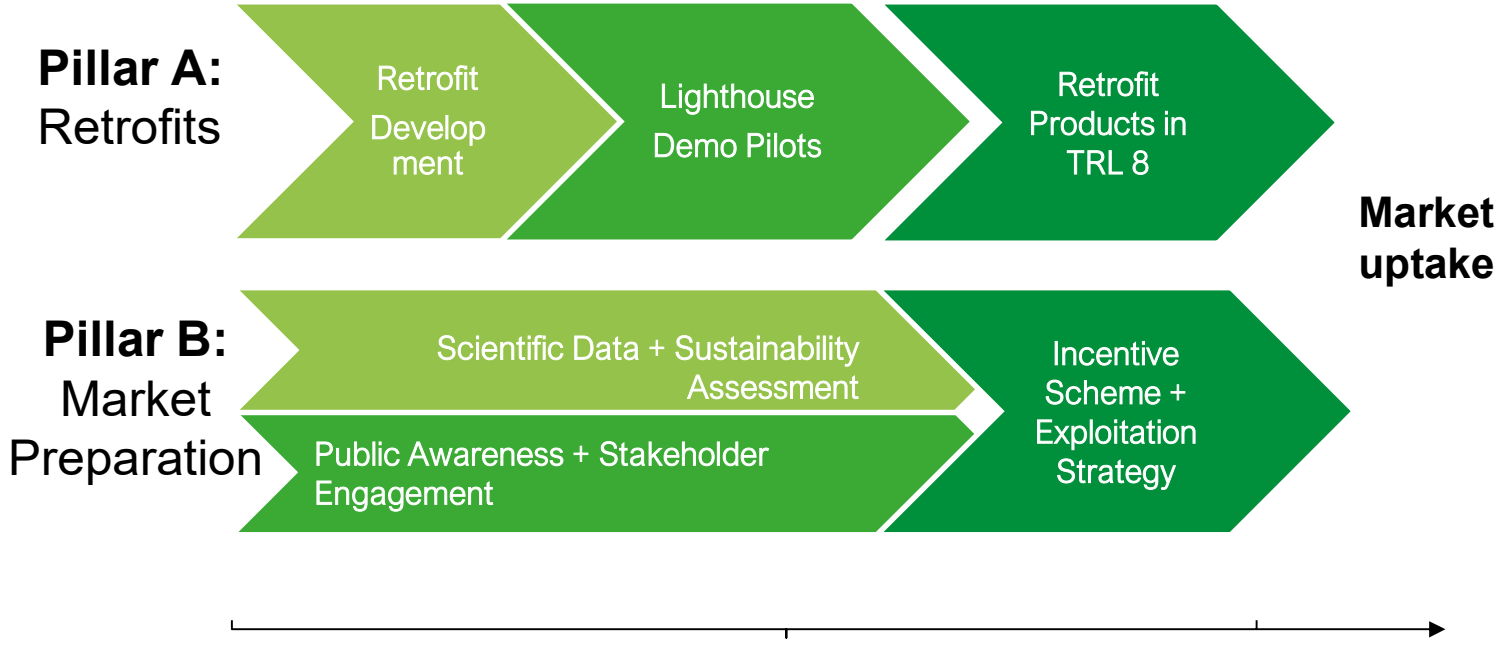
FOCUS: RETROFIT WITH PARTICLE FILTERS (GPF)

- AeroSolfd Solutions:

Reducing tailpipe emissions

G15



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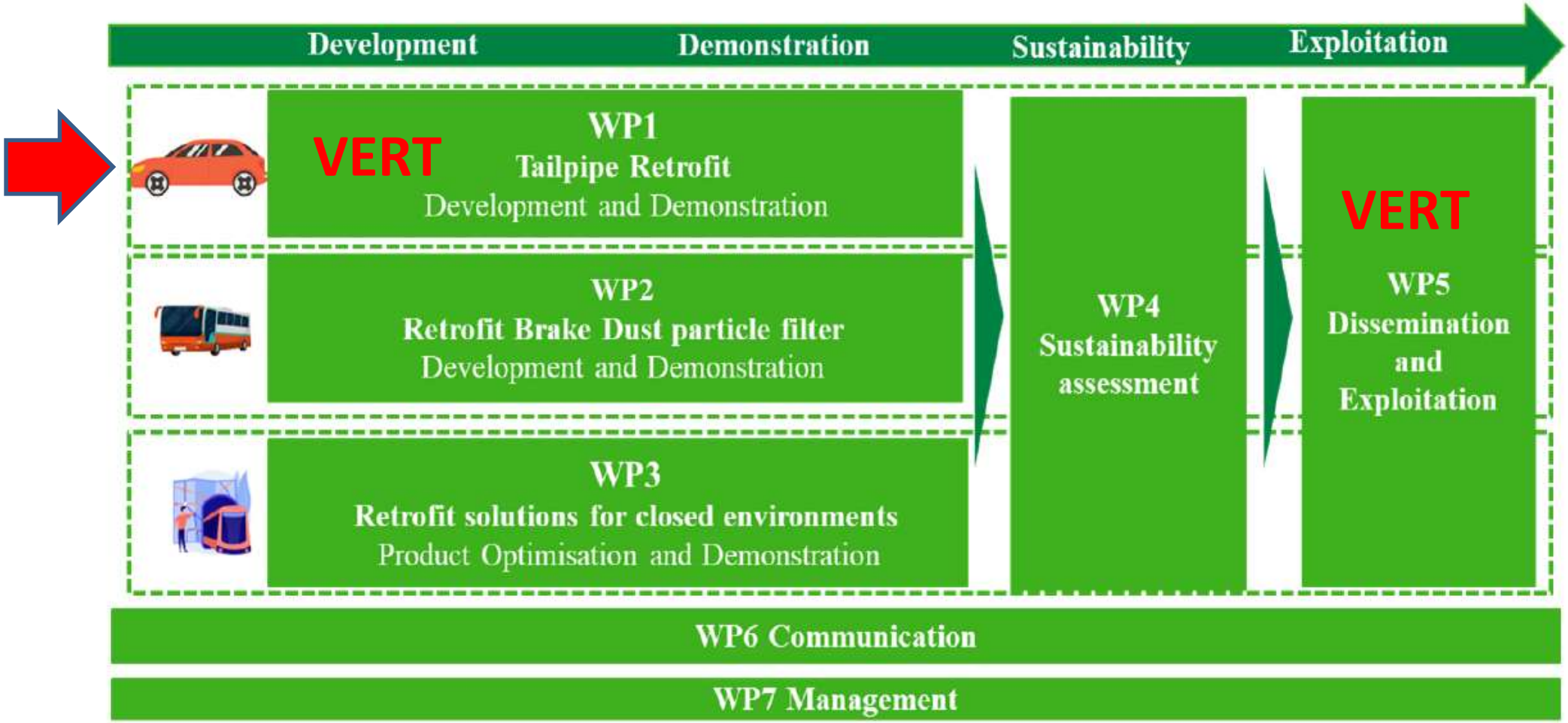
Activities in the EU/ *SBFI* funded project AeroSolfd

AeroSolfd
filtration devices



VERT with WP1 Partners: HJS, G-Technology, BFH, TÜV, Israel Partners

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Horizon Europe AeroSolfd
The project targets

- Adapt and demonstrate an affordable **high efficient gasoline particle filter (GPF)**
- Capable of reducing **95% of the exhaust particles**
- **Cost efficient solution** in a cost ranging from
  € 700 to € 1.000 depending on engine size and power rating
- **Fast track to market** by using an already proven technology in already high volume production
- **Exploitation plan for retrofitting 5 million vehicles** with the GPF by 2035

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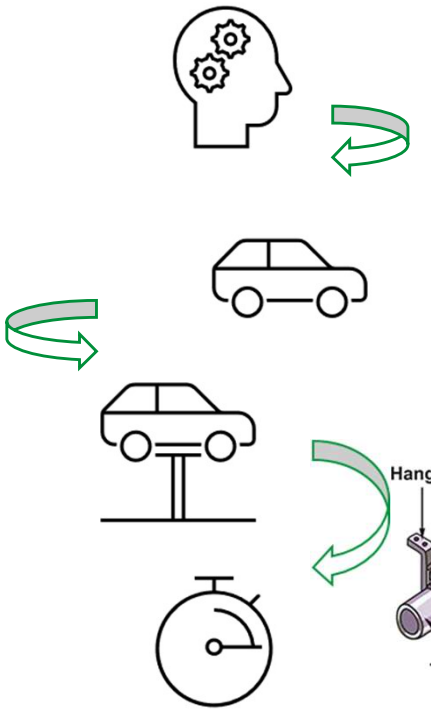
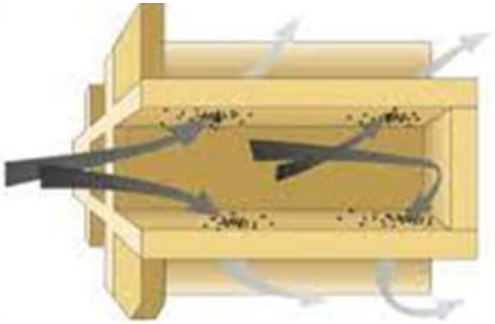
Overview



Exhaust System

GPF



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WP1 - Deliverables

AeroSolfd
filtration devices

CL5-2021-D5-01-15: Cost affordable and adaptable retrofit solutions *Innovation Action - Part B*

Table 3.1c: List of deliverables

No.	Deliverable name	WP	Lead	Type	Diss. level	Date
D1.1	Matching retrofit particle filter with 4 representative engine families, ready for installation	1	VERT	R	PU	M 9
D1.2	Emission reduction of PN and NOx validated on WLTC and real driving conditions	1	VERT	R	SEN	M 12
D1.3	Test results of emissions for PAH, Nitro-PAH, NH_3, N_2O and nanoparticles.	1	VERT	R	PU	M18
D1.4	Reports on tailpipe real driving particle emissions and data loggings from 50 vehicles split into three fleets	1	VERT	R	SEN	M 26
D1.5	Service and retrofit market chain concept for a broad market. Products with type approval ready for commerc. on TRL8	1	VERT	R	SEN	M 32
D1.6	Tail pipe PN emission results from 1,000 gasoline in-use DI engines/vehicles	1	VERT	R	PU	M26

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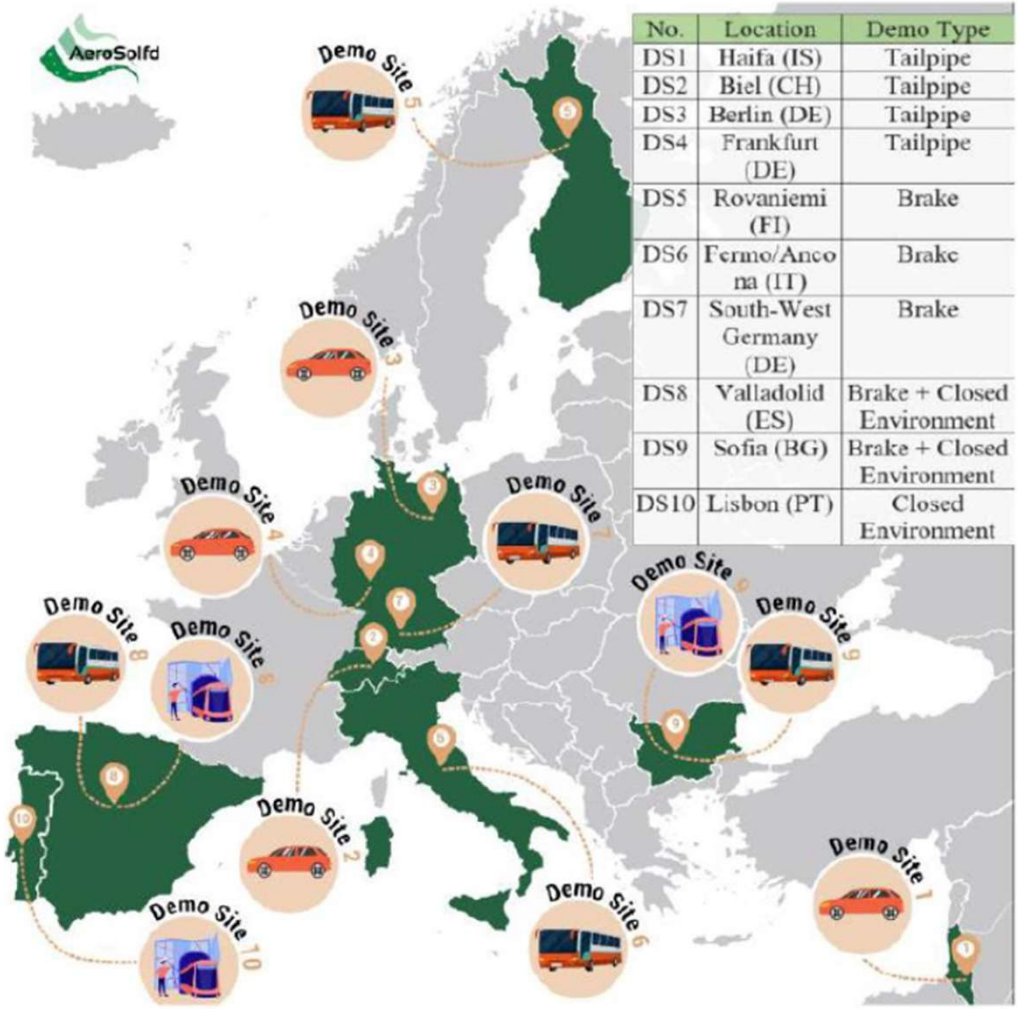
Demonstration sites (VERT)



No.	Location	Demo Type
DS1	Haifa (IS)	Tailpipe
DS2	Biel (CH)	Tailpipe
DS3	Berlin (DE)	Tailpipe
DS4	Frankfurt (DE)	Tailpipe
DS5	Rovaniemi (FI)	Brake
DS6	Fermo/Ancona (IT)	Brake
DS7	South-West Germany (DE)	Brake
DS8	Valladolid (ES)	Brake + Closed Environment
DS9	Sofia (BG)	Brake + Closed Environment
DS10	Lisbon (PT)	Closed Environment

one fleet in Germany,
one fleet in Switzerland
& one in Israel

operating 6-8 months

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OVERALL PROJECT TIMING

WP/Task	Description	Leader	1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24	25 26 27 28 29 30 31 32 33 34 35 36
			Year 1	Year 2	Year 3
WP 1	**Tailpipe Retrofit- Development and Demonstration**				
T 1.1	Matching retrofit solutions to 4 engine families representing the fleet vehicles and system Engineering	VERT			
T 1.2	Experimental Validation of family types on Chassis dyno and PEMS	VERT			
T 1.3	Testing of Secondary Emissions and Particles sub 23 nm	VERT			
T 1.4	Retrofit of vehicles; real driving performance, durability and resilience	VERT			
T 1.5	Retrofit product finalizatiot and deliver a cost effic., scalable and sust. retrofit prod. to TRL 8	VERT			
T 1.6	Evalu. of tail pipe particle emissions (PN) and identification of high PN emitting gasoline cars	VERT			
WP 2	**Retrofit Brake Dust particle filter – Development and Demonstration**	**M+H**			
T 2.1	Define meaning full driving cycle for a city and assess emissions of transport network	LINK			
T 2.2	Define dynamometer testing protocol and determine base line of brake polluting emissions	LINK			
T 2.3	Devel. virtual twin by adopting and optim. brake dust particle filter for retrofit. to bus/CV brake	M+H			
T 2.4	Lab-Testing of real brake part with real retrofit brake dust particle filter	ZF			
T 2.5	Vehicle integration and real-driving demonstration	ZF			
T 2.6	Defining approval process for retrofit parts	IUTA			
T 2.7	Develop cost affordable, scalable and eco-friendly retrofit product	M+H			
WP 3	**Retrofit solutions for semi-closed environments - Optimisation and Demon.**	**M+H**			
T 3.1	Establish contrib. of brake emis. on local expos., air and water quality and damage to build.	IUTA			
T 3.2	Measure baseline of exposure for commuters and workers at specific, closed demonstration sites	CSIC			
T 3.3	Optimise air purifier design for easy retrofitting to semi-closed environments	M+H			
T 3.4	Demonst. solut. in the field by exten. testing at one closed, restrict. workers only demo-site	CSIC			
T 3.5	Demonstrate reduction potential of air purifiers at selected demo-sites	CSIC			
WP 4	**Sustainability assessment**				
T 4.1	Defining the framework for retrofit sustainability assessment	NFA			
T 4.2	Data-collection for LCA and sustainability assessment	NFA			
T 4.3	Environmental and Social Life Cycle Assessment	CENEX			
T 4.4	Overall sustainability assessment for each product line	NFA			
WP 5	**Dissemination and Exploitation**	**Steinbeis**			
T 5.1	Plan for Dissemination and Exploitation	Steinbeis			
T 5.2	Dissemination to create awareness of the retrofit solutions	Steinbeis			
T 5.3	Recommendations for incentive schemes for adopting retrofit solutions	VERT			
T 5.4	Innovation and IP management	Steinbeis			
T 5.5	Business modelling and advanced commercialisation plan	M+H			
WP 6	**Communication**	**Steinbeis**			
T 6.1	Communication Strategy	Steinbeis			
T 6.2	Brand Identity	Steinbeis			
T 6.3	Communication tools and materials	Steinbeis			
T 6.4	Awareness-raising actions throughout Europe	INTEC			
WP 7	**Project Management**	**M+H**			
T 7.1	Overall project management	M+H			
T 7.2	Financial management and project reporting	M+H			
T 7.3	Technical coordination incl. quality and risk management	M+H			

VERT (WP1)

VERT (WP5)

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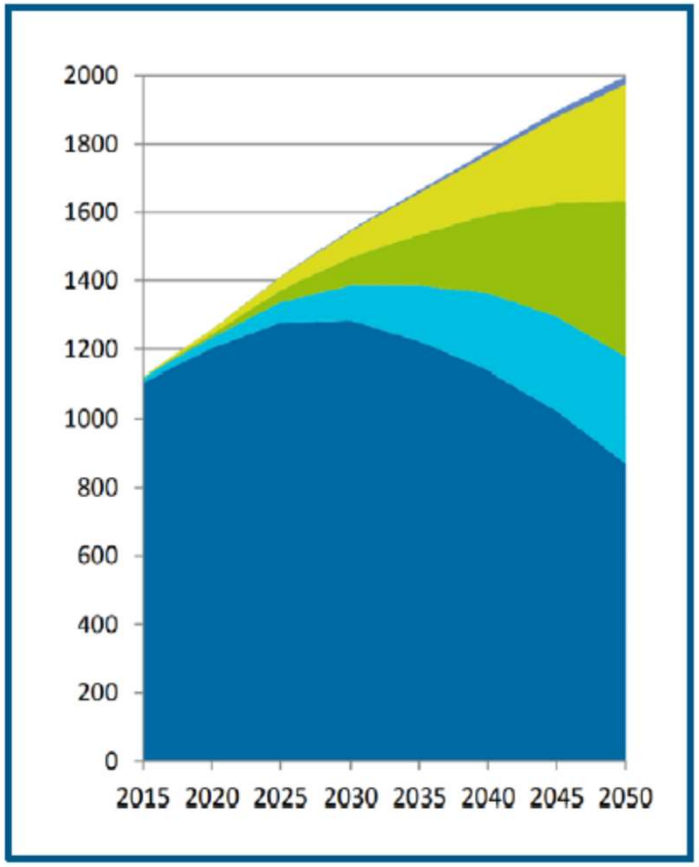
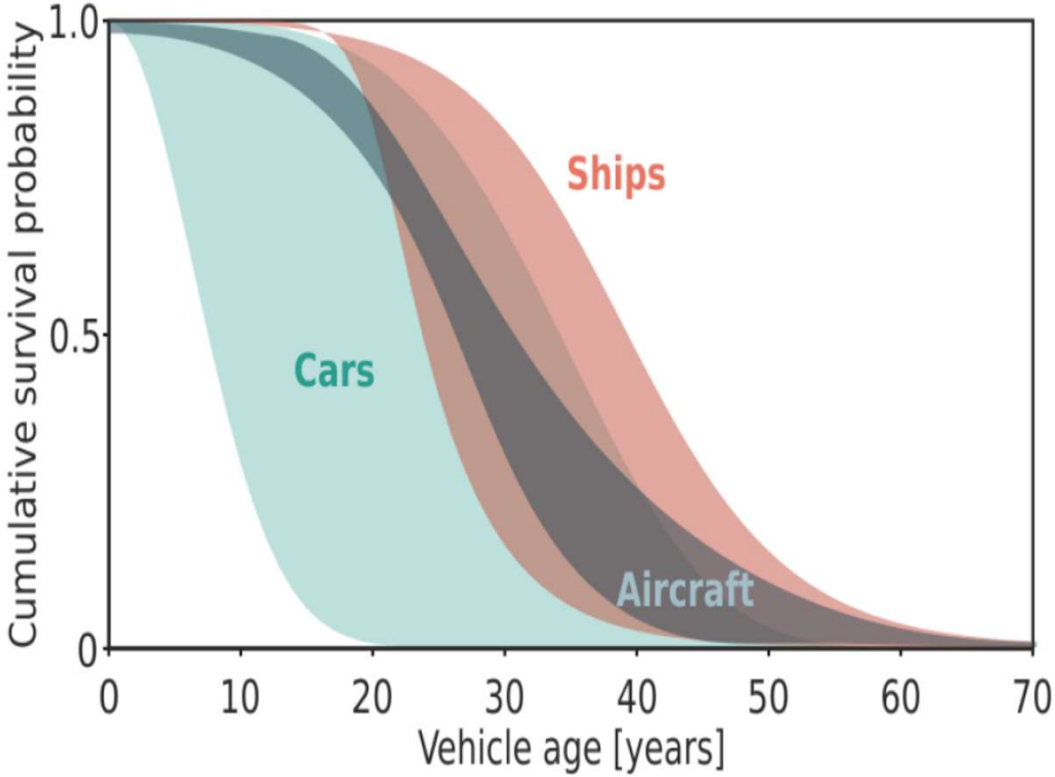
What will «really» happen after 2035? …..still many ICE vehicles



Fleet in Millions (International Energy Agency, 2017)



Service life of combustion engines (European Transport Research Review, 2021)

and they might be old and high emitters….and we will need emission upgrade by retrofit

Summary

- **Emissions of highly toxic** but invisible **nanoparticles (PN) of petrol engines** can reach levels higher to those of diesel engines in untreated exhaust gas and are therefore a widely underestimated **health and climate risk**
- **Exhaust gas filtration for petrol engines (GPF)** can effectively reduce those PN emissions (99%)
- **This paper shows** the technical, legal and, to some extent, political context of the introduction of DPF and the prospects for the widespread introduction of GPF
- **The likely "long presence" of gasoline vehicles** in individual transport (~ 40 years) confirms the need of GPF retrofit. Thus, the measures presented are not only technically feasible, but socially necessary

Acknowledgement

The authors would like to take this opportunity to express their sincere thanks to the partner organizations of the VERT scientific network for their valuable research and continuous cooperation, in particular the ETH, the University of Fribourg, EMPA, AFHB and FHNW, as well as the Swiss Federal Agencies FOEN, FEDRO and SERI for their financial support of the work to date and of the current project, and last but not least the **AeroSolfd partners**

Disclaimer

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AeroSolfd
filtration devices

Detailed information on website

The European Commission and the Swiss State Secretariat for Education, Research and Innovation award funding for an €8.2 million project on cleaner urban air

In May 2022, the innovation project AeroSolfd started with a kick-off event in Ludwigsburg, Germany. The AeroSolfd consortium – led by MANN+HUMMEL – will deliver affordable, adaptable, and environmentally friendly retrofit solutions to reduce tailpipe and brake emissions and pollution in (semi-) closed environments. This will allow a quick transition towards cleaner mobility and a healthier environment.

Questions / Comments?

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VERT association

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