

Exhaust Particle Emissions Elimination by Gasoline Particle Filter

Dr. Lauretta Rubino, VERT Association

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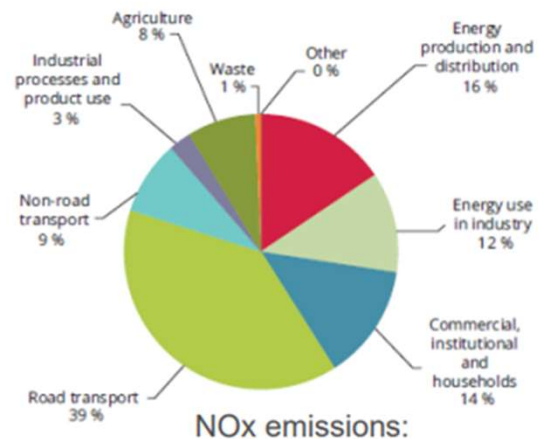
AGENDA

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



INTRODUCTION

- **Sub-50 nm particles** from traffic emissions pose high risks to human health due to their high lung deposition efficiency and potentially harmful chemical composition
- **EEA estimated circa 400 000 premature deaths** in 2019 in Europe due to Air pollution
- **Road Transport is the major contributor** above all in urban areas - LEZ & Zero Emissions Zone (ZEZ) increasing in Europe
- **Several studies** have shown that Petrol engines are of concern as they emit high PN and high PAHs
- **So far only GDI PN emissions** are regulated in Europe No PFI



*Source: EEA

NOx emissions:
2019 EU official emission inventories

In 2019: 39% of NOx and 11% of PM2.5 from road transport in Europe



Environ. Sci. Technol. 2022, 56, 11, 6847–6856

Typical Particle Emissions of Internal Combustion Engines

Diesel

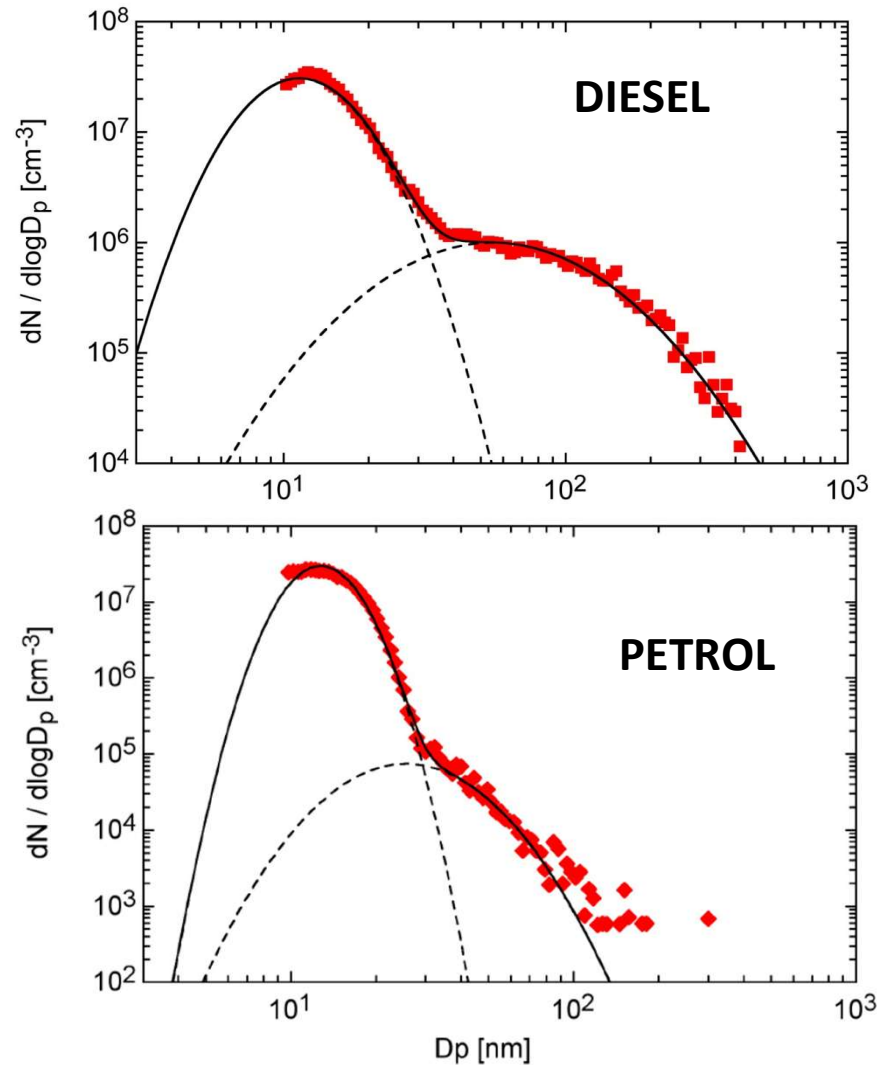
Soot peak: ~**80 nm**; 10^6 - 10^7

Ash peak: 10 nm;

Petrol

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

Ash peak: 10 nm;



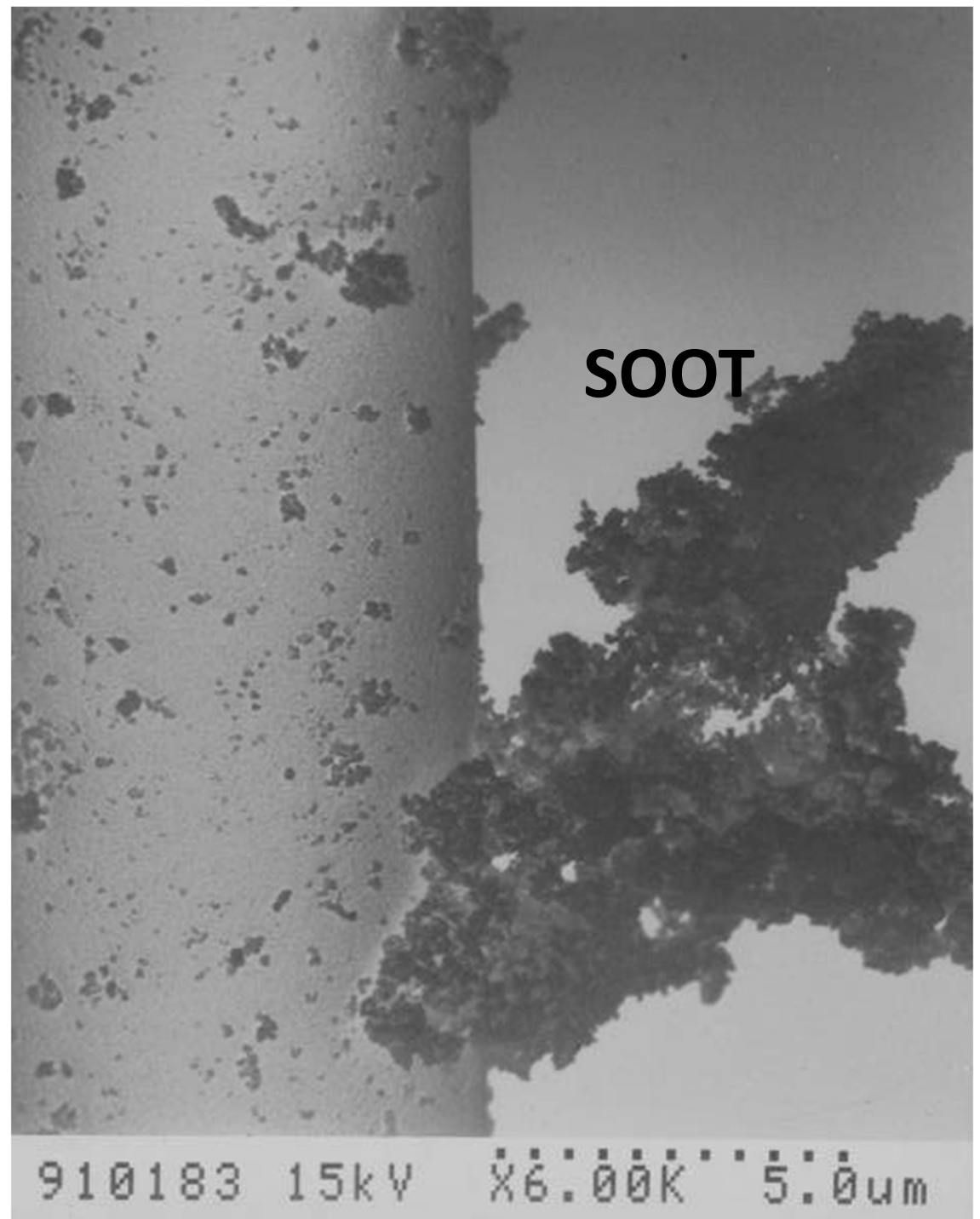
Source SAE 2012-01-841 Mayer et al



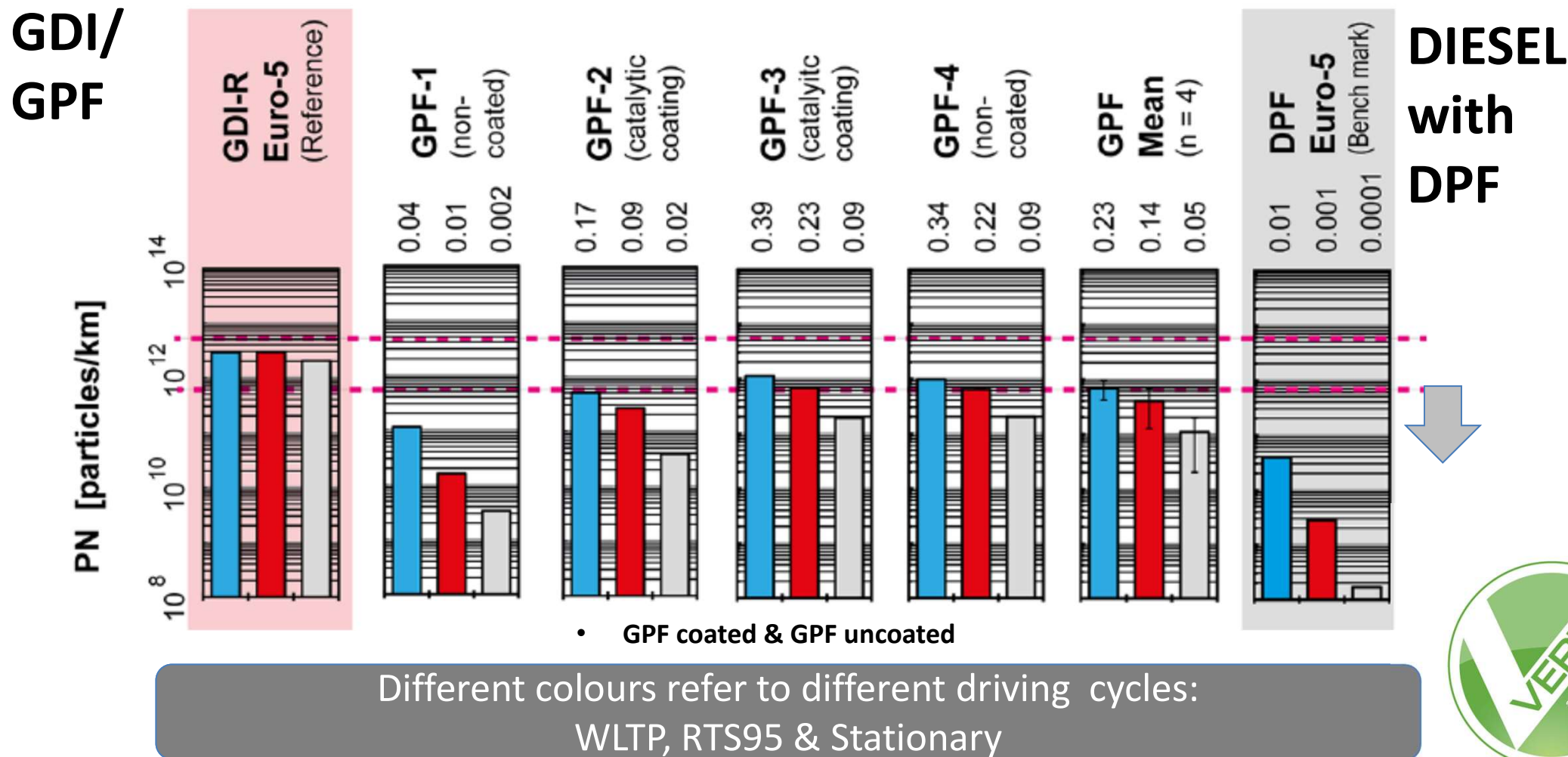
Soot Particles (UFP) a double Risk because of

- **size <100 nm**
- **surface > 100 m²/g**
- **carrying toxics**
- **persistent in organism**
- **carcinogenic**

→ long life toxic aerosol
weeks to months in air,
years in the organism



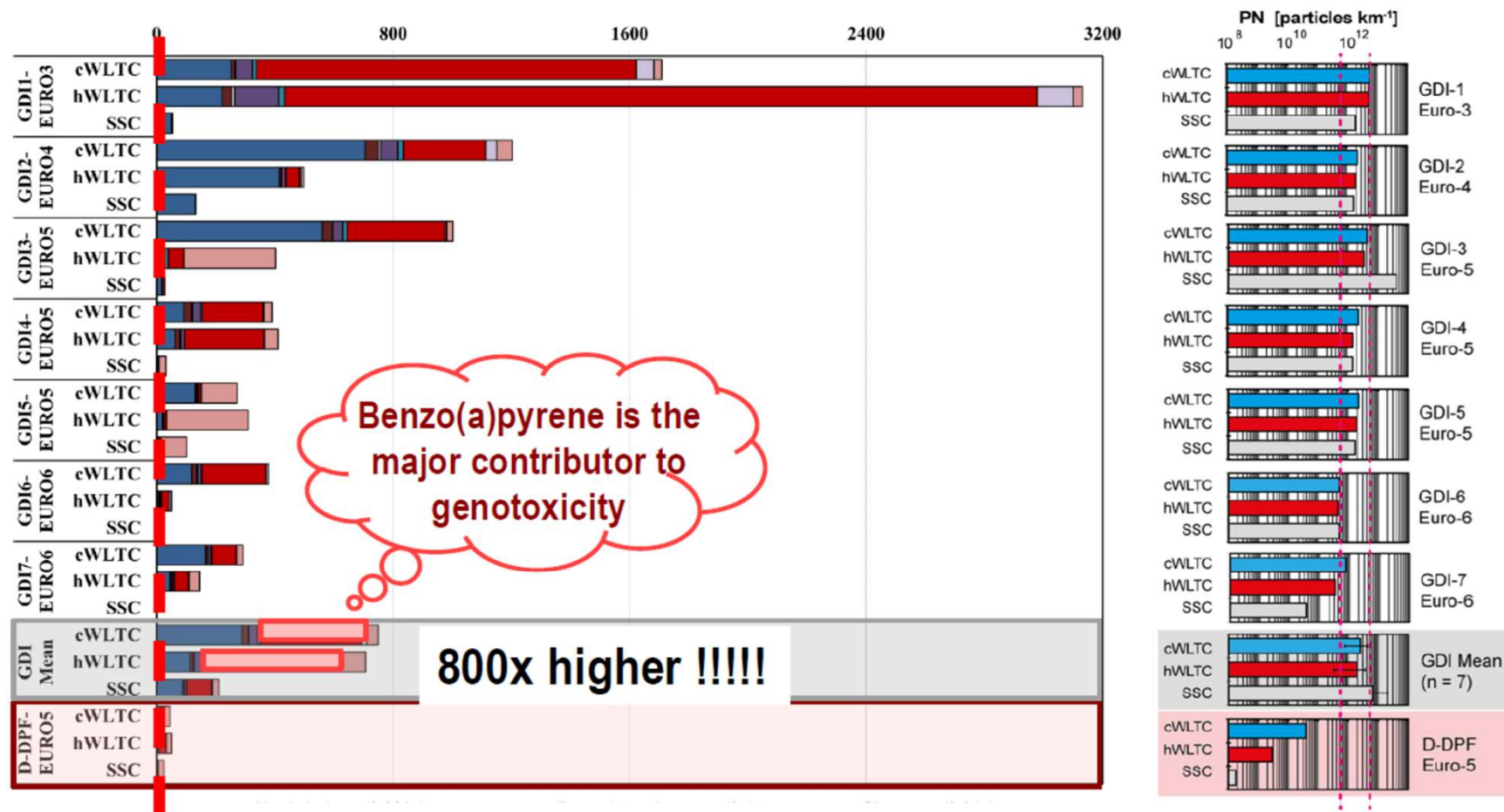
DI Petrol engines with/without GPF compared to Diesel with DPF – by far not good enough



*Source: Czerwinski J. / AFHB et al; SAE 2018-01-0363



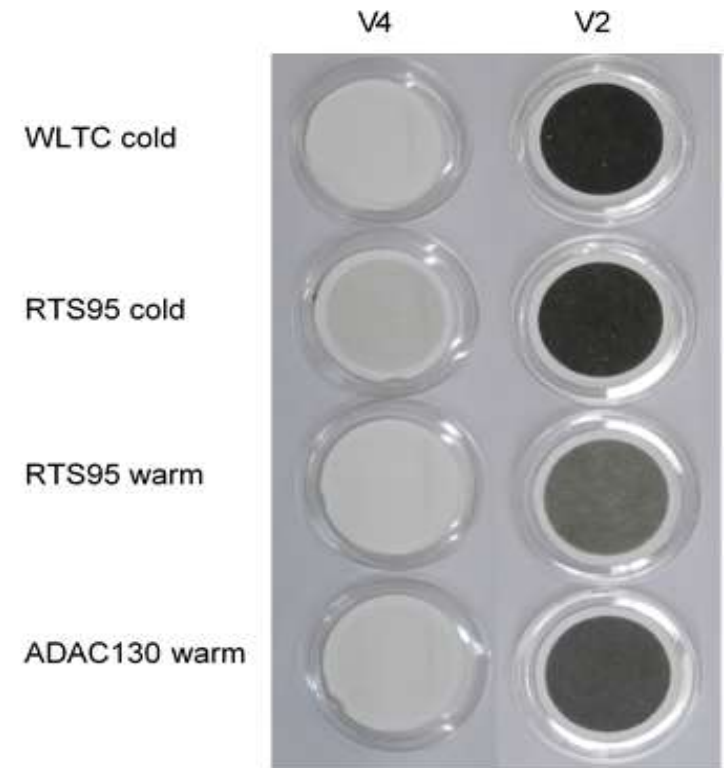
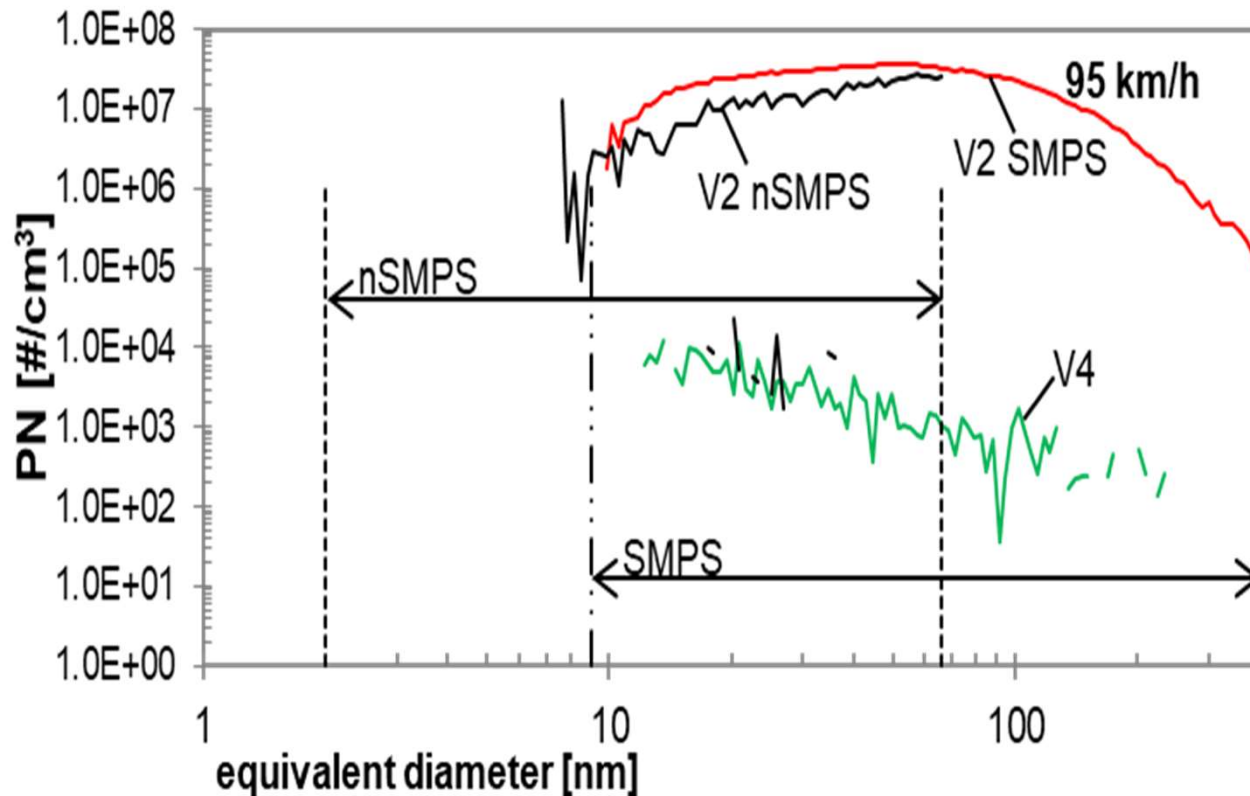
DI Petrol Engine – High PAH Emissions



*Source. Muñoz M. / EMPA et al, 2018

PFI engine may be even dirtier

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

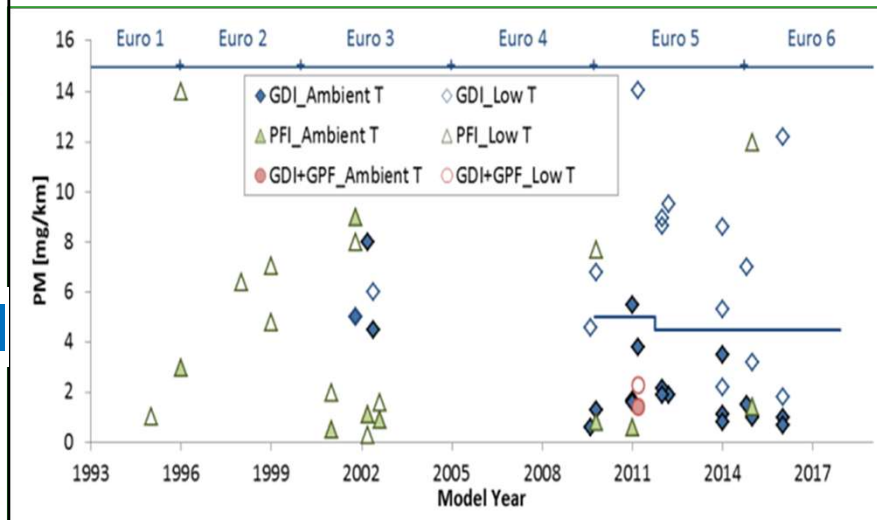
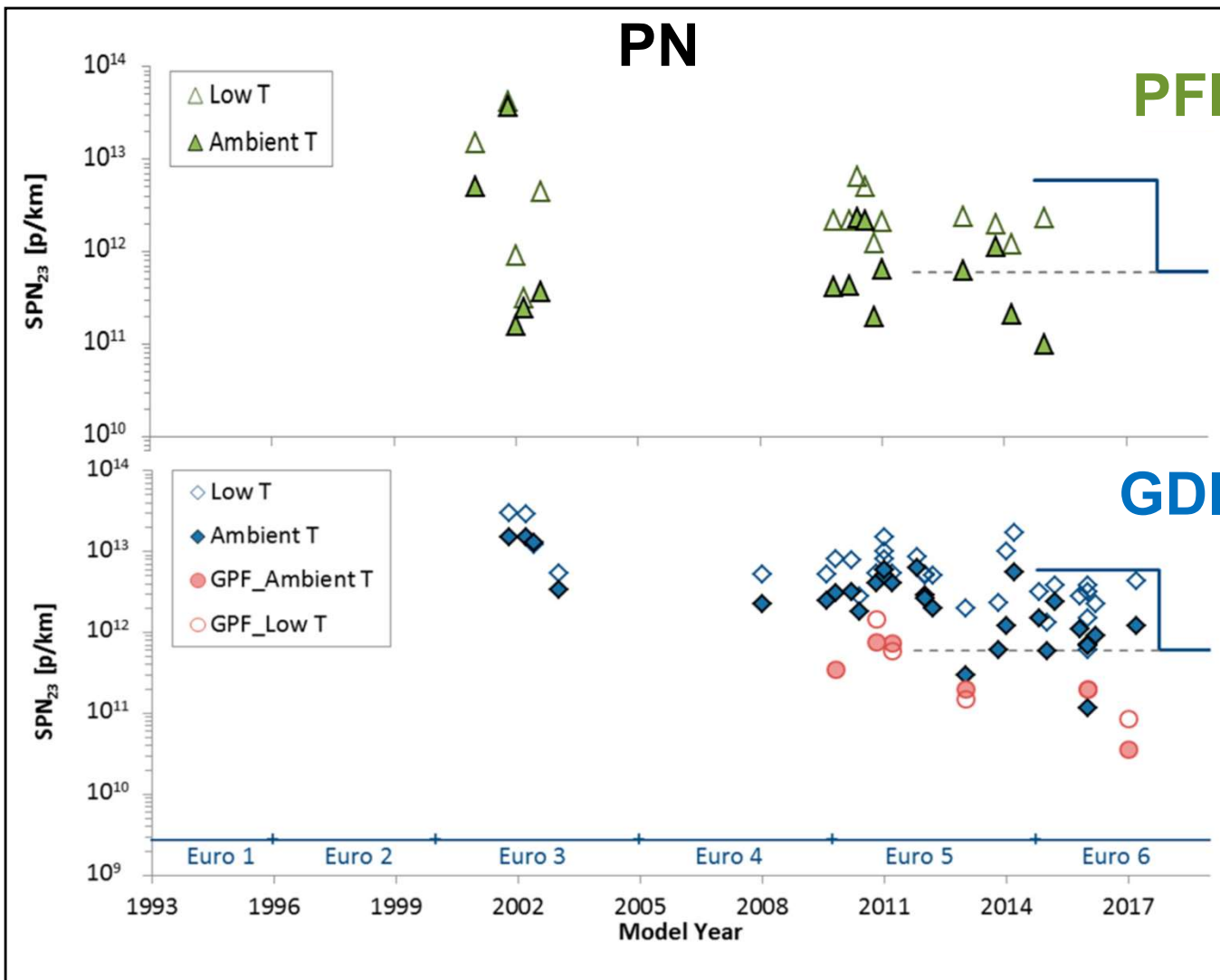


V2 vehicle

*source SAE 2018-01-0363 / FILTECH2023

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

GDI vs PFI

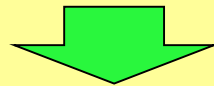


*Source: Review European Regulatory Framework and Particulate Matter Emissions of Gasoline Light-Duty Vehicles- B.Giechaskiel et al, 2019

Petrol Engine & GPF

	PM	Engine out Gas T (deg. C)	O2 Conc.
GDI	LOW PN (1-10x10E+12 #/Km) PM (2-10 mg/Km)	HIGH (up t 800) deg. C)	LOW (0-20%)
Diesel	HIGH PN 10-100x10E+12 #/Km PM (10-50 mg/Km)	LOW (Max 400 deg. C)	HIGH (10-20%)

- Fast soot accumulation (Diesel) vs. Slow soot accumulation (Gasoline)
- Higher impact on back pressure (Gasoline)
- Since gasoline engines exhibits very dynamic exhaust heating & cooling - Thermal Shock Resistance is critical for GPF

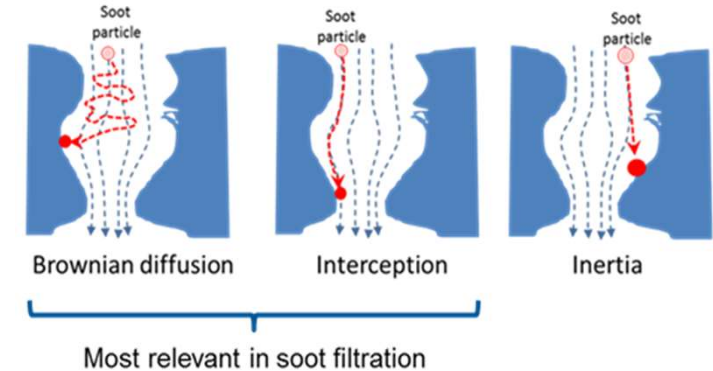


Cordierite best option material so far for GPF

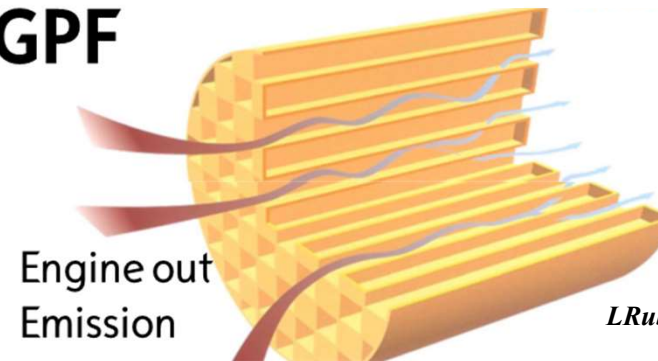
- ✓ Superior thermal shock performance (low CTE*)
- ✓ Better light off performance
- ✓ Isostatic strength & weight similar to substrate

*CTE= Coefficient of Thermal Expansion

Relevant Filtration Mechanisms



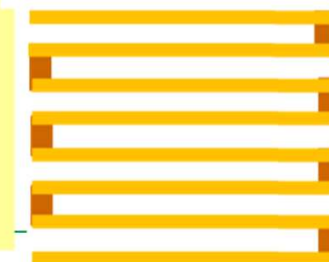
GPF



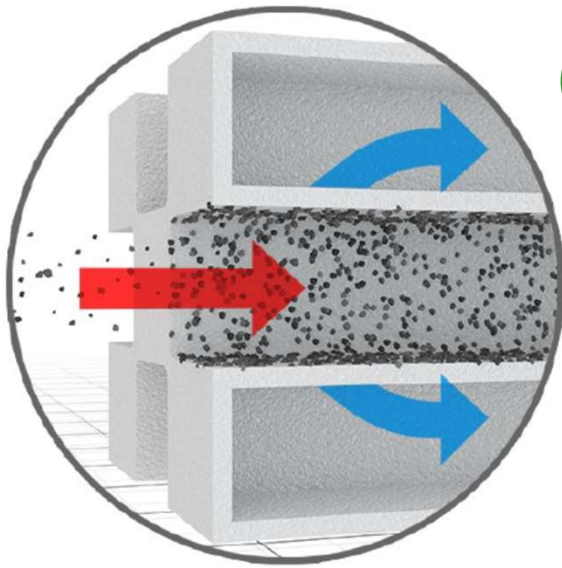
LRubino, Ludwisburg21_02_2018

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Alternately Open/Plugged cells

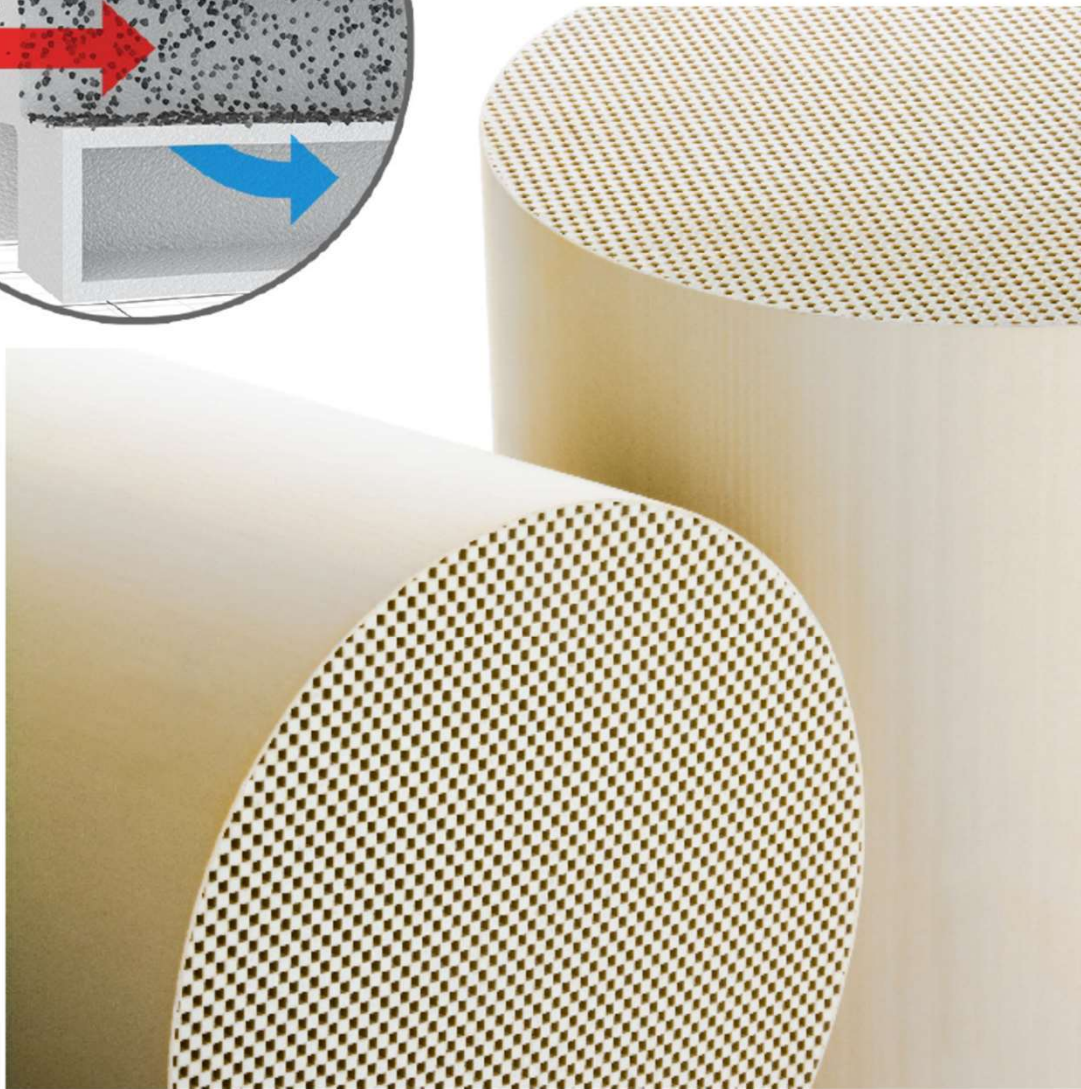


- **GPF filtration is dominated by the filter material vs. the soot cake in case of a DPF**

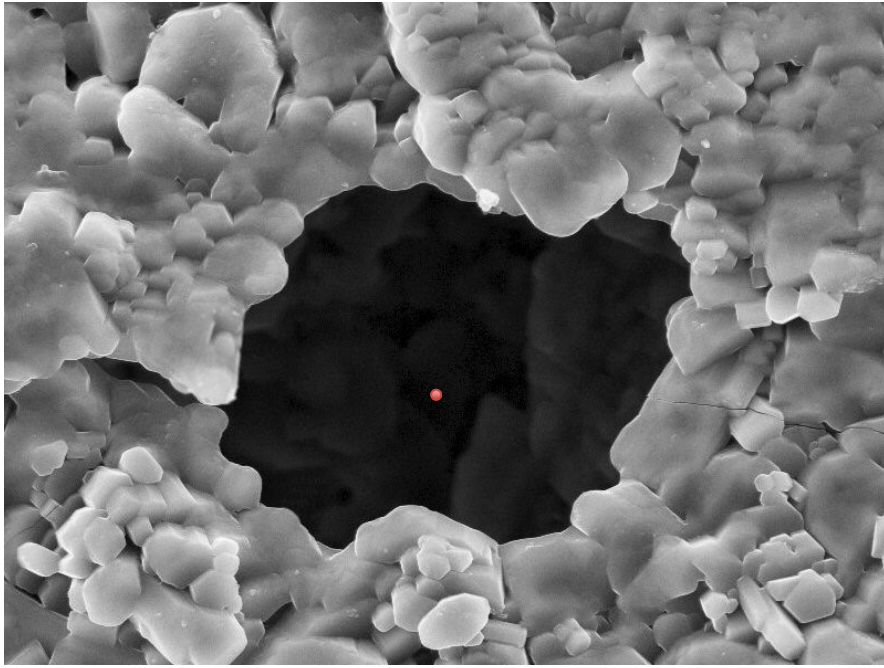


Ceramic wall flow multicell filter

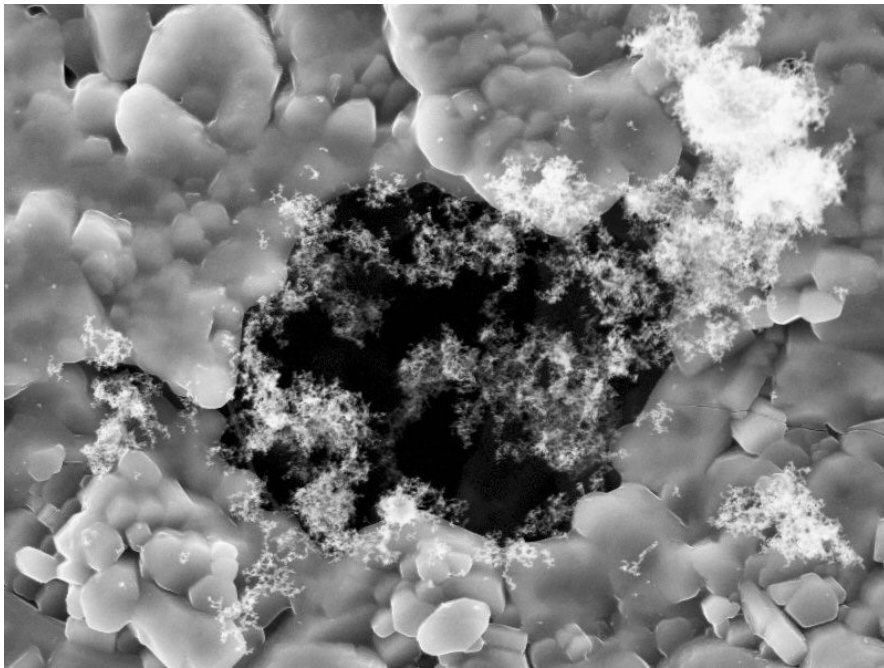
invented 1979, now > 200 Mio in Diesel cars



- pore size 10-20 μm
- porosity 45-65%
- 200 cpsi
- $>1 \text{ m}^2$ 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 $> 1000^\circ \text{ C}$
- no aging over vehicle life
- no vibration problem
- easy to clean

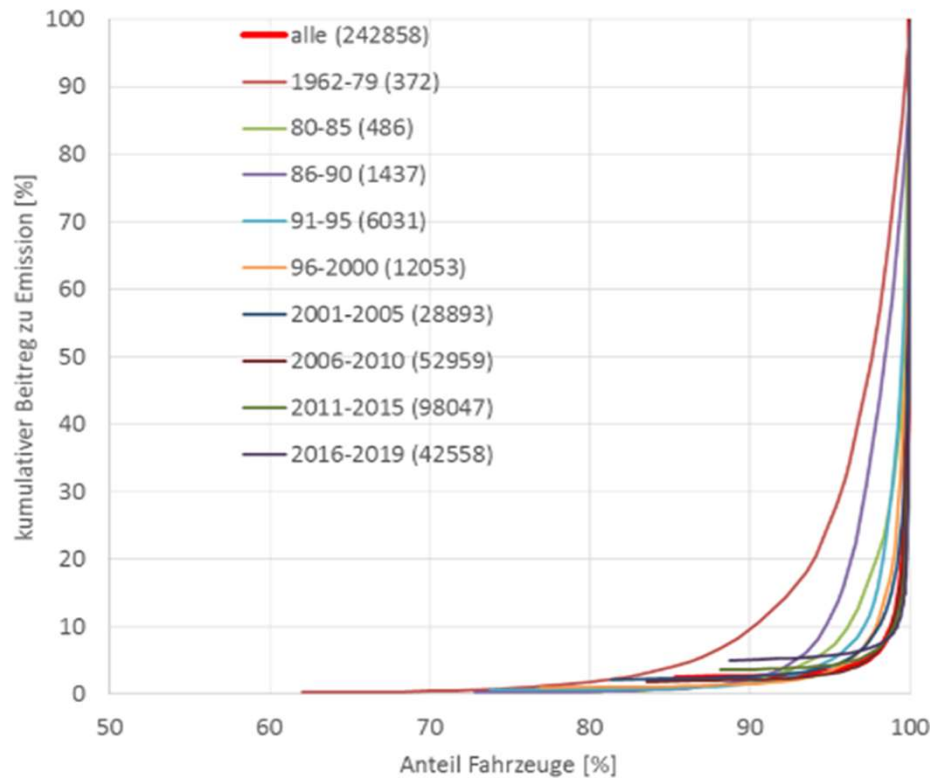


Particles 10-100 nm
are 100 - 1000 x
smaller than
filter pores 10-20 μm

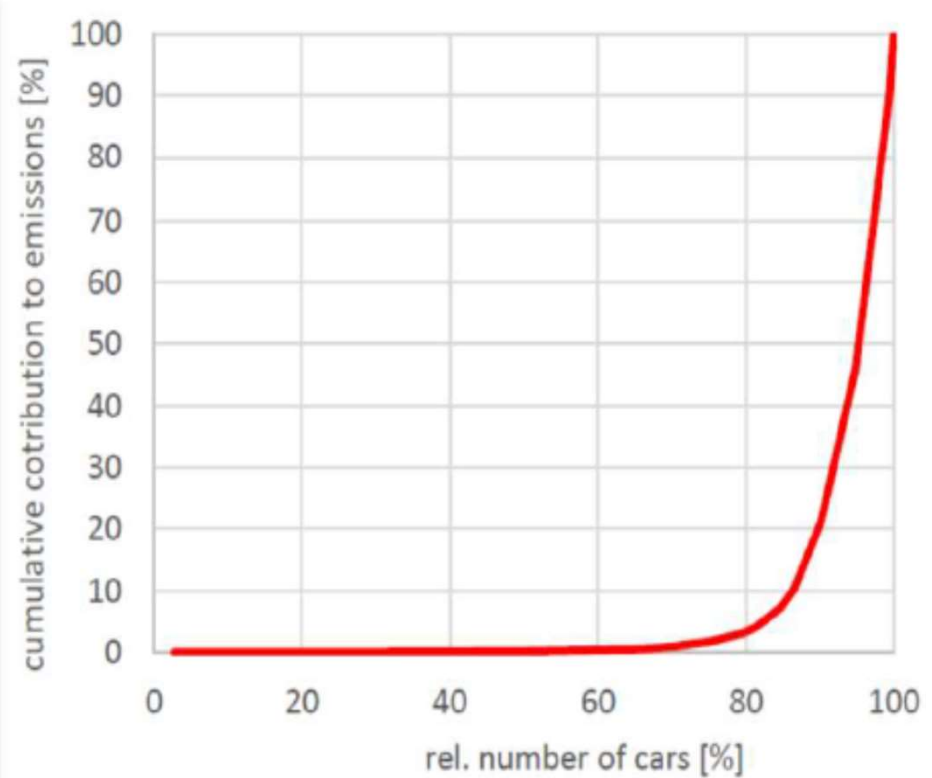


With ultrafine particle
structures we can
stepwise build a
“membrane” covering
the pore

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)

WHAT IS AEROSOLFD?

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

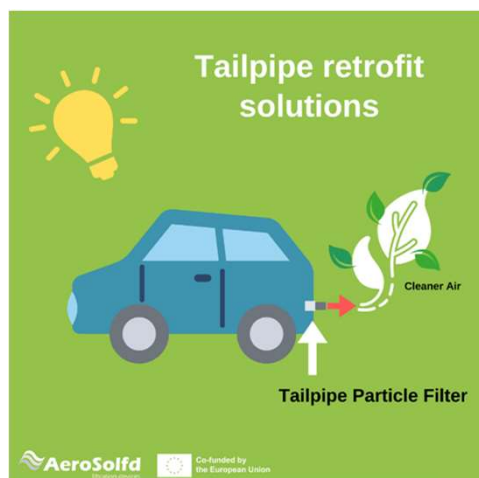
- **tailpipe**
- **brake systems**
- **(semi-)closed environments of retrofit Filtration Devices**

- EU funded Project within HORIZON Europe (IA)
- **VERT funded by SBFI** (the Swiss State Secretariat for Education, Research and Innovation)
- Total Funding for ~ €8.2 million

FOCUS: RETROFIT WITH PARTICLE FILTERS (GPF)

- AeroSolfd Solutions:

Reducing tailpipe emissions



Pillar A: Retrofits

Retrofit
Develop-
ment

Lighthouse
Demo Pilots

Retrofit
Products in
TRL 8

Pillar B: Market Preparation

Scientific Data + Sustainability
Assessment

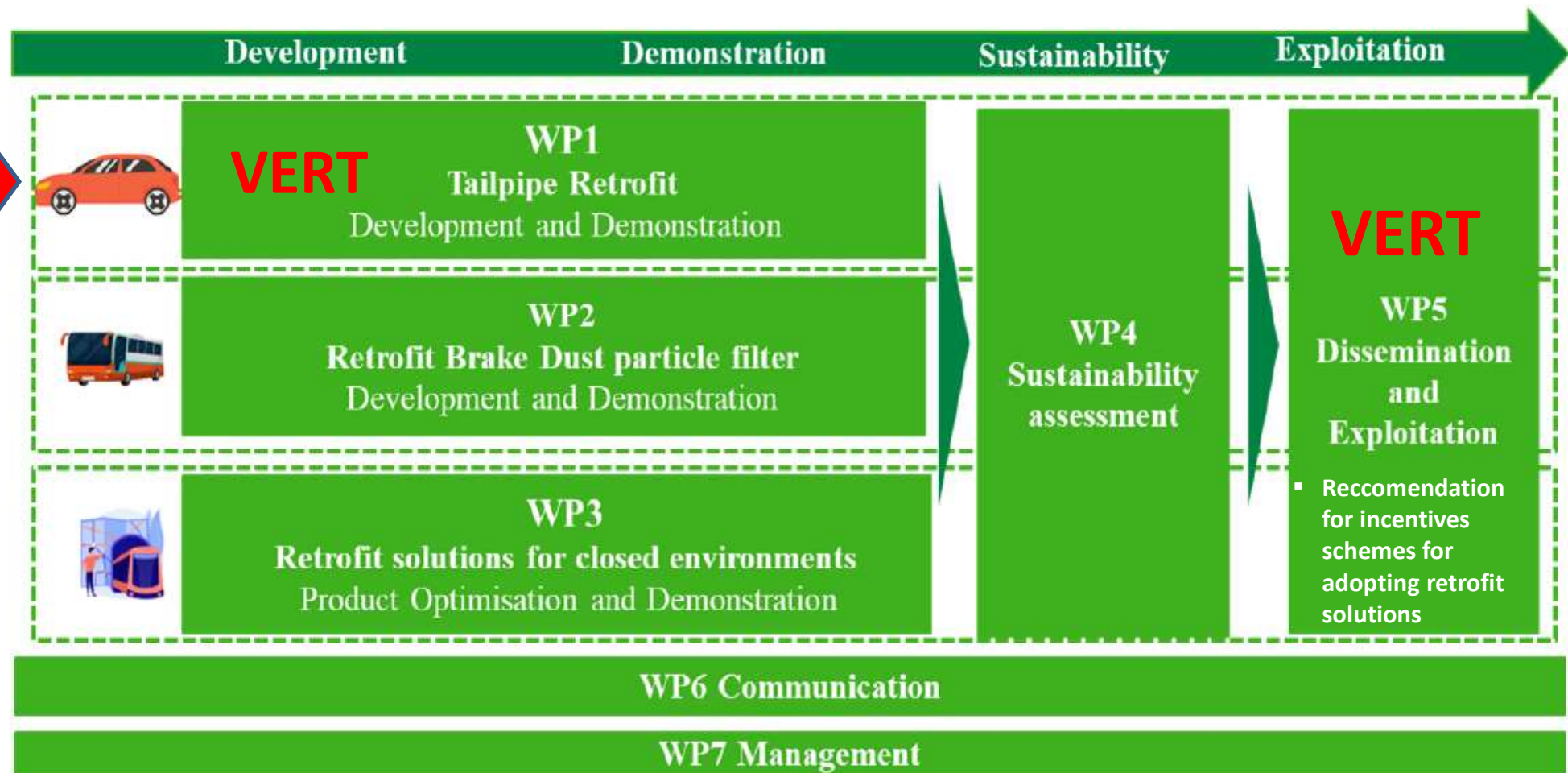
Public Awareness + Stakeholder
Engagement

Incentive
Scheme +
Exploitation
Strategy

Market
uptake

2025

Activities in the EU/ SBEI funded project AeroSolfd

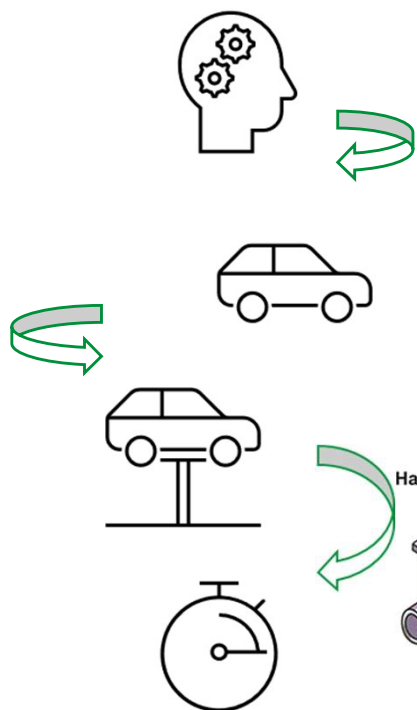


VERT with WP1 Partners: HJS, G-Technology, BFH, TÜV, Israel Partners

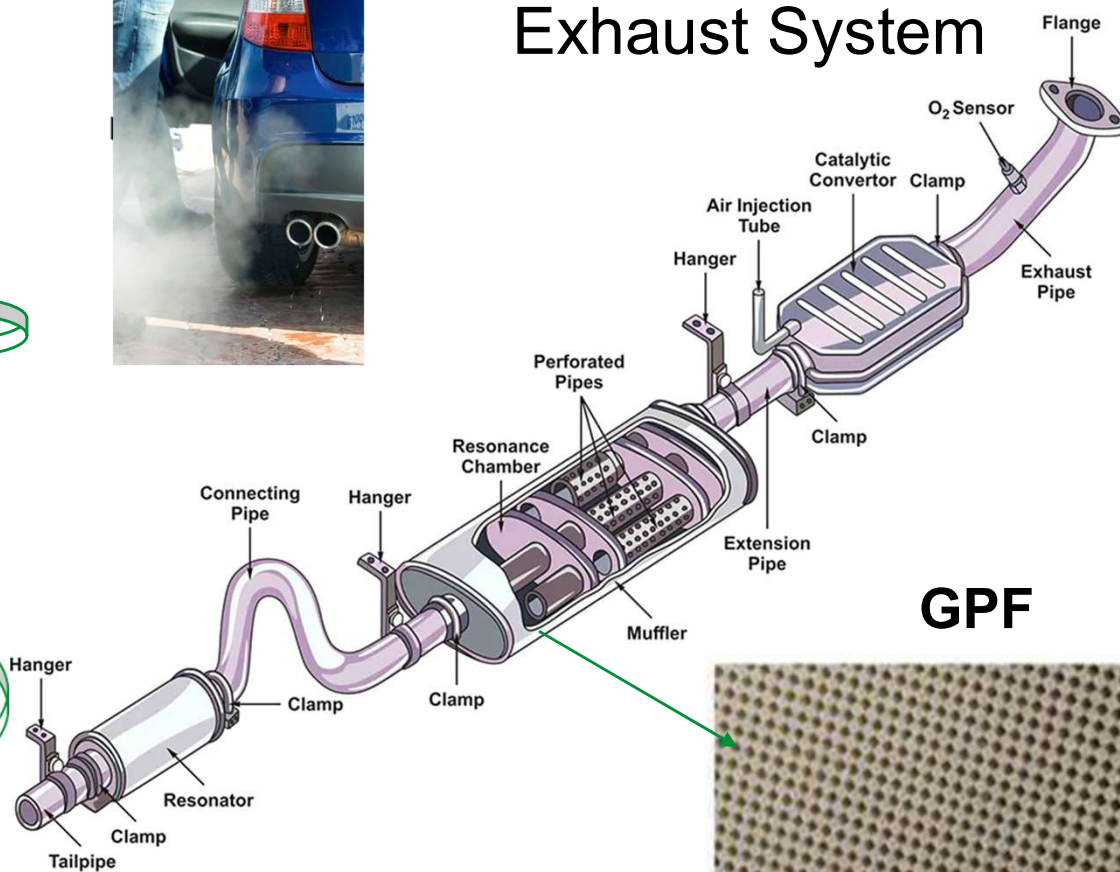
Horizon AeroSolfd - The project Targets

- Adapt and demonstrate an affordable **high efficient Gasoline Particle Filter (GPF)**
- Capable of reducing **95% of the exhaust particles**
- **Cost efficient solution** (circa € 700 - 1.000) depending on engine size and power rating
- **Fast track to market** by using an already proven technology in high volume production
- **Measure PN and secondary emissions** (i.e. PAH, Nitro-PAH, NH₃, N₂O) to evaluate the impact of the retrofit filter
- **Exploitation plan for retrofitting 5 million vehicles with GPF by 2035**

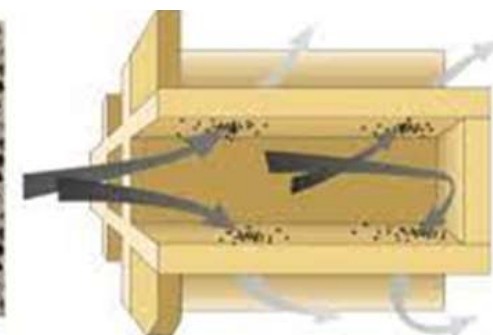
Overview



Exhaust System



GPF



Corning 200/8 GC2.0

HJS

- Retrofit System up to TRL 8

WP1 - Deliverables

CL5-2021-D5-01-15: Cost affordable and adaptable retrofit solutions

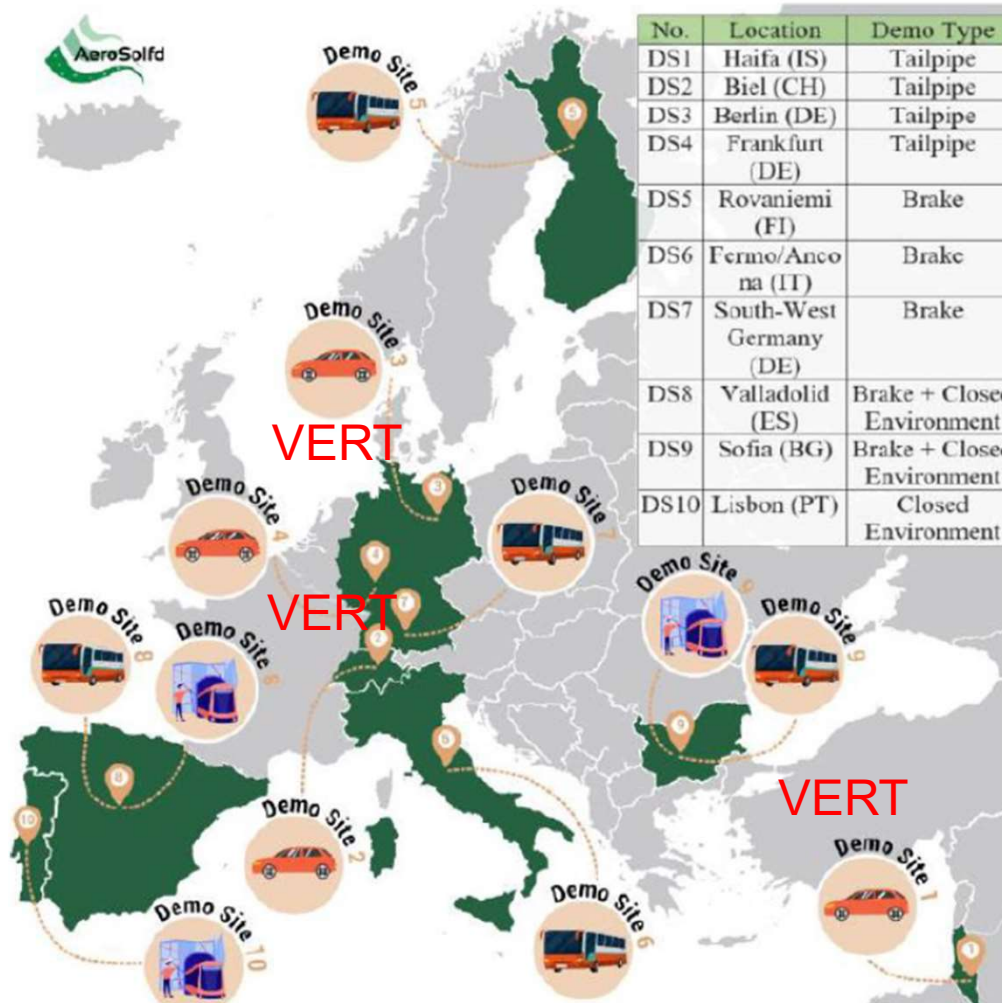
Innovation Action - Part B

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 ₂ O 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

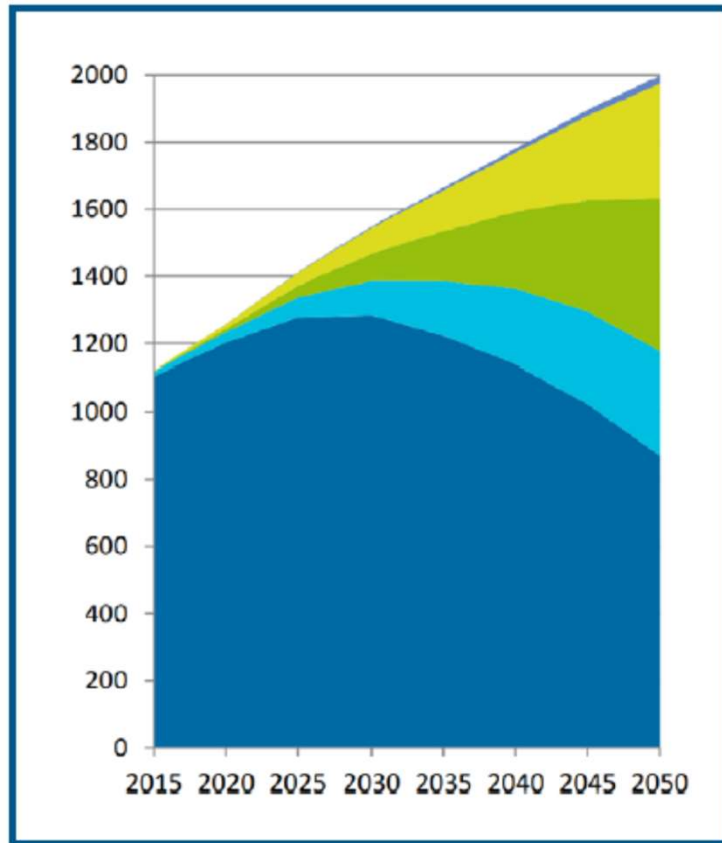
- The project will also serve as a platform to continue research on the “high emitter phenomena” with the NPTI test campaign of 1000 gasoline vehicle

Demonstration Sites (VERT)

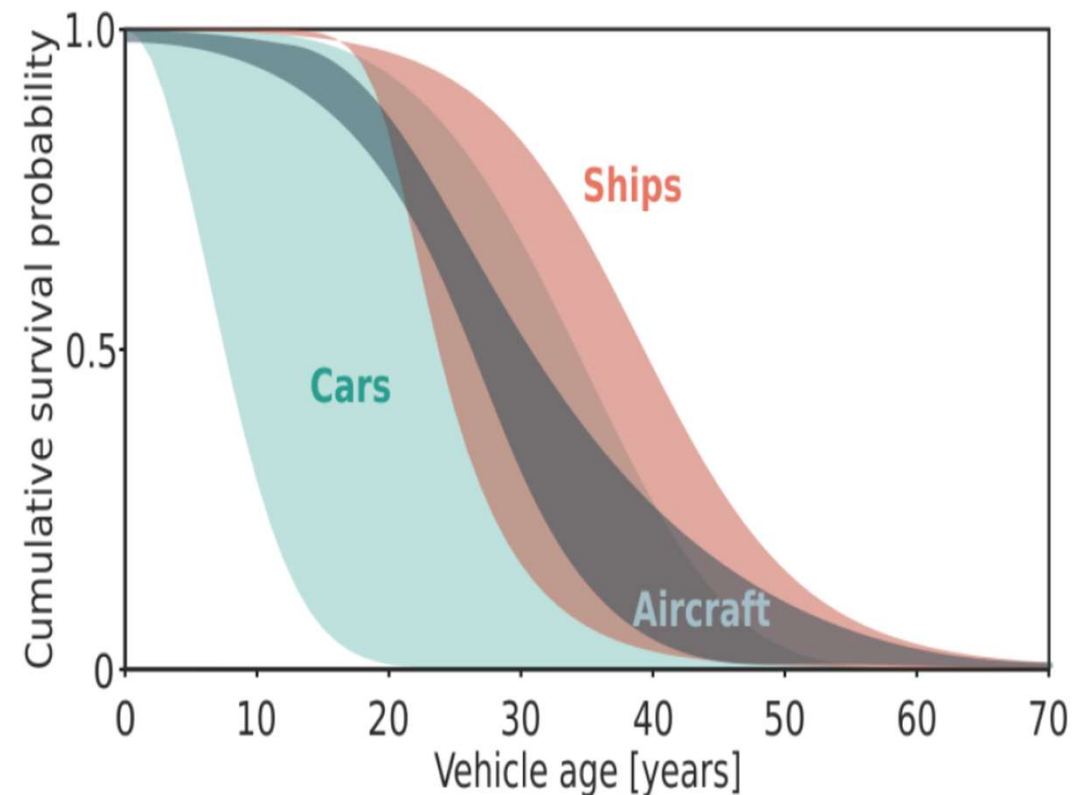


- one fleet in Germany
 - one fleet in Switzerland
 - one fleet in Israel
-
- **Tot 50 vehicles**
Operating 6-8 months

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



Fleet in Million (International Energy Agency, 2017)



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

*Source: FILTECH2023

and they might be old & high emitters... need emission upgrade by retrofit

Summary

- **Emissions of highly toxic 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**
- **Gasoline Particle Filter (GPF)** can effectively reduce PN emissions (~99%) **from Petrol engines**
- **The AeroSolfd project, with GPF retrofit** aims to the widespread introduction of GPF to reduce nanoparticle emissions from non-equipped high mileage gasoline vehicles **including PFI**
- **The likely “presence” of gasoline vehicles** until 2035 & beyond justify the need of GPF retrofit
- **Limiting the harmful effects of transport-related emissions** is urgently needed **in the transition towards cleaner mobility**

Acknowledgements

The VERT scientific network, in particular the ETH, the University of Fribourg, EMPA, AFHB, FHNW, and the Swiss Federal Agencies FOEN, FEDRO and SERI for their financial support of the work to date and for AeroSolfd, and last but not least the AeroSolfd Partners

Disclaimer

AeroSolfd is co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.“

THANK YOU FOR YOUR ATTENTION

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?

Lauretta.Rubino@vert-dpf.eu

