Horizon Europe AeroSolfd Project: VERT FILTER Retrofit and NPTI

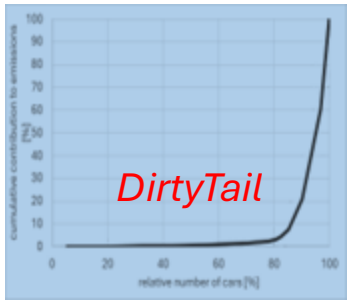
Dr. Lauretta Rubino, CEO VERT Association

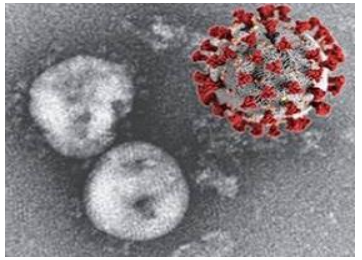
3rd Annual Mining Vehicle Powertrain Conference (MVPC)

Four Points Sheraton, Toronto, Ontario, Canada October 6th – 9th, 2025

AGENDA

- Introduction & Motivation
- HORIZON Europe AeroSolfd overview
- AeroSolfd VERT GPF-Retrofit
- NPTI
- Summary / Remarks





What is VERT?

- **VERT is a Non-Profit International Association** of filter, catalyst manufacturers, instrument, engine manufacturers, universities and research associates, **founded in 1993 in Switzerland during the NEAT New Transalpine Railways Program**
- **VERT stands for Verification of Emission Reduction Technologies** & it is a Particle Filter Testing, Certification & Quality Control System, a Trade Mark for Particle Filters of **Best Available Technology (BAT)**
- **VERT has played a key role in promoting PN emissions legislation**, emphasizing the focus on nanoparticle and secondary emissions from both diesel and gasoline vehicles - EU adopted VERT Criteria in 2006 for Euro 6 - EU Co-Decision (Art.12, Rec.15)
- **VERT has been very active on "New periodic technical inspection" (NPTI) since 2016**, **establishing a new test method within the international VERT-NPTI working group** (2016-19) for testing DPF-equipped Diesel vehicles, collaborating with different policymakers, environmental and type approval authorities, equipment manufacturers and PTI service providers, **as well as conducting different NPTI case studies**
- **VERT® has developed** some of the most important **particle filter testing procedures, supported various international partners with retrofit programs and consulting** and established a worldwide scientific network of manufacturers of components, systems, engines, vehicles and PN measurement devices specialized in the field of “air quality” and nanoparticle emissions control
- **VERT has 40 members** including **universities and research centres as associate partners**

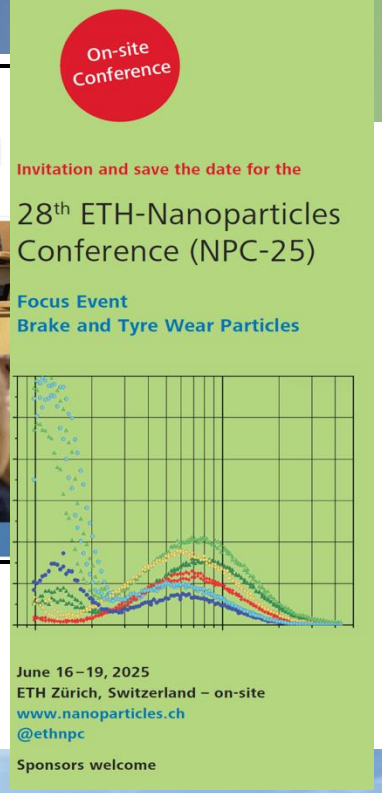
VERT Milestones / Achievements

- **2024 & 2025 NPTI of gasoline vehicle fleet and the DirtyTail phenomena**
- **2023 & 2024 DPF for Global Warming Mitigation**
- **2022-2025 GPF Retrofit within Horizon Europe AeroSolfd**
- 2022 DPF-Membrane for Marine heavy fuel oil application
- 2020 DPF for Virus Filtration
- 2016-2019 NPTI- the introduction of PN-count at idle for DPF-PTI control
- 2016-2018 High Emitter Analysis with Mexico Ciudad and EU-JRC
- 2015 Start of stakeholder process for Iranian national emission legislation to eliminate UFP
- 2015 Legislation for construction equipment with DPF for public projects in Berlin
- 2014 Euro VI legislation in Europe and Retrofit programs in China and Iran
- 2013 Retrofit programs in Bogotá/Colombia
- 2010 First VERT Forum Dübendorf with >60 participants
- 2010 Cooperation between Switzerland and China to introduce Low Emission Zones
- 2009 Legislation for construction equipment in Switzerland with DPF
- 2008 Retrofit programs in the Netherlands and Italy; Low Emission Zones in London, Berlin and Munich
- 2006 Low Emission Zones in all major Cities in the Netherlands
- 2005 DPF Retrofit program in Chile
- 2002 DPF duty for Diesels in all metal mines in the USA
- 2000 California Show Case Diesel Risk Reduction Program (Program to reduce diesel PM emissions in California by 75% by 2010 and 85% by 2020; London/United Kingdom starts to retrofit the transport system
- 2000 VERT-certified DPF for tunneling in Switzerland, Germany and Austria mandatory
- 1998 Boston: DPF duty for construction machines (“Big Dig”)
- 1997 First VERT Filter List published, based on PN and secondary emissions
- 1996 Retrofit program of 20,000 city buses in Germany
- **1994 VERT-Project started: DPF developed for Swiss Tunneling NEAT**
- **1993 VERT was founded**

International Diesel Particle Programs worldwide: Cile, Bogota, China, Iran, Israel, Berlin

VERT & its scientific network

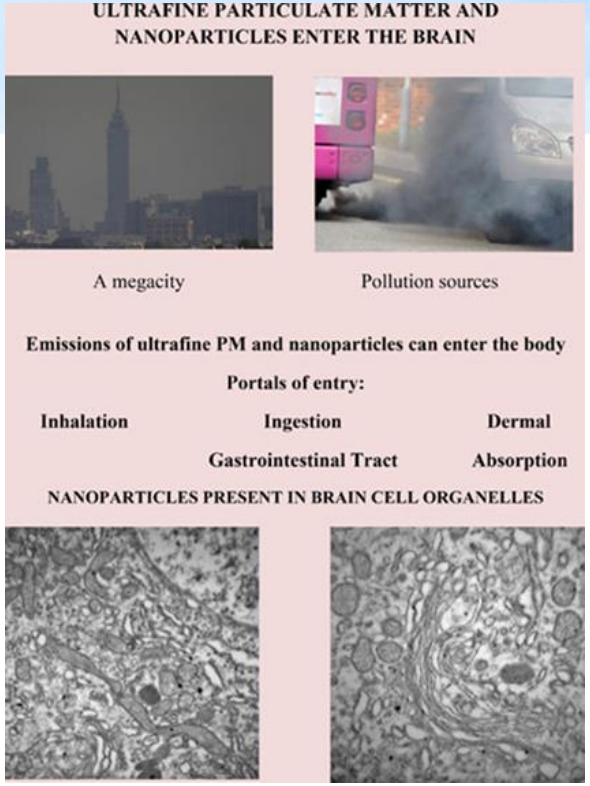
- **1997 first international ETH-NPC workshop** - 40 participants
- Today ETH-NPC is the annual event of UFP experts from science to technology
- **2010 First VERT Forum at EMPA** / VERT Forum every year
- VERT FORUM 2026 & Focus Day - March 19th-20th, 2026



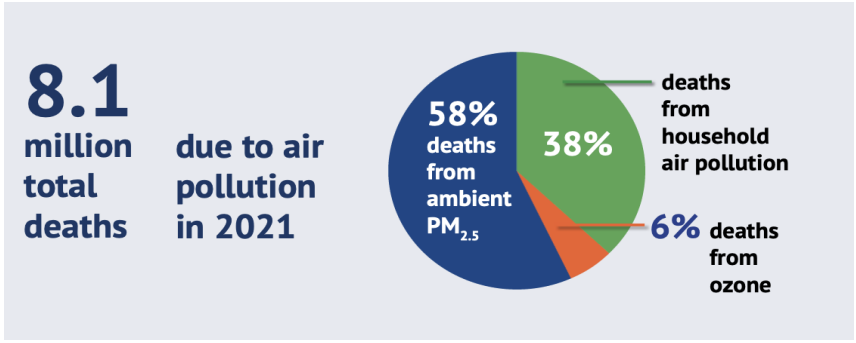
- **Many scientific publications in the field of nanoparticle** emissions control and filtration, over 200 reference available on the VERT website (Only for members)

Introduction

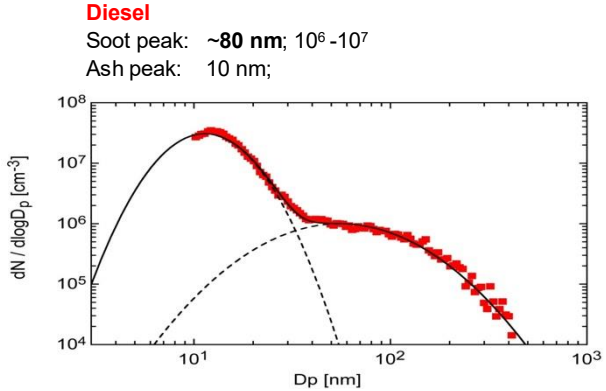
- **Sub-50 nm particles** originating from traffic emissions **pose high risks to human health** due to their high lung deposition efficiency and potentially harmful chemical composition
- **Road Transport is the major contributors** & above all in urban areas
- **Several studies have shown that Petrol engines are of concern as** they emit **high PN** and **in smaller sizes** compared to Diesel and **high PAHs**
- **So far only GDI PN emissions are regulated** in Europe, **No PFI** and no PN emissions legislation in USA



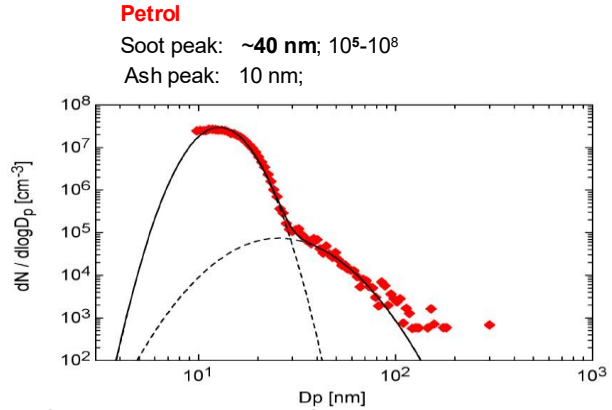
Environ. Sci. Technol. 2022, 56, 11, 6847−6856



*Source New State of Global Air Report 2024



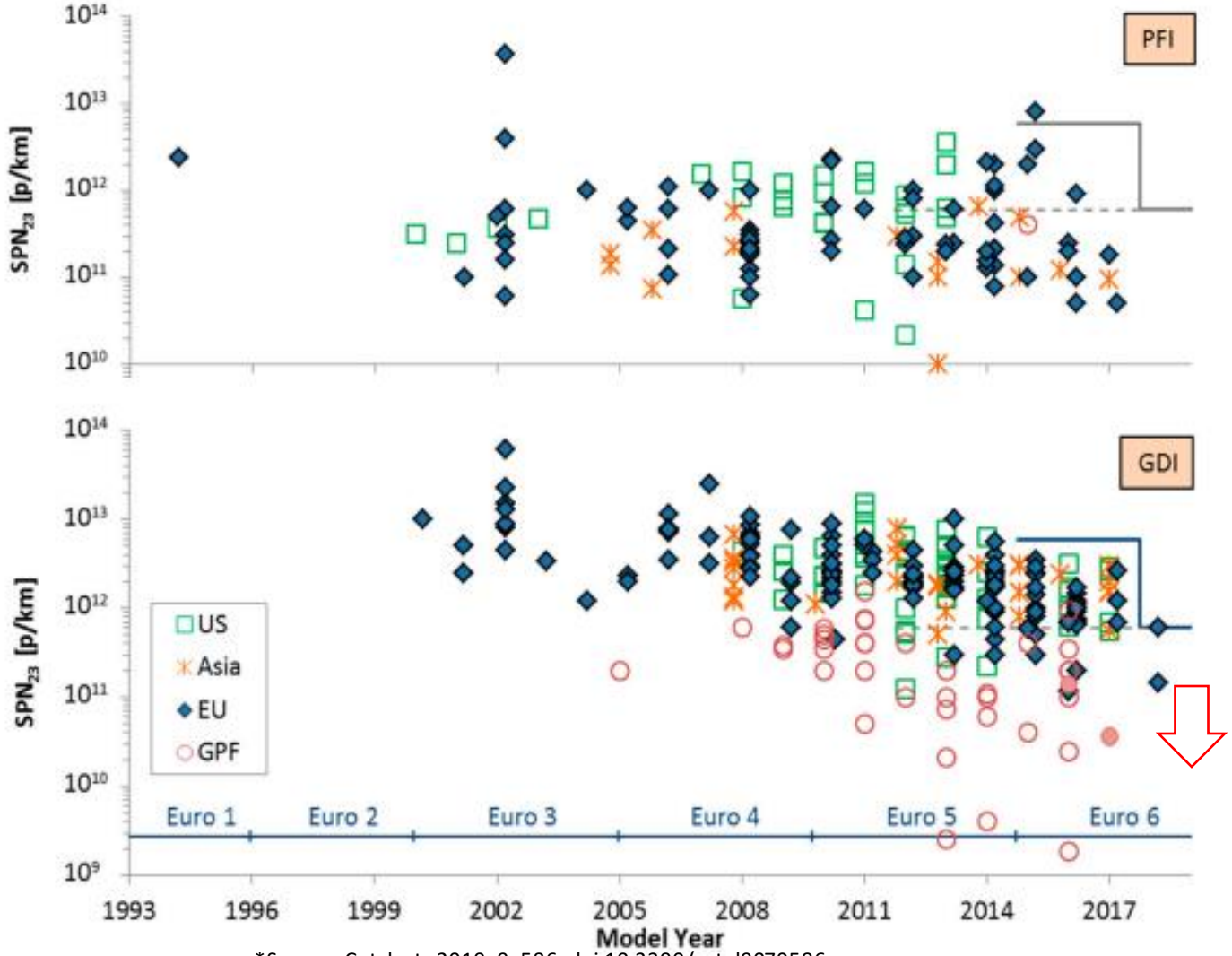
*Source SAE 2012-01-841 Mayer et al



*Source Dr. LRubino et Al. - SAE Paper 2023-24-0114

Introduction

GDI vs PFI



*Source: Catalysts 2019, 9, 586; doi:10.3390/catal9070586

- **Emissions levels from PFI** vehicles can exceed those from GDI vehicles
- **Low ambient temperature** conditions further increase the emissions
- **Assuming that PFIs still have an important market share**, they should be included in the next regulatory step

No EU PN Regulation for PFI


AeroSolfd
filtration devices
Fast Track to Cleaner Urban Air.

What is AeroSolfd?

AeroSolfd
filtration devices

The name AeroSolfd stands for: Fast track **to cleaner, healthier urban Aerosols market ready Solutions** for:
(1) tailpipe
(2) brake systems
(3) (semi-)closed environments of retrofit Filtration Devices

- **EU CO-FUNDED HORIZON Europe INNOVATION ACTION**
- Grant agreement ID: 101056661 - Topic: HORIZON-CL5-2021-D5-01-15
- „**Development and demonstration** of cost affordable and adaptable **retrofit solutions for tailpipe and brake polluting emissions**“
- Duration: 2022/05 – 2025/04 (36 months) **– end August 2025**
- EU contribution: € 5.00 million - Total cost: € 8.22 million
- Coordinator: MANN+HUMMEL
- **Swiss Fundings (SERI) to VERT for over 2.20 million CHF**

Co-funded by the European Union

Project funded by
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AeroSolfd Main Goals

(1) **Develop and demonstrate cost-efficient tailpipe retrofit filters for Petrol engines, both GDI and PFI. The Gasoline Particle Filter (GPF) retrofit replaces the underfloor silencer to reduce particle number (PN)-emissions with PN filtration efficiency above 95% in the existing high mileage urban fleets currently driving without any filter technology (Euro 6c and earlier)**

(2) **An existing passive brake dust particle filter (BDPF) concept developed by MANN+HUMMEL for passenger vehicles is modified for bus and commercial vehicle brake applications**

(3) **An optimized version of a stationary air filter is developed by MANN+HUMMEL for railway, metro companies or operators. By combining the latest technologies and simulation tools for smart applications, the exposure level will be lowered**

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AeroSolfd Market Ready Filtration Solutions

AeroSolfd
filtration devices

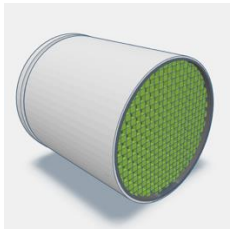
- AeroSolfd – **Fast track to cleaner urban air by market ready filtration solutions**

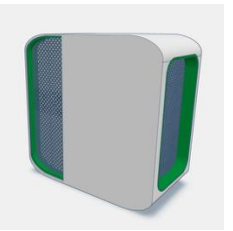
Reducing

1. **tailpipe emissions**
2. **brake emissions**
3. **pollution at metro stations**

VERT
GPF-Retrofit

Measure	Assess	D&C&E	Demo-site	Retrofit
VERT	VERT	Lead: Steinbeis Europa Zentrum	VERT	VERT
iuta	cenex nederland	all	LPP, Conerobus, AUVASA, Valladolid, Metropolitano de Lisboa, sofia development association	MANN+HUMMEL, ZF, MANN+HUMMEL
LINK	National Research Centre for the Working Environment			
idaea, Excelencia Severo Ochoa	INTEC			
CARTIF				





Budget in Mio €

- EU: 5.0
- Swiss: 2.2
- Industry: 1.0

8.2

16 Partners

8 Countries

Coordinator: Mann + Hummel

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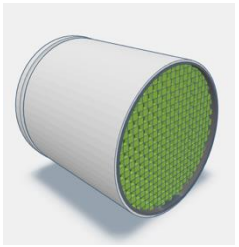
AeroSolfd Market Ready Filtration Solutions

AeroSolfd
filtration devices

- AeroSolfd – **Fast track to cleaner urban air by market ready filtration solutions**

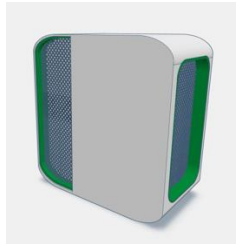
Focus: gasoline fleet (EURO 6c & earlier)

VERT GPF-Retrofit



- **Identifying four representative engine families** and adopt filtration solution (GPF)
- Validate retrofit solution on **4 vehicles to demonstrate PN and NOx reduction**
- Measure **secondary emissions (PAH, Nitro-PAH, NH_3, N_2O)**
- **Field test for 6-8 months to monitor performance of the VERT GPF-retrofi**t (42 vehicles)
- **NPTI testing campaign of 1000 gasoline vehicles (GDI, PFI, GPF-equipped)** to check for compliance and "high emitters" – **the Dirty Tail phenomena**

- **Develop representative brake cycle for urban** buses in a city (Valladolid, Ancona, Ljubljana)
- **Measure baseline emissions of raw emissions** of a typical brake on a dynamometer
- **Design and validate virtual twin of brake dust particle filter & test prototypes**
- **Demonstrate application on test vehicle on road** and in winter conditions
- **Define type approval process**



- **Identify how to trace emissions of typical metro brakes** (disc, block brake)
- **Measure exposure level** at demo-sites w/o and w/ filter at metro stations
- **Optimize design of stationary air purifiers** and manufacture prototypes for demonstration
- **Demonstrate the potential of air purifiers** to improve IAQ at a bus depot (3 different setups)
- **Define best practice for applying air purifiers as retrofit solution to metro stations**

Develop Framwork for Environmental-Social Life Cycle Assessment (LCA) of the three retrofit solutions

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Focus: Retrofit with GASOLINE Particle Filters (GPF)

- AeroSolfd Solutions:

Reducing tailpipe emissions

Pillar A: Retrofits

Retrofit Development

Lighthouse Demo Pilots

Retrofit Products in TRL 8

Market uptake

Pillar B: Market Preparation

Scientific Data + Sustainability Assessment

Public Awareness + Stakeholder Engagement

Incentive Scheme + Exploitation Strategy

2025

VERT Partners (WP1 & WP5)

HJS, TÜV Sud, G-technology, University of Applied Sciences Biel (BFH), CPK, Technion, Israel Institute of Technology, TCS (CH), AVLdiTest, Corning

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AeroSolfd - The Project Targets

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filtration devices

- Adapt and demonstrate an affordable **high efficient gasoline particle filter (GPF)**
- Capable of reducing **95% of the exhaust particles**
- **Cost efficient solution** (circa € 700 - 1000) 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
- **NPTI testing campaign of 1000 gasoline vehicles** (DI, PFI)
- **Exploitation plan for retrofitting 5 million vehicles with GPF** by 2035

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Results: Tailpipe Retrofit filter

AeroSolfd
filtration devices

Retrofit particle filter designed, tested, validated and demonstrated successfully

- **FILTRATION EFFICIENCY: 95 – 99 % (PN)**
- **Regeneration works** under normal operation conditions
- **No adverse effects on fuel consumption, noise, CO2 or secondary emissions**
- **Type approval process** started in Germany
- Durability testing on **42 vehicles equipped with the VERT GPF-retrofit** in different regions (Germany, Switzerland, Israel, Denmark) for a min of 6-8 months
- **No material damage of GPF** after durability testing
- **VERT GPF-retrofit is ready for implementation – cost-effective immediate solution to Clean Mobility**

Source: Retrofit in real life – VERT website https://www.vert-dpf.eu/

SAE 2025-24-0095

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VERT–Certified GPF Systems

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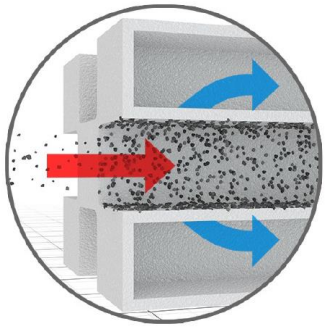
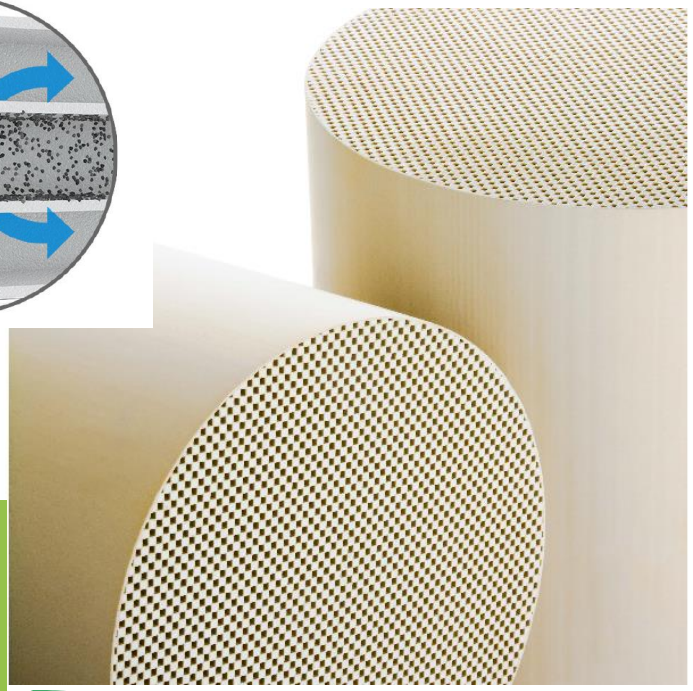
filtration devices

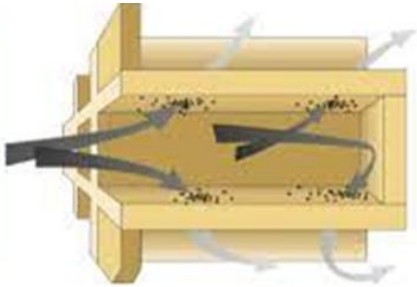




The VERT® seal of approval, used since September 2002, is known worldwide as a sign of particle filters of the highest quality and reliability.

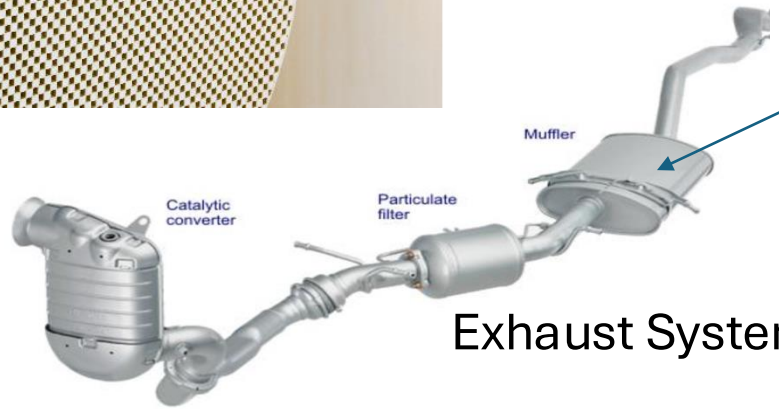
GPF

CORNING
Filter substrate



Corning 200/8 GC2.0

GPF serial production / GC2.0 APT2



Exhaust System

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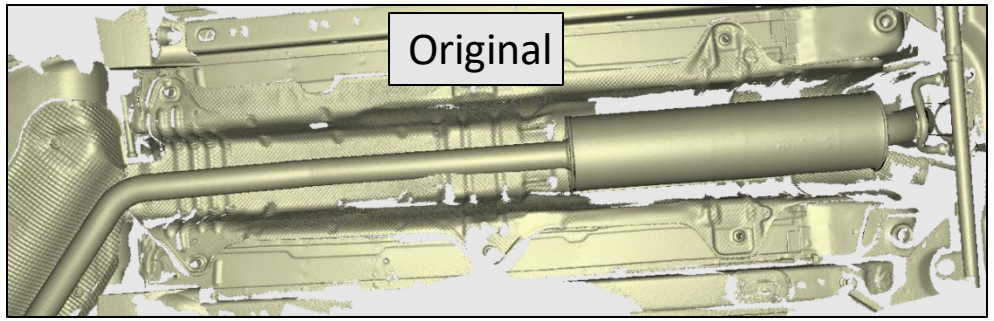
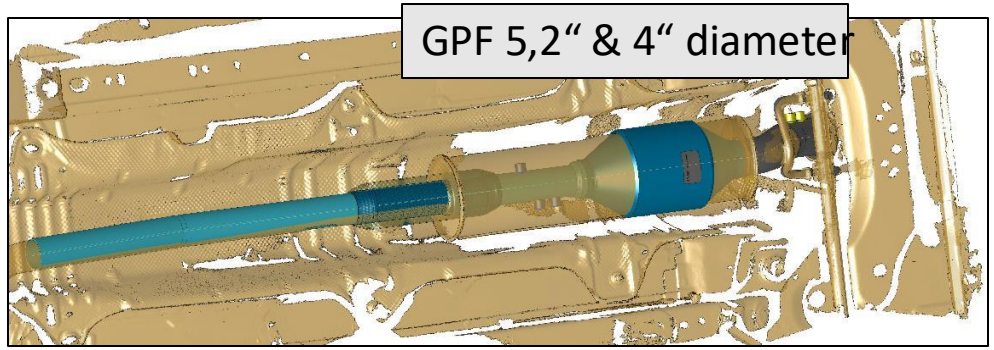
4 Engine Families Selected

Tailpipe GPF retrofit (example)





Peugeot 3008, DI ,1,6L

VW Golf

DI, 1,4L

FIAT, 500X

PFI, 1,6L

OPEL Corsa

PFI , 1,2L

Wiring, thermocouples, pressure sensor

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AeroSolfd – GPF retrofit Results

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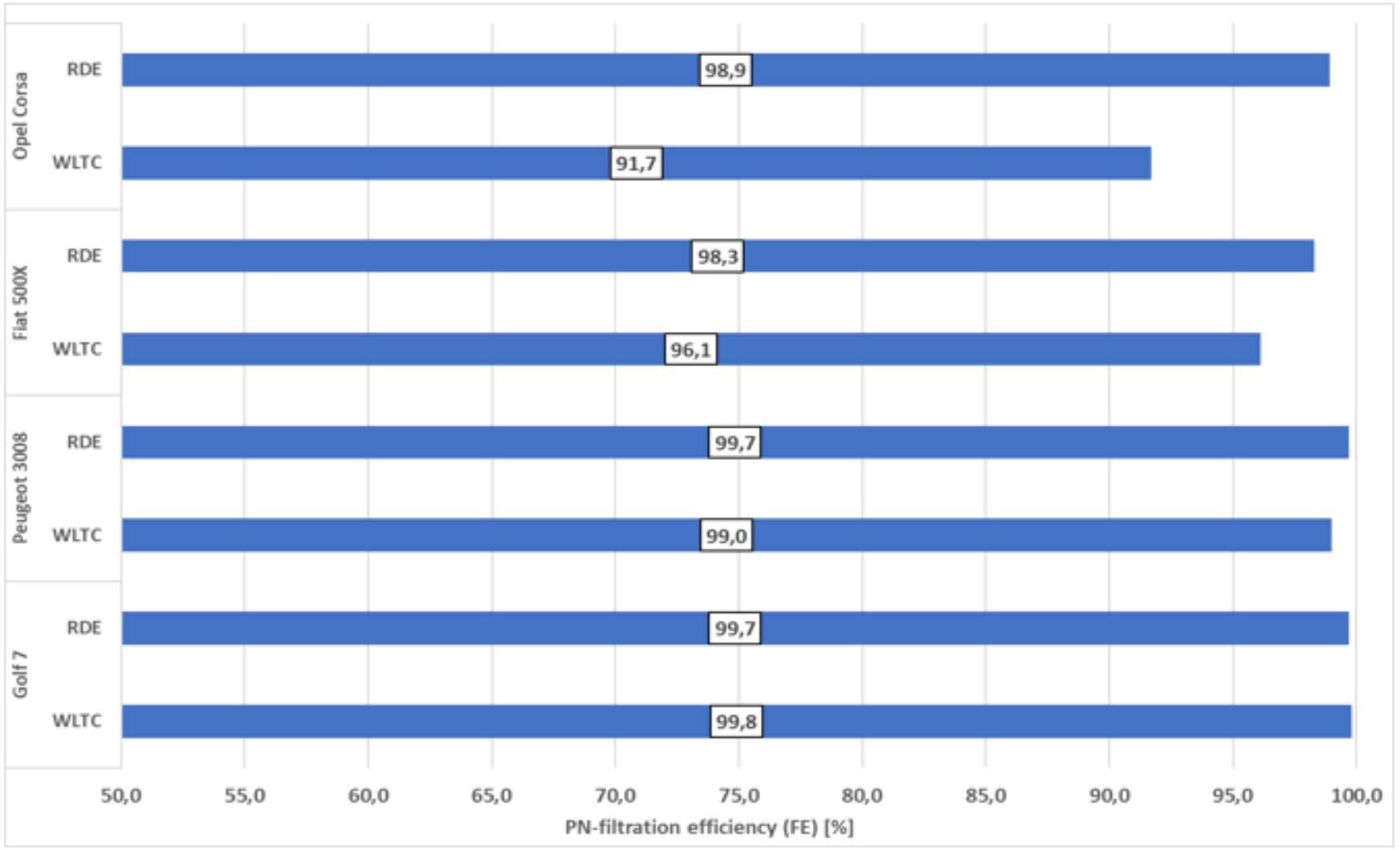

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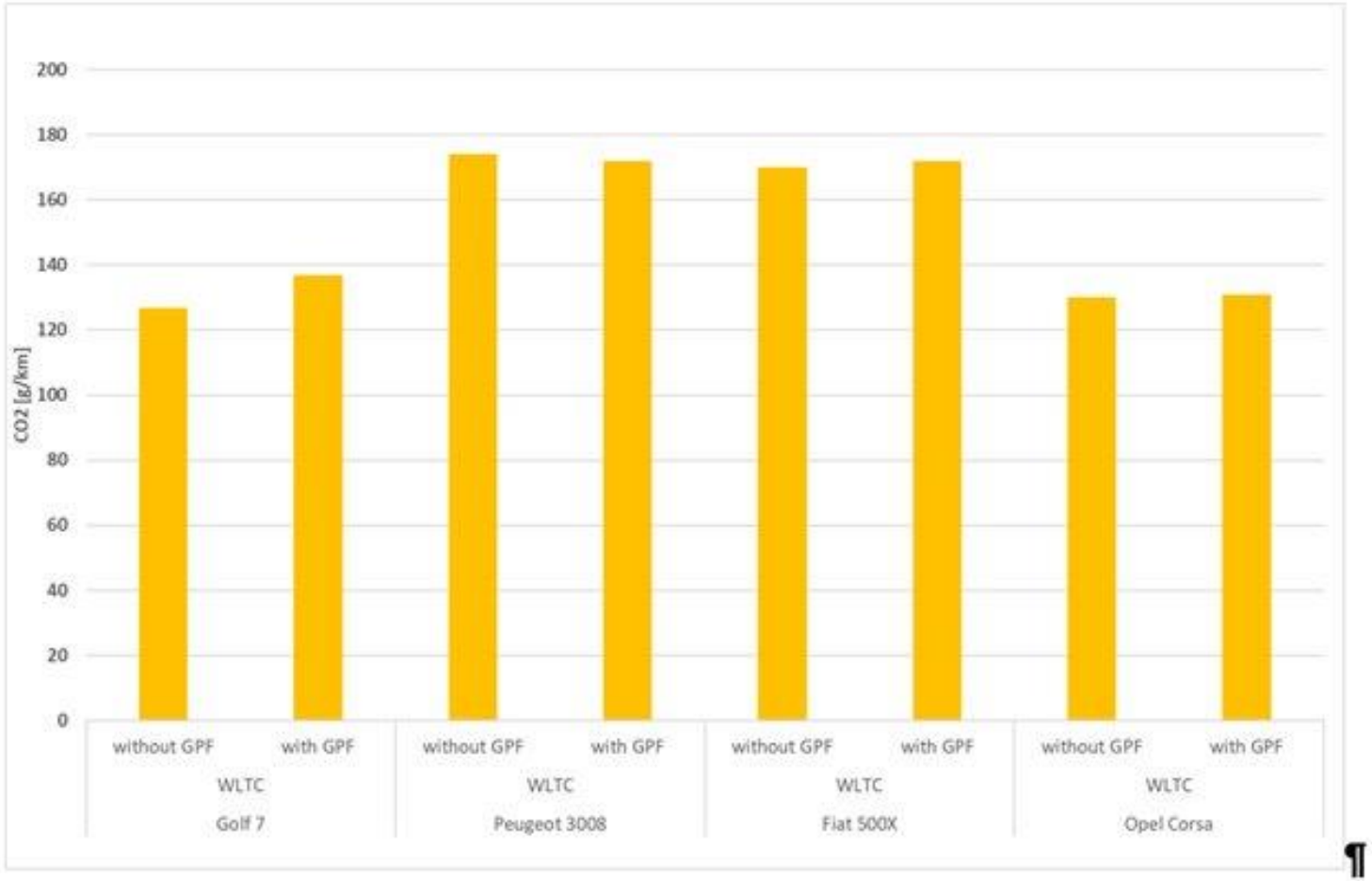
No issues with the GPF retrofit on CO2 / secondary emissions, drivibility or fuel consumption



Prüfbericht / *Test Report*
Nr. / No. : **TÜH TB 2025 – 017.00**
Teiletypgenehmigung (TTG)

TÜV Technische Überwachung Hessen GmbH
Automotive

Typ / *Type* : **OPF-01**
Hersteller / *Manufacturer* : **HJS Emission Technology GmbH & Co. KG**

Prüfbericht
Test Report

Gemäß der Regelung / *With regard to Regulation*

Nationale Teiletypgenehmigung (TTG) zur Nachrüstung von Partikelfiltern für Fahrzeuge mit Ottomotoren (OPF)
/
National Parts Type Approval concerning retrofit particle filters for gasoline Vehicles (GPF)

Gemäss KBA "grüner Liste" /
According to KBA „green list"

vom / *of* **19.12.2024**

- ✓ Type approval process started in Germany

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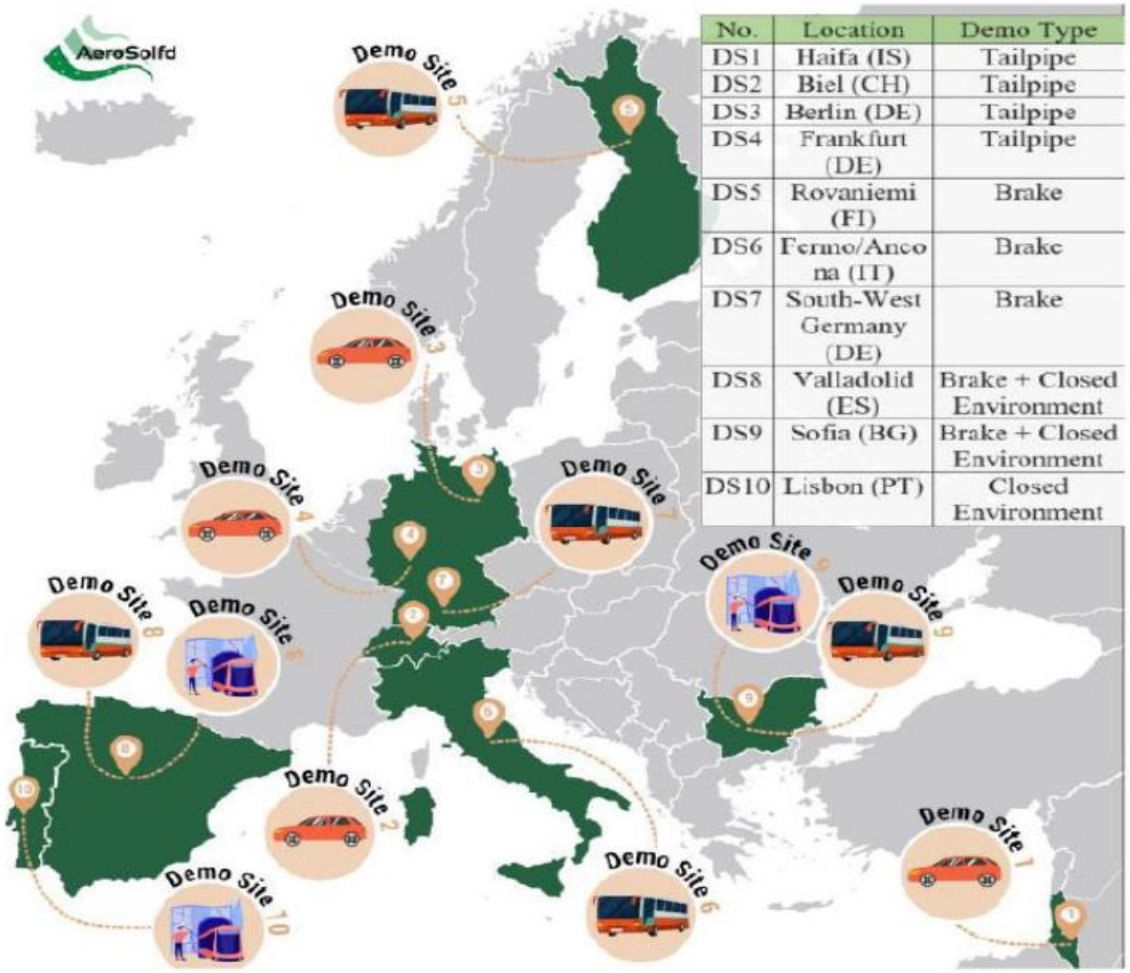
GPF Retrofit Demonstration Sites (VERT)



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

- **Tot 42 vehicles with GPF Retrofit**
  - one fleet in Germany
  - one fleet in Switzerland
  - one fleet in Israel and Denmark
- **Field operation for 6-8 months -** PN, PEMS measurements / data loggers to monitor continuously retrofit performance

Cloud interface with parameter visualization from CPK Automotive.

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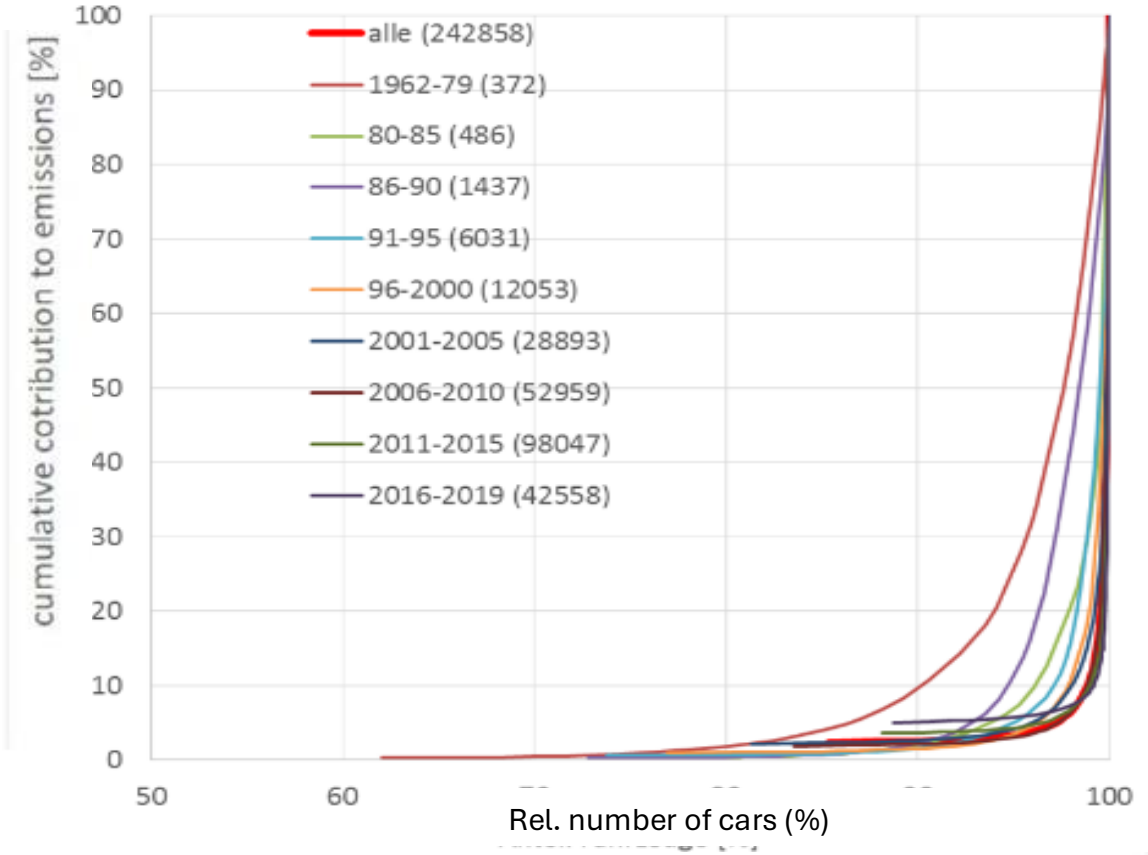
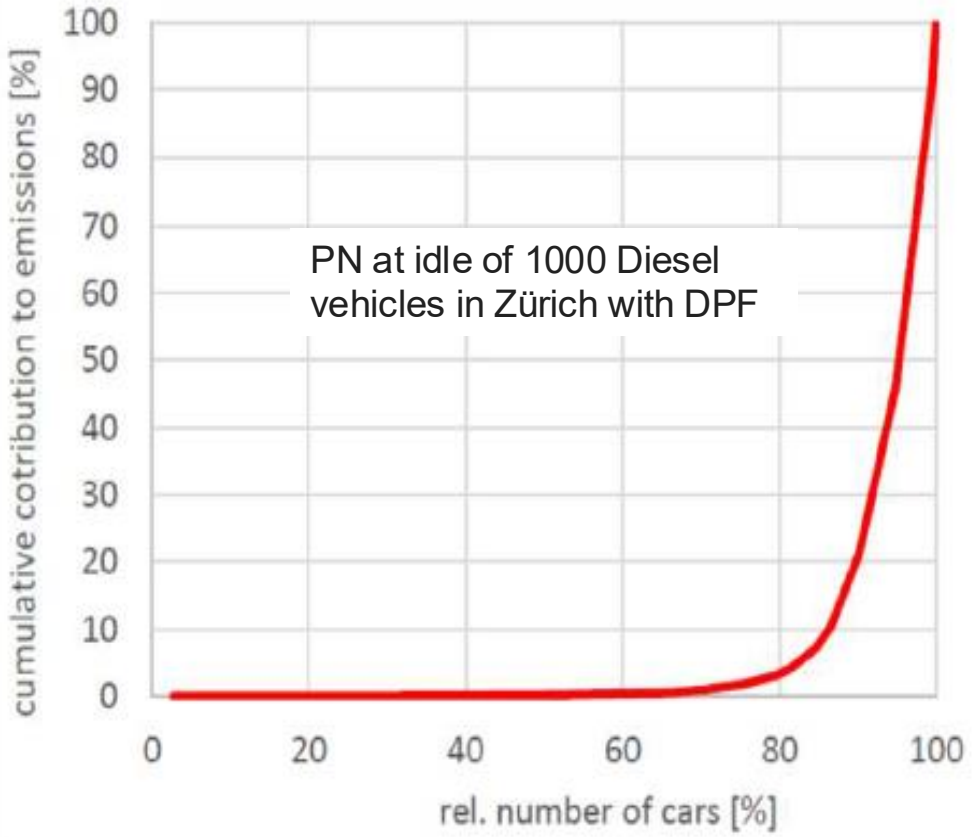
2-8% of the vehicles may produce > 90 % of the overall emission of the fleet



The «dirty tail» phenomenon with Petrol Engines – No Filters

PN-Emission of 400'000 cars in Mexico City (VERT+Sedema, 2018)

* Source= Dominguez C. / GESPA; 2018; JRC No. CTEX2020D380212-101



The «dirty tail» phenomenon with Diesels <u>with particle filters (DPF)</u>

Cumulative contribution of High Emitters to Zürich fleet emissions (Gloor, VERT Forum 2018)

NPTI Testing Campaign – 1000 Gasoline Vehicles

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filtration devices

Test procedure

- Measurement 1 (high idle) **without load**
  - Engine speed between 2000 – 3000 U/min
  - 15 s stabilization, 15 s measurement
  - Record mean value
- Measurement 2 (high idle) **with load**
  - A/C (air conditioning) max + rear window heating
- Engine speed between 2000 – 3000 U/min
  - 15 s stabilization, 15 s measurement
  - Record mean value

➢ Measurements carried out by TCS in Switzerland in collaboration with AVLdiTest & BFH

➢ Different **in-use gasoline vehicles**, including GDI, PFI and GPF-equipped vehicles

Measurement Equipment

- **AVL DiTEST Standalone Counter**

- Based on advanced diffusion charging principle
  - With heated measurement probe
  - With water trap
  - 23 nm cut-off

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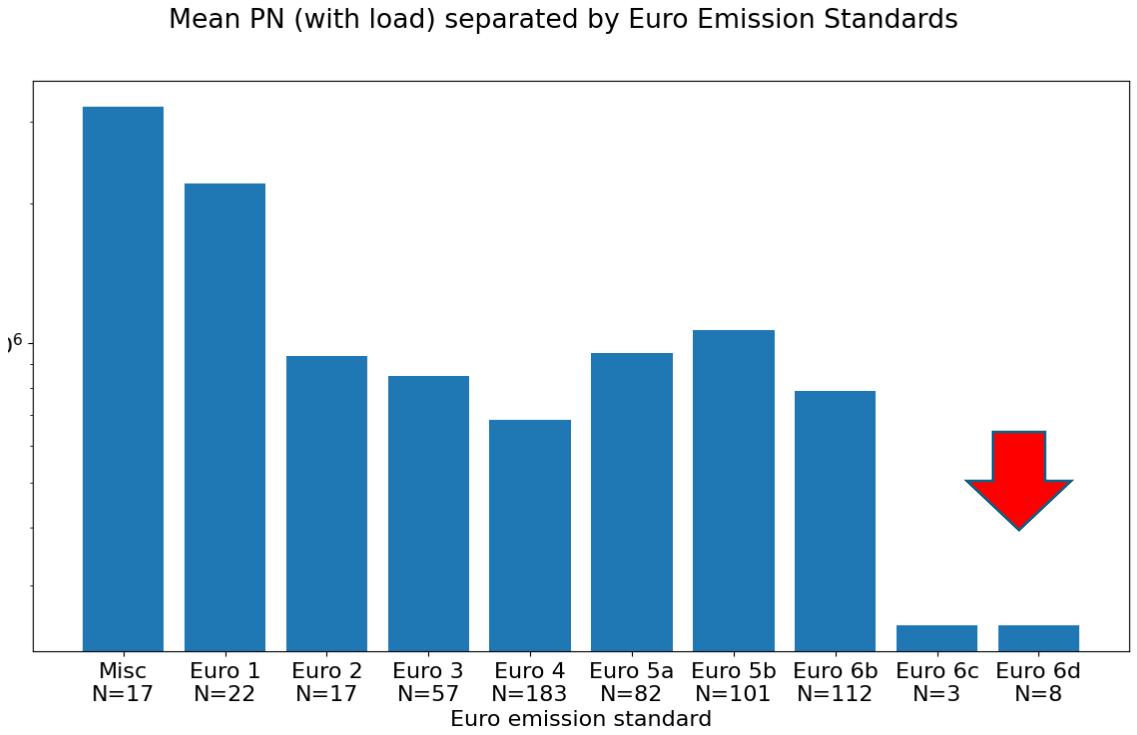
NPTI Testing Campaign – 1000 Gasoline Vehicles

- **Swiss Fleet tested:** Different **in-use gasoline vehicles**, including GDI, PFI and GPF-equipped vehicles



Euro 6d vehicles have significantly lower PN emissions (vehicles with GPF)

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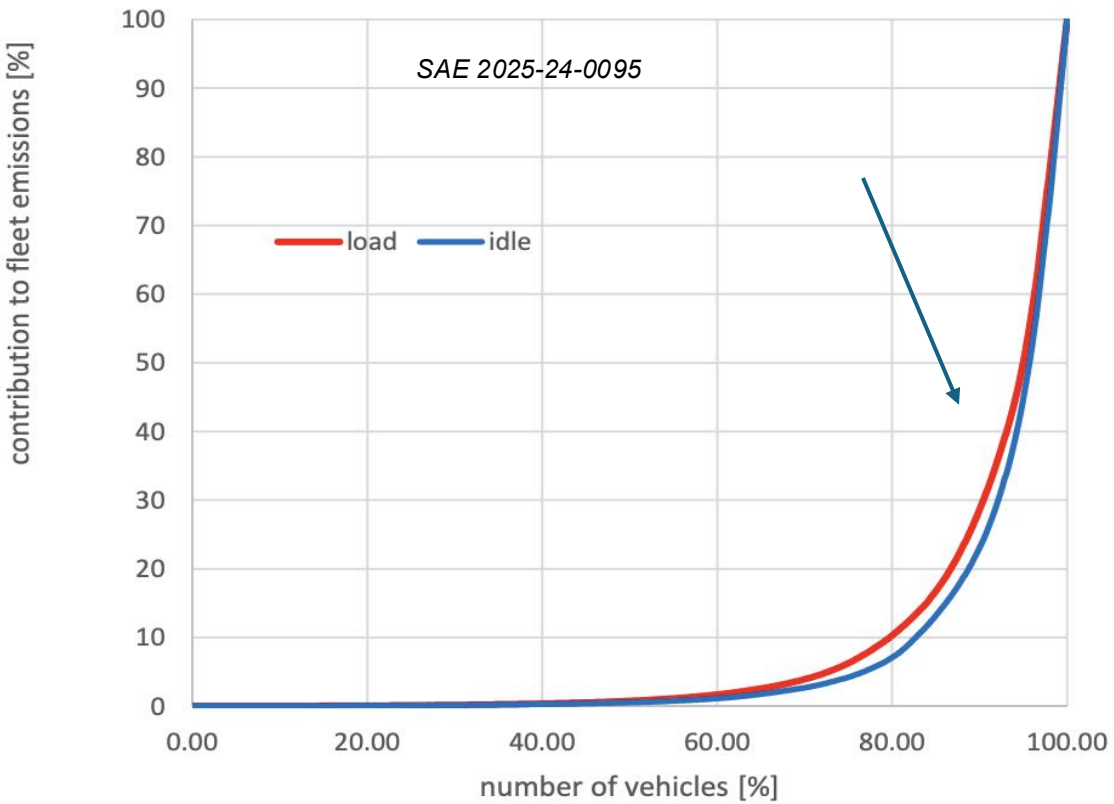
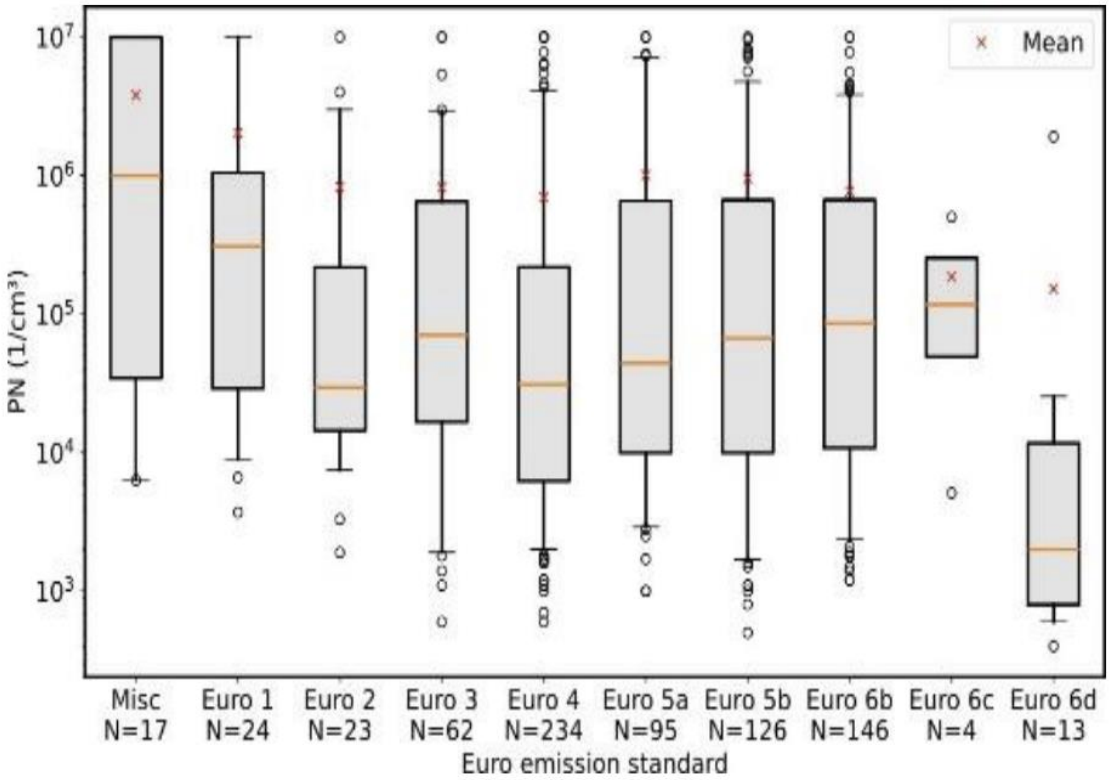
NPTI Testing Campaign 1000 Gasoline Vehicles



Dirty-Tail Phenomena of the gasoline vehicle fleet



Euro 6d vehicles have significantly lower PN emissions (vehicles with GPF)

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SUMMARY

- **The AeroSolfd project, with the VERT GPF-retrofit** of gasoline vehicles **aims to a widespread introduction of GPF to reduce nanoparticle emissions** from high mileage in-use vehicles, and serves also as a platform to **continue research on PN & secondary emissions** from both **DI and PFI engines**
- **VERT and partners HJS, CPK, BFH and CORNING**, **deliver a TRL 8 GPF-retrofit system for future market applications. The GPF-retrofit system shows filtration efficiency over 95% and up to 99%** on standard cycles and on road.
- **The New NPTI Investigation of 1000 gasoline vehicles** including DI, PFI and GPF-equipped vehicles **is an important contribution** to analyse and identify **the root-cause of "high emitters"** and **the "dirty tail" phenomena** of gasoline vehicle fleets in urban areas
- **The very likely "still presence" of gasoline vehicles until 2035 & beyond justify the need of GPF retrofit** and **mitigation measures for the "dirty tail phenomena" of vehicle fleets as fast and cost-effective solution to cleaner mobility**

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REMARKS -

AeroSolfd
filtration devices

What does this mean for the diesel engine?

- The “dirty tail” phenomena is observed in both the diesel and gasoline vehicle fleet and needs attention and mitigation measures
- VERT supports PN legislation worldwide and NPTI for the diesel and gasoline vehicle fleets worldwide
- GPF-retrofit, DPF-retrofit and NPTI implementation are extremely important to clean up urban congested areas and improve air quality with a simple, cost-effective and fast solution
- Clean Air & Clean Mobility is possible and it is a RIGHT for All

Acknowledgement

aerosolfd-project.eu

AeroSolfd
filtration devices

Co-autors – VERT Association

Dr. A. Mayer

Prof. J. Czerwinski

Mr. T. Lutz

Mr. L. Larsen



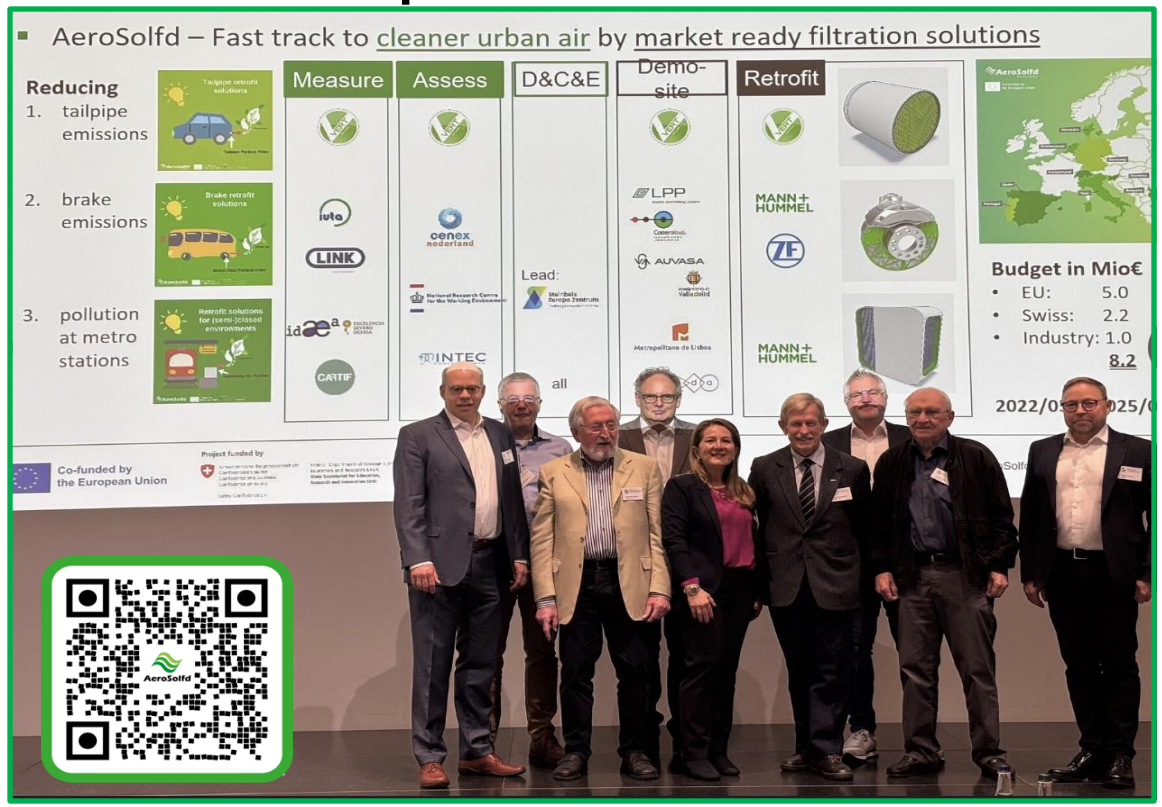

https://www.vert-dpf.eu/

Sincere thanks to the partner organizations of the **VERT scientific network** for their valuable research and cooperation (HJS, TÜV Sud, G-technology, University of Applied Sciences Biel (BFH), CPK Automotive, Technion, Israel Institute of Technology, TCS (CH), AVLdiTest, Corning) as well as **the Swiss State Secretariat for Education, Research and Innovation (SERI) for the financial support.**

Disclaimer

THANK YOU!

Horizon Europe AeroSolfd – VERT TEAM



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Questions?

Lauretta.Rubino@vert-dpf.eu

VERT FORUM 2026 & Focus Day - March 19th-20th, 2026

Backup slides

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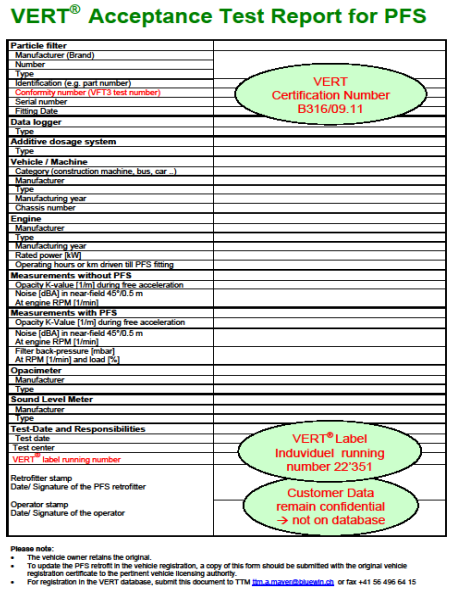
VERT Filter Testing Certification & Quality Control

- **The VERT® Filter List is an international industrial standard**; this standard has become a legally binding code in many countries for different applications where authorities require “Best Available Technology” (BAT)
- **The VERT® seal of approval, used since September 2002, is known worldwide as a sign of particle filters of the highest quality and reliability.** It is now applied to many retrofitted diesel units in Switzerland, Europe, USA, Canada, Chile and China. VERT® is protected as a trademark in all major industrialised countries.

for each Retrofit
- Warranty-Document
- VERT-Label with individual Number



VERT® Acceptance Test Report for PFS

Particle filter	
Manufacturer (Brand)	
Number	
Type	
Identification (e.g. part number)	
Conformity number (VFT3 test number)	
Serial number	
Fitting Date	
Data logger	
Type	
Additive dosage system	
Type	
Vehicle / Machine	
Category (construction machine, bus, car ...)	
Manufacturer	
Type	
Manufacturing year	
Chassis number	
Engine	
Manufacturer	
Type	
Manufacturing year	
Rated power [kW]	
Operating hours or km driven till PFS fitting	
Measurements without PFS	
Opacity K-value [1/m] during free acceleration	
Noise (dBA) in near-field 45°/0.5 m At engine RPM [1/min]	
Measurements with PFS	
Opacity K-Value [1/m] during free acceleration	
Noise (dBA) in near-field 45°/0.5 m At engine RPM [1/min]	
Filter back-pressure [mbar] At RPM [1/min] and load [%]	
Opacimeter	
Manufacturer	
Type	
Sound Level Meter	
Manufacturer	
Type	
Test-Date and Responsibilities	
Test date	
Test center	
VERT® label running number	
Retrofitter stamp Date/ Signature of the PFS retrofitter	
Operator stamp Date/ Signature of the operator	

VERT Certification Number B316/09.11

VERT® Label Induviduel running number 22'351

Customer Data remain confidential → not on database

Please note:
- The vehicle owner retains the original.
- To update the PFS retrofit in the vehicle registration, a copy of this form should be submitted with the original vehicle registration certificate to the pertinent vehicle licensing authority.
- For registration in the VERT database, submit this document to TTM jim.a.mayer@bluewin.ch or fax +41 56 496 64 15

Notes

Euro 7 non-exhaust emissions standards

•Brake Emissions

- **The regulation limit is set only for PM10 for LDVs**, blank limit tables for PN are set, this will be further discussed, will be decided before 2027, limits starting from 2030

•**The UN GTR (Global Technical Regulations) No. 24[*7] will be adopted as the test method for LDV. In addition to PM10, this GTR defines measurement methods for PM2.5, SPN10, and TPN10.** The tire wear rate regulation will be based on the difference in the weight of the tire before and after the test as the amount of wear.

•**Although the regulation limits are currently under consideration, the real world test method of UNR (UNECE Regulation) No. 117 is planned to be adopted for the test method.**

OPS DustTrak (PMtotal), PM10, PM2.5, and PM1 Fast Mobility Particle Sizer

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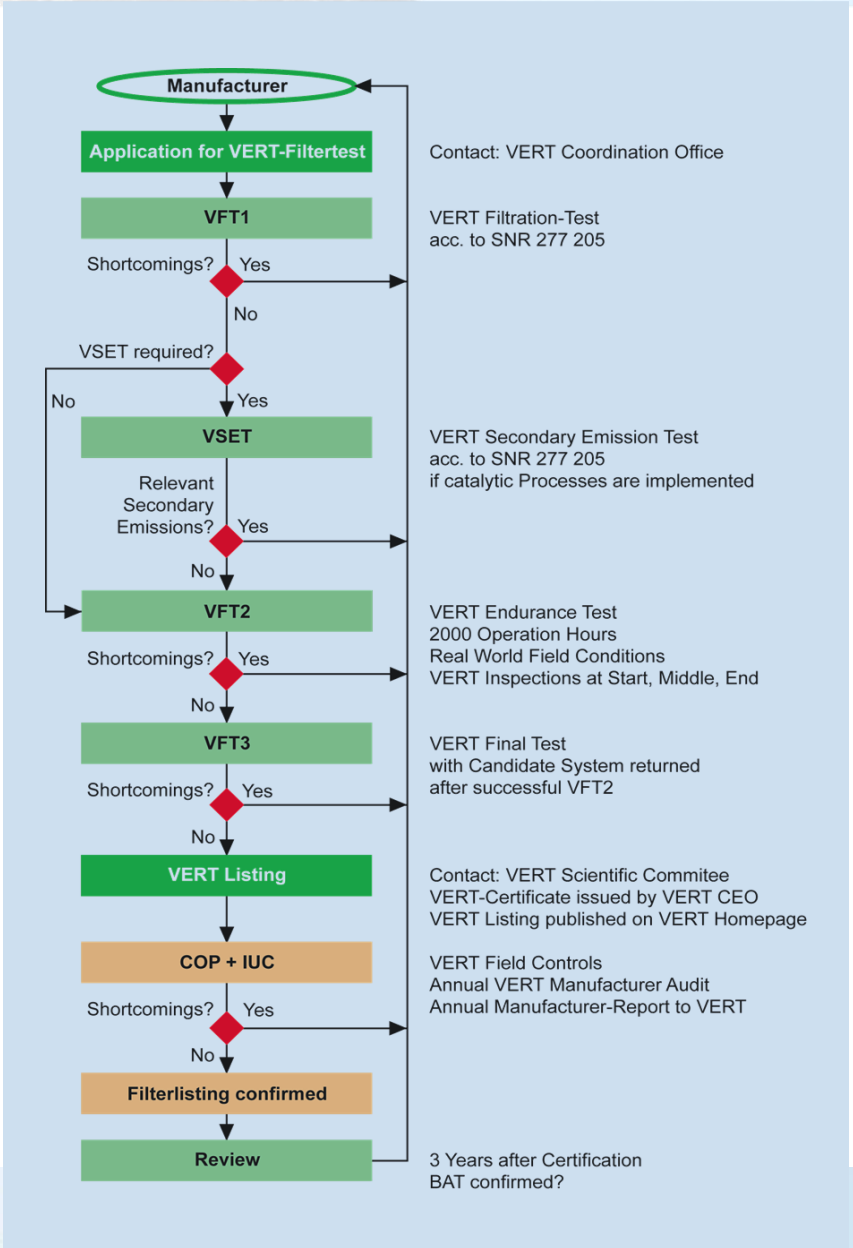
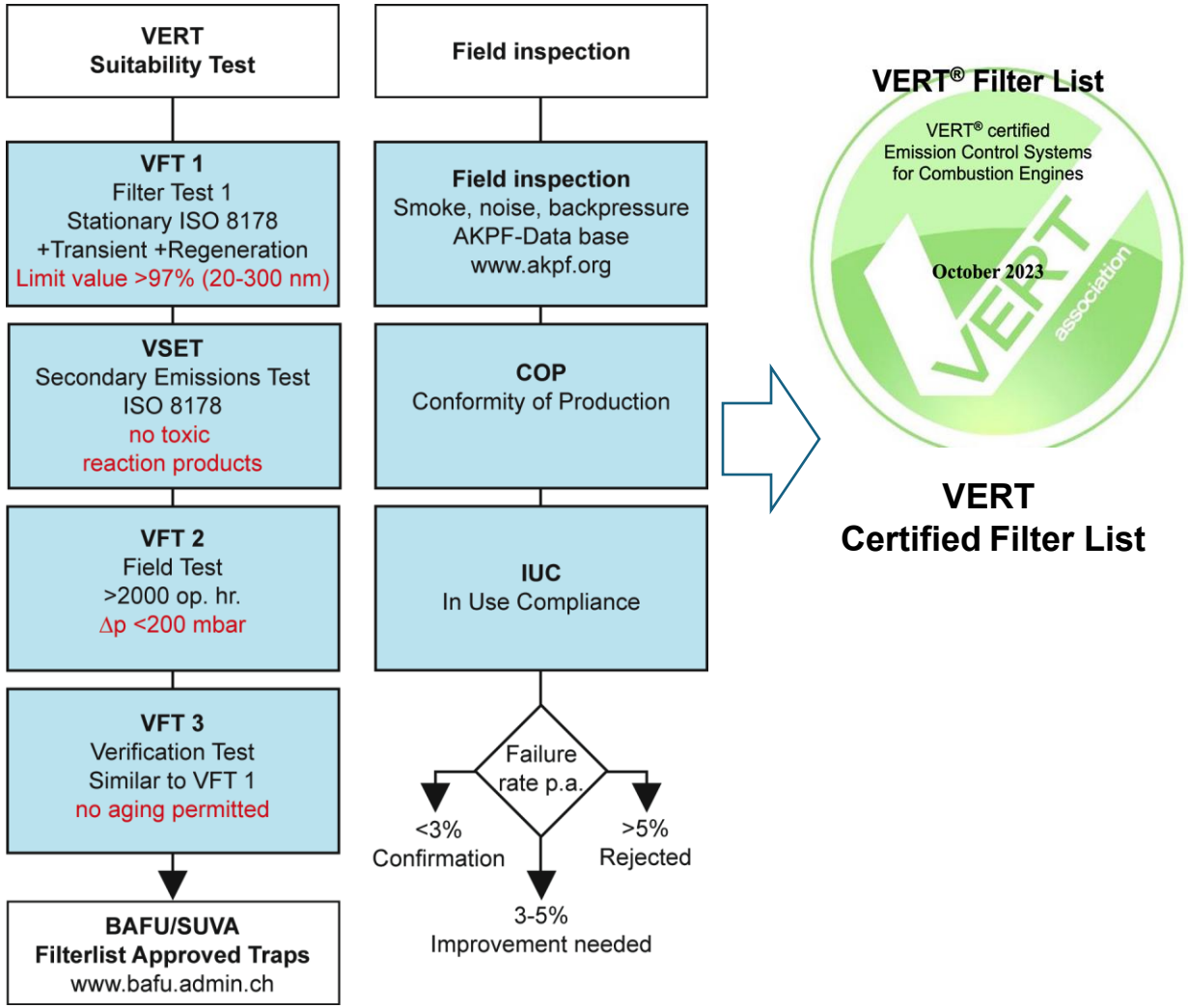
VERT Filter Testing Certification & Quality Control

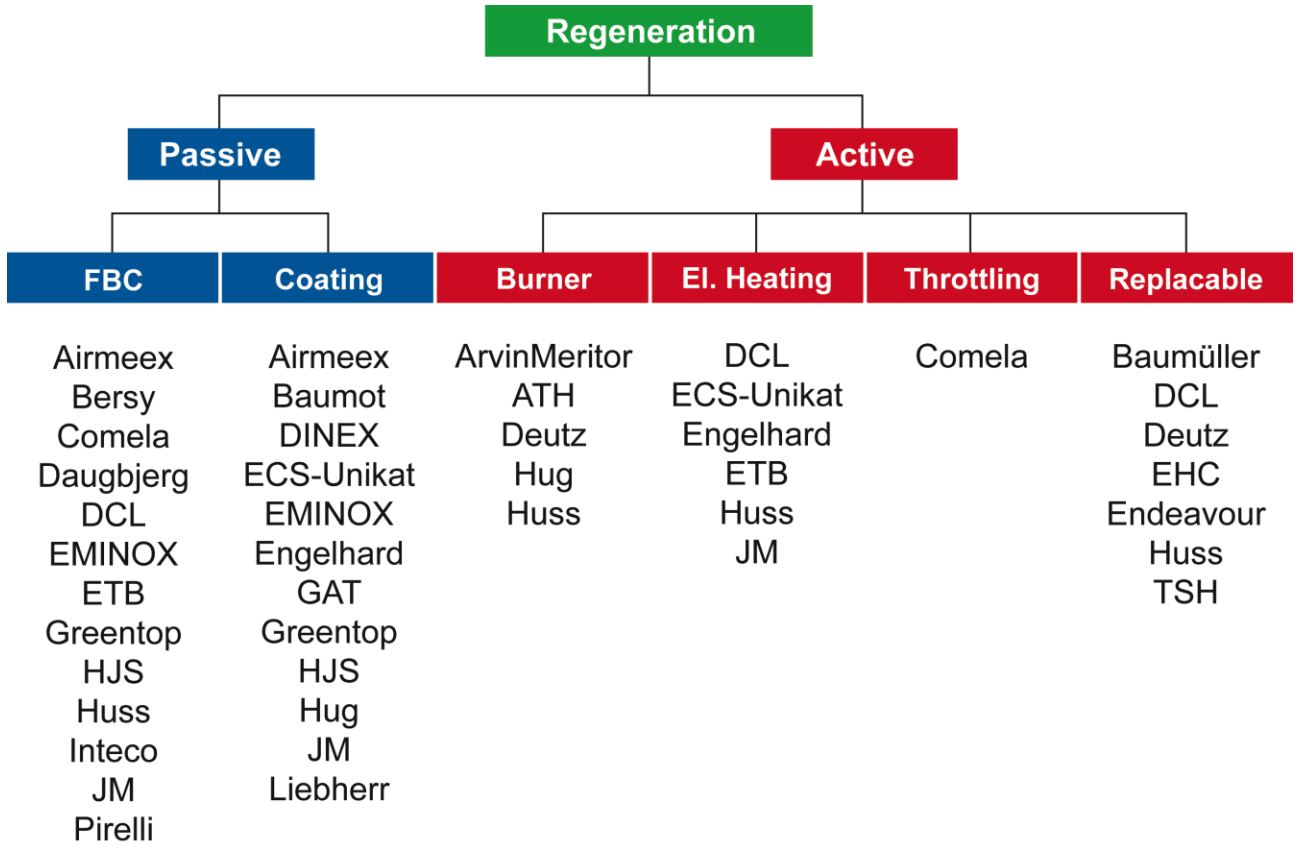
- The VERT® filter test protocol, in place since 1997, is codified by the **Swiss Technical Standard SN 277206**

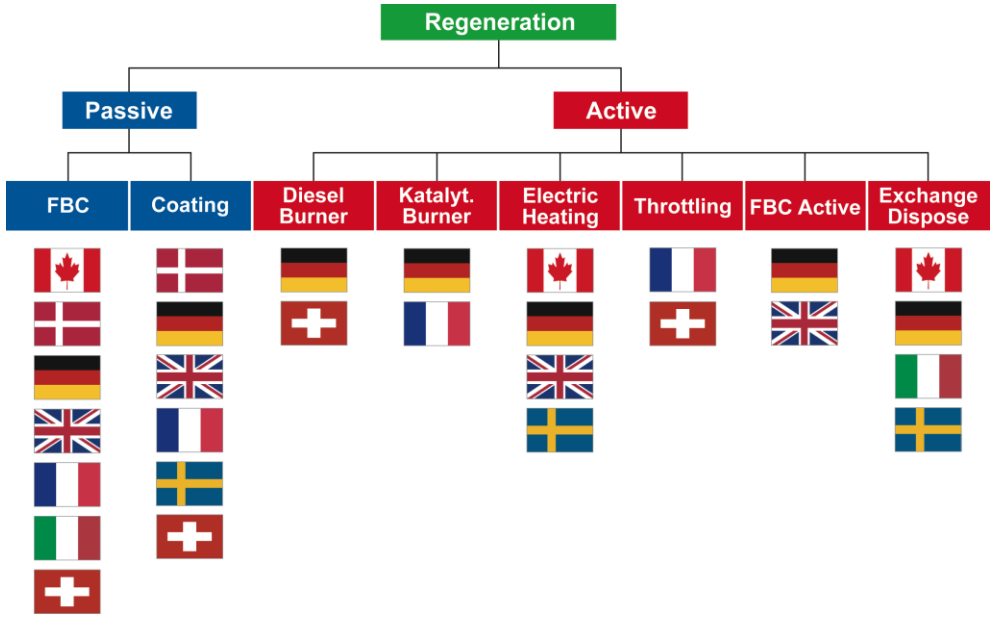




VERT® testing of particle filter systems

VERT–certified DPF Systems





VERT–certified DPF Systems

for different targets and applications