The VERT GPF-Retrofit Program for Cleaner Urban Mobility: Nanoparticle emissions reduction via Filtration within the HORIZON Europe AeroSolfd Project

Dr. Lauretta Rubino, CEO VERT Association

28th ETH NPC Conference, June 18th, 2025, Zürich, Switzerland

AGENDA

- Introduction & Motivation
- HORIZON Europe AeroSolfd overview
- AeroSolfd VERT GPF-Retrofit
- 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 over 37 members** including **universities and research centres as associate partners**

VERT Milestones / Achievements

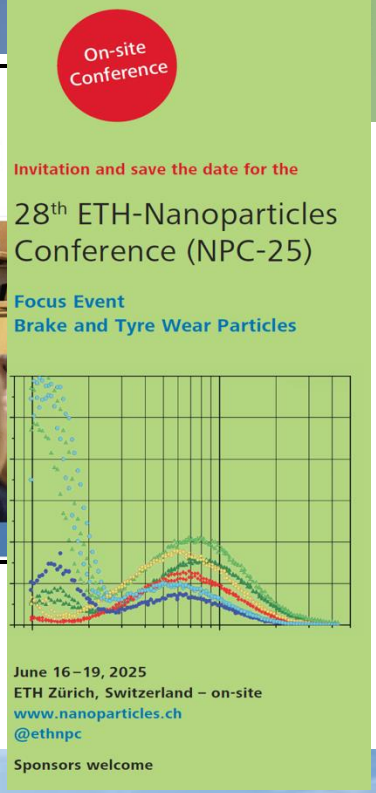
- **2024 & 2025 NPTI of gasoline vehicle fleet and the DirtyTail phenomena**
- **2023 & 2024 DPF for Global Warming Mitigation**
- **2022-2025 GPF Retrofit within Horizon Europe AeroSolfd**
- 2022 DPF-Membrane for Marine heavy fuel oil application
- 2020 DPF for Virus Filtration
- 2016-2019 NPTI- the 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

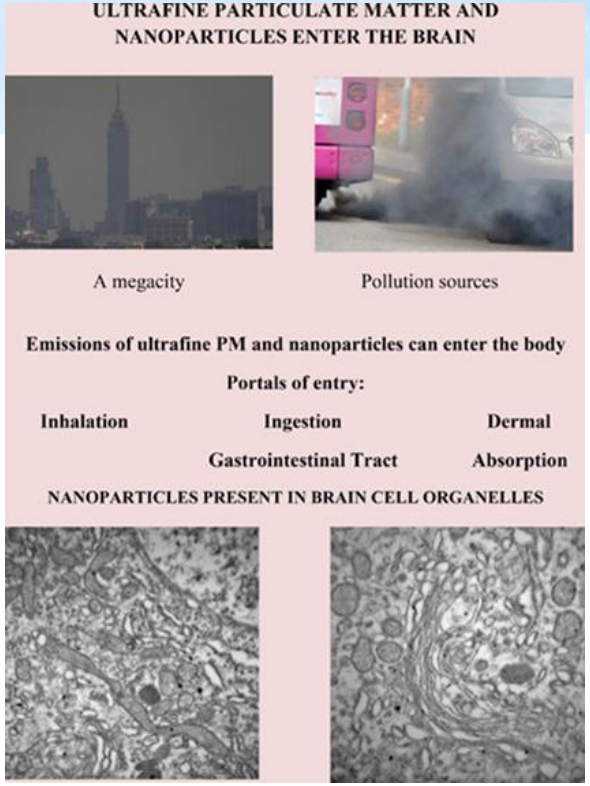
and this year with Focus Day event



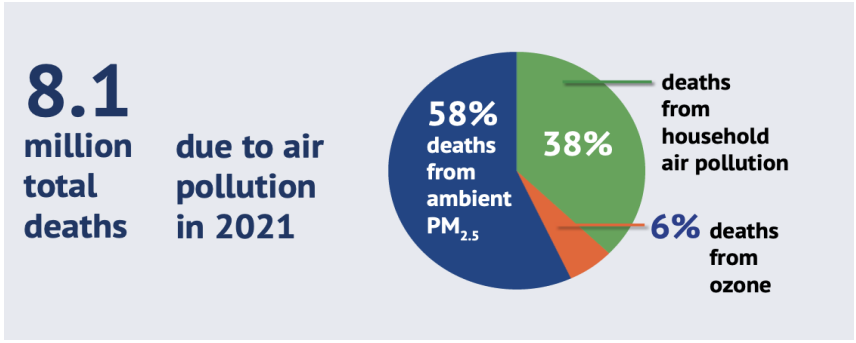
- **Many scientific publications in the field of nanoparticle** emissions control and filtration, over 200 reference available on the VERT website (Only for members)

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

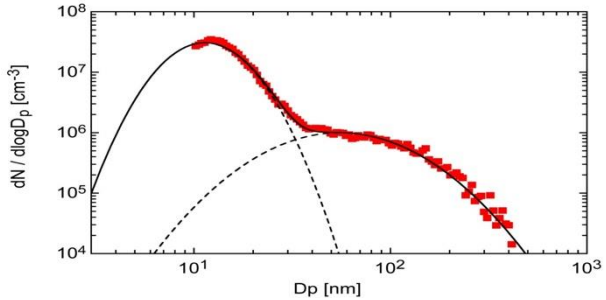


Environ. Sci. Technol. 2022, 56, 11, 6847−6856



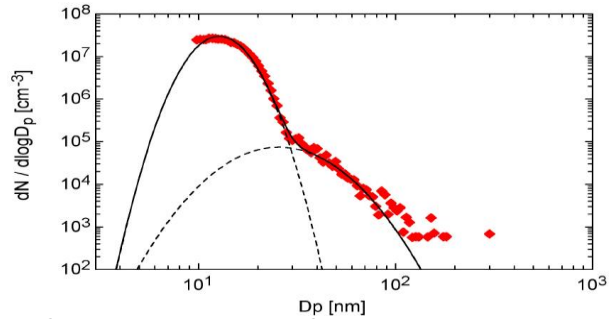
*Source New State of Global Air Report 2024

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



*Source SAE 2012-01-841 Mayer et al

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



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

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**

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AeroSolfd Main Goals

AeroSolfd
filtration devices

(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

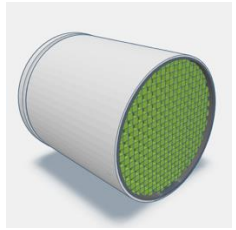
1. **tailpipe emissions**

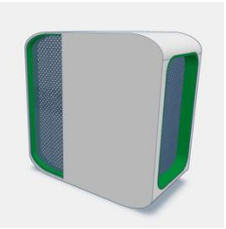
VERT GPF-Retrofit

2. **brake emissions**

3. **pollution at metro stations**

Measure	Assess	D&C&E	Demo-site	Retrofit
VERT	VERT	Lead: Steinbeis Europa Zentrum	VERT	VERT
iuta	cenex nederland		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	all		
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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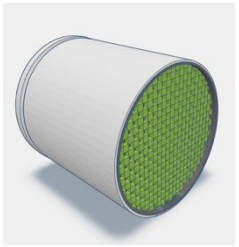
AeroSolfd Market Ready Filtration Solutions

AeroSolfd
filtration devices

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

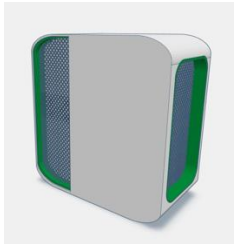
VERT GPF-Retrofit



Focus: gasoline fleet (EURO 6c & earlier)

- **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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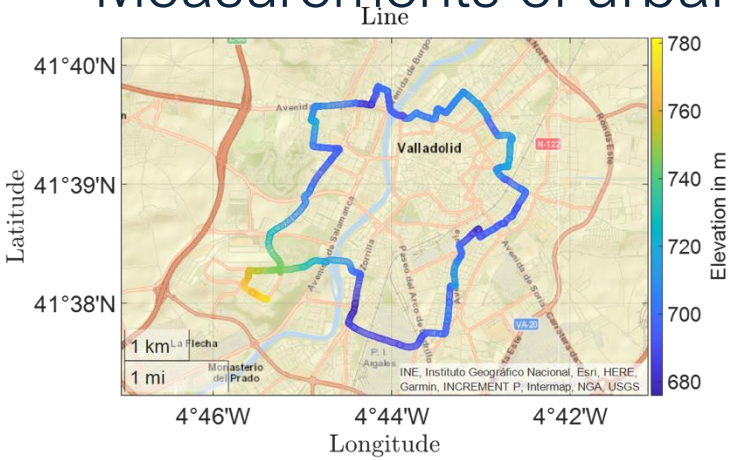
Results: Brake Dust Filter

- Measurements of urban brake pattern in partner cities



- ✓ Valladolid, ES: 3 busses
- ✓ Ancona, iT : 2 busses
- ✓ Ljubljana, SI 2 busses
- ✓ ICE and Hybrid

- Method for obtaining city specific brake cycle (D2.1) to run on dyno
- Measurements a bit delayed

Source: Ljubjana bus depot

Source: LINK project activities

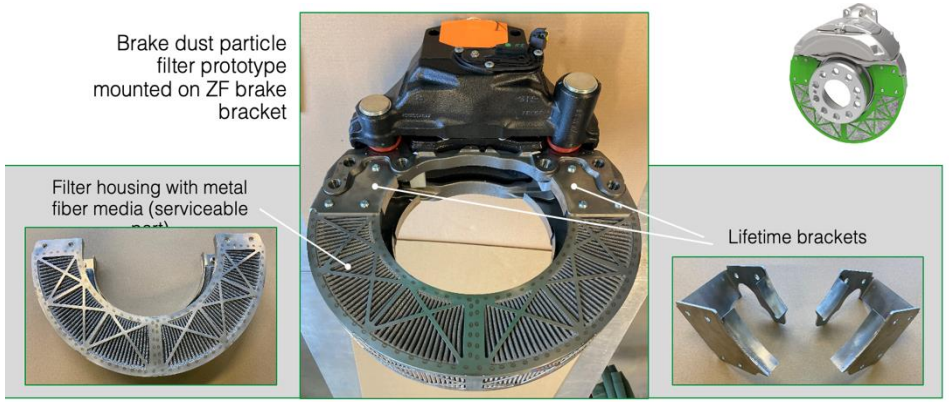
Site visit @LINK April 15, 2025

Results: Brake Dust Filter

AeroSolfd
filtration devices

Retrofit Brake Dust Particle Filter

- Passive brake dust particle filter concept with non-woven metal fibers
- Specially designed for retrofit to commercial/ bus brakes
- Adopted to MAXX Low-Emission Air Disc Brake
- Efficiency acc. AeroSolfd cycle for urban busses about 35-40 %.



Source: LinkedIn

Source:IAA Transportation

- Lab-Testing successful finished

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Results: Brakes & Metro Station Air purifier

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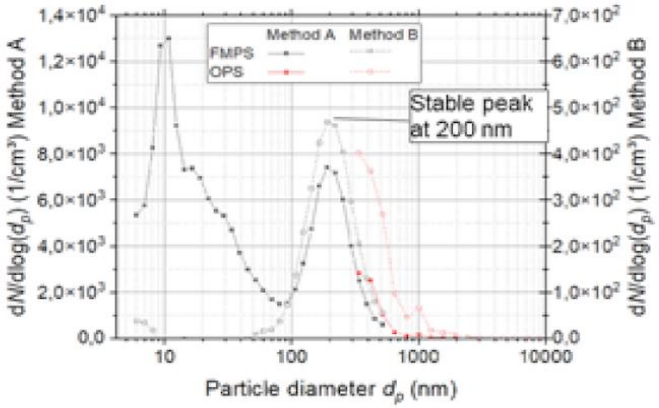
filtration devices

Brake Emissions

✓ characterized

Tracer: **Sb(Antimony) 200 nm** (A: 45.1 % friction, 54.9 % recuperation; B: friction brake only below 10 km/h)



Filter Installation

✓ successful at 1st location

Source: Fotografia de Renata Pessoa © Metropolitano de Lisboa, E.P.E

- Evaluation of measured data ongoing (24 low-cost sensors & scientific grade equipment)

- Preliminary results indicate efficiency range 30-70 % at air exchange rate of about 2 L/hour

- Experienced challenges with logistic, installation, sensors, Sahara dust, … → lessons learnt

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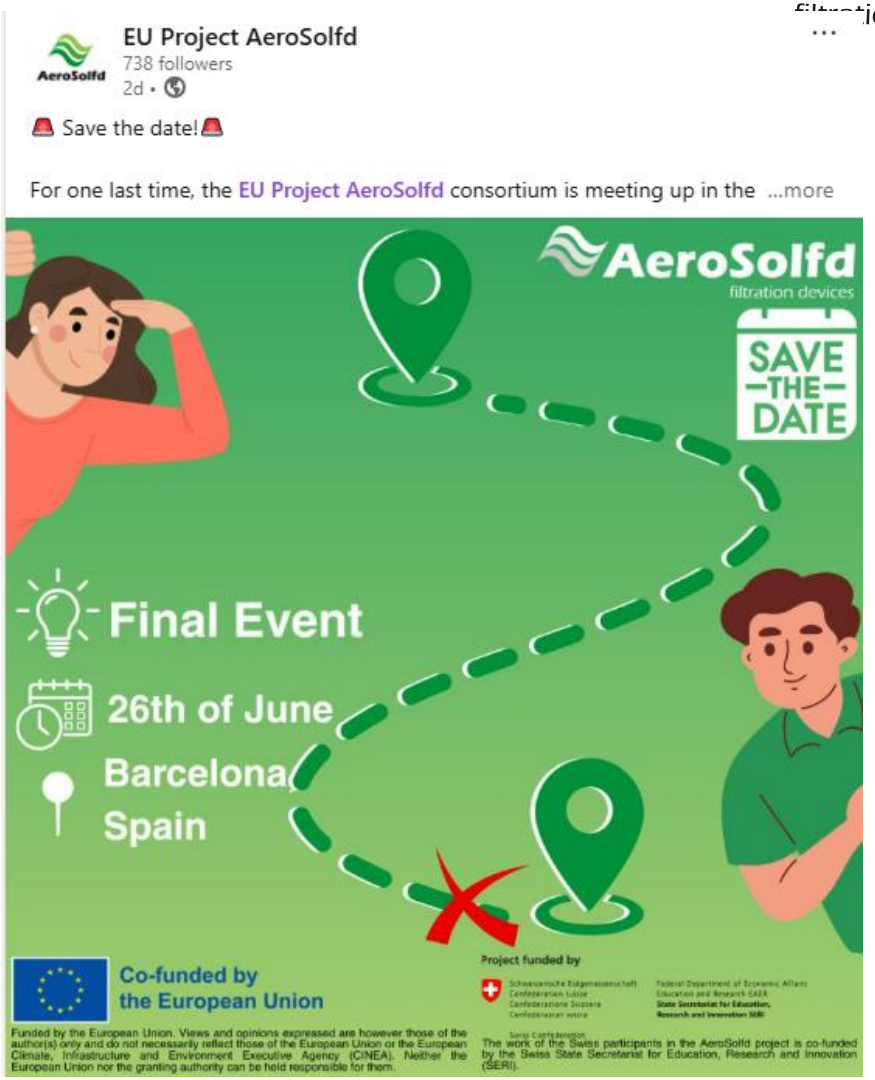
Final Event: GA June 26 (hybrid)

- 📍 Location: CSIC Delegation in Catalonia
- 📅 Thursday, 26 June 2025
- ⏰ Time: 09:30 – 16:30
- 🎥 Format: Hybrid (on-site + livestream)
- 💶 Costs: Free of charge
- Presentations, Panel Discussion
- Collaboration with other EU Projects

Registration: https://eveeno.com/2025-06-26-aerosolfd

Environmental-Social Life-Cycle-Assessment and results are presented



Focus: Retrofit with GASOLINE Particle Filters (GPF)

AeroSolfd filtration devices

- AeroSolfd Solutions:

Reducing tailpipe emissions

Pillar A: Retrofits

Retrofit Development → 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

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

AeroSolfd
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/

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VERT–Certified GPF Systems

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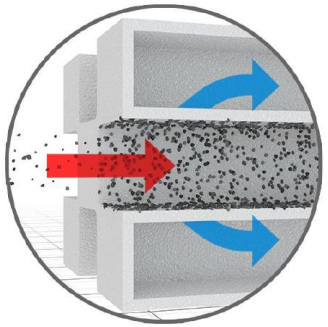
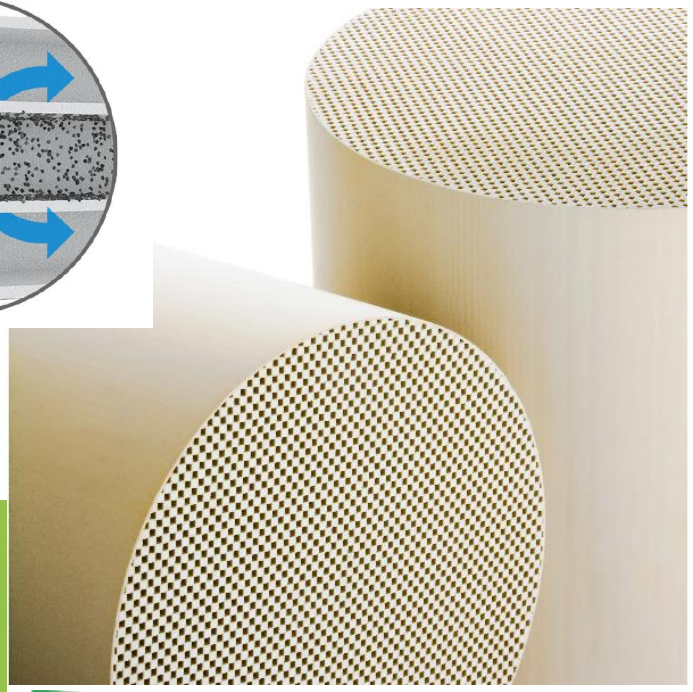
filtration devices

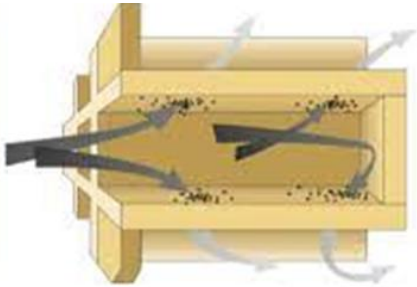




The VERT® seal of approval, used since September 2002, is known worldwide as a sign of particle filters of the highest quality and reliability.

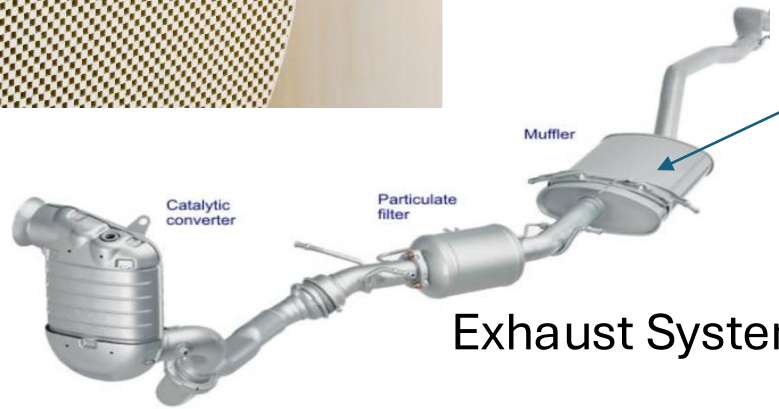
GPF

CORNING
Filter substrate



Corning 200/8 GC2.0

GPF serial production / GC2.0 APT2



Exhaust System

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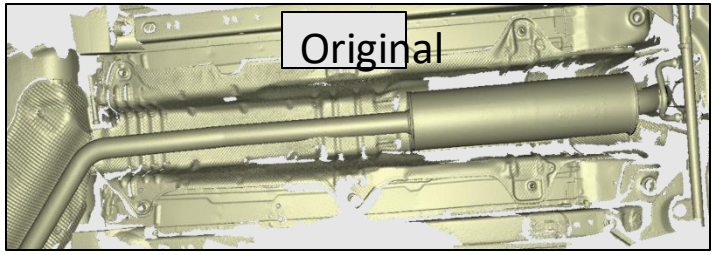
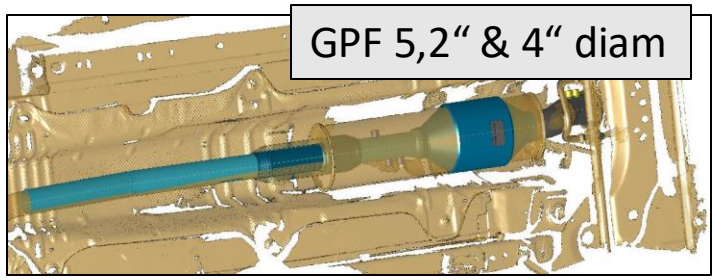
4 Engine Families & Durability Study of 42 in-use Gasoline vehicle – VERT GPF-Retrofit

AeroSolfd
filtration devices

HJS Tailpipe GPF retrofit (example)





Peugeot 3008, DI ,1,6L

VW Golf

DI, 1,4L

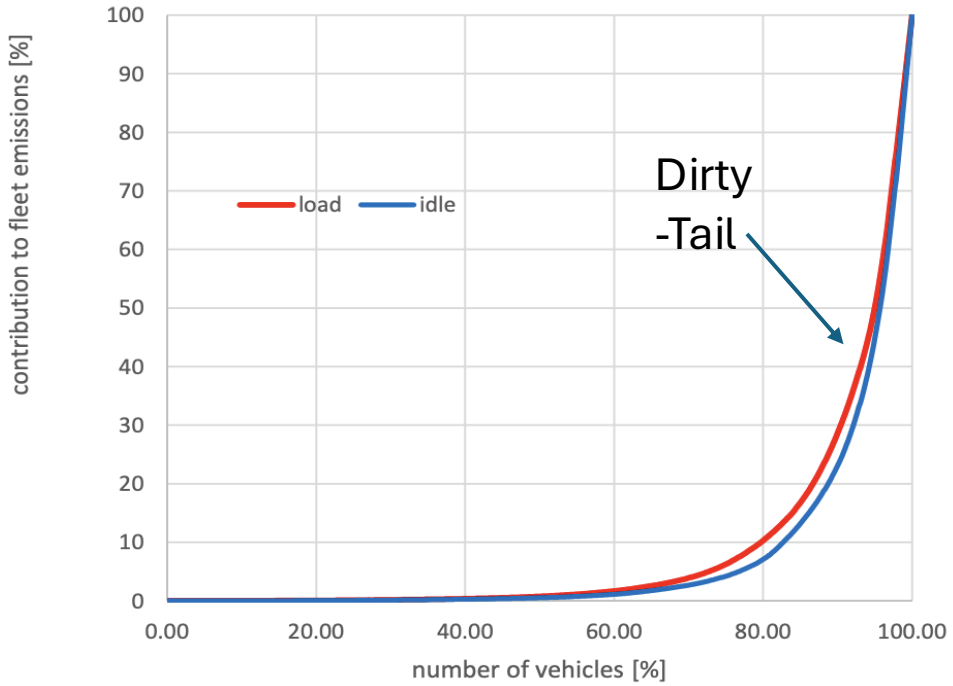
FIAT, 500X

PFI, 1,6L

OPEL Corsa

PFI , 1,2L

NPTI Testing Campaign 1000 Gasoline Vehicles



Dirty-Tail Phenomena of the gasoline vehicle fleet

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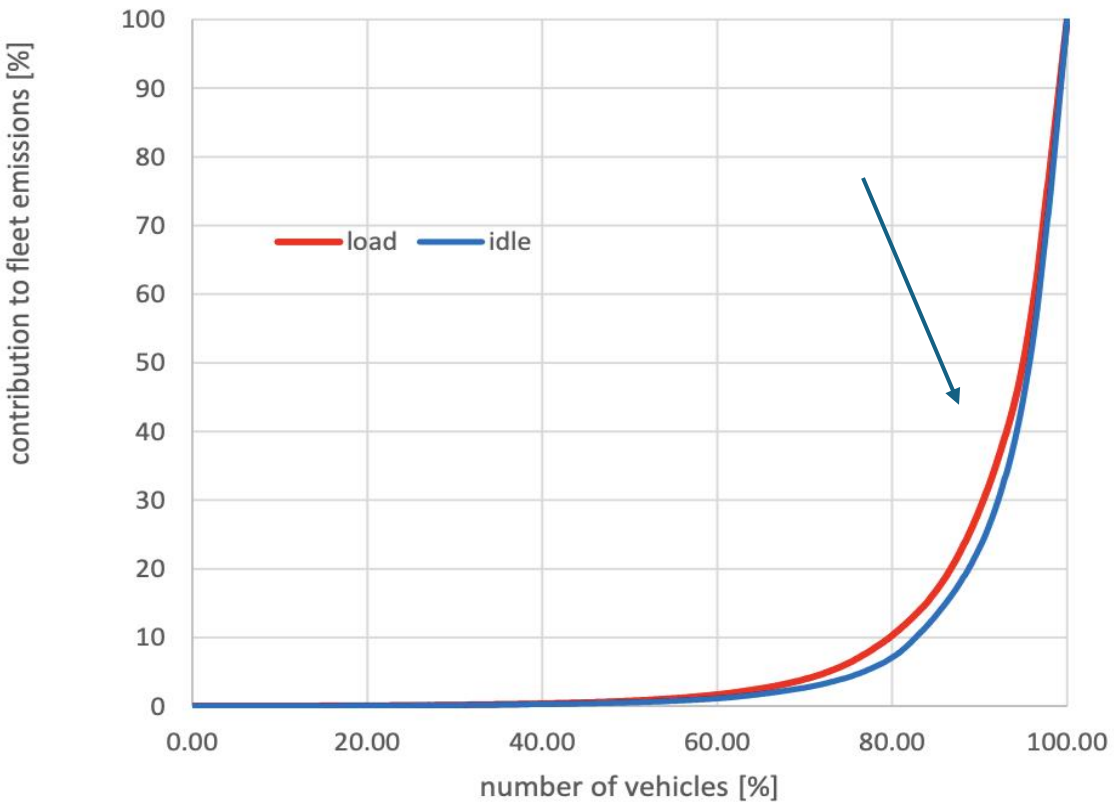
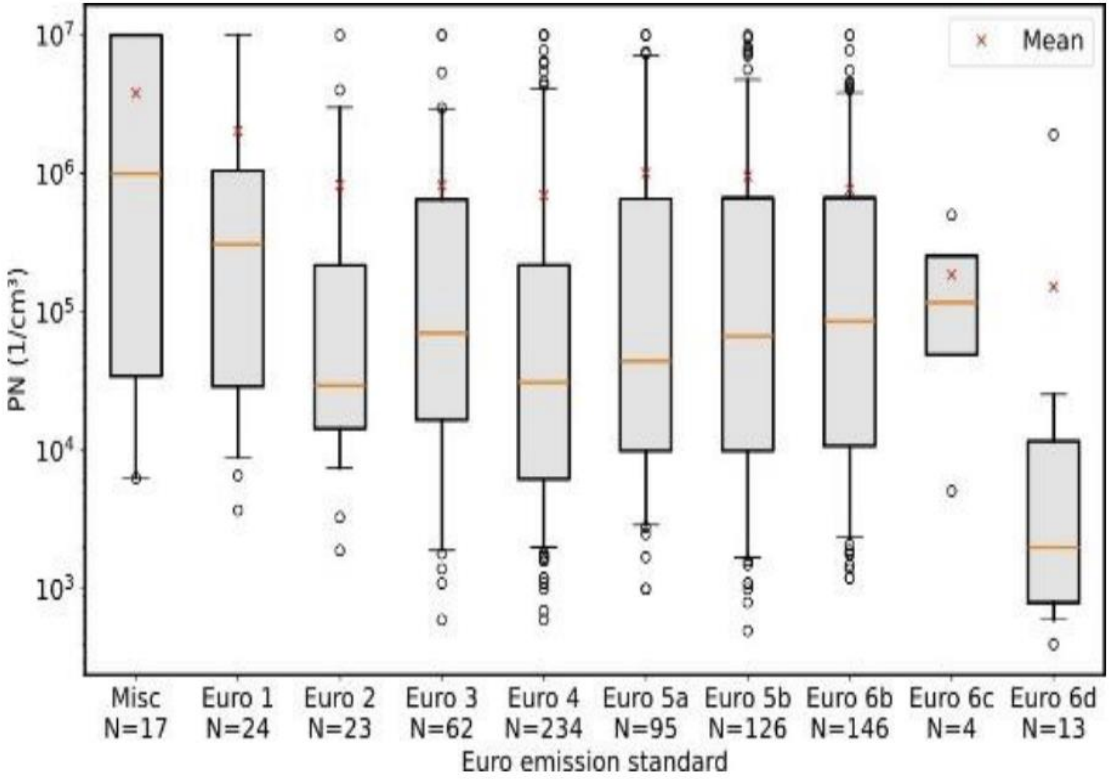
NPTI Testing Campaign 1000 Gasoline Vehicles



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%** 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

- **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 “dirty tail” phenomena observed in the in-use gasoline fleet needs attention and mitigation measures**
- **VERT supports PN legislation worldwide and NPTI for the diesel and gasoline vehicle fleets worldwide**
- **GPF-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 NOT a privilege but a RIGHT for All**

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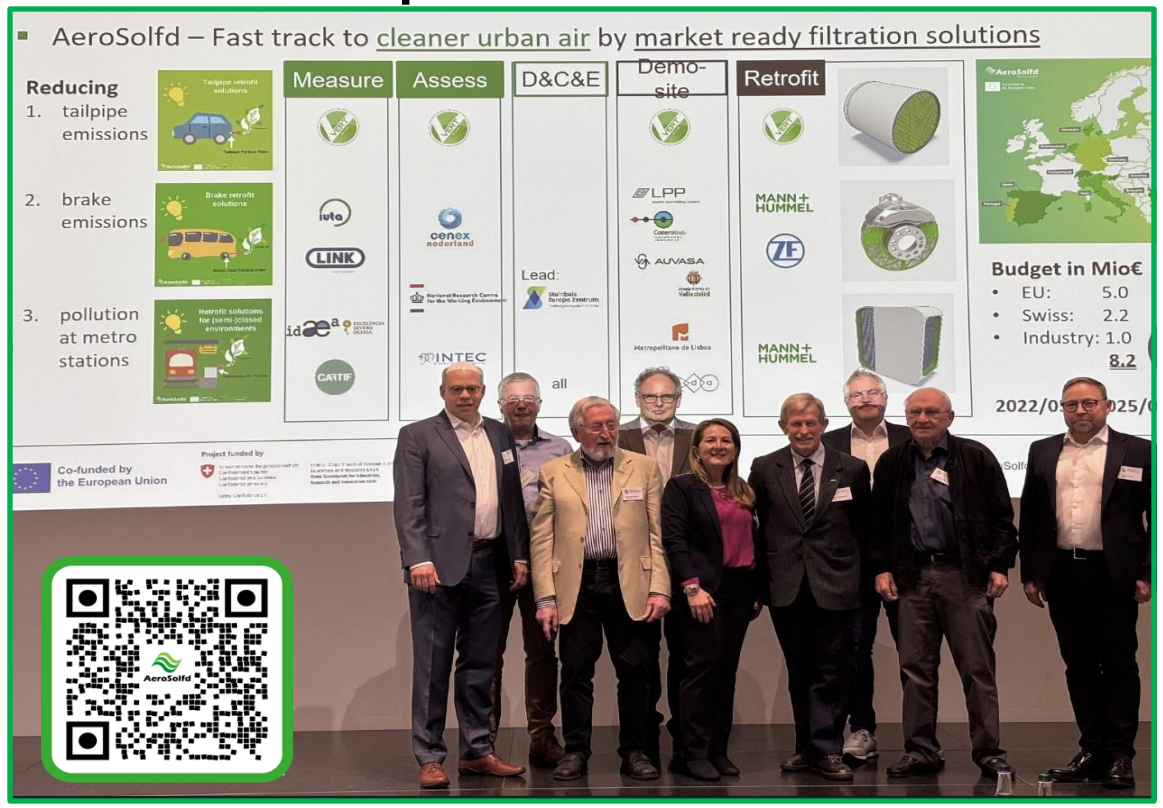
THANK YOU!

Horizon Europe AeroSolfd – VERT TEAM



aerosolfd-project.eu

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

Questions?

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THANK YOU & PROJECT PARTNERS

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filtration devices

MANN+HUMMEL

AUVASA

Ayuntamiento de Valladolid

CARTIF

cenex nederland

Conerobus
società per la mobilità intercomunale S.p.A.

idaea EXCELENCIA SEVERO OCHOA

INTEC
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Test Smarter.

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skupina Javni holding Ljubljana

Metropolitano de Lisboa

National Research Centre for the Working Environment

sofia development association sda

Steinbeis Europa Zentrum
Enabling Innovators to Grow

VERT association

ZF

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Dissemination & Exploitation

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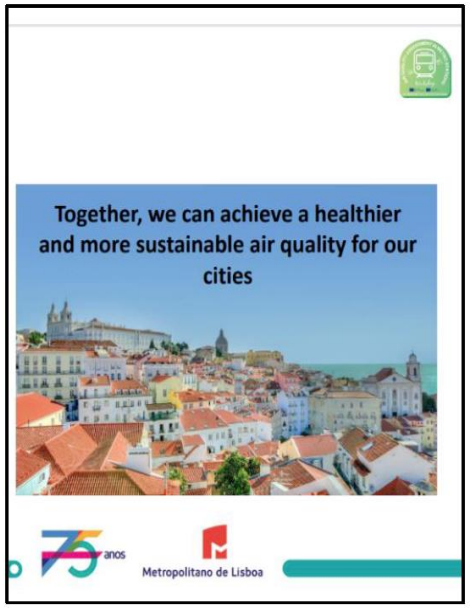
D4.4 Life-cycle assessment for each product line

City & Metro openly talking about innovation, like Lisbon



SDG

Environmental Social Governance (ESG)

Investment in technologies to reduce air-pollution?

→ Looking for **innovative cities** as **early adaptors** for cleaner urban air solutions

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NPTI Testing Campaign – 1000 Gasoline Vehicles

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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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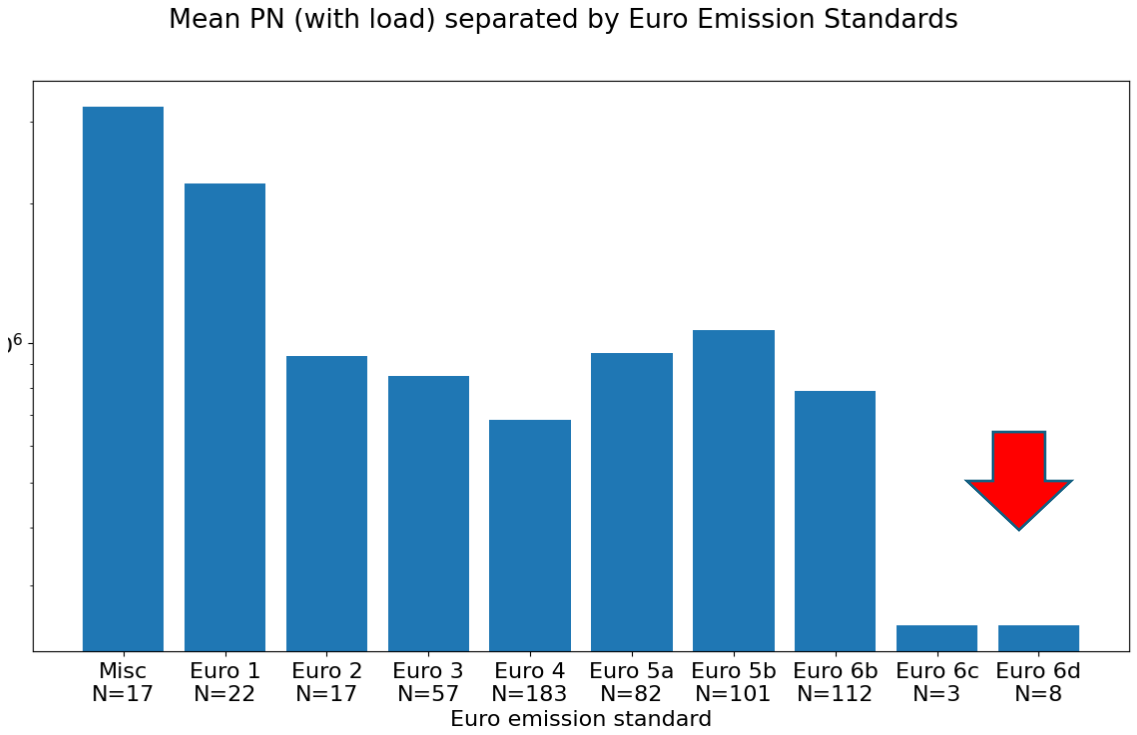
NPTI Testing Campaign – 1000 Gasoline Vehicles

- **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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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 Role

- **VERT's focus on nanoparticles but also secondary emissions** from both diesel and gasoline vehicles
- **VERT's past and present work** in promoting legislation and demonstrating effective best available technologies (BAT), including the latest AeroSolfd GPF-retrofit of the gasoline fleet, directly supports future certification standards, their implementation in the existing fleet, and continous control of nanoparticle emissions
- **VERT Filter Certification & VERT Filter List:**
  - **A new chapter for GPF certification is open** (CORNING GPF)
- **Potential future implementation of GPF retrofit in the current gasoline vehicle fleet & GPF Filter certification**
- **GPF-retrofit as immediate solution** for congested and polluted urban areas
- **VERT is committed to clean urban mobility and use of BAT** for reducing nanoparticle emissions from all sources

➢VERT role is to generate Health Protection, Global Warming Mitigation, Fast & Cost-effective solutions to Clean Urban Mobility