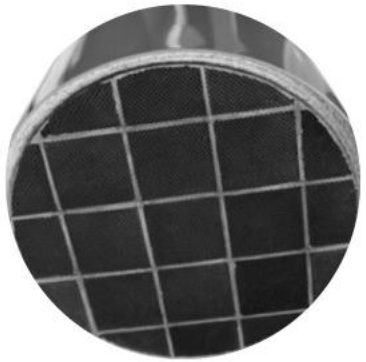
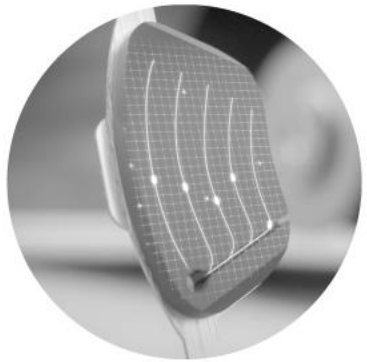
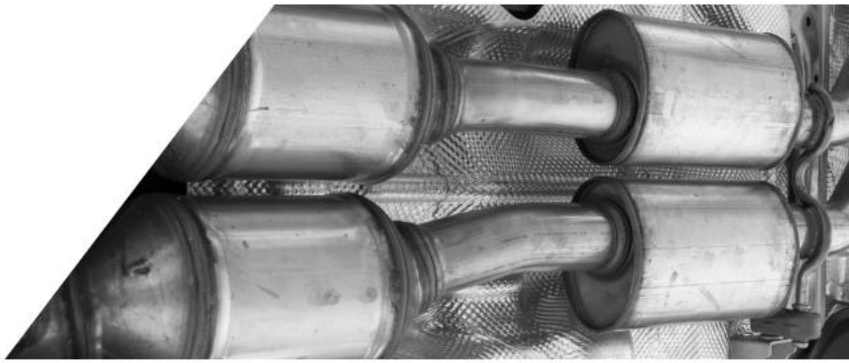





VERA: Vehicle Emission Retrofit Activities

A. Dimaratos, Z. Samaras
LAT/AUTH, VERA Coordinator

VERT Forum
19-20 March 2026, Bern

V·E·R·A

Less particles, better air quality

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Overview

- ***18 partners from 10 countries***
  - *Academia, R&D organizations, industry, engineering companies, fleet operator*
  - *Strong background on emissions & emission control technologies, environmental & health impacts*
  - *Ensuring access to critical infrastructure & facilities for testing, evaluation, exposure studies*
- ***Budget***
  - *Total:* 6.06 M€
  - *EU contribution:* 4.70 M€
- ***Duration: Dec 2022 – May 2026***

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Structure & Objectives

	Objective 1	Objective 2	Objective 3
Detail	Develop, demonstrate and optimise **tailpipe retrofit solutions** for road vehicles	Develop, demonstrate and optimise **brake retrofit solutions** for road vehicles and metro/rail applications	**Assess the overall impacts of retrofitting**, better understanding of health impacts of air pollution from transport emissions, IA of retrofitting
Actions	From conceptualisation to **full-scale demonstration**, testing and evaluation	Development and optimisation of components, **complete system testing** and evaluation	Physico-chemical characterisation of exhaust and brake particles, assessment of **air quality and health impacts**, incentive & regulatory schemes, CBA of retrofitting
Targets	• **>90% less particles (PN10)** • **Considerable NO_x reduction** • **NH_3 considerations** • **Cost ≤10% of vehicle market value**	• **>90% reduction of PN, PM** • **Low cost, high adaptability** • **Retrofits, replacements & first installation systems**	**Reduced emission impacts** by retrofitting (both environmental & health), **low cost of implementing retrofitting as a viable solution to improve air quality**

Tailpipe retrofits for road vehicles

Brake retrofits for road vehicles and metro/rail applications

Environmental and Health impacts, Incentives, Regulation, Cost-Benefit Analysis

Reduction of environmental impact of transport
Improvement of air, water and soil quality
Reduction of people exposure in metro network

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

Tailpipe Retrofits Results

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

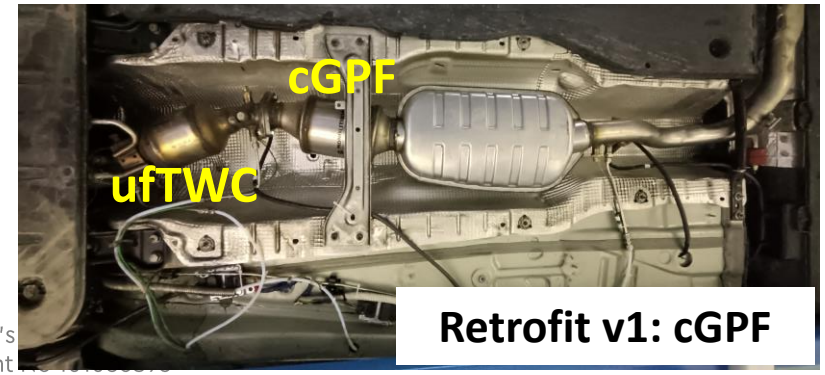
VERA Tailpipe Retrofits: coated GPF and catalysts

- ***3 use cases***

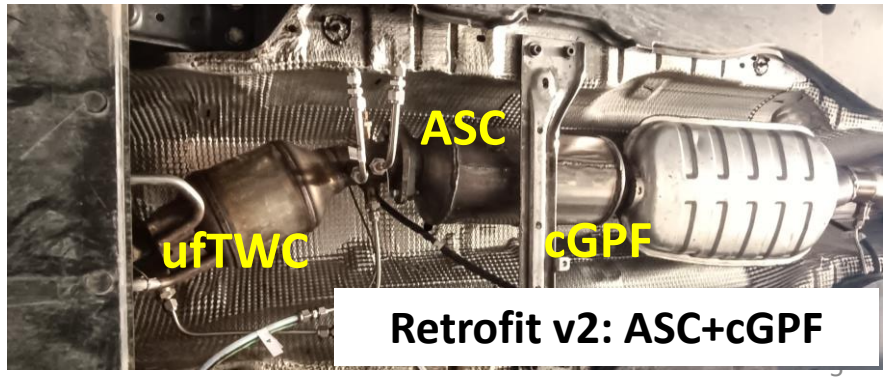
Vehicle type	Fuel & Powertrain	Emission std	Application
Passenger Car (PC)	Bi-fuel CNG/Gasoline (GDI) – SI	Euro 6d	Taxi
Light Commercial Vehicle (LCV)	Gasoline PFI – SI	Euro 6b	Delivery van
Heavy-Duty Vehicle (HDV)	CNG – SI	Euro VI	City bus

- ***Innovations***
  - *LDV: Cu-based coating on GPF, Prometheus catalyst by MONOLITHOS, ASC integration*
  - *HDV: low PGM coated GPF by DINEX (TWC & AOC coatings), integration of LNT*
- ***Development & Evaluation Methodology***
  - *Small-scale testing: SGB, ETB*
  - *Modelling: Filtration efficiency, pressure drop, catalytic reactivity*
  - *Full-scale testing: Chassis dyno (LDV), on-road validation (LDV & HDV)*

Original EATS



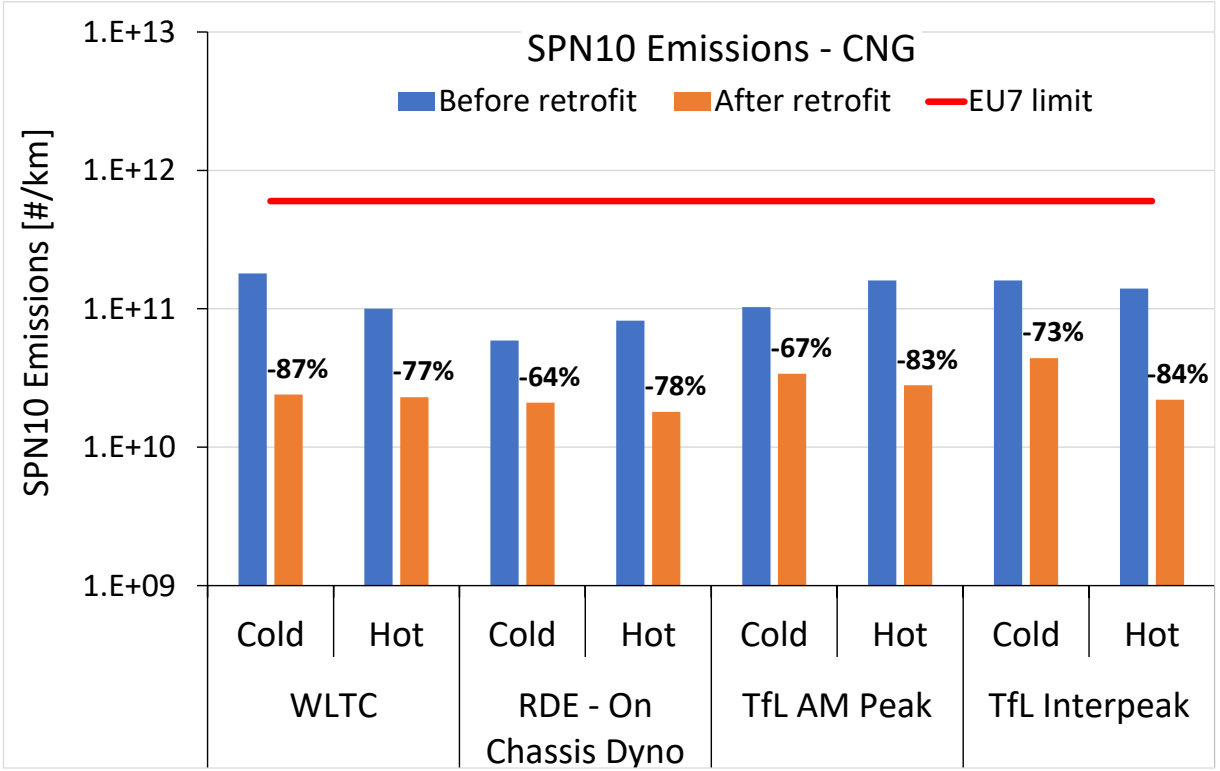
Retrofit v1: cGPF

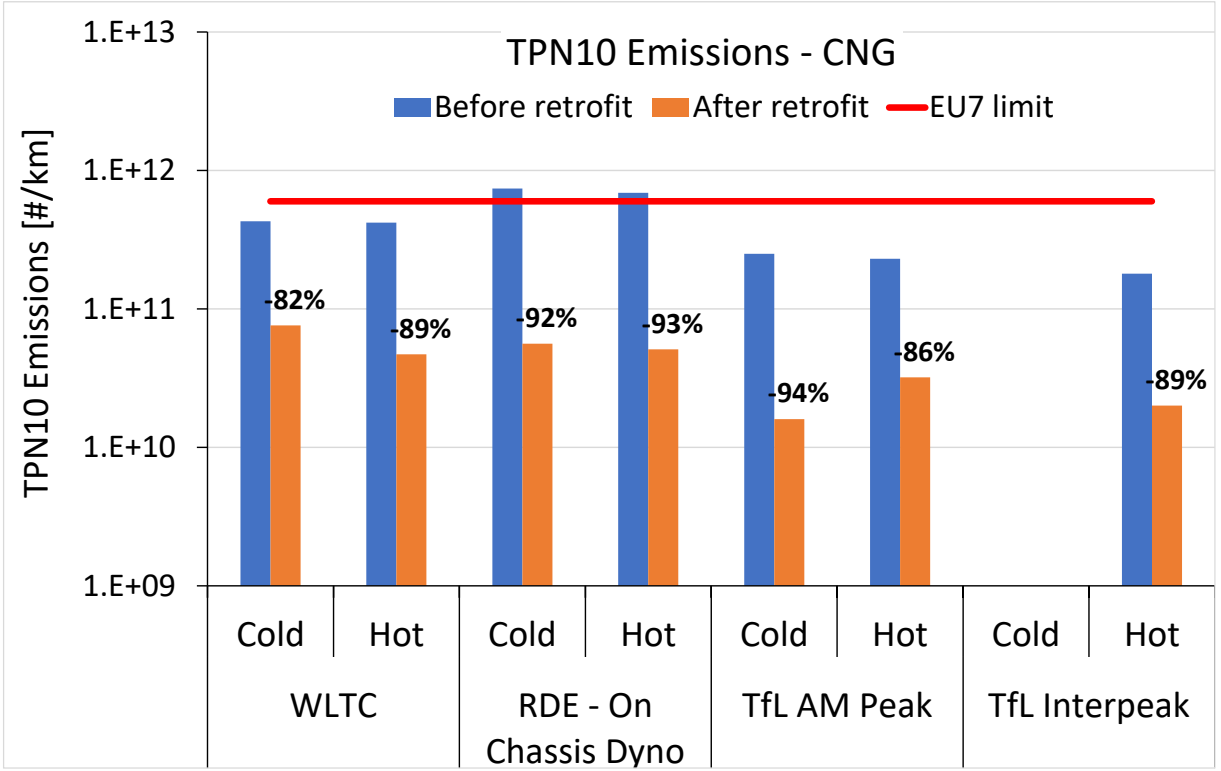


Retrofit v2: ASC+cGPF

VERA Tailpipe Retrofits: particle emissions reduction [1/2]

- ***PN Emissions – down to 23/10/2.5 nm both solid & total***
  - *SPN10: Below Euro 7 with CNG, exceeding the limit in urban driving with gasoline*
  - *TPN10: Higher than SPN10, above EU7 limit in many cases*
- ***Filtration Efficiency***
  - *Reaching/exceeding 90% at fresh conditions – aged filter testing ongoing with first tests showing FE>95%*

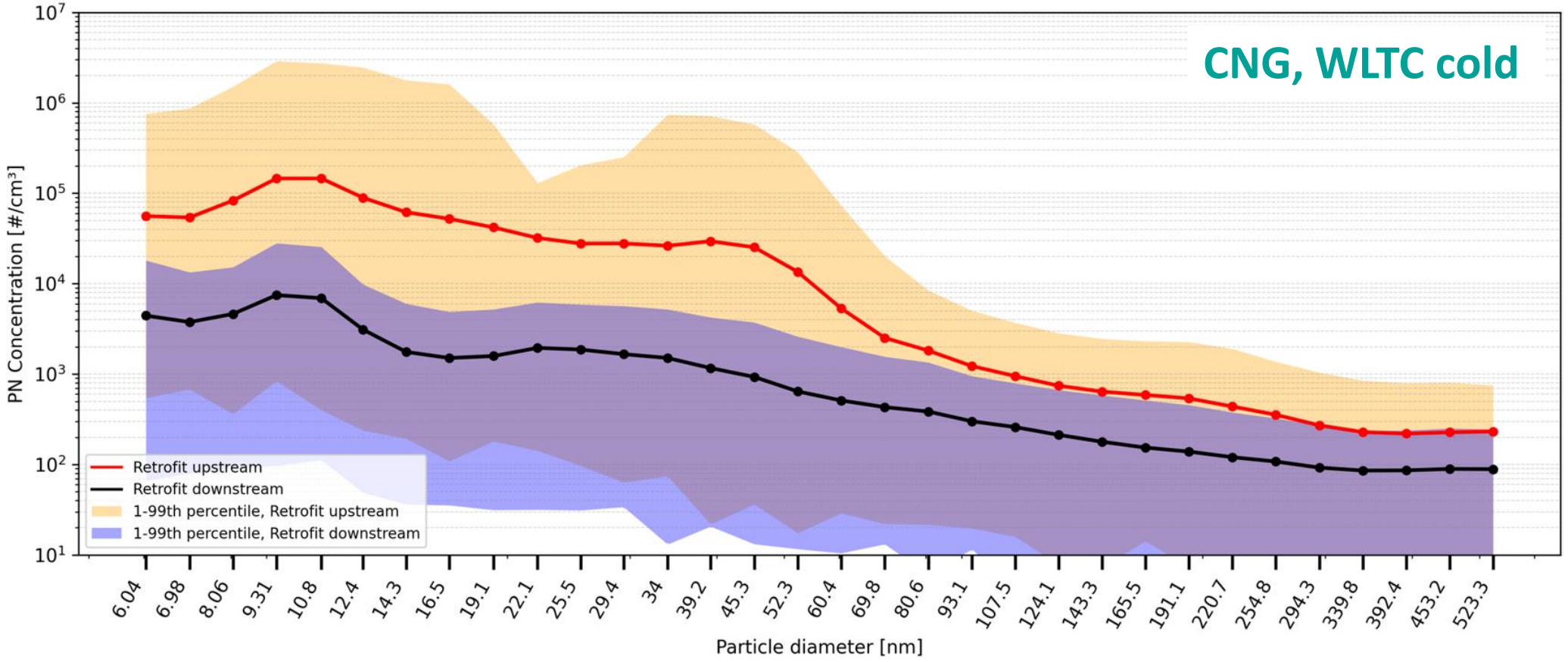




This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

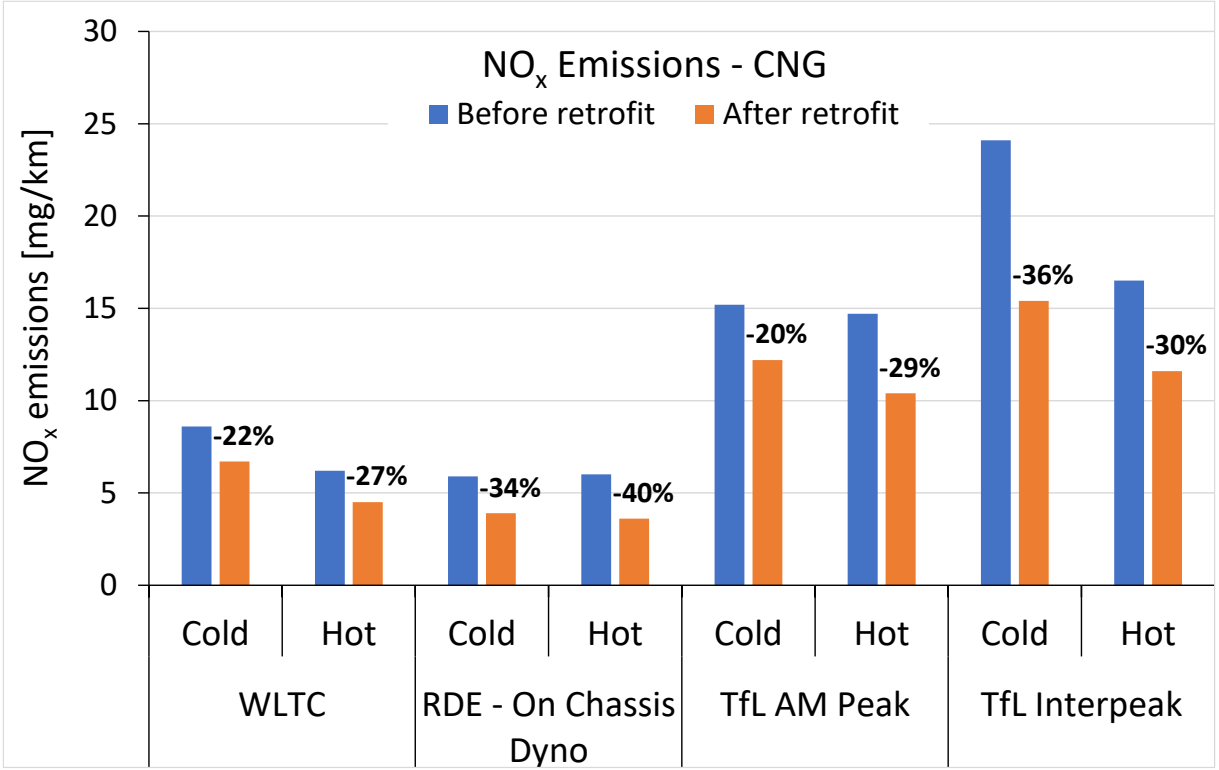
VERA Tailpipe Retrofits: particle emissions reduction [2/2]

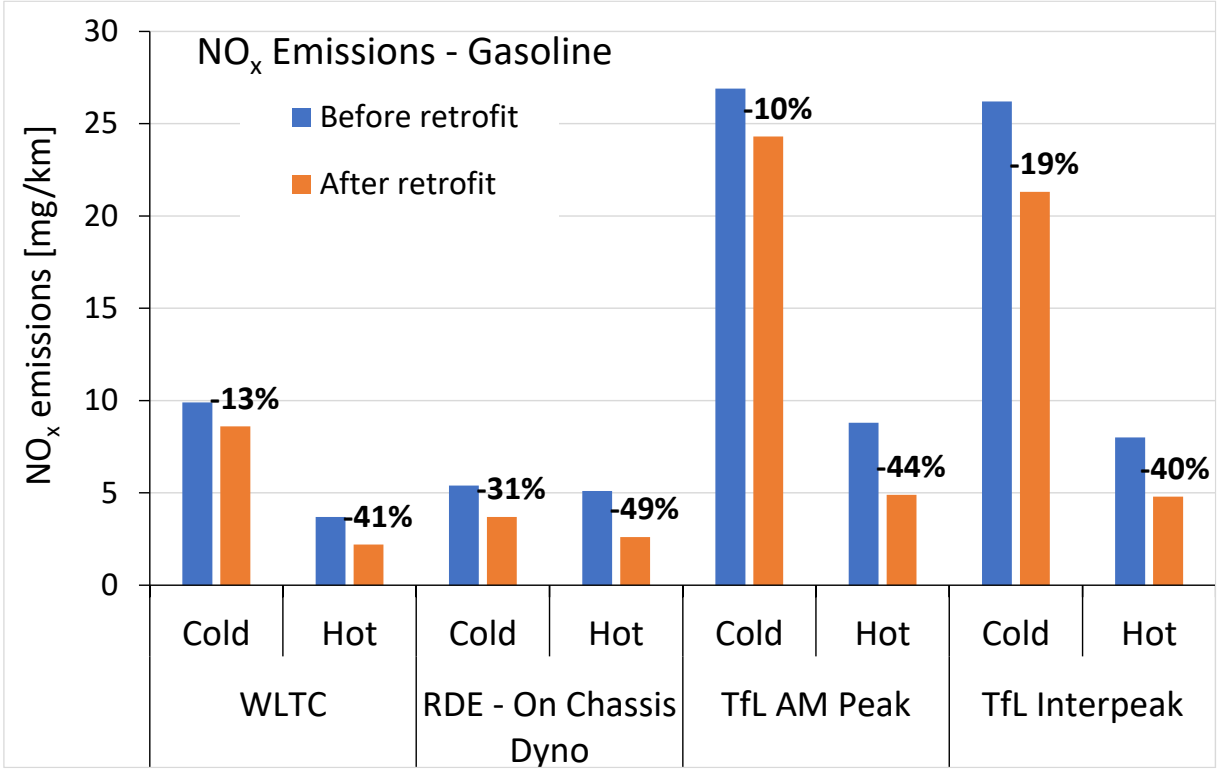
- Bi-modal particle side distribution, increased filtration efficiency for smaller particles (<70nm)
- **No significant impact on CO_2 emissions**



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Tailpipe Retrofits: gaseous pollutants [1/2]

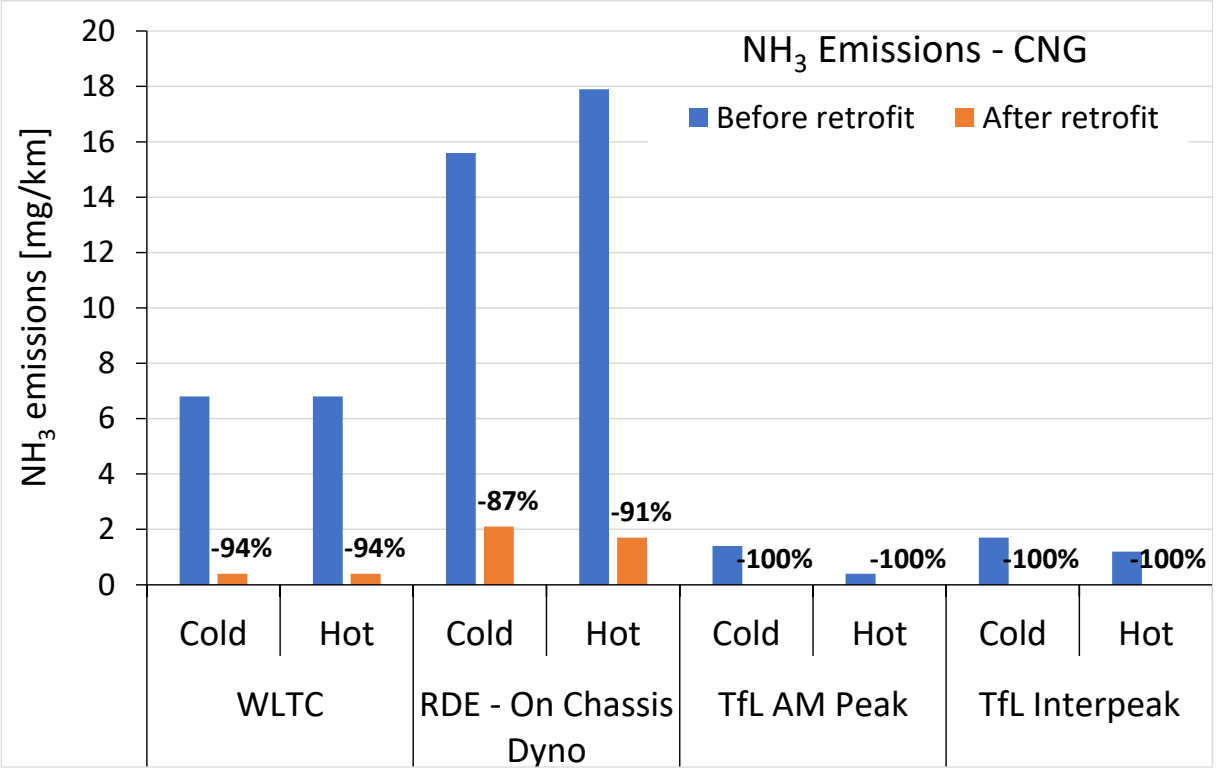


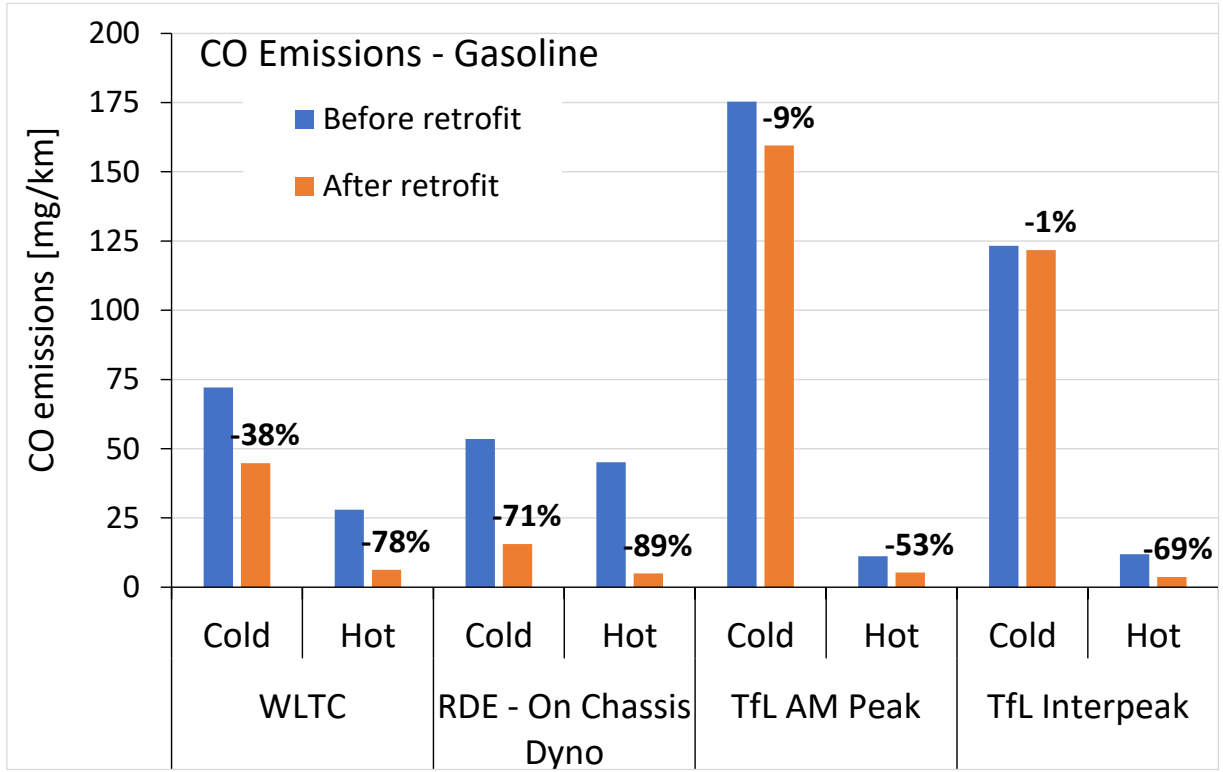


- **Consistent NO_x emissions reduction ~20-40% in all test conditions, with both CNG and gasoline**
- Higher reduction in hot-start cycles, where the system is already at high temperature (above the catalyst light-off threshold)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Tailpipe Retrofits: gaseous pollutants [2/2]

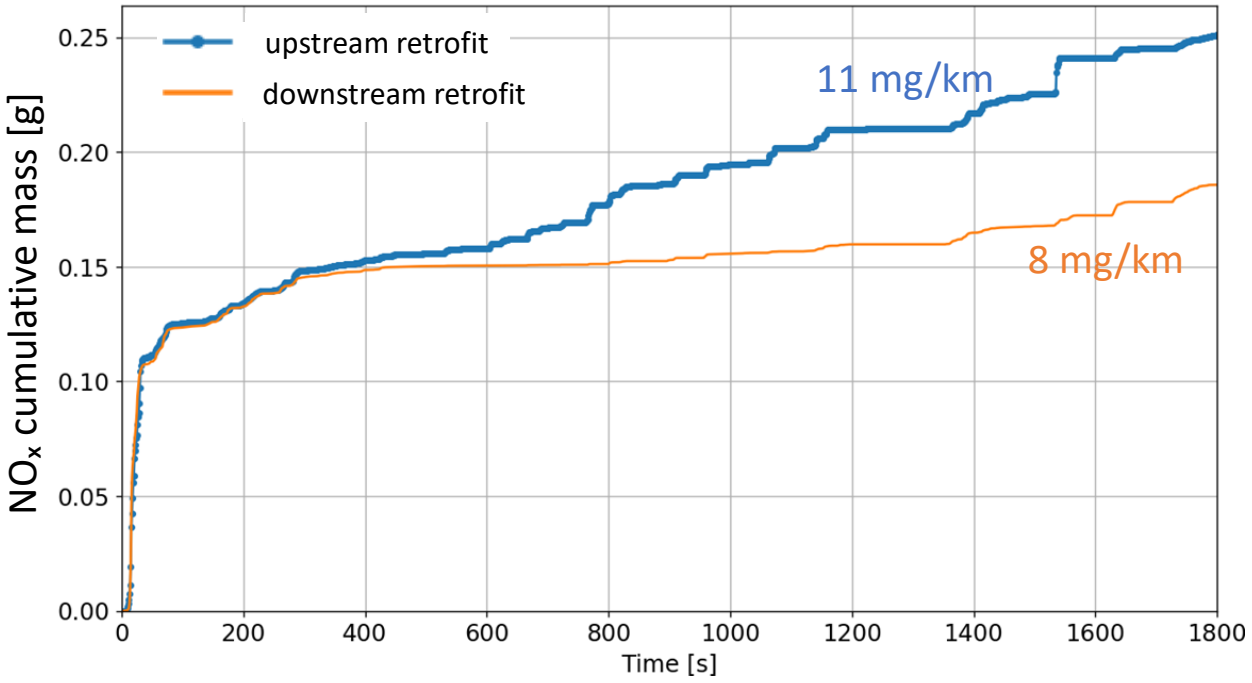


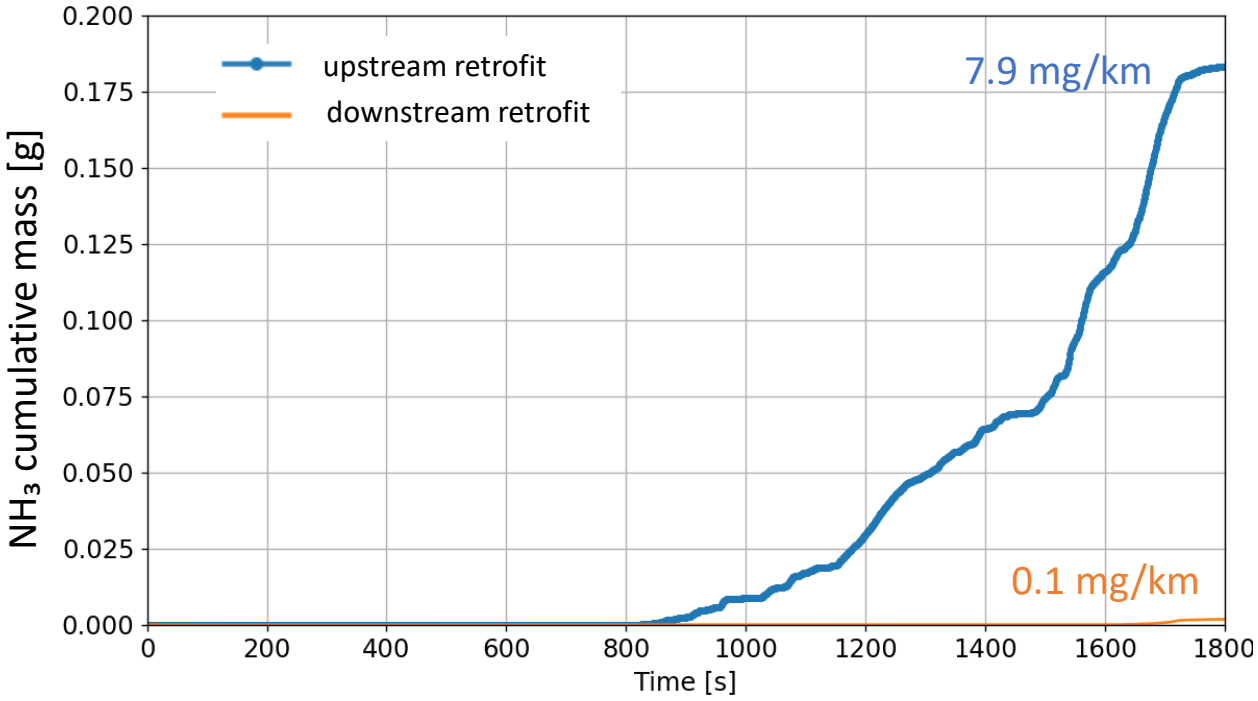


- **Complete elimination of NH_3 emissions, which are considerable before retrofitting in the case of CNG**
- Significant reduction of CO emissions, which are higher in the case of gasoline

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Tailpipe Retrofits: NO_x and NH_3 emissions control





- **Very low NO_x emissions** – Euro 6d passenger car
- ~30% NO_x emissions reduction with retrofitting
- Significant reduction after catalyst light-off

- Before retrofitting: **considerable NH_3 emissions at the tailpipe of a Euro 6d passenger car**
- Complete elimination of NH_3 with retrofit system v2
- Investigation of consecutive tests did not reveal any NH_3 storage into the ASC and subsequent release

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

Brake Retrofits Results

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Brake Retrofits: discs/pads & filtration system

- ***Road vehicles***
  - *3 use cases: Sedan, SUV, LCV (+ simulated HDV)*
  - *3 retrofits:*
    1. *Engineered cast iron disc + tailored pad*
    2. *Coated disc + tailored pad*
    3. *Filtration system*
  - *3 test campaigns*
    - *Brake dyno: performance, NVH, emissions*
    - *LCV (on road): emissions*
    - *LCV (on road): collateral/side effects*

- ***Metro/rail applications***
  - *2 use cases: Disc Brake (DBU), Tread Brake (TBU)*
  - *2 retrofits:*
    1. *Filtration system for DBU*
    2. *Filtration system for TBU*
  - *Test campaign*
    - *Brake dyno: performance, emissions*

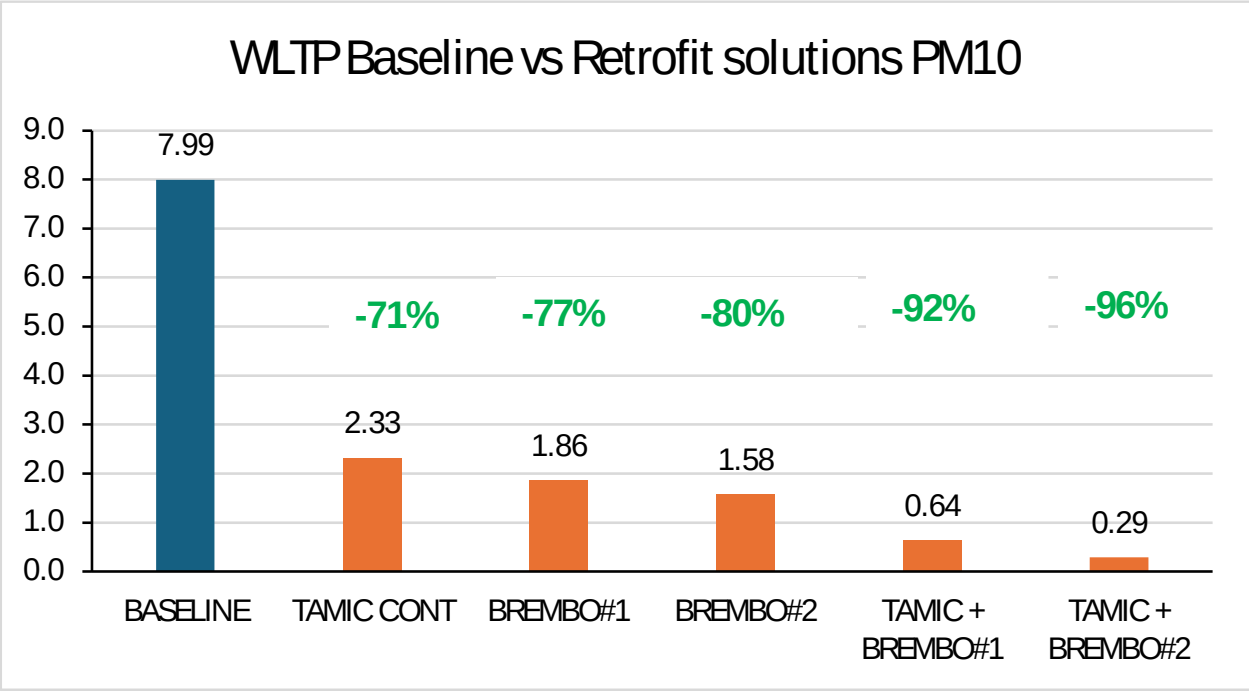
Tread brake unit (TBU)

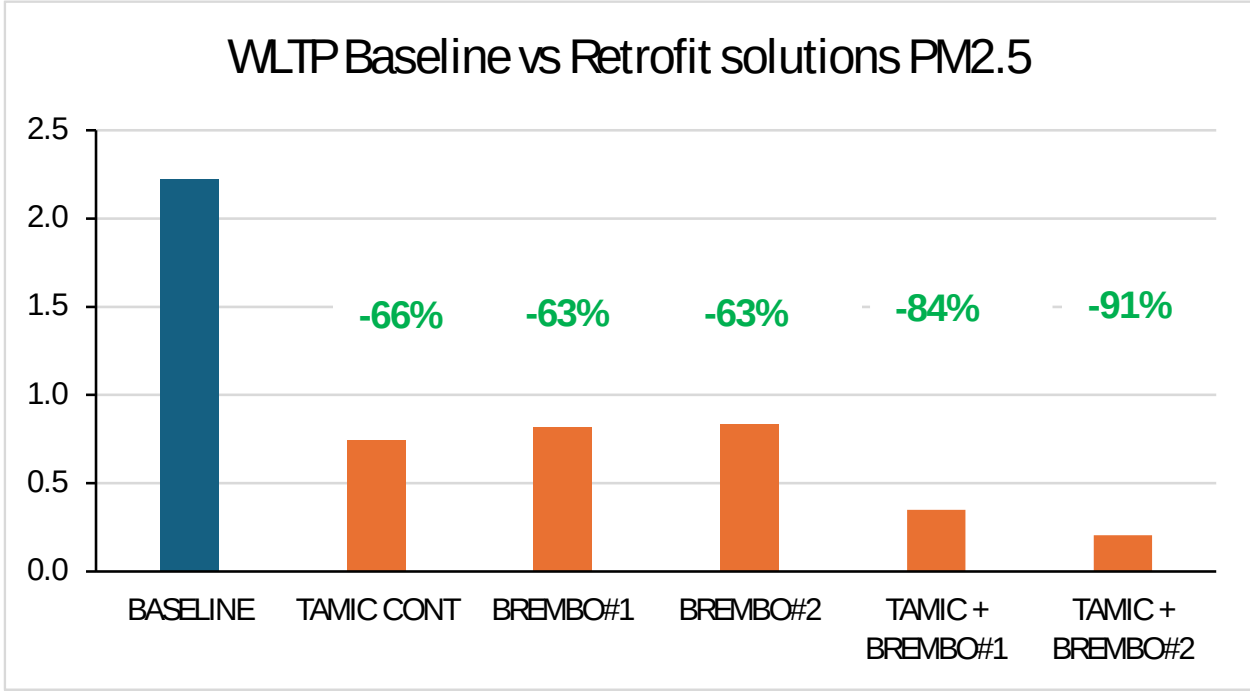
Disc brake unit (DBU)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Brake Retrofits: road vehicles – brake dyno testing

- **Combination of technologies exceeds 90% reduction in PM10 and PM2.5**
- Individual technologies achieve significant reductions





BREMBO#1: Engineered cast iron disc + Low Emissions friction pads

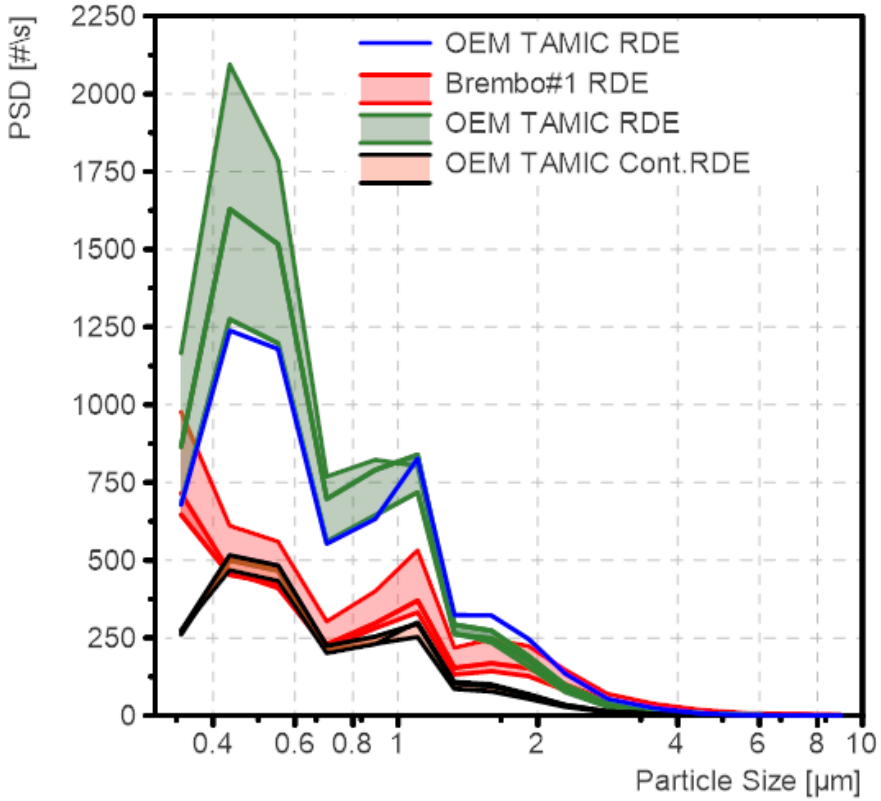
BREMBO#2: Coated Brake disc + Low metal friction material

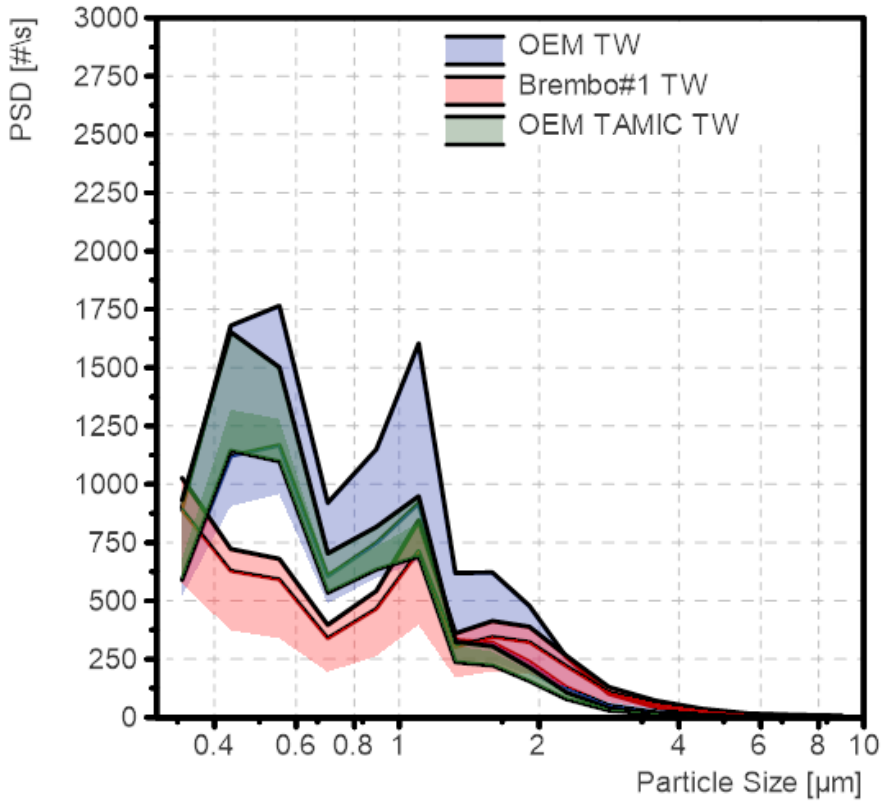
TAMIC: Filtration system for brake particles (TALLANO)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Brake Retrofits: road vehicles – on-road testing

- **Combination of technologies achieves high emissions reduction in real-world conditions**
- Validation of lab results, differences in temperature profiles
- Significant challenges in measurement and repeatability of brake PN emissions in on-road conditions

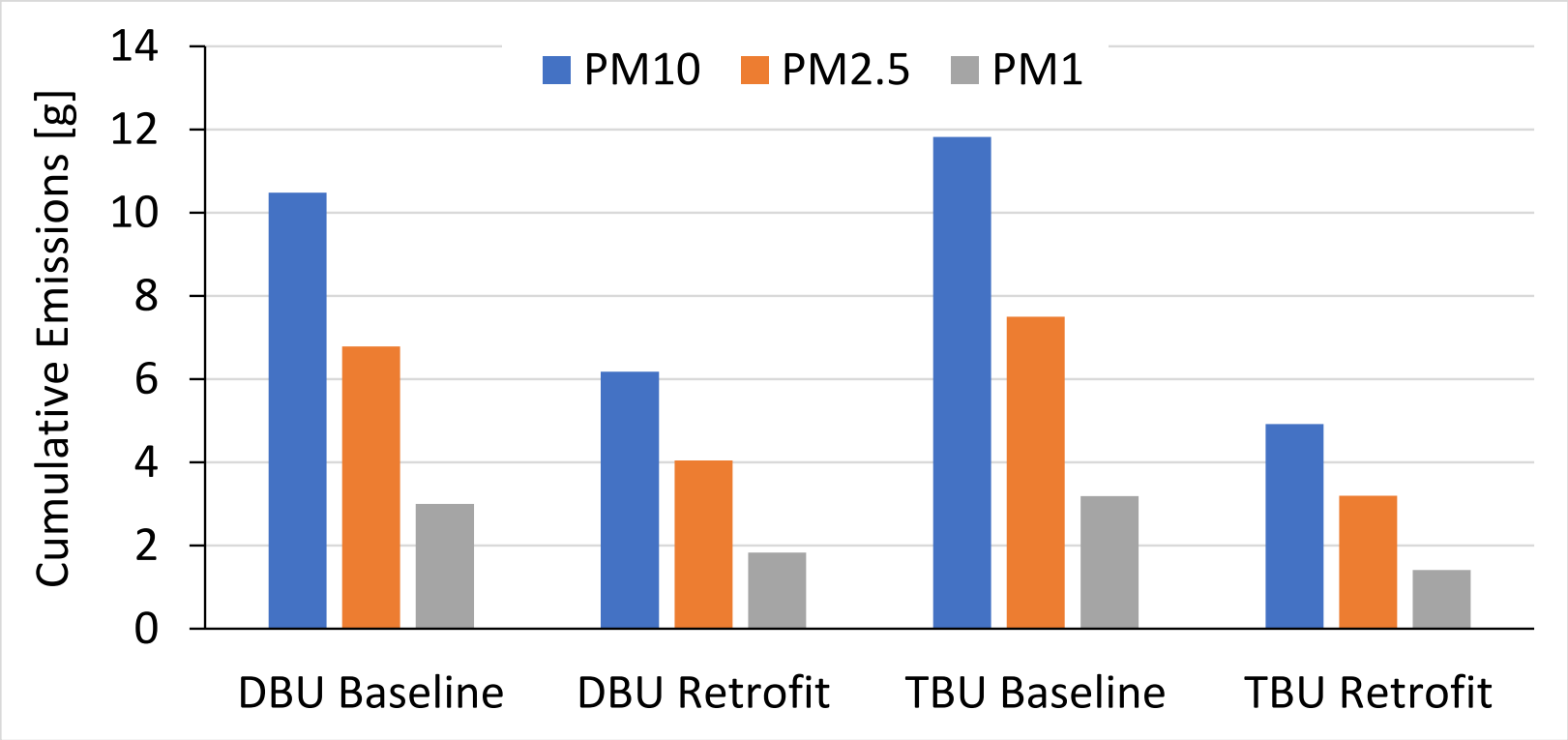




This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Brake Retrofits: metro/rail applications

- Smaller particles <1µm are mostly emitted in both systems (DBU & TBU)
- ~40% reduction in DBU
- ~60% reduction in TBU



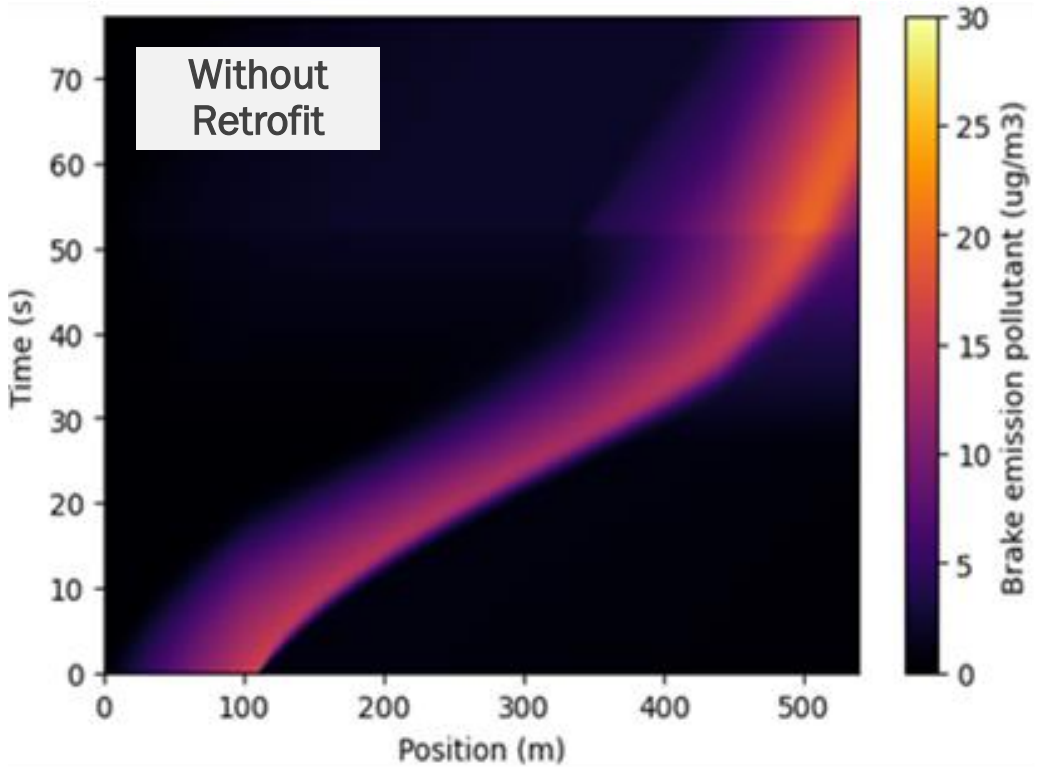
Baseline: Standard metro brake pads/blocks

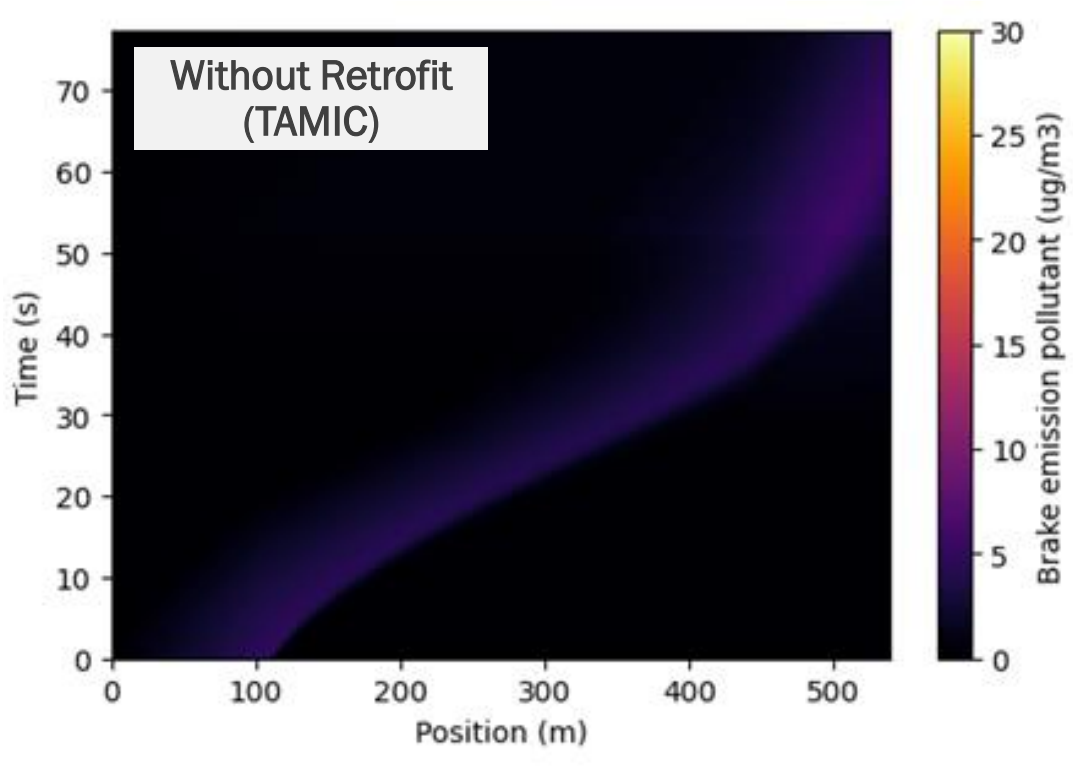
Retrofit: Adapted brake pads/blocks & filtration system (TALLANO/TAMIC)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VERA Brake Retrofits: metro/rail applications

- Air Quality in Confined Environments
- Contribution of retrofit solution – filtration system to brake particle emissions and particle concentrations
- Modelling tool simulating the spatial-temporal evolution of airborne brake particle emissions within the underground tunnel/platform network



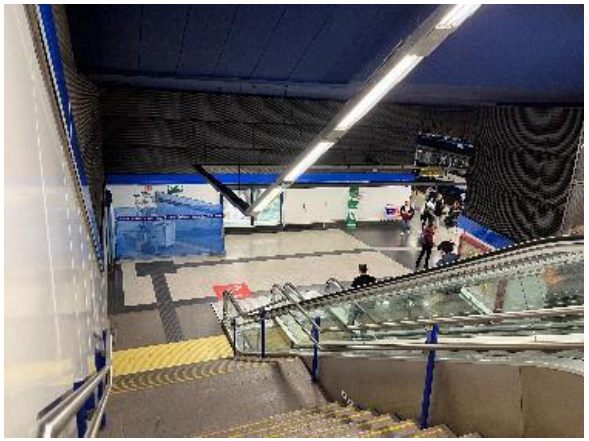


This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

Impacts

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

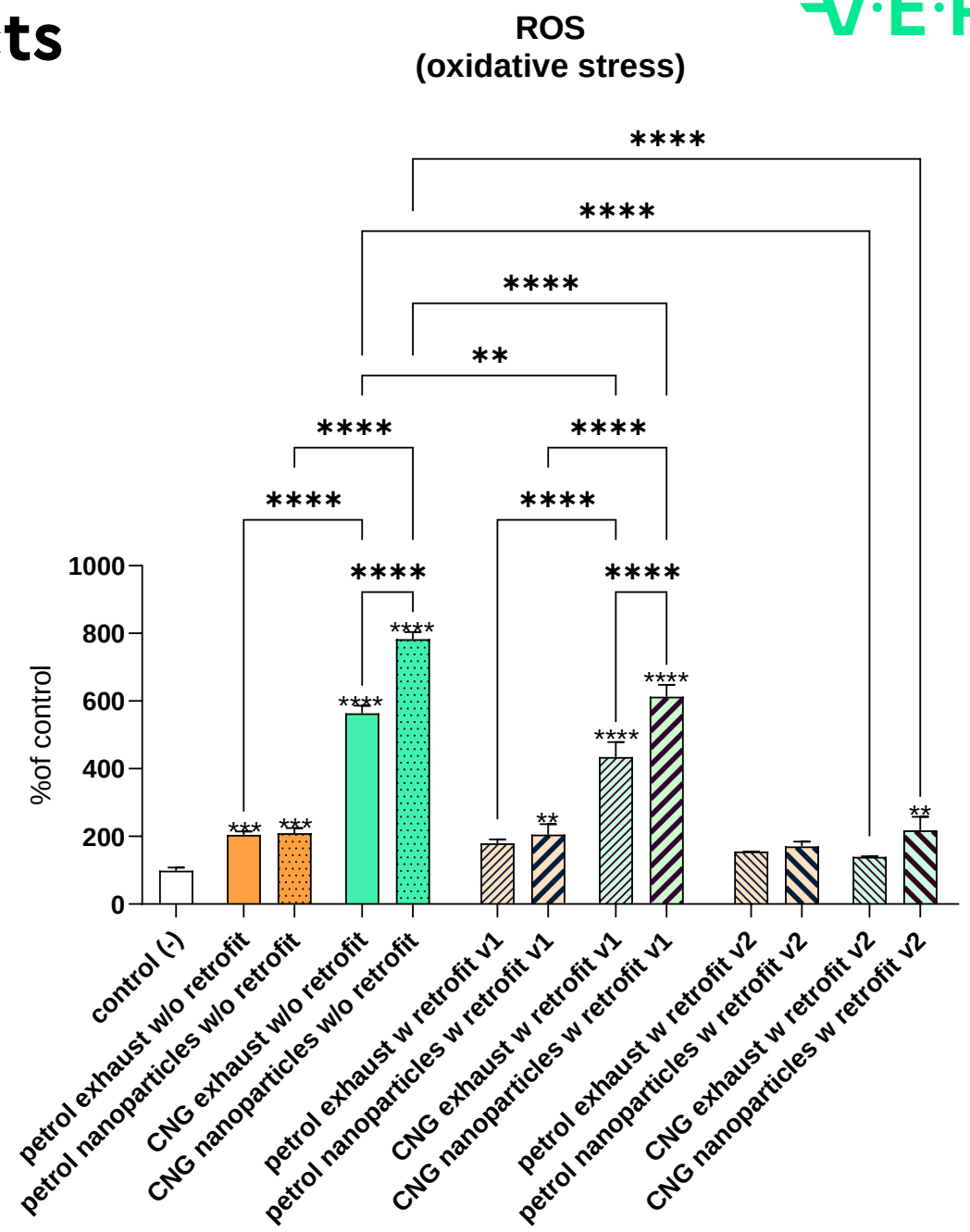
Exposure studies – Air quality impacts



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

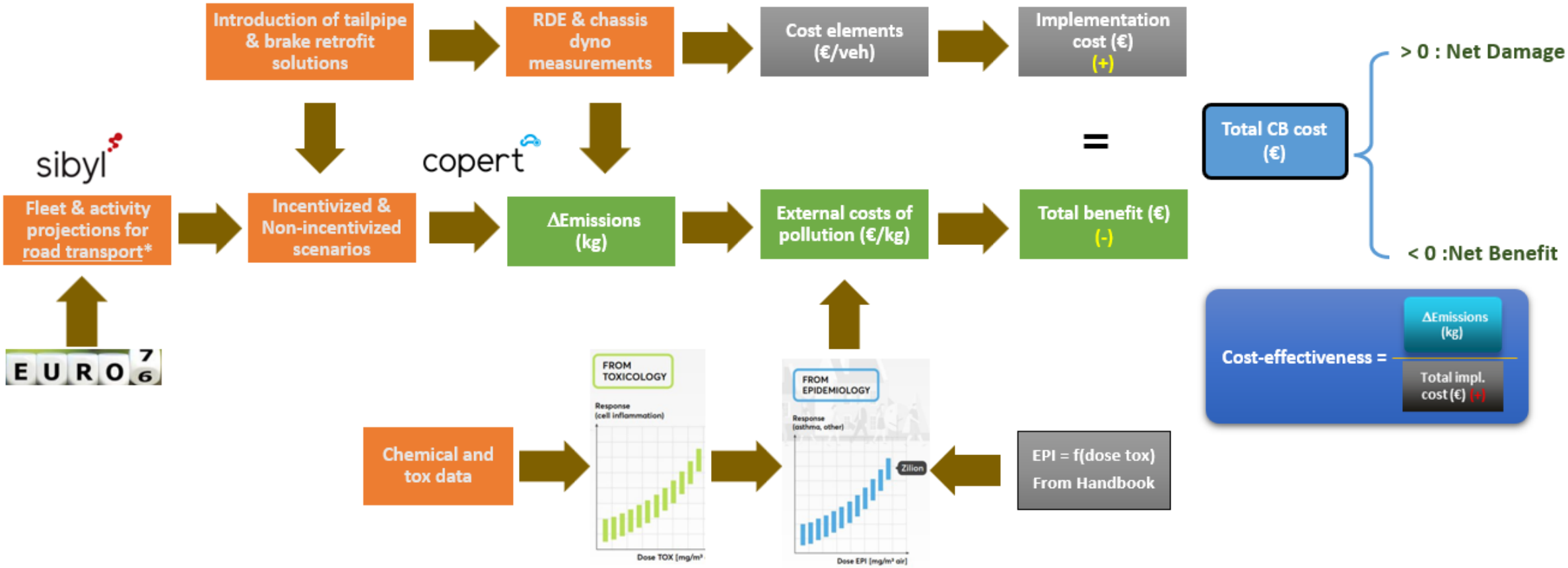
Toxicological Effects – Health Impacts

- A549 human lung epithelial cells exposed to exhaust emissions – gaseous and nanoparticles
- ALI & submerged analyses – Similar analysis for brake particles
- ***Results with tailpipe retrofit system***
  - The presence of nanoparticles in the exhaust gas increases the toxic impacts
  - The original exhaust gas of CNG causes higher oxidative stress
  - The application of the VERA retrofit system reduces the toxic effects by removing nanoparticles
  - The elimination of NH_3 reduces strongly the toxicological impacts of CNG exhaust gas
- ***Further evaluation is ongoing – further investigation of impacts of NH_3 and nitrates***



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

CBA of Retrofit Solutions



- Calculated external costs for health effects, climate change and measures to reduce air pollution
- Quantification of the benefit-over-cost ratio and net benefits per retrofit solution, scenario, MS & sensitivity analysis
- Summary of the results per retrofit explaining main costs and human and environmental impacts

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

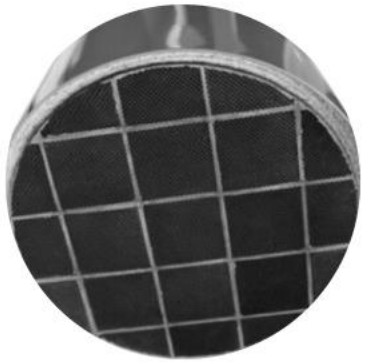
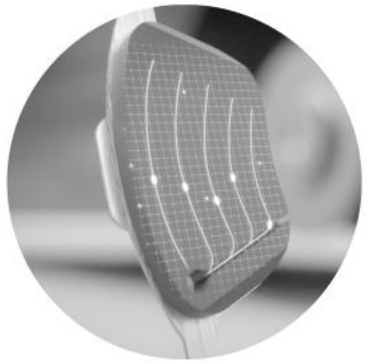
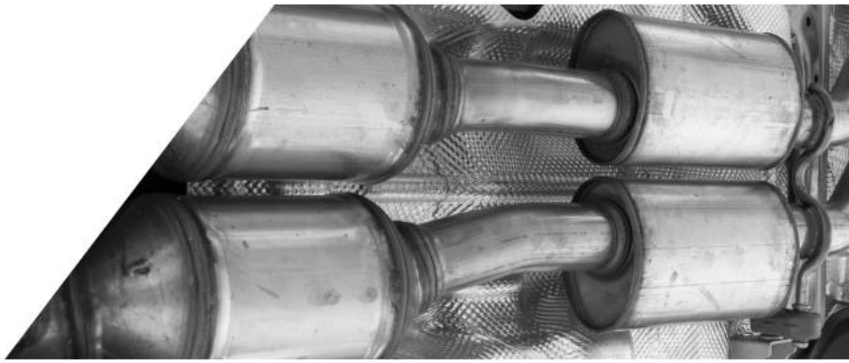
Wider Outcomes and KERs

- ***Key Exploitable Results***
  - ***Commercial***
    - *Coated GPFs, integrating various coatings, for light and heady-duty vehicles*
    - *Tailored discs and pads and brake particle filtration system for road vehicles*
    - *Brake particle filtration system for different brake technologies of metro/rail (DBU, TBU)*
    - *Target system cost: below 1,000 € (for the smaller application ranges)*
  - ***Scientific***
    - *Definition and standardization of a model-assisted approach for development and optimizing tailpipe emission control systems*
- ***Commercial advancements***

  - *Homologation of the patented PROMETHEUS technology of MONOLITHOS, the first Cu-based TWC for Euro 6*
    - **Approval No: *E24*103R00/04*0796*00***
- ***Policy feedback***
  - *Modern Euro 6d cars can emit high levels of NH_3, not regulated for LDVs in the Euro 7 emissions standard*
  - *Development of regulatory framework and incentive schemes to support retrofitting*
  - *Inputs towards real-world testing of brake particle emissions*

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893

VEHICLE EMISSION RETROFIT ACTIVITIES

Thank you

Athanasios Dimaratos
adimaratos@auth.gr

Zissis Samaras
zisis@auth.gr

VERA final dissemination event at TRA 2026 Exhibition

V·E·R·A

Less particles, better air quality

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056893