VERT retrofit projects worldwide based on Best Available Technology

Soot Free Tehran

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VERT®: Created to eliminate particle emissions from internal combustion engines (ICE) by means of best available technology

Agenda

- Introduction
- Motivation
- Particle Filters - Best Available Technology
- Technology Comparison
- VERT Retrofit Projects Worldwide

Introduction | What does VERT® stand for?

- Non-profit organization to eliminate particles and harmful substances from internal combustion engines
- Certification of diesel particle filters with respect to Best Available Technology (VERT® filterlist)
- International membership out of manufacturers of Emission Control systems, testing devices, substrate producers, chassis builders, engine manufacturers and others
- Acting as partner of Megacities to support and execute pollution reduction programs from road traffic and nonroad

VERT® is a Trade Mark
for Particle Filters based on Best Available Technology

Introduction | The Challenge is increasing

- Population is growing
- Need for mobility is increasing
- Total emissions are increasing
- Combustion engines will be used for decades
- **No alternative for Best Available Emission Control Technologies**

Introduction | Substances of Diesel Exhaust

- Solid particles:
  - Soot particles
  - Ash particles
- Liquid droplets
- Gases:
  - O_2, HC, NO, NO_2
  - PAH, Nitro-PAH
- Many trace substances

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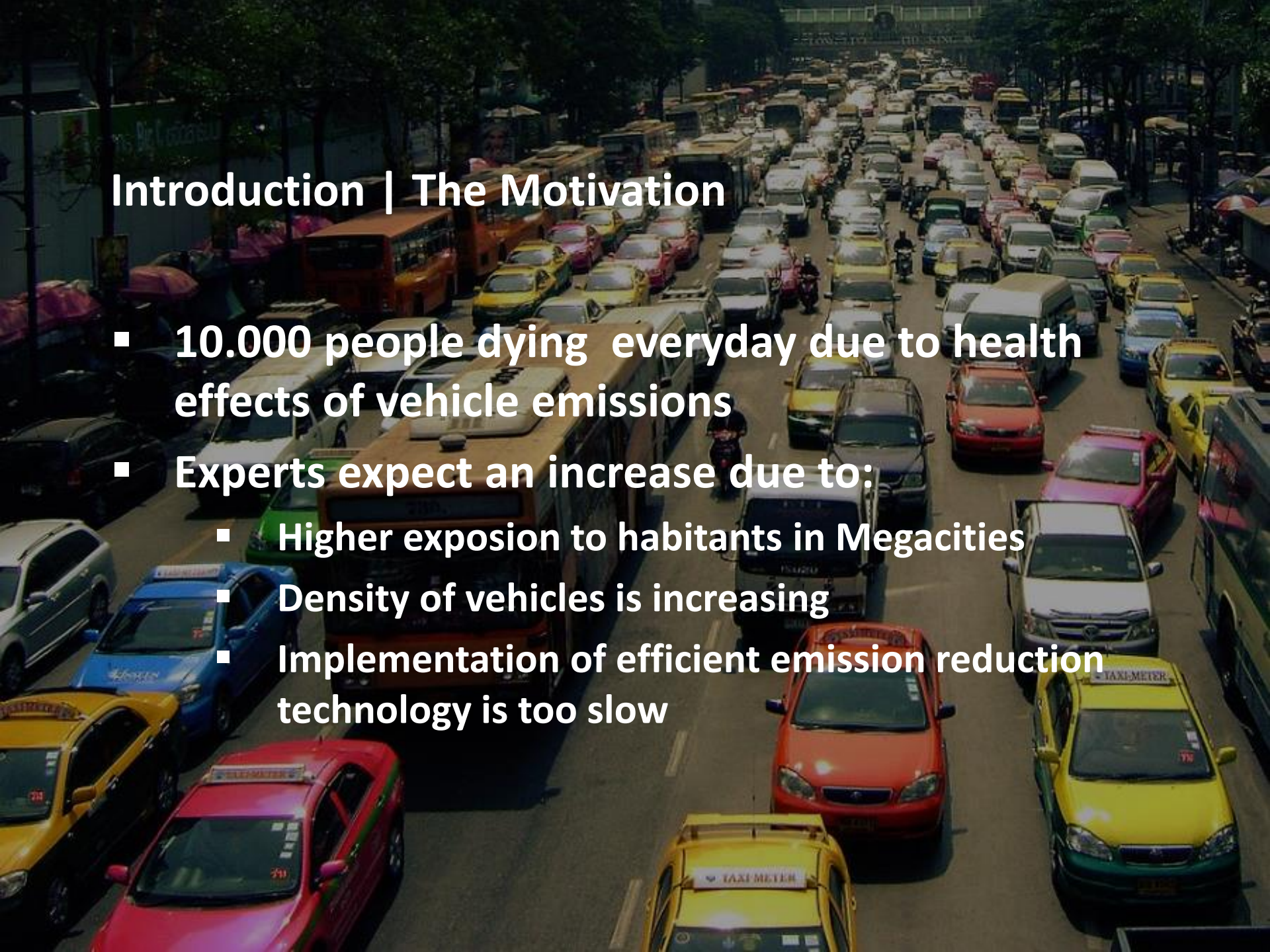
- Very small 20 … 500 nm
- High surface > 100 m^2/g
- Transporting toxics persistent in organism
- Carcinogenic
- Black colour | global warming effect

Long life toxic aerosol (weeks to month)

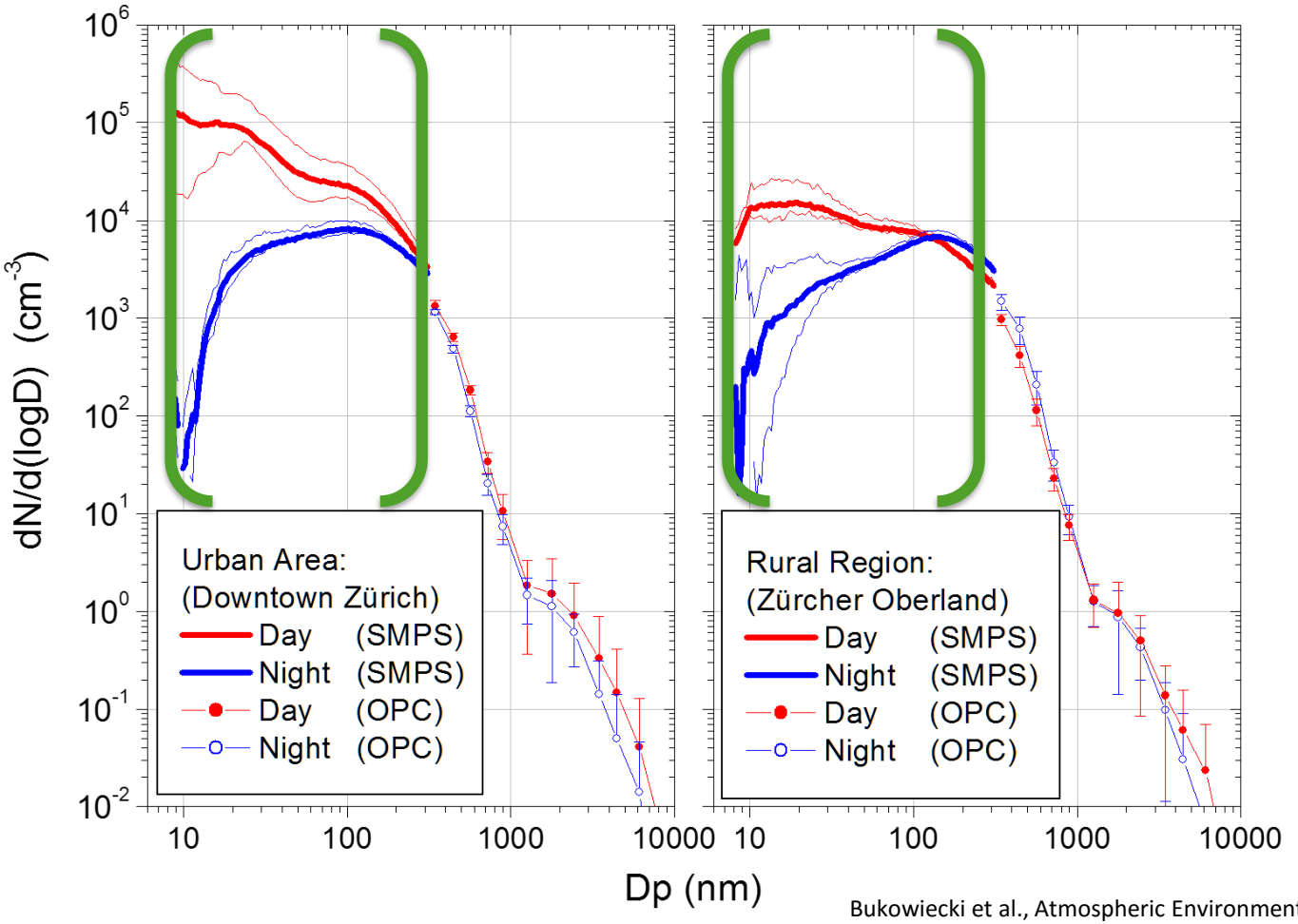
Defined by WHO since 2012 as evidenced carcinogenic (class 1 like asbestos)



Introduction | The Motivation

- 10.000 people dying everyday due to health effects of vehicle emissions
- Experts expect an increase due to:
  - Higher exposion to habitants in Megacities
  - Density of vehicles is increasing
  - Implementation of efficient emission reduction technology is too slow

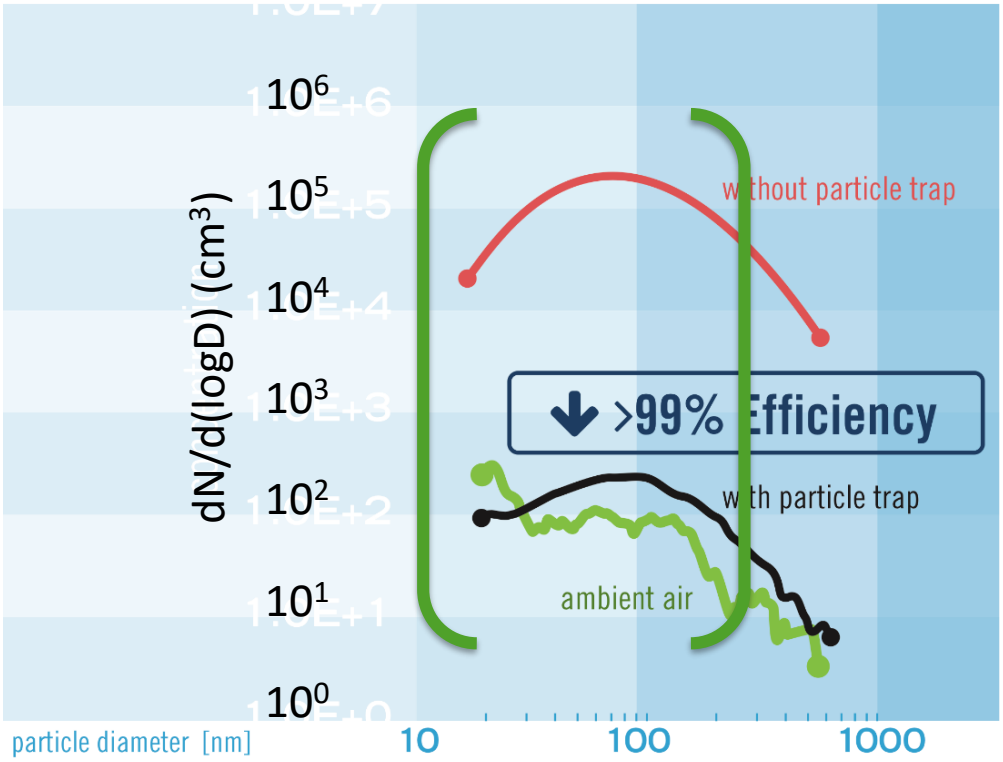
Motivation | Road Traffic Effects to Urban Air Pollution



Bukowiecki et al., Atmospheric Environment, 2002

Particle Filters - Best Available Technology

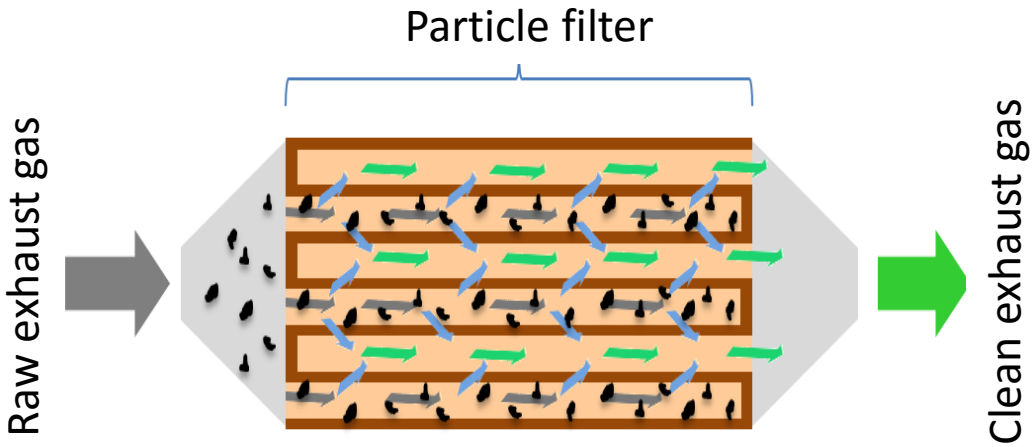
Size distribution of an typical diesel engine w and w/o closed DPF



- DPF remove 99.99% of engine generated particles
- Only 0.01 % released to the environment
- DPF removes all particles

Particle Filters - Best Available Technology

“Closed” Filter Systems are holding > 99% of the particles back



- Channels are reciprocally closed
- Exhaust gas is forced to penetrate the porose, to air permeable, walls
- Soot particles are hold back and collected on the walls of the filter materiel

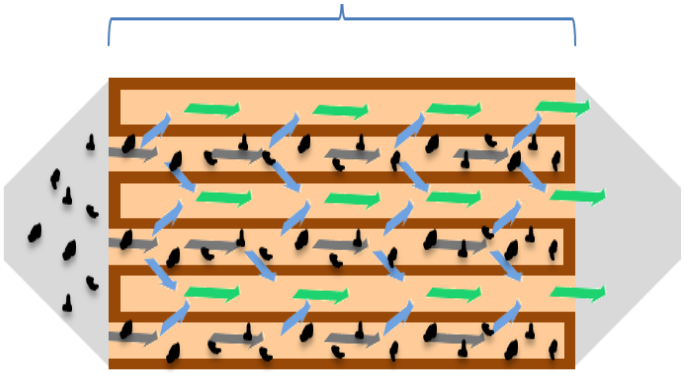
Particle Filters - Best Available Technology

“Closed” Filter Systems are holding > 99% of the particles back

Inlet side of filter

Raw exhaust gas

Particle filter



Clean exhaust gas

Outlet side of filter

- Real results from a vehicle > 1,200 hours in operation
- Coach bus | age at retrofit 20 years
- Engine: DD Series 60; 470hp @ 2100 rpm

Particle Filters - Best Available Technology

Heavy Duty Emission Standards

2012: WHO classified solid fine particles as carcinogenic class 1

EURO 3	EURO 4	EURO 5	EURO 6
PM: 0.1 g/kWh	PM: 0.02 g/kWh	PM: 0.02 g/kWh	PM: 0.01g/kWh
PN: ---	PN: ---	PN: ---	**PN: $8x10^{11}$ 1/kWh**
NOx: 5.0 g/gkWh	NOx: 3.5 g/kWh	NOx: 2.0 g/kWh	NOx: 0.4
Fuel: EN590: 1999 (< 350 ppm S)	Fuel: EN590: 1999 (< 50 ppm S)	Fuel: EN590: 1999 (< 10 ppm S)	Fuel: EN590: 1999 (< 10 ppm S)
2000	2005	2010	2014

Implementation of particle number limitation! Lessons learned by European Union

Typical solutions

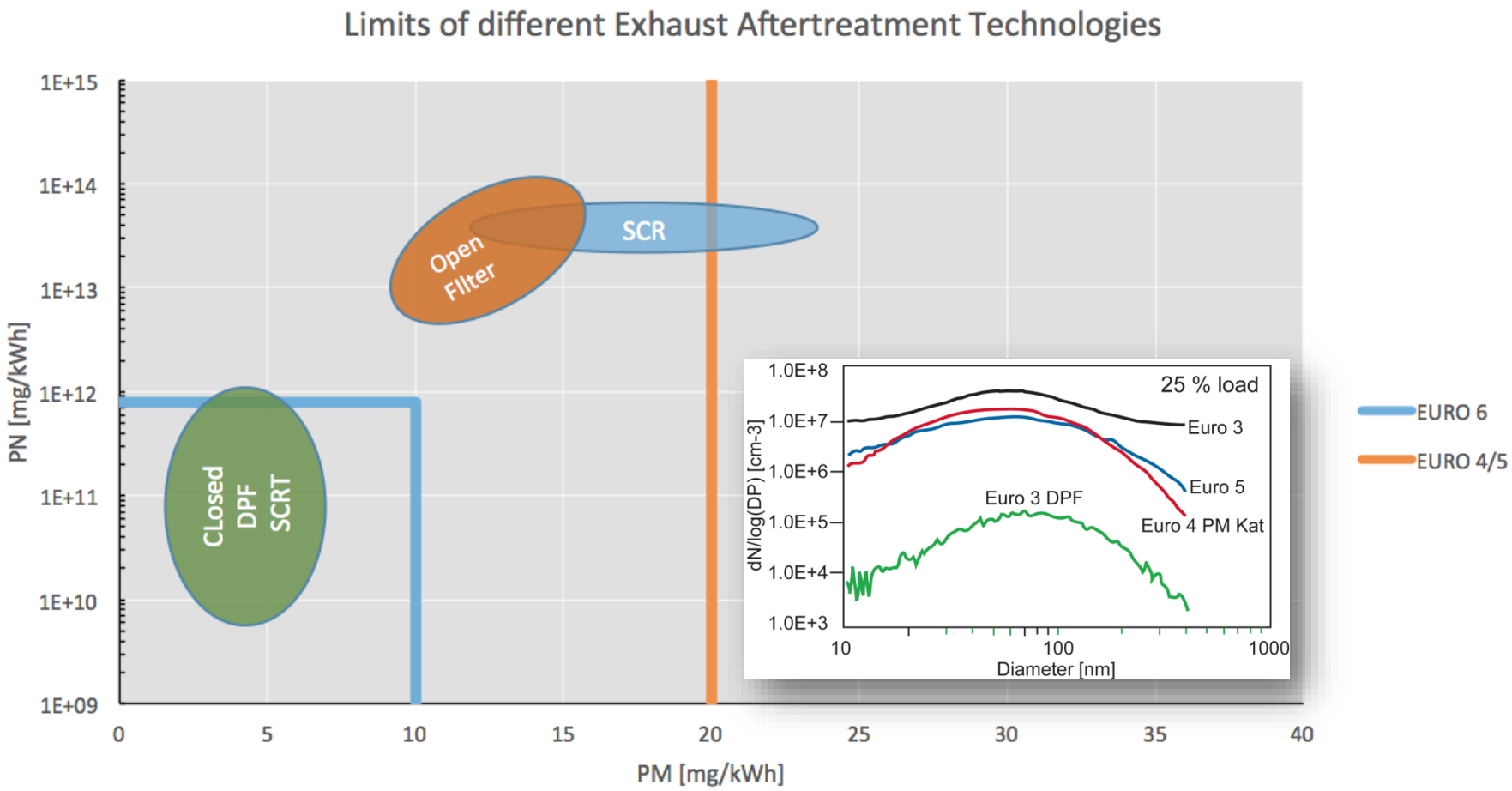
- Optimization of combustion
- Electronic control
- EGR

- Optimization of combustion
- Electronic control
- EGR + partial PM filter or SCR

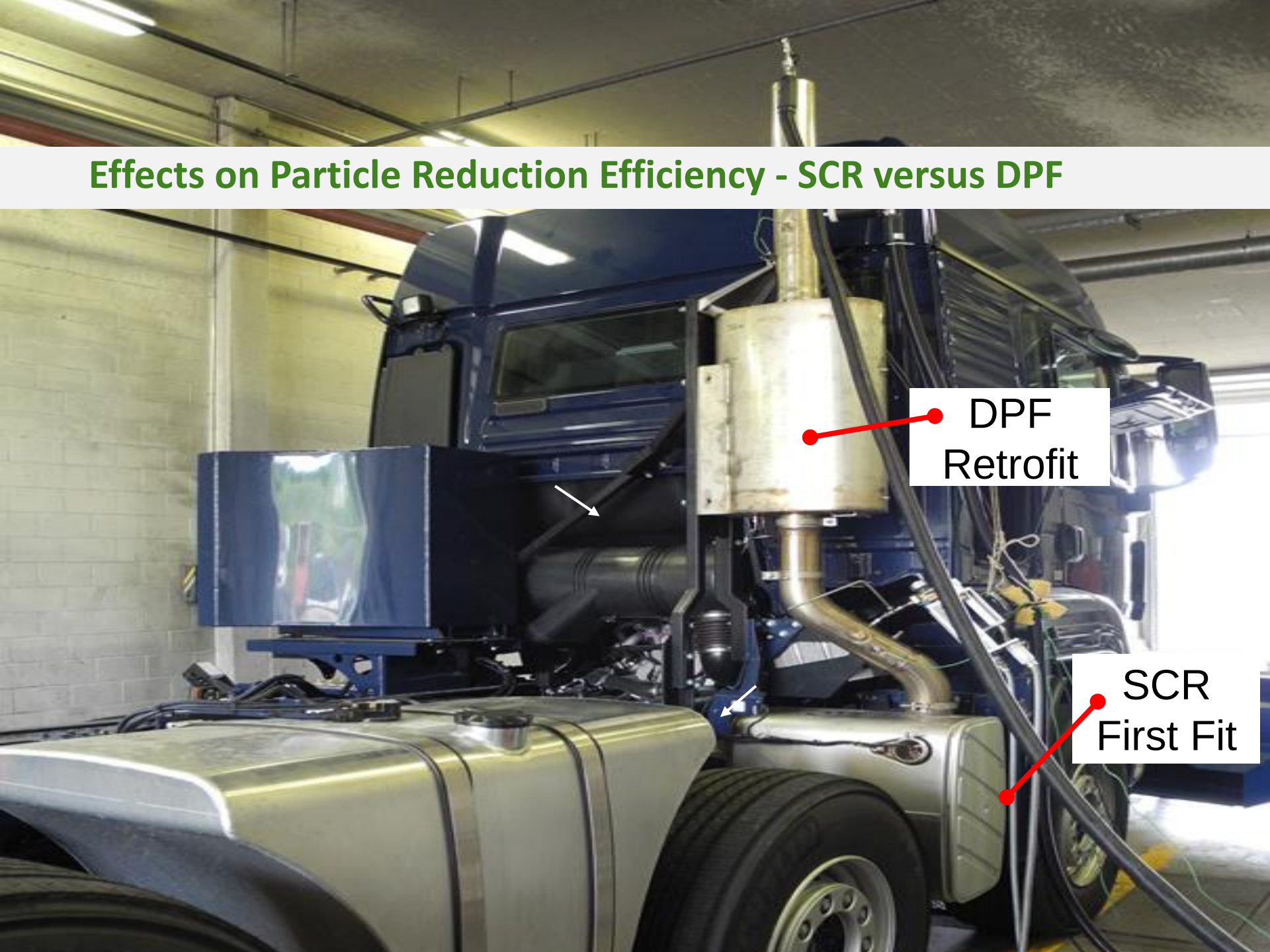
- Optimization of combustion
- Electronic control
- SCR w or w/o partial PM filter

- Optimization of combustion
- Electronic control
- SCR plus closed particle filter

Particle Filters - Best Available Technology

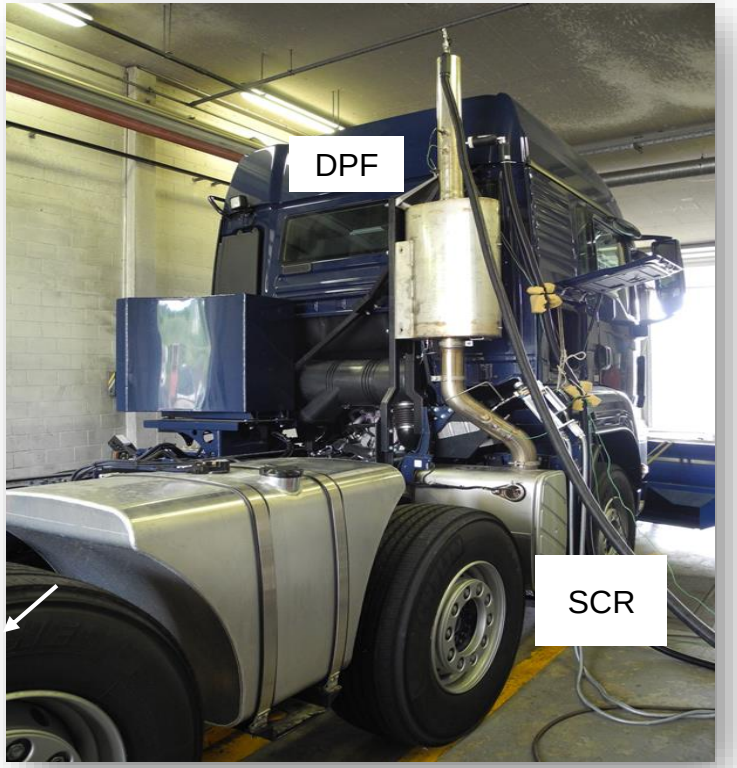


Effects on Particle Reduction Efficiency - SCR versus DPF



Effects on Particle Reduction Efficiency - SCR versus DPF

- Vehicle
  - MAN TGS
  - 397 kW
  - 220 km
- Aftertreatment system
  - OEM SCR
  - **DPF retrofitted**
- Test parameters
  - SCR dosing activated
  - ULSD
  - Chassis dyno
  - Measurements before and after DPF



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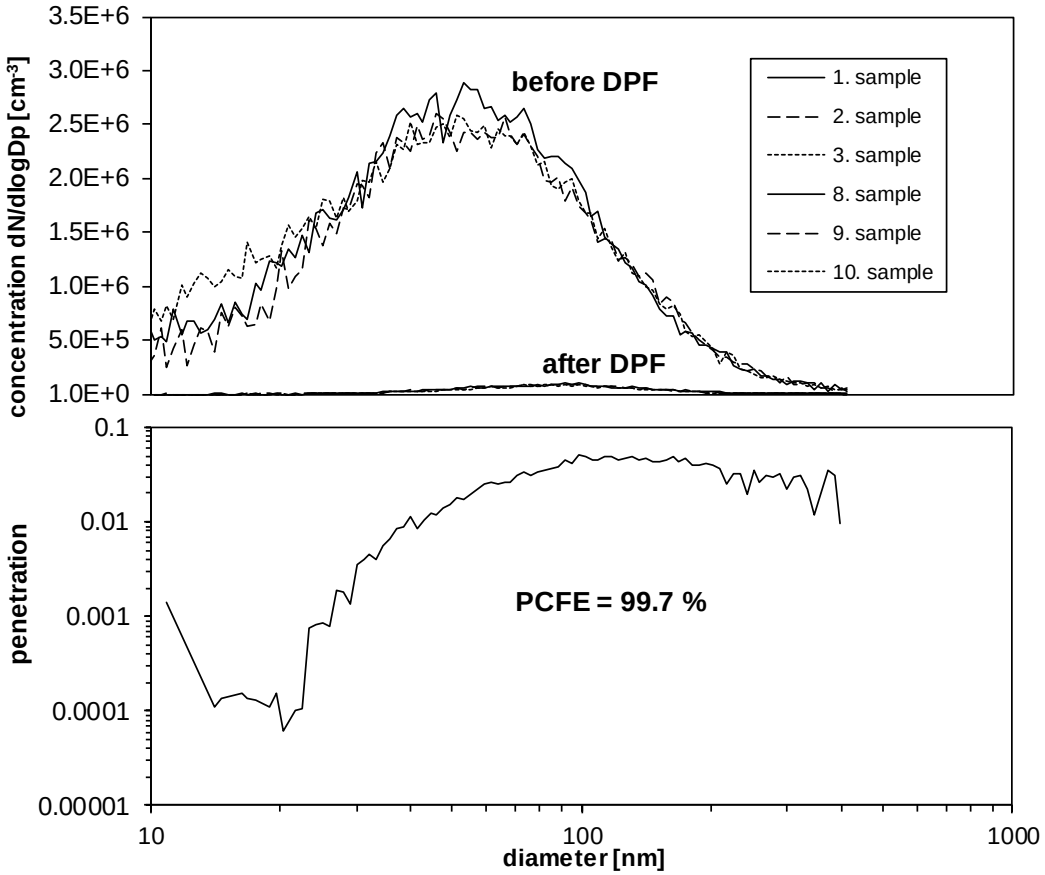
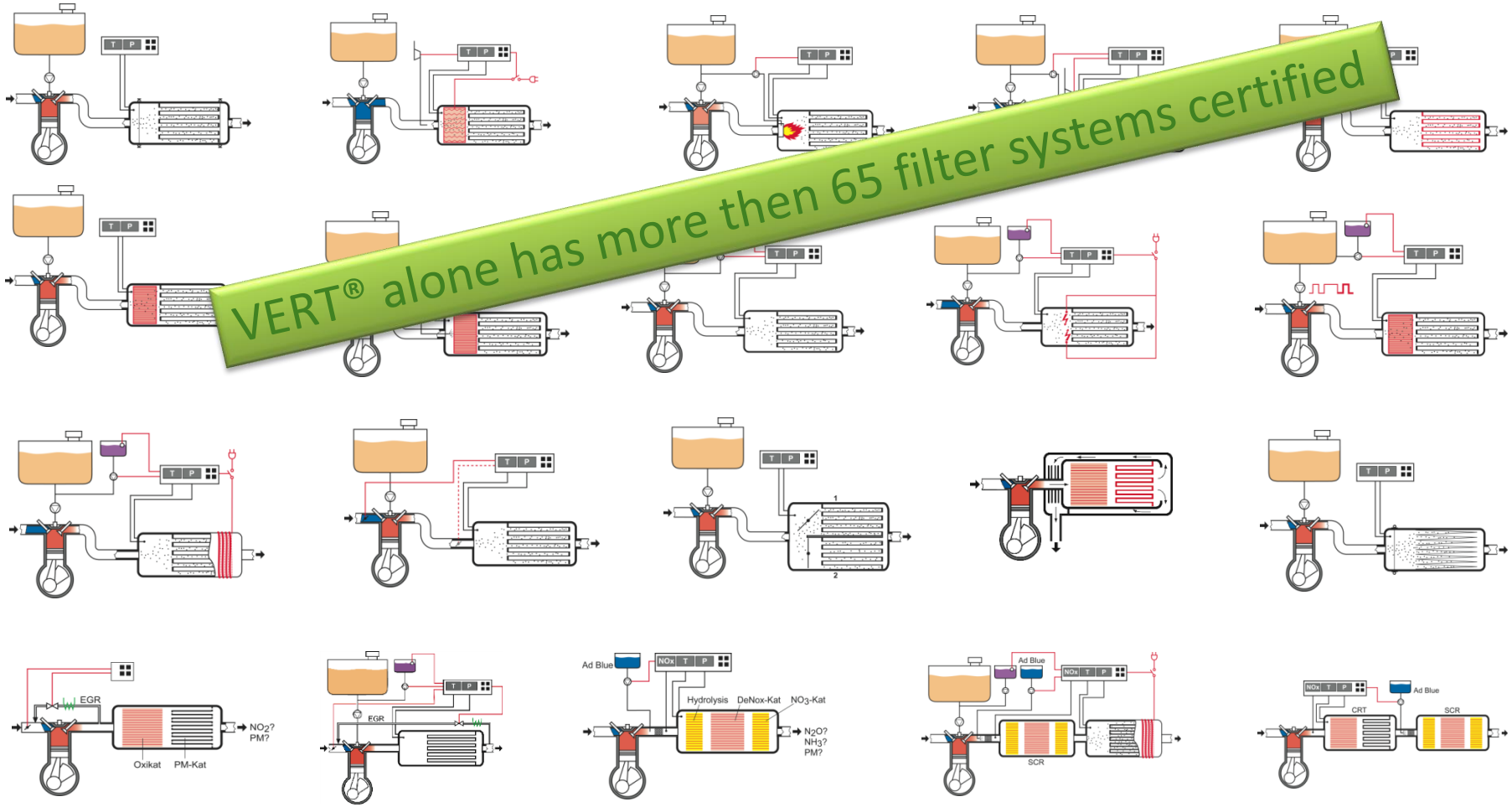


Source: **SAE Paper 2014 -1-1569**

J. Czerwinski, Y. Zimmerli/AFHB, A. Mayer/TTM, N. Heeb/EMPA, H. Berger/ASTRA, G. D'Urbano/BAFU

Technology for Retrofit and Option Fit



Retrofit/Option Fit of a Diesel Particulate Filter

- Particle filters substitute the original muffler

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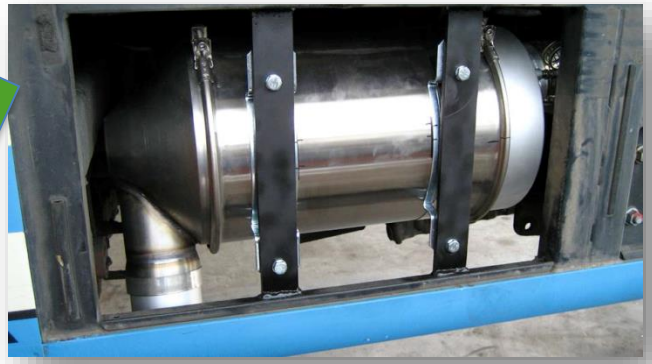


Retrofit/Option Fit of a Diesel Particulate Filter

- Particle filters substitute the original muffler

VERT Projects - Example Iran

Current DPF retrofits for the public bus fleet of the capital of Iran. VERT® association has been invited by AQCC (Air Quality Control Company), based in Tehran to organize the implementation phase and support OEM legislation of the national DPF schema.

Policy framework for in-use heavy duty
National legislation for heavy duty vehicles from 2016 on.

DPF Retrofit Pilot Tests with 10 city busses, chosen out of 9 manufacturers and 11 different DPF systems in Tehran, test run until end of 2014.

Implementation Phase: Commercial Retrofit Phase starting now, goal retrofit of 2.000 city busses,

VERT Projects - Example Bogotá

The **Bogotá DPF Project [BDPF]** aims at the introduction of DPF applications in Colombia's capital, supports the realization of DPF retrofit pilot tests, the introduction of a local approval schema and the preparation and initiation of DPF implementation under the integrated system of public transport.

Policy framework introduction of 10-year plan of air pollution per decree. **Control emission systems (DPF) for busses**

DPF Retrofit Pilot Tests
Know-how & technology transfer, leverage the participation of main DPF manufacturers

Implementation Phase
Stage 1 – 18 busses, stage 2 – 300 busses until

Pictures: Secretaría Distrital de Ambiente Bogota-Colombia

VERT Projects - Santiago de Chile

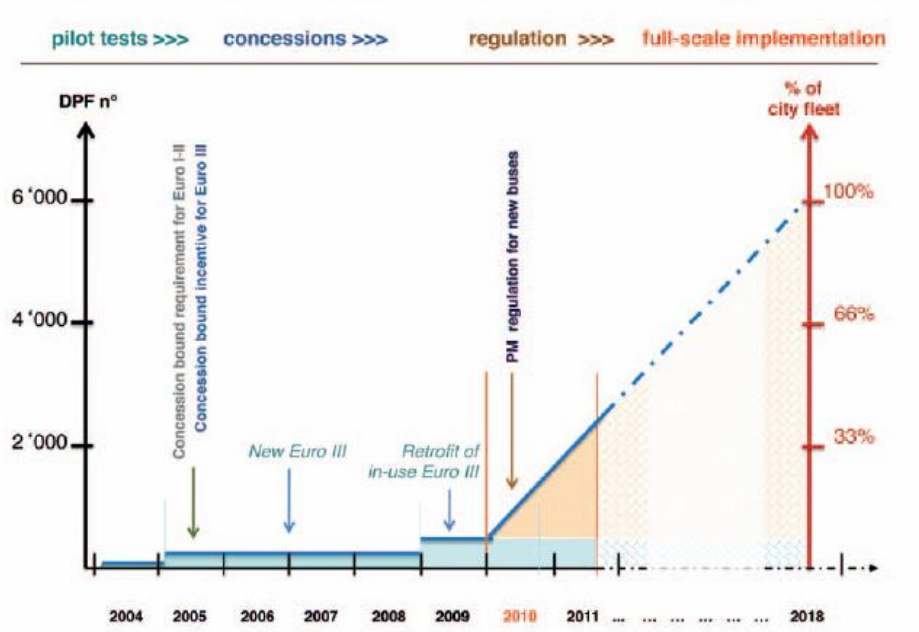
The **Santiago de Chile DPF Follow-Up Project [SFU]** is conceived as a continuation of earlier efforts with a successful DPF introduction (2004-2009). It addresses the enforcement scheme and environmental benefits of the ongoing DPF program and defines steps on future policies

Policy framework
For in-use and new busses DPF Regulation for EURO III busses

DPF Retrofit Pilot Tests
Pilot bus fleet of 12 busses. Representative bus routes, data logging, installation and operation

Implementation Phase
approximately 3200 city busses operate in 2013 with DPF in the city

VERT Projects - Santiago de Chile



Overview of DPF test and implementation phase, policy tools applied and schematically the level of application achieved

VERT Projects - Example China

China and Switzerland authorities supported by VERT® started the Sino-Swiss program Black Carbon Emission of Mobile Sources (BCEMS) with VERT® certified DPFs.
Based on these experiences a national diesel vehicle aftertreatment guideline was drafted.

Policy framework for in-use heavy duty
National diesel vehicle after treatment guideline is drafted

DPF Retrofit Pilot Tests 10 coaches in Nanjing, 10 city busses in Xiamen, 11 construction machines in Beijing

Implementation Phase
About 10,000 diesel vehicles in Beijing are already retrofitted and got the green labels

Global Experience with Heavy Duty Diesel Particulate Filters

- **USA:** California retrofit program for in-use heavy duty onroad vehicles, since 2007 all new heavy duty with DPF
  New York, New Jersey; many activities in cities under local law, large funds for school busses and transit busses > 60.000 DPF
- **UK:** London Low Emission Zone 3 phases –total > 100,000 retrofits, DPF for construction machines in London cross rail
- **Italy**: DPF for LDV and DPF for construction machines in public construction in Südtirol, Low Emission Zones in Lombardia and Emilia Romana, „Decreto“ for retrofit of HDV retrofits in the Milan and Turino area > 15.000 retrofits
- **Netherlands**: Low Emission Zones in all major cities, starting with onroad HDV, nonroad vehicles following
- **Denmark**: retrofit in Copenhagen, LEZ in all major cities > 4.000 retrofits
- **Japan and Korea**: retrofit activity started with bus and truck in Seoul and Tokyo, 2008 intensified, some are partial DPF > 150.000 retrofits
- Today 84 mil. vehicles with DPF in-use

Conclusion

Due **to health effects and economical benefits** the **focus should be solid particle** reduction out of diesel engine emissions

EURO 6 values for PN can be reached with DPF , even with retrofitted EURO 3 and EURO 4 engines

Local challenges like high sulphur content in **fuel can be managed with adapted technologies.** Euroepan EURO 6 standard OE solutions are developed for ULSD.

Diesel emissions are Carcinogenic. Technical solutions to eliminate harmful and Carcinogenic substances are available and already in use.
DON'T USE DIESEL ENGINES WITHOUT A FILTER

"*Few risks have a greater impact on global health today than air pollution; the evidence signals the need for concerted action to clean up the air we all breathe*."

Dr. Maria Neira,
Director of WHO's Department for Public Health, Environmental and Social Determinants of Health, 2012

Thank you for your attention

For more information www.visit vert-certification.eu