Exhaust Aftertreatment of Gasoline Engines with Coated Particulate Filters

9th VERT Forum – Dübendorf

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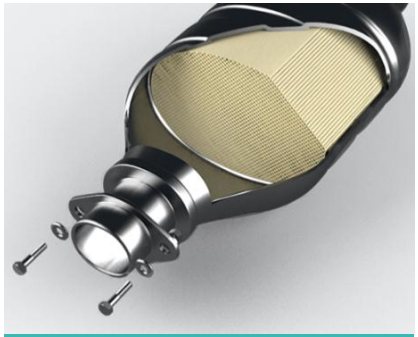
Agenda

- Umicore – Who we are
- Global Automotive World
- Market and System Trends
- Umicore c-GPF Portfolio - Technical Requirements
- Performance Data
- Durability Run Data
- Summary

Who we are

A global materials technology and recycling group

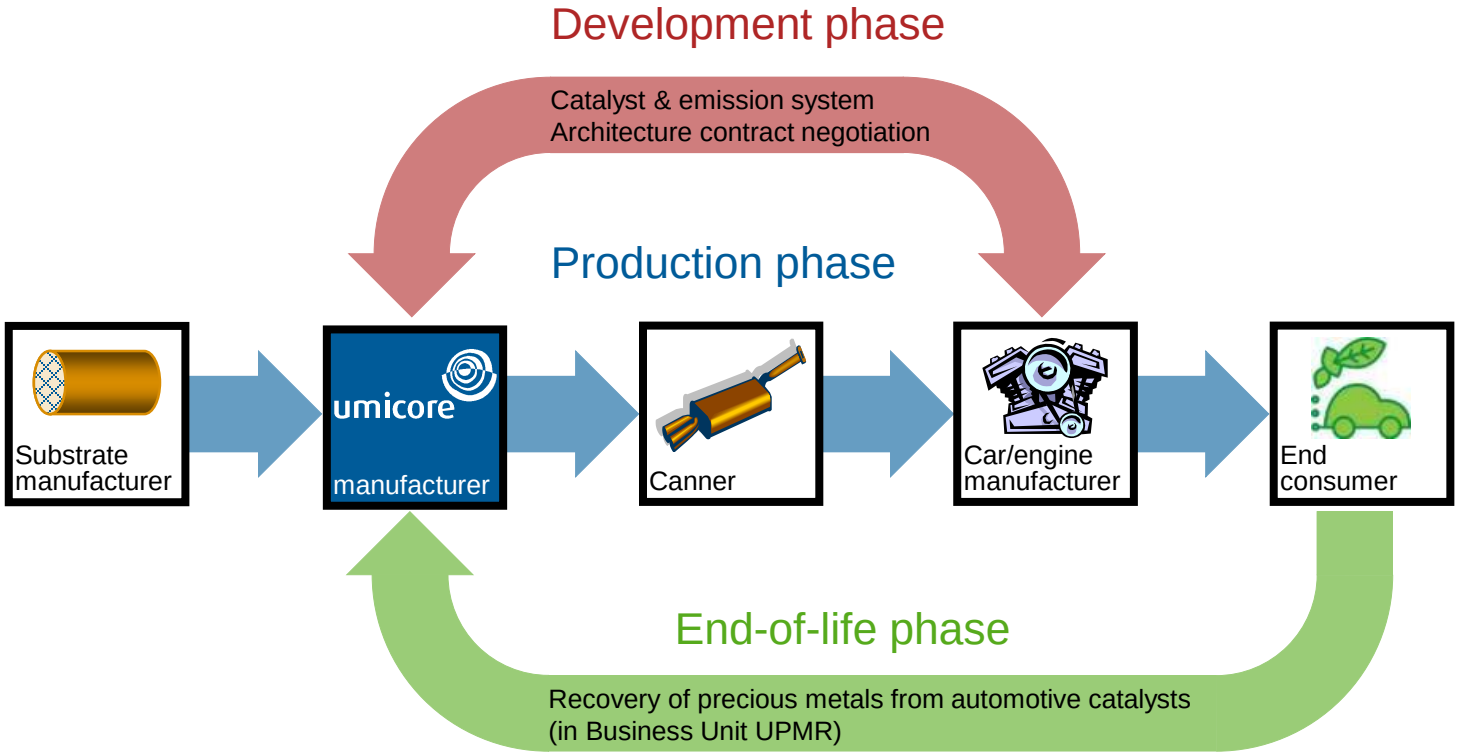


One of three global leaders in emission control catalysts for light-duty and heavy-duty vehicles and for all fuel types

A leading supplier of key materials for rechargeable batteries used in portable electronics and hybrid & electric cars

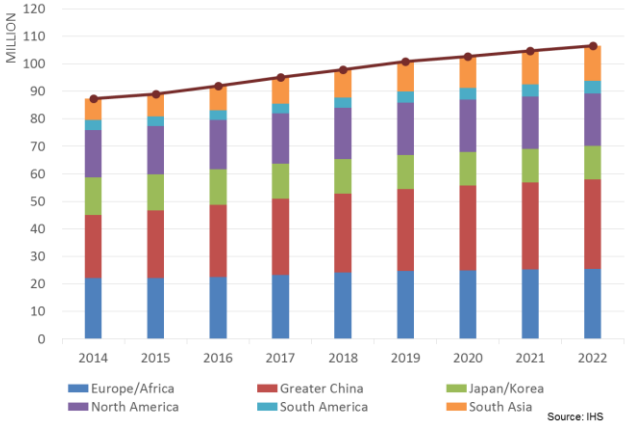
The world's leading recycler of complex waste streams containing precious and other valuable metals

From substrate to end consumer



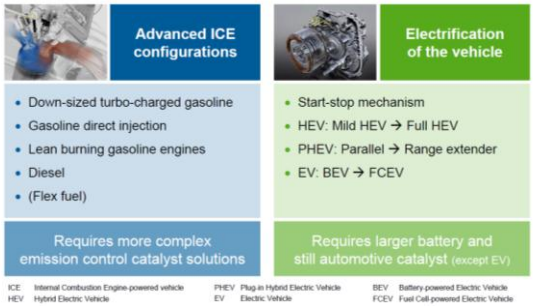
Global Automotive World

LDV Production by Region

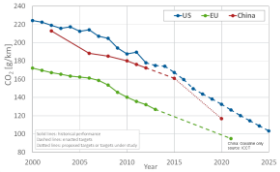


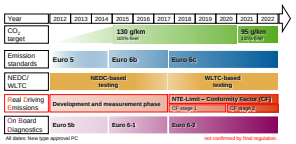
Air Pollution

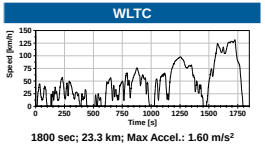
Sustainable Solutions



Upcoming legislation…







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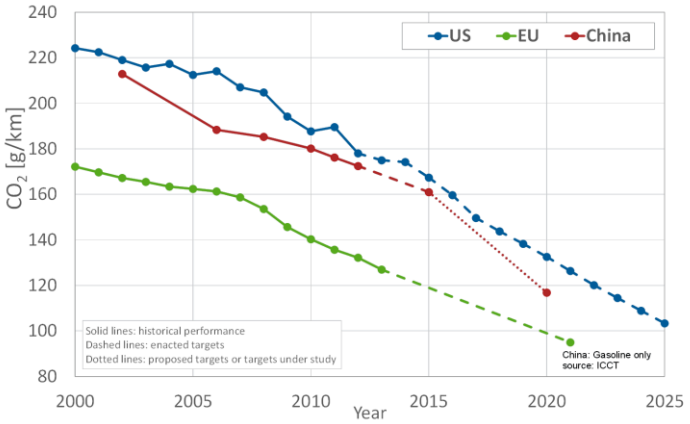
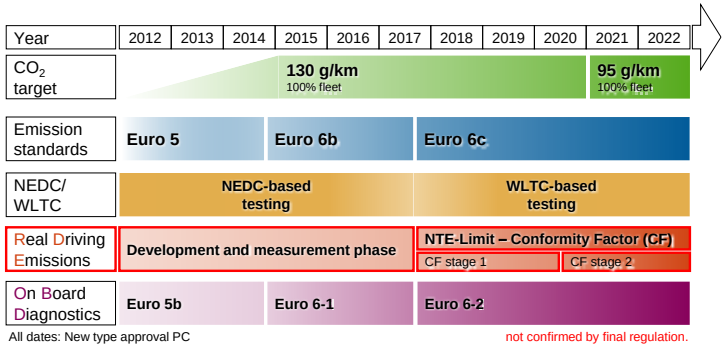
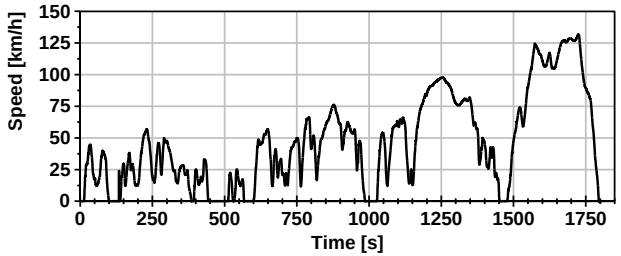
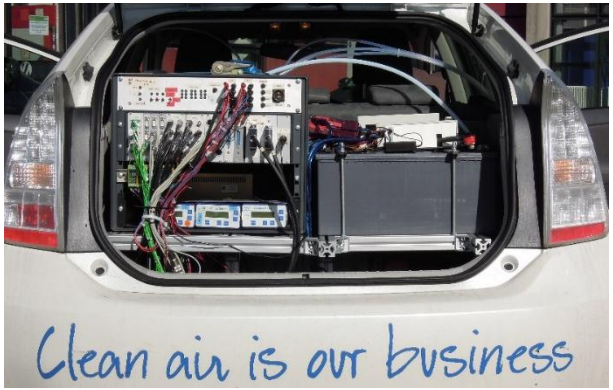




WLTC



1800 sec; 23.3 km; Max Accel.: 1.60 m/s²



Sustainable solutions

Advanced ICE configurations

- Down-sized turbo-charged gasoline
- Gasoline direct injection
- Lean burning gasoline engines
- Diesel
- (Flex fuel)

Requires more complex emission control catalyst solutions

Electrification of the vehicle

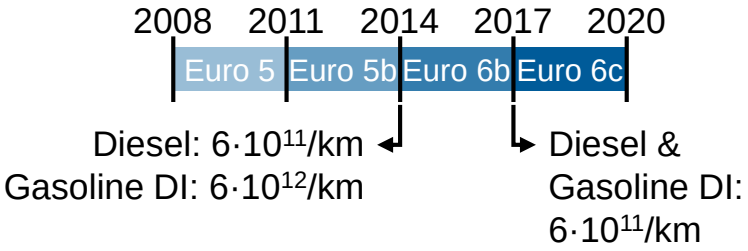
- Start-stop mechanism
- HEV: Mild HEV → Full HEV
- PHEV: Parallel → Range extender
- EV: BEV → FCEV

Requires larger battery and still automotive catalyst (except EV)

ICE	Internal Combustion Engine-powered vehicle	PHEV	Plug-in Hybrid Electric Vehicle	BEV	Battery-powered Electric Vehicle
HEV	Hybrid Electric Vehicle	EV	Electric Vehicle	FCEV	Fuel Cell-powered Electric Vehicle

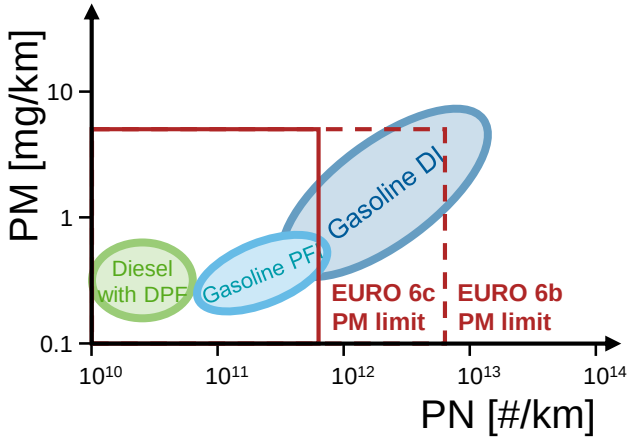
Strengthening EURO 6 PN limits require GPF

EURO 6 legislations addresses the number of particulates, with a transition period of 3 years for gasoline engines



Gasoline Direct Injection (DI) engines have higher Particulate Number (PN) emissions compared to diesel engines with Diesel Particulate Filter

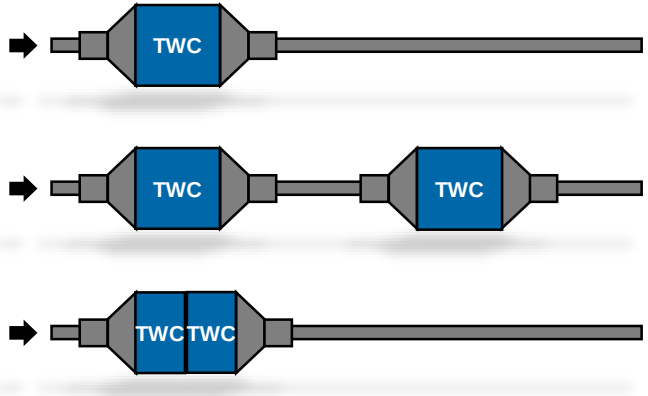
With RDE introduction most of the gasoline vehicles will need a GPF



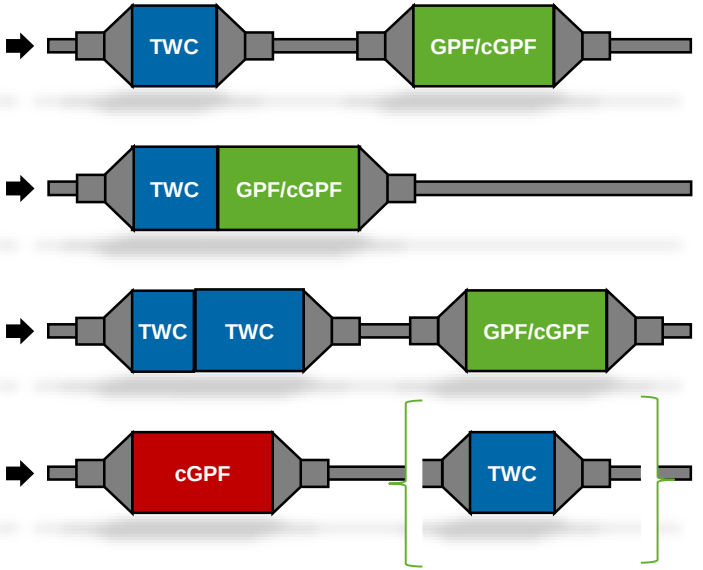
Market Trend

System Trends – Regions with PN Limits

Usual Layouts



Layouts from 2017



Trends:

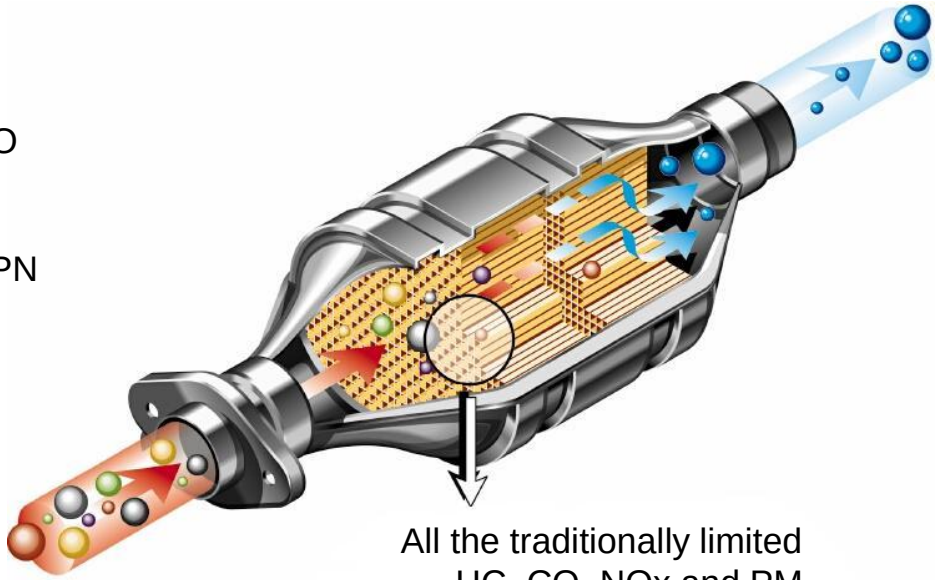
- more Volume
- more PGM
- GPF Introduction for almost all DI

Catalyzed Gasoline Particulate Filter

The catalyzed Gasoline Particulate Filter c-GPF

Addressing:

Hydrocarbons HC
Carbon Monoxide CO
Nitrous Oxides NOx
Particulate Mass PM
Particulate Number PN



All the traditionally limited
HC, CO, NOx and PM
as well as the new challenge PN
are substantially being reduced in parallel

Advantages of Different GPF Positions

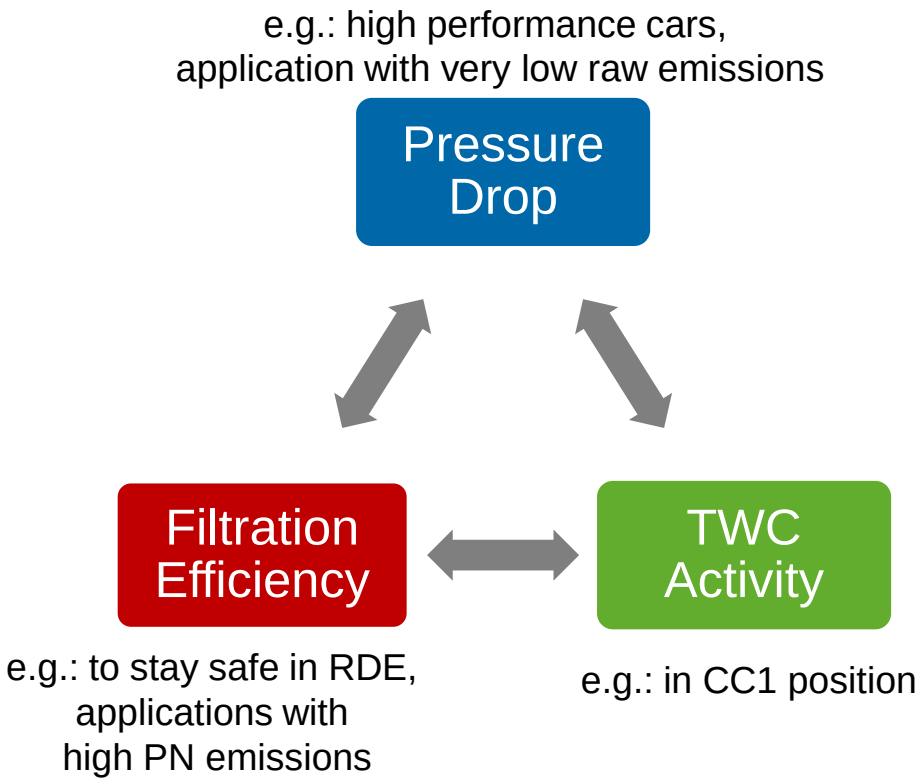
- Diagnosis unchanged over CC1 TWC
- Good filtration efficiency
- Additional conversion of traditional emissions, especially regarding RDE

- Diagnosis unchanged over CC1 TWC
- Good conversion of traditional emissions
- Good soot regeneration

- Packaging and system costs benefit
- Good soot regeneration

Umicore c-GPF Portfolio

Technical Requirements

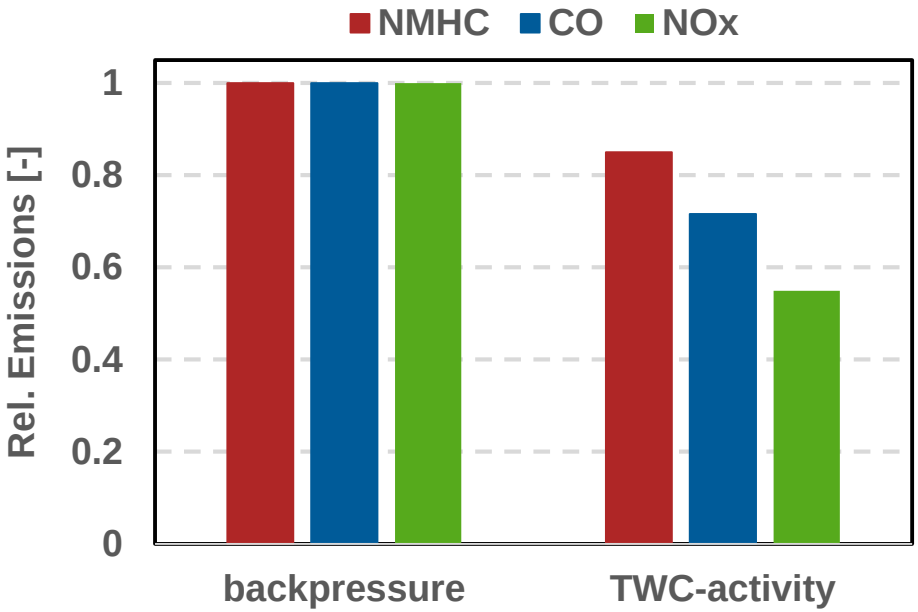


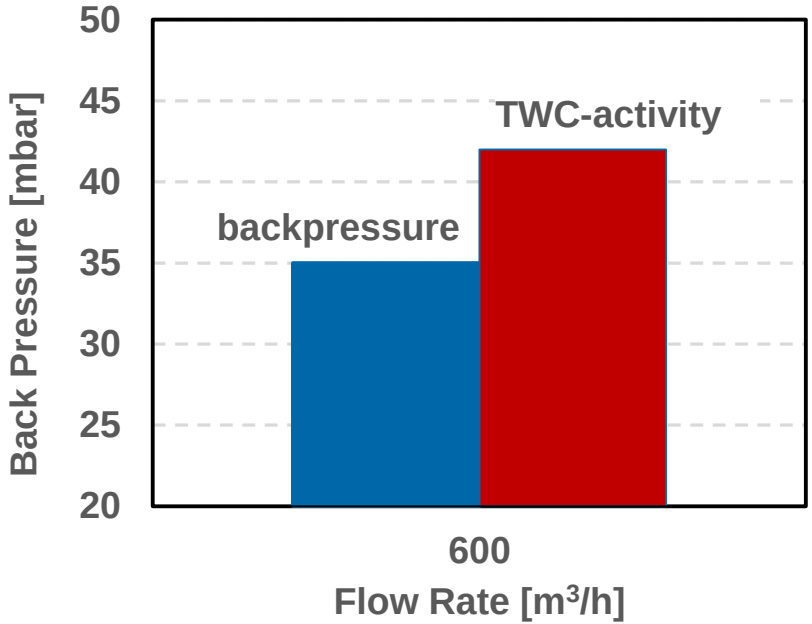
Different technical requirements call for dedicated technologies

- Special technologies for lowest pressure drop
- Portfolio of high three-way active GPF designs
- Designs for increased fresh filtration efficiency

GPF-Development

High-TWC Performance c-GPF

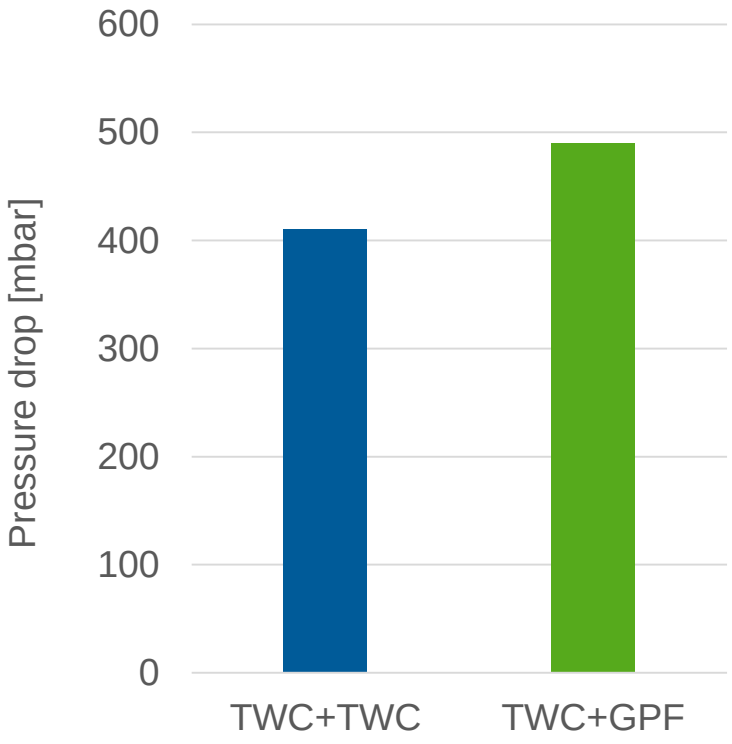


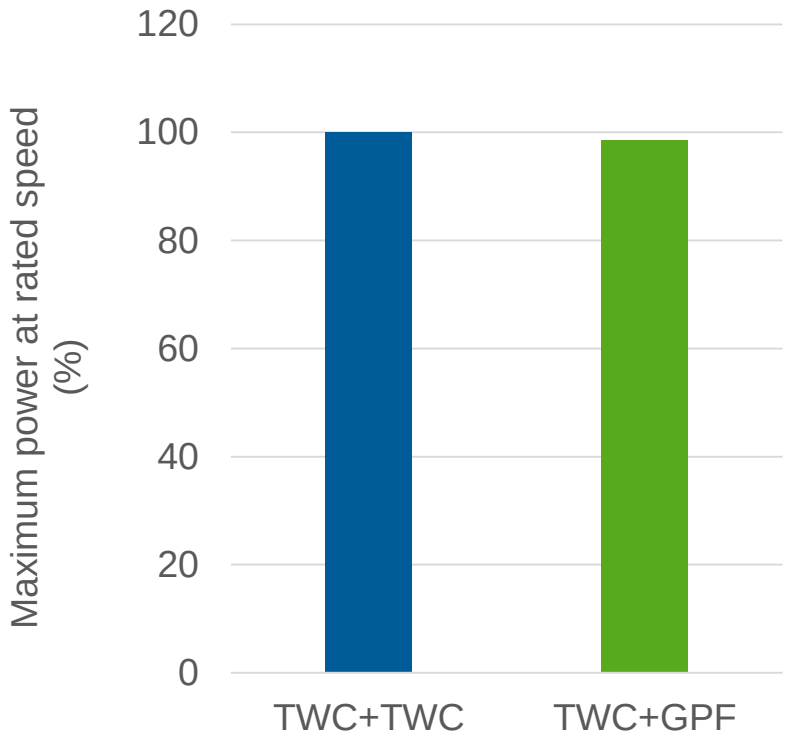


- Significant Improvements of TWC activity
- Stress Field: Activity vs. Back Pressure continues

Pressure Drop and Maximum Power

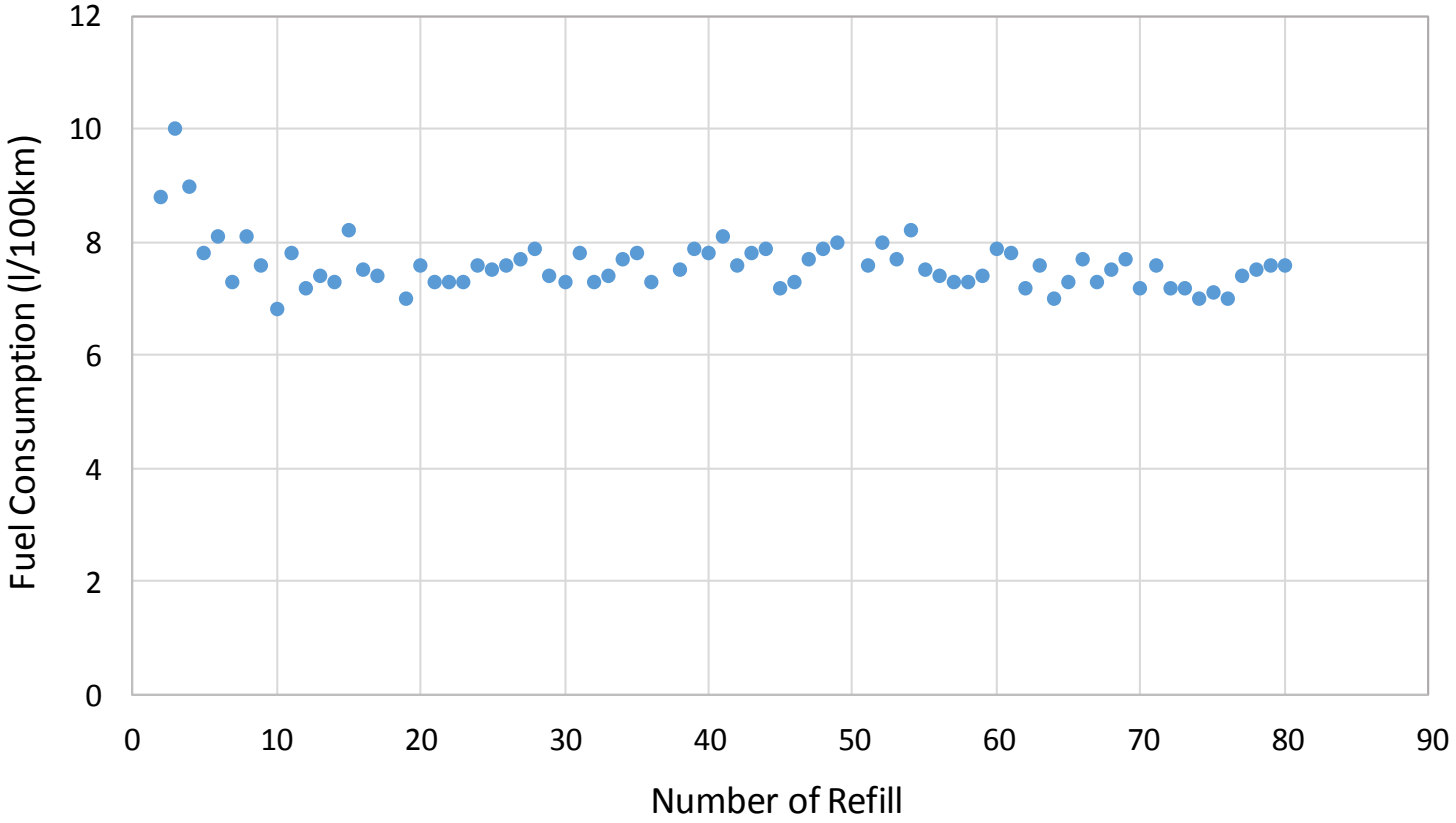
@ Rated Engine Speed





Real World Fuel Consumption

Central European Driving, German Motorway included



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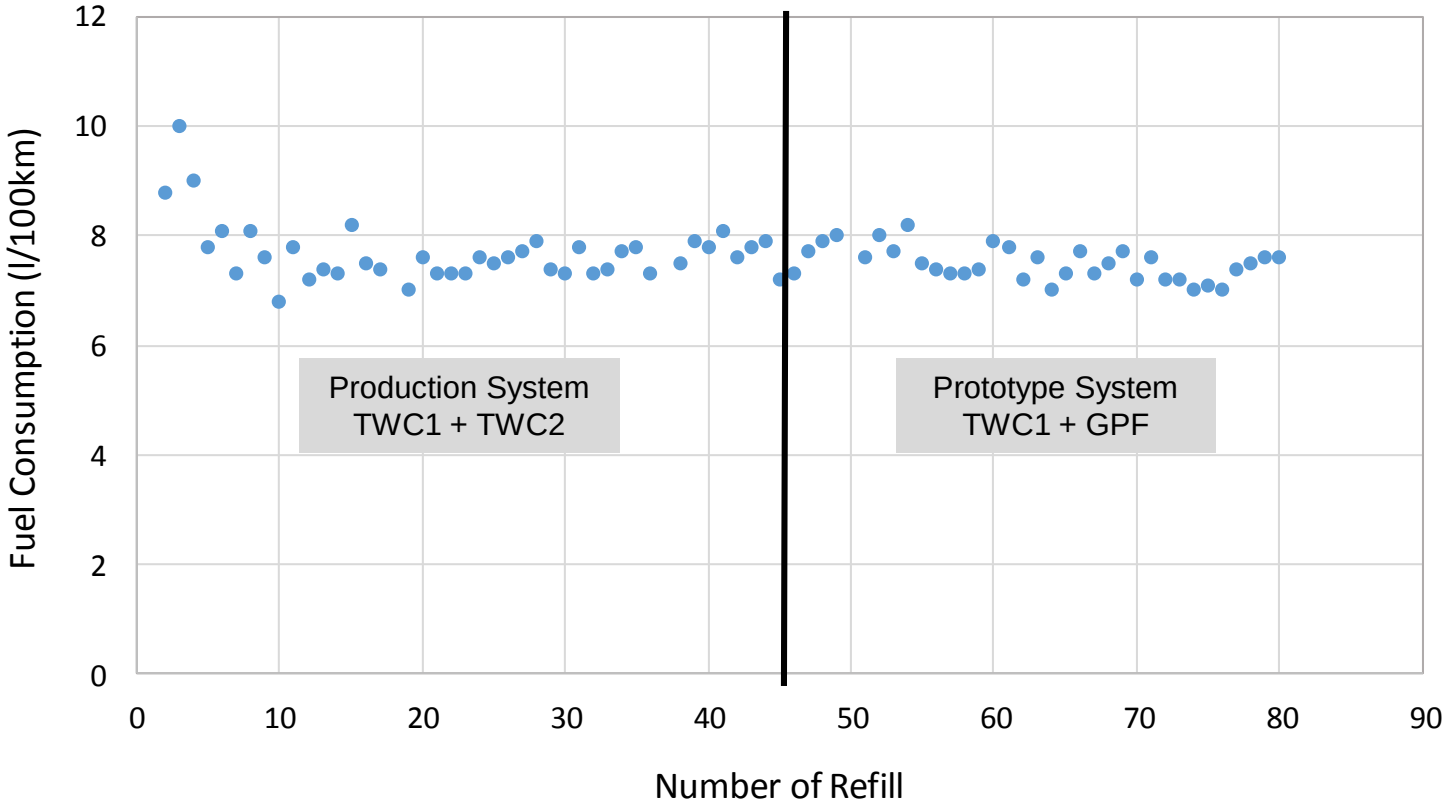
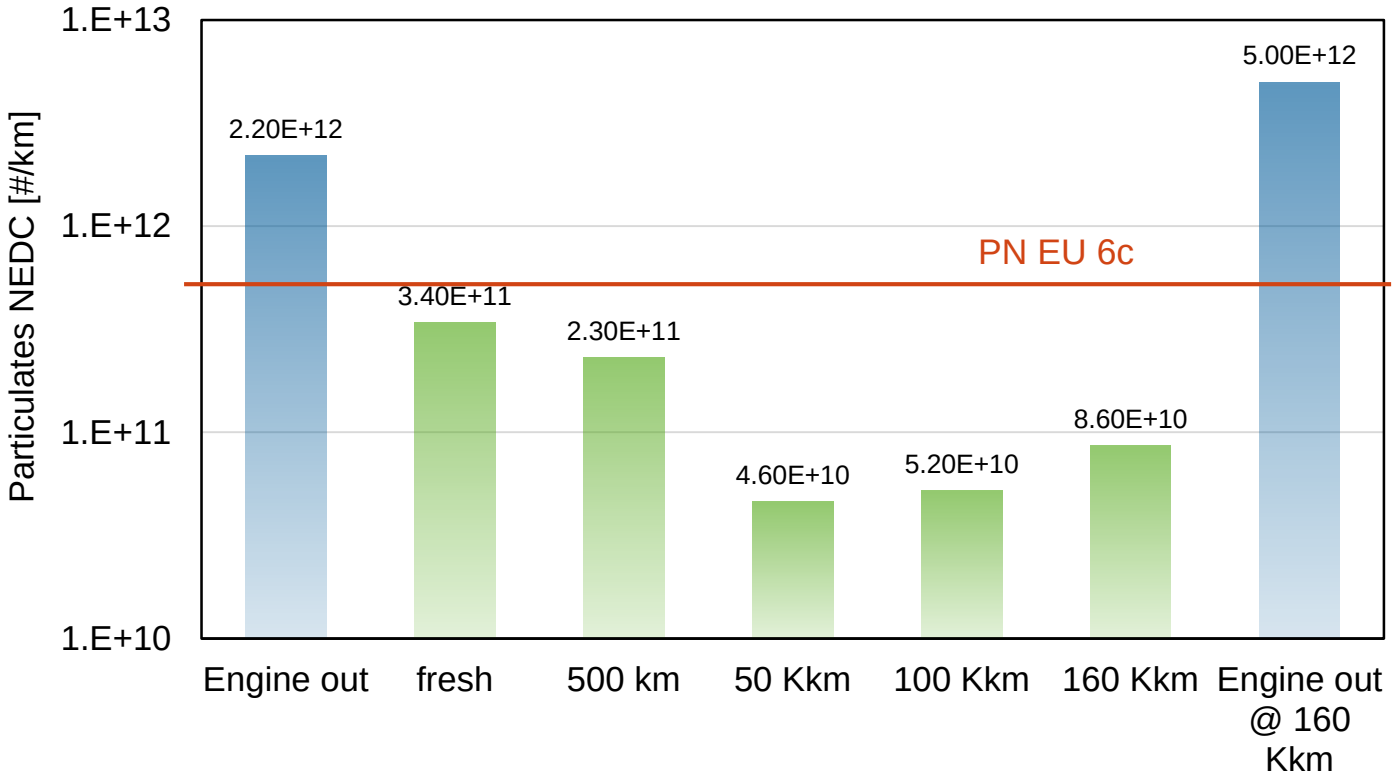


Real World Road Durability Validation

TWC + Add On c-GPF downstream, PN over Durability Distance



Summary

Strengthening EURO 6 PN limits require GPF for Gasoline (DI) Engines

Variable coatings in the c-GPF family are available:

- Pressure drop optimized technologies
- Portfolio of high three-way active GPF designs
- Designs for increased fresh filtration efficiency

Attention has to be turned to the conversion of gaseous emissions due to:

- High aging requirements in a CC1 position
- Lower washcoat amounts on a filter compared to a flow through substrate → assure sufficient conversion of harmful emissions over lifetime

Filtration efficiency is increasing over lifetime due to ash accumulation

Thank you for your attention

Questions ?