

Five Recent Challenges in Mobile Emission Control

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BASF Environmental Catalysts and Metal Solutions becomes **Metivo**

BASF Branded

- BASF's businesses and brands which are strategically aligned to the core.
- Their value is maximized by being an expression of BASF. Therefore, they use the BASF umbrella brand.



BASF Endorsed

- Majority-owned standalones with high strategic contribution to BASF but high need for market distinction.
- Need their own identity to compete and connection to BASF is mutually beneficial.



Metivo

Evolving from early days of Engelhard to a leading BASF division to defining a unique position as a global market leader.



Challenge I

Raw materials for TWC – Heavy Rare Earth Metal Oxides

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
La		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
Ac		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

Heavy Rare Earths

Light Rare Earths

- The mining and processing is **highly** regionally **focused**.
- Especially Heavy Rare Earth Metals are being **stricter export** controlled for their dual-use application possibility.
- Supply chain **disruptions** have to **be prevented**.

- **Rare Earth Elements** (REE) are a group of elements including the Elements Scandium (Sc) and Yttrium (Y) as well as the Lanthanoides.
- They are crucial for many modern applications ranging from lasers to sensors to high performance ceramics.



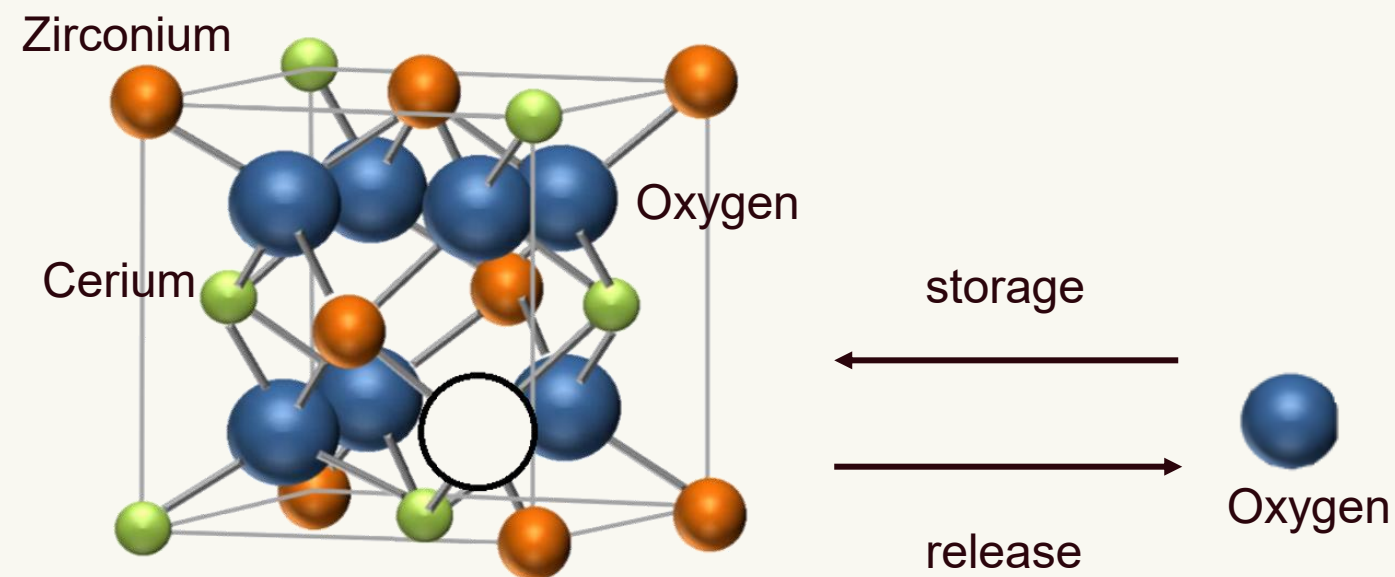
TWC = Three Way Conversion Catalyst



Challenge I

Raw materials for TWC – Heavy Rare Earths

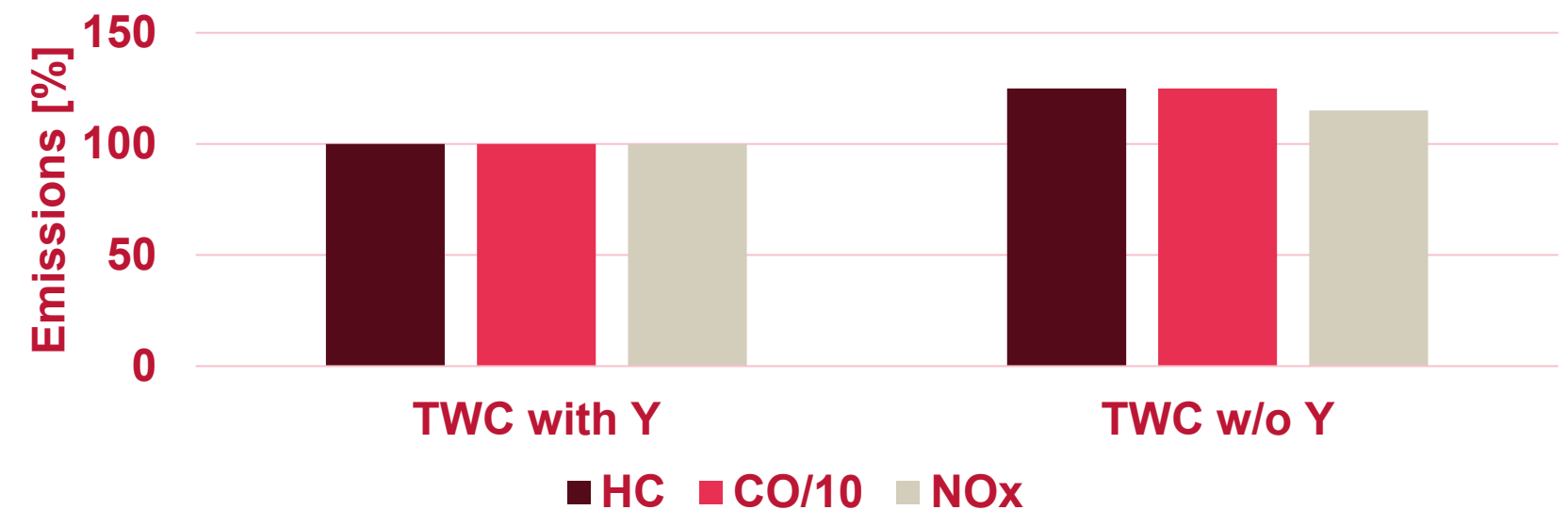
Oxygen-Storage-Material (OSC)



Essential to to balance Lambda-Variations and maintain high covnersion of the TWC

- Doping the Cerium-Zirconium-Oxide (OSC material) with **Yttrium** Y^{3+} leads to changes in properties:
 - Defects in crystal structure enhancing oxygen diffusion
 - Supression of sintering
 - TWC-performance improvement after harsh aging

Normalized FTP-75 Emissions after 50h High Temperature Engine Bench Aging



Challenge I

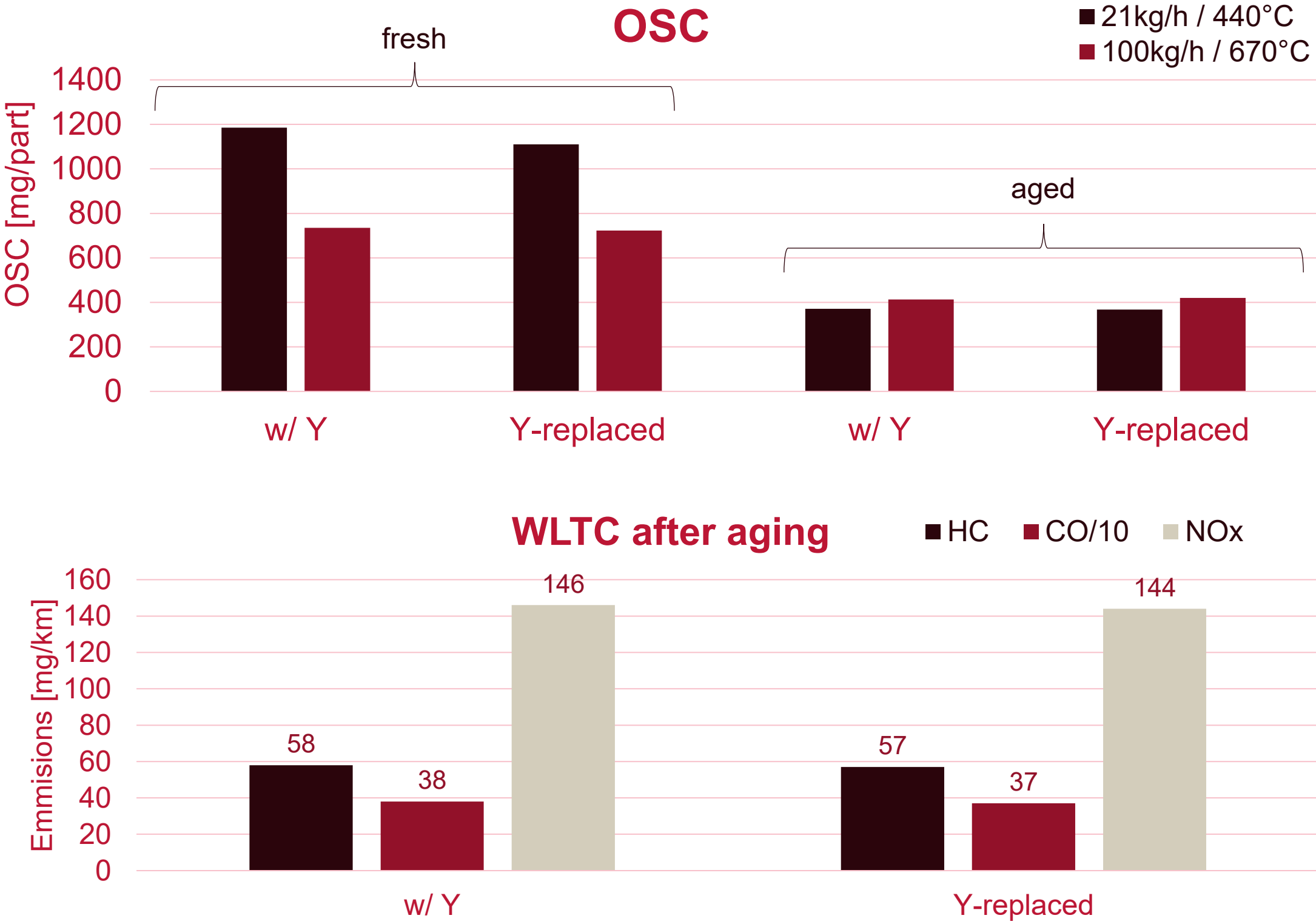
Raw materials for TWC – Heavy Rare Earths



Solution: Replacement of Y

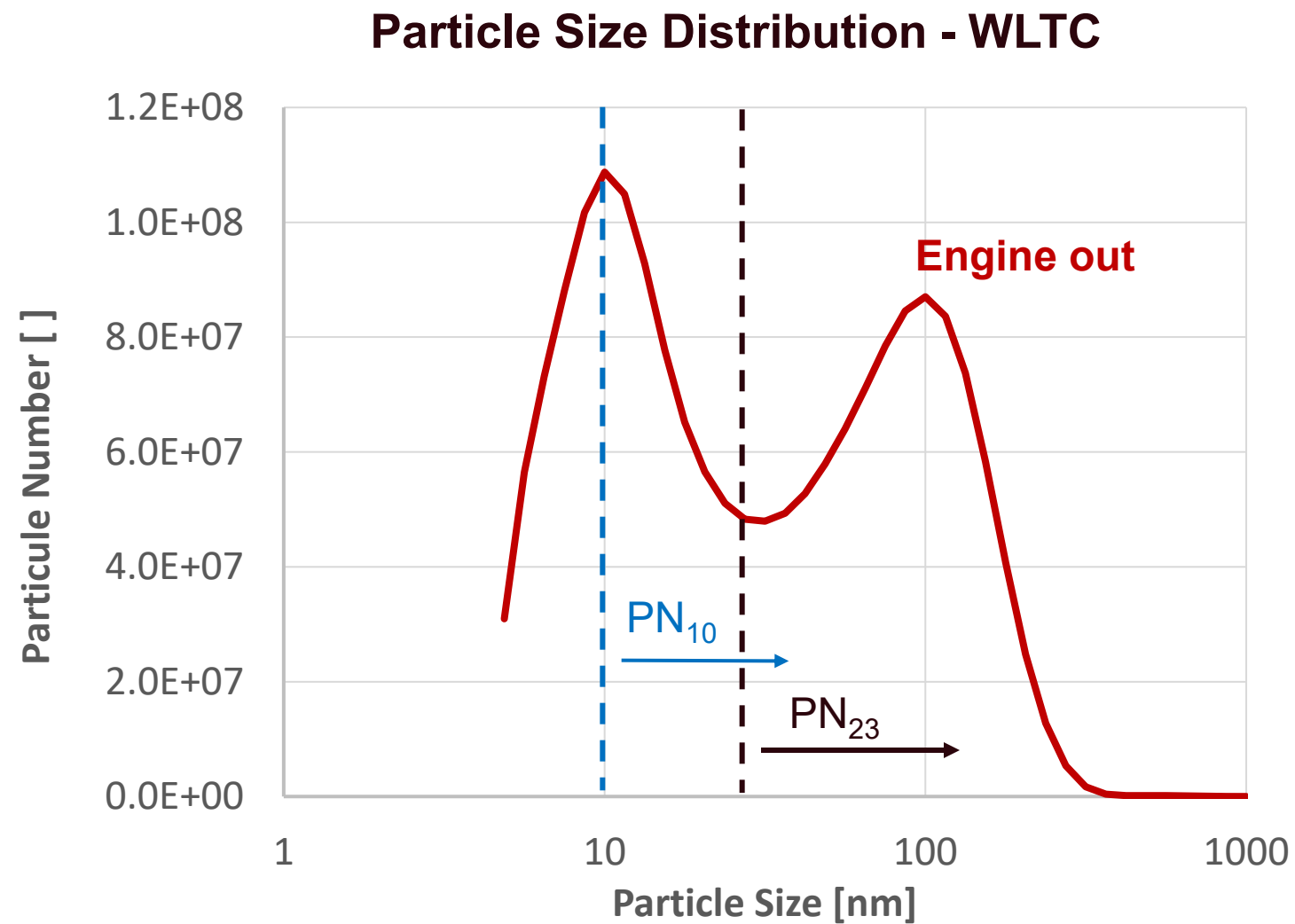
- Other elements are identified to mimic the positive impact of Yttrium on OSC materials.
- Fresh and aged OSC levels tested to be similar to the Y-containing reference.
- Emissions in WLTC after engine bench aging are comparable

Catalyst: TWC with 60g/ft³ 0/56/4
Aging: 100h 1030°C Fuel-Cut aging
Test bench: 2.0L T-GDI



Challenge II

(Small-) Particle filtration on gasoline cars



2.0L T-GDI engine
pure gasoline

- BS-7 will likely include PN limits for both DI and PFI gasoline engines.
- PN₁₀ consideration increases the total number of particles emitted significantly.

→ GPF requirements:

- High Filtration Efficiency
- Low backpressure
- Space requirements
- Fast soot regeneration

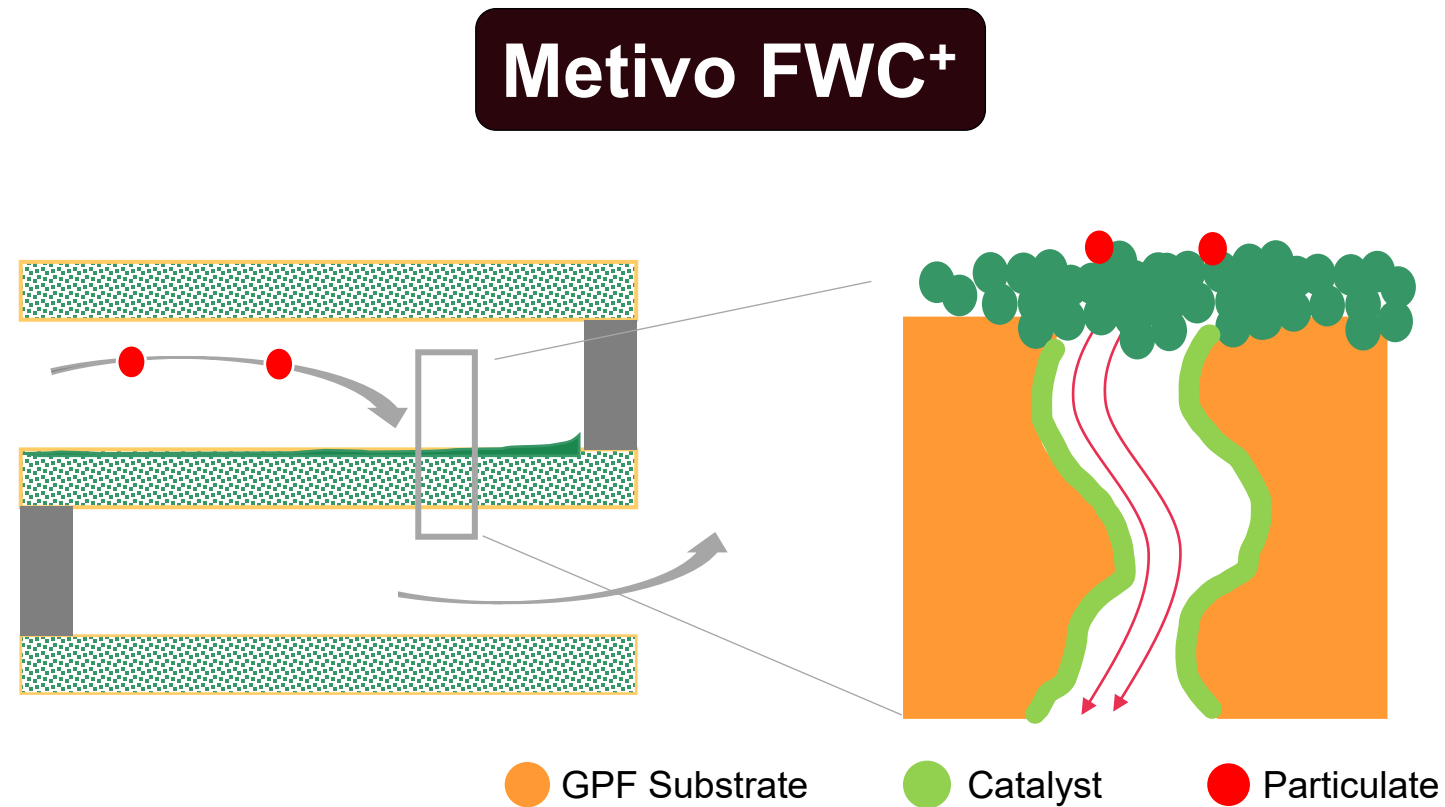


GPF = Gasoline Particulate Filter

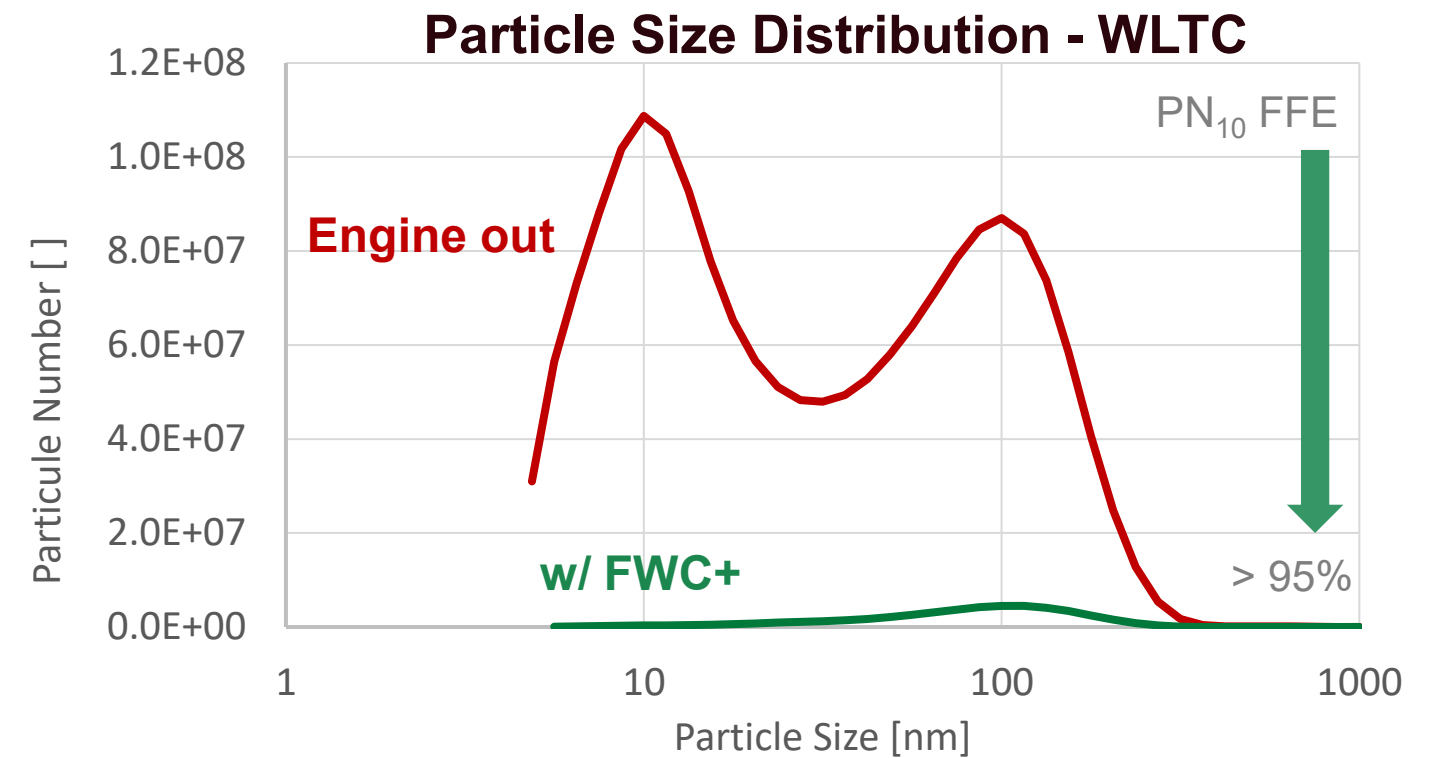
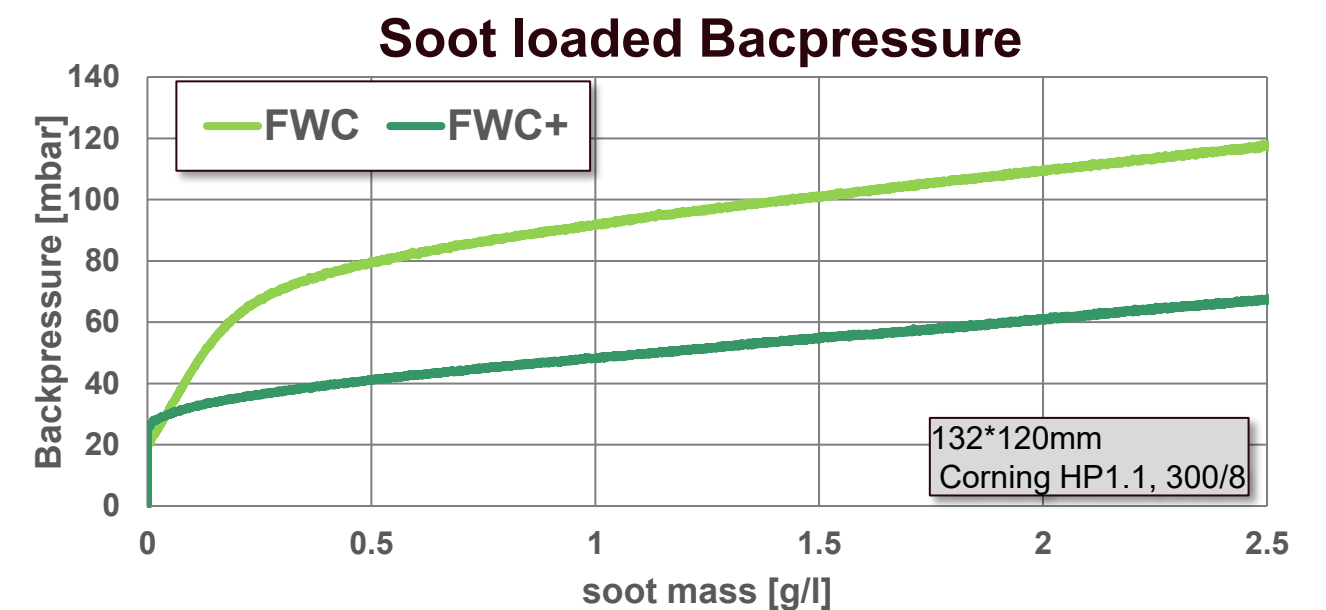


Challenge II

(Small-) Particle filtration on gasoline cars

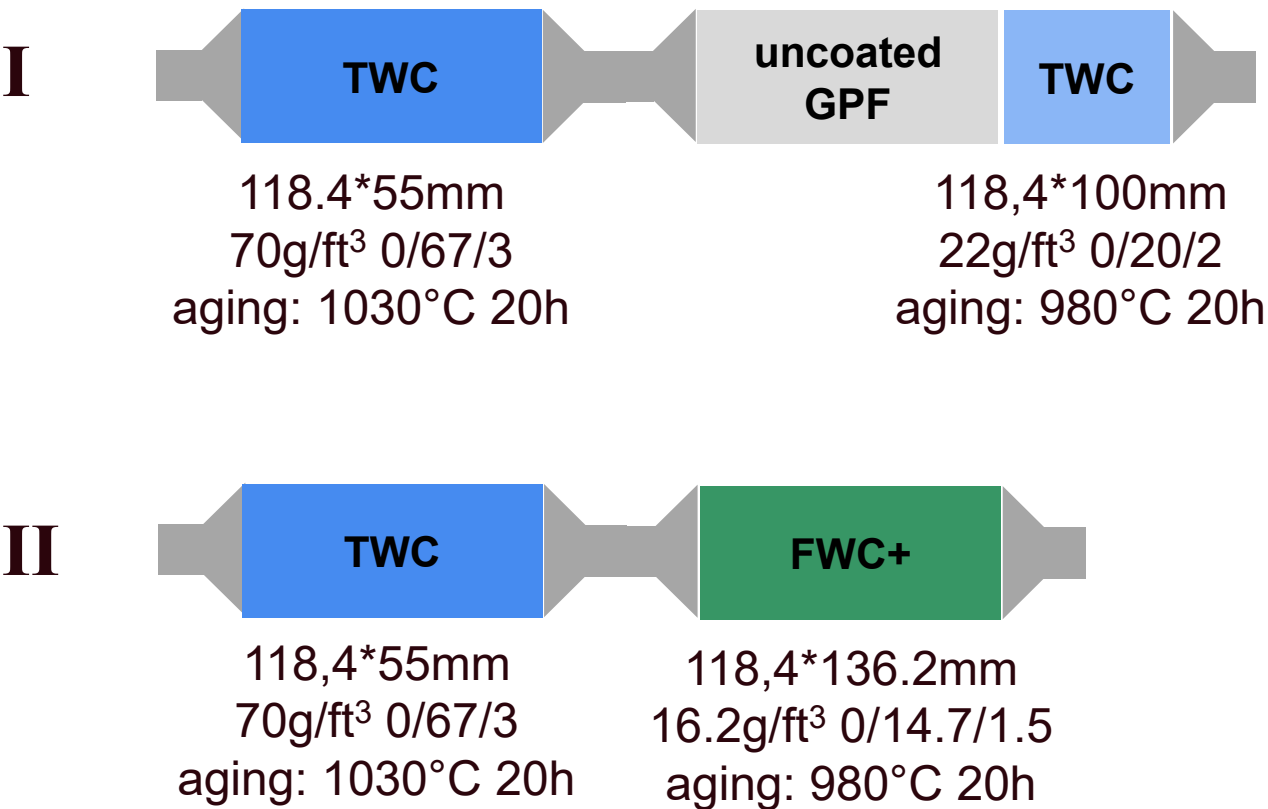
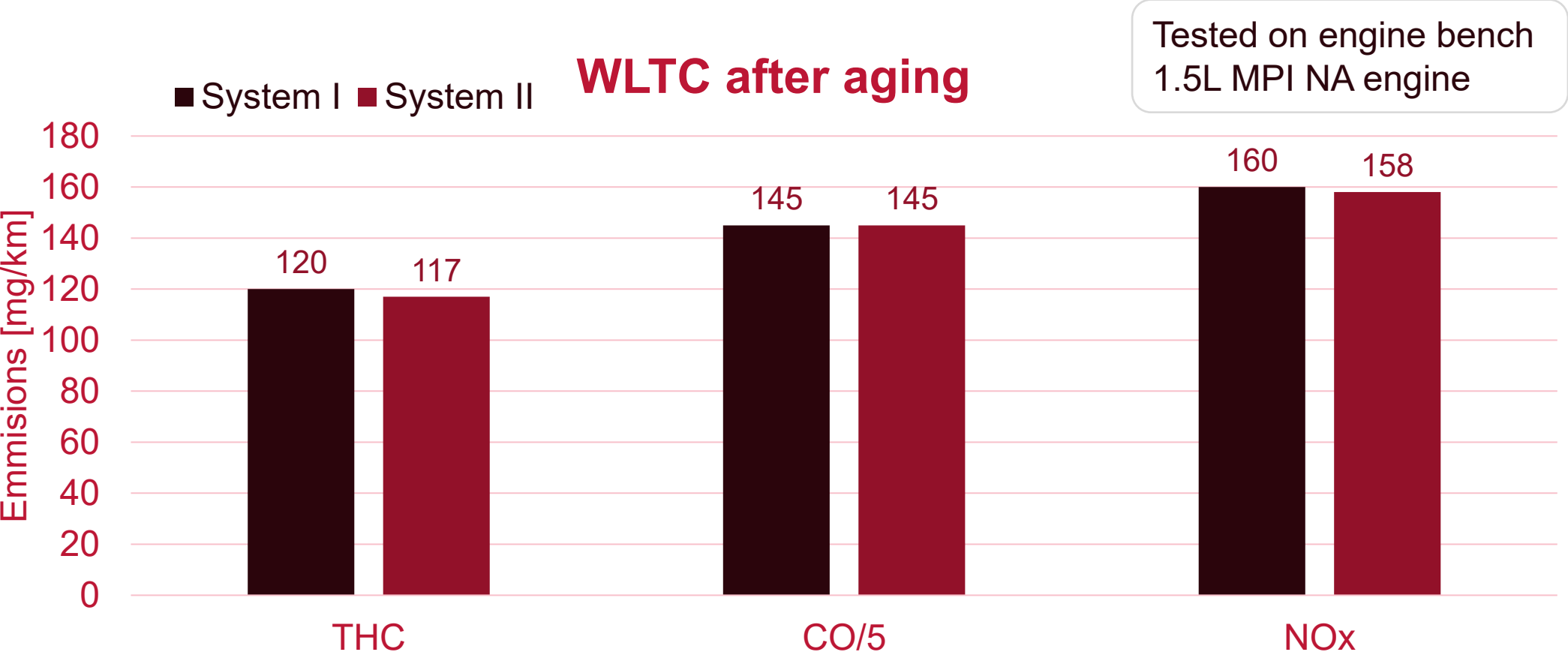


- Four Way Conversion Catalyst (+)
 - TWC washcoat on GPF Substrate = FWC
 - Dedicated layer for ultra high filtration at low back-pressure impact = FWC+



Challenge II

(Small-) Particle filtration on gasoline cars



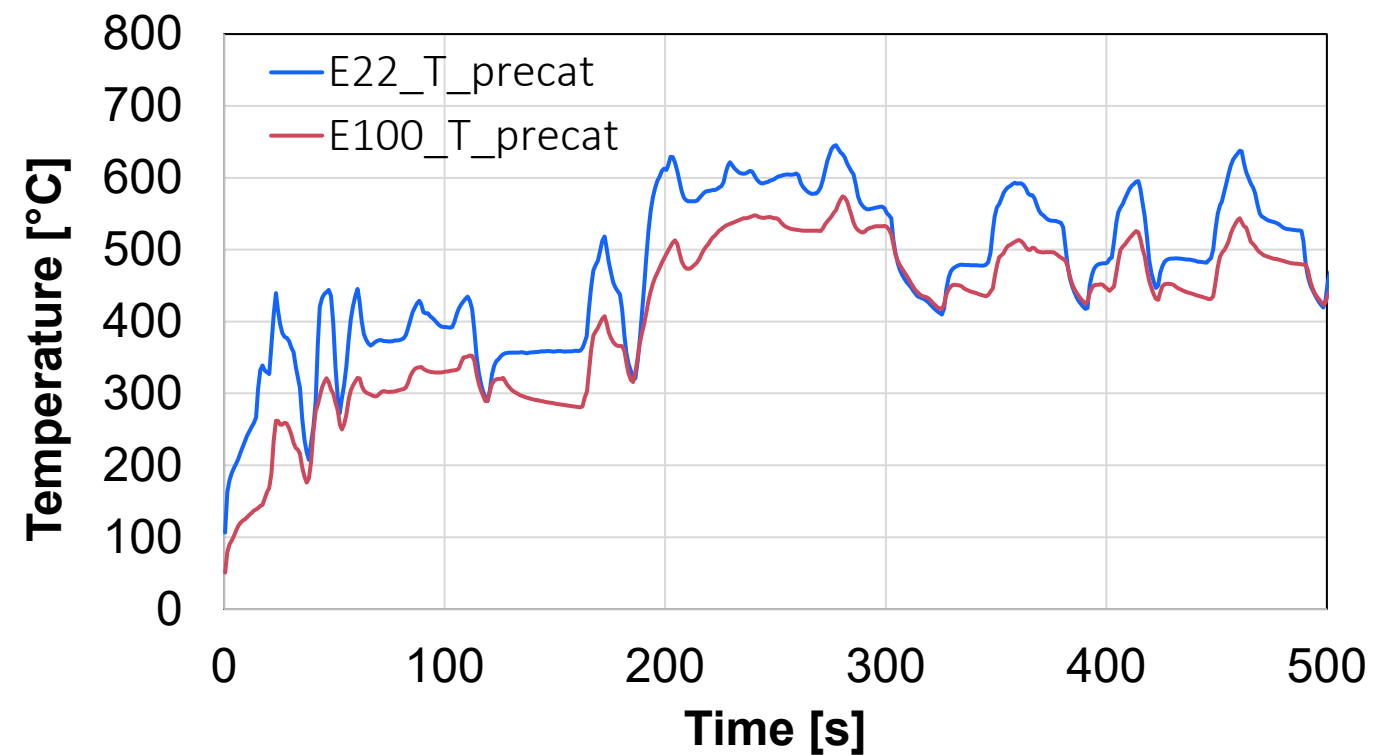
Latest coated GPF generation (FWC+) can solve the PN challenge and contribute to HC/CO/NOx robustness of the exhaust system.



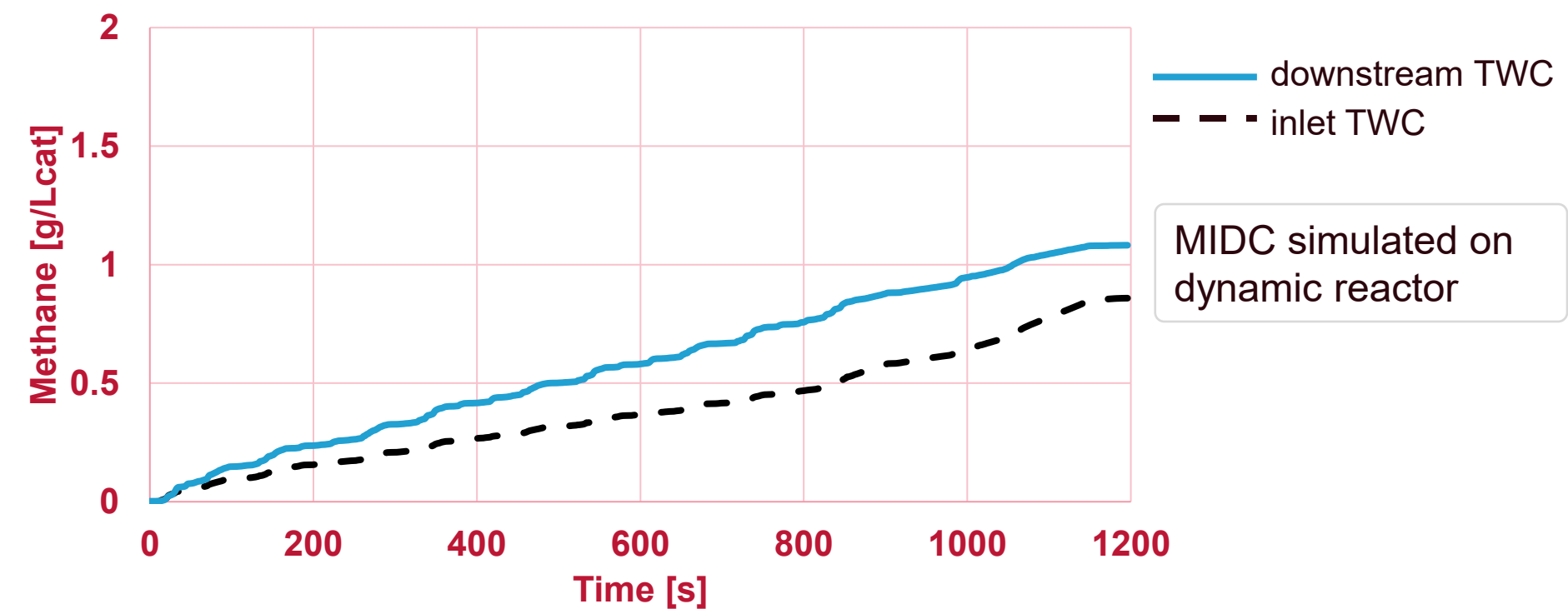
Challenge III

Meeting THC emissions in Ethanol-fueled applications

FlexFuel Vehicle in FTP-75



Methane Emissions in E100 mode



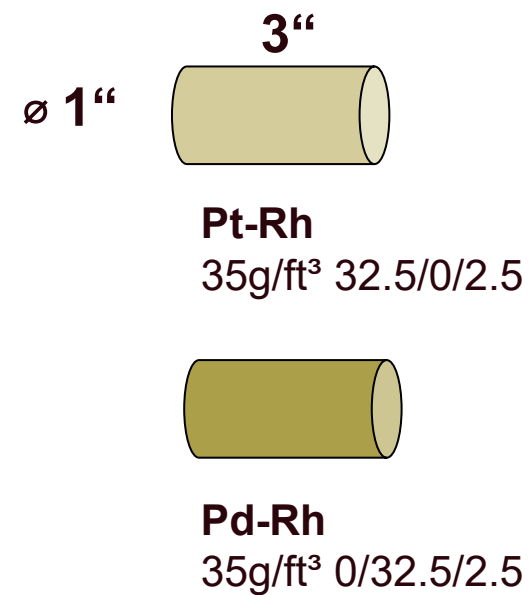
- Usage of Ethanol as a fuel results typically in slower heat up of the exhaust system.
- Tailpipe Methane emissions can be higher than engine-out due to Methane generation on the TWC.



Challenge III

Meeting THC emissions in Ethanol-fueled applications

Core size TWCs

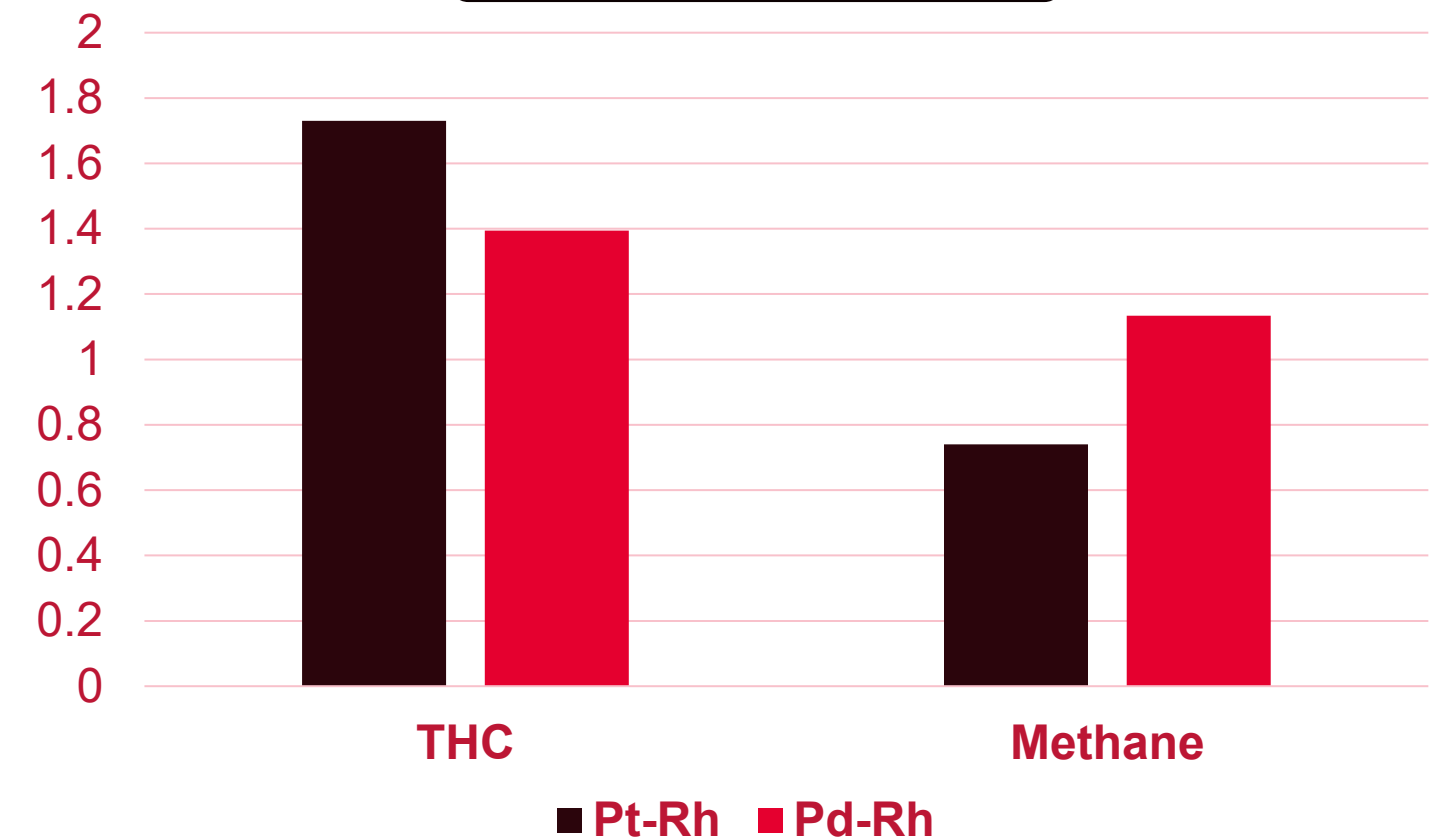


Aging: 950°C Lean/Rich 50h

Vehicle Emission Simulator



E93 simulated MIDC



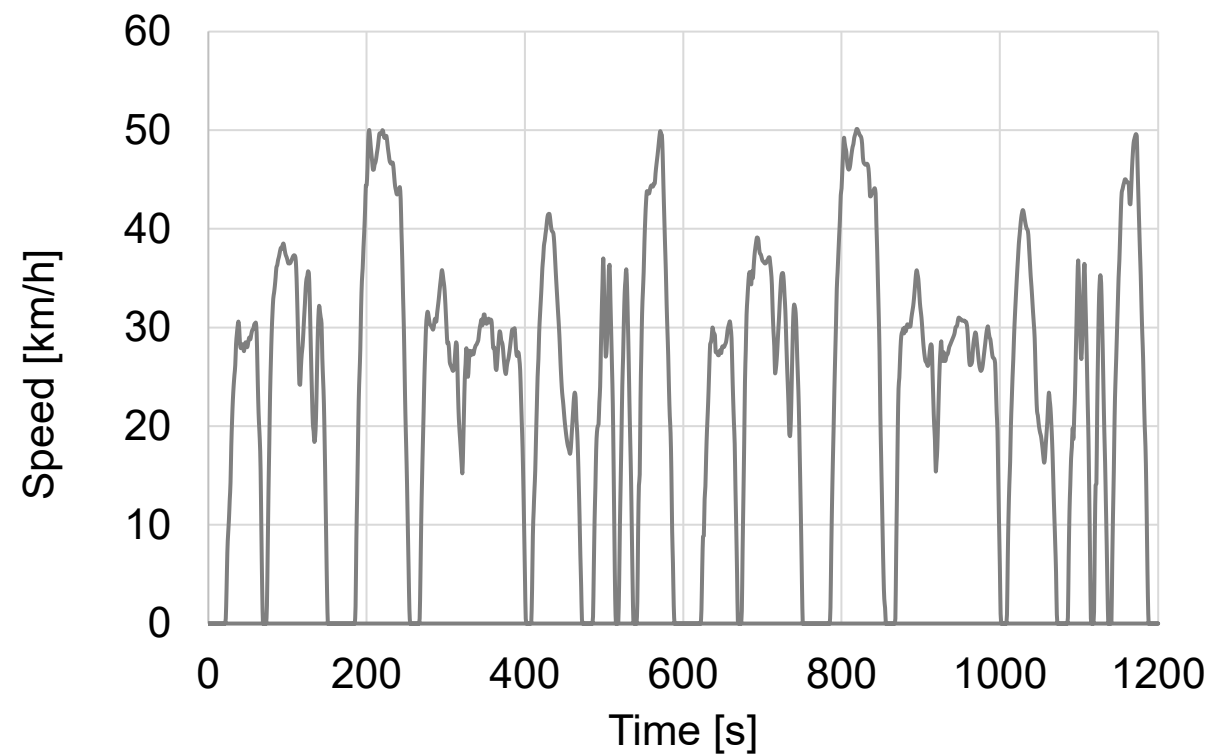
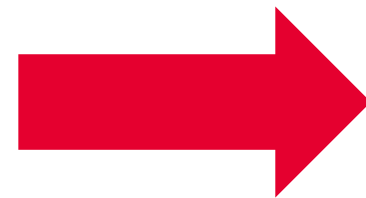
- Methane formation can be addressed with PGM selection and other TWC design parameters.
- More in Session 9 on Friday –
 - Technical Paper: Development of advanced 3-way catalyst for flex-fuel vehicles to meet BS-VII
Yogesh Shinde, et al, BASF Catalysts India



Challenge IV

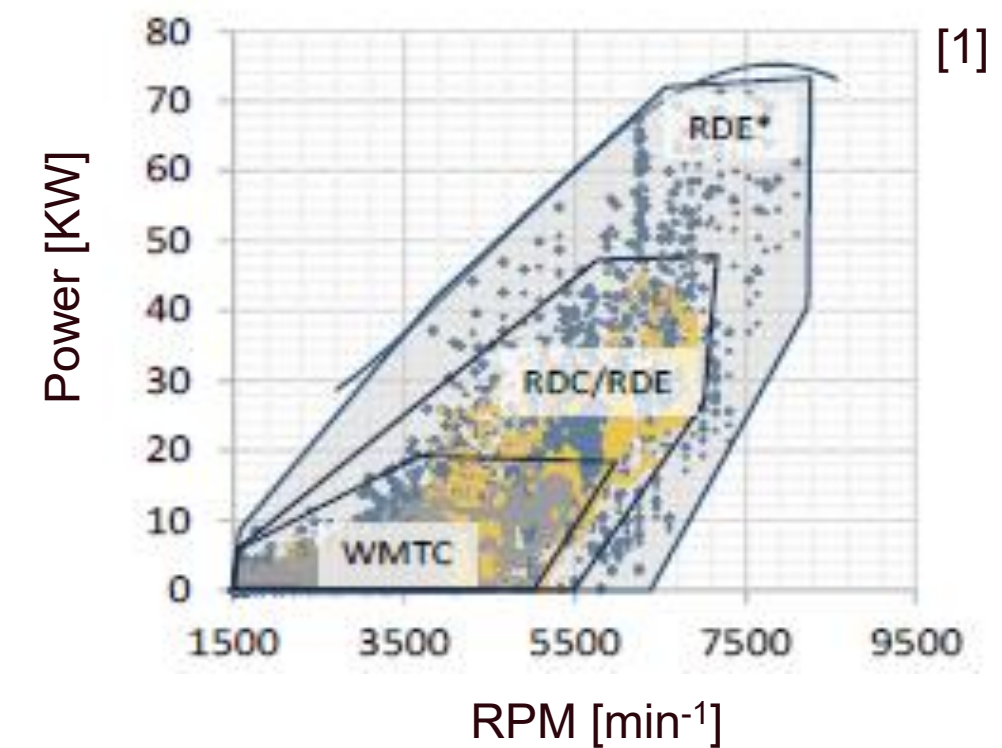
RDE for 2-Wheeler Applications

Now: WMTC



RDE

- Higher Average & Top Speed
- More dynamics ($V \times a_{pos}$)
- Ambient conditions (Temperature / Altitude)
- Harsher Aging ?



[1] from <https://lens-horizoneurope.eu/>



Challenge IV

RDE for 2-Wheeler Applications

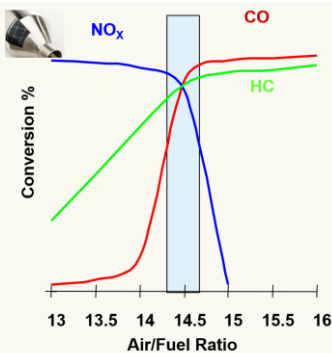
TWC Design parameters for RDE readiness



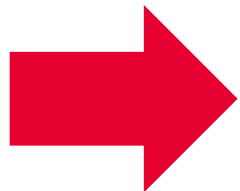
TWC: 14g/ft³ 2/11/1
Aging: 30h SBC 890°C
Testing on Reactor: SV 60k h-1



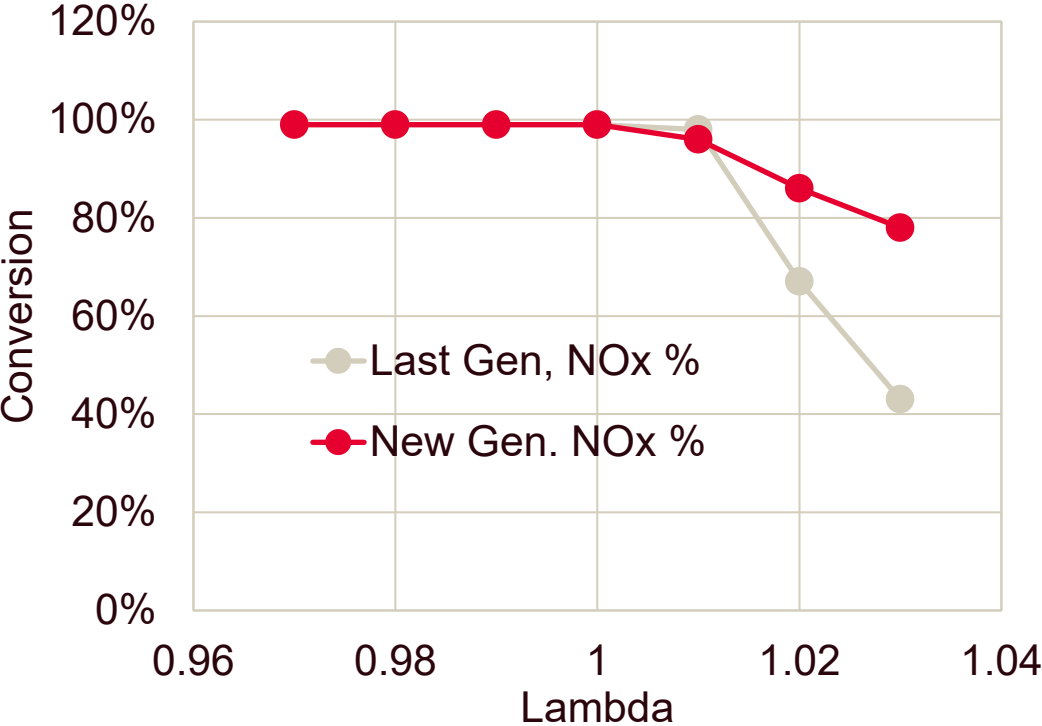
Durability



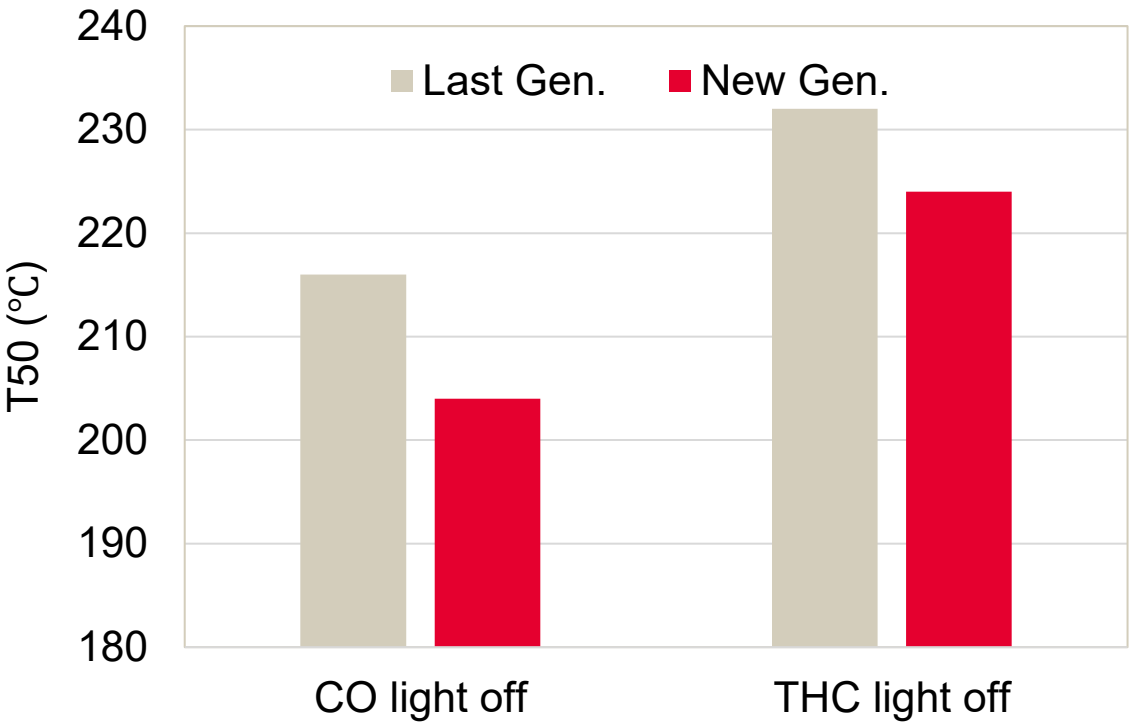
Lambda Operation Window



Lambda-Window



Light-off



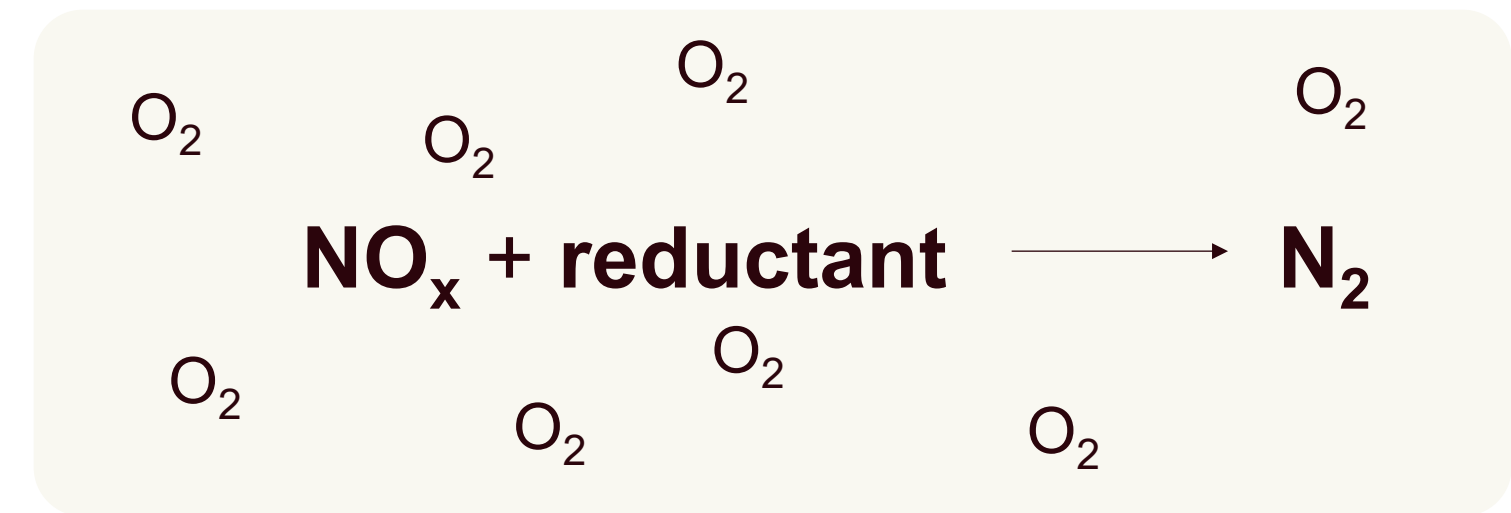
New TWC technologies for 2-Wheelers are ready providing wider Lambda-Window and higher aging resistance



Lean NOx treatment in Diesel passenger cars

Emission standards for Diesel Cars & Light Trucks

	BS-6/3	BS-7 ?
CO g/km	0.5	0.5
NOx g/km	0.08	0.08
HC + NOx g/km	0.17	0.17
Cycle	WLTP – 3P	WLTP
Durability	160k km	200k km
OBM	no	yes



Diesel Exhaust condition

- Reduction of NO_x to N_2 under oxidizing conditions necessary
- More dynamic test cycles create more challenging environment
- Durability and low temperature performance of catalysts necessary



Challenge V

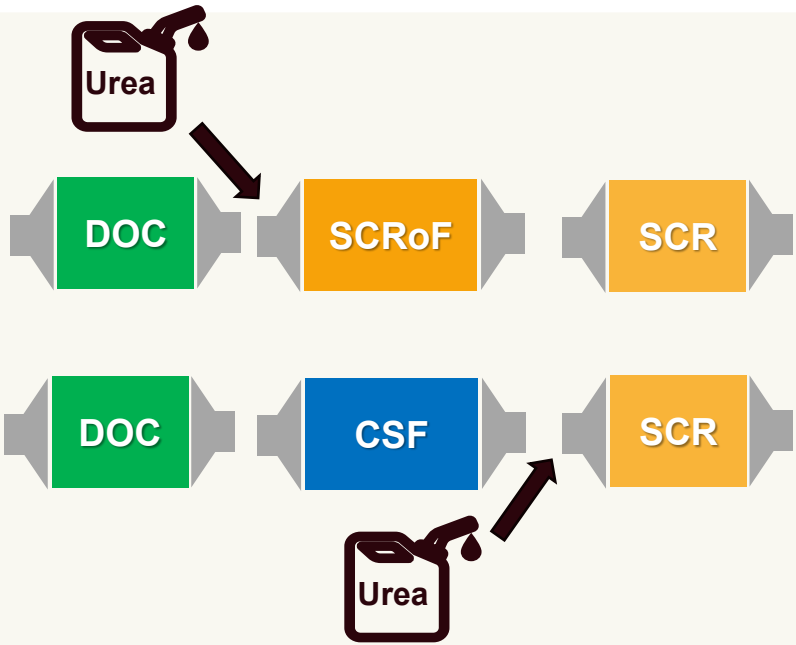
Lean NOx treatment in Diesel passenger cars

DOC based Systems

LNT based Systems

Components

NOx reduction: SCR
HC & CO oxidation: DOC
Filtration: CSF or SCRoF
Reducing agent: Urea via injector



NOx reduction: LNT and passive SCR
HC & CO oxidation: LNT

Filtration: CSF or SCRoF
Reducing agent: in situ via fuel injection



Pros and Cons

- + Wider application window for NOx reduction
- + No influence on fuel economy
- Additional urea injector and tank

- + Compact system
- + NO Additional urea injector and tank
- Fuel injection needed to remove stored NOx from LNT and enable NOx reduction via passive SCR

DOC = Diesel Oxidation Catalyst
SCR = Selective Catalytic Reduction
SCRoF = SCR on Filter

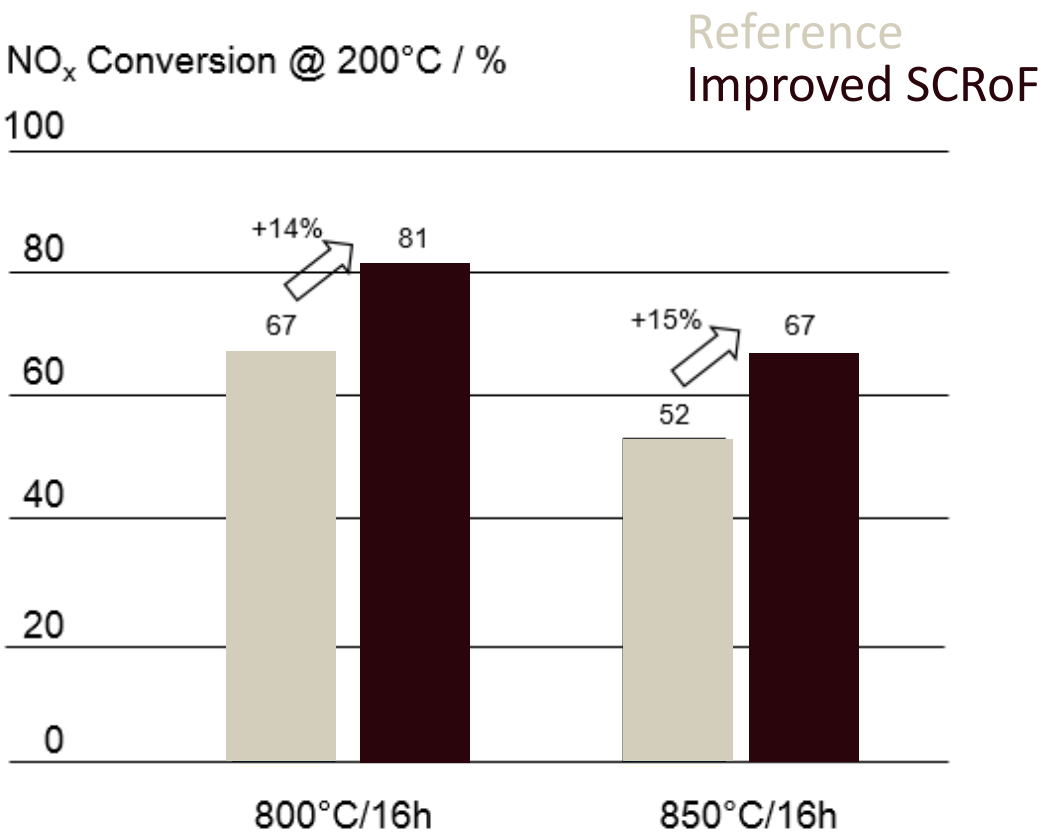
CSF = Catalyzed Soot Filter
LNT = Lean NOx Trap



Challenge V

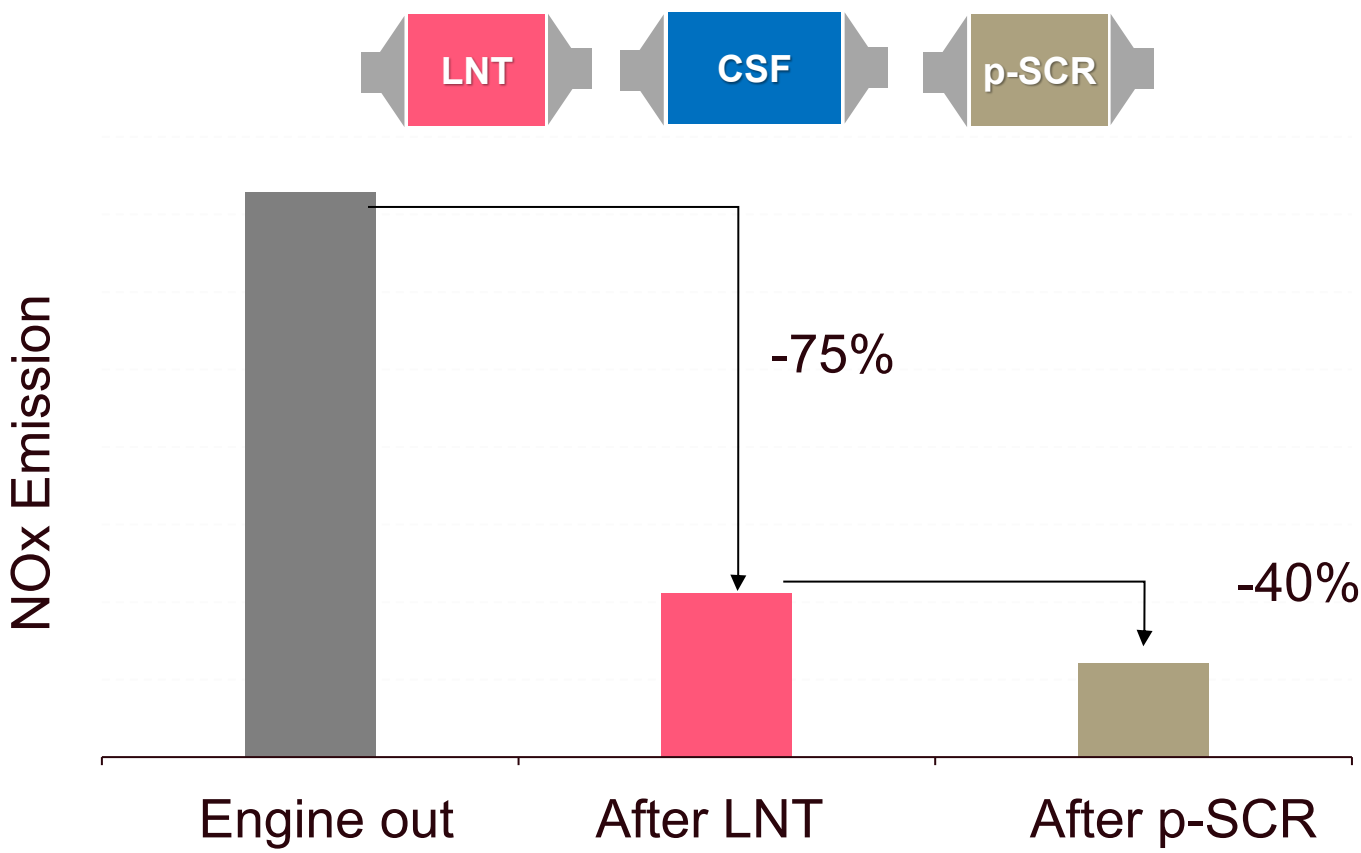
Lean NOx treatment in Diesel passenger cars

DOC + SCRoF based Systems



Reactor Testing: 500 ppm NO only, SV 80 k/h
Aging: 800°C 16 hydrothermal

LNT based Systems



DOC+SCRoF and LNT based systems can be designed to meet Bharat 7 emission requirements



Tackling the Challenges in Emission Control

- Metivo is dedicated to deliver and further develop Solutions for Cleaner Air
- Technologies ready for upcoming BS7

More to come at ECT conference...

Advanced V-SCR technology for Euro 7 and BS 7 applications

Shravan Kumar et al.

Development of advanced 3-way catalyst for Flex-fuel vehicles to meet BS-VII

Yogesh Shinde et al.





Part of BASF Group