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Automotive Catalysts

Topic: Euro 7 HD Legislation & Exhaust Aftertreatment for Heavy Duty Engines

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Umicore SENSITIVE document

Content

- Euro 7 HDD Legislation Overview
- Layout Evaluation
- Data Analysis
- Summary & Conclusion

Umicore’s positioning within Mobility transformation

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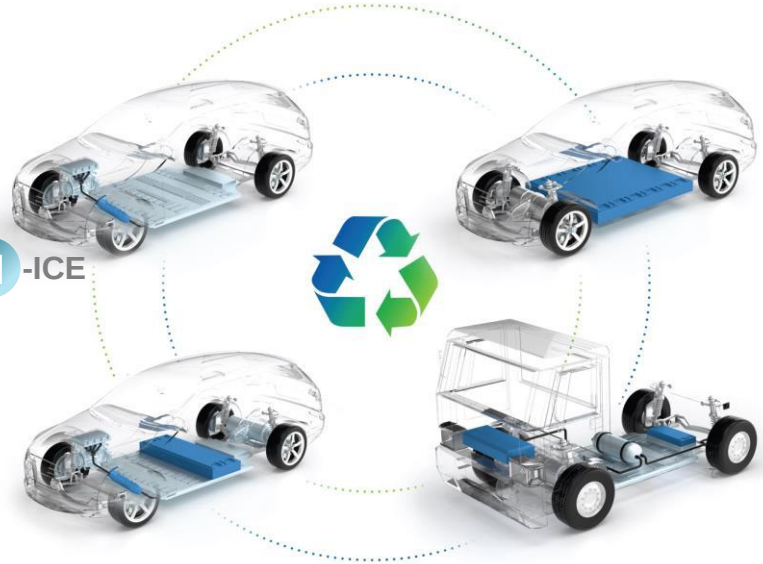
Umicore materials are essential in all clean mobility drive train concepts

ICE will remain the dominant drive train for the next 10+ years

Internal Combustion Engine
Emission control catalysts
Incl. for H-ICE

Plug-in Hybrid Electric Vehicle
Battery active materials & emission control catalysts



Full Electric Vehicle
Battery active materials

Fuel Cells Vehicle
Electro-catalyst & battery active materials

Prime electrification path for light transportation

Important electrification path for heavy transportation

Green: Umicore content

Country-Wise Outlook Of Electrification targets And Emission regulations

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2025

NORWAY: All new Cars sold by 2025 should be ZEVs(EVs or FCVs)

2030

SWEDEN: Banning Sales of all new gasoline Cars sold by 2030

NETHERLANDS: All new Cars sold by 2030 should be ZEVs(EVs or FCVs)

2035

UK: All new Cars sold by 2035 should be ZEVs

2040

FRANCE: Banning Sales of all new gasoline Cars sold by 2030

SPAIN: All new Cars sold by 2040 should be ZEVs

2050

GERMANY: Ending the use of Gasoline & Diesel engine vehicles including PHVs by 2050

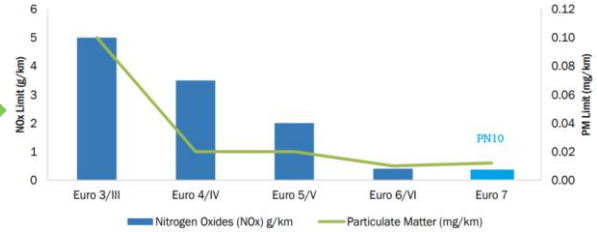
2060

CHINA: Pledge of Carbon Neutrals by 2060

2070

INDIA: Pledge of Carbon Neutrals by 2070

BS 7 **Reduced NOx & PN limits**



Emission Limits EU7 HD

Pollutant	"Cold" emissions[1]	"Hot" emissions[2]	Budget (W_{trip}<3 W_{WHTC})
NO_x [mg/kWh]	350	90	150
PM [mg/kWh]	12	8	10
PN_{10} [#/kWh]	$5x\ 10^{11}$	$2x\ 10^{11}$	$3x\ 10^{11}$
CO [mg/kWh]	3500	200	2700
NMOG [mg/kWh]	200	50	75
NH_3 [mg/kWh]	65	65	70
CH_4 [mg/kWh]	500	350	500
N_2O [mg/kWh]	160	100	140
HCHO [mg/kWh]	30	30	

Limits to be provided under a vast range of driving conditions

Red numbers: assessed to be most challenging for HD Diesel

Orange numbers: assessed to be highly demanding for HD Diesel

1) refers to 100th percentile of moving windows (MW) of 1 WHTC for vehicles, or $WHTC_{cold}$ for engines

2) refers to 90th percentile of MW of 1 WHTC for vehicles or $WHTC_{hot}$ for engines

Main Challenges & Countermeasures

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Cold start NO_x	• Engine calibration: fast ramp-up, low NO_x @cold phase • External heating, e.g. electrical heater • 2 Stage SCR (i.e. cc SCR) • Low light-off SCR temperature	• cc SCR with low N_2O selectivity e.g. V-SCR • Inlet main SCR with low N_2O selectivity (e.g. Fe-Zeo) • Engine calibration: reduce NO_x • Moderate NO_2 levels • Minimize NH_3 load on ASC	N_2O
Low load NO_x	• Engine calibration: avoid cool-down, low NO_x @cold phase • Insulation • External heating, e.g. electrical • Low light-off SCR temperature • Efficient low T urea injection	• Low porous filter substrates • UHFE* coating • Manage urea based PN → shift dosing to LO-SCR • 2nd filter?	PN
CO_2	• Engine calibration: high NO_x, minimize heating • Δp optimized coatings • Techs with low light-off	• Robust catalyst technologies • Exchangeable cc components?	Dura-bility

Most important measures in red *) ***U**ltra-**H**igh **F**iltration **E**fficiency*

System options

Heater debated
ccDOC enables DeSOx of ccSCR
heat loss during regen
UHFE measure on 1st DPF, 2nd DPF debated

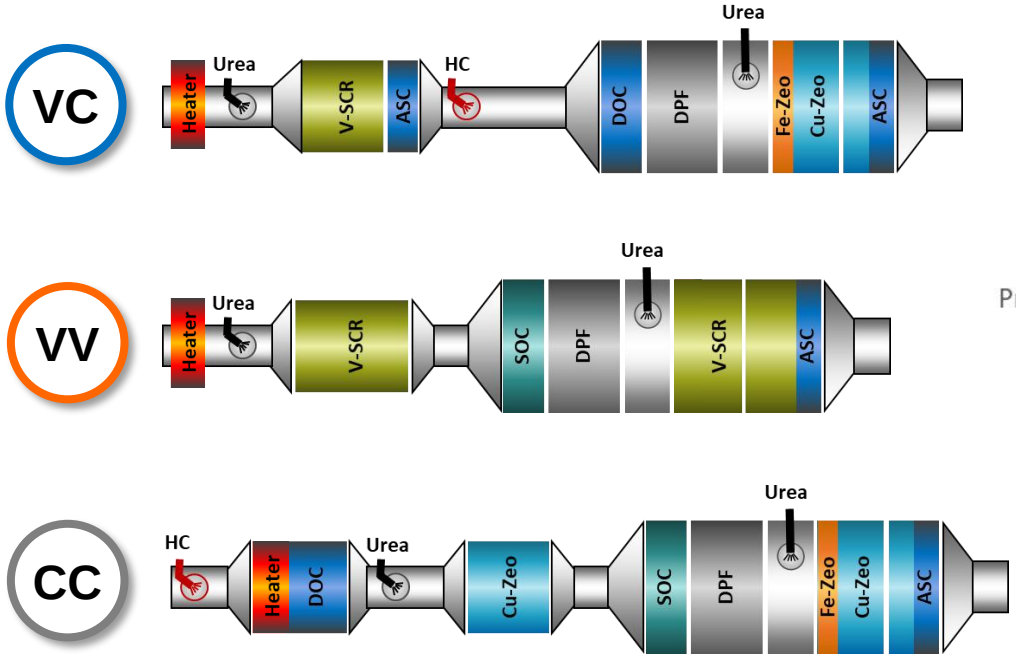
Heater debated
No chemical heating for SCR1 (prone to poisoning)
Option to move Diesel injection to front
UHFE measure on 1st DPF, 2nd DPF debated

Diesel injector (or late PI in front position)

Urea injector

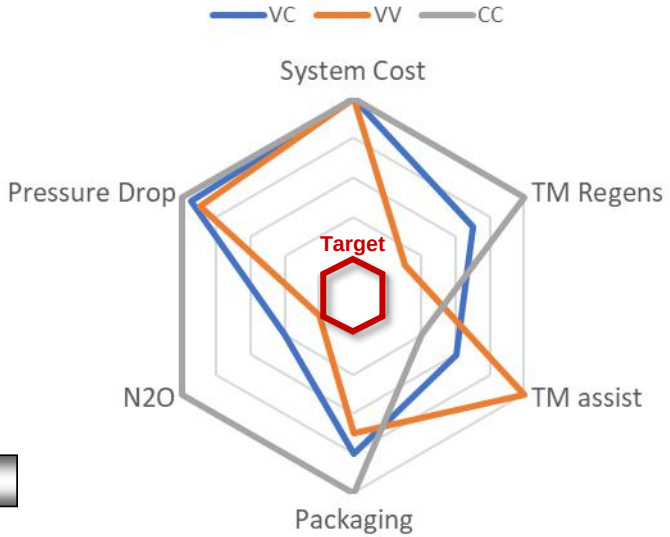
There is a vast range of options…

3 potential layouts



Qualitative Assessment

(reality is complex, though)



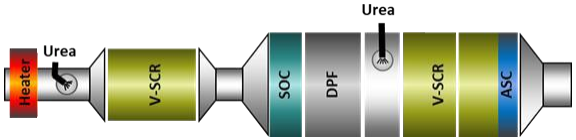
TM assist: thermomanagement amount to support SCR activity

TM Regens: thermomanagement amount to support regenerations (SCR & DPF)

V-SCR or Cu-SCR for the 2nd SCR unit?

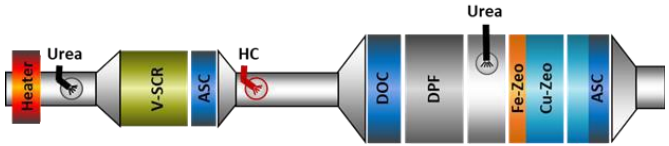
Advantages for both system configurations

V-SCR – V-SCR



- No DeSOx requirements
- High robustness (esp. SCR)
- Low N_2O (normal operation conditions)
- Lower PGM content / cost
- Lower pressure drop

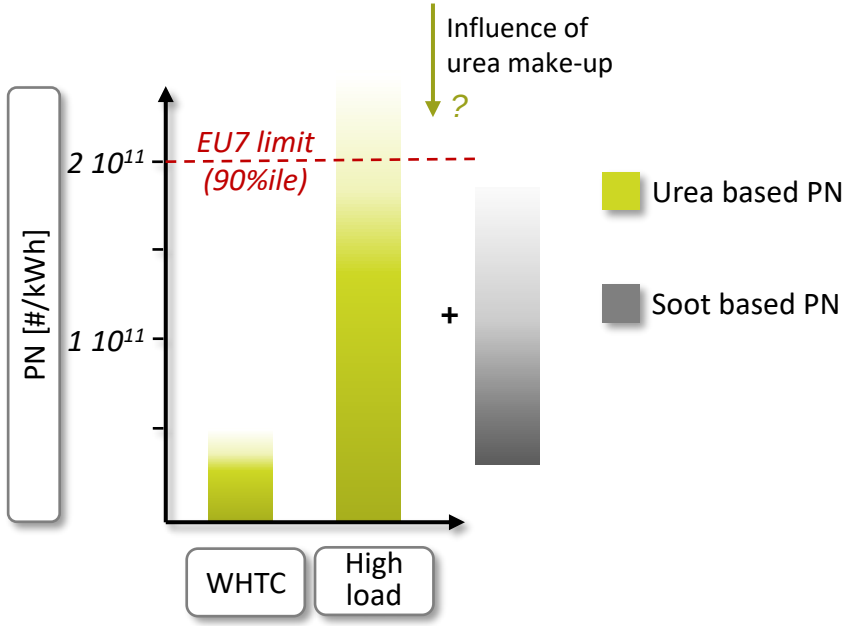
V-SCR – Cu-SCR



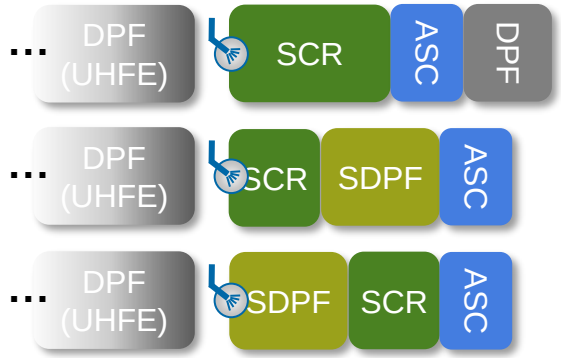
- Less heating support during low load operation
- Lower SCR Volume demand
- Better high temperature NO_x conversion

Solutions for Urea based PN

The Challenge

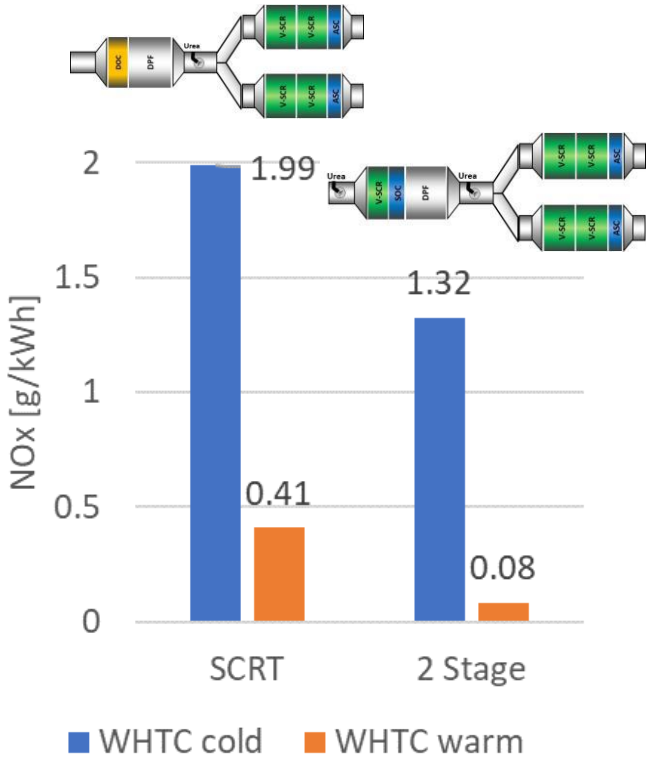


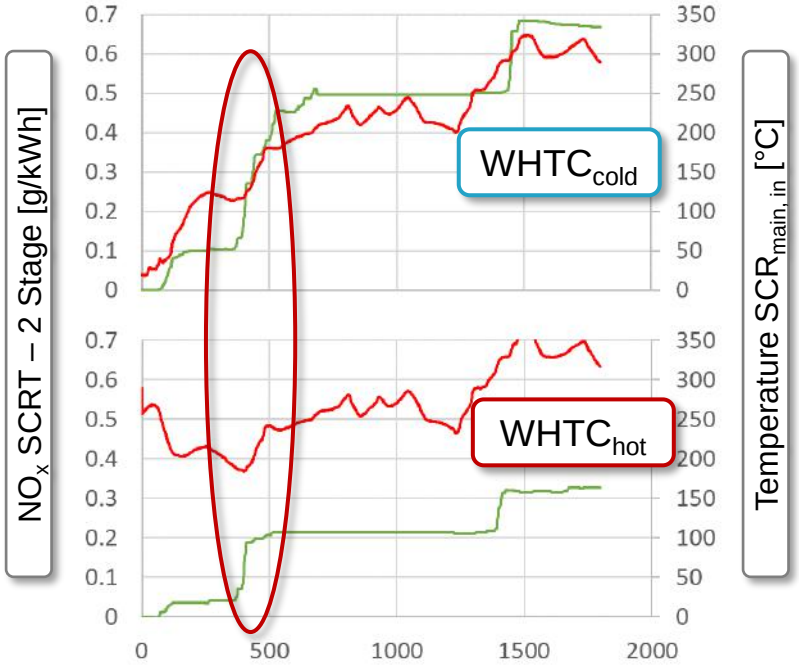
Potential System solutions



2nd filter with moderate FE requirement
→ can be optimized for low Δp

Advantage vs. SCRT system

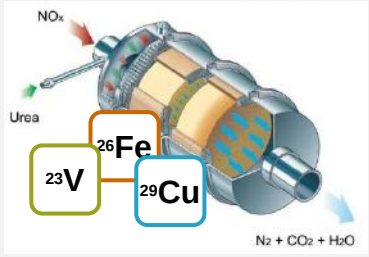




>50% of the gap generated in acceleration @ t =400 s

Conclusions

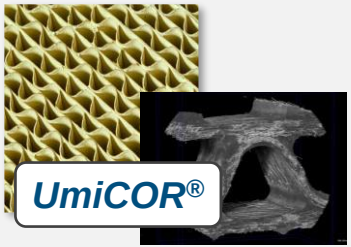
Umicore's solutions to the latest aftertreatment challenges



SCR Portfolio

Competitive SCR Technologies based on Vanadia, Cu- or Fe-Zeolites

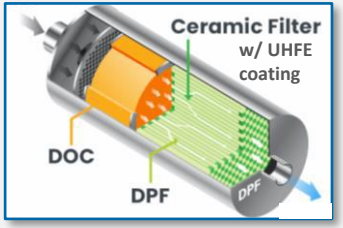
- High DeNOx potential at broad operation window
- Solutions for low N_2O



UmiCOR®

Corrugated Catalysts: Unique Combination of Substrate & SCR coating

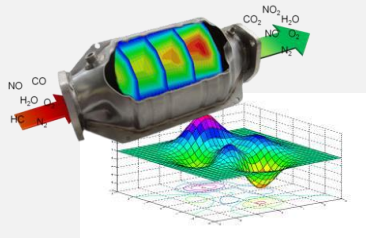
- Reduced weight & Δp
- Improved light-off
- Potential for volume & system cost reduction



UHFE, DOC

Ultra-high Filtration Efficiency Coatings on DPF

- UHFE solutions ready for future legislations
- Competitive low PGM DOC solutions



Modeling

Catalytic Modeling for System Studies

+ dynamic gas bench studies simulating transient engine exhaust

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materials for a better life