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Non-Road and Stationery Emissions Control
Johnson Matthey India

Emission Control Manufacturers Association

November 11th, 2022

Agenda

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Bharat Stage (BS) Norms – Heavy Duty off Road Application

Bharat (CEV/Trem) Stage V - Effective from 1st April, 2024

		CO	HC	NOx	PM	PN	Test Cycle
Category, kW	Category, HP	g/kWh				#/kWh	
P < 8	< 10	8.0	7.5 (HC + NOx)		0.4	-	NRSC
8 ≤ P < 19	10 – 25	6.6	7.5 (HC + NOx)		0.4	-	
19 ≤ P < 37	**25 – 50**	**5.0**	**4.7 (HC + NOx)**		**0.015**	**$1x10^{12}$**	NRSC & NRTC
37 ≤ P < 56	**50 – 75**	**5.0**	**4.7 (HC + NOx)**		**0.015**	**$1x10^{12}$**	
56 ≤ P < 130	75 – 175	5.0	0.19	0.4	0.015	$1x10^{12}$	
130 ≤ P < 560	175 – 750	3.5	0.19	0.4	0.015	$1x10^{12}$	
P > 560	> 750	3.5	0.19	3.5	0.045	-	NRSC

DF - NRSC & NRTC	
CO	1.3
HC	1.3
NOx	1.15
PM	1.05

Durability	
Category, kW	Emission durability period (hours)
≤37 (Constant speed engine)	3000
≤37 (Variable Speed Engine)	5000
>37	8000

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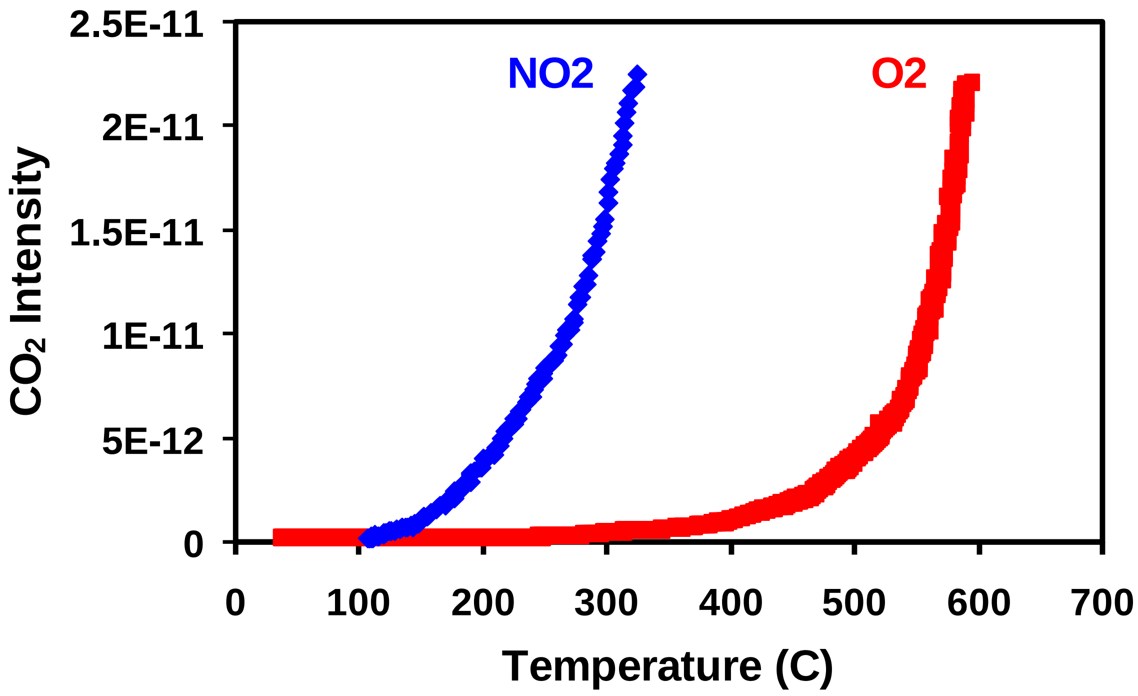
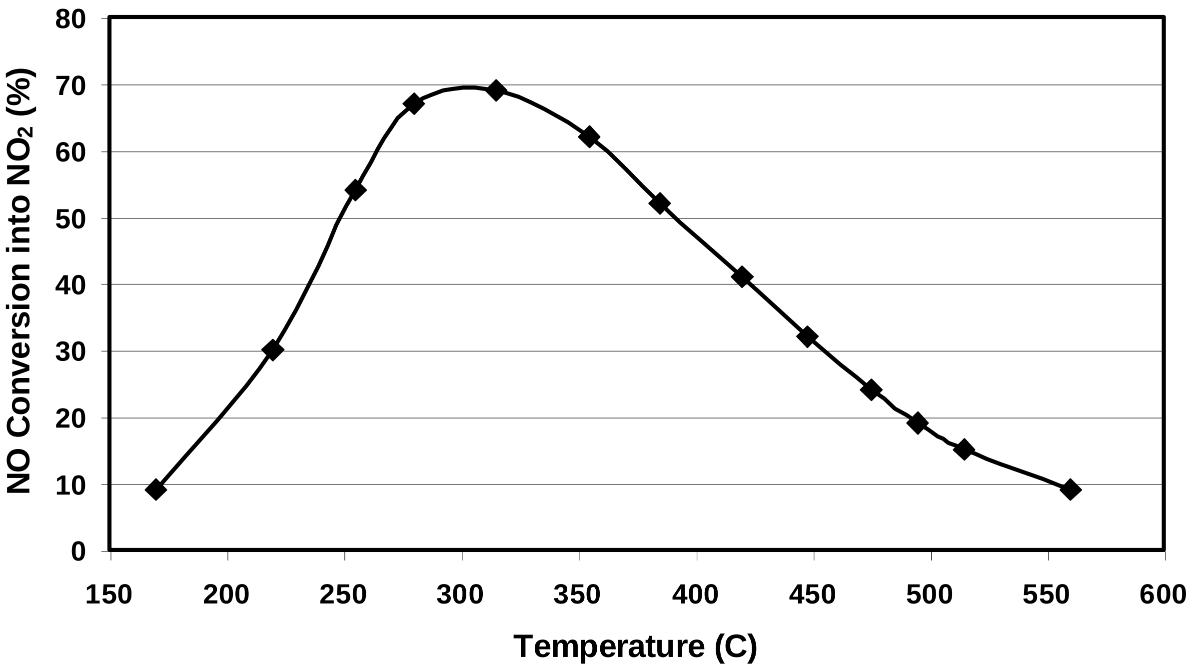
Aftertreatment Systems for diesel particulate control

Carbon soot burns at a faster rate at lower temperature in NO_2 than in O_2
Oxidation catalysts convert engine out NO to NO_2

Carbon burn experiment shows greater rate of oxidation to CO_2 using NO_2 rather than O_2, at lower temperatures.



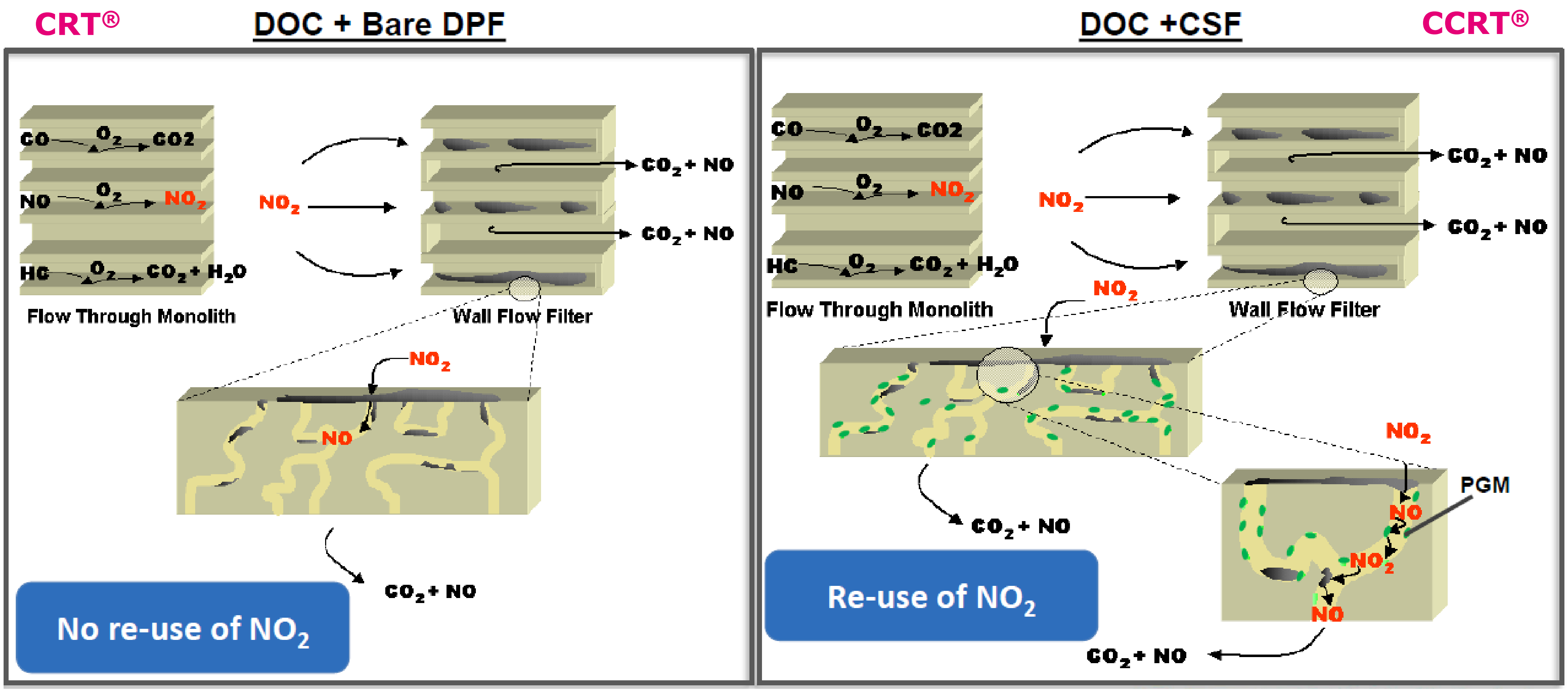
NO oxidation to NO_2 is an equilibrium reaction and the equilibrium varies with temperature. At lower temperatures the reaction is **kinetically** limited, at higher temperatures the reaction is **thermodynamically** limited.



The data included herein were collected in a Johnson Matthey laboratory which has not been certified by the relevant authorities/agencies to perform emissions testing. These are indicative data and do not represent a guarantee that the tested catalyst or emissions system will pass the relevant emissions legislation.

Presence of active catalytic sites in both DOC and CSF increases carbon removal by NO2

System design to optimise distribution of active sites for best control of C is required



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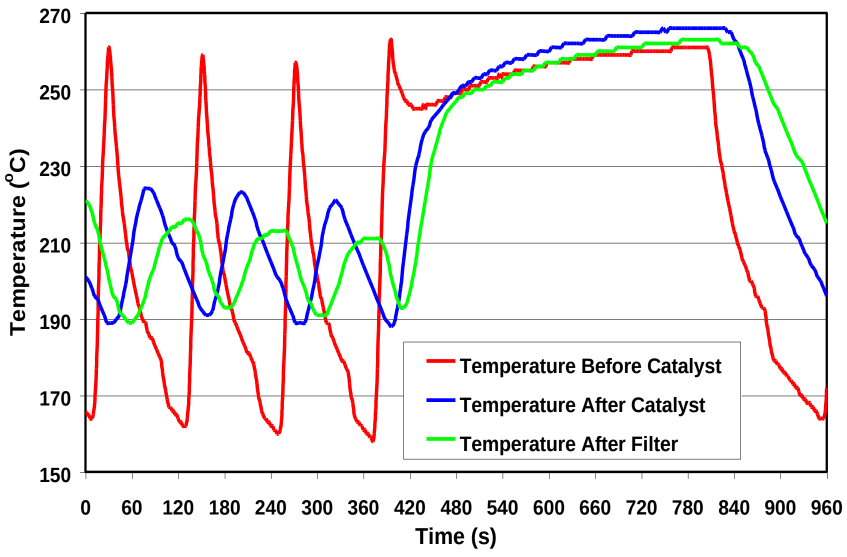
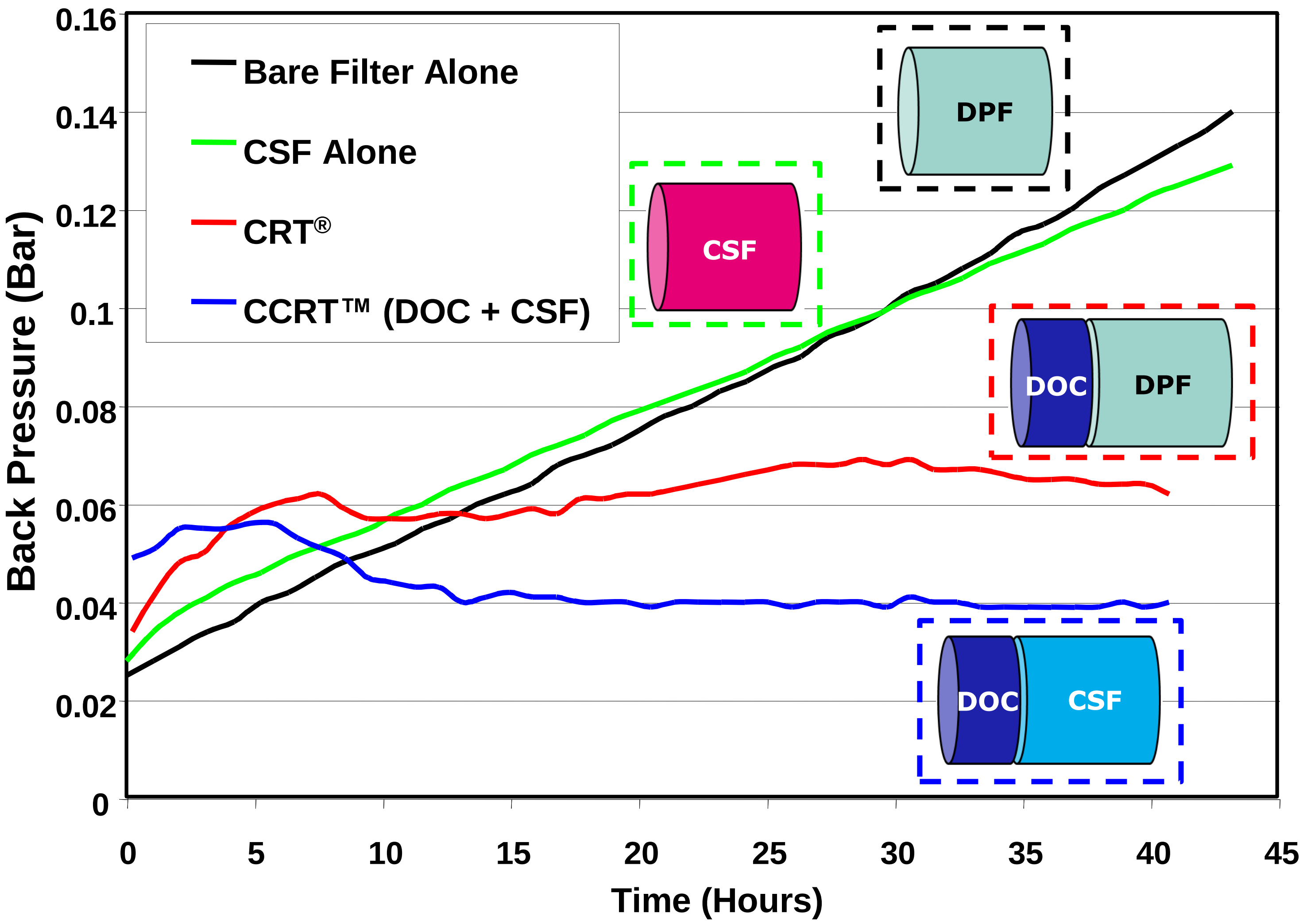
DOC + CSF system is best system for minimising pressure drop on diesel engine

Transient + steady state cycle run on HD engine





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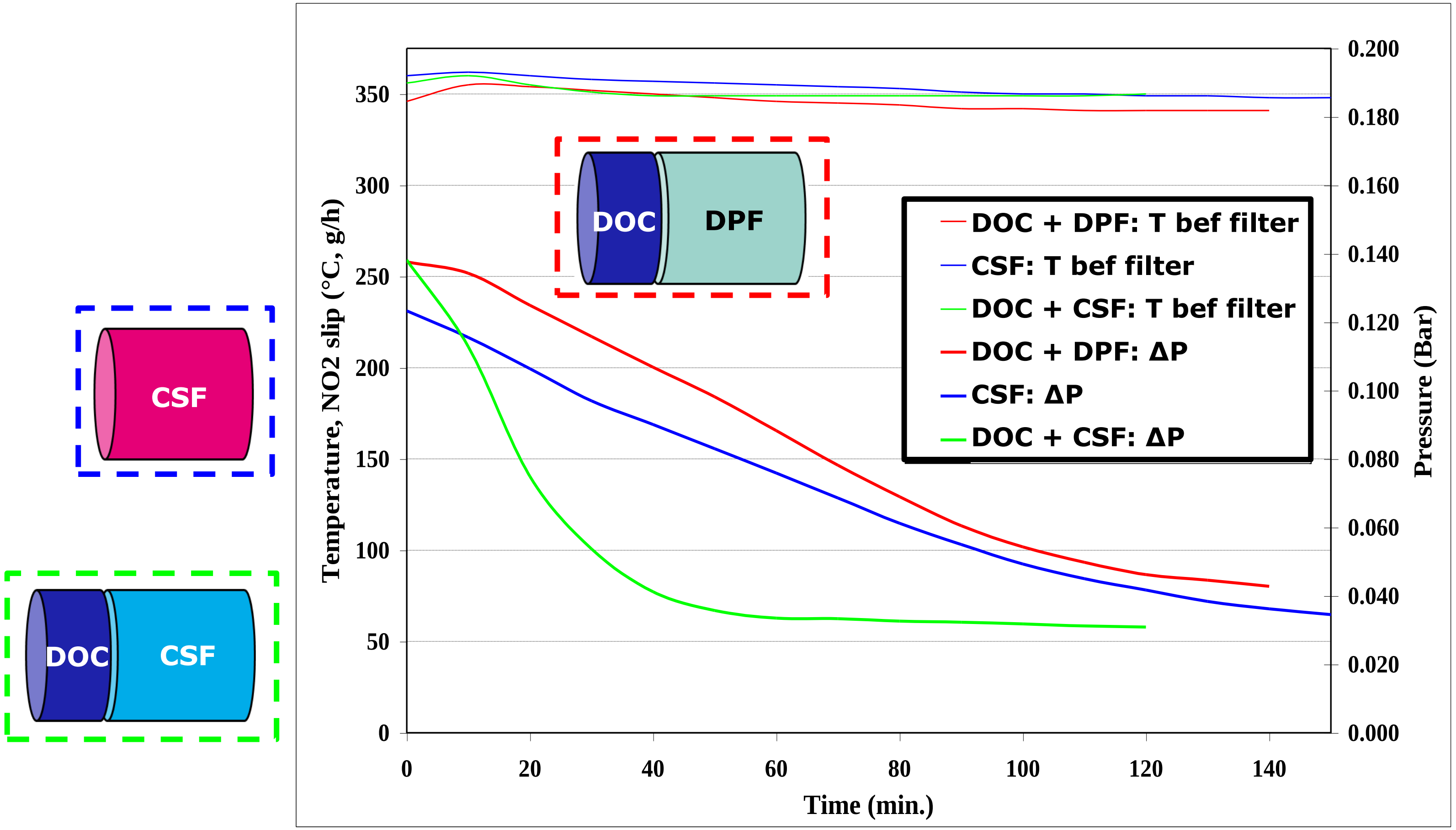
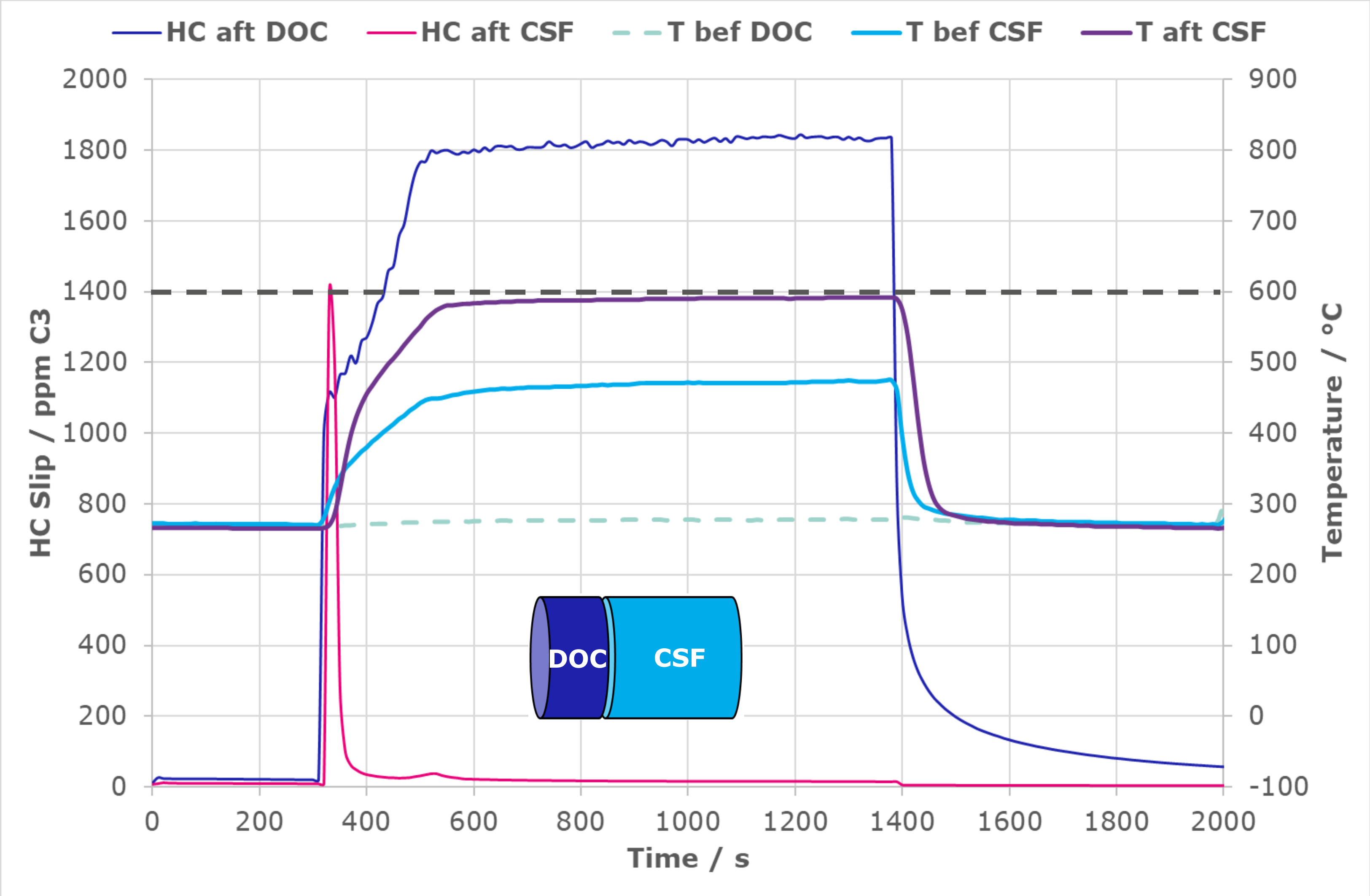
DOC + CSF system removes soot fastest during elevated temperature exposure

Soot loaded systems were exposed to 350°C catalyst inlet temperature; change in pressure drop gives a guide to the rate of removal of carbon soot.



Alternative to passive regeneration control is to use oxygen burn of C

Active regeneration systems take filter to high temperature to burn Carbon



Active regeneration requires the filter temperature to be increased beyond normal operating conditions.

In this example, the temperature increase is achieved through injecting fuel over the oxidation catalyst.

Both catalysts oxidise HC to avoid HC slip.

These catalysts meet performance requirements after representative lifetime ageing.

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Particulate Regeneration for BT V applications

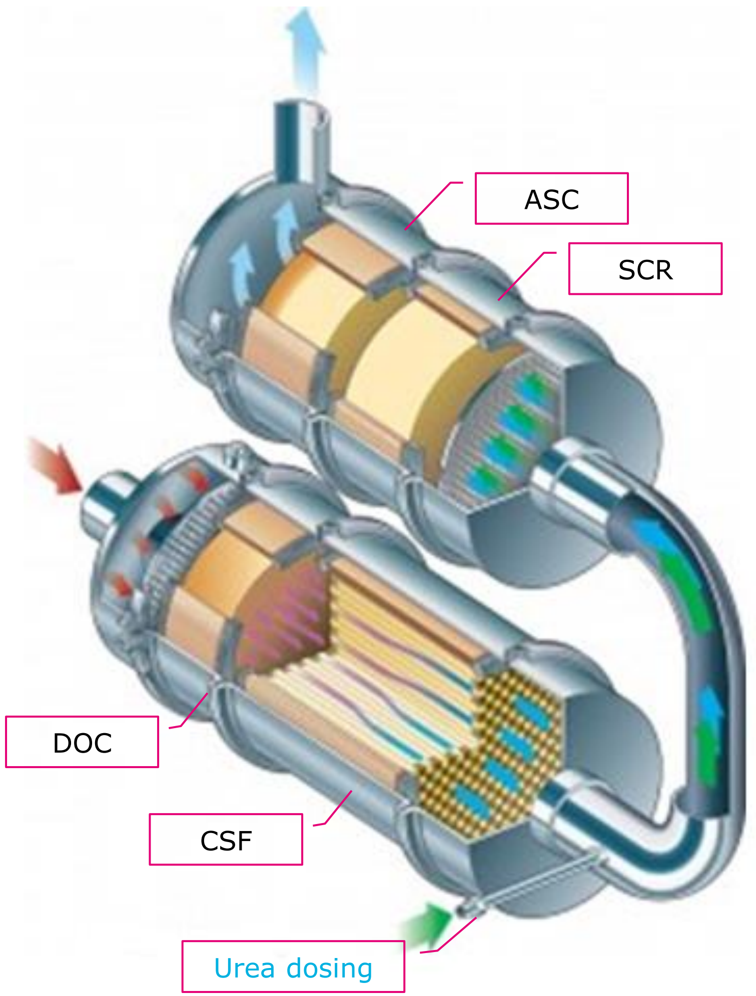
DOC + CSF technology can be applied to the aftertreatment challenge for BT V applications that now require particulate control.

Application optimisation is required to define balance between passive regeneration and active regeneration for non-road machines.

Robustness of systems needs to meet end user requirements which may include a range of fuels which set engine and aftertreatment challenges to manufacturers, such as biodiesels.

Diesel Aftertreatment Layout for higher power NRMM machines

Same catalyst layout as BS VI on road commercial vehicles



DOC

- Oxidizes CO and HC
- Generates sufficient amount of NO_2 for filter regeneration and optimal SCR efficiency
- May also oxidize injected fuel to generate heat for active regeneration of the CSF ("Exotherm")

CSF

- Filters PM (particulate matter) and PN (particulate number)
- Generates some NO_2 for improved regeneration and optimal SCR efficiency

SCR

- Reduces NOx with NH_3, which is formed from urea hydrolysis

ASC

- Oxidizes excess NH_3 from the SCR
- Reduces NOx with NH_3

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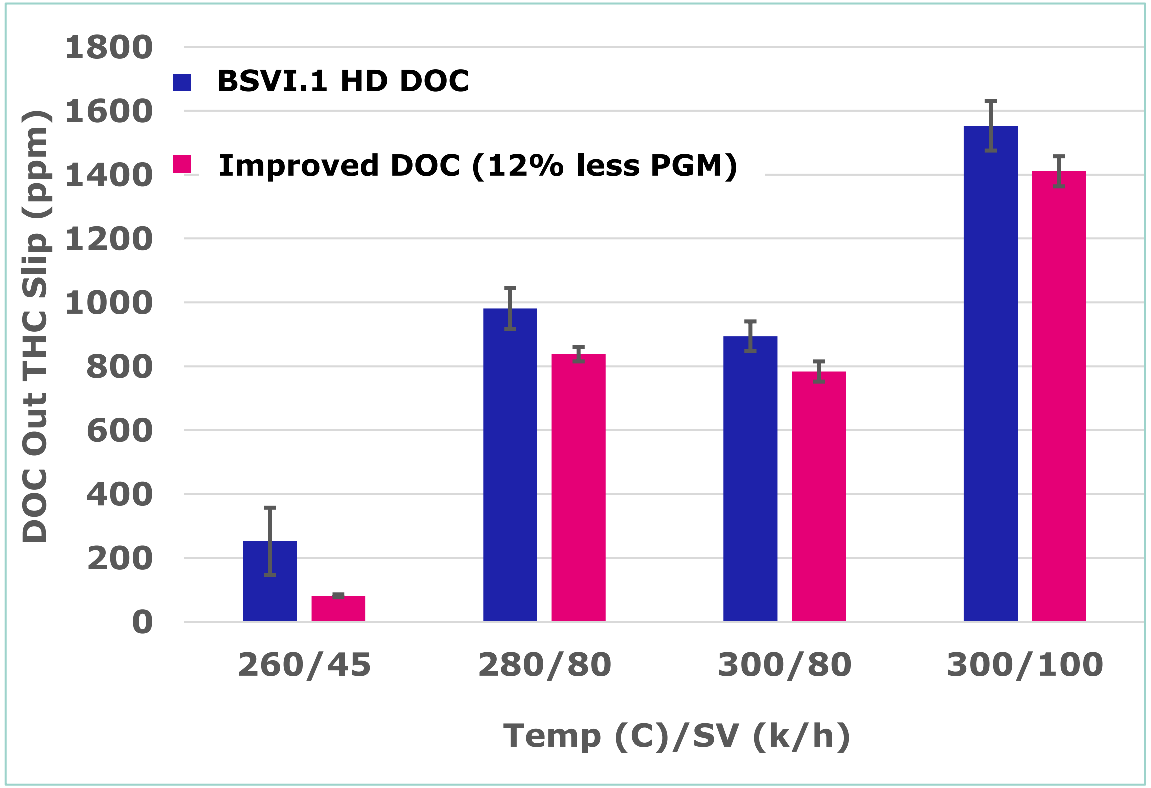
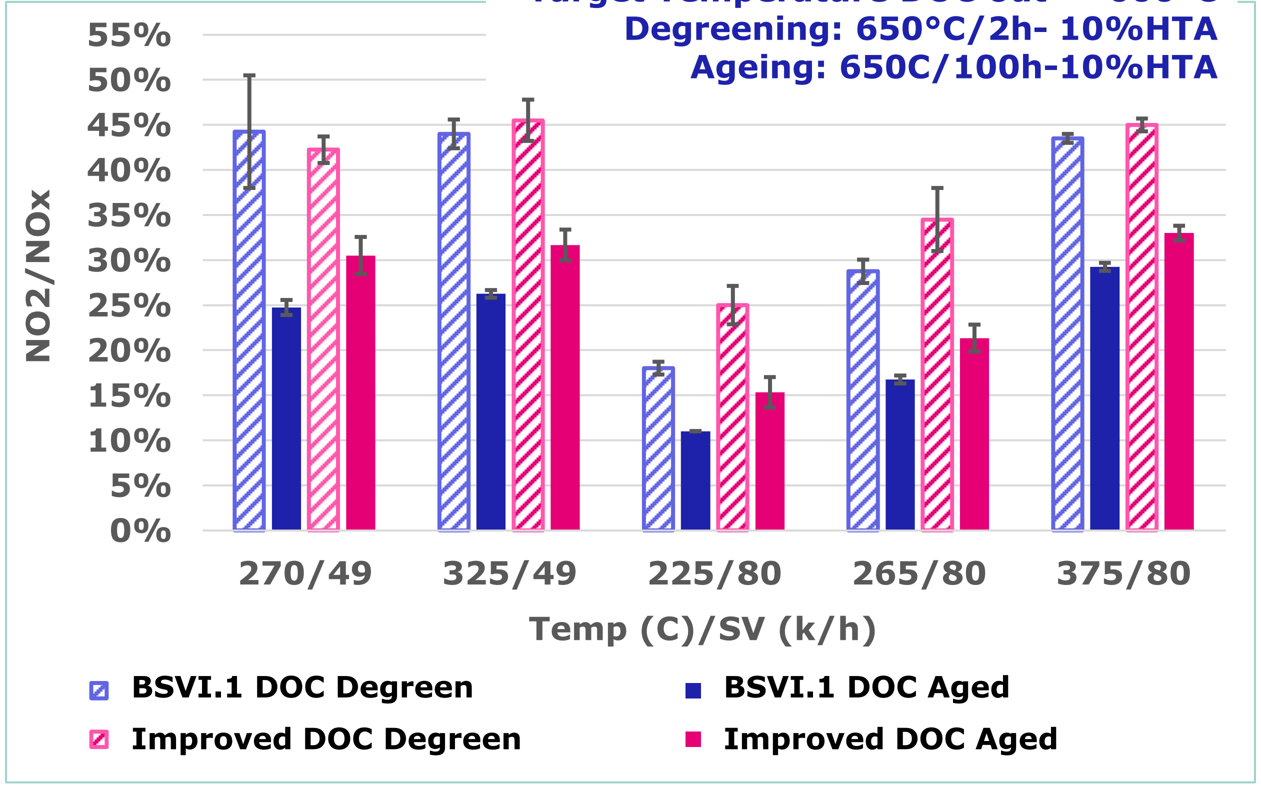
Improved DOC for on-road systems can be used in non-road systems

Improved DOC is equivalent or better than existing DOC for NO oxidation and HC oxidation; performance is delivered with lower pgm cost.



Target Temperature DOC out = 600ºC
Degreening: 650°C/2h- 10%HTA
Ageing: 650C/100h-10%HTA



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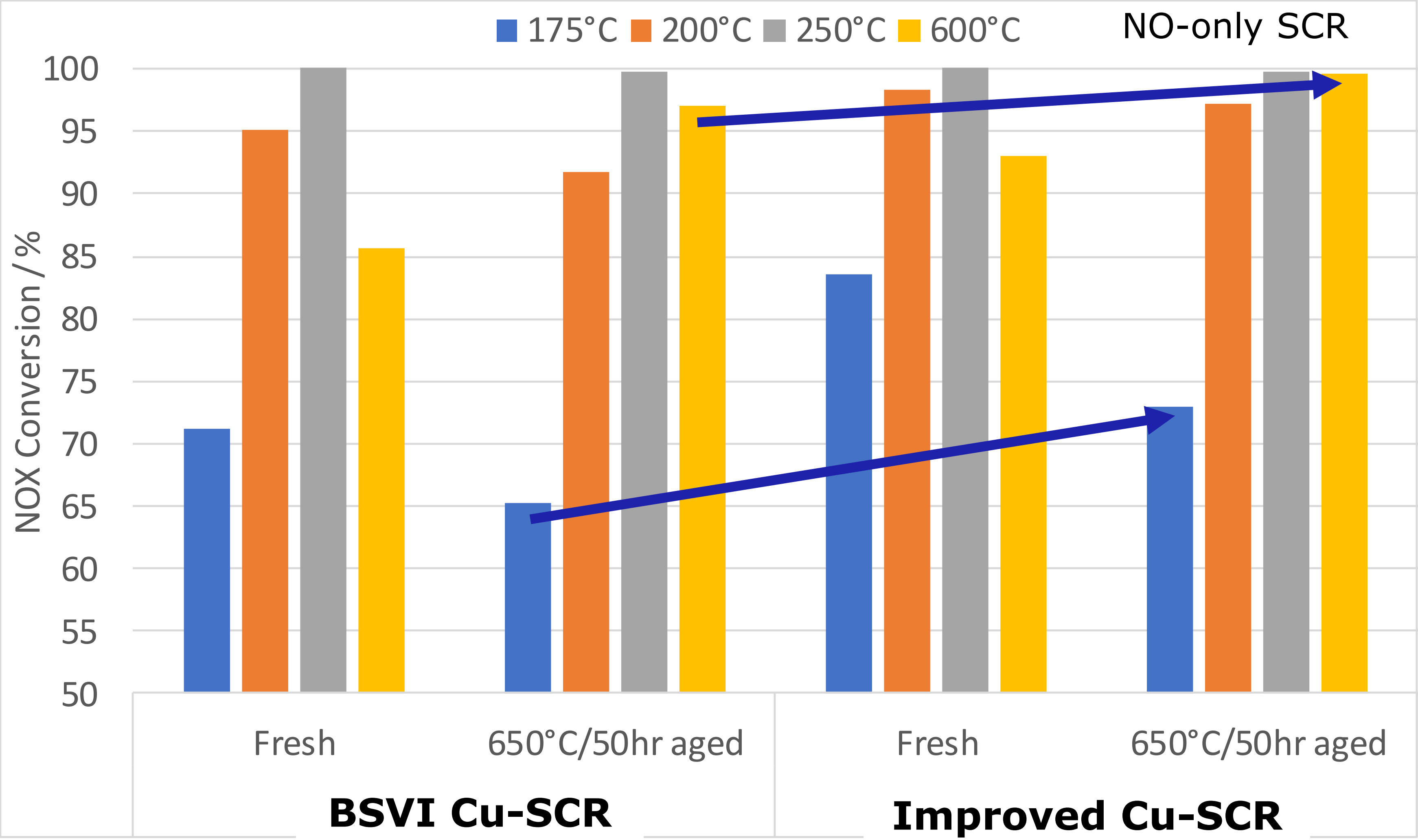
Improved Cu-SCR shows better NOx conversion than BSVI.1 reference

- Latest JM technology offers improved low and high temperature performance
- Maintains low N_2O make



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The move to net zero is accelerating

Commercial drivers may move faster than legislation

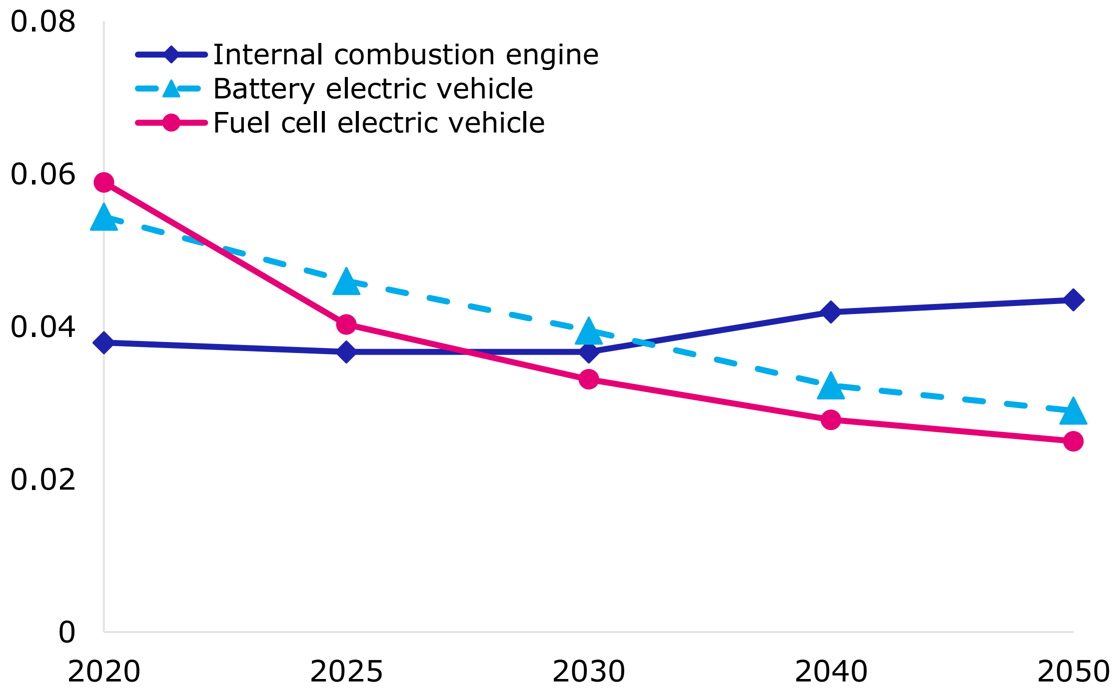
46
countries and states have defined dates to become net zero

79%
of global GDP with net zero targets; 16% two years ago

73%
of global GDP with Hydrogen Strategies

Heavy duty vehicle total cost of ownership

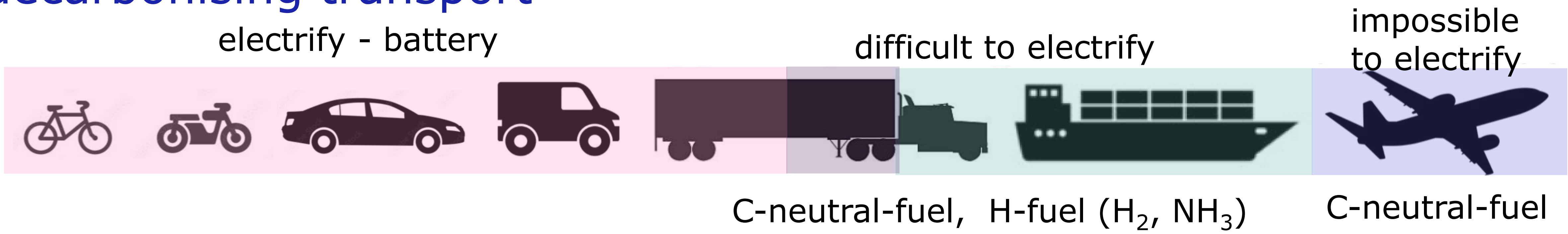
($/tonne-km)



Long Haul Trucks: fuel cell trucks potentially have lower TCO than diesel on the 2027/28 timeframe

Source: McKinsey/Hydrogen Council

H_2-ICE as a near zero emissions vehicle can offer solutions in decarbonising transport



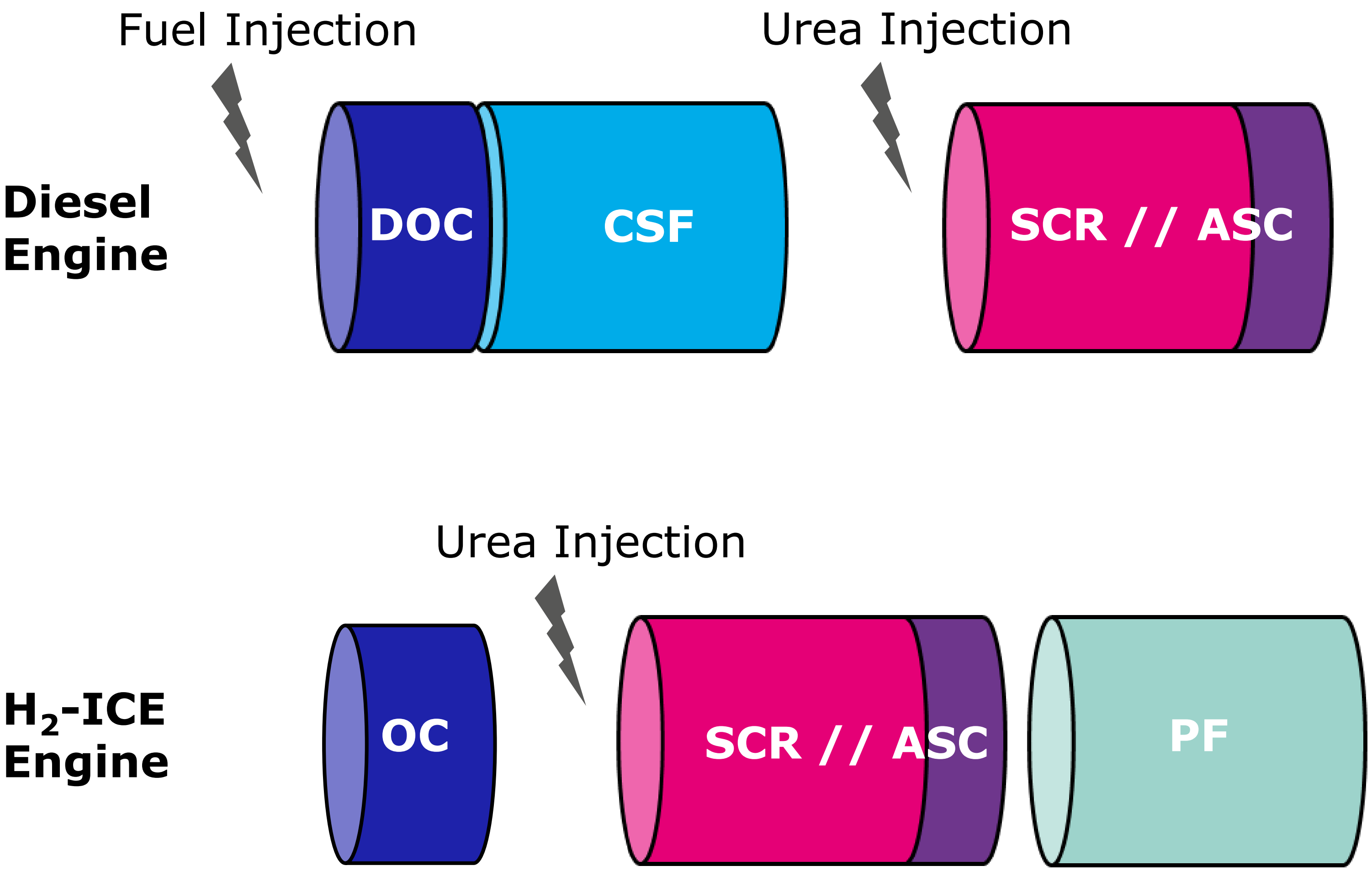
- H_2-ICE being seriously considered as future powertrain by multiple OEMs and in many publications
  - Engine “evolution” from Diesel or natural gas engines
  - Mainly lean, spark ignited combustion with low (NO_X and PN) raw emissions

- Low level GHG emissions from H_2-ICE should be minimised, but may not be regulated for H_2-ICE
  - GHG contributing emissions:
    - H_2 slip (11x CO_2 equivalency)
    - CO_2 from oil consumption (ca. 0.5-1g/kWh), and from urea (~0.5g/kWh CO_2 per 1g/kWh NO_X removed)
    - N_2O (312x CO_2 equivalency)

- Expectation that dealing with emissions from H_2-ICE will be best met by catalytic aftertreatment.

H_2-ICE Layout – what might change from Diesel system?

Oxidation Catalyst and SCR functionality expected to be retained; filter requirement is lower without need to remove C soot



H_2-ICE aftertreatment requirement:

DOC

- Oxidizes H_2 slip
- Oxidize NO to NO_2 to improve SCR performance

SCR // ASC

- Low temperature NOx conversion and low N_2O make will be key requirements for SCR in H_2-ICE

PF

- Filtration will focus on oil ash
- No requirement for soot regeneration
- May move to rear of the system

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Summary

Indian non-road market segregation above and below 56kW power level for Trem V legislation separates engines into those that require particulate control and particulate control and NOx control.

Low power, high torque engines requiring particulate control often show high exhaust temperatures, meaning significant passive regeneration contribution is possible.

Alternatively, particulate control can be achieved using active regeneration.

Larger engines are meeting emissions requirements with technologies similar to those adopted for BSVI with both particulate control technologies and NOx control technologies.

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Thank you for your attention!

Picture shows the Hydrogen Fuelling Station at our Manufacturing Site in the UK