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DRAFT for ECMA 2024

Challenges and opportunities for Off-road applications to meet Bharat Stage-V regulations

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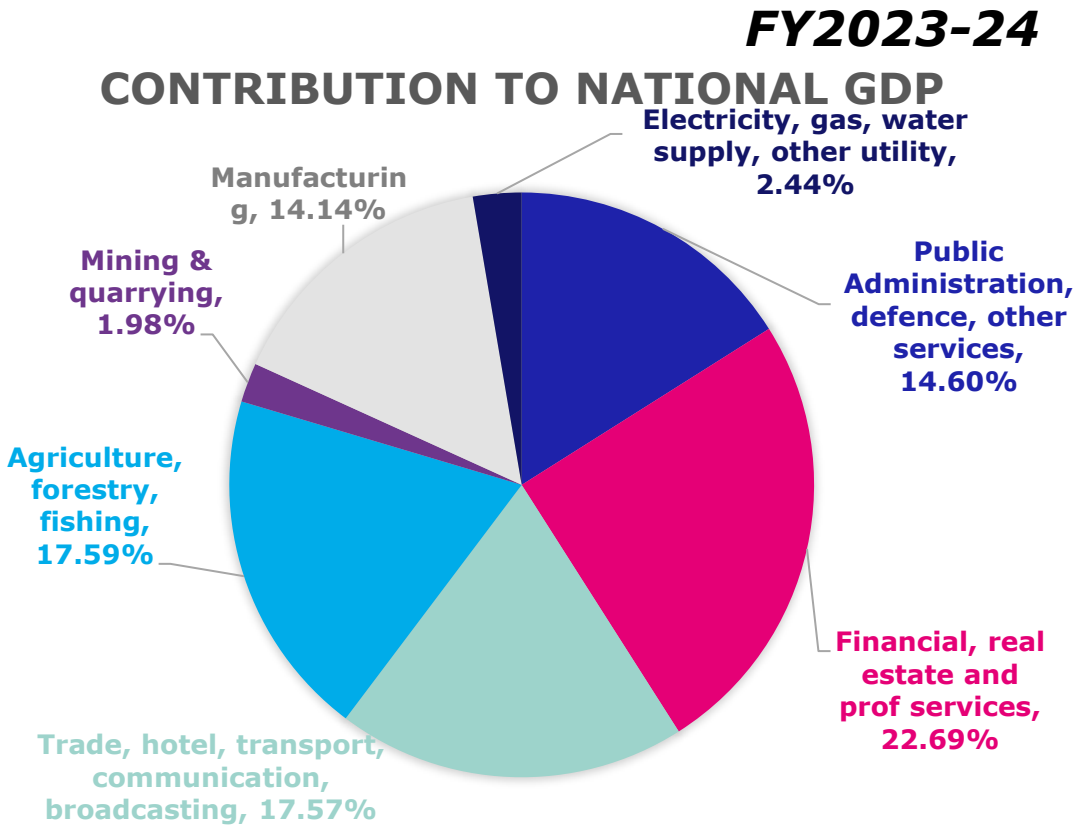
Sethuraman, S., Sitamraju, S., Lopez-De Jesus, Y., and Markatou, P., "Experimental and Computational Study of DOC on CSF for Heavy Duty Diesel Applications," SAE Technical Paper 2019-01-0586, 2019, https://doi.org/10.4271/2019-01-0586.

Introduction

- Off-road segment is key as rural India is largely an agriculture-based economy and current infrastructure push across India.
- BS TREM V (eff. Apr'26) and CEV V (eff. Jan'25)
  - PM:0.015g/kwh, PN: $1x10^{12}$ #/kWh ➔ 19-56kW : CSF
  - NOx (0.4g/kWh) ➔ >56kW : SCR
  - Cost and vehicle hood design aesthetics are key factors.
- Use of innovative technology to reduce the ATS volume help to serve both.
- Similarly, advanced Catalyst technology for Genset application CPCB IV+ can help reduce catalyst volume.



Ref: https://statisticstimes.com/economy/country/india-gdp-sectorwise.php#:~:text=Sector%2Dwise%20GDP%20of%20India&text=The%20services%20sector%20accounts%20for,and%20allied%20sector%20share%2017.59%25.

Key requirements to meet Legislation in dominant market segment

19kW to 56kW ➔ DOC+CSF (Key Focus)
Above 56kW ➔ DOC + CSF+ SCR+ASC

Farm Segment

TRACTORS

Bharat TREM-V/April'2026

CO	g/kwh	5.0
HC+NO$_X$	g/kwh	4.7
PM	g/kwh	0.015
PN	#/kwh	1X 10^{12}

Emission cycle:
NRTC & NRSC

Filter mandatory

Construction Equipment Vehicles

Bharat Stage-V/Jan'2025

CO	g/kwh	5.0
HC+NO$_X$	g/kwh	4.7
PM	g/kwh	0.015
PN	#/kwh	1X 10^{12}

Emission cycle:
NRTC & NRSC

Filter mandatory

19kW to 56kW ➔ DOC
Above 56kW ➔ DOC + SCR

Stationary Engines

Diesel Generator

CPCB-IV+/July'23

CO	g/kwh	3.5
HC+NO$_X$	g/kwh	4.7
PM	g/kwh	0.03
PN	#/kwh	N.A

Emission cycle:
5 – mode cycle

Filter not needed

Tractor and CEV Application

<56kW ➔ DOC+CSF

>56kW ➔ DOC+CSF+SCR+ASC

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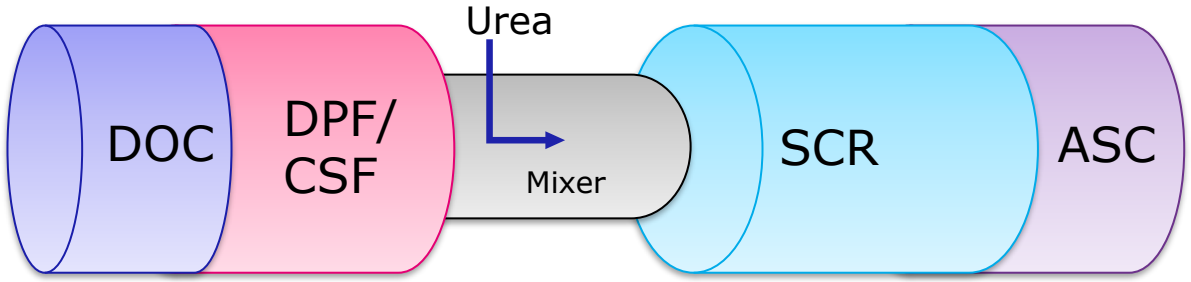
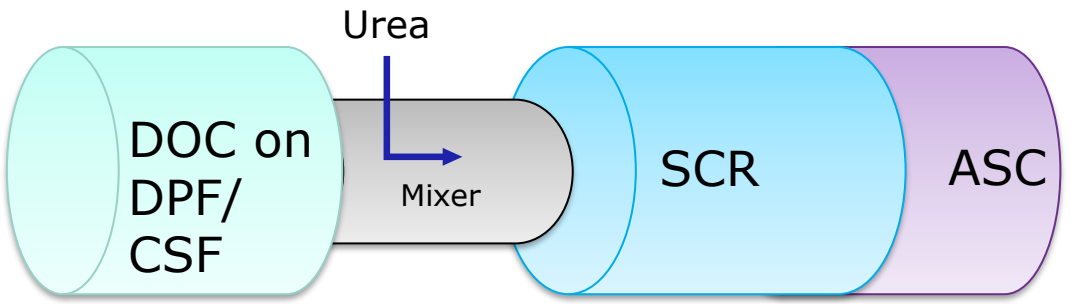
DOConDPF Technology

- DOC on DPF provides the flexibility of reducing the total aftertreatment system volume
- DOC on DPF also helps move the SCR to a warmer location, thereby enabling earlier injection of urea in the cycle

Current System/ Reference



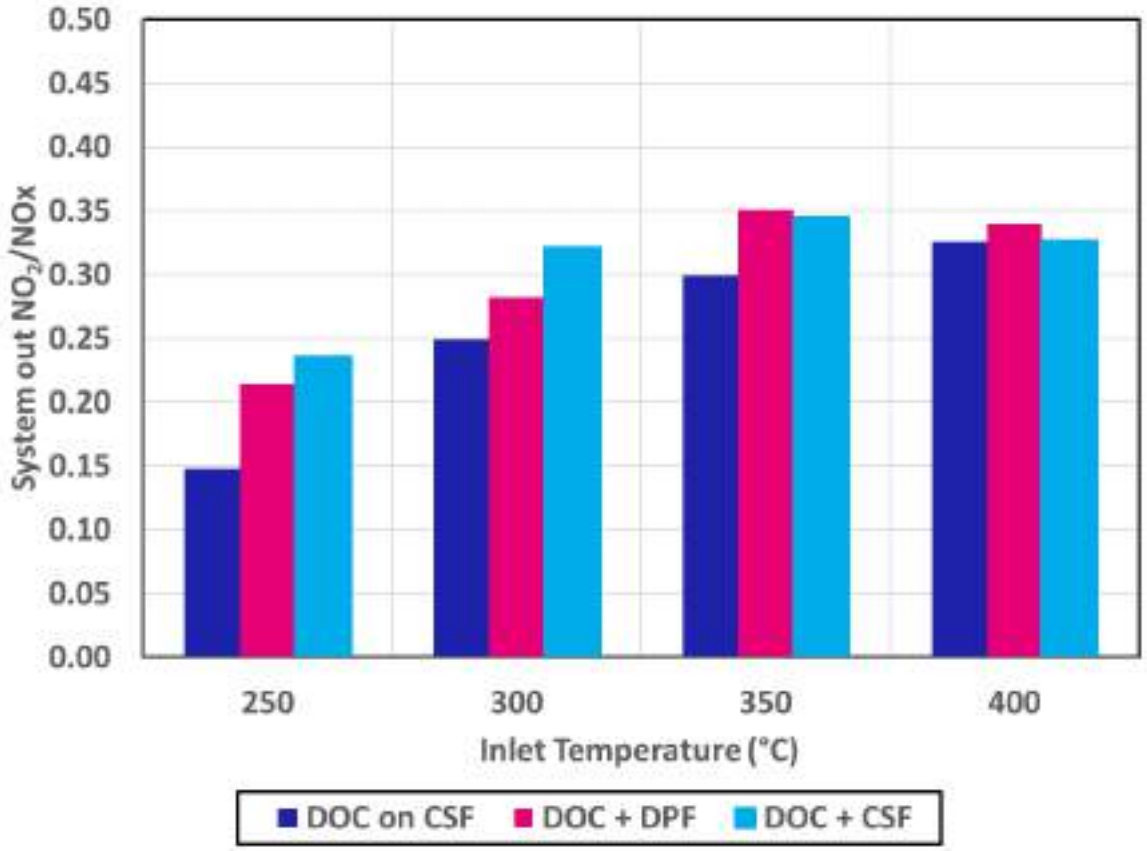
System with reduced packaging space

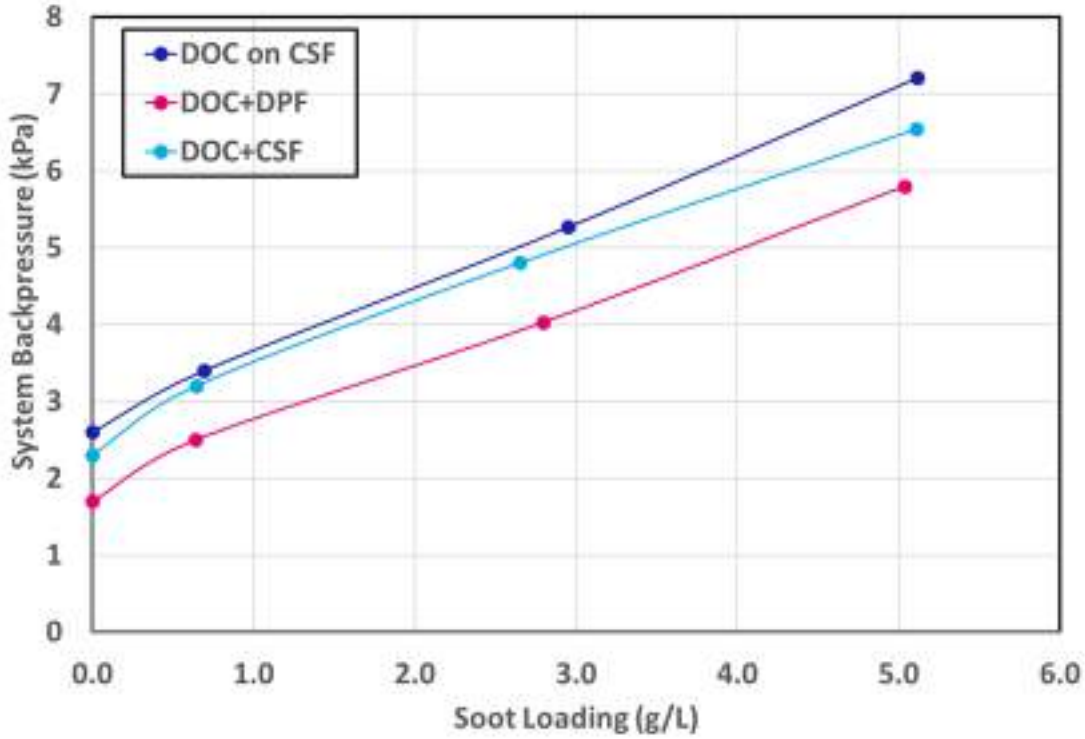


NO Oxidation Performance and SLBP

DOC on DPF performance can be tuned to match the DOC+DPF or DOC+CSF performance

Inlet NOx = 500-1300ppm, Filter SV = 100k h^{-1}

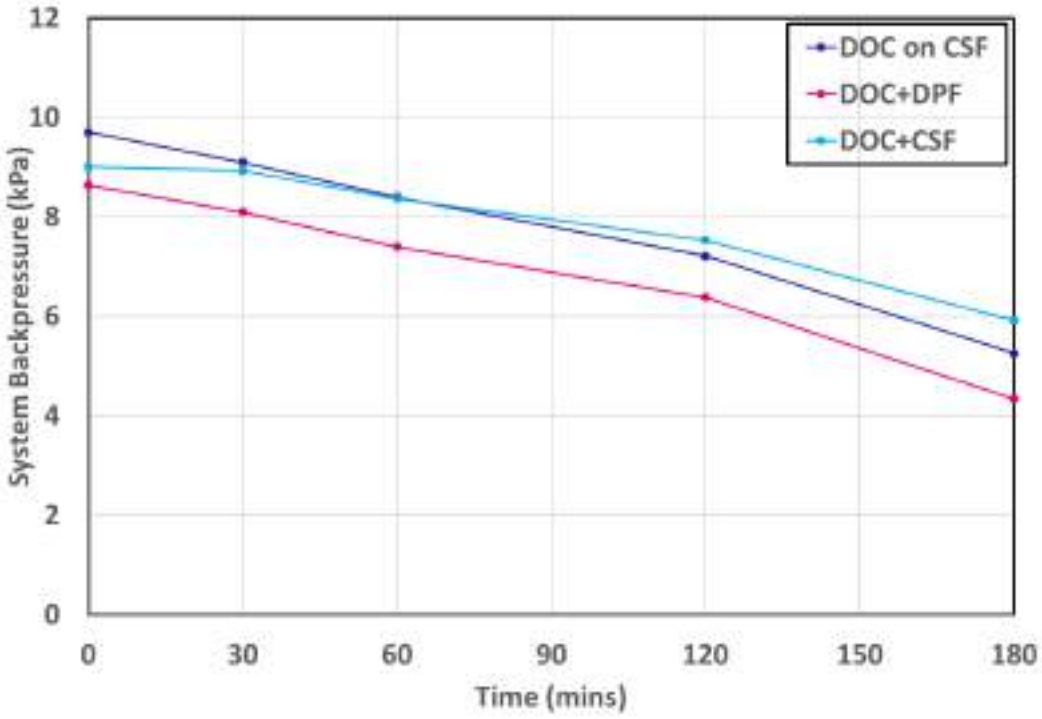




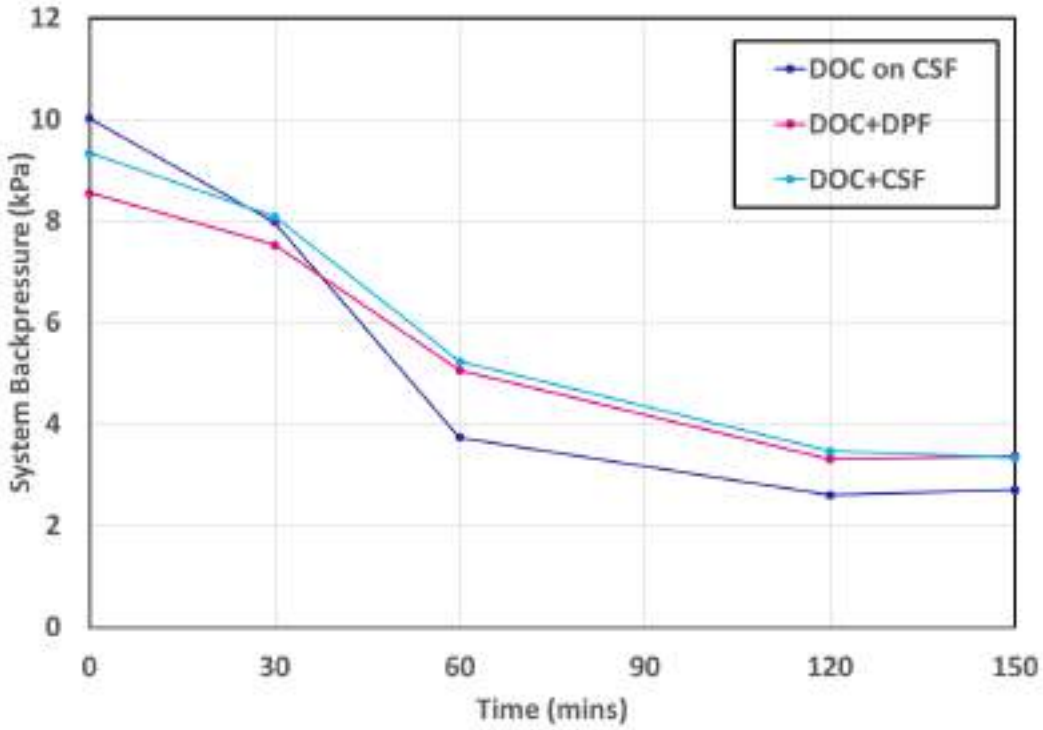
CSF Functionality – Passive Soot Oxidation

Engine Testing after 5 g/L soot loading

Inlet NOx = 1000 – 1800ppm, Filter SV = 100k h^{-1}



At 300°C, overall the backpressure drop is similar for all the systems

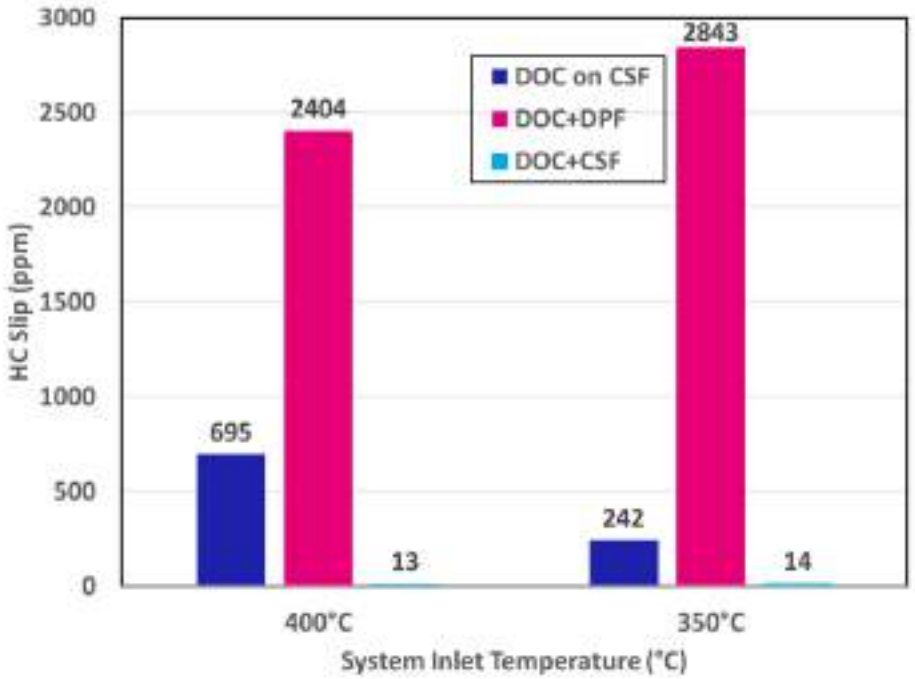


At 350°C, there is a significant drop in backpressure for DOC on CSF system

Active regeneration efficiency of DOConDPF is better than DOC+DPF

DOC Functionality - SS HC Oxidation

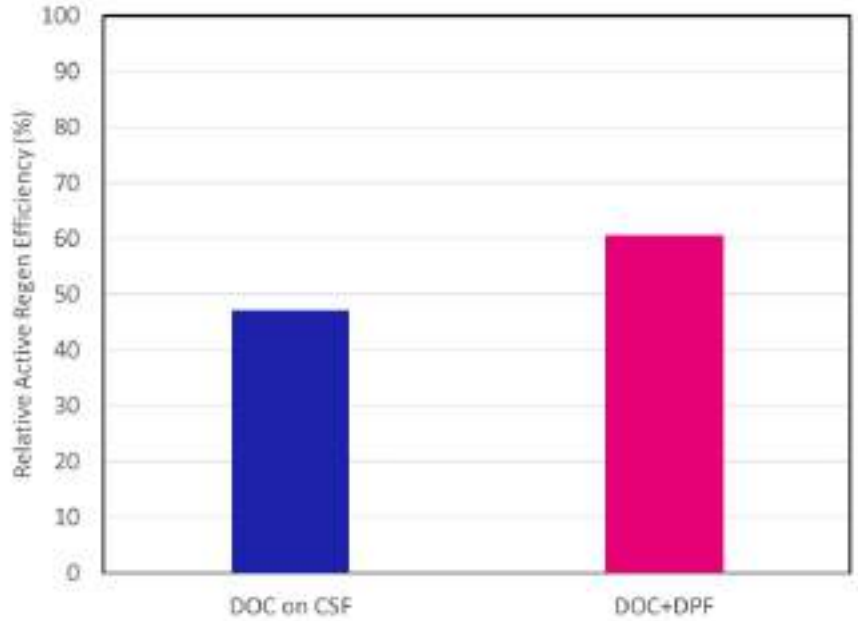
- DOC on CSF has considerably less HC slip compared to DOC + DPF system
- DOC+CSF has additional PGM and catalyst volume



Target DOC/DOC on CSF Out Temp = 600°C, Filter SV = 110k h^{-1}

CSF Functionality – Active Regen after 3g/L soot

- DOC on CSF has lower active regeneration efficiency compared to DOC + DPF

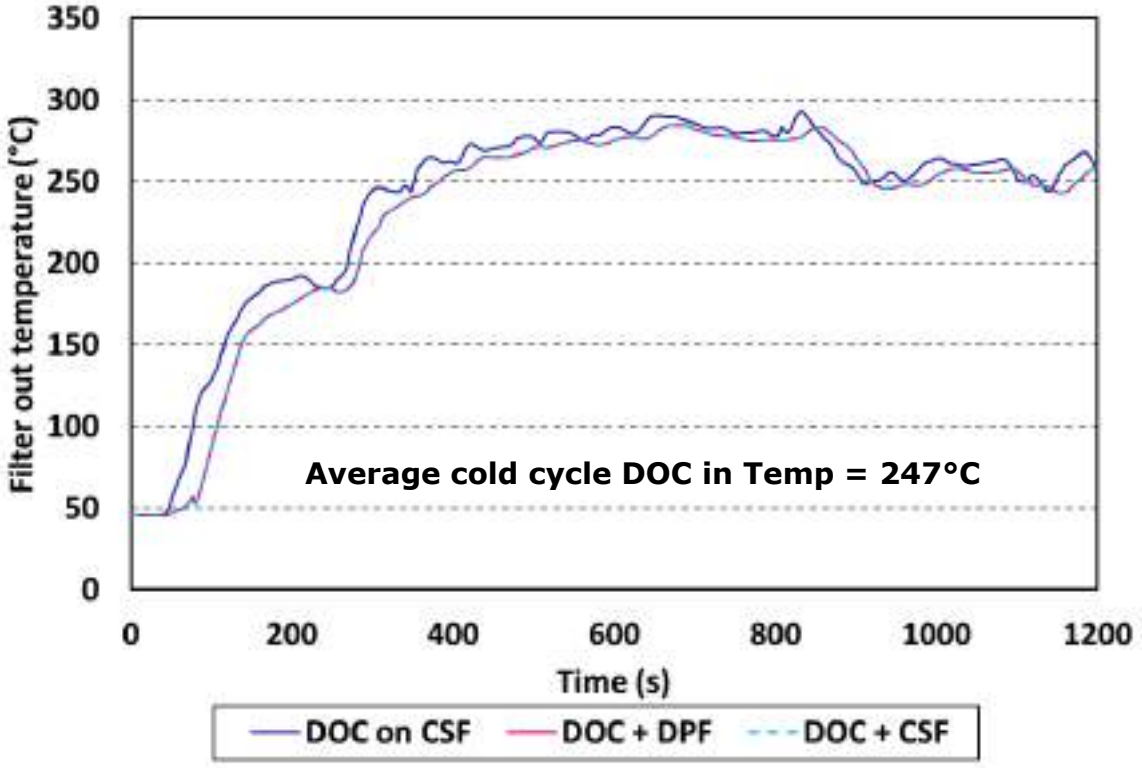


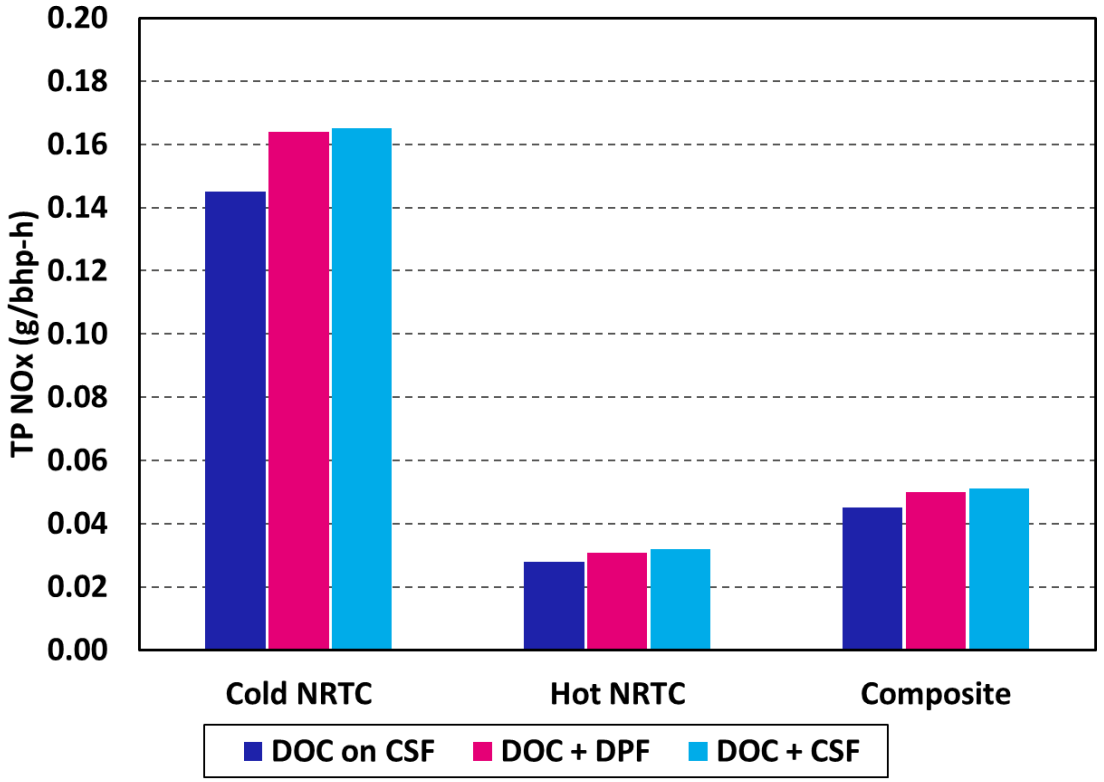
Target DOC/DOConCSF Out Temp = 600C

Cold cycle NOx emission lower as SCR comes closer to engine.

Benefit in NOx reduction is reduced when the operating temp is higher

Engine out NOx = 1.4g/bhp-h, Avg. SCR SV = 60k h^{-1}, ANR =1.1





Genset Applications

<56kW ➔ DOC

>56kW ➔ DOC + SCR ASC

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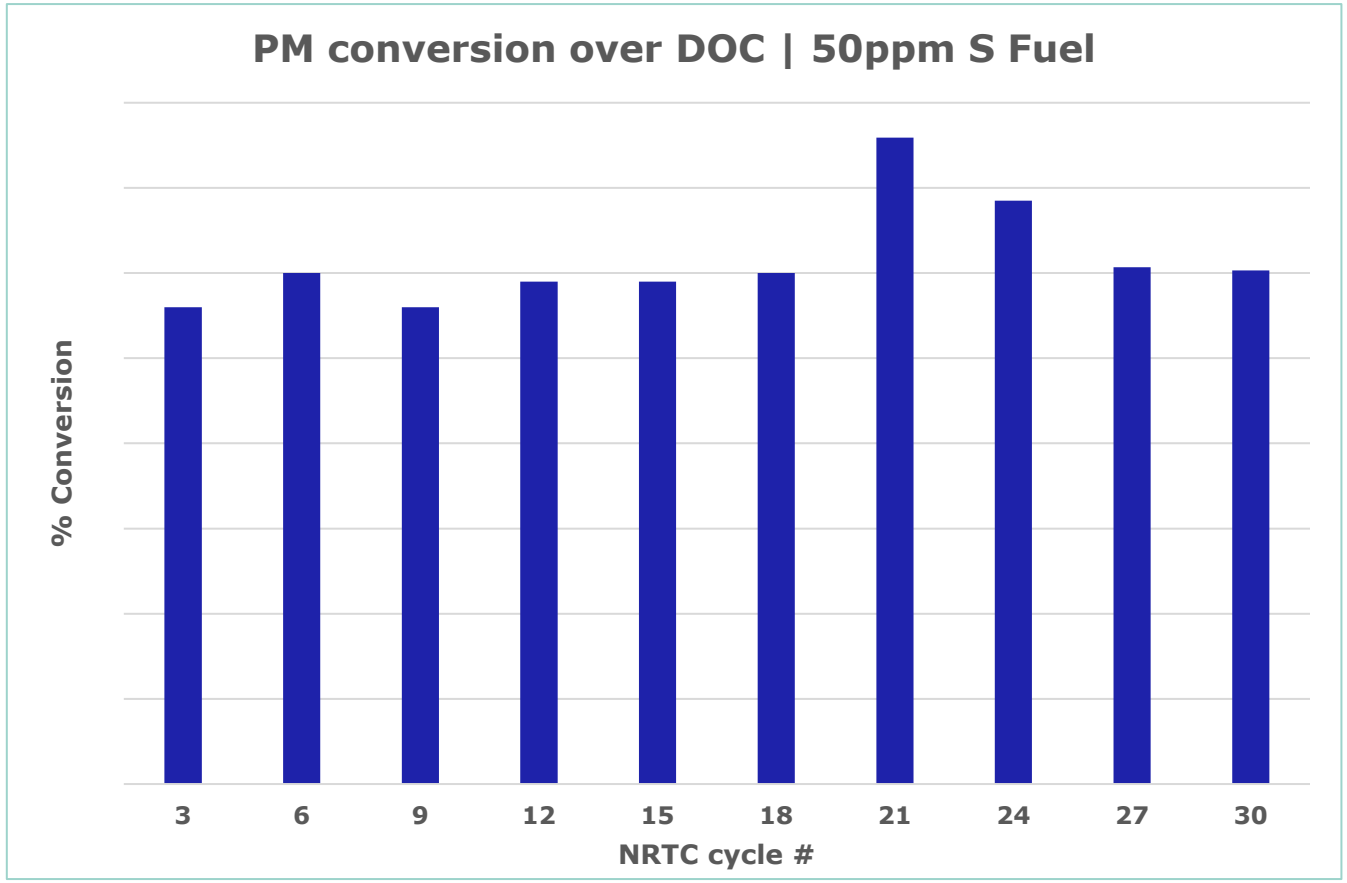
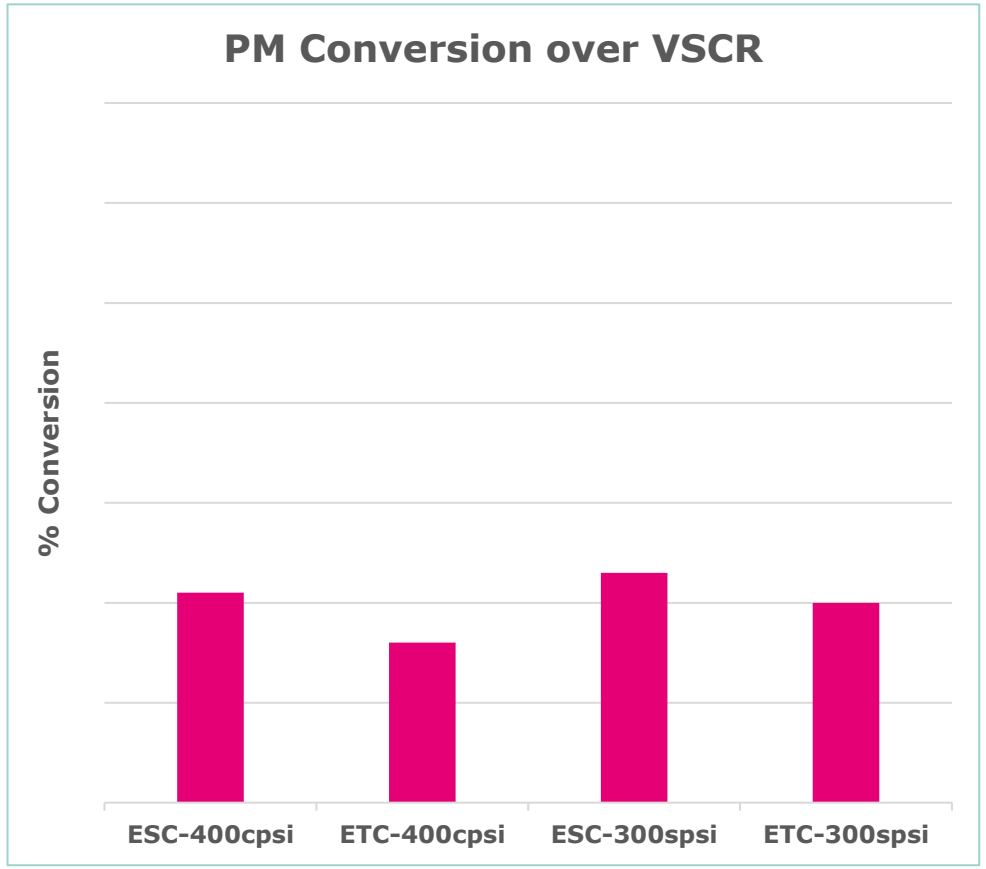
DOC shows good PM oxidation activity
VSCR also supports PM oxidation activity to some extent





PM conversion activity depends on % content of organic shell and soot core
DOC, VSCR is expected to oxidize organic shell

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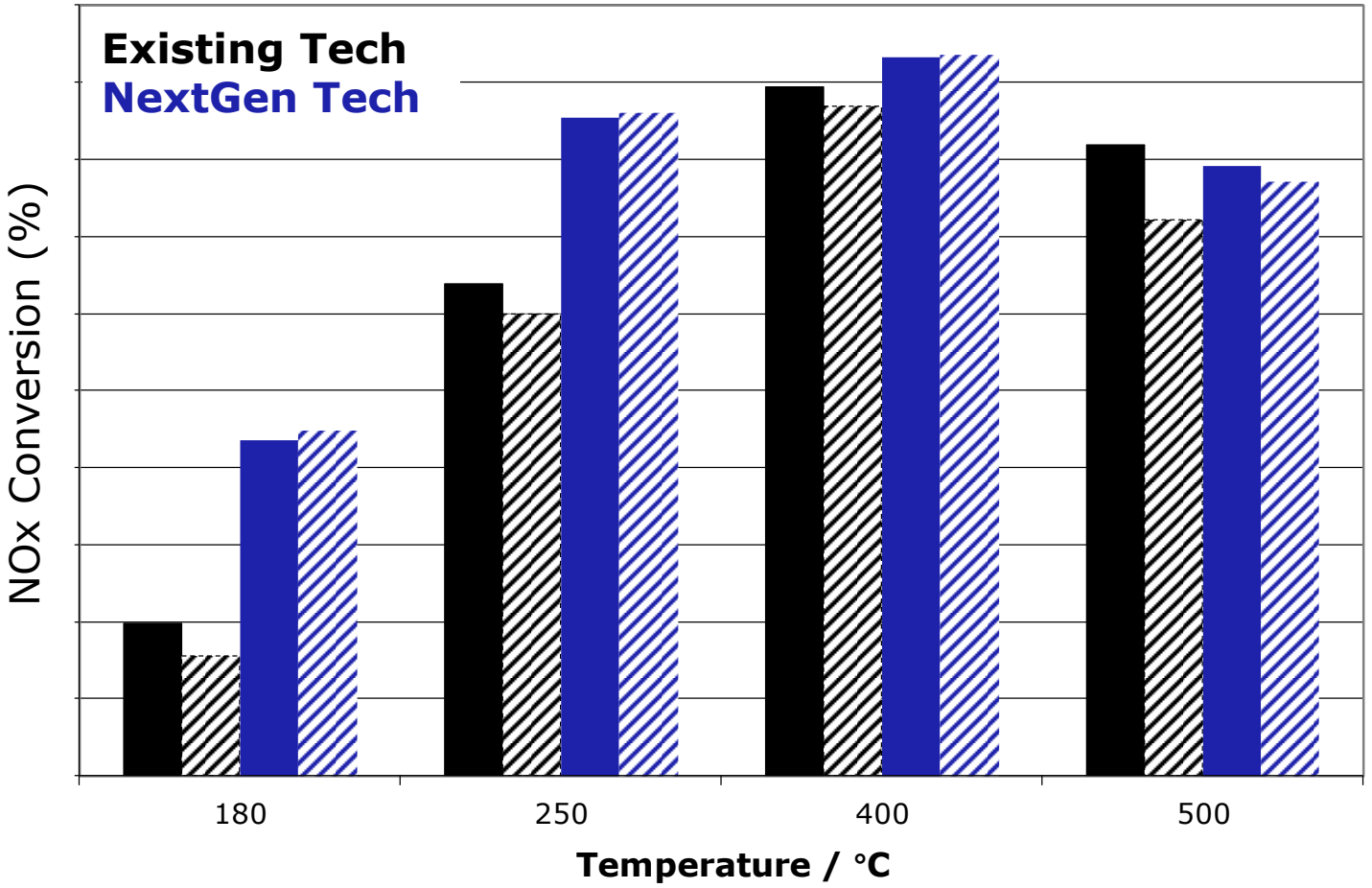
Advanced VSCR technology help to reduce catalyst volume



SV 120000h^{-1} 300ppm NO, ANR: 1.0
9.3% O_2, 7% H_2O, Balance N_2
400cpsi

Full bar fresh
Dashed bar 100h@580°C

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Summary

- Tractor applications bring challenge for volume reduction
- DOConCSF technology could be the potential technology to optimised solution for off-road
- NO oxidation and soot loaded backpressure with DOConCSF technology is slightly poor.
- Active regeneration HC slip is lower with DOConCSF however, relative soot mass burn is lower than DOC+DPF
- DOConCSF improves tailpipe NOx emissions by allowing early urea injection.
- For Genset applications, PM oxidation on DOC and VSCR help to meet PM emission limit; advanced VSCR technologies can help to reduce system volume.


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