ECT-2018
BSVI and Real Driving Emissions …. Path Forward
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LDV Diesel SCR on DPF Technology to meet tighter NOx and PN emission in RDE condition

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SCR: Selective Catalytic Reduction
DPF: Diesel Particulate Filter
RDE: Real Driving Emission

1. System Trend to Meet Tighter NOx and PN Regulation

2. SCR on DPF Technology

3. Investigation of PN Emission in RDE condition

- Future Development
- Summary

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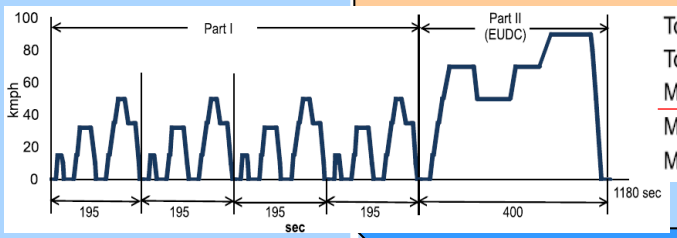
Indian Diesel Regulation

India

Now

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Regulation	BSIV			BSVI Stage I			BSVI Stage II		
Cycle	MIDC			RDE + MIDC					



Total test time: 1180 sec
Total distance: 10.647 km
Max. speed: 90 km/h
Maximal Acceleration: 0.833 m/s^2
Maximal Deceleration:1.389 m/s^2

Wide driving range

Tighter NOx and PN

	2017	2018	2019	2020	2021	2022	2023	2024	2025
NOx [mg/km]	250			80+RDE monitor			80+ RDE CF ?		
PN [#/km]				$6x10^{11}$ + RDE monitor			$6x10^{11}$ + RDE CF ?		
CO_2 [g/km]	130						113		

Lower CO_2

MIDC : Modified Indian Driving Cycle
RDE : Real Driving Emissions
PN : Particle Number
CF : Conformity Factor

Tighter regulation for NOx and PN with Real Driving Emission from 2023.

Technique to Meet Tighter NOx emission in RDE

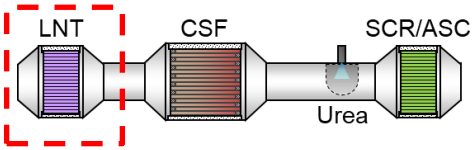
How to accomplish high NOx conversion in RDE?

RDE ➔ Wide driving range ➔ Wide range of exhaust temperature

At low exhaust temperature

At high exhaust temp.

Apply LNT



Improve light off of SCR

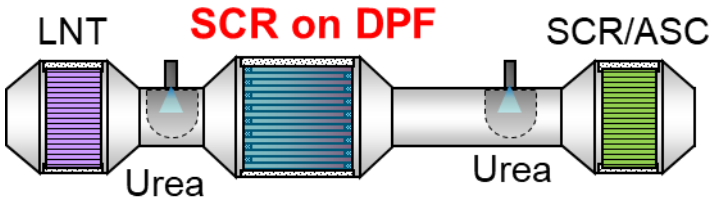
SCR in Close Coupled

Increase SCR volume

Space Constraint in Underfloor

Only LNT will be not enough.

Apply SCR on DPF in Close Coupled



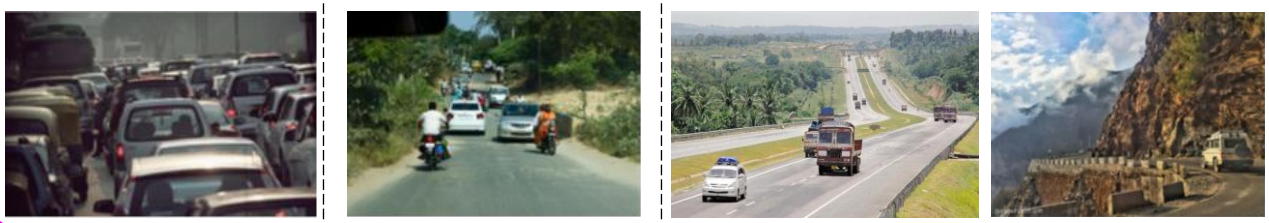
UF : Under Floor
DOC : Diesel Oxidation Catalyst
LNT: Lean NOx Trip
SCR : Selective Catalytic Reduction
ASC : Ammonia Slip Catalyst

SCR on DPF will be a mainstream in RDE implementation.

Schematic consideration of NOx Conversion

Assumption in NGK understanding

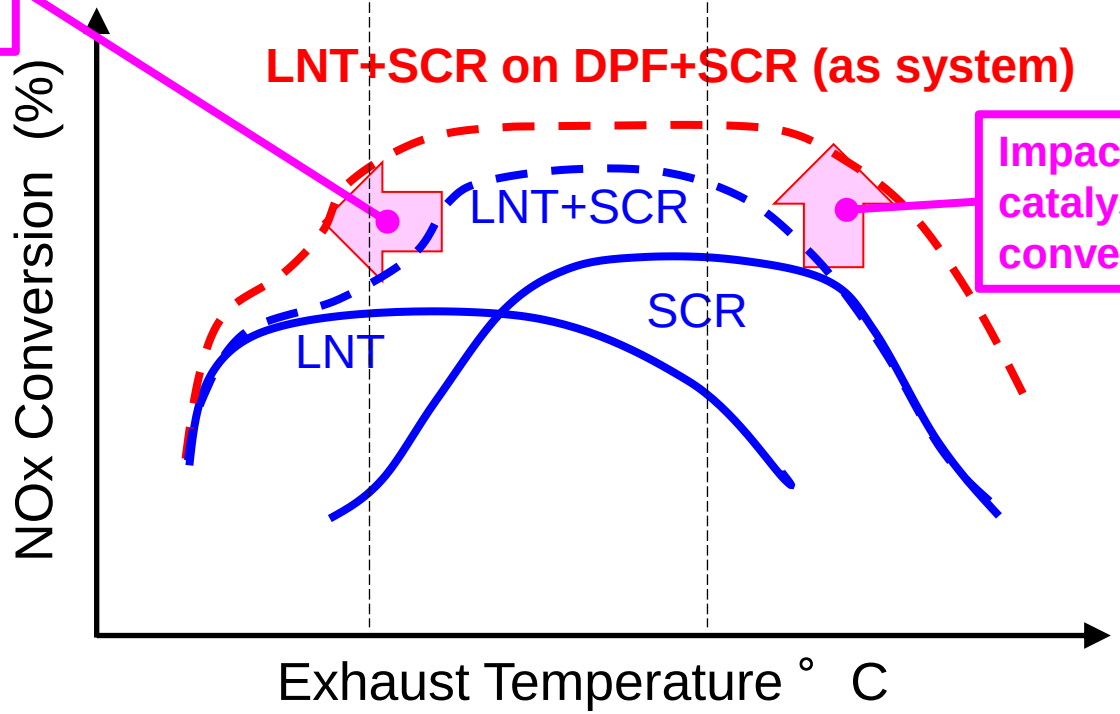
City | Rural Area | Highway | Uphill Driving



Impact of SCR in Close Coupled ➔Faster light off

LNT+SCR on DPF+SCR (as system)

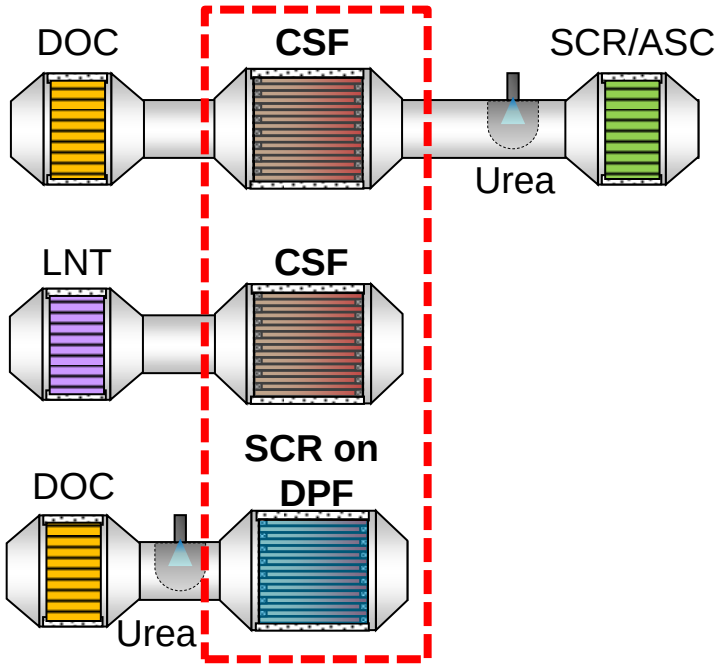
Impact of More SCR catalyst ➔Higher NOx conversion



SCR on DPF system will cover wide range of exhaust temp.

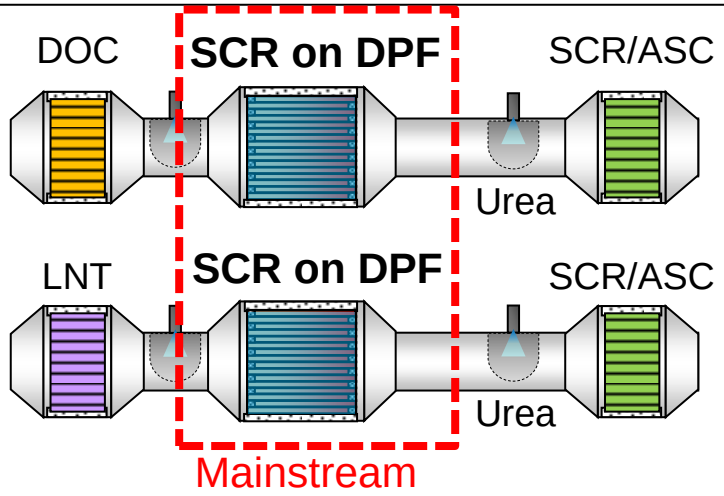
Diesel System Layout Consideration

BSVI stage I (RDE monitoring)



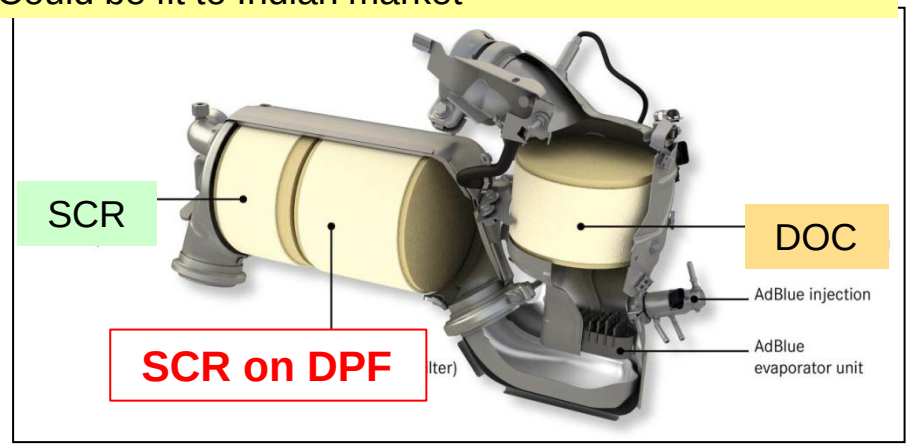
Tighter NOx regulation

BSVI stageII (RDE implementation)



Before RDE implementation,
both CSF and SCR on DPF can be applied.

SCR catalyst loading on DPF achieved compact system
➔ Could be fit to Indian market



Source: Automobile and Engine Technology 2015, Daimler

CSF: Catalyzed Soot Filter (Oxidation catalyst coating)

SCR on DPF will be required from RDE implementation.

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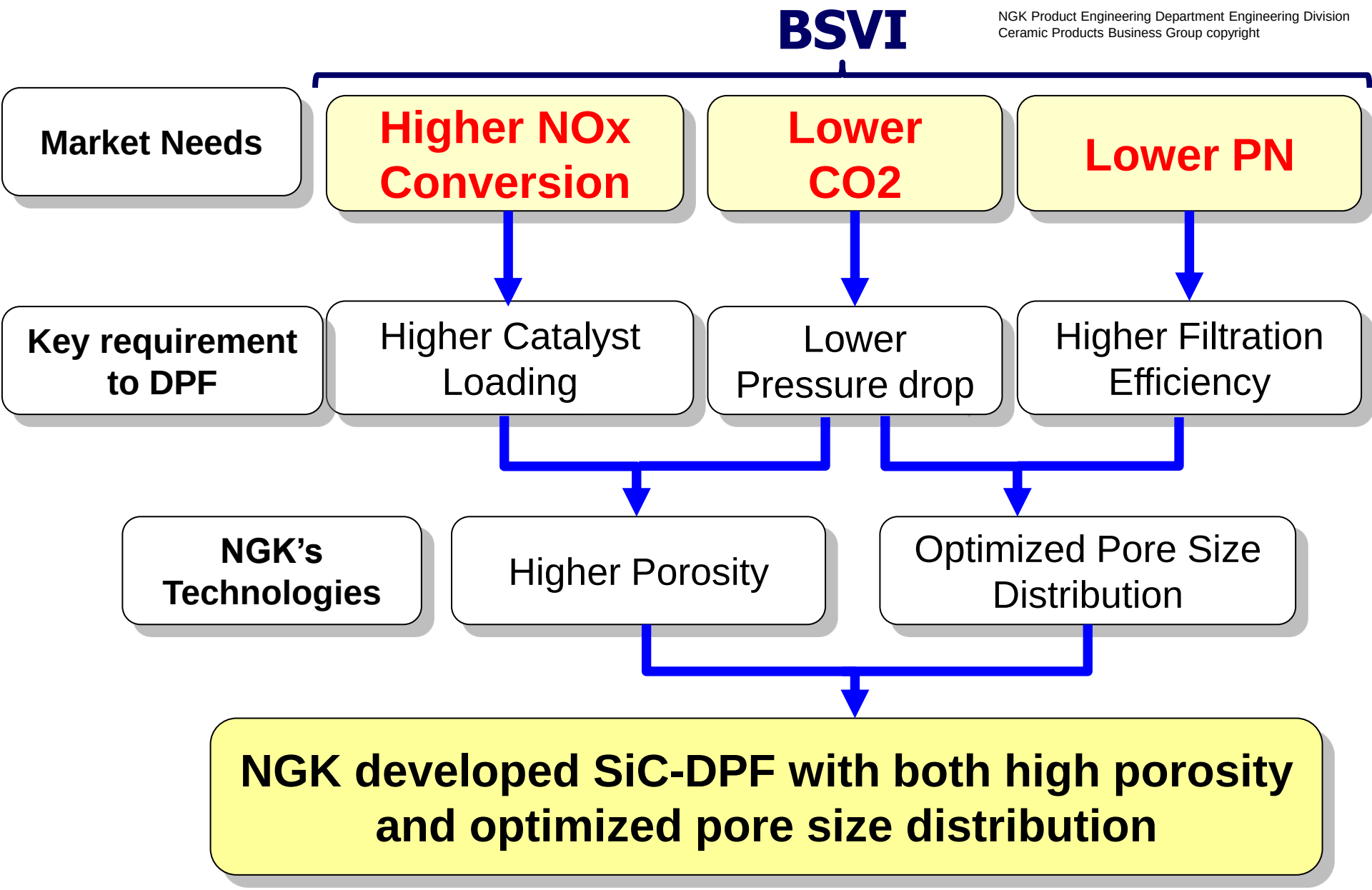
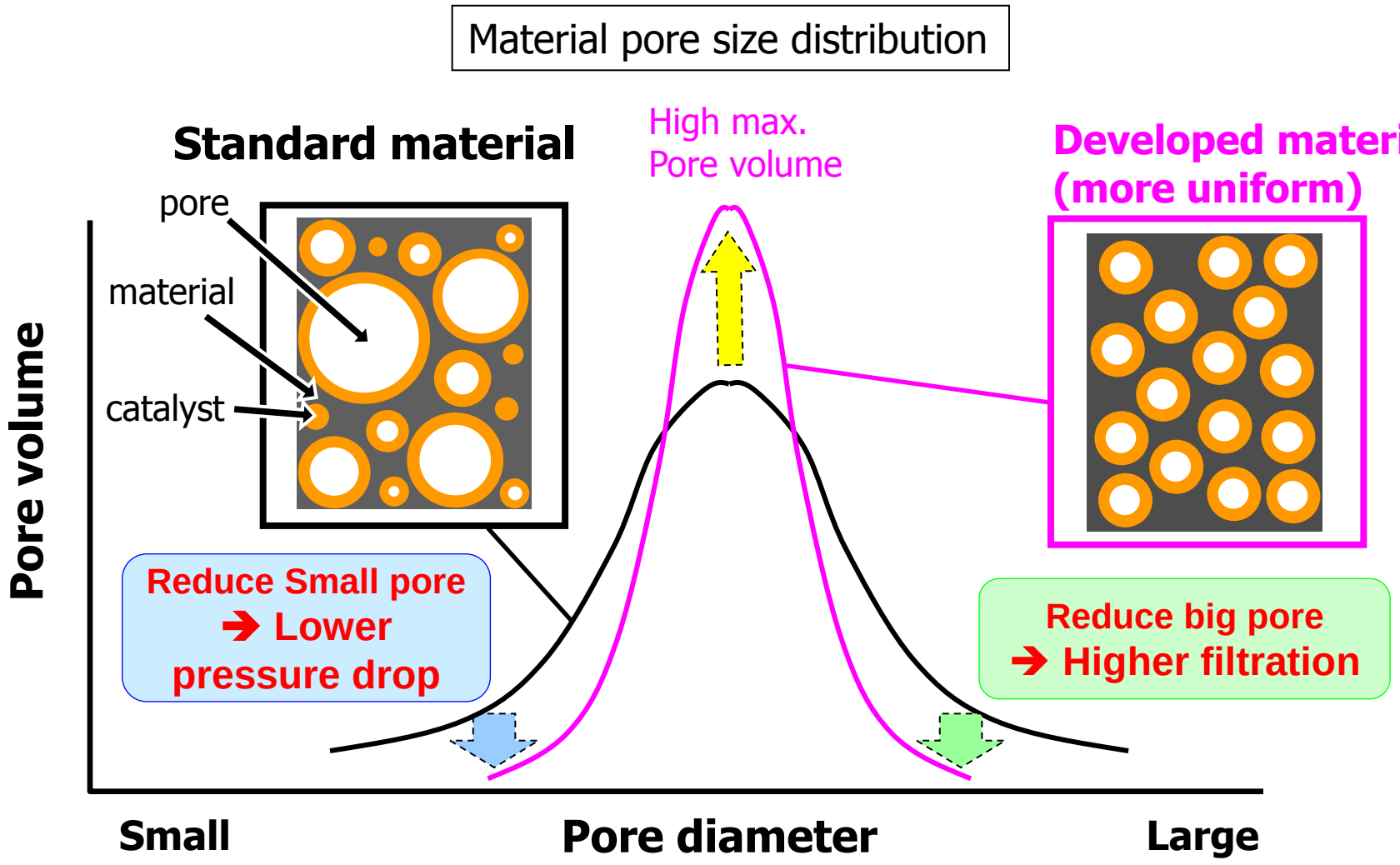
NGK's developed DPF to Meet Requirement



Optimized Pore Size Distribution for high Porosity SiC-DPF



Developed material reduced small pore size and big pore size
➔ achieved lower pressure drop and higher filtration

Basic SCR on DPF Performance

- NOx conversion
- PN filtration
- Pressure drop
- Max DPF Temperature at uncontrollable regeneration

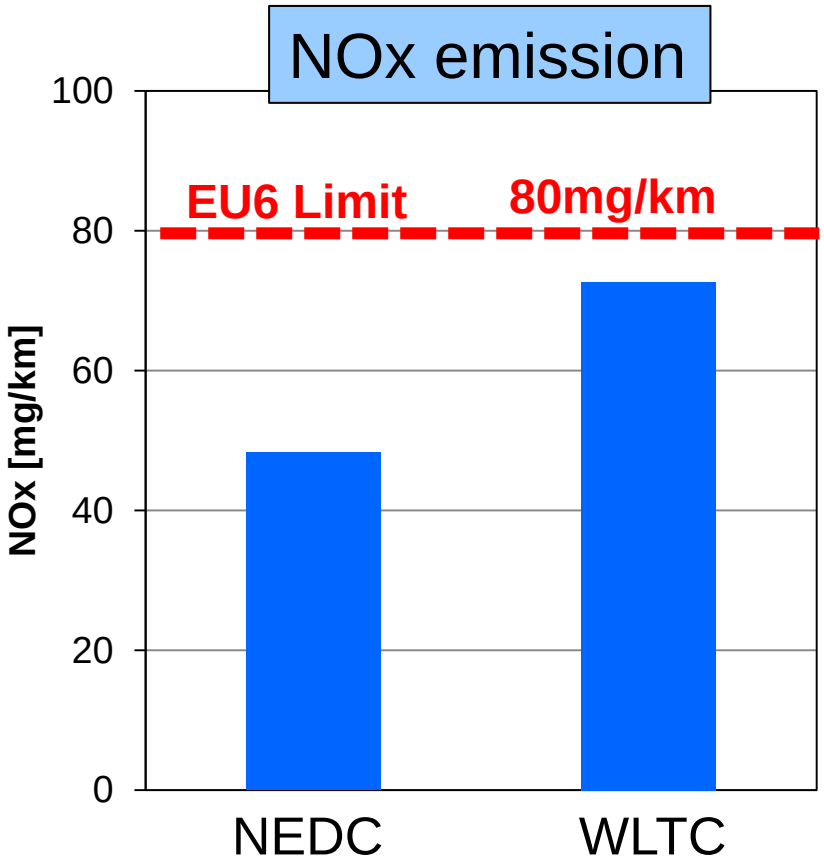
➔ Drop to Idle (DTI) test procedure

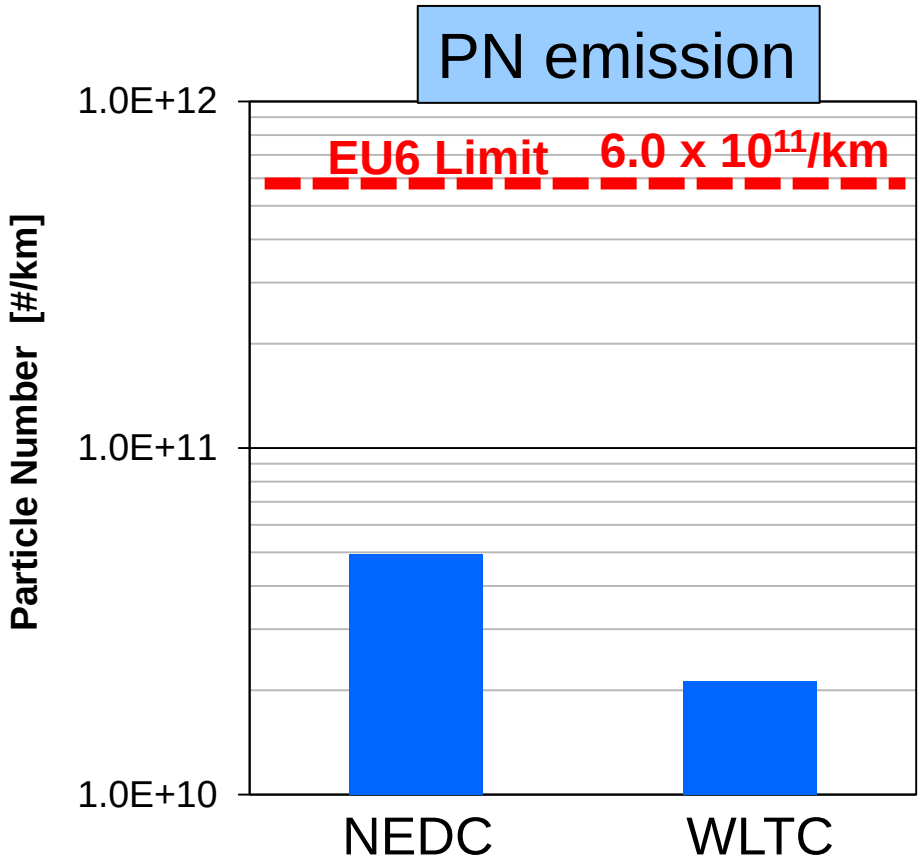
NOx/PN Emission by Vehicle on the Market in EU6 cycle as basic performance

NGK Product Engineering Department
Engineering Division
Ceramic Products Business Group copyright

Test condition

Vehicle on the Market: 2.0L Diesel engine with 3ltr round DPF,
System layout: DOC+SCR on DPF+SCR



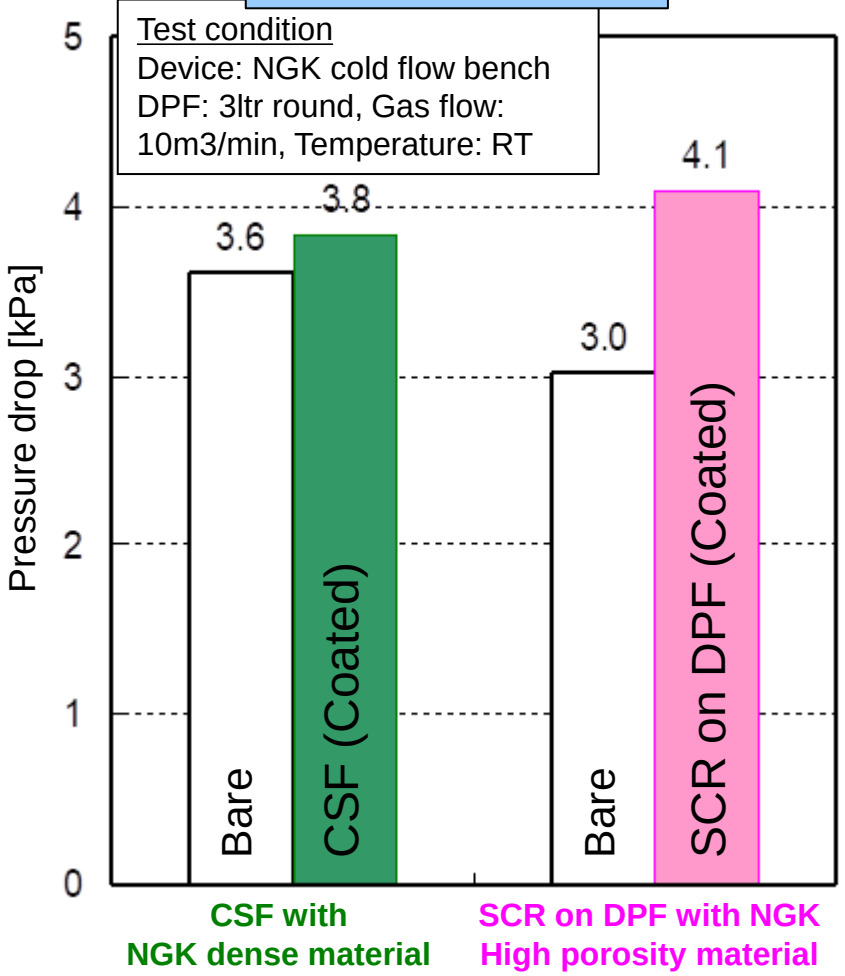


NEDC : New European Driving Cycle
WLTP : World harmonized Light-duty Test Procedure

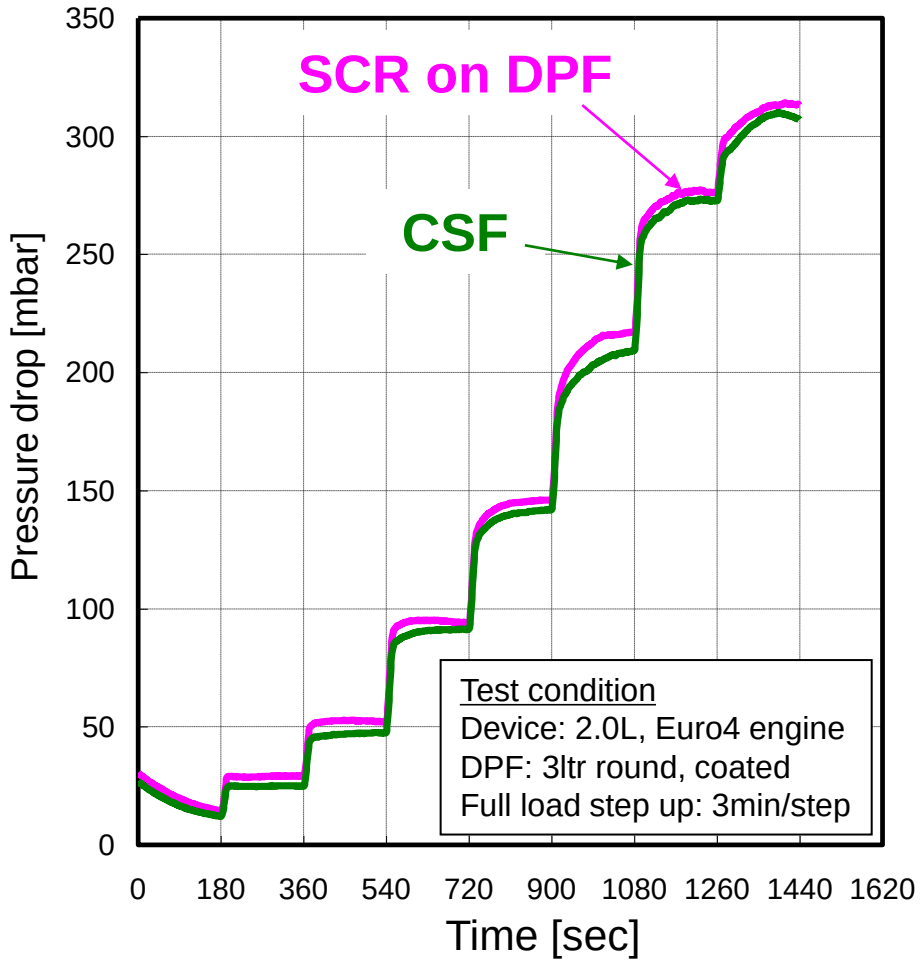
SCR on DPF with high porosity SiC-DPF meets NOx/PN regulation in EU6 cycle.

Pressure Drop Comparison with Conventional CSF System

Cold flow bench

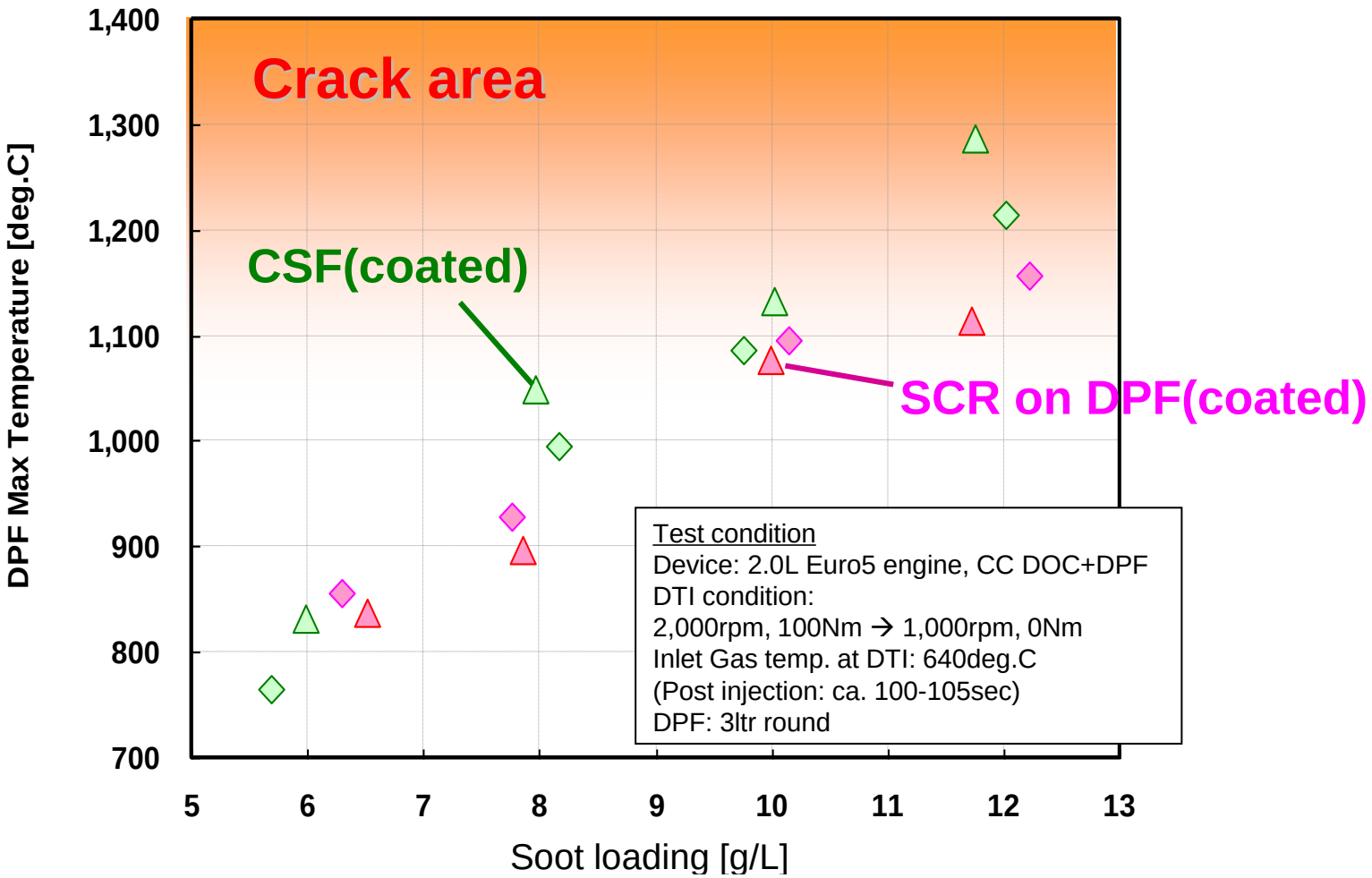


Engine (Full load step up)



Similar pressure drop was confirmed although SCR on DPF was coated by much higher catalyst loading than CSF.

DTI Test Result with Conventional CSF System



Max DPF temperature behavior with different soot loading was similar between SCR on DPF and CSF in DTI test.

Basic Performance Test Results for SCR on DPF

DPF performance	Result
NOx conversion*	**Potential to achieve NOx limit with EU6 cycle**
PN filtration*	**Potential to achieve PN limit with EU6 cycle**
Pressure drop* (compared with conventional CSF system)	**Equivalent with CSF**
Temperature behavior at DPF regeneration* (compared with conventional CSF system)	**Equivalent with CSF**

*All performance results are catalyzed DPF

NGK high porosity SiC-DPF has at per performance as SCR on DPF.

As further investigation,

NGK confirmed PN emission in RDE as filter responsible performance ➔ Next section

NOx emission is not focused because not only DPF but also vehicle calibration, catalyst etc. influence NOx.

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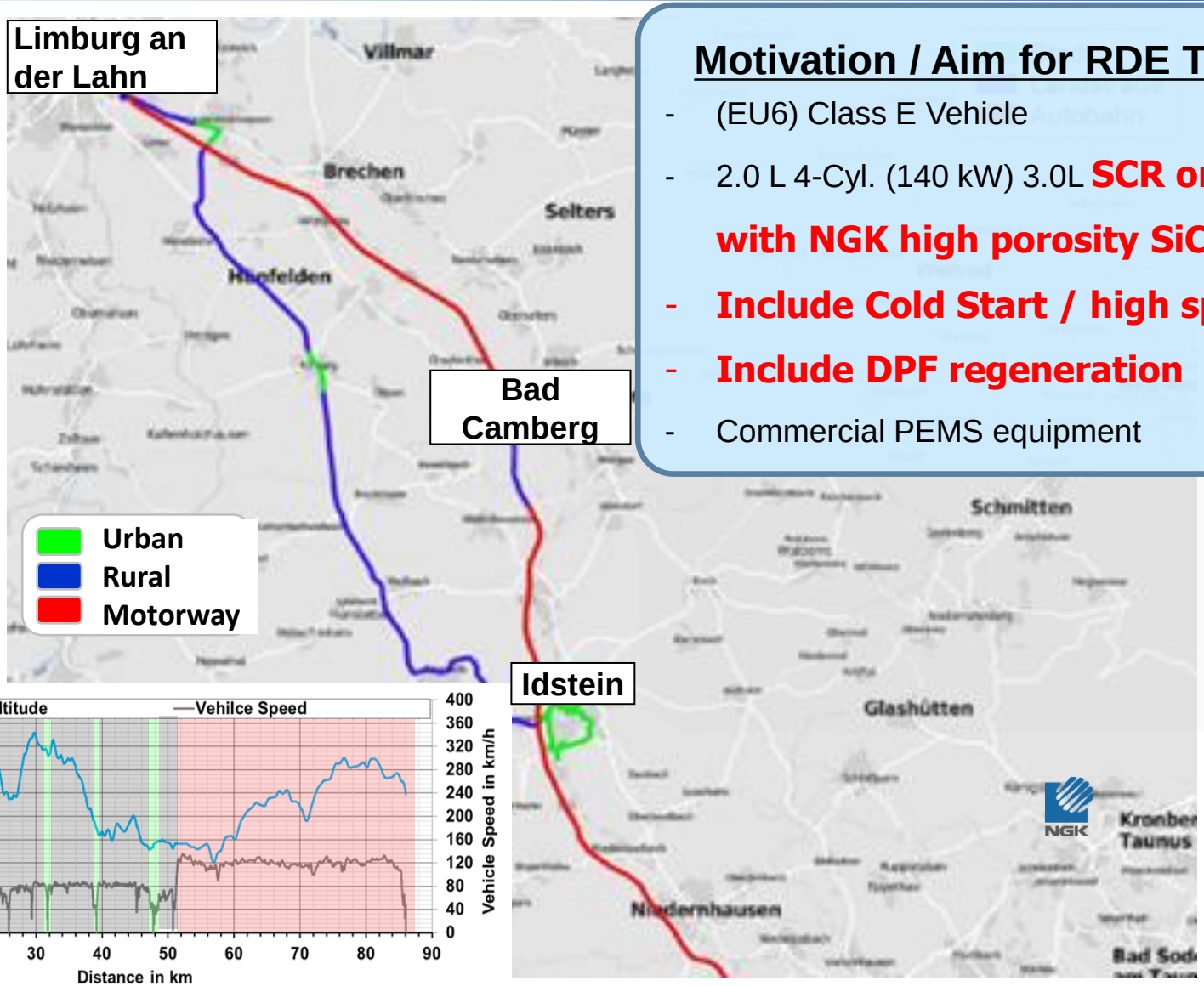
PN Measurement in RDE Condition on the Road



Motivation / Aim for RDE Tests

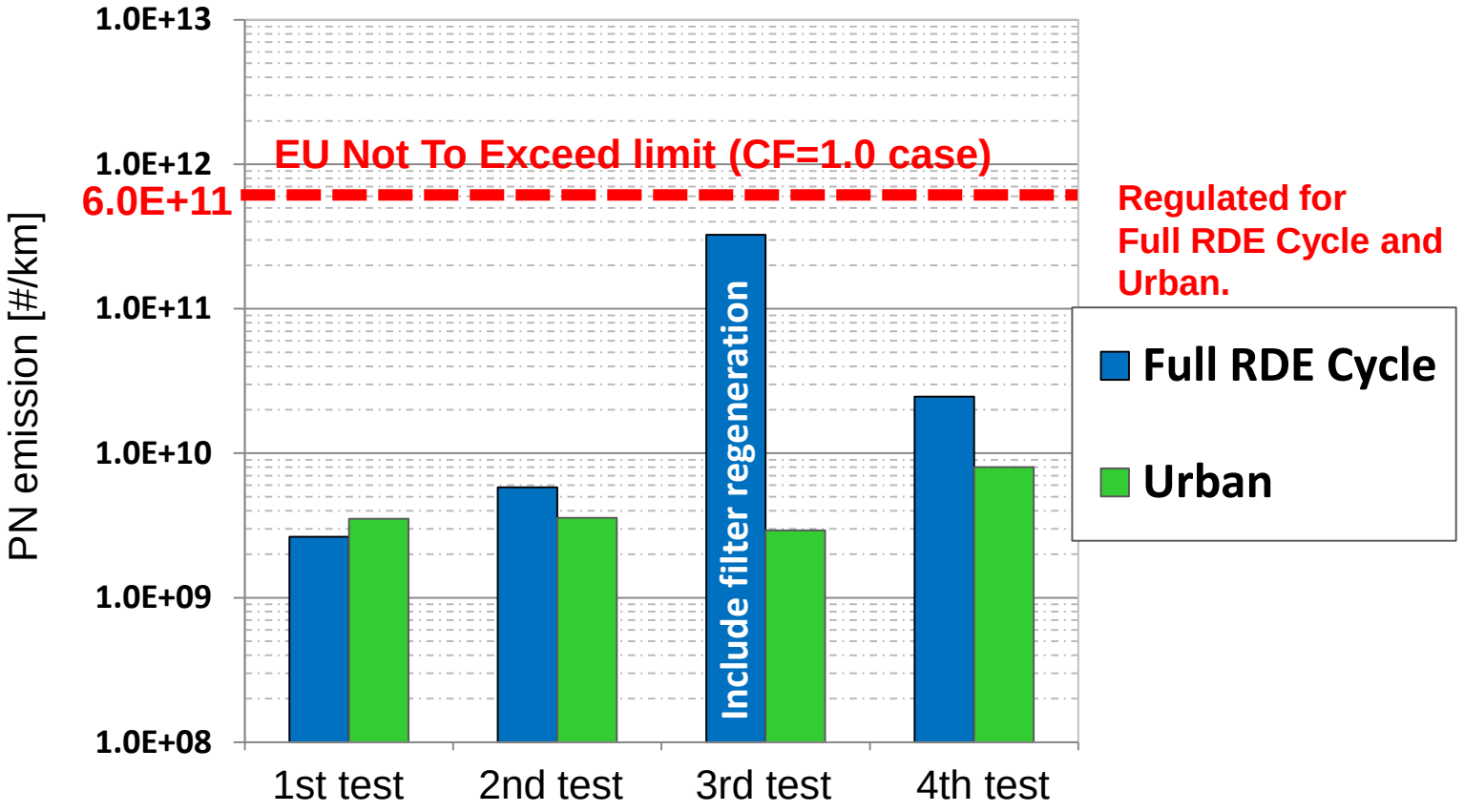
- (EU6) Class E Vehicle
- 2.0 L 4-Cyl. (140 kW) 3.0L **SCR on DPF with NGK high porosity SiC-DPF**
- **Include Cold Start / high speed**
- **Include DPF regeneration**
- Commercial PEMS equipment

RDE testing with vehicle was conducted on the EU road

PN Emission Results in RDE

PN emission data (weighted by EMROAD)

Test condition : 2.0L 4-Cyl. EU6 Vehicle with 3ltr round SCR on DPF with NGK high porosity SiC-DPF
Before PN measurement, the vehicle ran the RDE route to check equipment.



PN is affected by soot loading and regeneration events.
PN is under NTE limit even when active regeneration occurred.
PN in the urban section remains under NTE limit also after filter regeneration.

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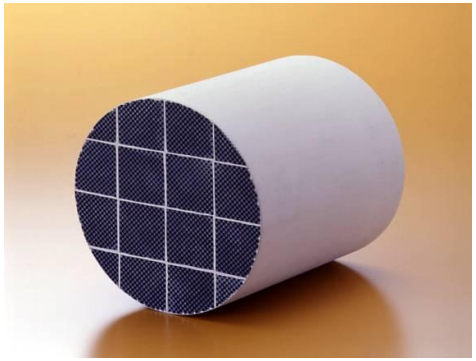
Future Development

BSVI



NGK high porosity SiC-DPF for SCR on DPF

- Well Established and Ready for Mass Production
- Market experience **(11 OEMs globally)**

Tighter regulation

Future

NGK Continues to develop DPF for SCR on DPF!!

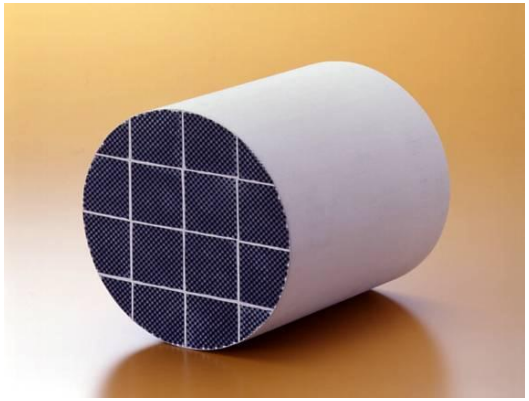
Further Design Optimization of Balanced Performance to meet Future RDE

Summary

- *SCR on DPF will be required from the timing of RDE implementation.*
- *NGK high porosity SiC-DPF has at per performance as SCR on DPF.*
- *NGK high porosity SiC-DPF shows possibility to meet PN limit with RDE.*

Thank you for your attention!

DIESEL PARTICULATE FILTER



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