



Proposal for a Diesel Particulate Filter for BS7 Based on Insights from Euro 7 Development

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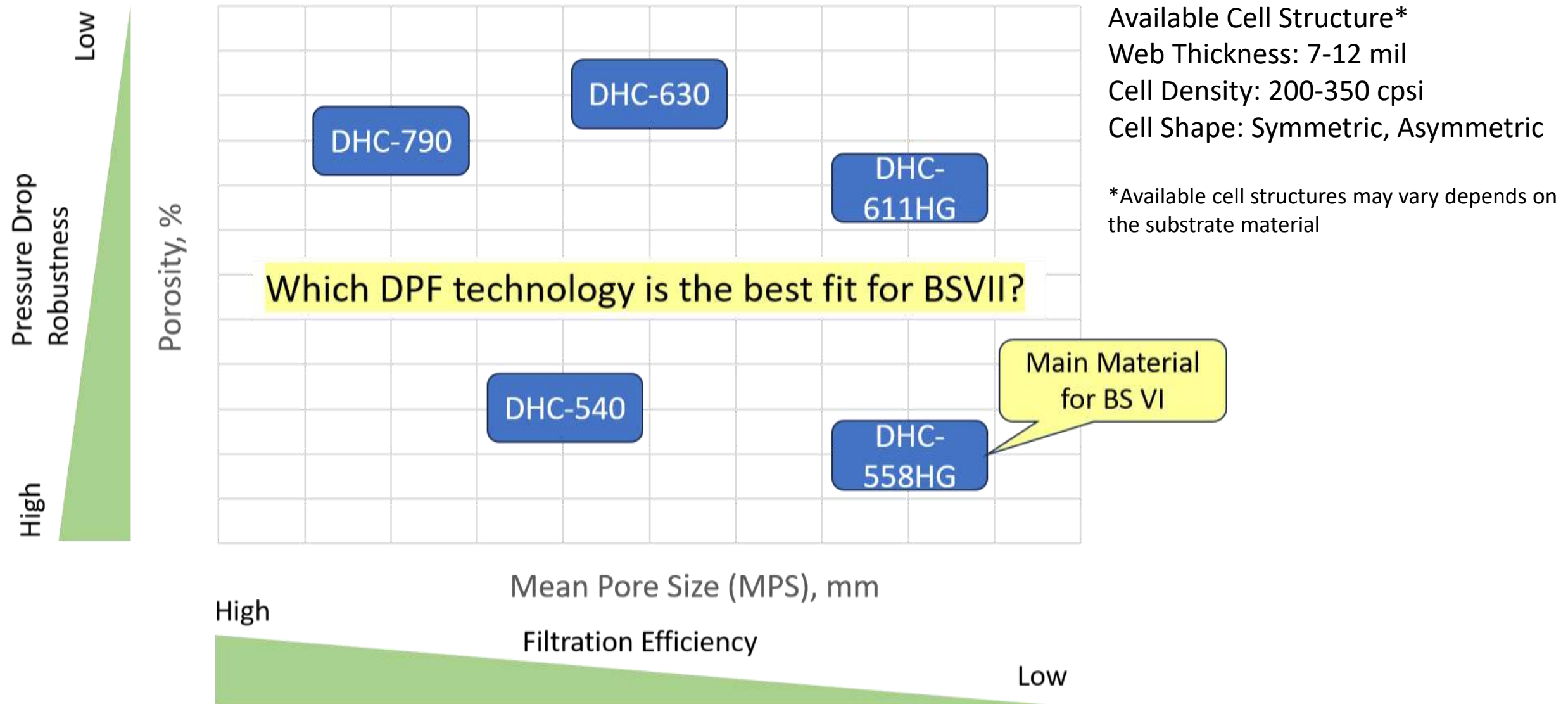
NGK Corporation

Product Engineering Department.

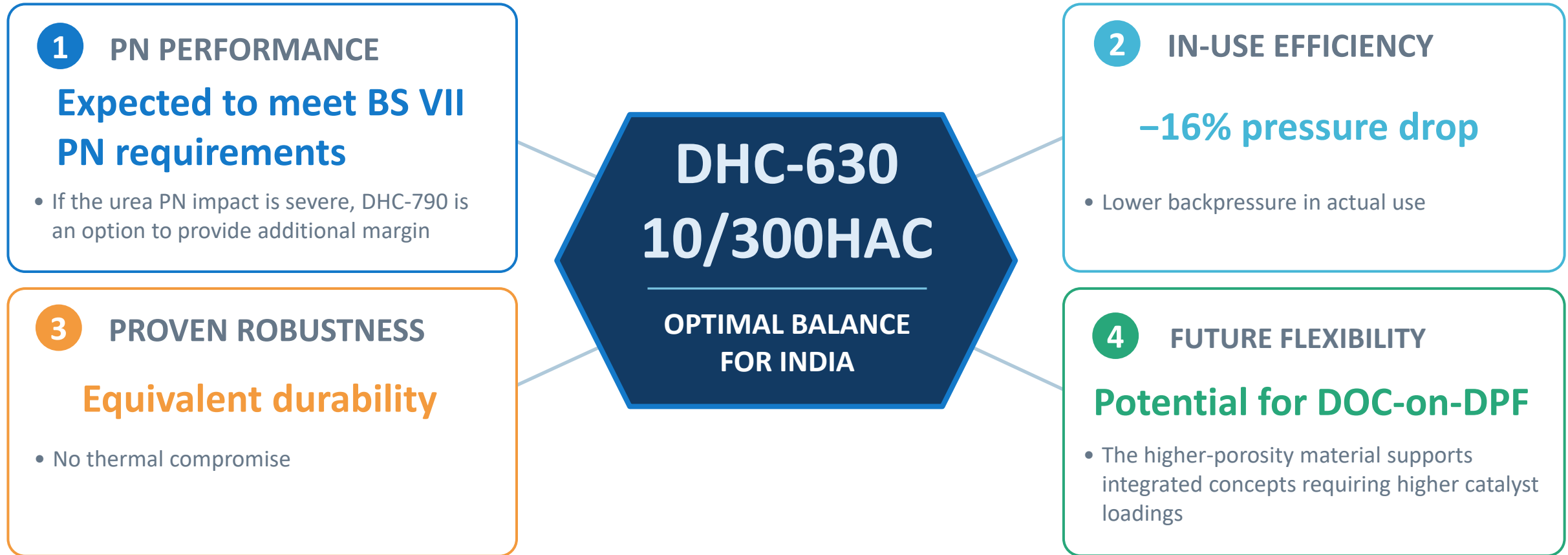
Engineering Division

Environment Business Group

NGK Has Developed Various Cordierite DPF Technologies in Response to Global Emission Regulations



HAC: High Ash Capacity

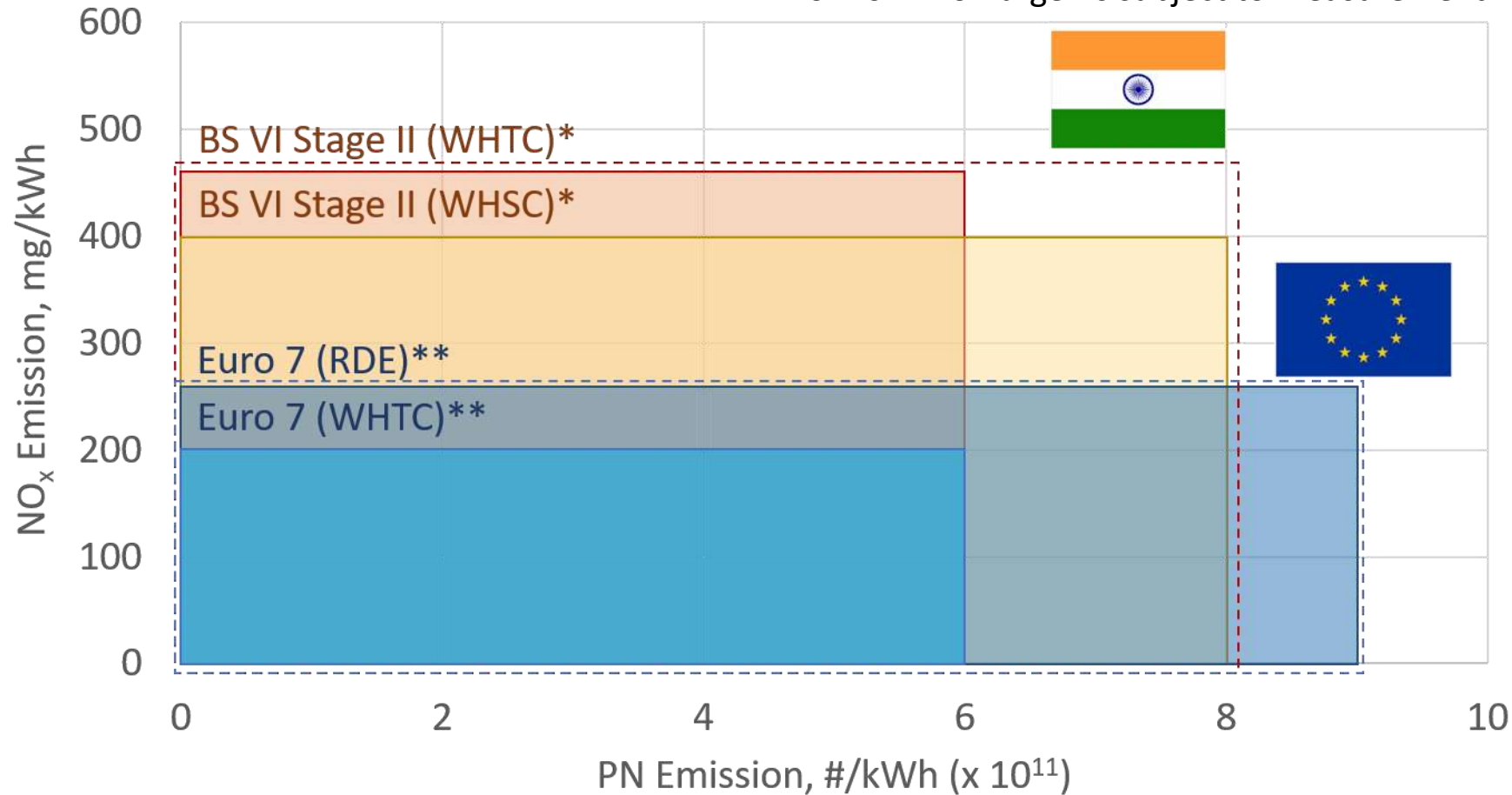


DHC-630 10/300HAC offers an optimal balance of PN margin, pressure drop, robustness, future flexibility.

BS VII Is Expected to Follow the Euro 7 Direction

* PN of 23 nm or larger is subject to measurement

**PN of 10 nm or larger is subject to measurement

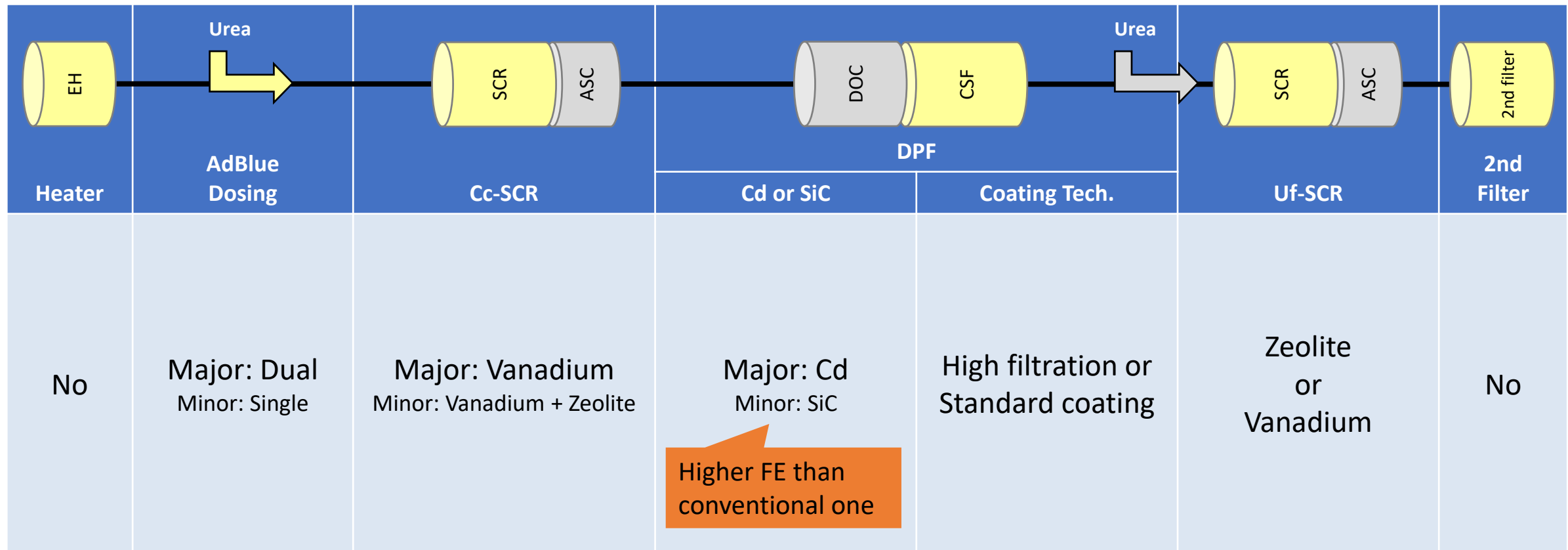


Key Points

- Tightened NO_x (-60% at WHTC)
- Implementation of PN10
- Emission regulation under real driving conditions

- In addition to tighter emission limits, BS VII is expected to introduce PN10 requirements, including under real-driving conditions. This will require DPF technology with higher filtration efficiency.

Aftertreatment System Equipped With Dual Urea Dosing and Higher-Filtration Efficiency DPFs Will Become Mainstream Among European OEMs for Euro 7

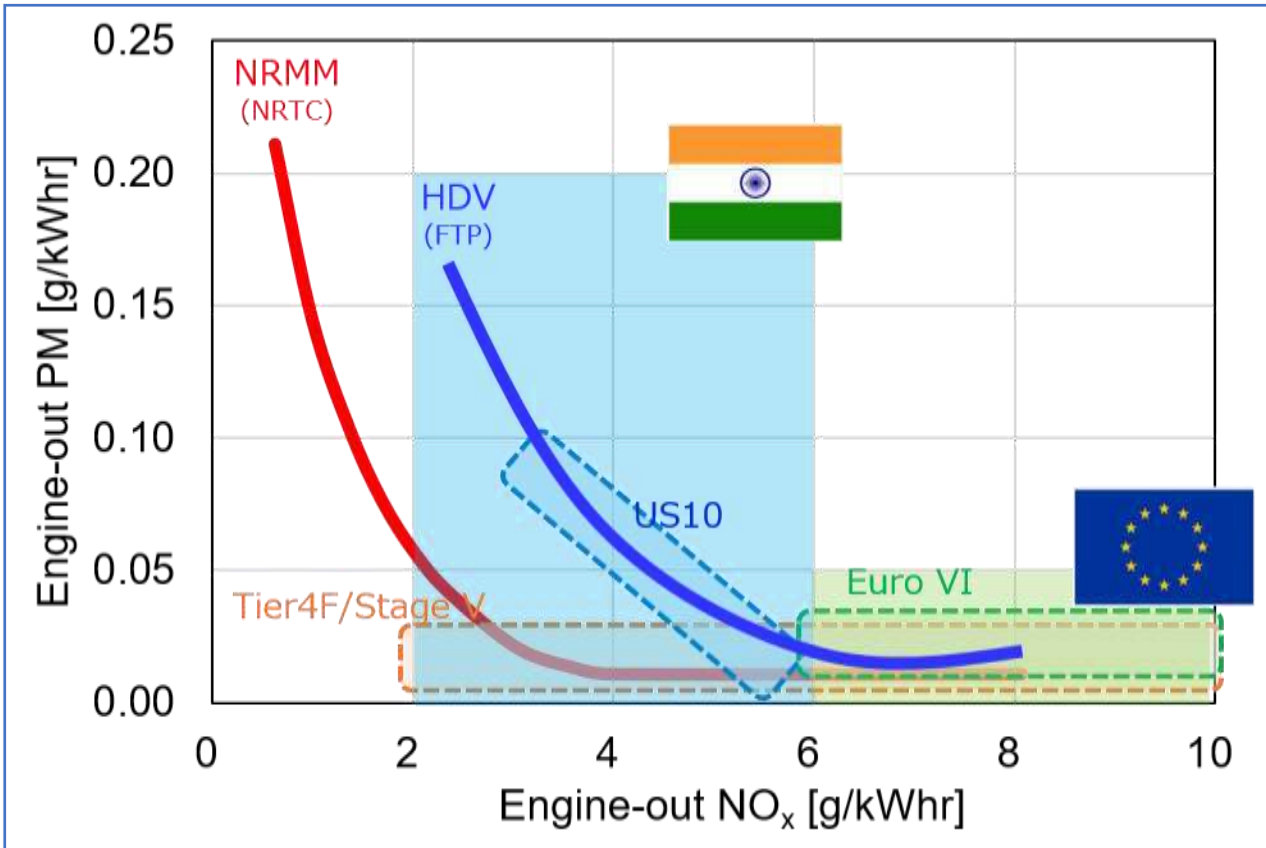


- Dual-dosing is emerging as the main Euro 7 solution.
- While the UF-SCR catalyst remains largely unchanged, Vanadium-based SCR is primarily used for the CC-SCR.
- Higher-filtration DPF materials are being considered to control PN10 emissions.

Strict CO₂ Reduction Targets Are Driving This Shift in Europe

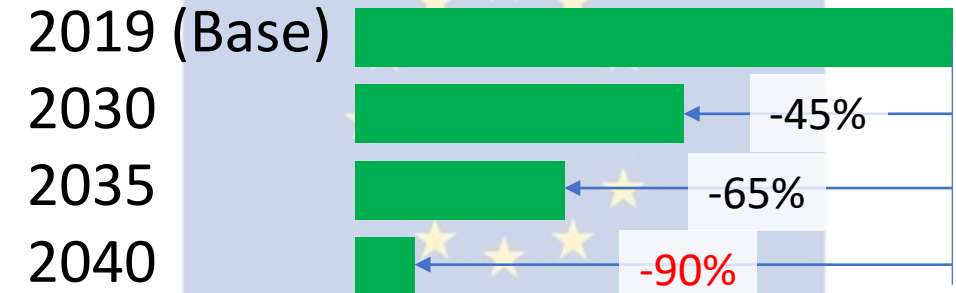
Engine Calibration (NGK Understanding)

Typical Engine-out (E/O) PM vs. NO_x



Reason behind

Strict CO₂ reduction target



CO₂ target won't be severer than EU
(Draft: fuel consumption -30% for 2027 - 2032)
A Simpler, lower-cost system will be preferred.

- High-E/O NO_x requires higher SCR performance → Dual-dosing system.
- Low to medium-E/O NO_x may not require a significant increase in SCR performance → Single-dosing system.

Dual Urea Dosing Systems Can Be Combined with High-E/O NO_x Calibration to Balance NO_x Reduction and DPF Regeneration

Optimization of The Urea Dosing Strategy

Influence of Urea Dosing Switch from cc-SCR to main-SCR



Two ISC cycles 20t & 60t

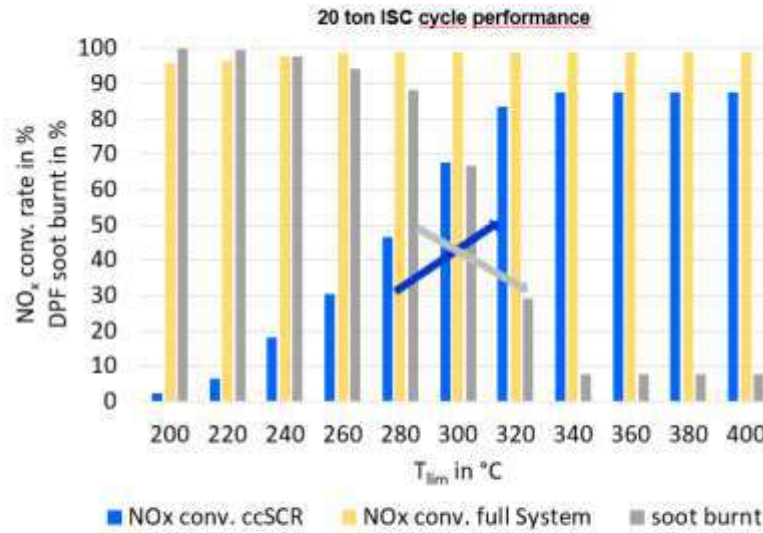
Variation of control temperature T_{lim}

T_{lim} describes the shut off temp of cc-SCR dosing

T_{lim} = DPF inlet T

e.g. If T_{lim} is set at 280°C means cc-SCR dosing from *179°C to 280°C

* General urea dosing release T



- Trade-off between cc-SCR NO_x conversion and soot burn rate.
- T_{lim} at 260°C – 300°C good NO_x conversion and passive soot oxidation.
- T_{lim} > 300°C is limiting the soot burn rate significantly in the ISC 20 ton cycle.

8th International MinNO_x Conference for Sustainable Mobility October 26-27, 2022

Slide 10

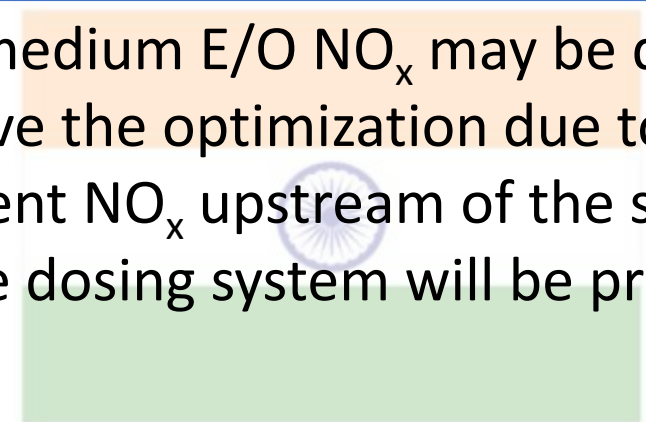
Simulation Study on Real Driving Passive Soot Regeneration in a Dual-Stage SCR System for EUVII
8th International MinNO_x Conference for Sustainable Mobility, October 26-27, 2022

Feasibility of The Optimization

Higher E/O NO_x enables this optimization
→ Dual-dosing system will be achievable



Low to medium E/O NO_x may be difficult to achieve the optimization due to insufficient NO_x upstream of the system
→ Single dosing system will be preferred

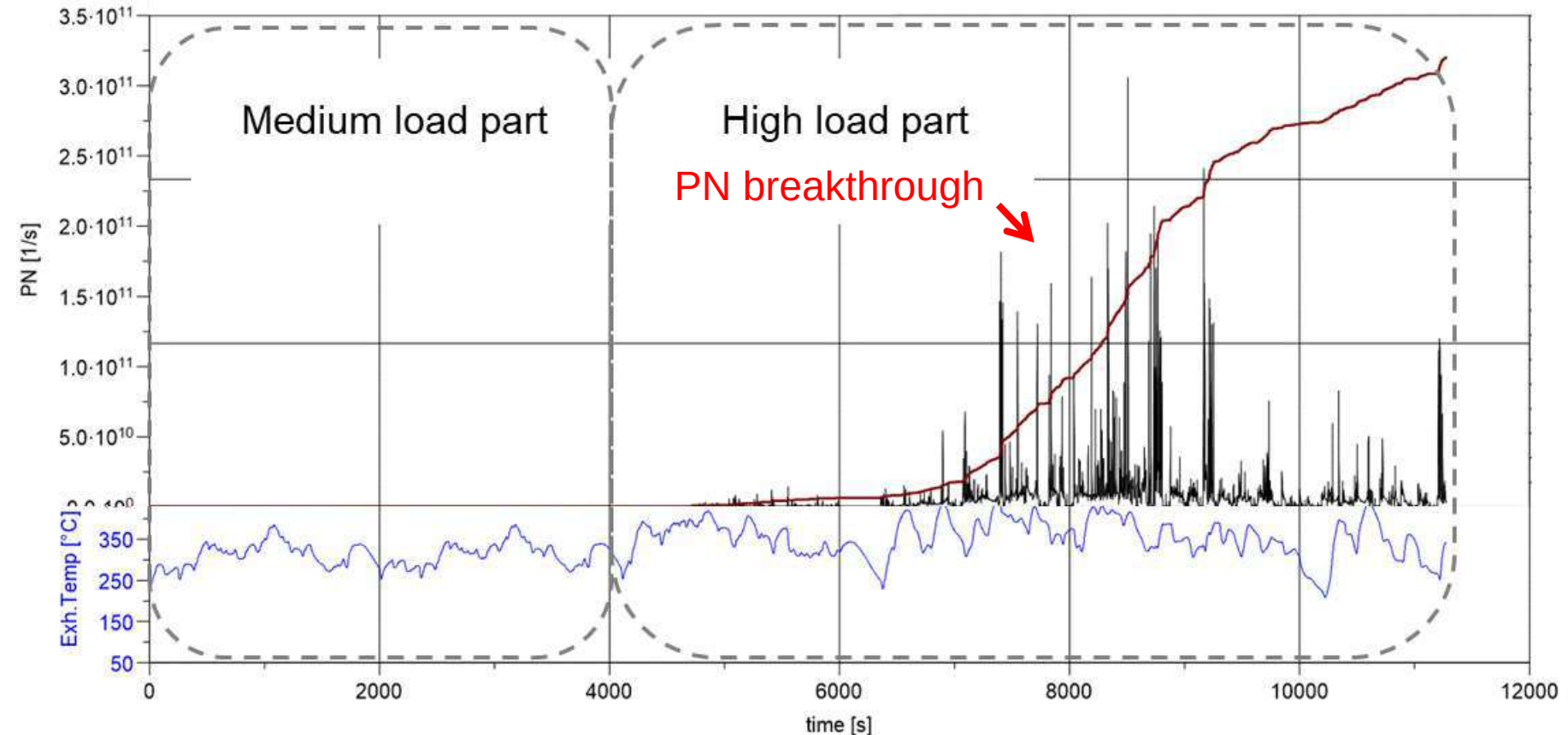


- A Single-dosing system is preferred for low-to-medium E/O NO_x calibration.

PN leakage During a Hot-Start, High-Payload Simulated RDE Test

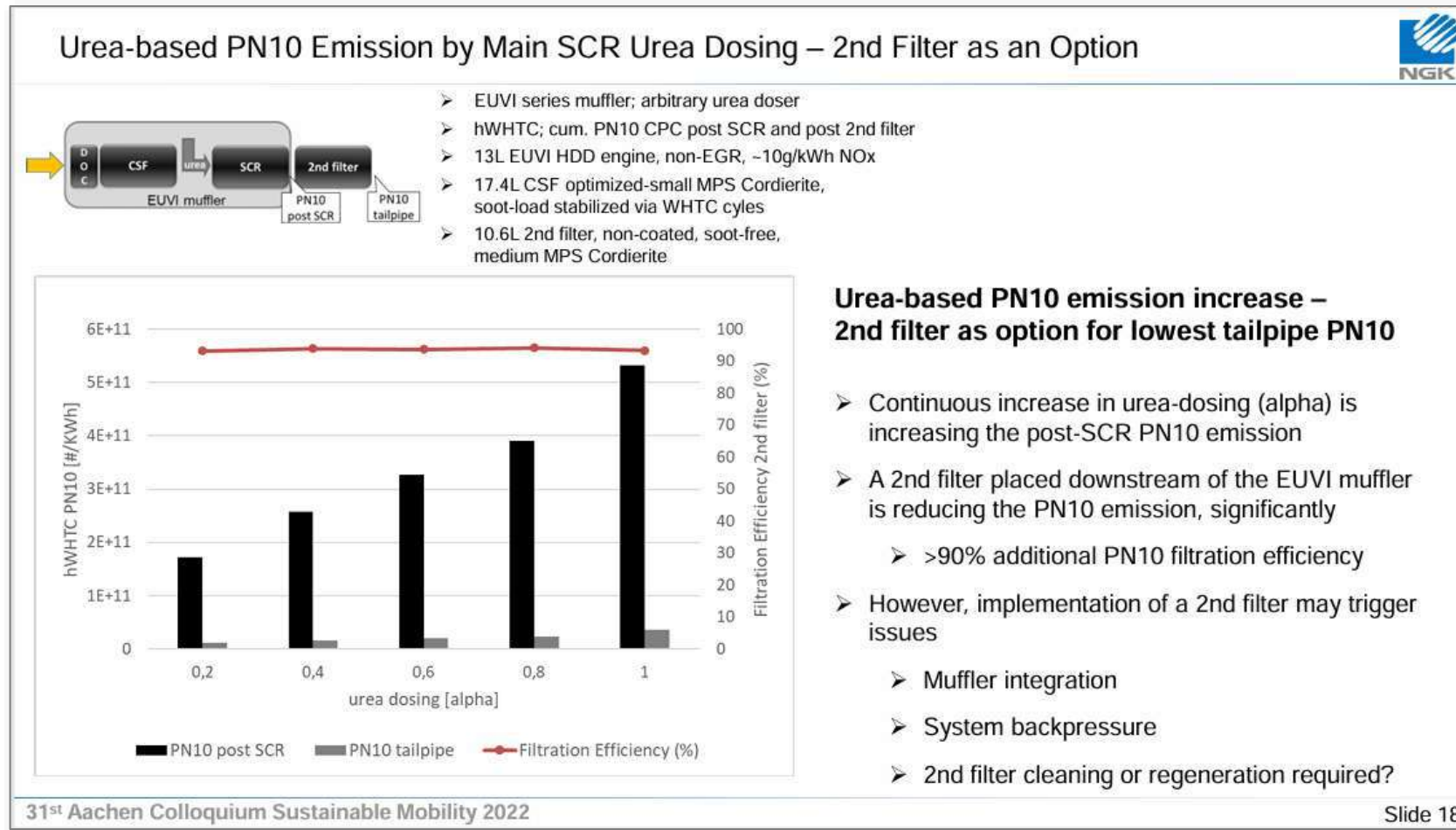
Test Condition

- 13L HDD EUVI engine
- System layout : DOC+CSF
- CSF size:16.7L
- EGR condition : No EGR
- Initial soot loading 2.6g/L
- PN10 CPC cumulated / modal



- At elevated temperatures and during prolonged driving, the soot cake may collapse, resulting in PN breakthrough.
- Higher engine-out NO_x may intensify this behavior and increase PN compliance risk, requiring a DPF with significantly higher filtration efficiency.

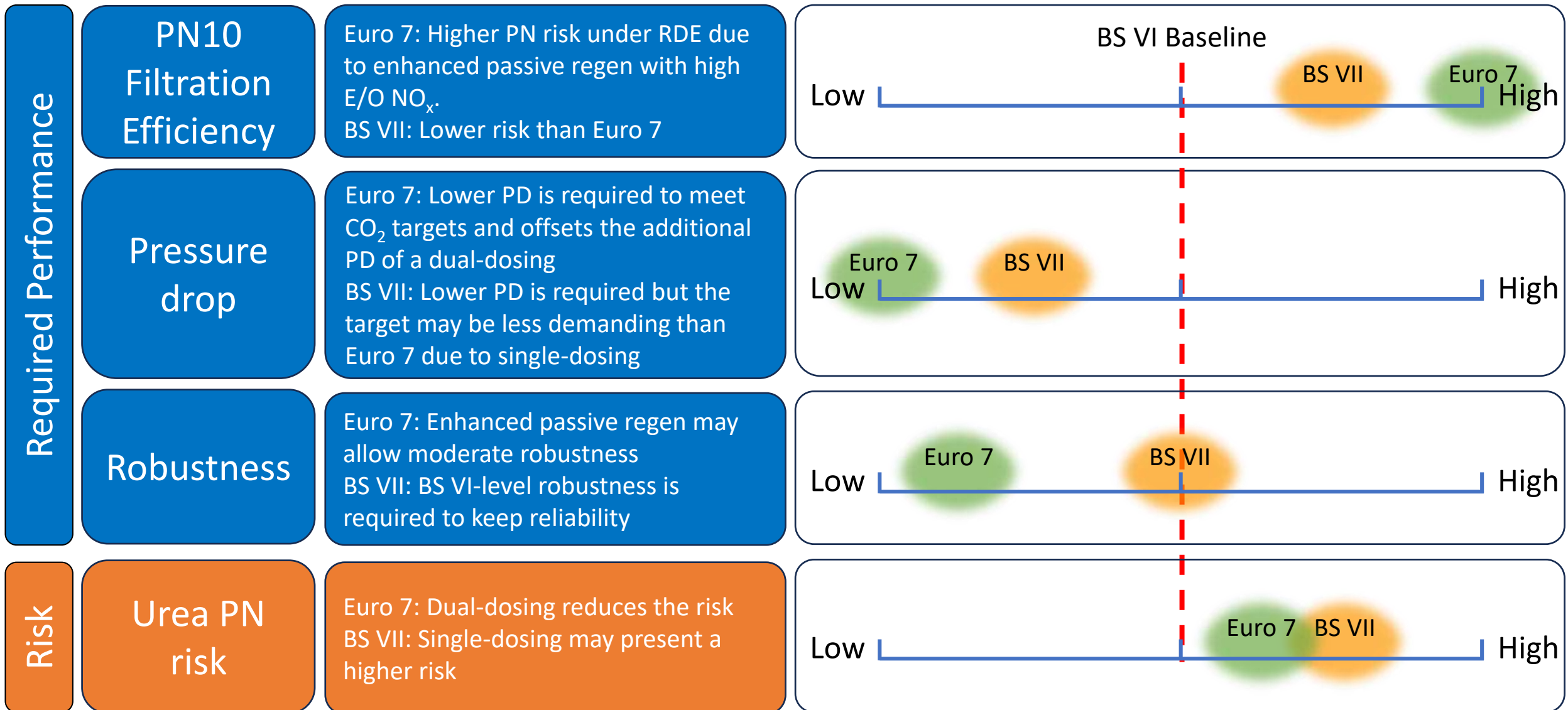
The Introduction of PN10 Regulations Requires Consideration of the Urea-Induced PN Compliance Risk



Lowest PN Emission For Future Heavy Duty Diesel Applications An Aftertreatment System Approach, 31st Aachen Colloquium Sustainable Mobility 2022

- A single-dosing system may present a higher urea-induced PN risk than a dual-dosing because all urea is injected upstream of the UF-SCR.

BS VII Needs Balanced DPF Performance, Not Maximum Performance



DHC-630 10/300HAC: The Best-Balanced Choice for BS VII

Euro 7

BS VII

Performance Image

**PN10
Filtration
Efficiency**

Required

Low

High

Product

DHC-558HG
9/300HAC

DHC-630
10/300HAC

DHC-790
7/350HAC

**Pressure drop
w/soot**

Required

Low

High

Product

DHC-790
7/350HAC

DHC-630
10/300HAC

DHC-558HG
9/300HAC

Robustness

Required

Low

High

Product

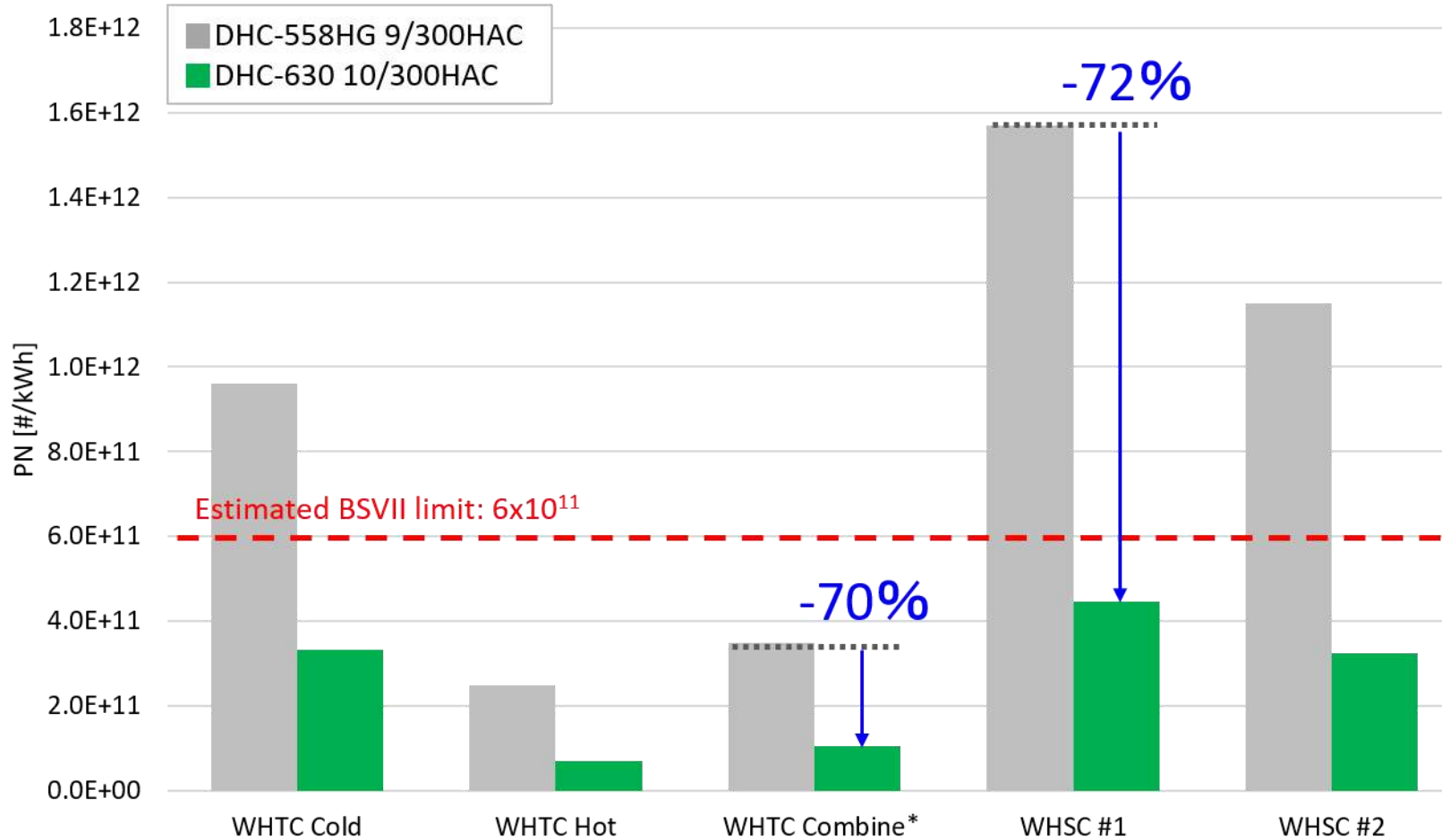
DHC-790
7/350HAC

DHC-630
10/300HAC

DHC-558HG
9/300HAC

DHC-630 Reduces PN10 Emissions by Approximately 70% in WHTC and WHSC Testing

Filtration Efficiency
Pressure Drop
Robustness



Test condition

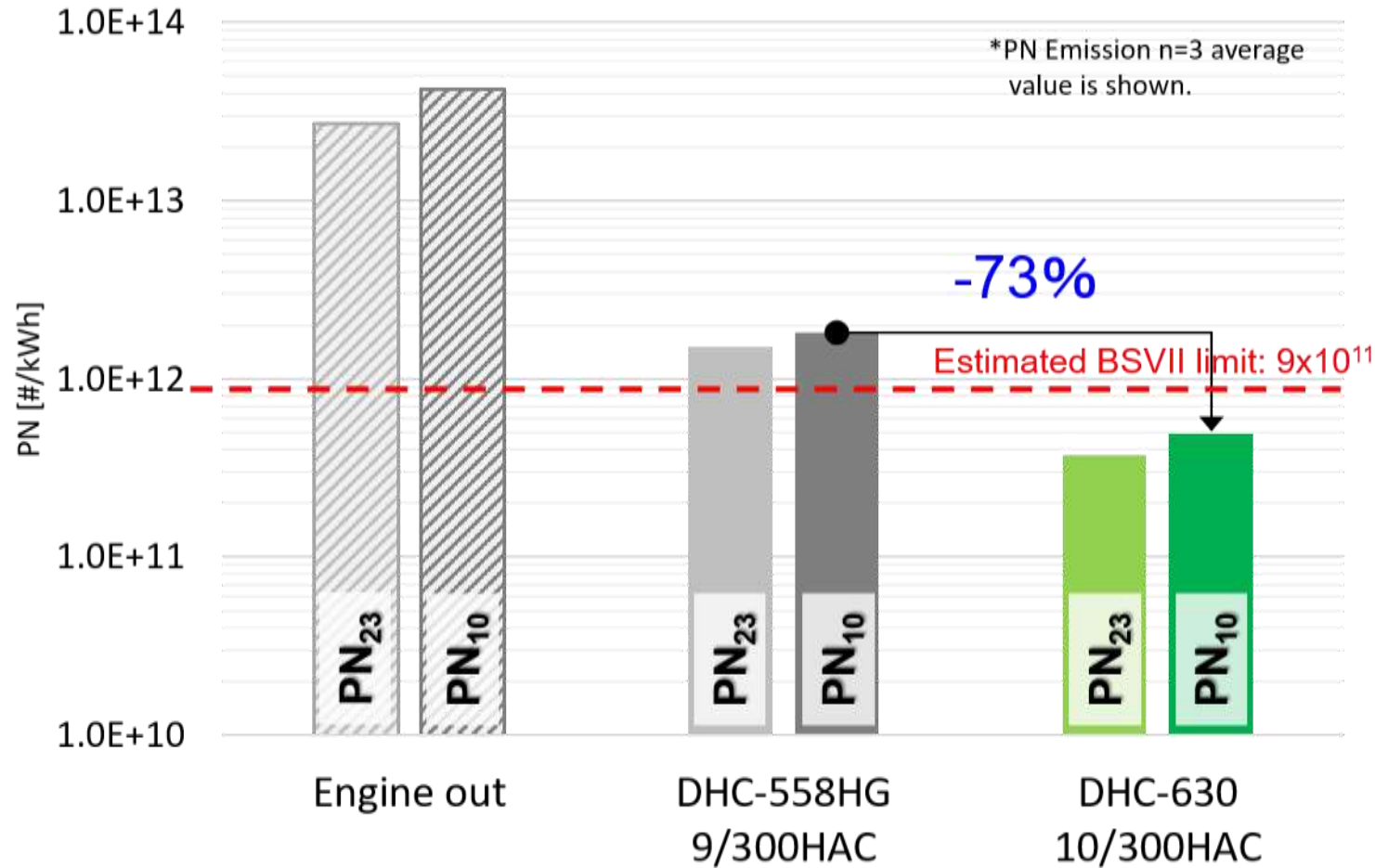
- Engine : On-highway 9L class
- Catalyst : CSF coating
- DPF Volume : 11L
- EGR condition : Off
- PN Measurement Range : >10nm

*Combine: Cold 14% + Hot 86%

- Compared with DHC-558HG 9/300HAC, DHC-630 10/300HAC reduced combined-cycle WHTC PN10 emissions by 70% and WHSC #1 PN10 emissions by 72%.

DHC-630 Delivers Over 70% Lower PN10 Emissions, Even Under RDE Conditions

✓	Filtration Efficiency
	Pressure Drop
	Robustness

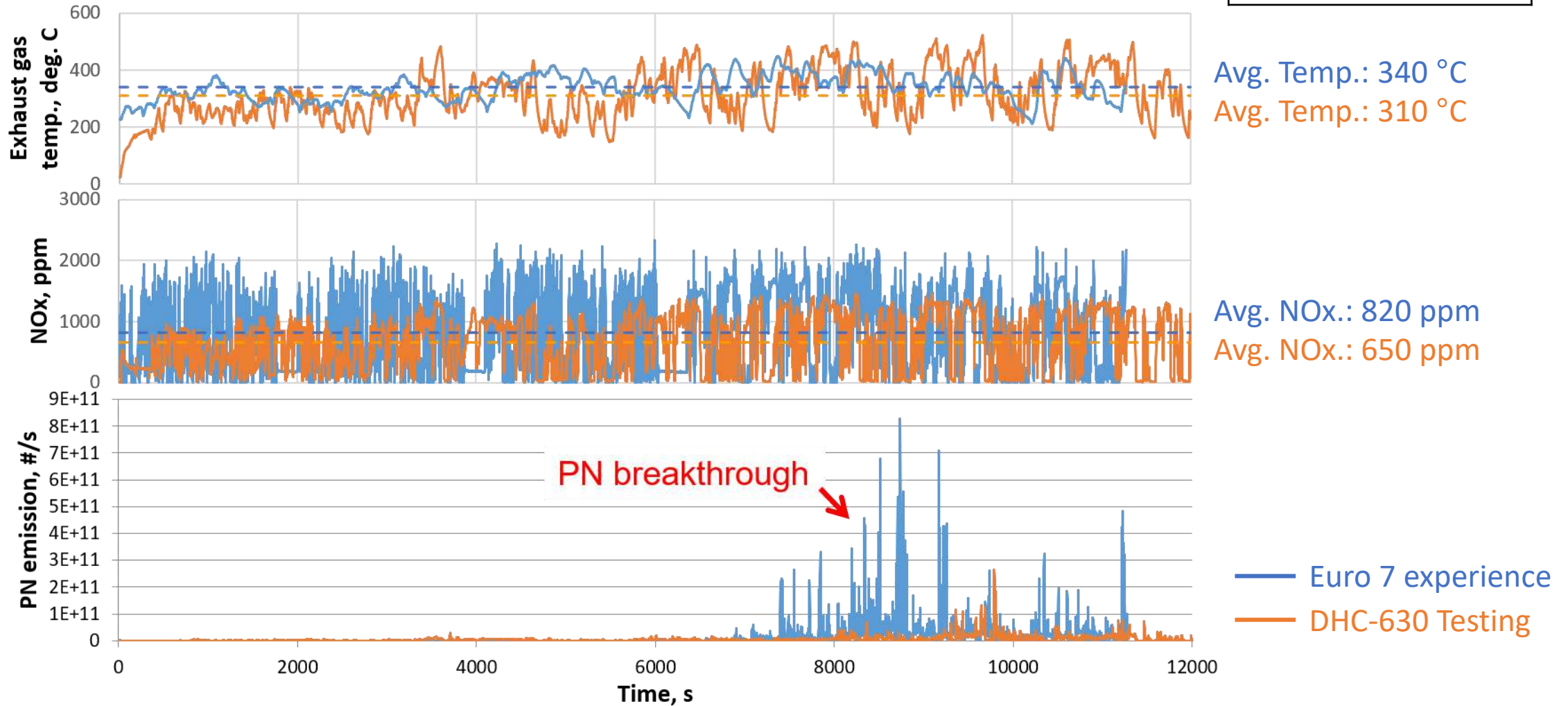


Engine	13L class diesel
Urea injection	On
Test cycle	RDE cycle (Cold start)
Initial soot loading	2.5g/L
Sample Size	12"D×8"L
Coating technology	CSF standard coating
Test Procedure	<div> DPF installation ↓ Soot loading (2.5g/L) ↓ Precondition(run 1 PEMS cycle) using dummy DPF ↓ Soak 14hr Replacement test DPF ↓ PEMS cold start </div>

- DHC-630 10/300HAC reduced PEMS-measured PN10 emissions by 73% at initial soot loading of 2.5 g/L compared with DHC-558HG 9/300HAC.

Engine-Out Conditions Will Be One of the Key Factors in Reducing PN Compliance Risk

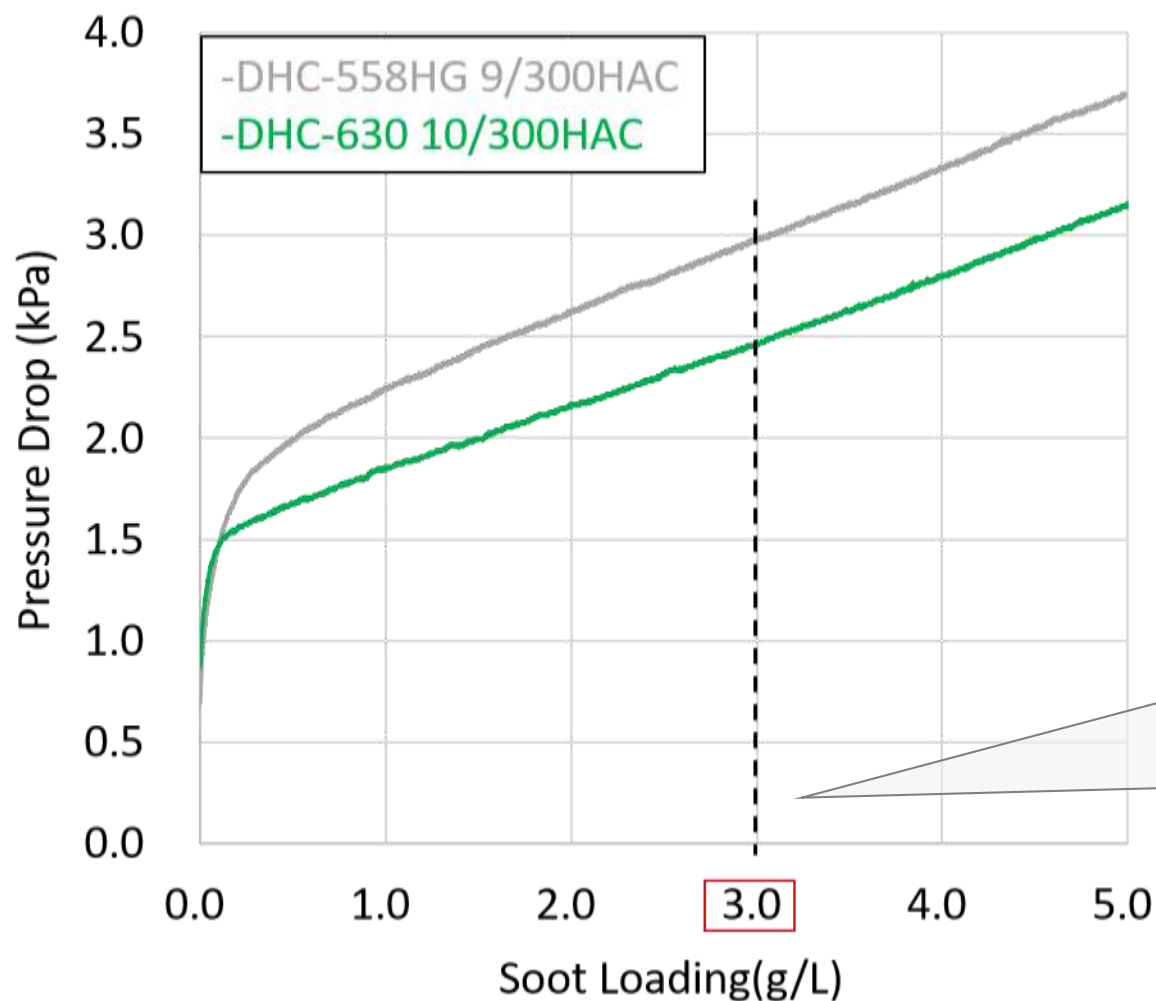
✓	Filtration Efficiency
	Pressure Drop
	Robustness



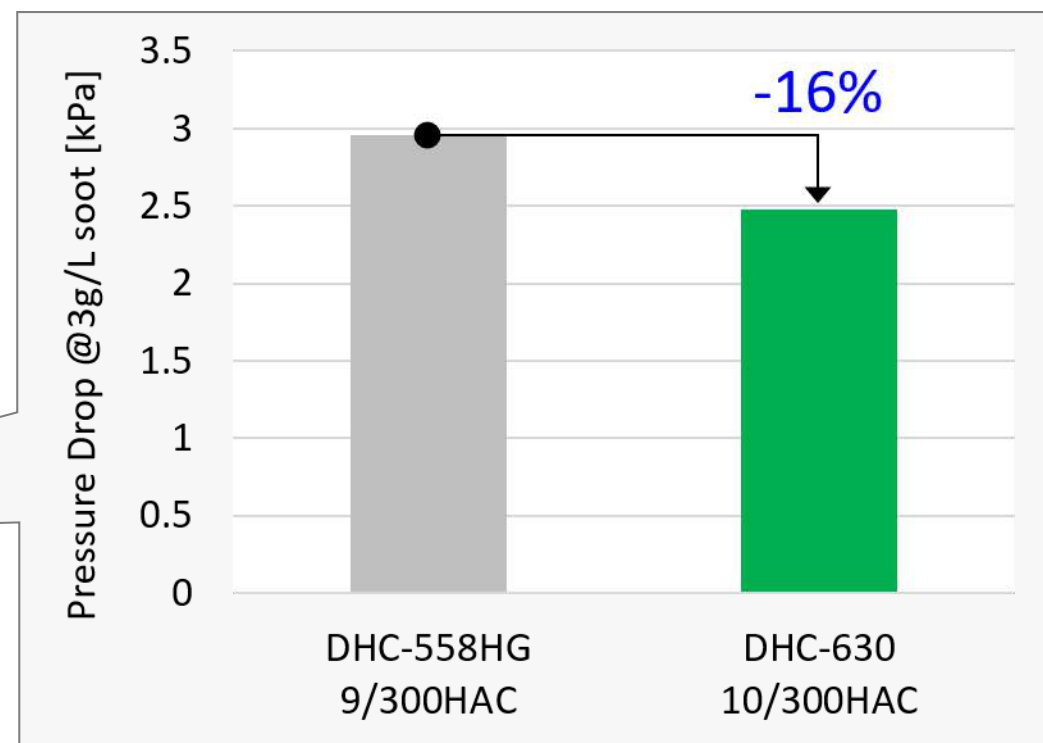
- Low-to-medium engine-out NOx is expected to reduce the risk of PN breakthrough caused by soot-cake collapse during enhanced passive regeneration.

DHC-630 10/300HAC Shows a 16% Lower Pressure Drop While Delivering 70% Better PN Filtration

✓	Filtration Efficiency
✓	Pressure Drop
	Robustness



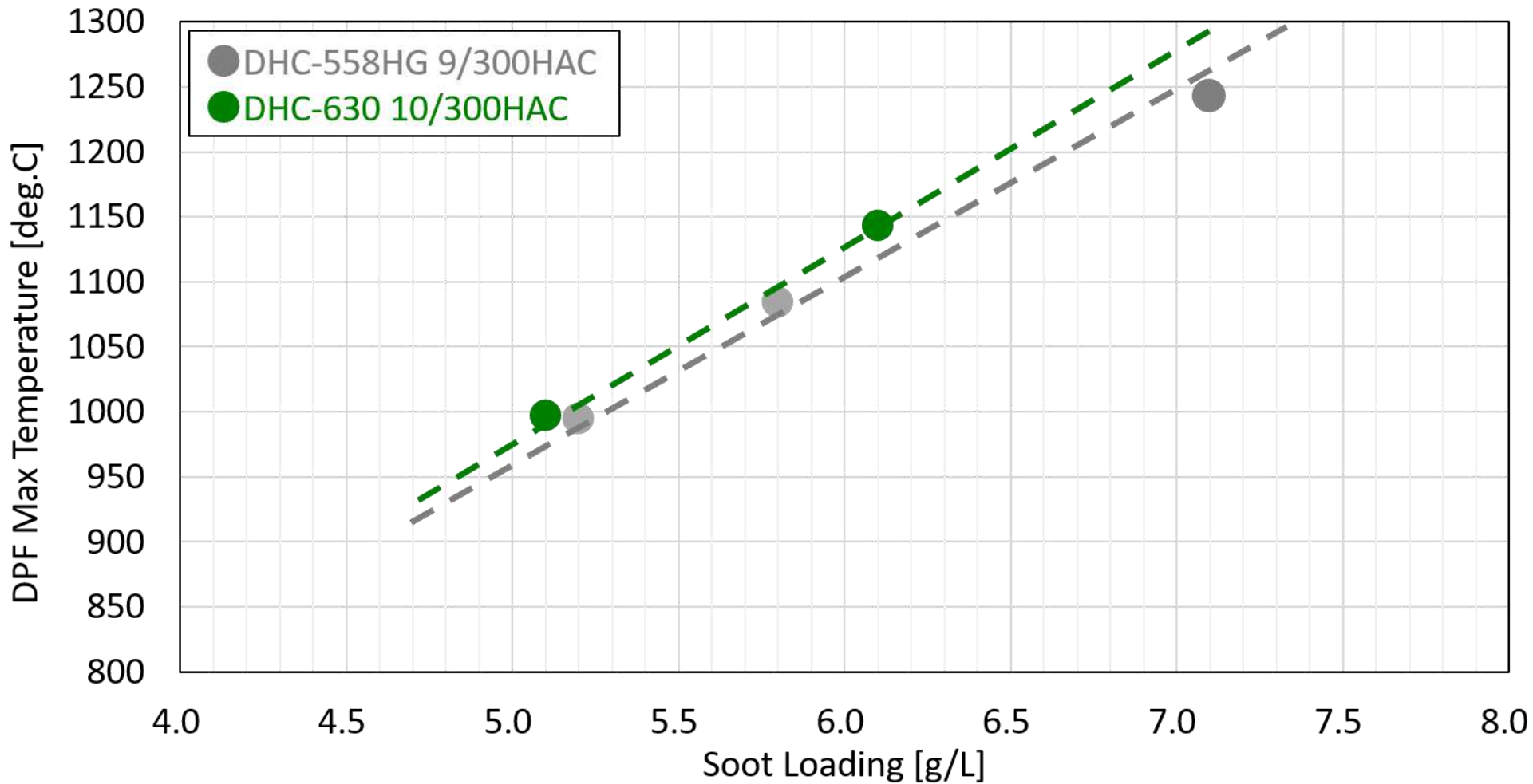
- Engine: 13L class engine
- Flow rate: 650kg/h
- Temperature: 220deg.C
- DPF Size: 12"D x 8"L
- Coat/Bare: CSF



- DHC-630 10/300HAC delivers a lower pressure drop under soot-loaded conditions due to its high porosity.

DHC-630 Delivers Equivalent Robustness with No Thermal Compromise

✓	Filtration Efficiency
✓	Pressure Drop
✓	Robustness



Engine: 13L class engine
Flow rate : 410 → 250kg/h
Kicker Temp: 590deg.C
DPF Size: 12"D x 8"L
Coat/Bare: CSF coating

- The maximum DPF temperatures under DTI conditions are nearly identical for DHC-630 10/300HAC and DHC-558HG 9/300HAC.

Urea-Induced PN Risk May Change the Required Filtration Margin

Euro 7

BS VII

**PN10
Filtration
Efficiency**
+
Urea PN risk

Performance Image

Required

Low

Product

DHC-558HG
9/300HAC

DHC-630
10/300HAC

DHC-790
7/350HAC

High

Required

Low

Product

DHC-790
7/350HAC

DHC-630
10/300HAC

DHC-558HG
9/300HAC

High

Required

Low

Product

DHC-790
7/350HAC

DHC-630
10/300HAC

DHC-558HG
9/300HAC

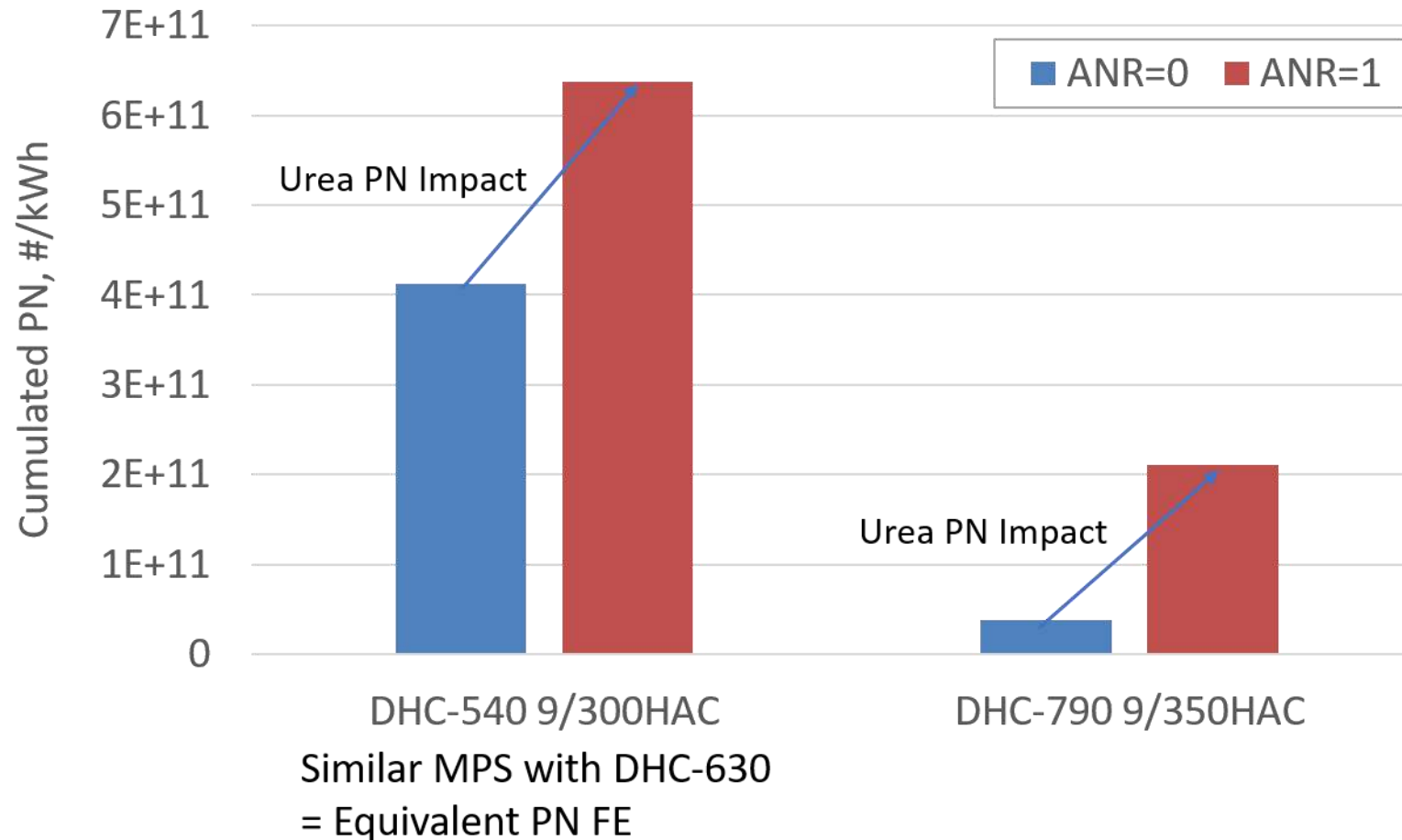
High

Pressure drop
w/soot

Robustness

NGK Can Offer a DPF Technology Option To Minimize Urea PN Risk

ISC-PEMS Results in Cumulated PN, #/KWh

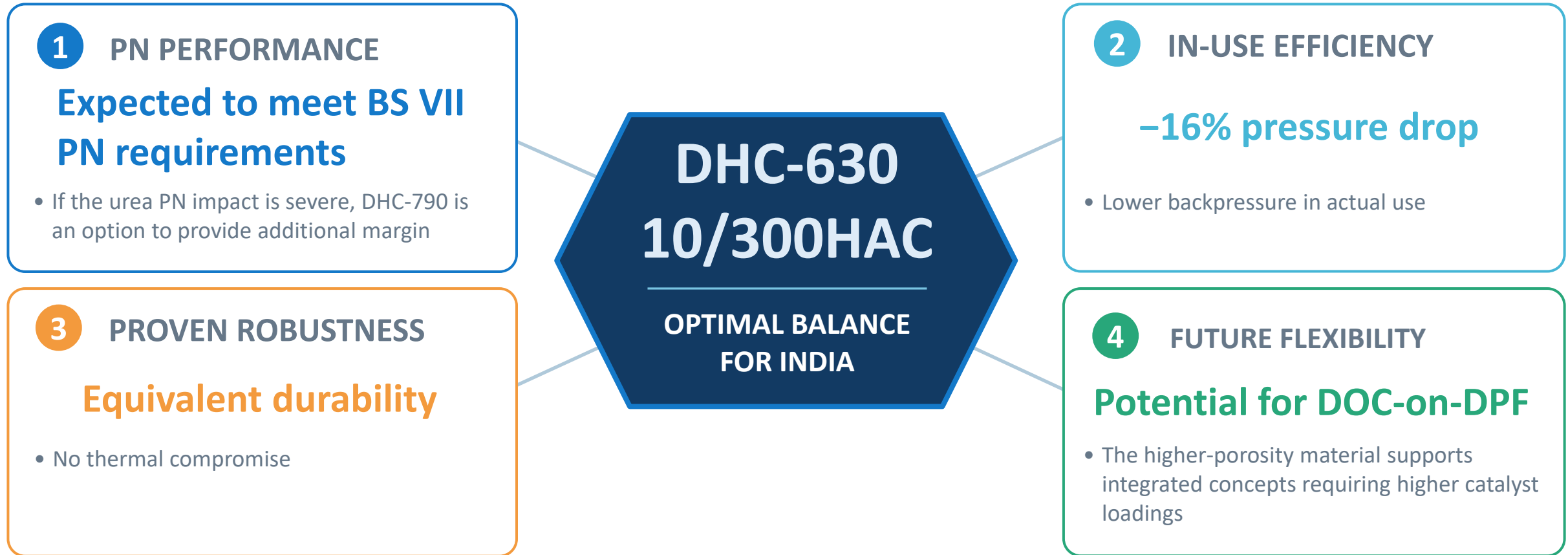


Test Engine: 13L engine w/ low EGR

Test-Procedure:

1. oven-regeneration of both DPF
2. WHTC cold
3. 4x WHTC hot
4. Soot-loading to 2,5 g/l
5. ISC-100% test ← Cumulated PN measurement
6. Weighing

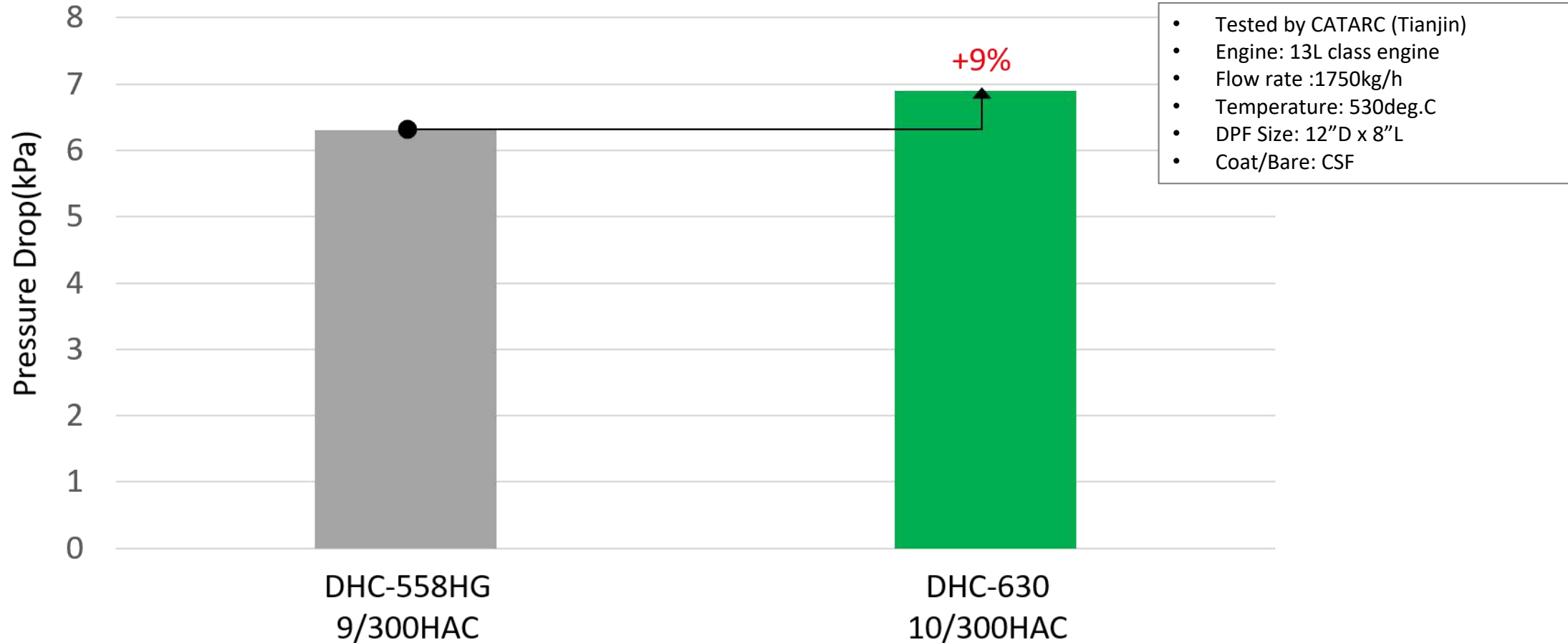
- DHC-630 can meet PN requirements, but may approach the compliance boundary under severe conditions. DHC-790 is an option to provide additional margin for robust PN compliance.



DHC-630 10/300HAC offers an optimal balance of PN margin, pressure drop, robustness, future flexibility.

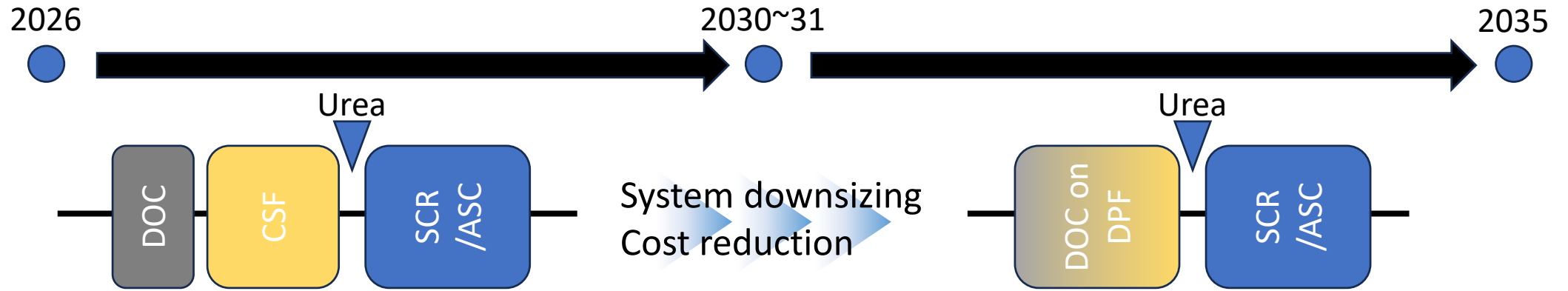


DHC-630 10/300HAC Shows Only a 9% Increase in Initial Pressure Drop While Delivering 70% Better PN Filtration

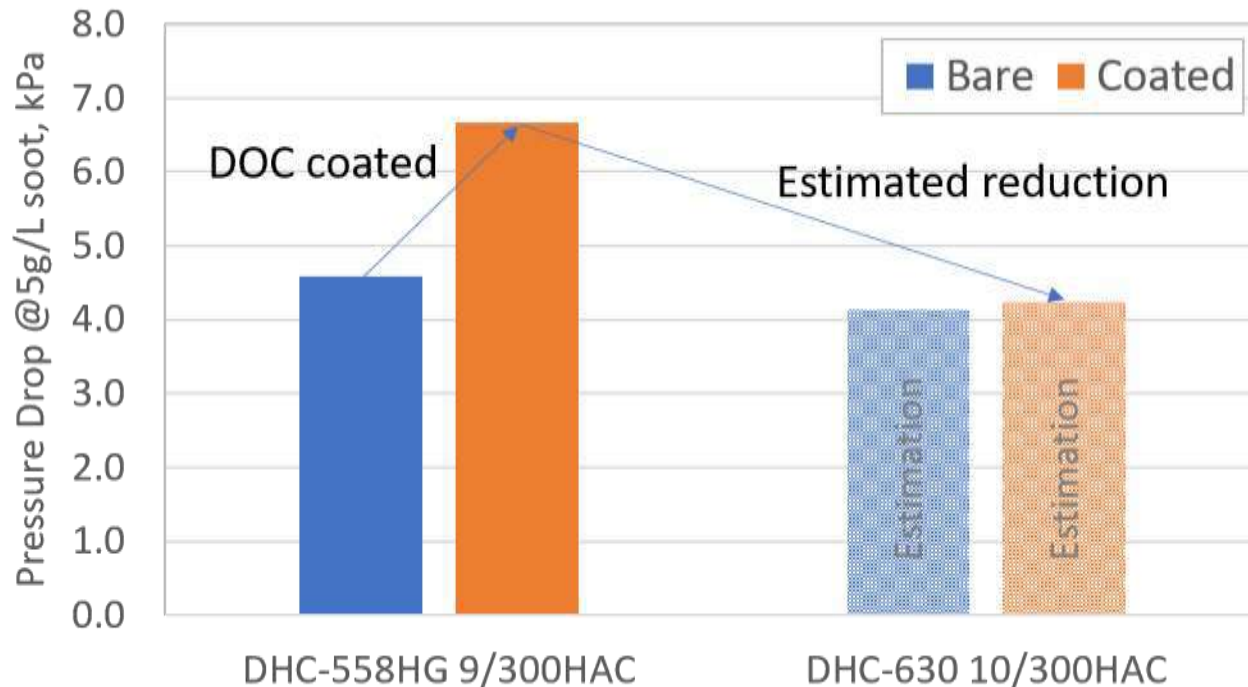


- The initial pressure-drop difference is mainly attributable to the difference between the 9-mil and 10-mil cell structures. However, pressure drop under soot loading is more relevant to actual vehicle operation.

Future-Proof for BS VII and Beyond: DHC-630 10/300HAC Provides Flexibility for Technologies Beyond CSF Applications



Advantage of DHC-630 10/300HAC for DOC on DPF applications



Higher porosity helps reduce pressure drop even after a DOC catalyst is coated onto the DPF.

DHC-630 10/300HAC is a versatile technology applicable not only to CSF systems but also to DOC-on-DPF and other function-integrated concepts.