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Advanced TWC Substrates for Cost Optimization and Future Regulations in India

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- 1. Background**
- 2. Test Conditions**
- 3. Test Results**
- 4. Summary**

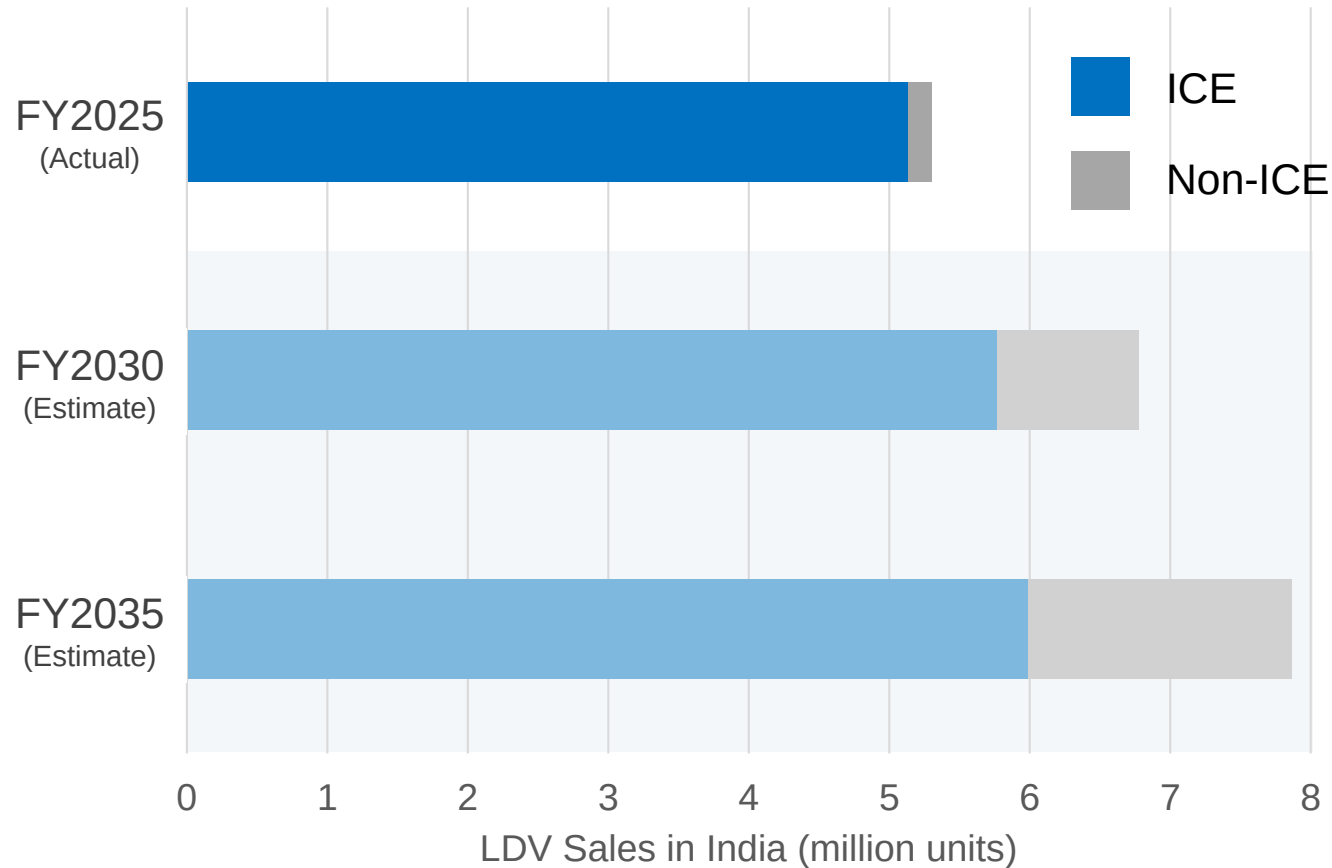
1. Background

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4. Summary

ICE-based powertrains stay dominant through India's powertrain transition.



Based on NGK understanding and estimation



Market Expands

- Vehicle demand keeps growing



ICE Stays The Core

- ICE remains the majority of sales in FY2035.
- ICE units keep rising in absolute terms



Non-ICE Ramps Gradually

- Non-ICE grows steadily but remains a minority.
- Adoption pace stays gradual, not disruptive

BS7 Expands the Need for GPF and Raises the Bar for TWC

Regulation timeline and limit comparison — BS (India) and EU

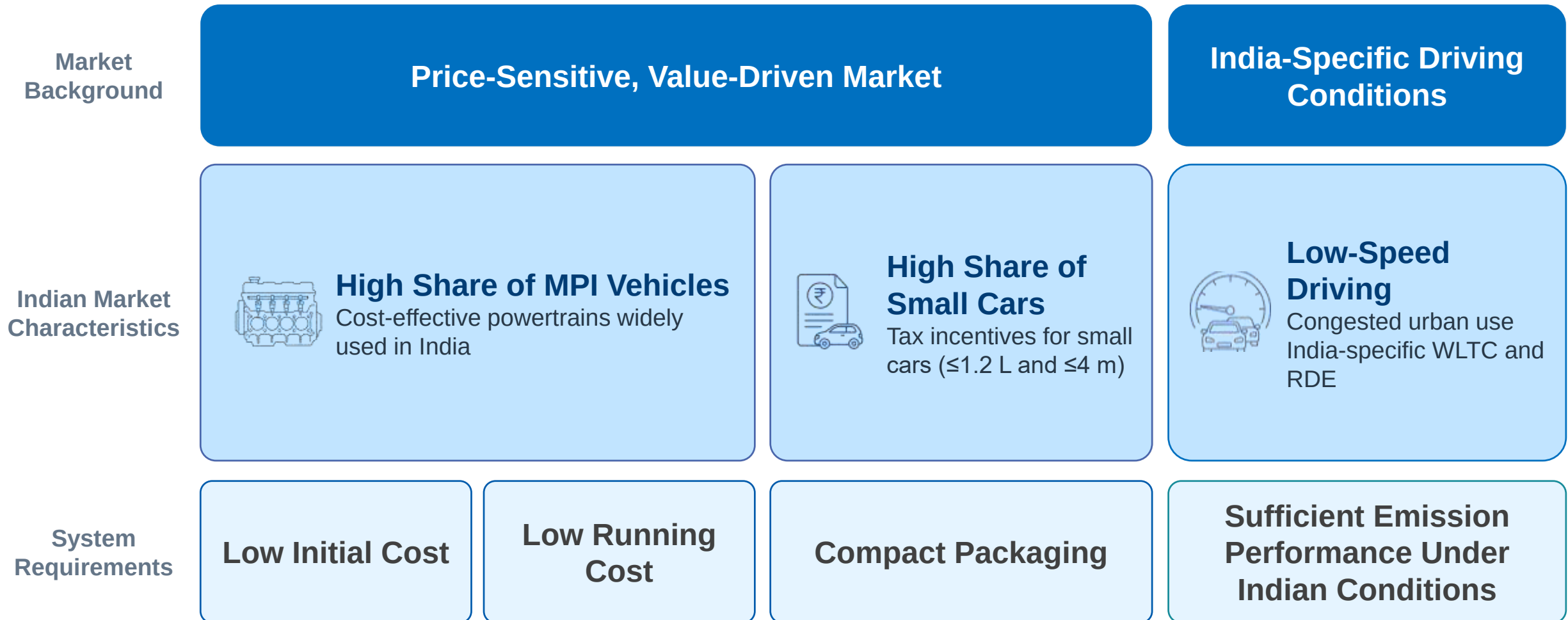
		2026	2027	2028	2029	2030	2031
BS		BS6 Stage2	BS6 Stage2 + WLTP		BS7 (Draft)*		
						*RDE/CF from April 2030	
EU		Euro 6e	Euro 7				

	INDIA			EU	
Regulation	BS6 Stage2	BS6 Stage2 + WLTP	BS7 (Draft)* *RDE/CF from April 2030	Euro 6e	Euro 7
Test Cycle	MIDC + RDE	WLTC (to Ph.3) + RDE	WLTC (to Ph.3) + RDE	WLTC + RDE	WLTC + RDE
PN (#/km)	6.0×10 ¹¹ CF 1.5 PN23 · GDI only	6.0×10 ¹¹ CF 1.5 PN23 · GDI only	6.0×10 ¹¹ CF 1.0 PN10 · GDI + MPI	6.0×10 ¹¹ CF 1.34 PN23 · GDI only	6.0×10 ¹¹ CF 1.34 PN10 · GDI + MPI
NOx (mg/km)	60 CF 1.43	60 CF 1.43	60 CF 1.0	60 CF 1.1	60 CF 1.1
THC (mg/km)	100	100	100	100	100
NMHC (mg/km)	68	68	68	68	68
CO (mg/km)	1,000	1,000	1,000	1,000	1,000

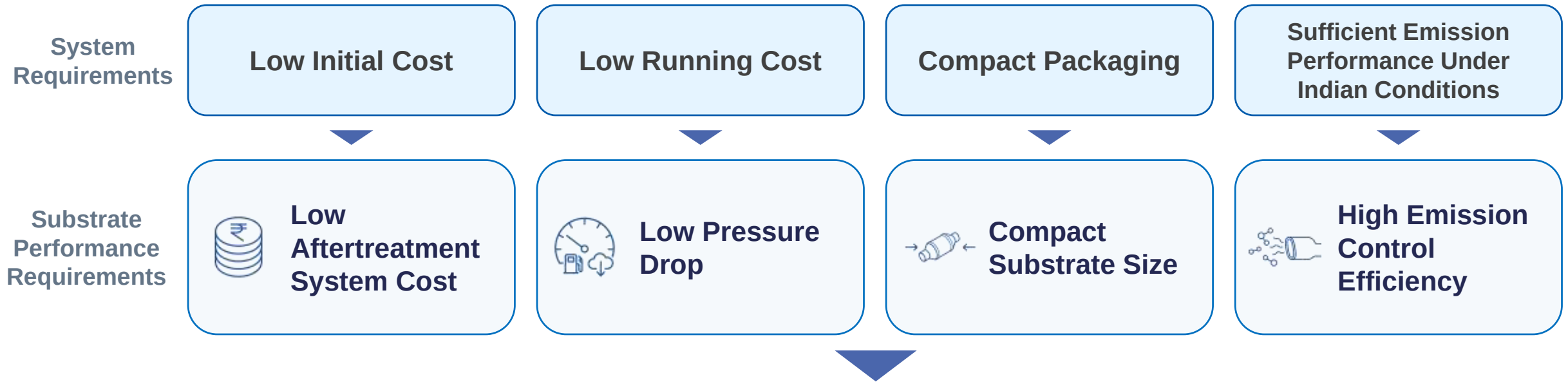
Along with the market growth, emission regulations are expected to become increasingly stringent.

What the Indian Market Requires of the Aftertreatment System

India-specific market and driving conditions make aftertreatment system optimization essential.

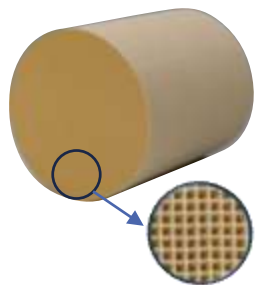


System Requirements Translated into Substrate Capabilities



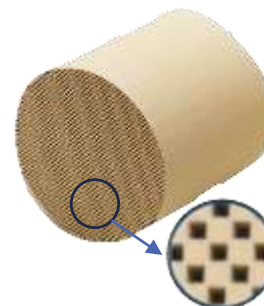
Technology-Specific Substrate Requirements

TWC



- ✓ High Conversion Efficiency
- ✓ Fast Light-Off
- ✓ High Catalyst Utilization
- ✓ Low Pressure Drop

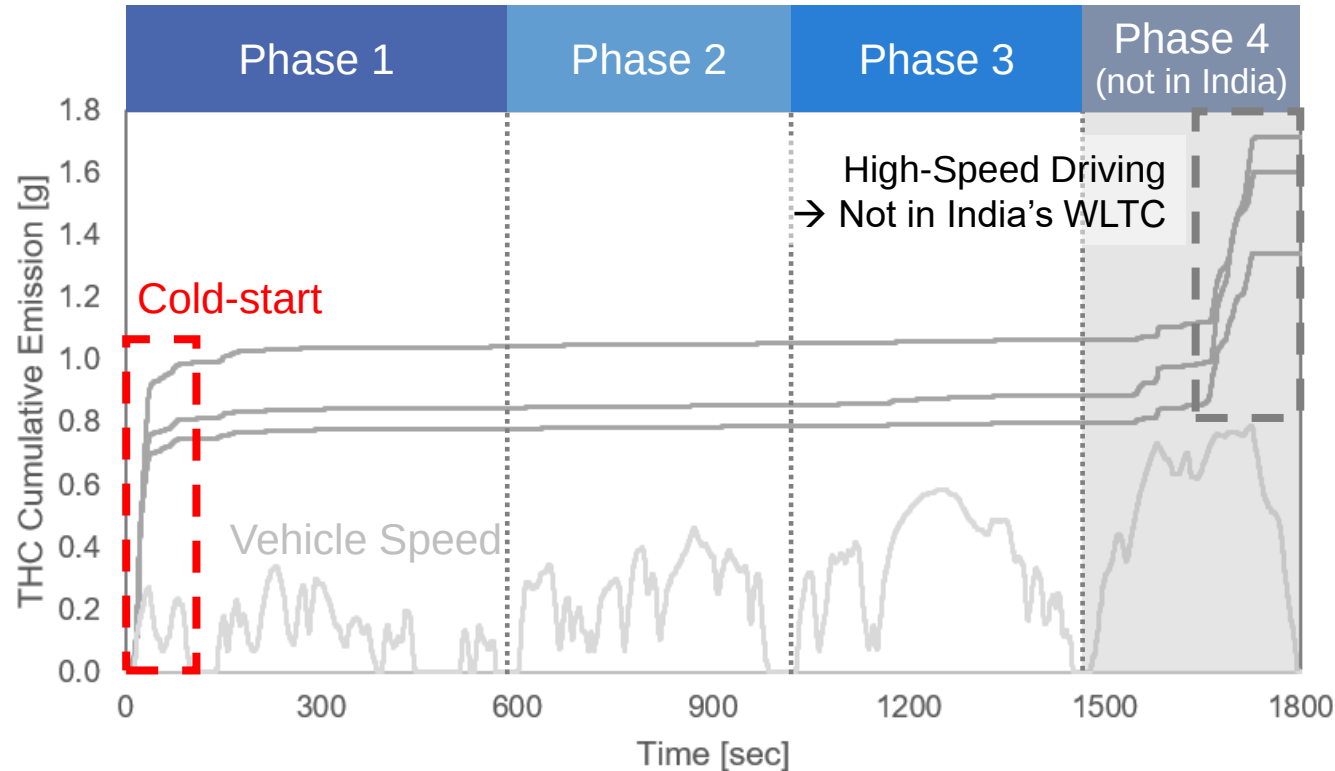
GPF



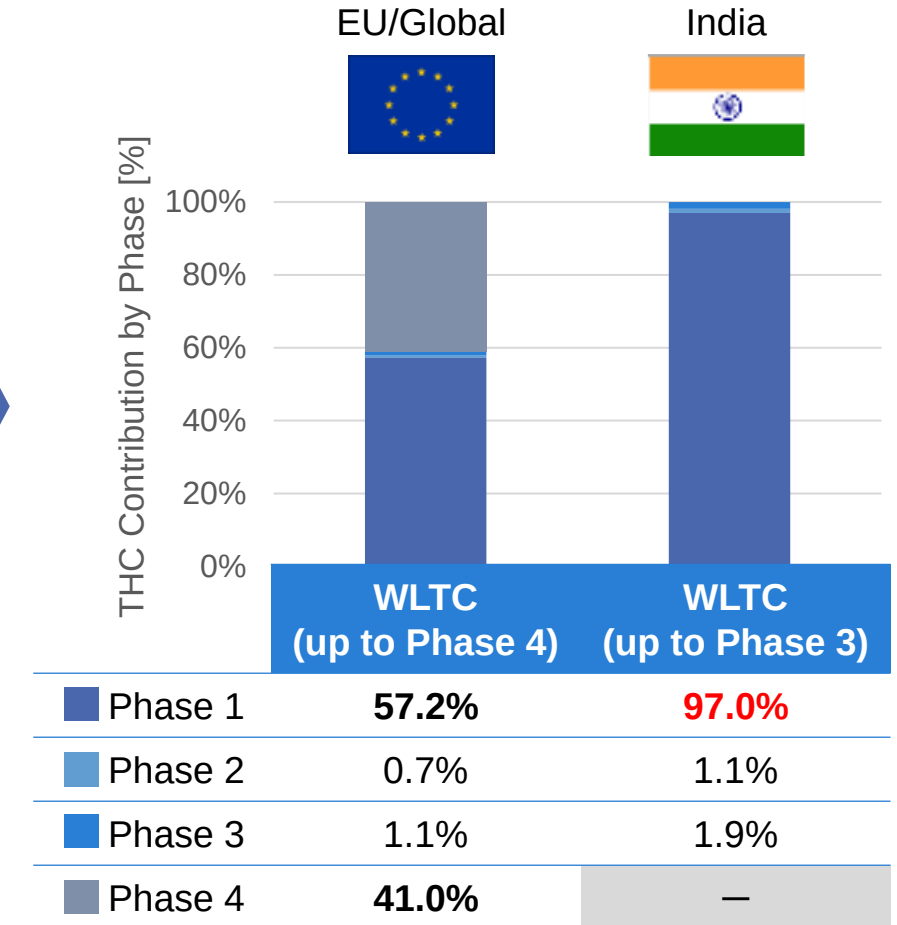
- ✓ High Filtration Efficiency
- ✓ Low Pressure Drop
(May instead be used to reduce GPF size)

India's WLTC Makes Cold-Start Emissions More Critical

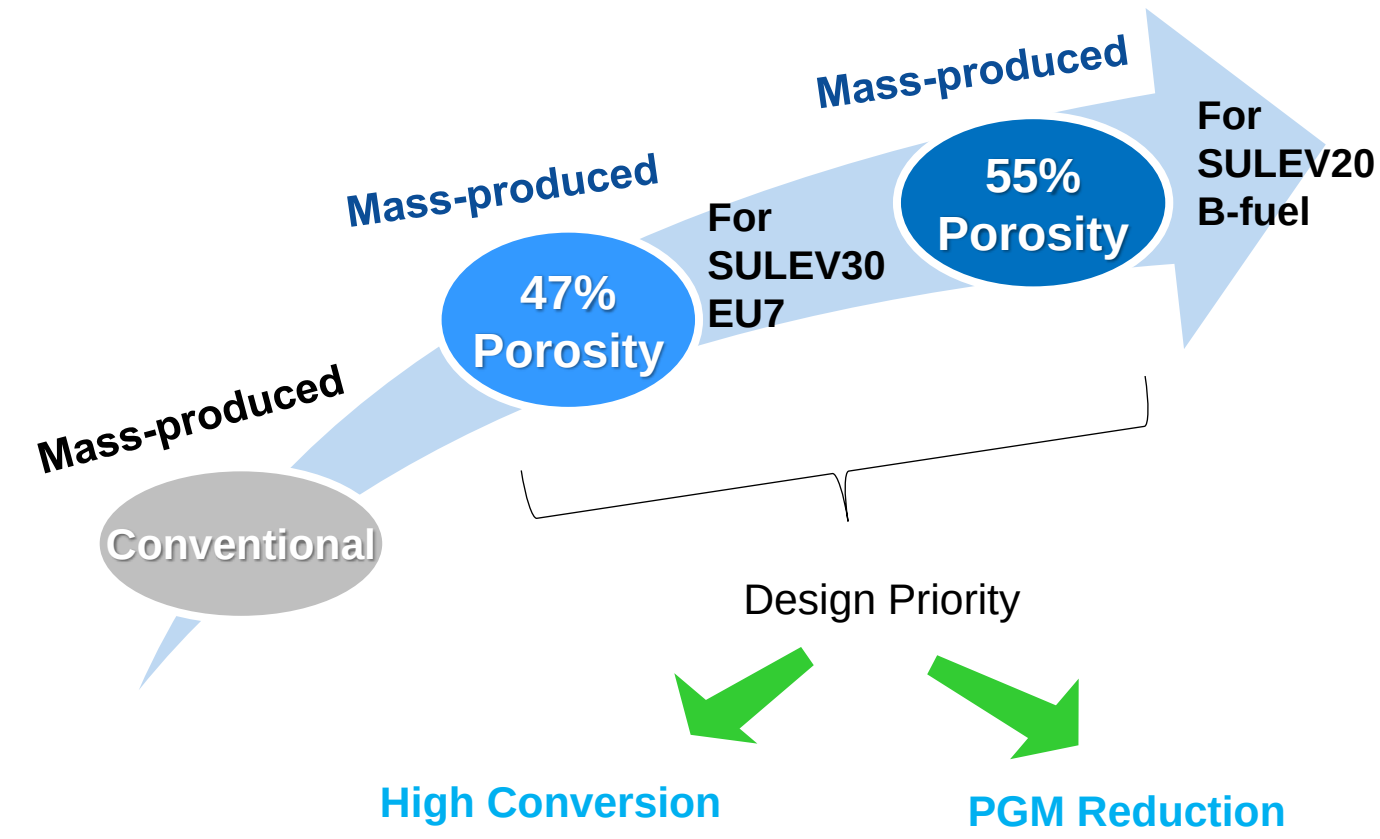
Substrate: 27% porosity, 2/600, PGM loading $\times 1.0$ | $n = 3$

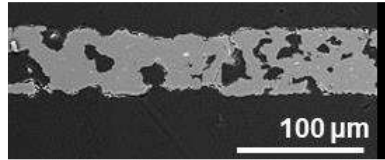
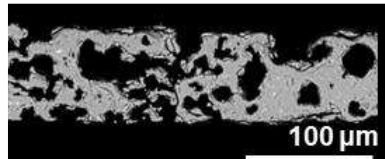
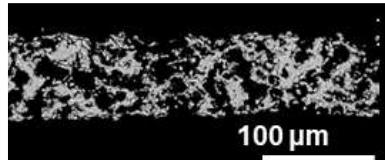
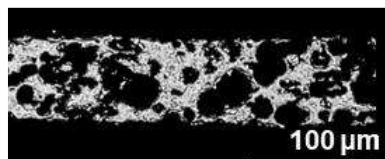


In this test, 97% of cycle THC was emitted during Phase 1.



India applies WLTC up to Phase 3, making cold-start emissions more critical.



Material	Porosity	SEM Image
Conventional	27%	
Conventional	35%	
High Porosity Gen1	47%	
High Porosity Gen2	55%	

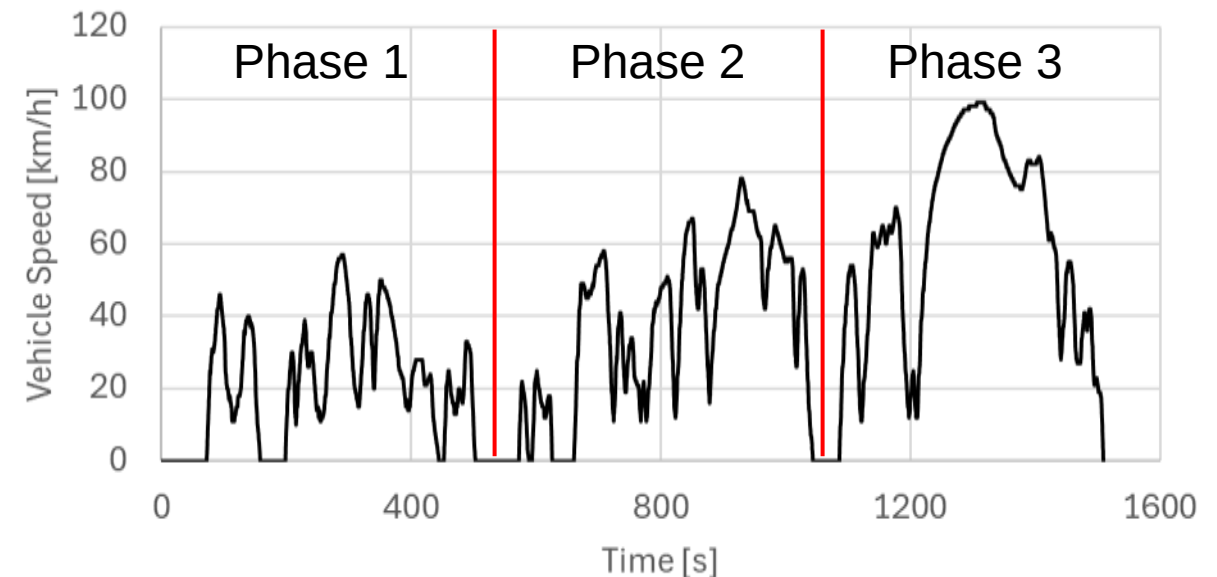
Higher porosity

- ✓ NGK has developed high-porosity TWC substrates to improve cold-start performance.
- ✓ This study evaluates their emission and PGM reduction potential under Indian conditions.

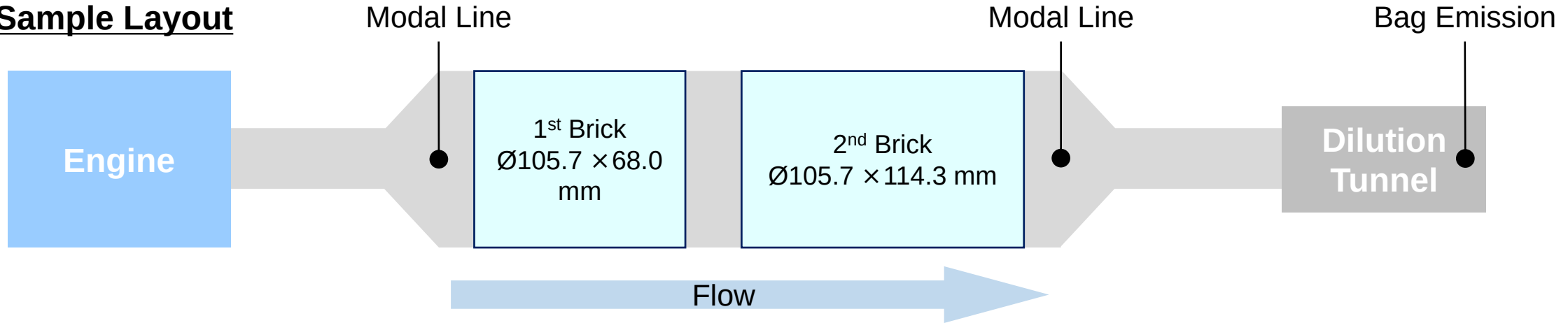
1. Background
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Item	Detail
<u>Vehicle</u>	BS6 Stage I
<u>Engine displacement</u>	1.2 L NA MPI
<u>Aftertreatment layout</u>	Close-coupled two-brick TWC system (aged)
<u>Coating</u>	BS6 Stage II basis
<u>Aging</u>	Oven aging at 1050 °C for 5 h
<u>Tested cycle</u>	WLTC up to Phase 3 Three runs per specification
<u>Sample size</u>	Ø105.7 × 68.0 mm (1 st brick) Ø105.7 × 114.3 mm (2 nd brick)
<u>Testing Facility</u>	Chassis Dynamometer at AVL India

Tested cycle: WLTC up to Phase 3



Sample Layout



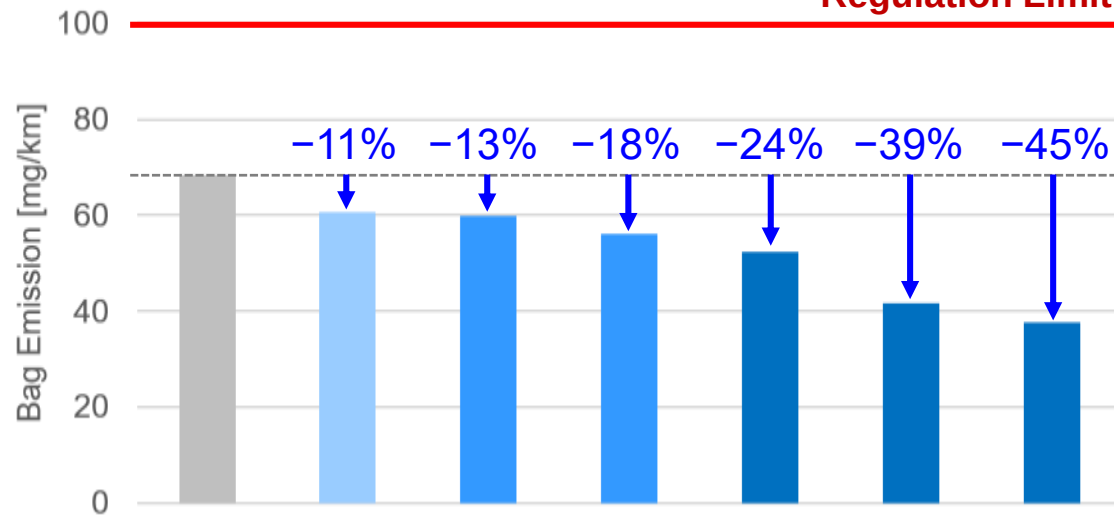
Only the 1st brick specification was varied; the 2nd brick was fixed.

#	1 st Brick: Ø105.7 × 68.0 mm			2 nd Brick: Ø105.7 × 114.3 mm	
	Cell Structure	Porosity [%]	Relative PGM Loading	Cell Structure	Porosity [%]
1	2/600	27	×1.0 (Base)	2/600	27
2	2/750	35	×1.0		
3	2/600	47	×1.0		
4	2/750	47	×1.0		
5	2/900	55	×0.6		
6	2/900	55	×1.0		
7	2/900	55	×1.3		

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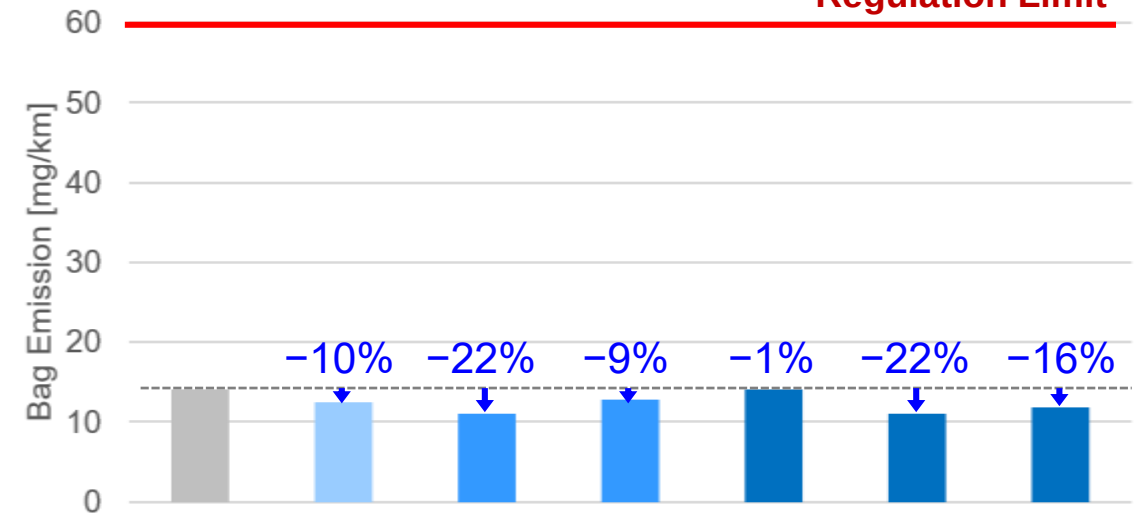
THC Emission (mg/km)

Regulation Limit



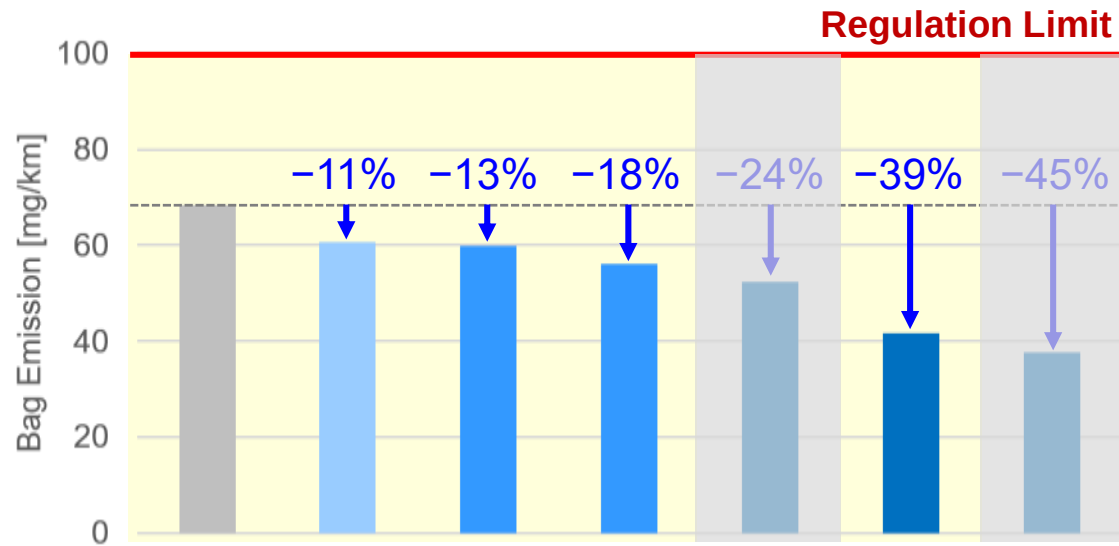
NOx Emission (mg/km)

Regulation Limit



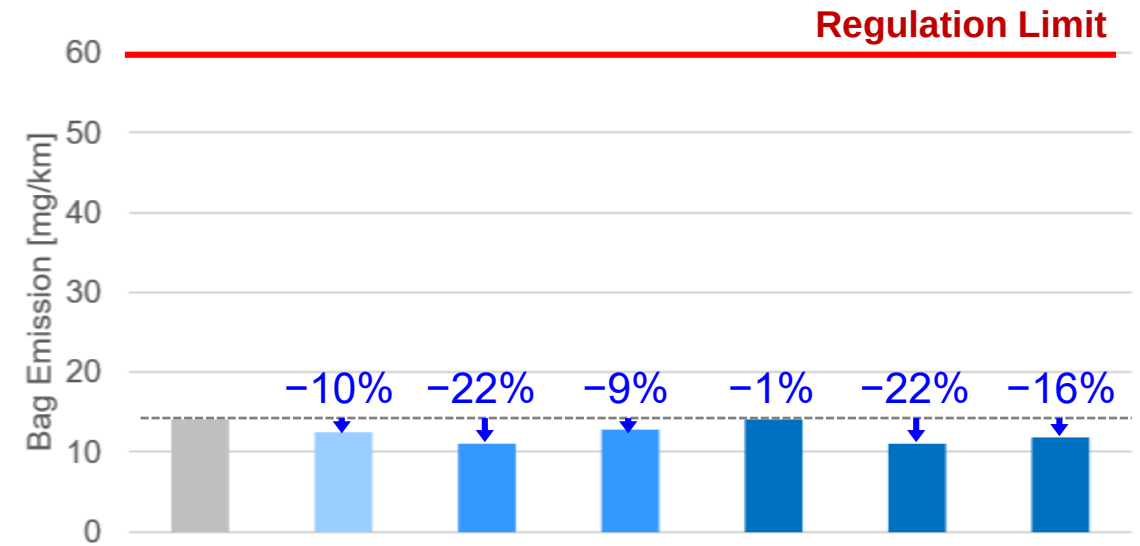
THC decreases toward higher-porosity specifications, while the low NOx level limits clear differentiation under the tested conditions.

THC Emission (mg/km)



Porosity [%]	27	35	47		55		
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3

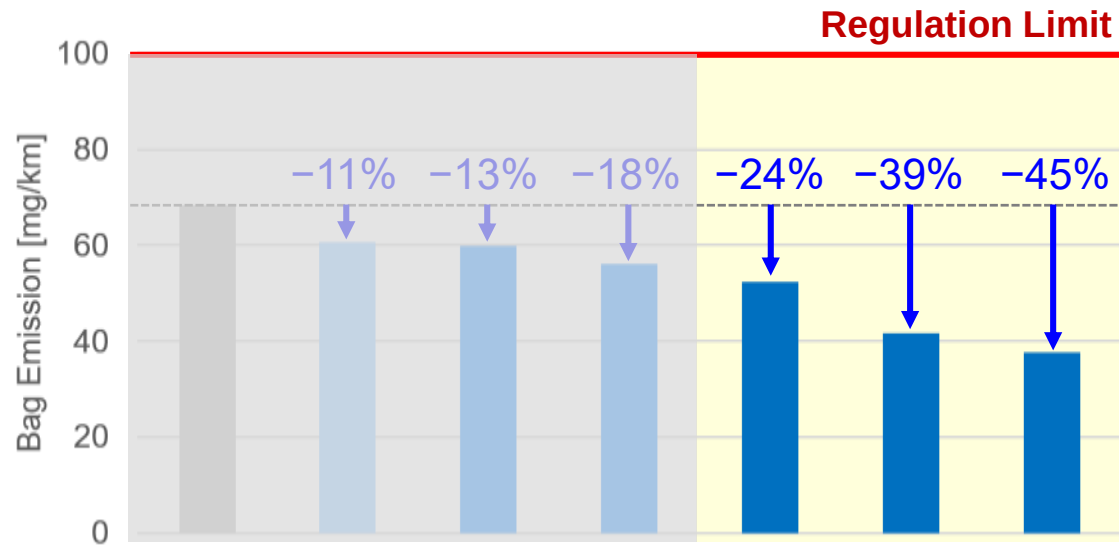
NOx Emission (mg/km)



Porosity [%]	27	35	47		55		
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3

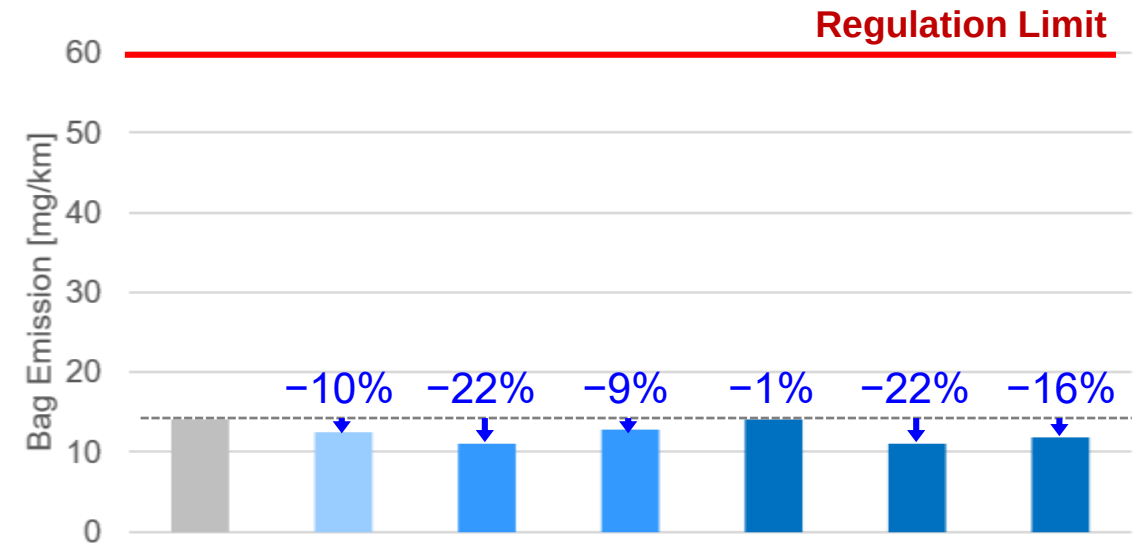
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THC Emission (mg/km)



Porosity [%]	27	35	47		55		
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3

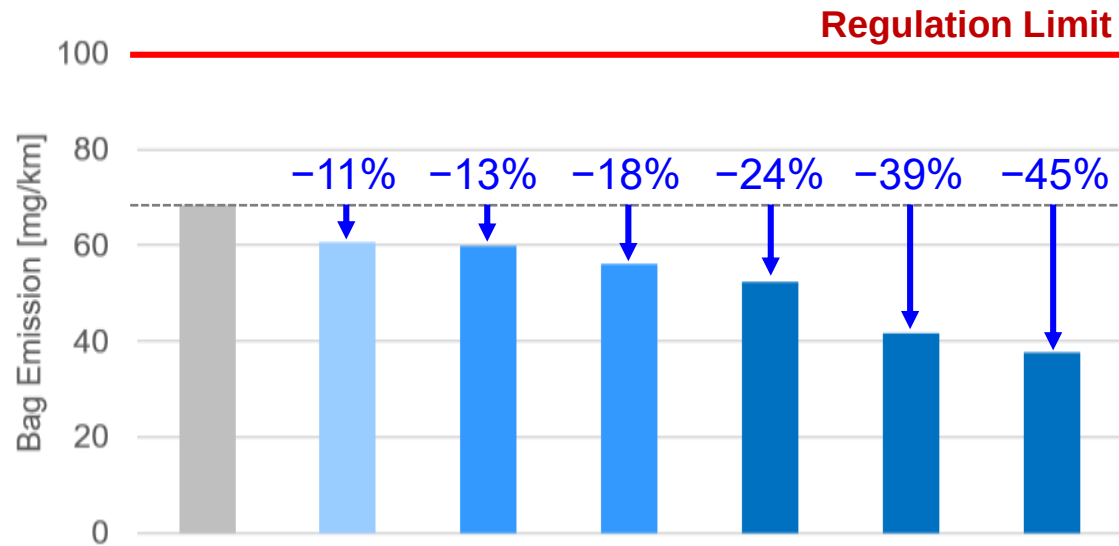
NOx Emission (mg/km)



Porosity [%]	27	35	47		55		
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3

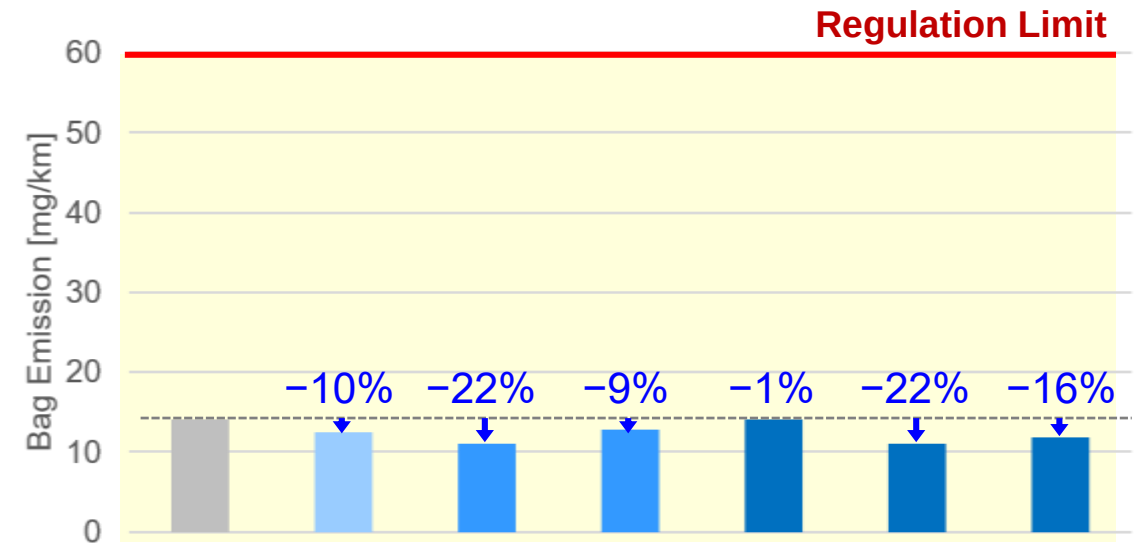
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THC Emission (mg/km)



Porosity [%]	27	35	47		55		
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3

NOx Emission (mg/km)

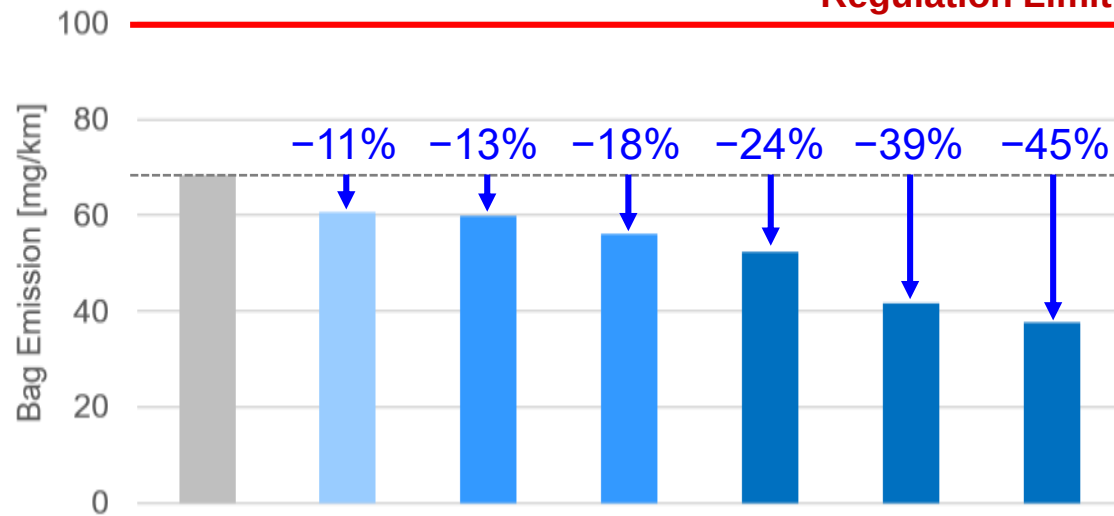


Porosity [%]	27	35	47		55		
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3

THC decreases toward higher-porosity specifications, while the low NOx level limits clear differentiation under the tested conditions.

THC Emission (mg/km)

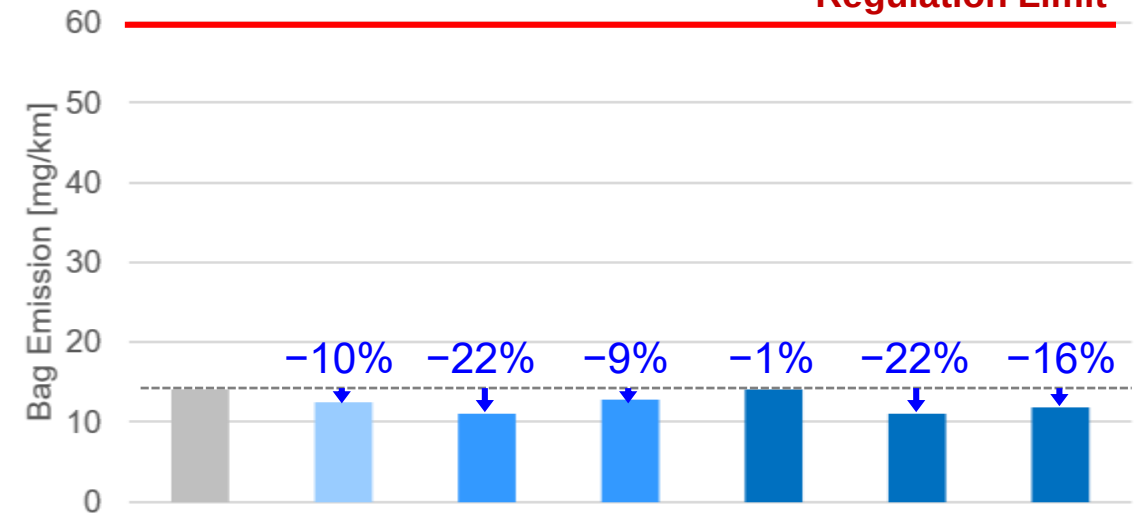
Regulation Limit



Porosity [%]	27		35		47		55	
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3	×1.3

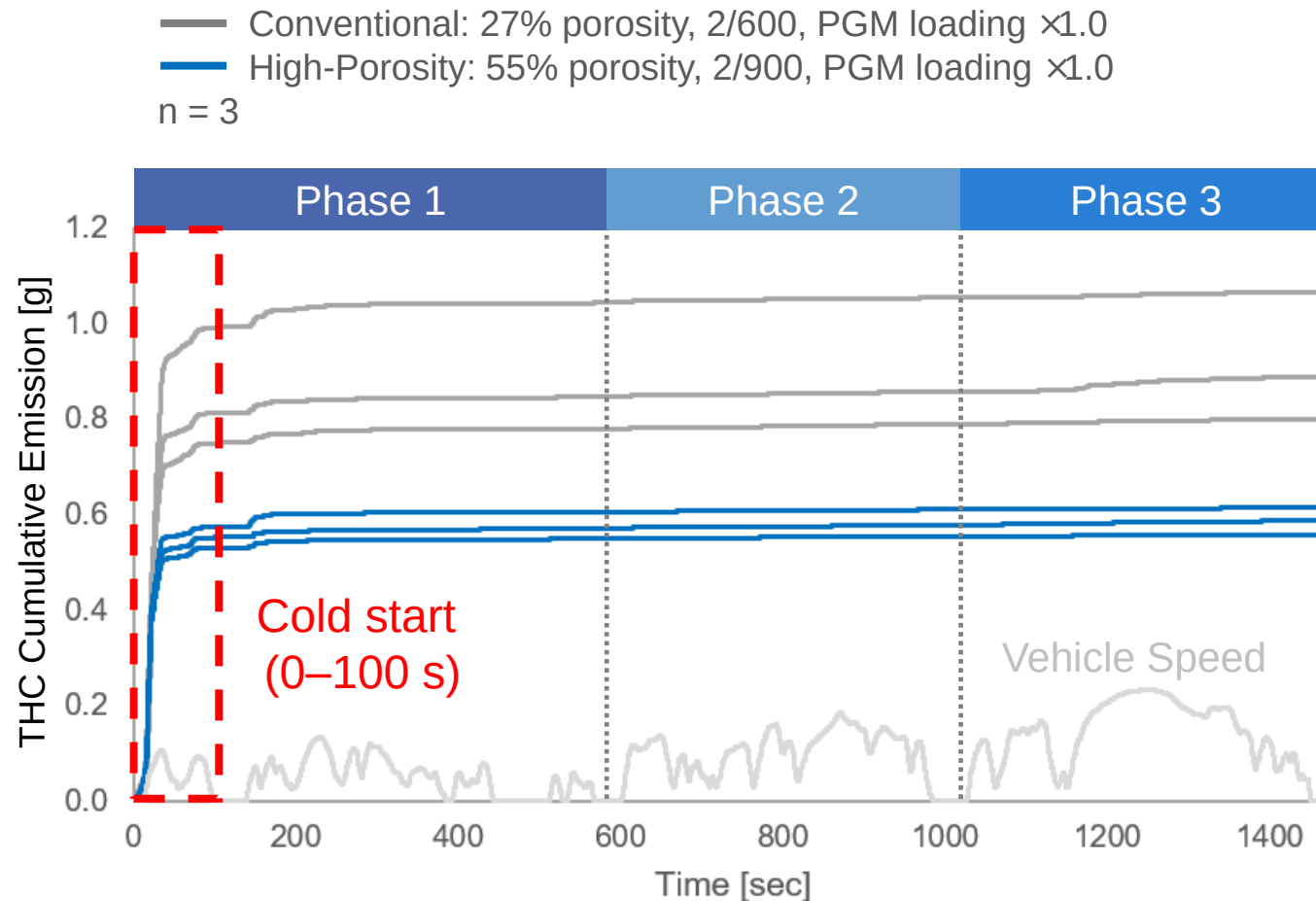
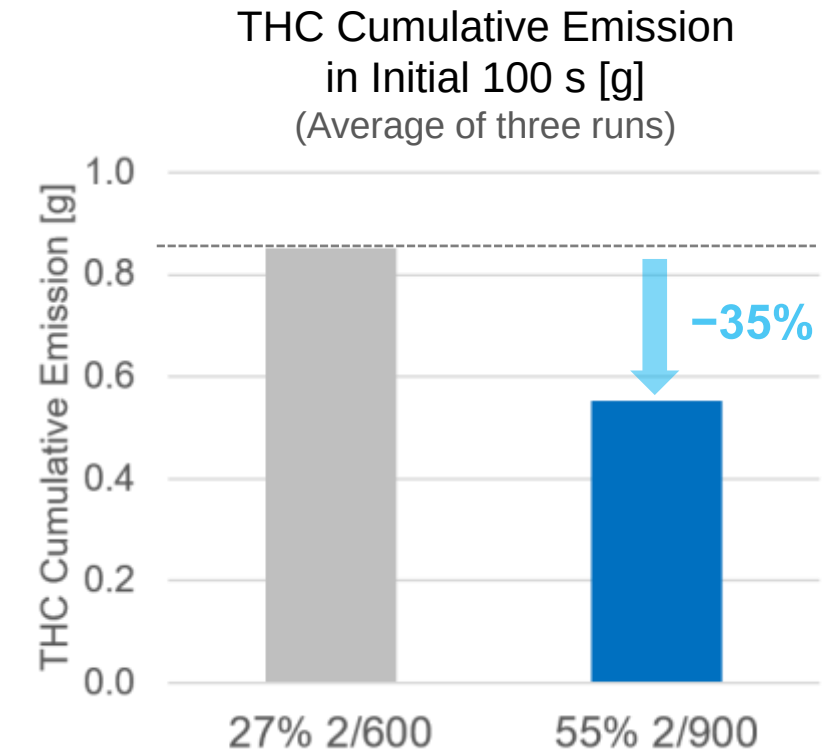
NOx Emission (mg/km)

Regulation Limit



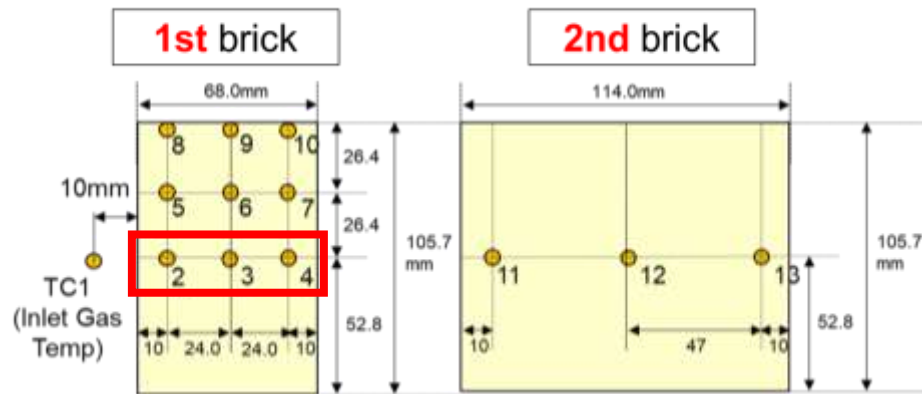
Porosity [%]	27		35		47		55	
Cell Structure	2/600	2/750	2/600	2/750	2/900	2/900	2/900	2/900
PGM Loading	×1.0 (Base)	×1.0	×1.0	×1.0	×0.6	×1.0	×1.3	×1.3

THC decreases toward higher-porosity specifications, while the low NOx level limits clear differentiation under the tested conditions.

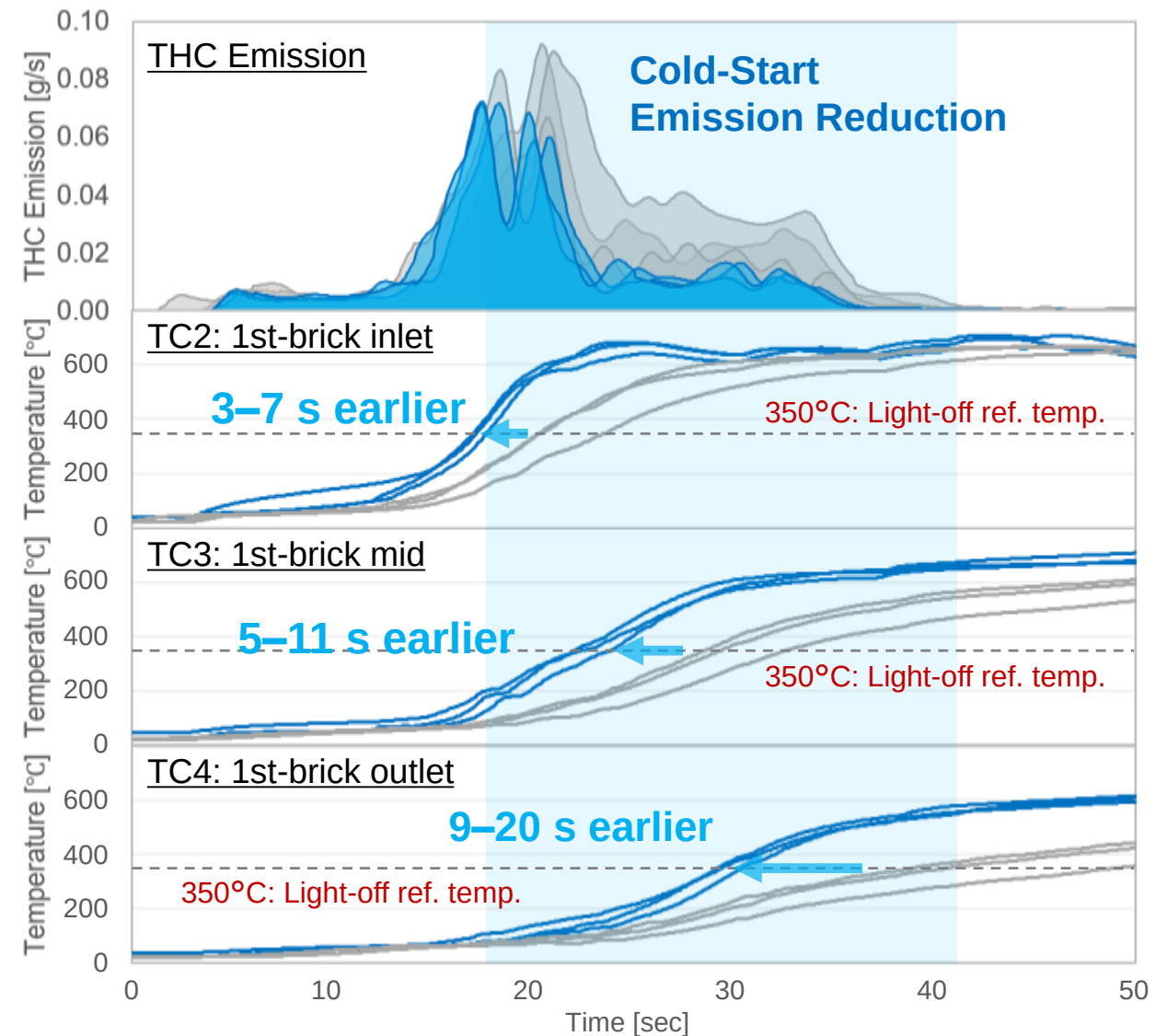


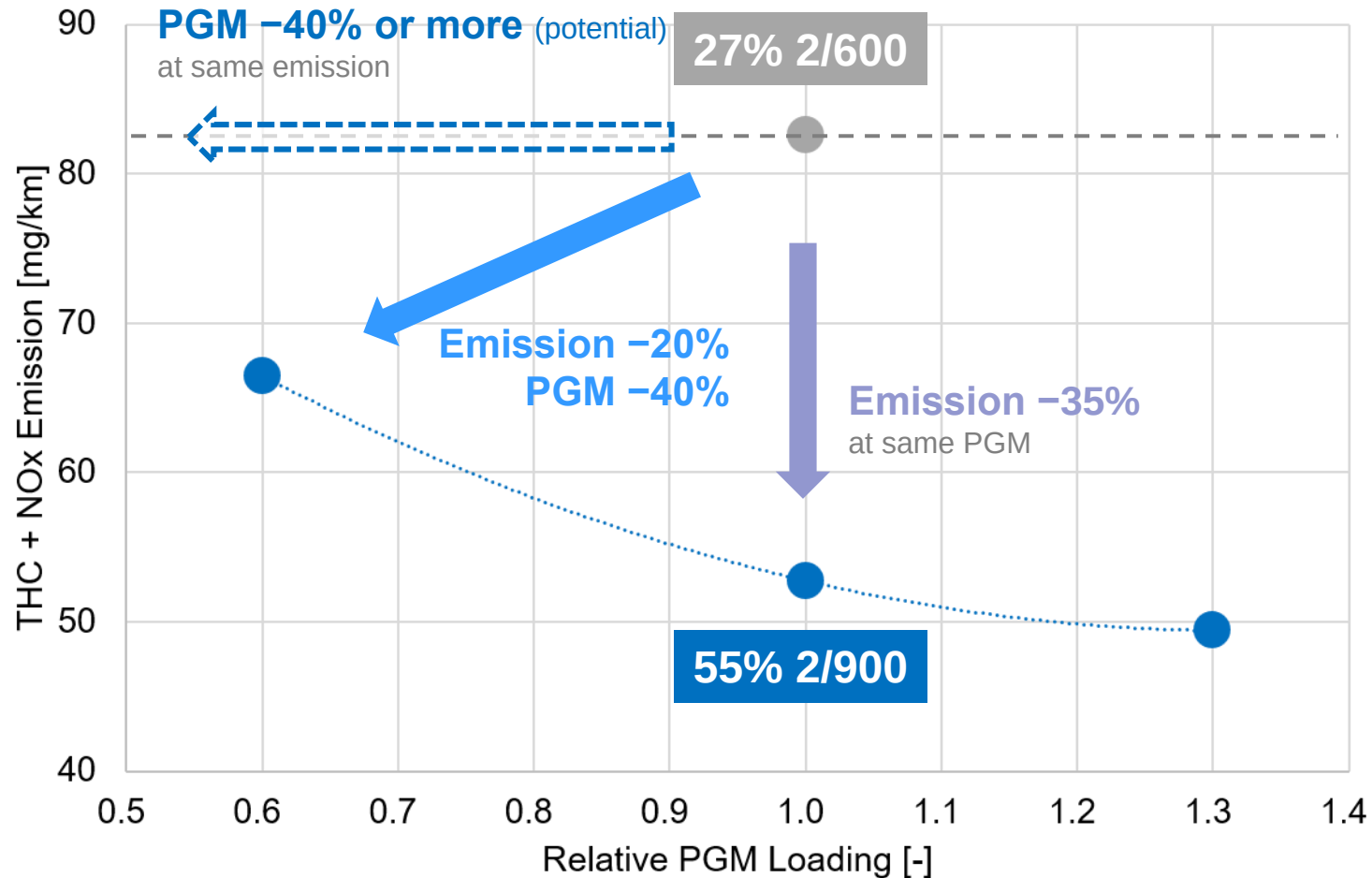
The high-porosity substrate reduces THC primarily during the critical cold-start period.

- Conventional: 27% porosity, 2/600, PGM loading $\times 1.0$
 - High-Porosity: 55% porosity, 2/900, PGM loading $\times 1.0$
- n = 3



The high-porosity substrate heats the catalyst faster, supporting earlier catalyst activation and lower cold-start emissions.





—●— Conventional: 27% porosity, 2/600
—●— High-Porosity: 55% porosity, 2/900
Average of three runs

The balance can be selected based on application needs.

Emission-Focused

1. Emission-first
Emission -35%, PGM ±0%

2. Balanced
Emission -20%, PGM -40%

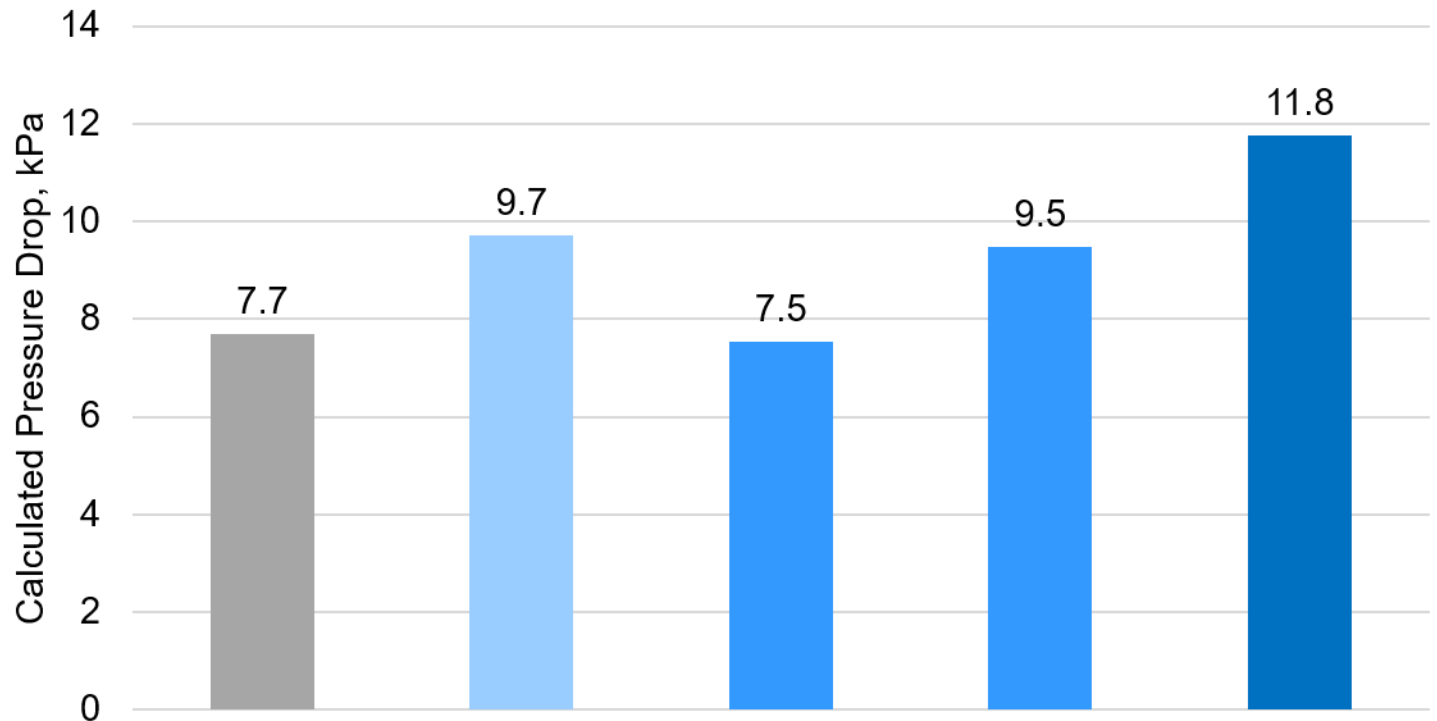
3. PGM-first
Emission ±0%, PGM -40% or more (potential)

Cost Optimization-Focused

High porosity creates an emission margin that can be used to reduce emissions, lower PGM loading, or achieve a balance between the two, depending on application needs.

Calculation condition

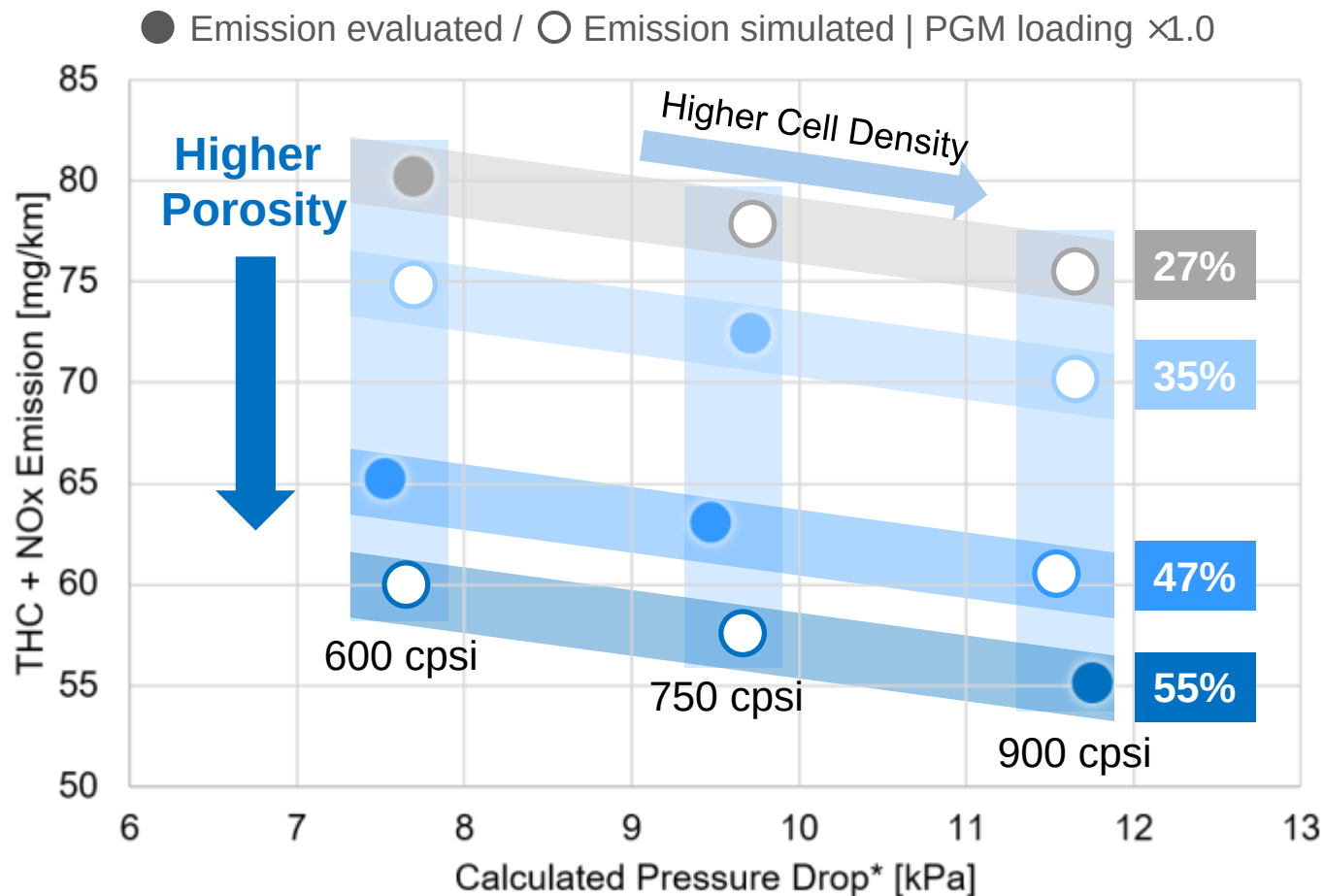
- Substrate size: Ø118.4 × 60.0 mm
- Exhaust temperature: 900 °C
- Mass flow rate: 600 kg/h
- Washcoat loading: 200 g/L



Porosity [%]	27	35	47		55
Cell Structure	2/600	2/750	2/600	2/750	2/900

Pressure drop rises with cell density but changes little with porosity.

Performance Map – Higher Porosity Improves the Balance



*Calculation condition

- Substrate size: $\varnothing 118.4 \times 60.0$ mm
- Exhaust temperature: 900 °C
- Mass flow rate: 600 kg/h
- Washcoat loading: 200 g/L

Higher porosity improves the performance balance, while cell density provides flexibility to meet application-specific pressure-drop requirements.

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1. Vehicle Evaluation

Vehicle testing confirmed the benefit of the high-porosity specification.

Vehicle testing showed earlier catalyst heating and significantly lower THC emissions.

2. Use of the Emission Margin

The emission margin provided by the high-porosity substrate can be used in different ways.

The balance between lower emissions and lower PGM loading can be selected according to application needs.

3. Emission–Pressure Drop Balance

Higher porosity is the key to improving the balance between emissions and pressure drop.

Cell density can then be selected to meet application-specific pressure-drop requirements.



High Porosity Enables Application-Specific Optimization

Emissions, PGM loading, and pressure drop can be balanced by jointly selecting porosity and cell structure.

