



Virtual Benchmarking in Emission Prediction and ATS Development across ICE applications

Bosch Limited, India

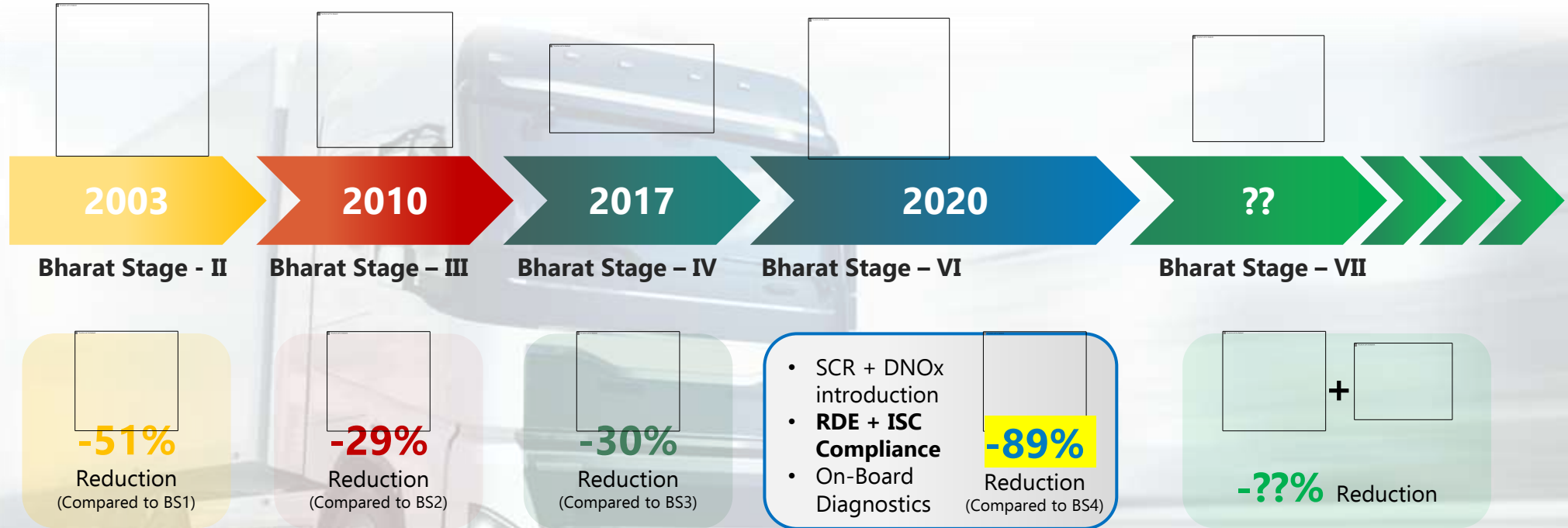
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Emission Prediction and ATS Performance Benchmarking

Overview for CV regulations

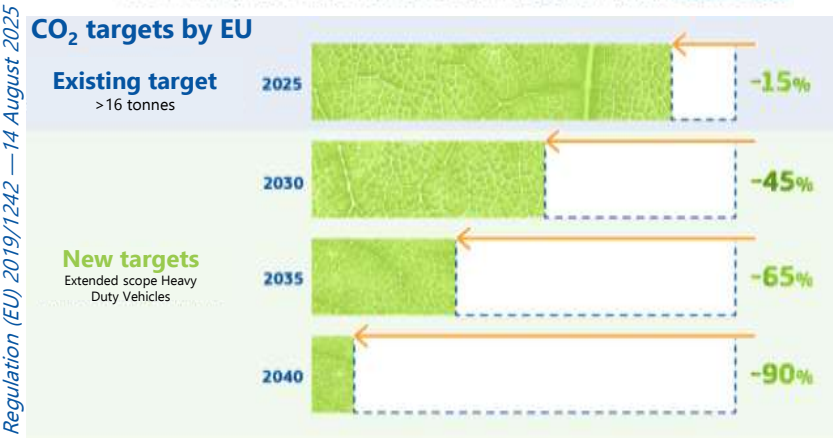
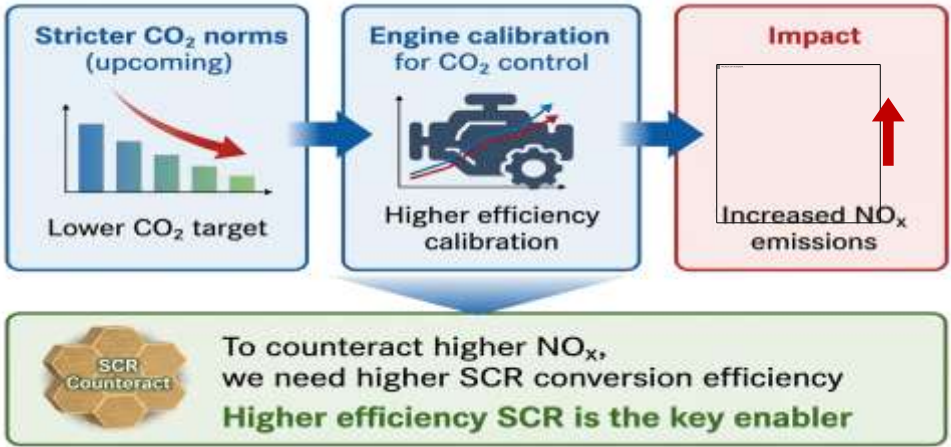
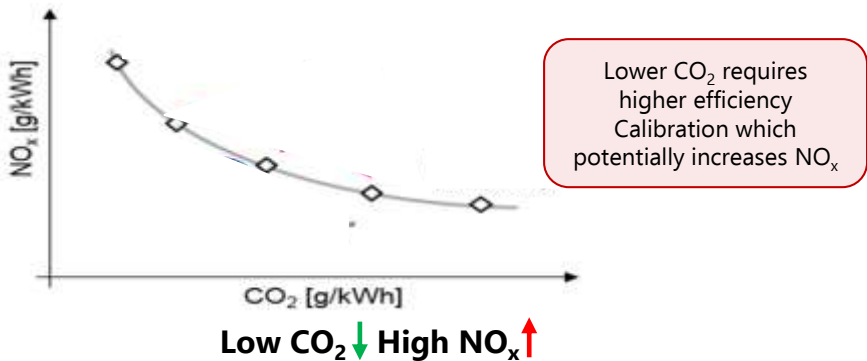


- ❑ Each step forward in legislation has called for tighter limits with aggressive development roadmap.
- ❑ Aggressive Development in the Automotive Segment (EO, ATS, calibration, Electronics & Systems) has been key to meeting legislation requirements.

Emission Prediction and ATS Performance Benchmarking

Overview for CV regulations - Outlook

Fleet Vehicle Km Travelled (VKT) share of Heavy Duty powertrains in India *April 2024



- ❑ Stringent CO₂ targets will drive engine calibration towards higher NO_x out emissions
- ❑ Higher SCR conversion efficiency becomes a critical enabler for future compliance

Emission Prediction and ATS Performance Benchmarking

From Development to Driveway: Across the Lifecycle

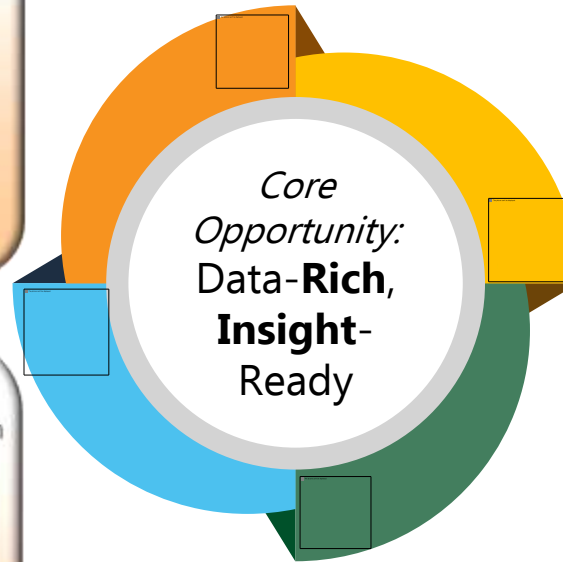


Testing Limitation

Development cannot achieve **100% coverage** of real-world scenarios. Field failures lead to tedious, expensive in-person investigations.

Correlation Incongruity

- Transient behavior differs from steady-state; Real-world operation could deviate from WHTC;
- with static CFD simulations difficult to capture dynamic effects & expensive to be adopted.



Time & Complexity

- Data-driven models offer potential for up to 15-20% overall effort optimisation across the SCR development stack.



Virtual Diagnostic Paradigm

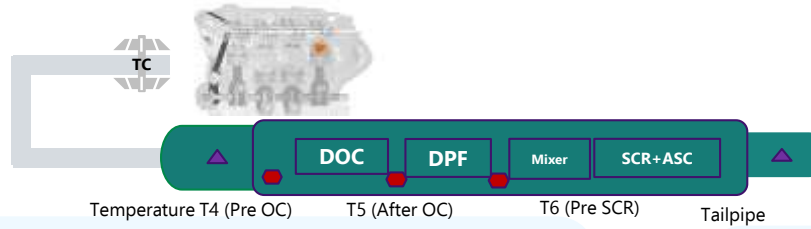
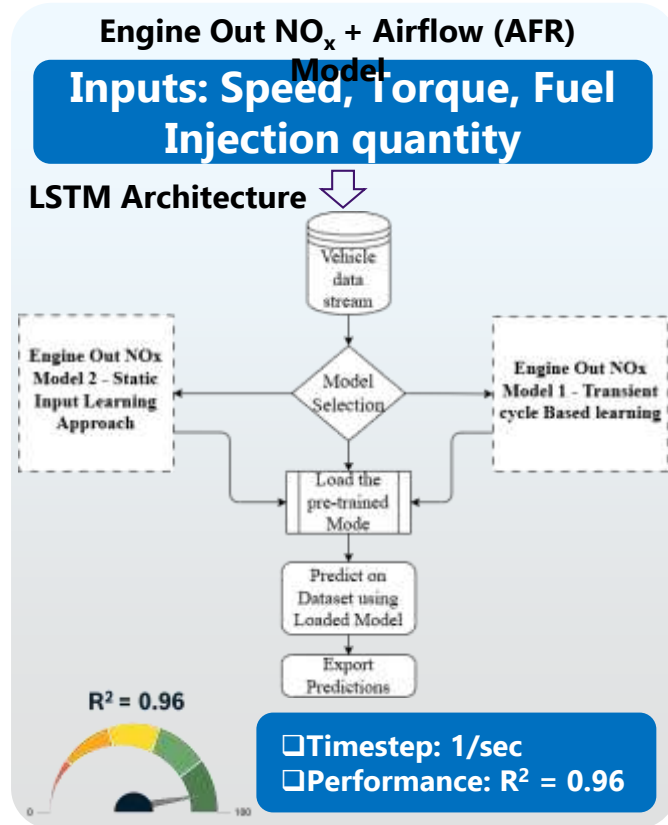
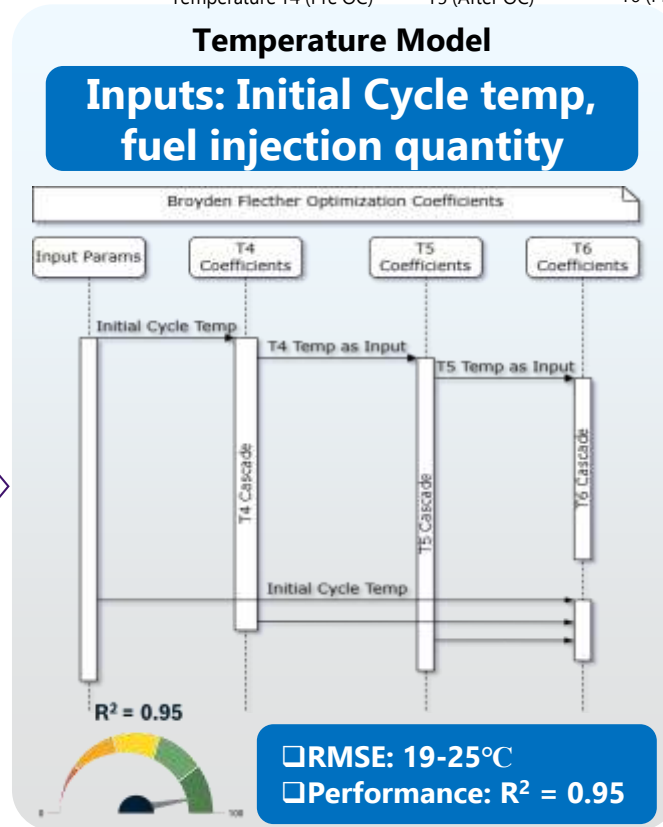
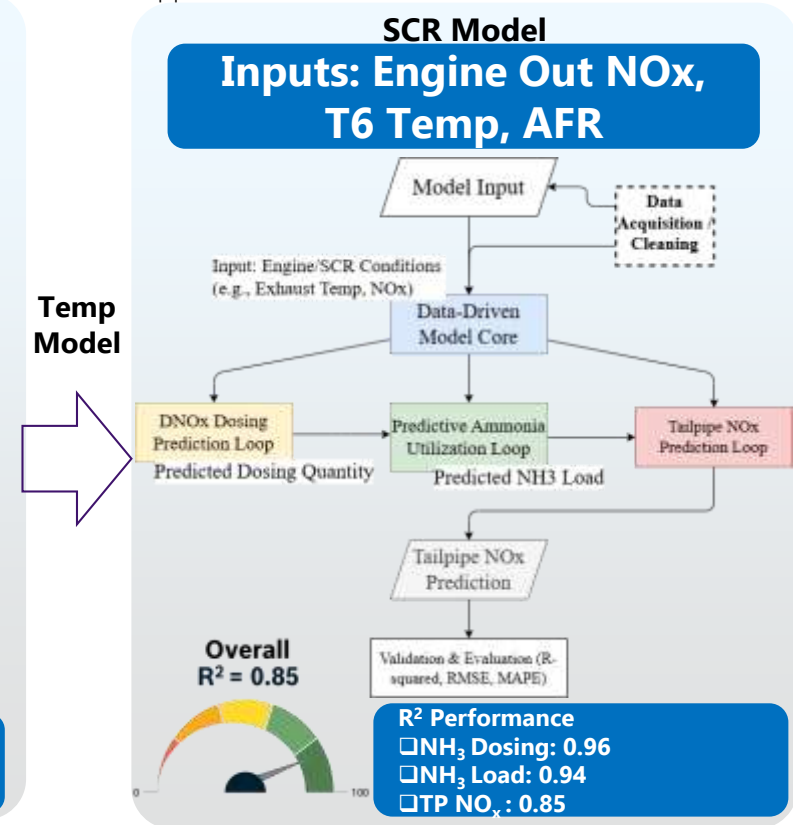
Traditional diagnostic approaches address existing problems. Potential to perform root cause analysis by emulating failure scenarios. The solution could troubleshoot field failures.



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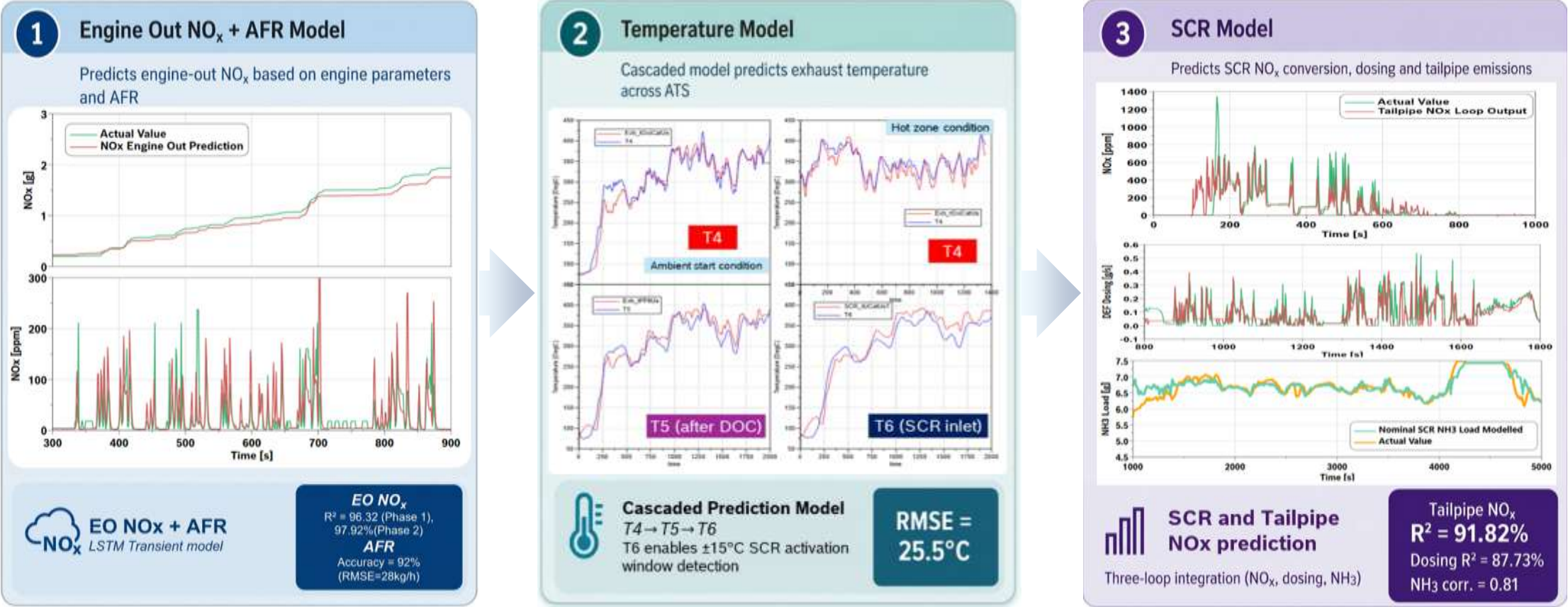
Data driven architecture

● Temperature Sensor
▲ NO_x Sensor



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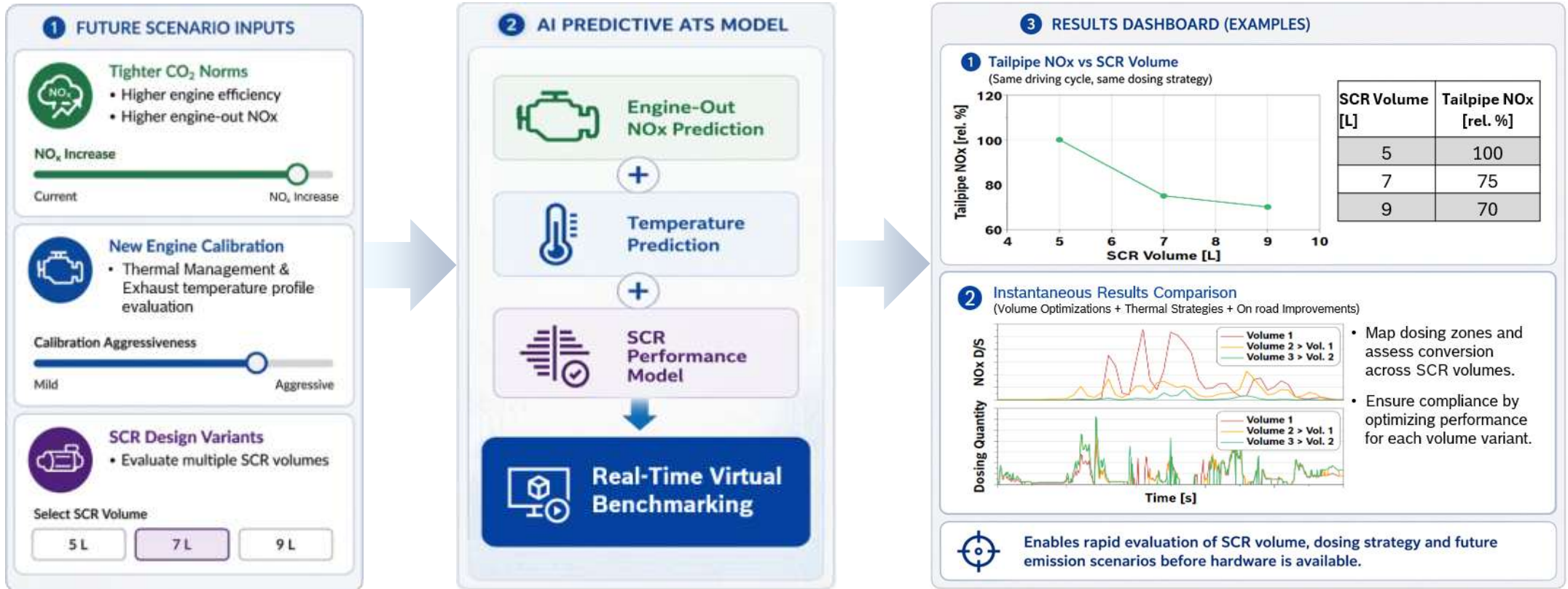
Results & validation



Model Performance Summary						
✓	NO _x Model	AFR Model	Temperature Model	SCR Model	Dosing Model	WHTC Compliance
	R ² = 97.92%	92% accuracy (RMSE = 28 kg/h)	RMSE = 25.5°C	(Tailpipe NO _x) R ² = 91.82%	R ² = 87.73%	Within 10%

Emission Prediction and ATS Performance Benchmarking

Use-Case: Virtual Evaluation of future emission scenarios w/ ATS design Tradeoffs



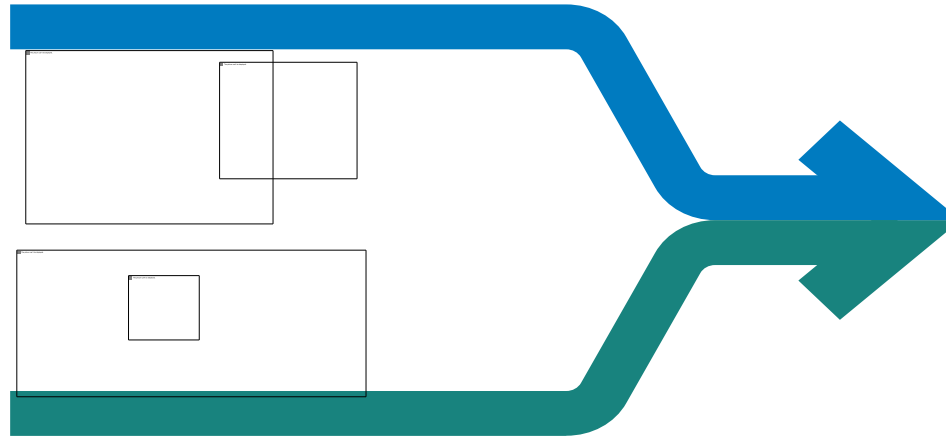
❑ Balancing aggressive calibration with optimized SCR volume and targeted dosing ensures compliance under elevated engine-out NOx conditions also considering preserving engine conditions.

Emission Prediction and ATS Performance Benchmarking Demonstration @ BMGE



Diesel Systems

Current BS6 Regulations,
bulky & complicated ATS
Systems



H2 ICE Systems

Lower Emissions
Simpler, efficient ATS

Lower NOx Emissions

Current Diesel Systems
operating @ $\lambda > 1$
Higher need for Dosing

Horizontal synergies

Existing Systems

Vertical synergies

Enable & improve upcoming Bosch offerings

H2ICE Benefits

- Optimized System Integration
- Improved run-time
- Reduced NOx
- Lower AdBlue Dosing
- Optimized SCR Volume

- ❑ Predict Diesel performance, quantify H₂ICE benefits in real time
- ❑ Accelerate development through AI-powered virtual benchmarking

Emission Prediction and ATS Performance Benchmarking

Future Scope

Employing parallel optimization strategies for improved Engine out NO_x prediction model.

Assessment and validation of DEF injection strategies and ATS configurations

Developing data informed predictive models for enhanced vehicle diagnostics

Accelerated virtual validation of SCR catalyst technology for broad spectrum of application scenarios

