

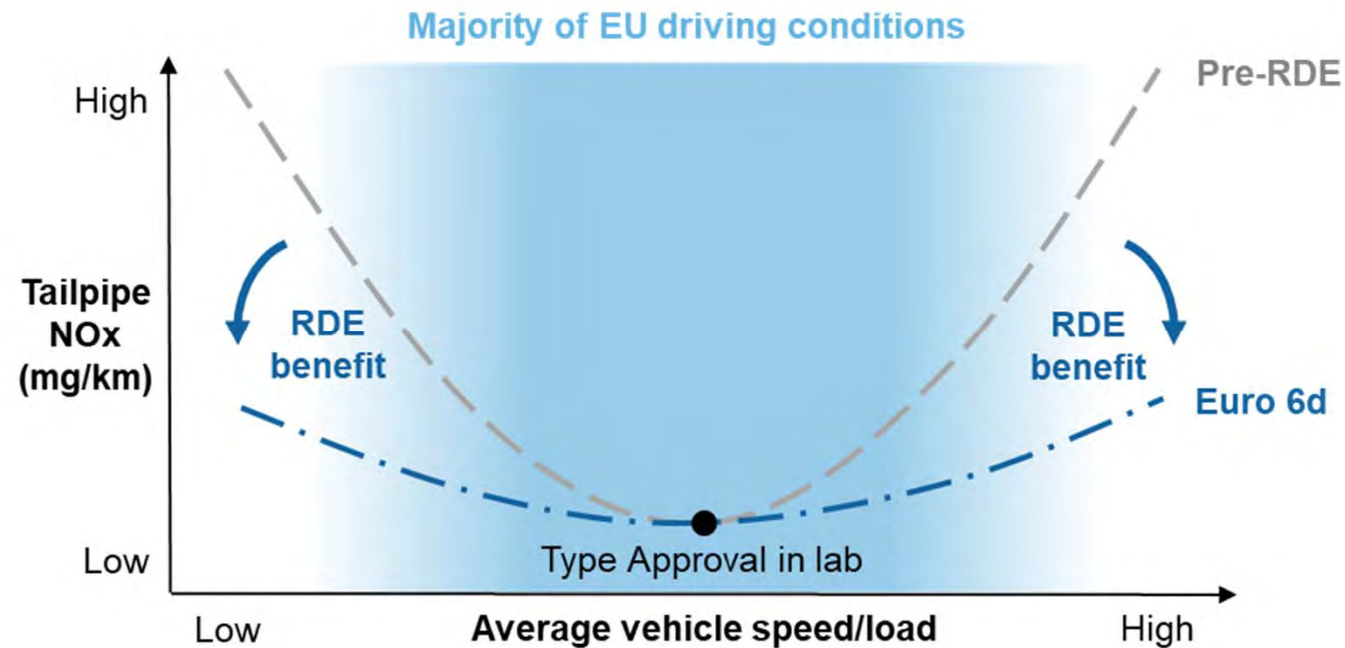
Ultra-low on-road NOx emissions of a 48V mild-hybrid diesel with LNT and dual-SCR

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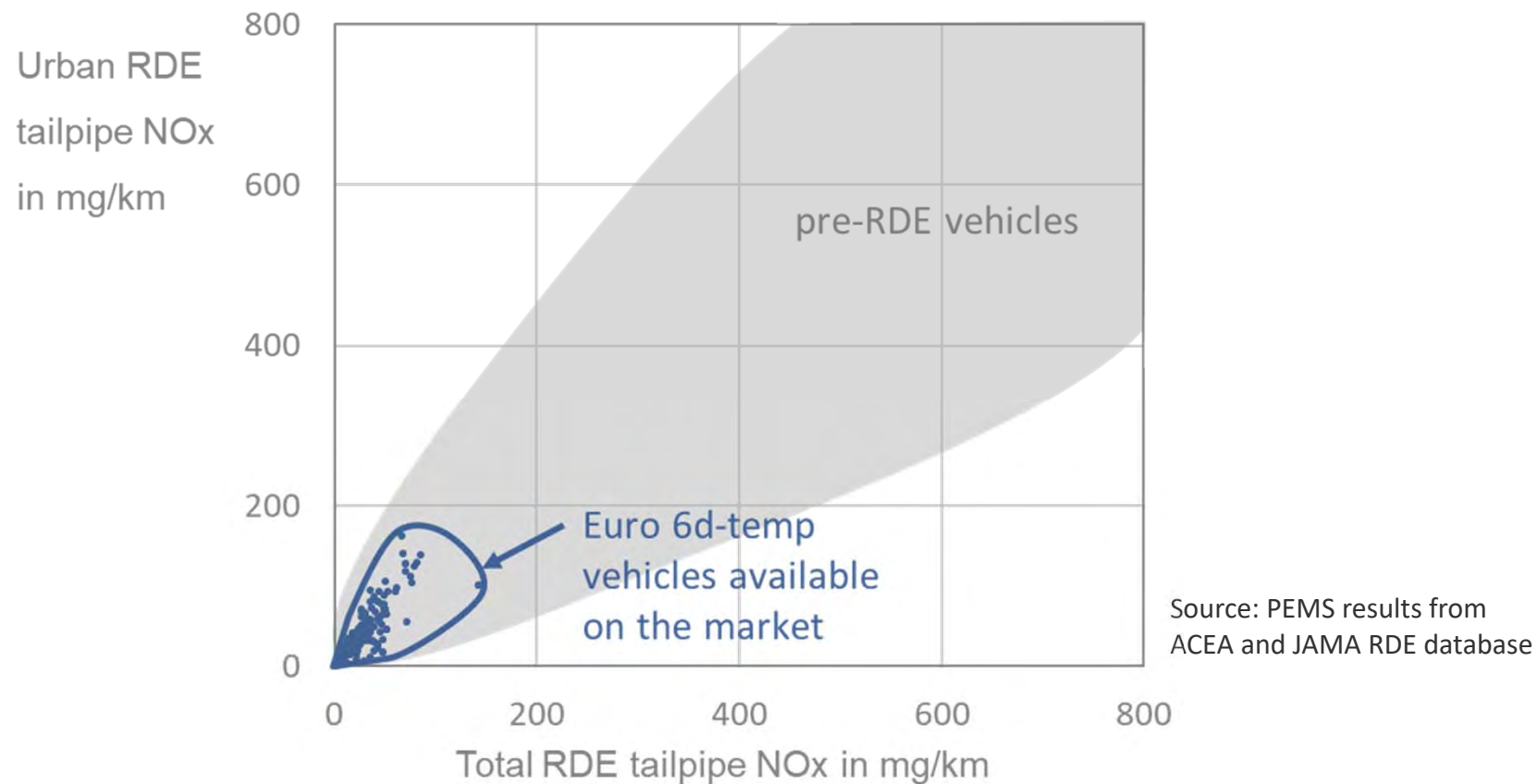
RDE legislation has improved real-world NOx emissions

- RDE requirements ensure that emissions are controlled over wider range of conditions



RDE legislation has improved real-world NOx emissions

- On-road emissions of Euro 6d-Temp cars are well within standards



Objective: demonstrate consistent low NOx emissions

➤ Challenging driving conditions

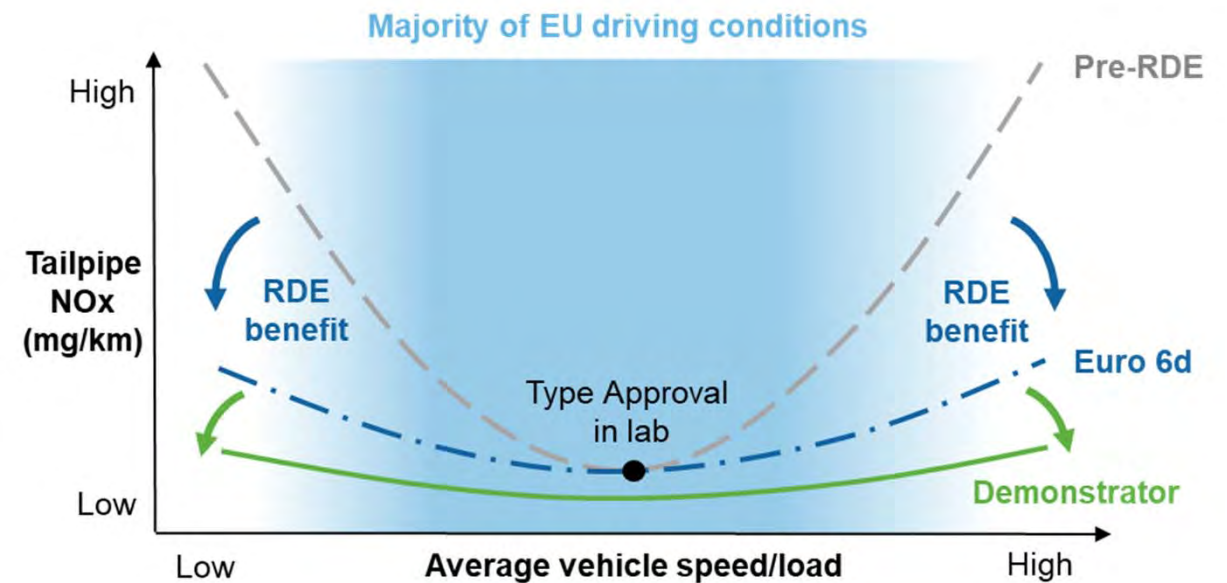
- Low speed/load
e.g. city driving



- High speed/load
e.g. motorway driving



- Transients
e.g. overtaking



Content

- Demonstrator concept
 - Emissions control technologies combined in integrated approach
 - 48V mild-hybrid to support emissions control
- Emissions tests conducted
- Tailpipe NOx and deNOx efficiency
 - RDE
 - City
 - Motorway
- Conclusions



Vehicle and powertrain characteristics

➤ Vehicle

- C-segment
- 1700 kg

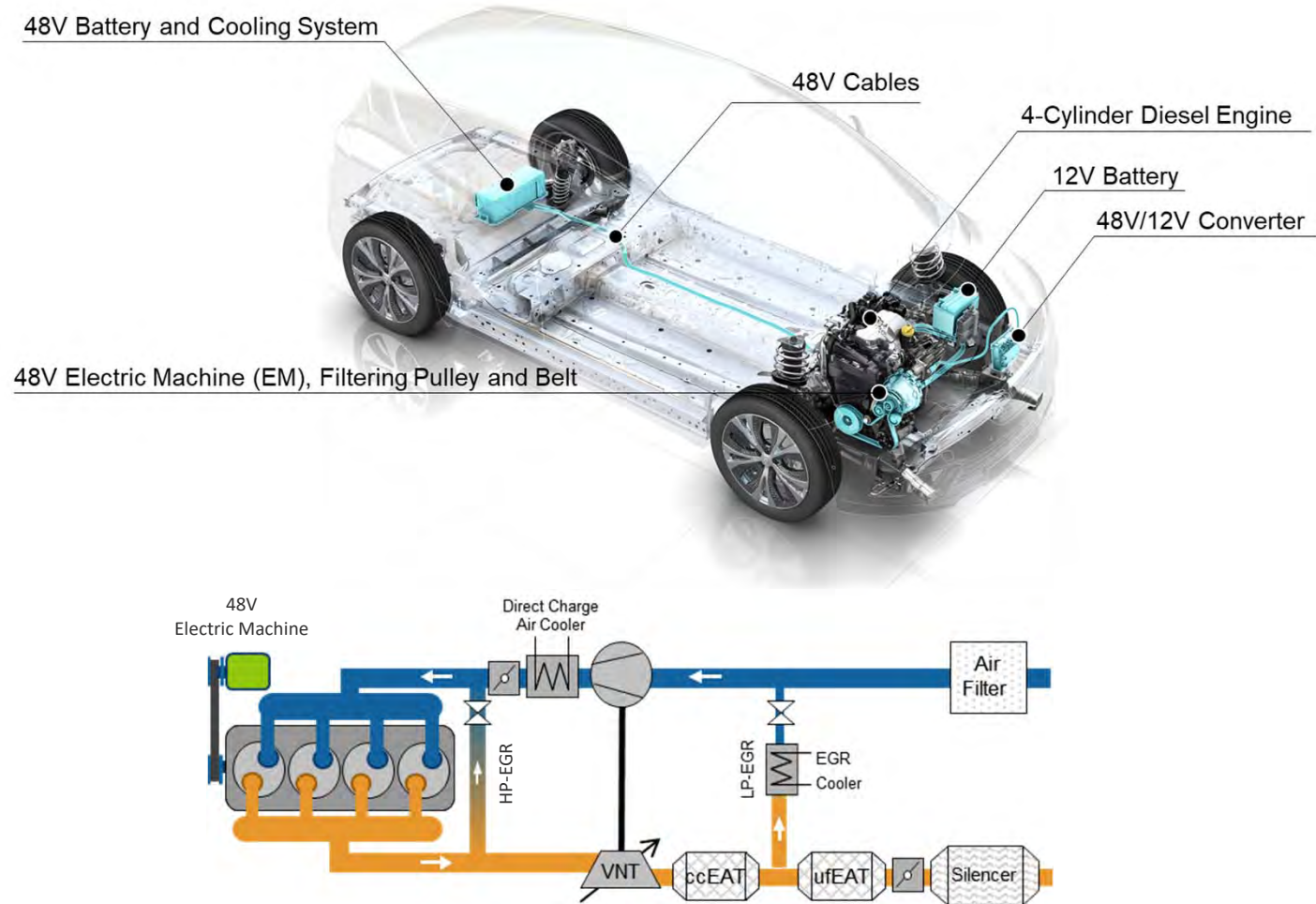
➤ Drivetrain

- Manual gearbox, 6-speed
- 48 Volt mild-hybrid (belt-driven, P0)

➤ Engine

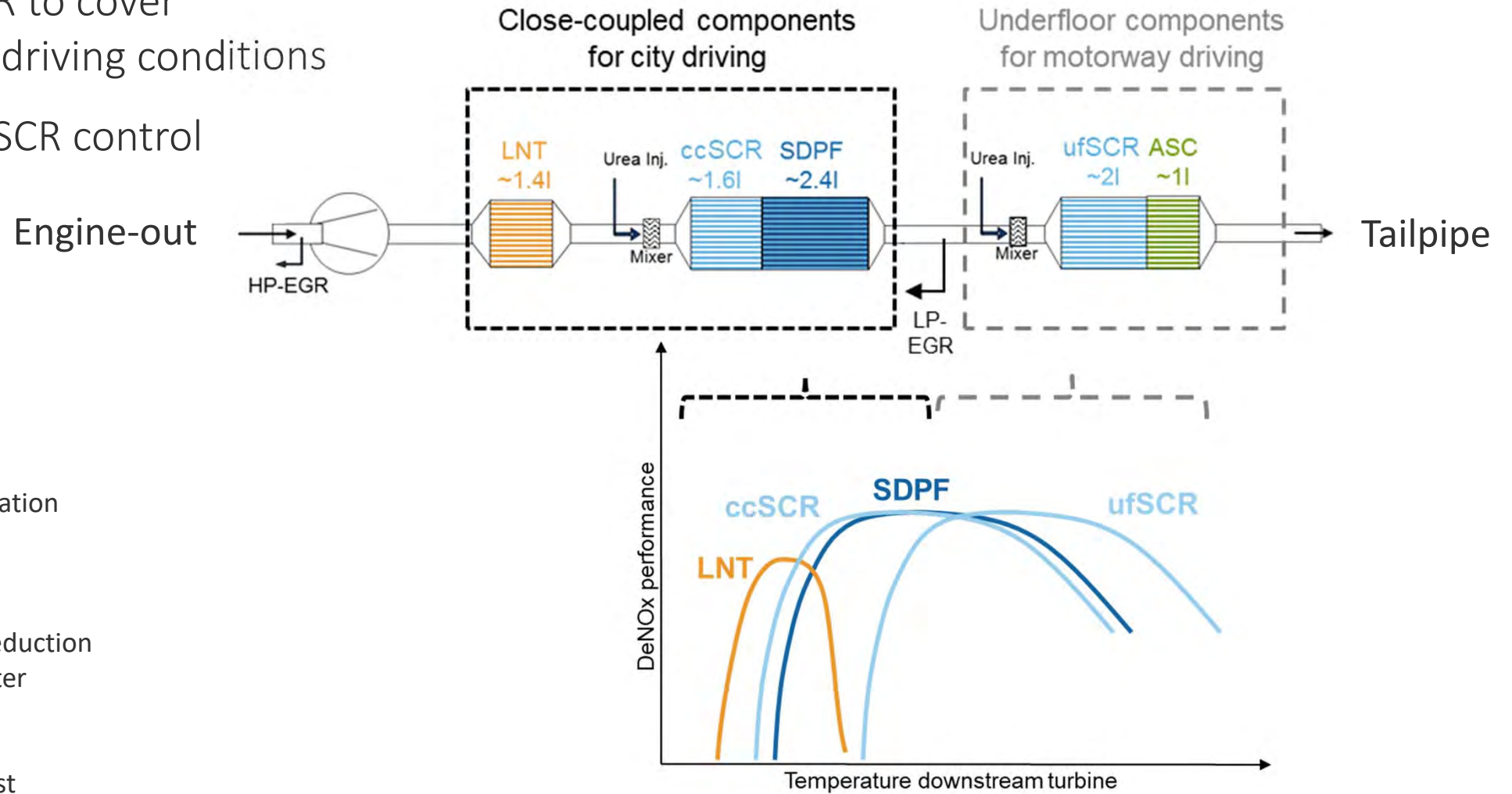
- 1.5l, 4-cylinder, 2-valve
- EGR: uncooled HP and cooled LP

➤ Euro 6b type approval (LNT + DPF)



Emissions control technologies

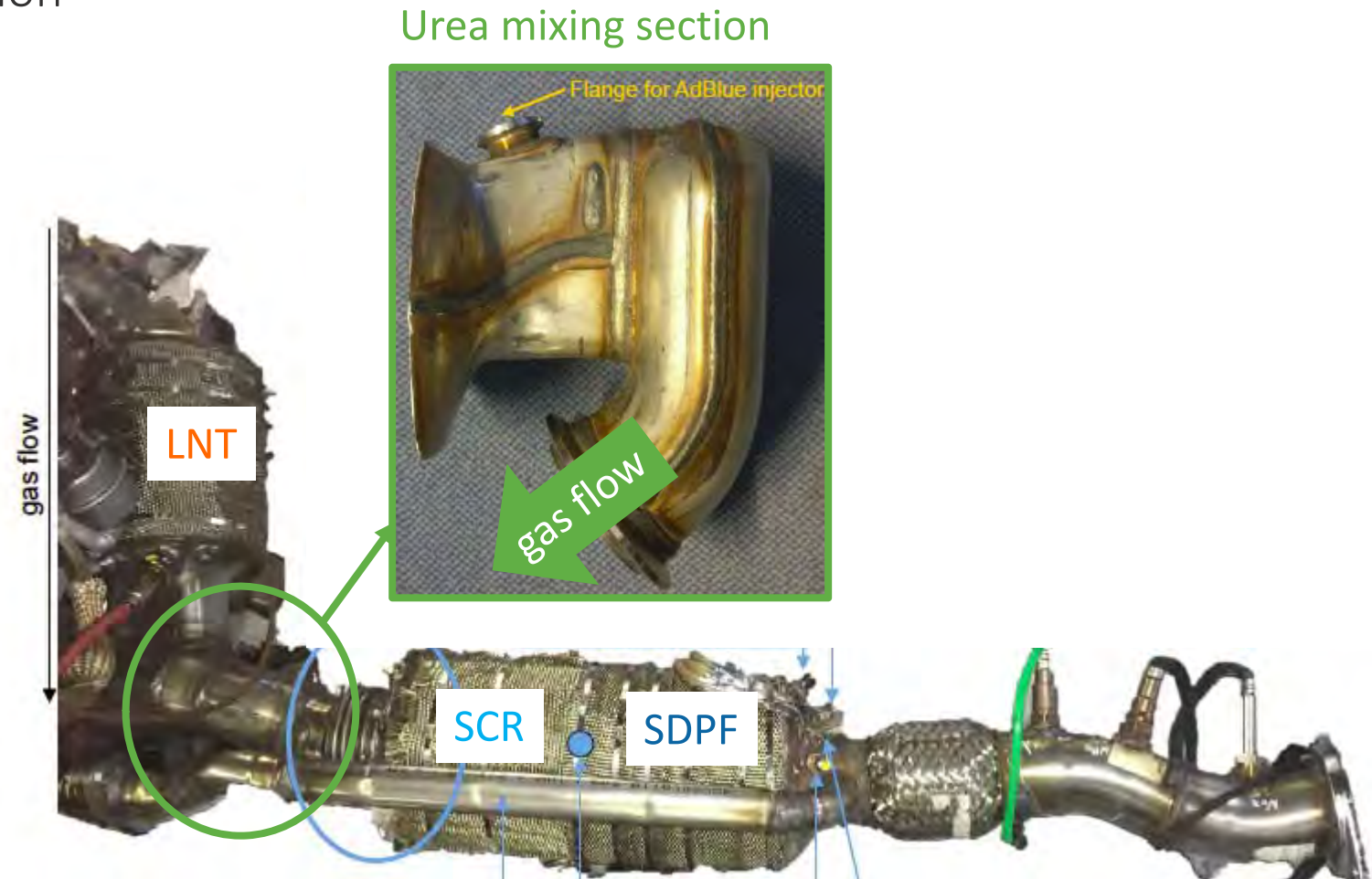
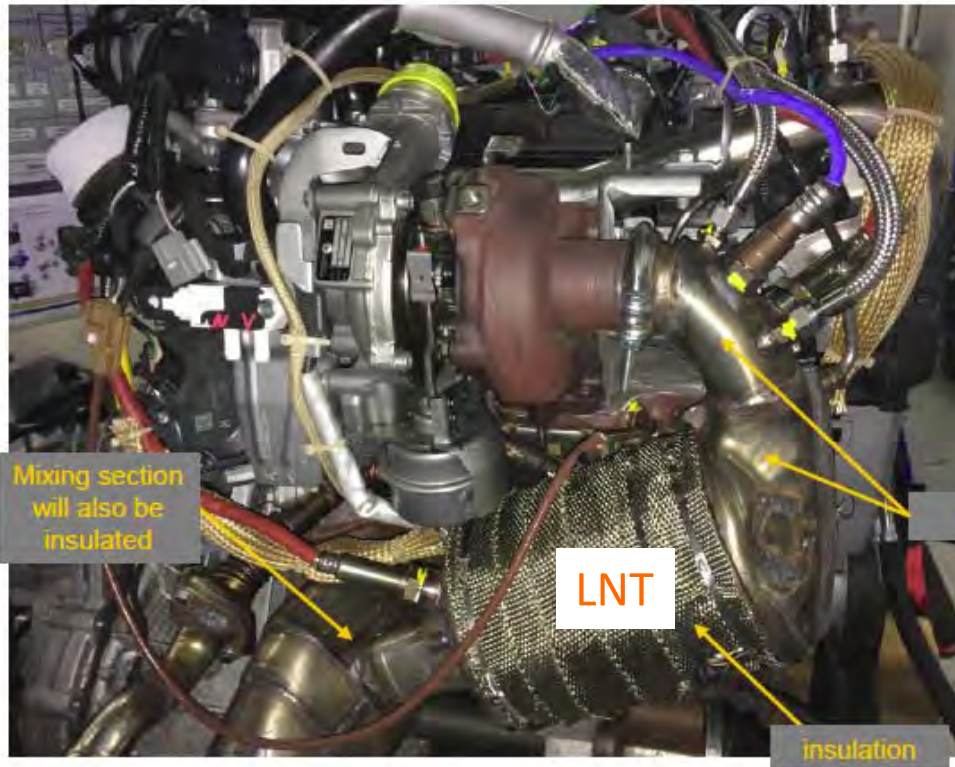
- LNT + dual-SCR to cover wide range of driving conditions
- Model-based SCR control



EGR: Exhaust Gas Recirculation
HP/LP: High/Low pressure
cc: close-coupled
LNT: Lean NO_x trap
SCR: Selective Catalytic Reduction
DPF: Diesel Particulate Filter
SDPF: SCR on DPF
uf: underfloor
ASC: Ammonia Slip Catalyst

Emissions control technologies

➤ Components in close-coupled position



48V mild-hybrid support to emissions control

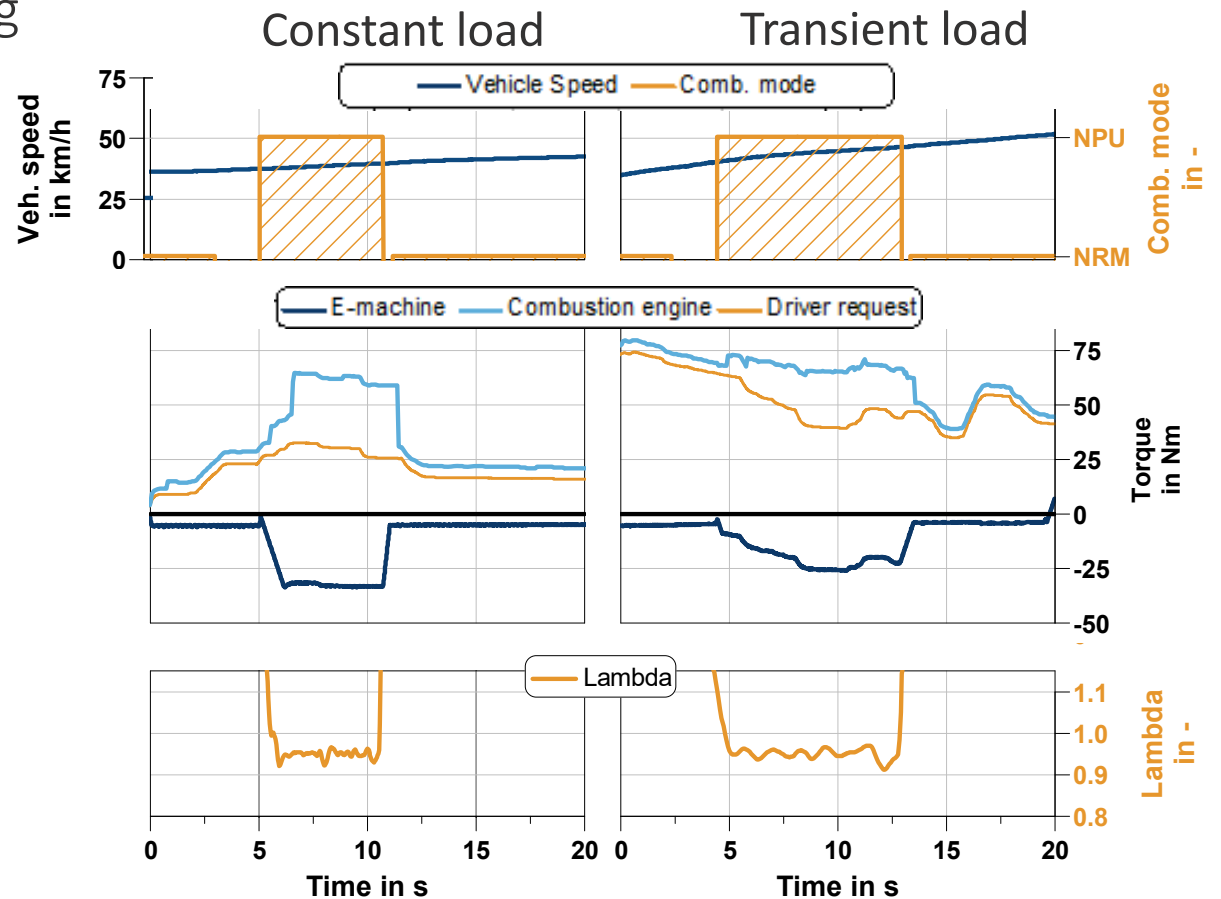
➤ To stabilise LNT regeneration during city driving

- Constant load increase
in case of low load conditions
- Transient load compensation
in case of unstable driver request

➤ To cut transient engine-out NO_x peaks

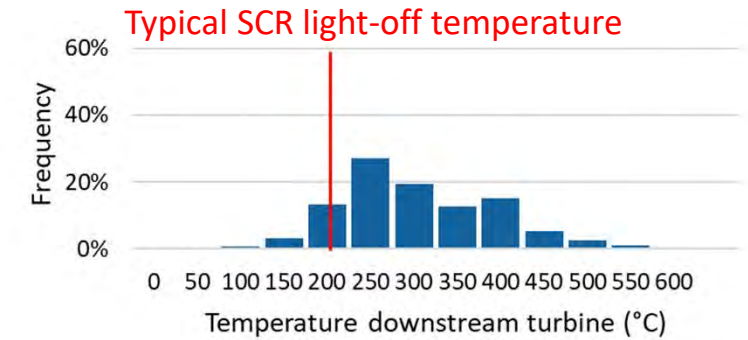
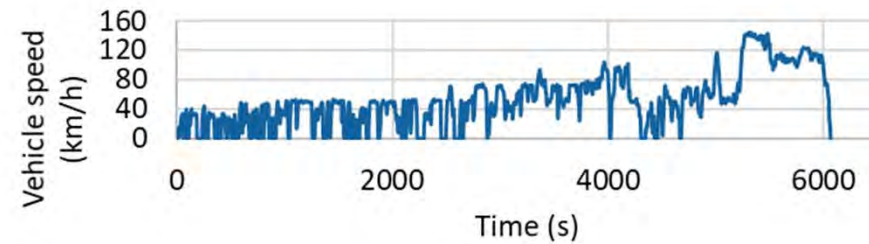
➤ To support active thermal management

- In addition to late post-injection in ICE
when $LNT > 170^{\circ}\text{C}$ & $ccSCR < 220^{\circ}\text{C}$
- Throttle valve used when $LNT < 170^{\circ}\text{C}$

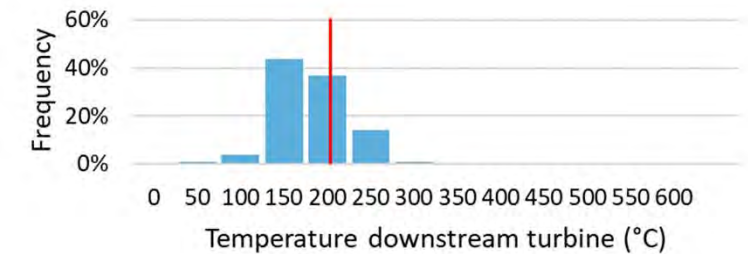
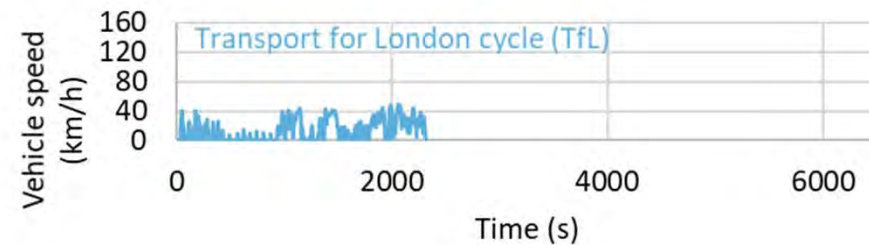


Combination of emissions tests on the road and in the lab

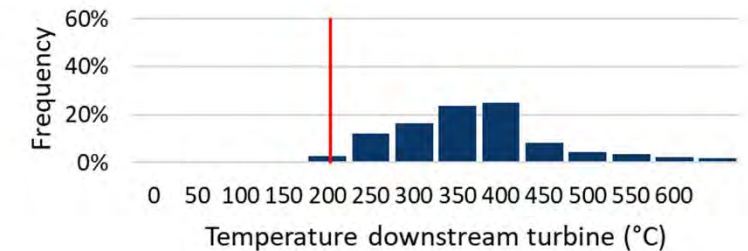
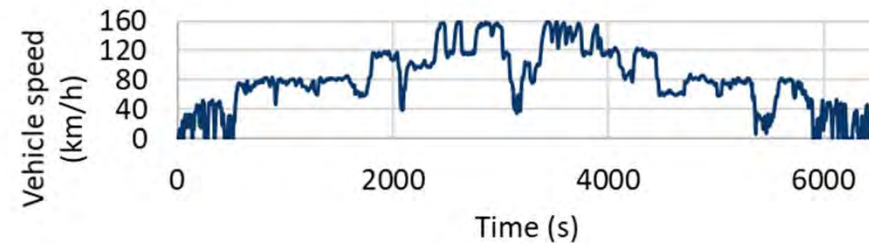
➤ RDE



➤ City

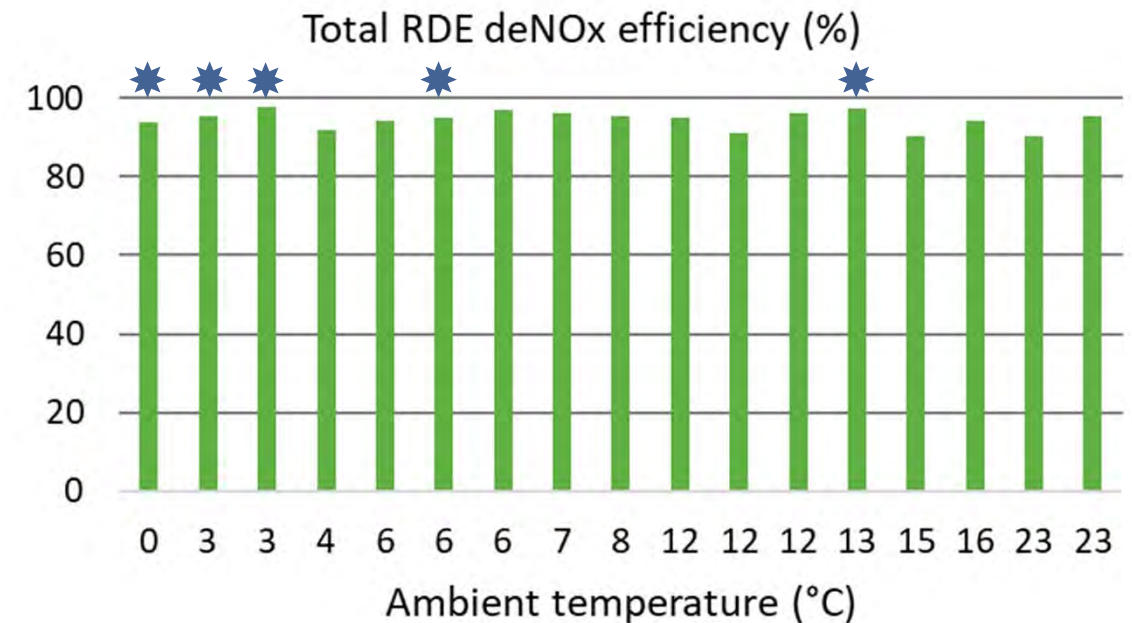
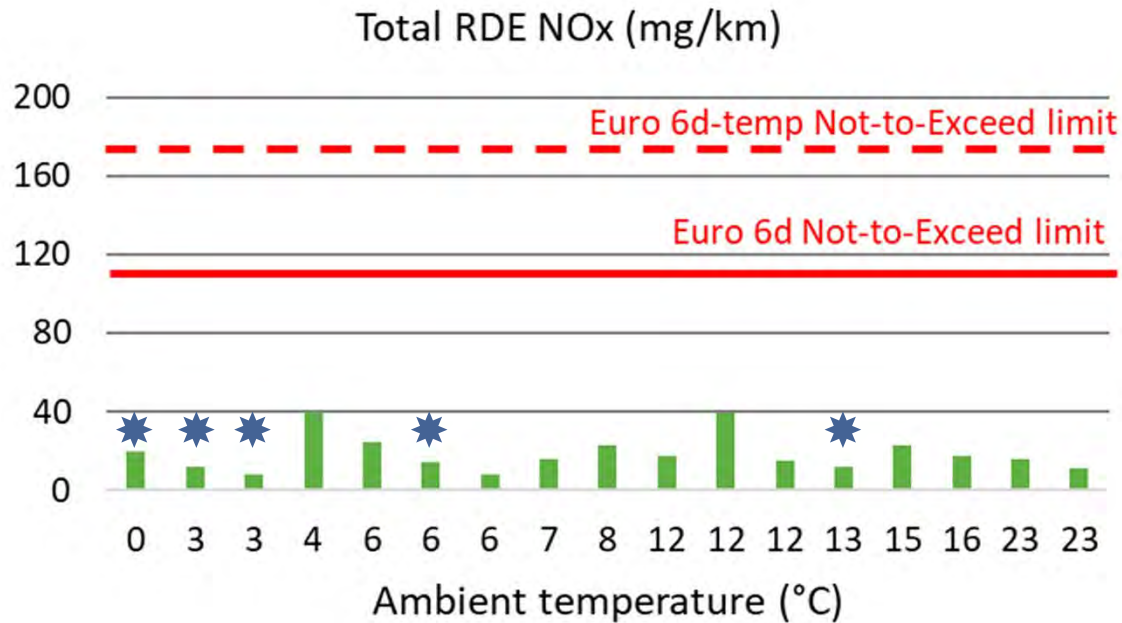


➤ Motorway



8-40 mg/km achieved on RDE

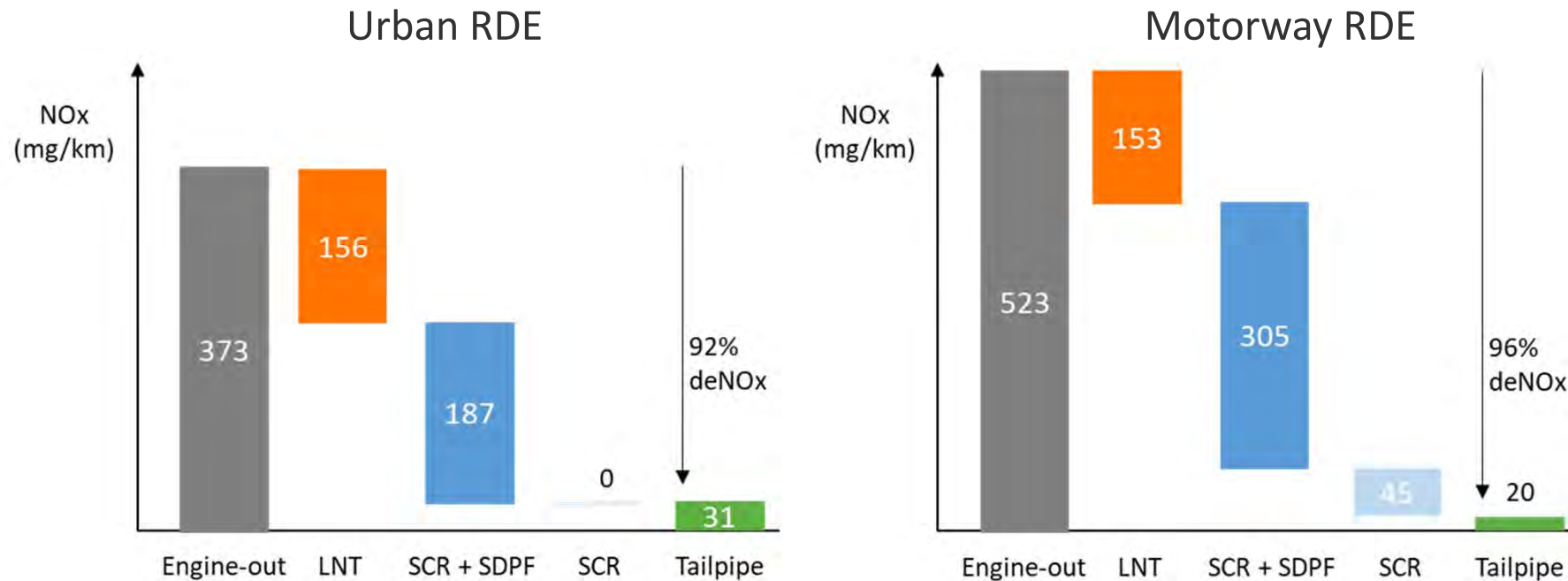
- 90-96% deNO_x efficiency
- No impact of ambient temperature



★ Results at end of programme with refined calibration

All aftertreatment components contribute to NOx control

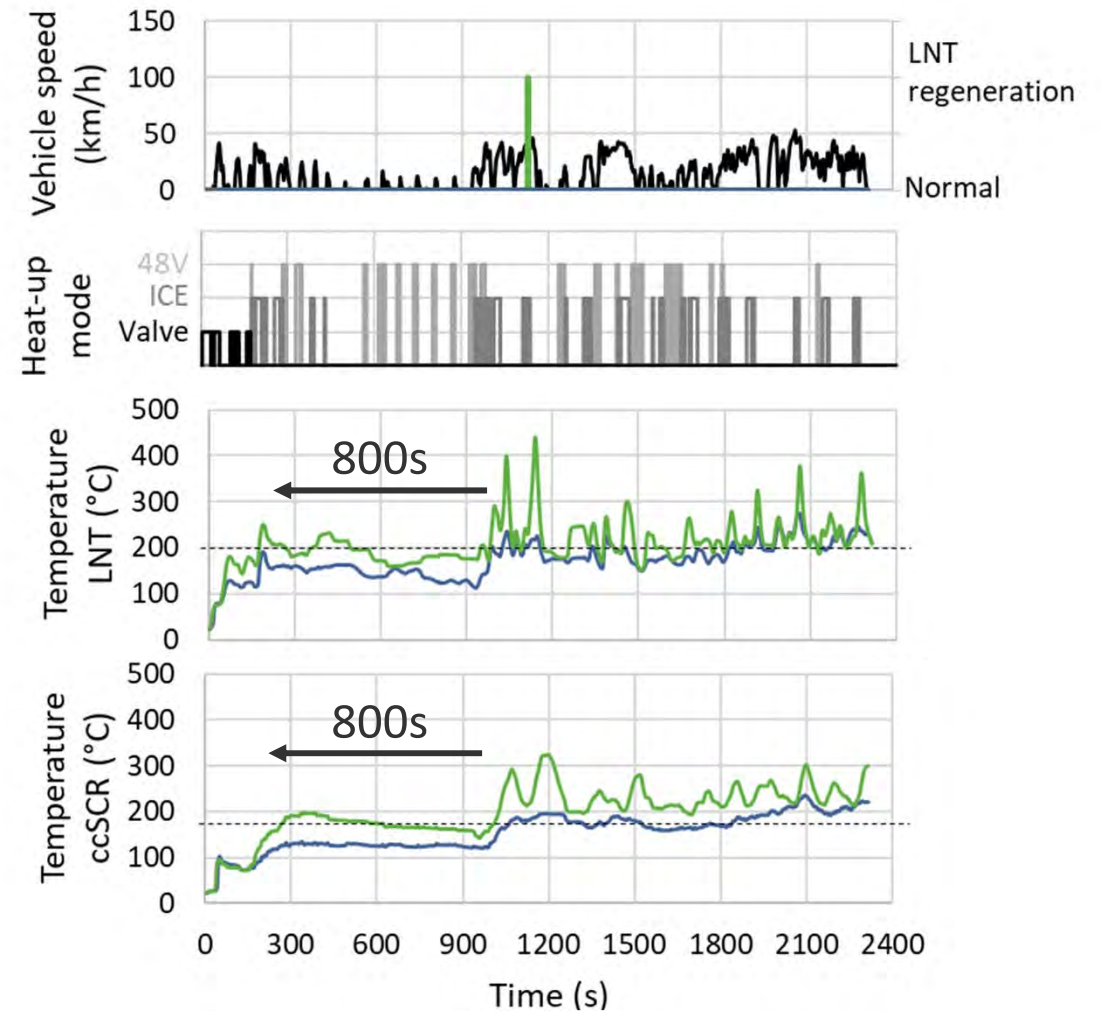
- City driving: LNT and close coupled SCR+SDPF
- Motorway driving: underfloor SCR required to secure robust emissions control



Robust NOx control in the city, including cold-start

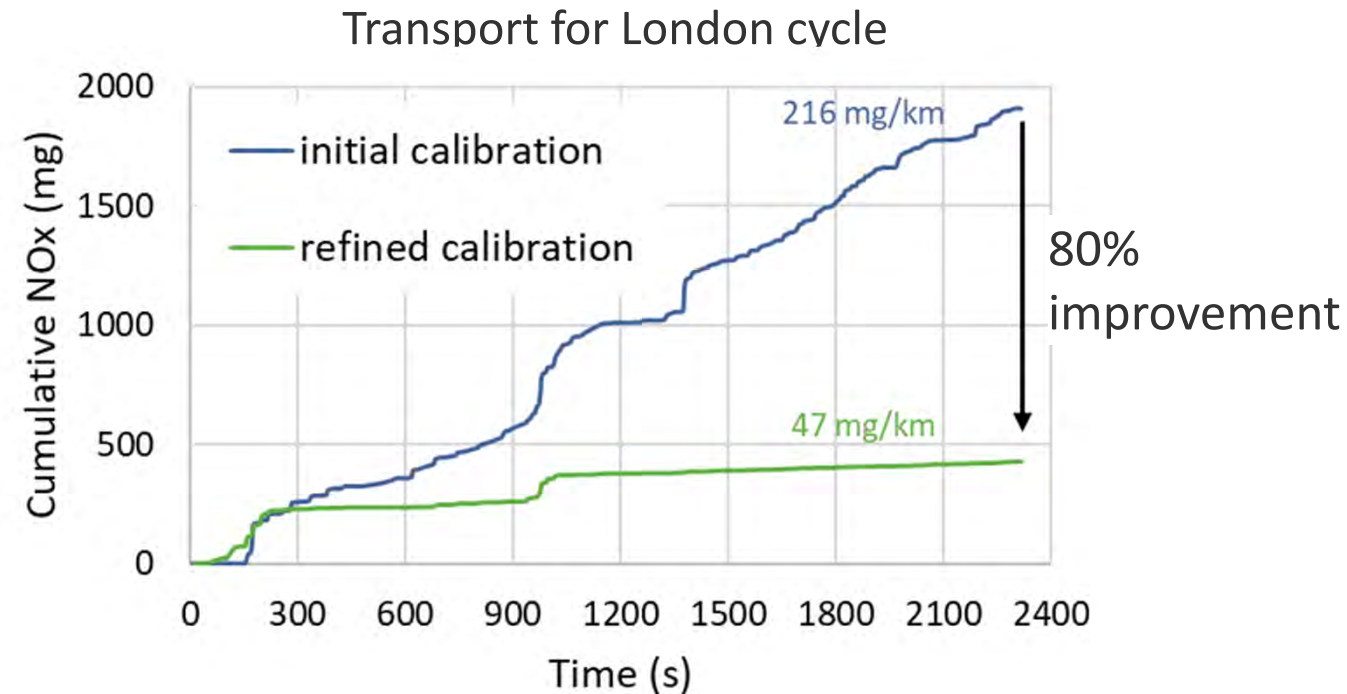
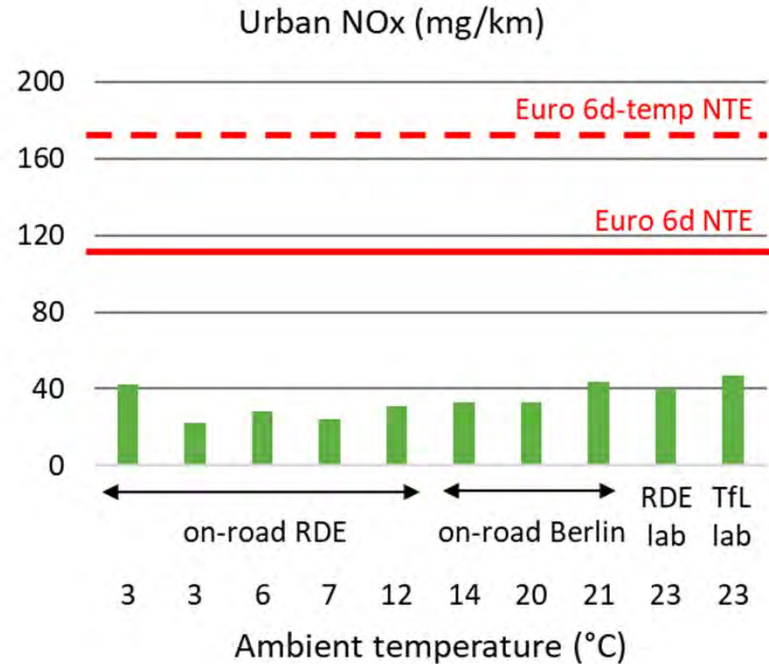
- LNT regeneration enabled at low load
- Active thermal management to ensure early heat-up
 - Active throughout entire TfL test
 - Typical light-off temperature reached within 300s after cold-start (800s gained)

Thermal management:
Initial calibration: not active
Refined calibration: active



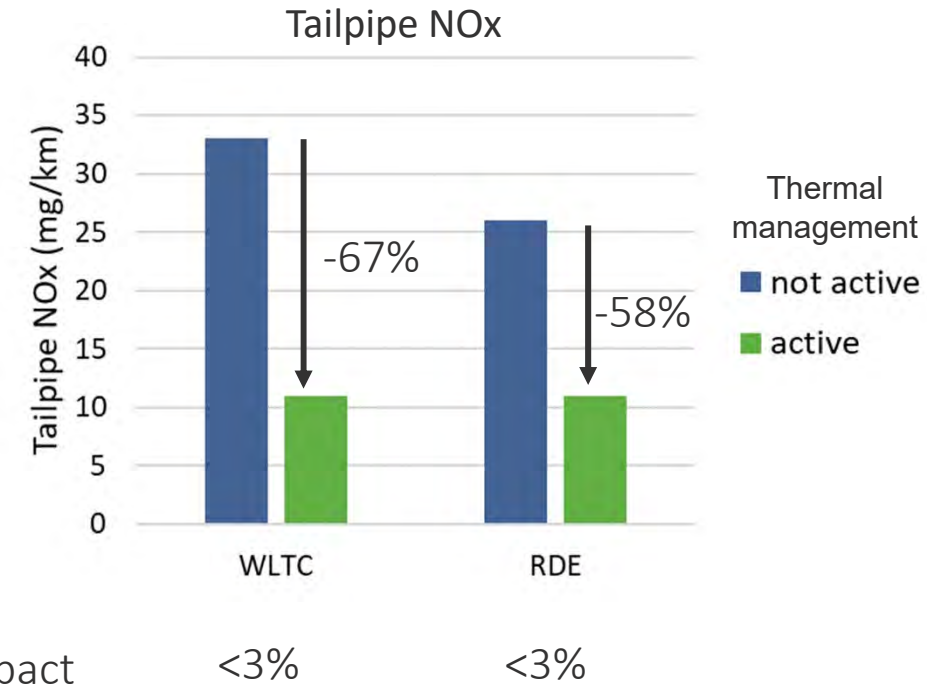
24-47 mg/km NO_x in the city

- Including challenging Berlin and Transport for London (TfL) tests
- TfL NO_x: 80% improvement due to LNT regeneration stabilisation and active thermal management



Ultra-low NOx achieved with low impact on CO₂

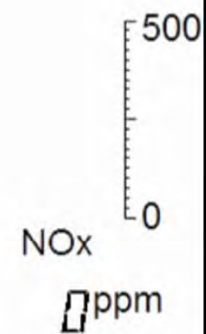
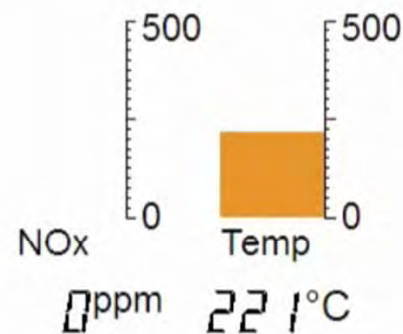
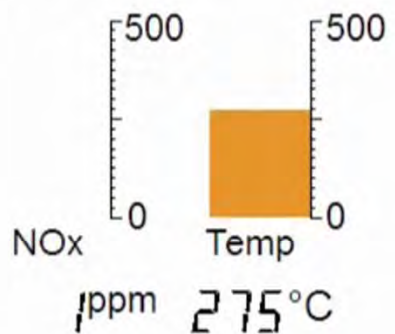
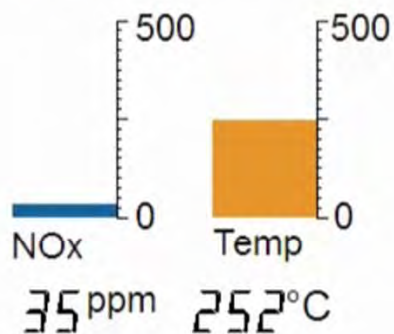
- Impact of thermal management implemented
 - CO₂ increase on WLTC and RDE < 3%
- Other technologies are under development for thermal management with minimal CO₂ impact
 - Variable Valve Train (VVT) [1-2]
 - Electrically heated catalyst [3-4]
 - Fuel injection rate shaping [5]
 - P2 / P3 / P4 Hybridisation [6]



1. Brauer (IAV) „Schaltbare Ventiltriebselemente in Dieselmotoren als Beitrag zur Erfüllung der RDE-Gesetzgebung“, 9th Emission Control Conference, Dresden 2018
2. Lückert (Daimler) “OM 656 – The New 6-Cylinder Top Type Diesel Engine of Mercedes-Benz”, 26th Aachen colloquium 2017.
3. Hartland (JLR) “Exhaust Gas Aftertreatment System to meet Future Low Emissions Requirements”, 5th MinNOx Conference, Berlin, 2014
4. Avolio (Continental) “Super Clean Electrified Diesel: Towards Real NOx Emissions below 35 mg/km.” 27th Aachen Colloquium 2018.
5. Brauer (IAV) „Vorteile der Einspritzverlaufsformung für den Kraftstoffverbrauch und die Schadstoffemission von Dieselmotoren“, Tagung Diesel- und Benzindirekteinspritzung, Berlin 2010
6. Bunar (IAV) “Exhaust Aftertreatment Systems for Hybridized Diesel Powertrains in RDE Context”, in 7th MinNOx Conference, Berlin 2018



Engine load: 11% Vehicle speed: 0 km/h



Engine
heat-up

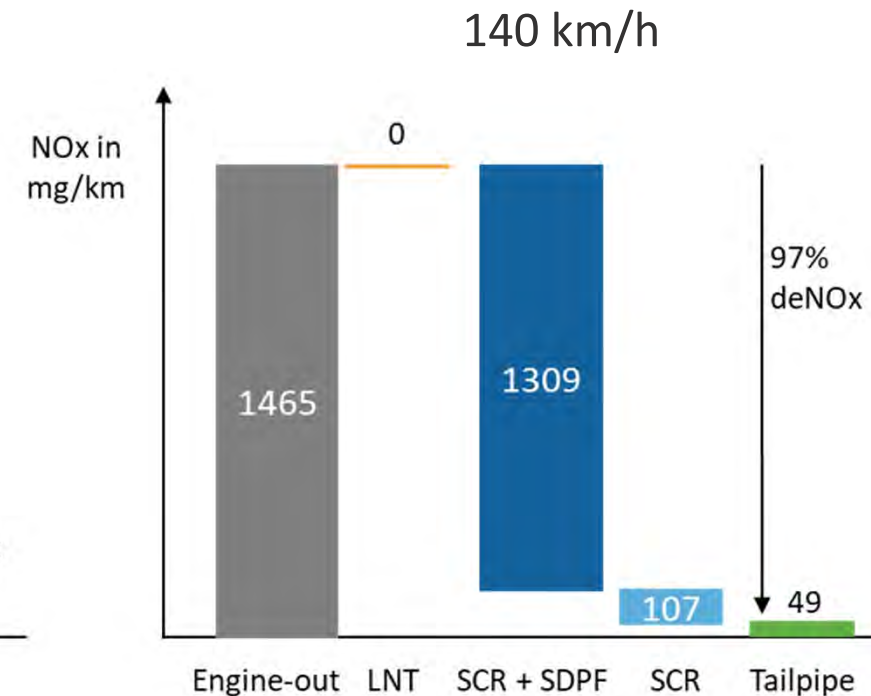
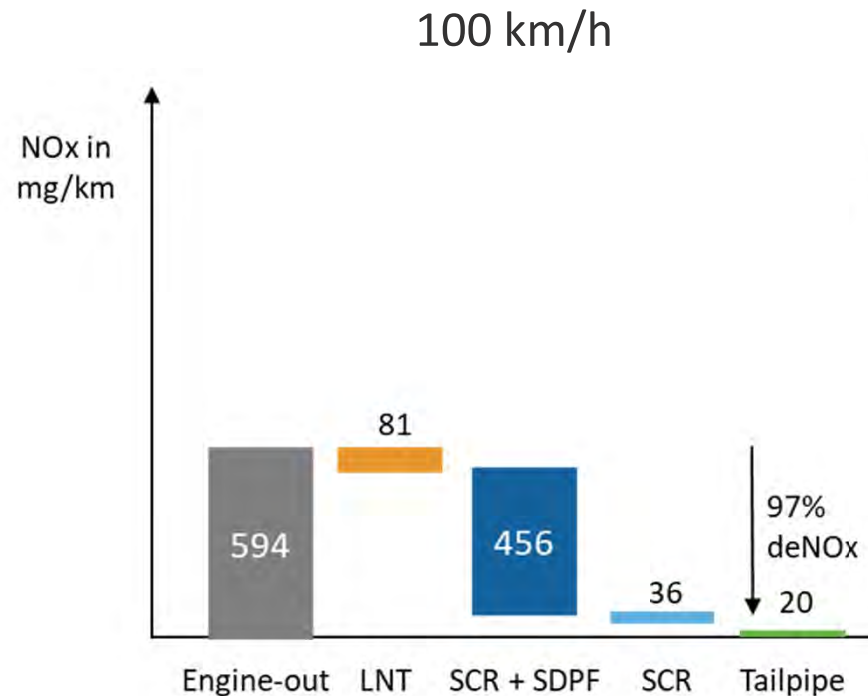
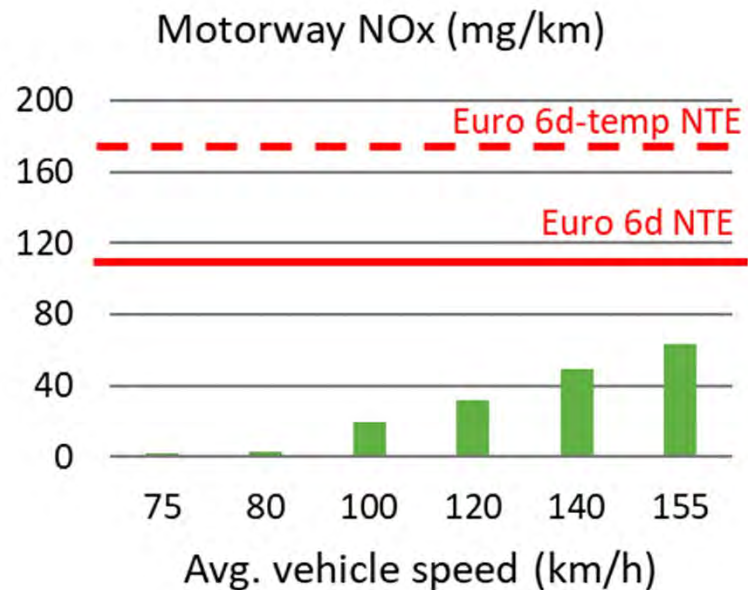
LNT
regeneration

Urea
doser 1

Urea
doser 2

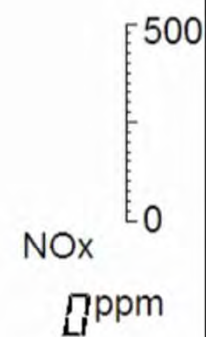
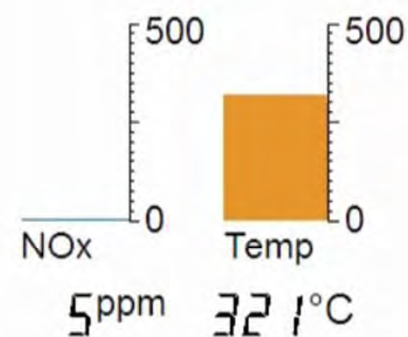
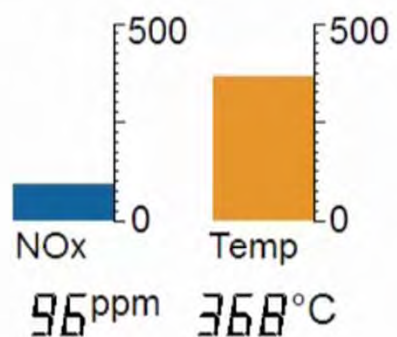
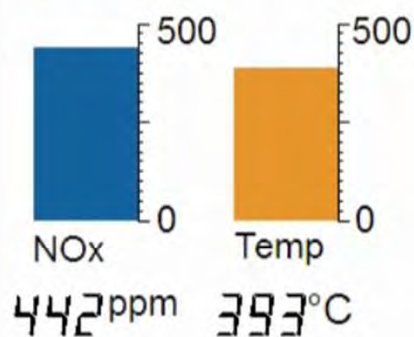
3-63 mg/km on the motorway

- 95-99% deNO_x efficiency
- Main deNO_x by dual-SCR
- Challenge is increase in engine-out emissions





Engine load: **57%** Vehicle speed: **118** km/h



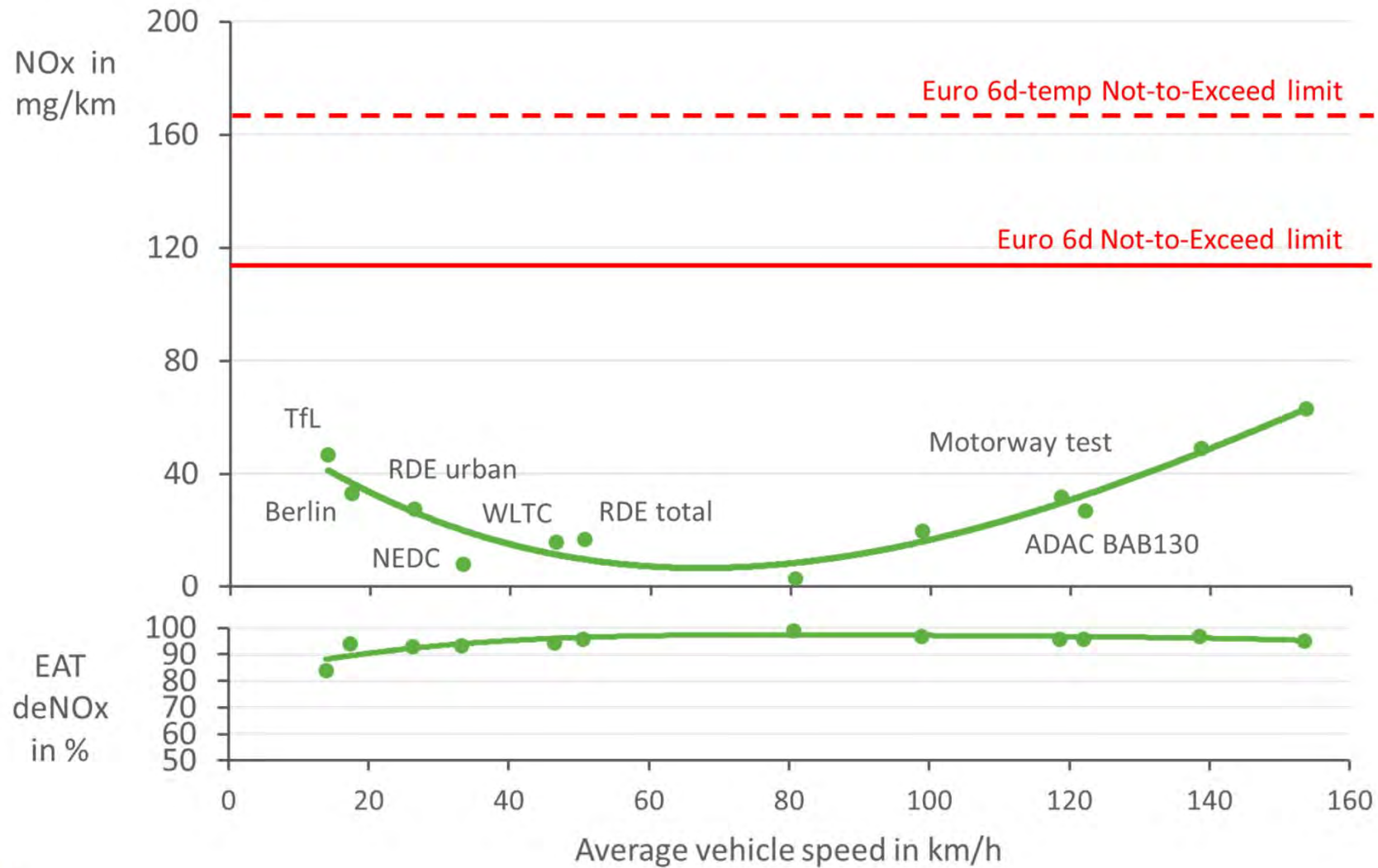
Engine
heat-up

LNT
regeneration

Urea
doser 1

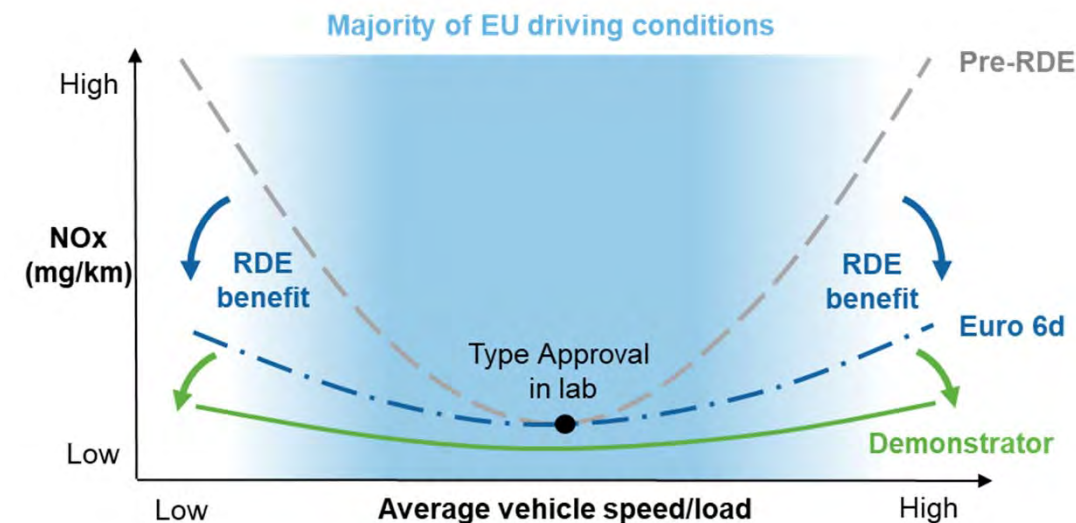
Urea
doser 2

Tailpipe NOx and deNOx efficiency summary



Conclusions

- RDE requirements have ensured better control of NOx emissions under most EU driving conditions – these Euro 6d-temp cars are on the road today.
- This demo car shows that diesel NOx emissions can be kept at a very low level in a consistent way, over a wide range of driving conditions.
- Tailpipe NOx measured are 24-47 mg/km in the city and 3-63 mg/km on the motorway.
- This is achieved by combining existing catalyst technologies with improved emissions control functions supported by hybrid technology.



THANK YOU !

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