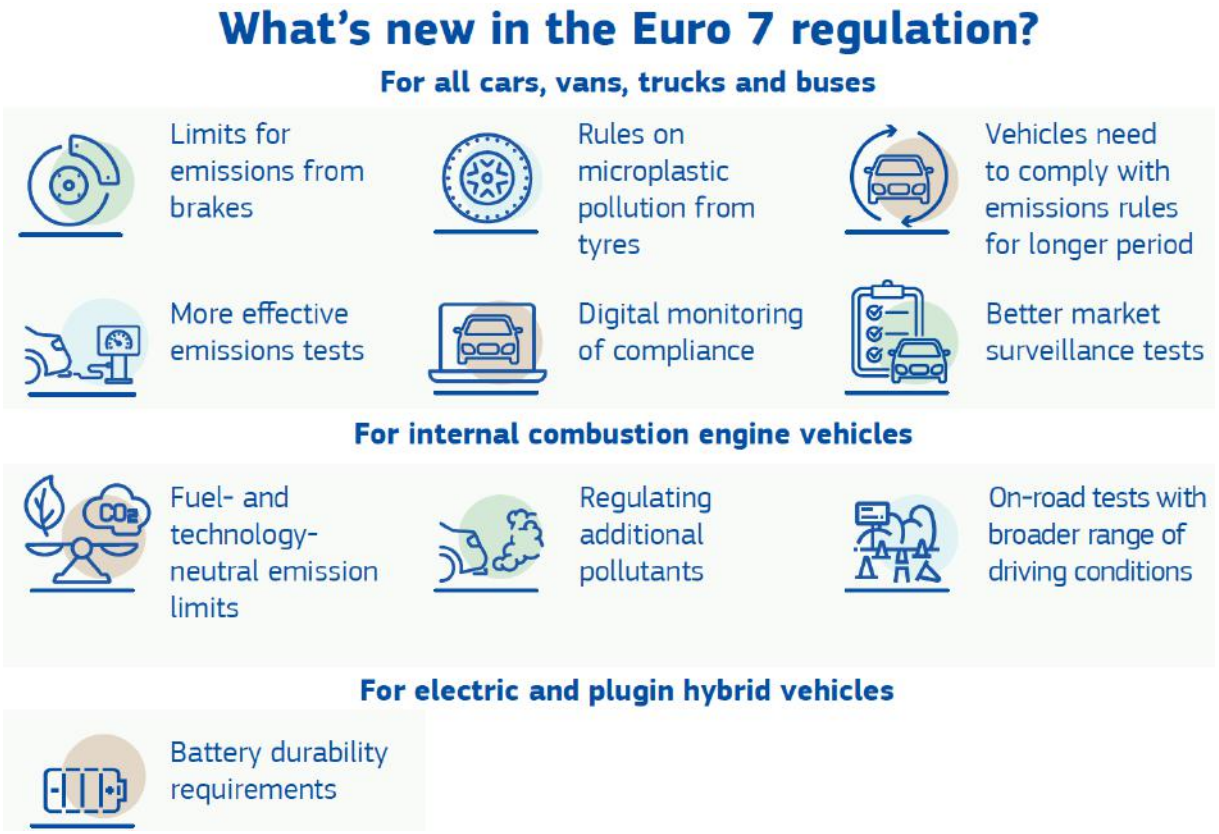
Innovative Aftertreatment Systems for Heavy Duty Applications to fulfill future demands

ECT 2023 Conference

3rd November 2023

Dr. Georg Hüthwohl (MD Albonair GmbH)

European Commission: EU 7 proposal - overview



Lower emissions of the fleet by 2035 compared to EU 6/VI		
Reduction of	**trucks/busses**	**cars/vans**
NOx emissions	> 56 %	> 35 %
tailpipe particles	> 39 %	>13 %
brakes particles	> 27 %	

- **Technology and fuel neutral**
- **Commission's proposal in discussion: European Parliament and European Council**
- **Implementation proposal: 2025 for cars/vans, 2027 for trucks/busses**
- **due to personnel restructuring: several changes seem possible, even to omit EU 7 and extend EU VI instead**

EU 7 Legislation Process – Nox Emission Proposals

10. Nov 2022
EU Commission's EU 7 proposal

	cold emissions (mg/kWh)	hot emissions (mg/kWh)	budget for trips < 3*WHTC long (mg/kWh)	Optional idle limits (mg/h)
NOx	350	90	150	5000

It is unpredictable how EU Parliament will decide on proposals.

ACEA, lobby of truck manufacturers vote for no significant changes,
NGO and supplier organisation CLEPA vote for strict limits as proposed by the EU Commission.

25. Sept. 2023
Council's General Approach

	WHSC/ WHTC	RDE
NOx (mg/kWh)	230	300

12. Oct. 2023
ENVI Committee adopted proposal

	WHSC/ WHTC	RDE
NOx (mg/kWh)	230	345

9. Nov. 2023
EP plenary vote on ENVI report

Timetable not to scale

Next steps

Q4 2023
Trilogues

Q1 2024
first reading agreement

Q2 2024
Translation, formal adoption

Negotiation between **EU council** and **EU Parliament** on EU 7 to reach a provisional agreement on a legislative proposal. Moderated and mediated by **EU Commission**.

EU Commission: executive branch of the European Union (EU), independent from governments, accountable to the EU Parliament.
EU Council: Consisting of the Heads of State or Government of the EU Member States
EU Parliament: directly elected EU body
ENVI: Parliament's Committee on the Environment, Public Health and Food Safety

Basic Technology to meet EURO 7

add. close-coupled catalyst and urea injection

- higher NOx conversion rate and faster light-off under cold-start/low-load conditions
- Dual Dosing increases system complexity
- Packaging is an issue

vanadium-based catalysts

- several OEMs are considering using vanadium-based catalysts (EU VI: Cu-zeolite)
- simpler chemistry: cheaper and minimizes N_2O formation
- suitable, low-cost alternative to copper catalysts for the close-coupled SCR stage, where the exhaust temperature is easier to control than in a post-filter location.
- Better durability if high temperatures are avoided

external exhaust heating

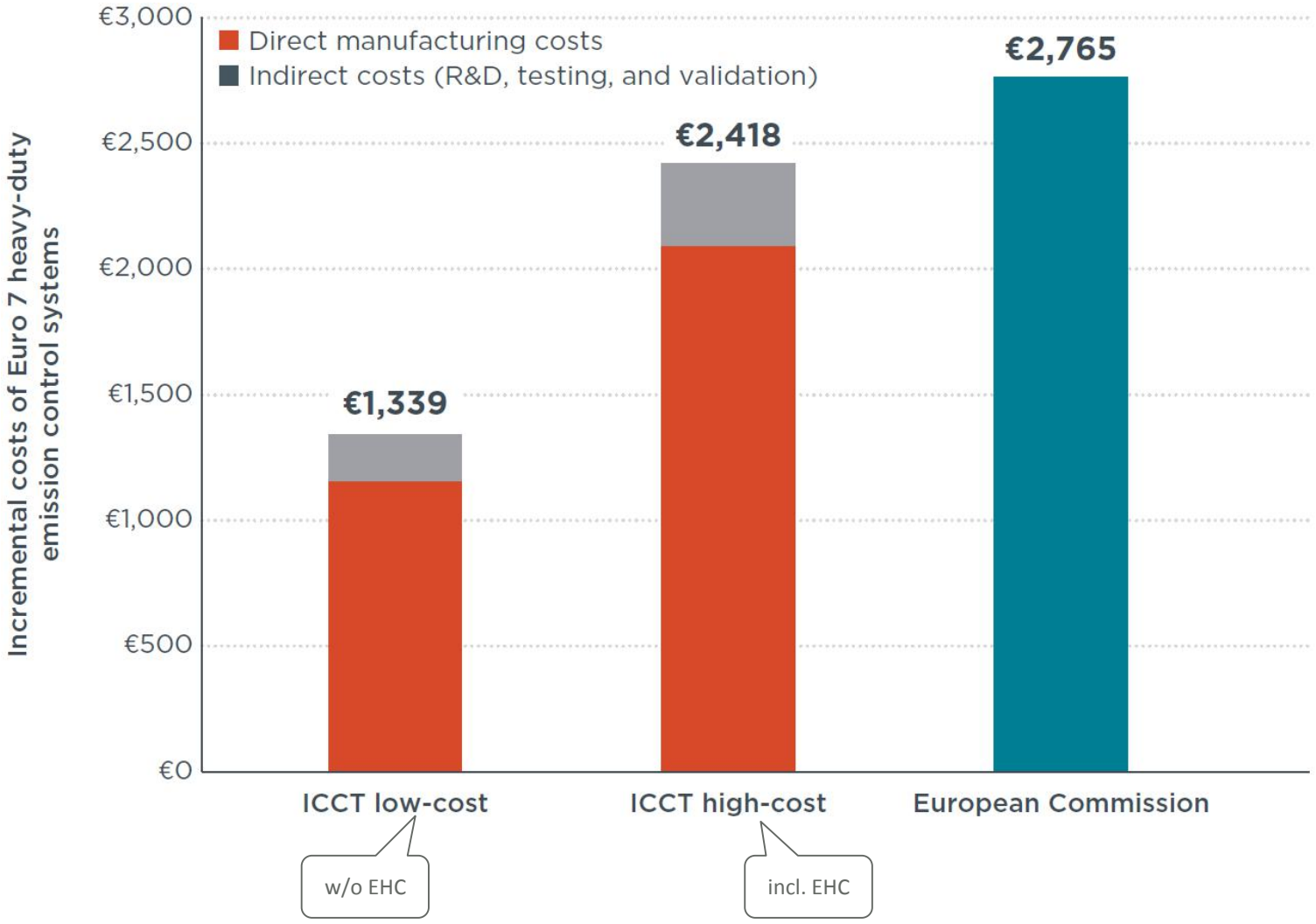
- accelerates SCR warm up to the light-off temperature
- reduces the need for larger catalyst volumes, increased catalyst loading, or advanced urea injection strategies
- Electrically Heating may force 48 V systems
- Burner Systems require an Air Blower which makes the system complex
- Catalytic Heating gives high power supply

ultra-high filtration DPFs

- Enhanced design is required to increase the filtration efficiency especially for an unloaded DPF while ensuring only a small drop in pressure across the filter, to avoid a CO_2 penalty

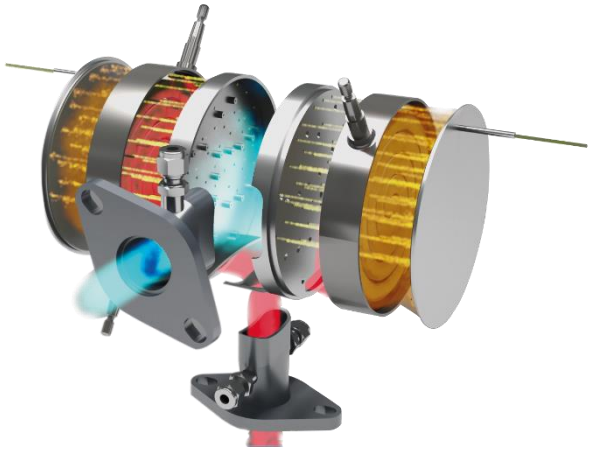
Source:
P.-L. Ragon, Estimated cost of diesel emissions control technology to meet future Euro 7 standards for heavy-duty vehicles, ICCT, 2023

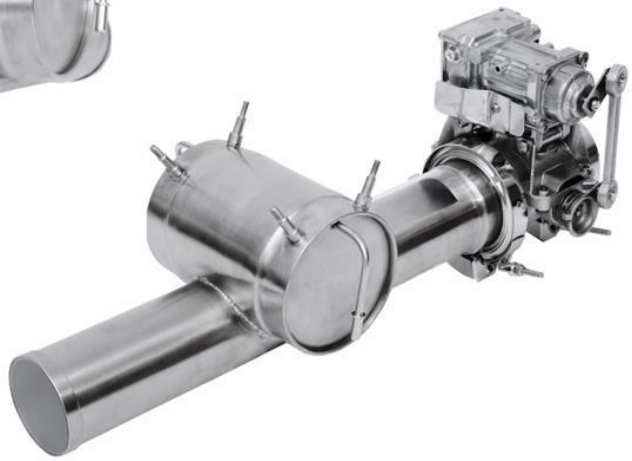
Cost of technology to meet EURO 7



Source:
P.-L. Ragon, Estimated cost of diesel emissions control technology to meet future Euro 7 standards for heavy-duty vehicles, ICCT, 2023

CatVap®
flexible heating and heat retention system

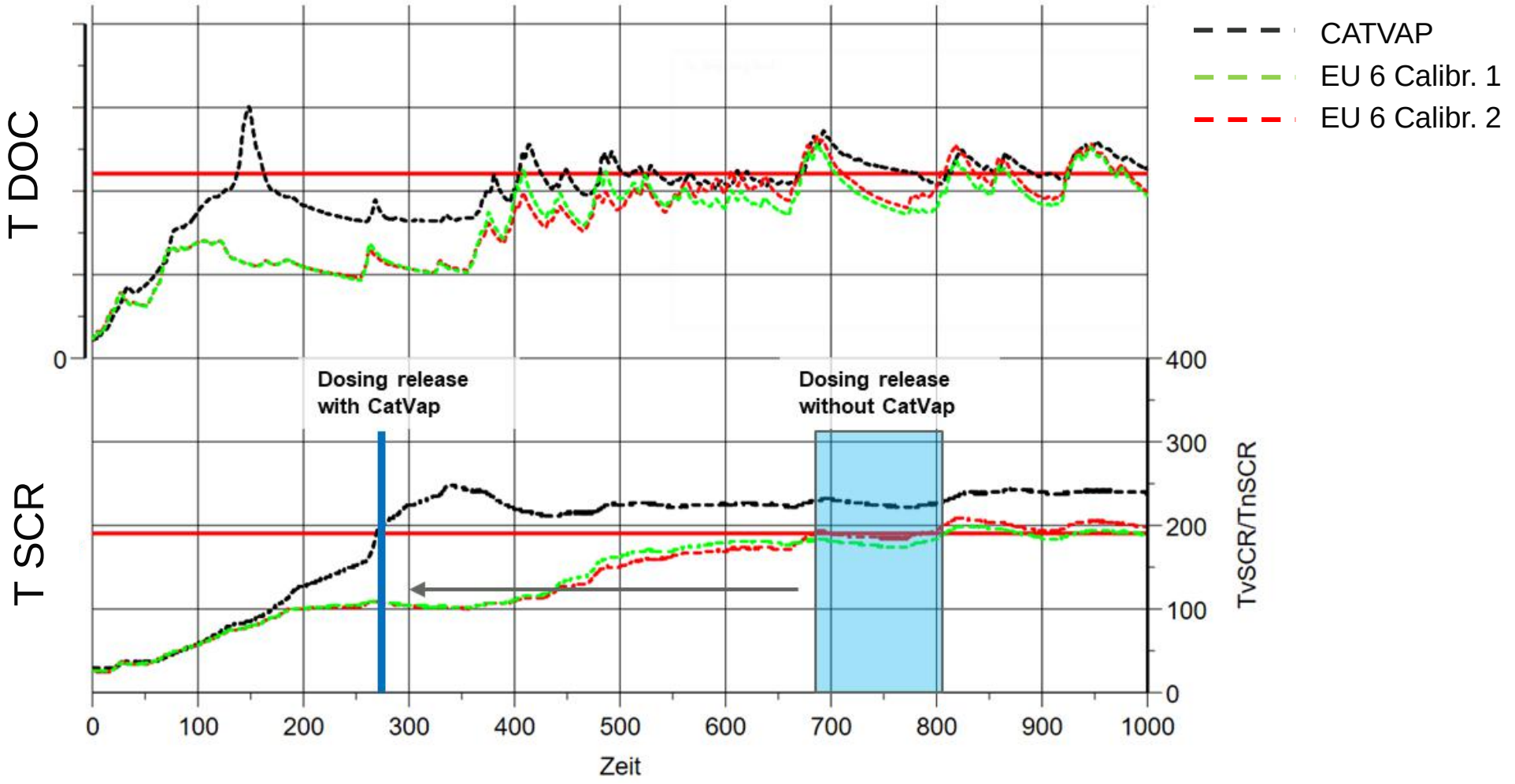




System Characteristics

- Efficient and flexible aftertreatment thermo-management
- Powered with fuel only, after short electrical system start
- Intermittent/continuous heater performance up to 20 kW
- Variable heating output with a large spread up to 100 kW using the DOC for conversion of cracked fuel (process gas)
- Continuous DOC / SCR temperature stabilization in “Heat retention mode”
- Enables active DPF regeneration (replacing HC dozer) with high efficiency
- Heater ready for operation after 20 seconds
- Aftertreatment system ready for operation after approx. 60 seconds in high conversion mode
- Compliance with future emission norms
- 12 V / 24 V / 48 V on-board network compatibility,

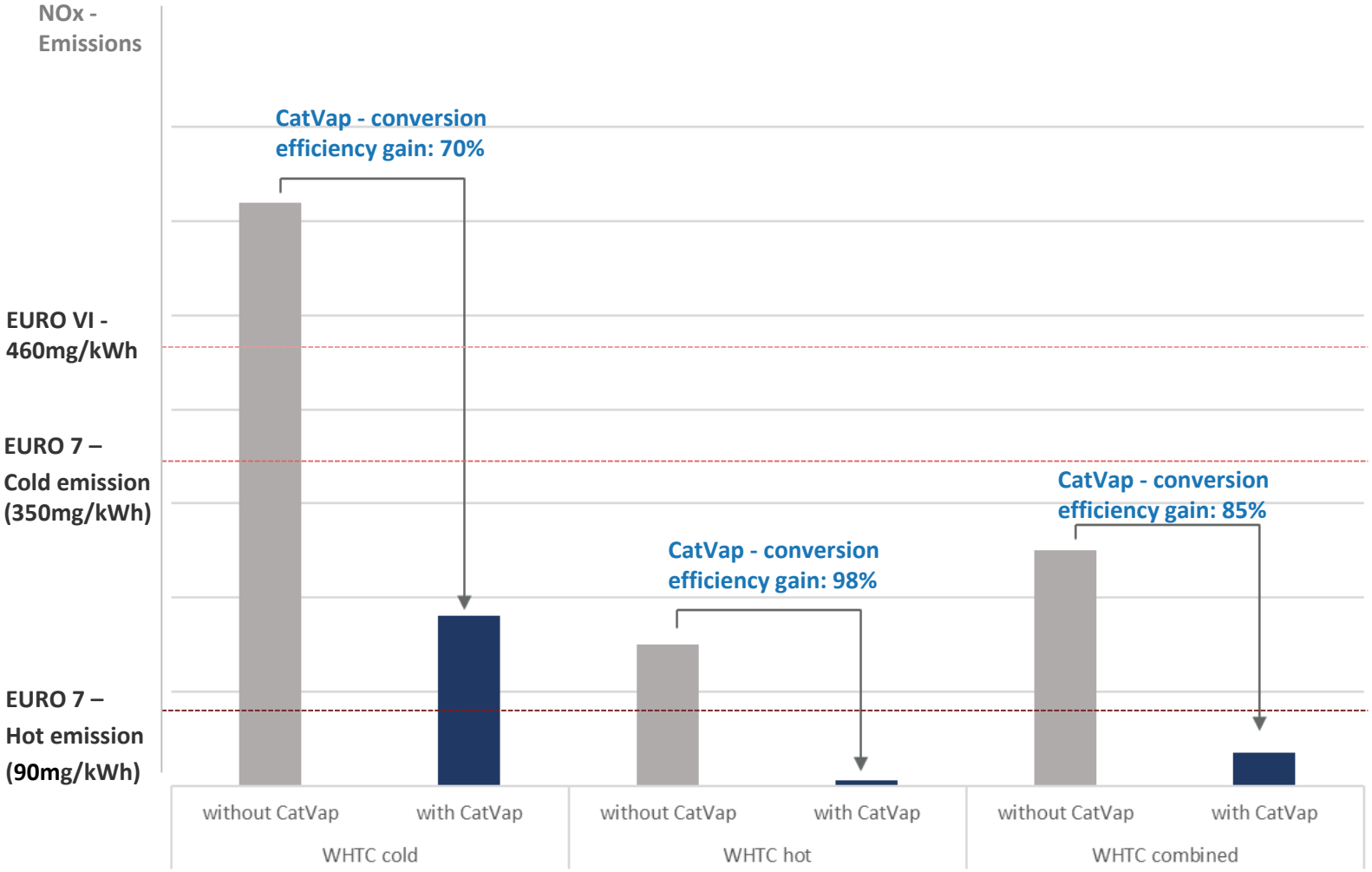
Dosing release temperature



✓ Dosing release time improved by approx 420 sec.

Engine test bench results with CatVap of MD diesel engine

NOx emissions in WHTC



➢ **EURO 7 limits achieved on existing EURO VI EATS with integration of CatVap**

CatVap® Capability

- CatVap®:
  - heating up the exhaust gas/system and reducing start up time for the aftertreatment
  - keeping the temperature on a sufficient level for SCR conversion, even during low load and idle operations
- Engine Temperature Management can be avoided
- Engine can be calibrated for best efficiency, with high engine-out NOx emissions
- Engine fuel savings are higher than the energy consumption of the CatVap® device
- EURO 7 can be achieved using standard BS 6 exhaust design, SCR catalyst needs sufficient size for NOx conversion

1 Future Demands for EATS

2 CatVap: an effective Exhaust Heating System

3 **Heated Nozzle: close the gap**

4 Robust AdBlue Dosing Systems: reduce complexity and Cost

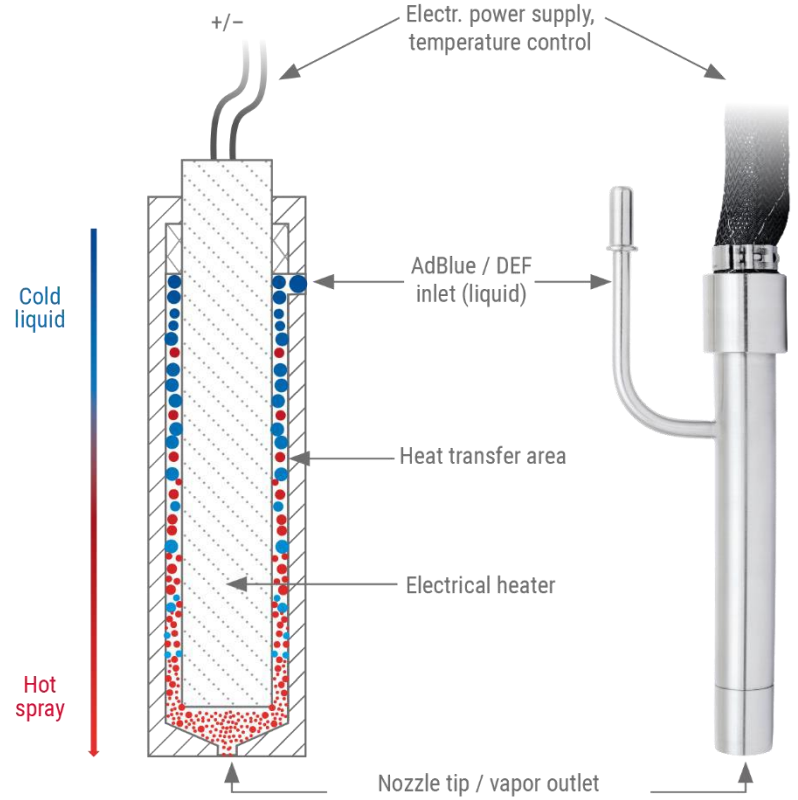
5 Summary

Albonair Heated Nozzle

Improves SCR catalyst efficiency at low load/temperatures

System Characteristics

- Airless operating (air only for purging routine)
- Electrical heating of AdBlue / DEF inside nozzle
  - Evaporation of water
  - Transforming urea into liquid phase
  - Injection of urea droplets and water steam
- Initiation of urea de-composition/pre-reactions: HNCO and NH_3 before catalyst
- enable SCR operation at low exhaust/catalyst temperature with minimum energy supply



Albonair Heated Nozzle: Motivation, Benefits and Operational Field

location and heat source of main SCR process steps/reaction	WATER EVAPORATION $t_1 \geq 100\ °C$		UREA IN LIQUID PHASE $t_2 \geq 133\ °C$		UREA DECOMPOSITION (THERMOLYSIS, HYDROLYSIS), SCR ACTIVITY	
	location	heat source	location	heat source	location	heat source
State of the art "cold" UWS injection	tailpipe	exhaust gas	tailpipe	exhaust gas	tailpipe, catalyst	exhaust gas, exhaust gas
Albonair Heated nozzle: beneficial UWS injection	in nozzle	el. heater	in nozzle	el. heater	in nozzle, tailpipe, catalyst	el. heater, exhaust gas, exhaust gas,

Pre-heated close coupled AdBlue® dosing, combined with suitable SCR-catalysts:

- **potential for very early NOx reduction (low load, cold start)**
- **improves catalyst light-off and NOx reduction rate**
- **to meet future (stringent) On-/Off-Road emission regulations (EU 7, CN 7,…)**

Heated Nozzle:
suitable option (also single dosing) for applications with basically low NOx emissions, like H2-ICE.

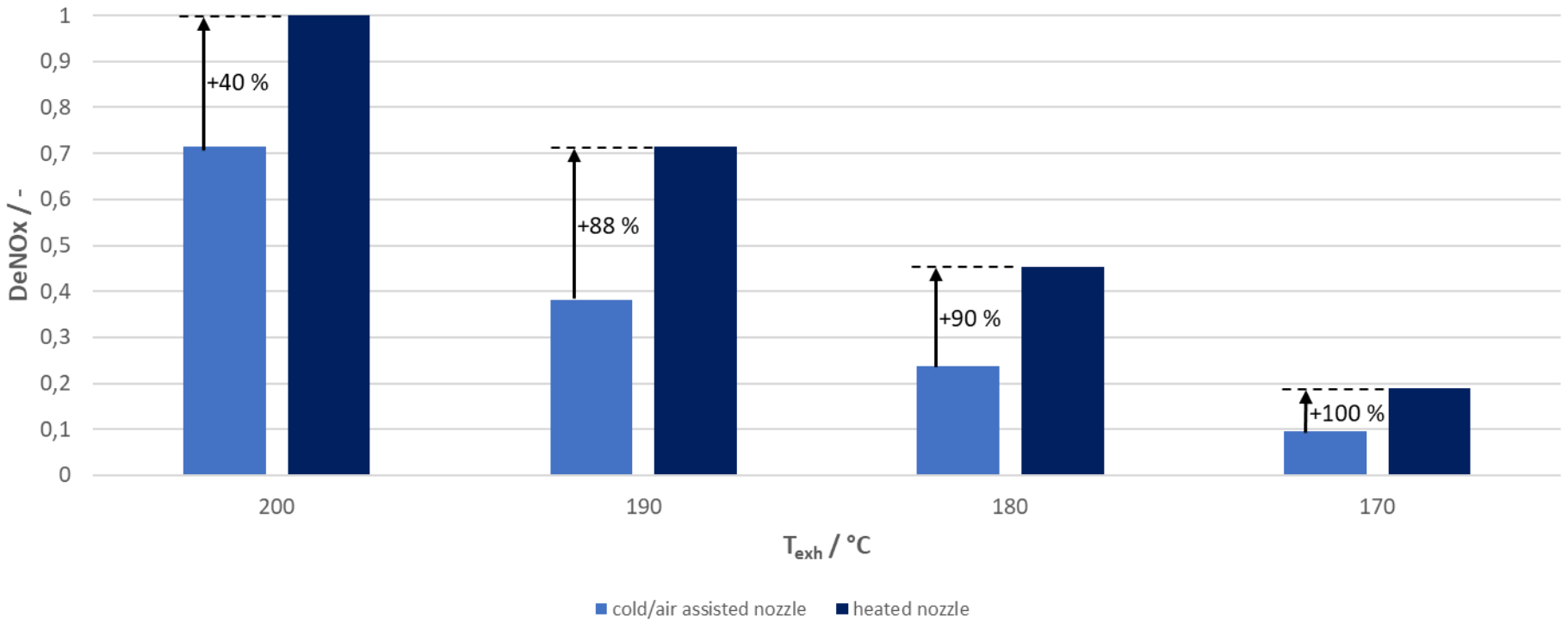
Heated nozzle: always higher DeNOx rate than conventional nozzle

- $\dot{m}_{exh} = 200\,kg/h$
- $\dot{m}_{UWS} = 100\,g/h$
- $\dot{V}_{NO} = 875\,cm_s^3/min$

➢ qualitative experiment

➢ Pre-reaction/urea decomposition (NH_3, HNCO) inside of the heated nozzle clearly visible

➢ DeNOx potential for low exhaust gas temperatures (cold start, low load)

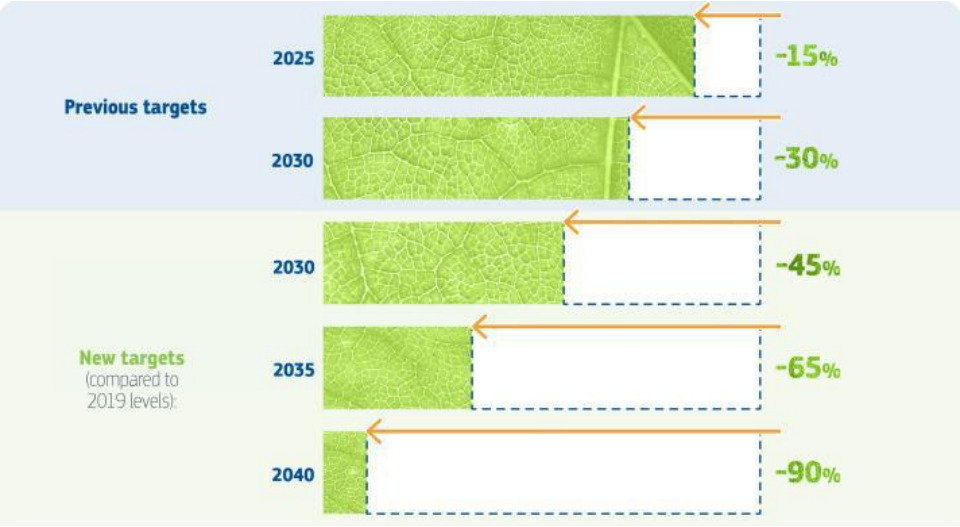


Heated Nozzle Capability

- Evaporation of the water content of the AdBlue/DEF (aqueous urea solution) before injection
- Partly Urea decomposition into NH3 and HNCO in the Nozzle
- Reducing deposit formation of AdBlue in the exhaust system at low temperatures
- Increasing the SCR catalyst efficiency at low temperatures

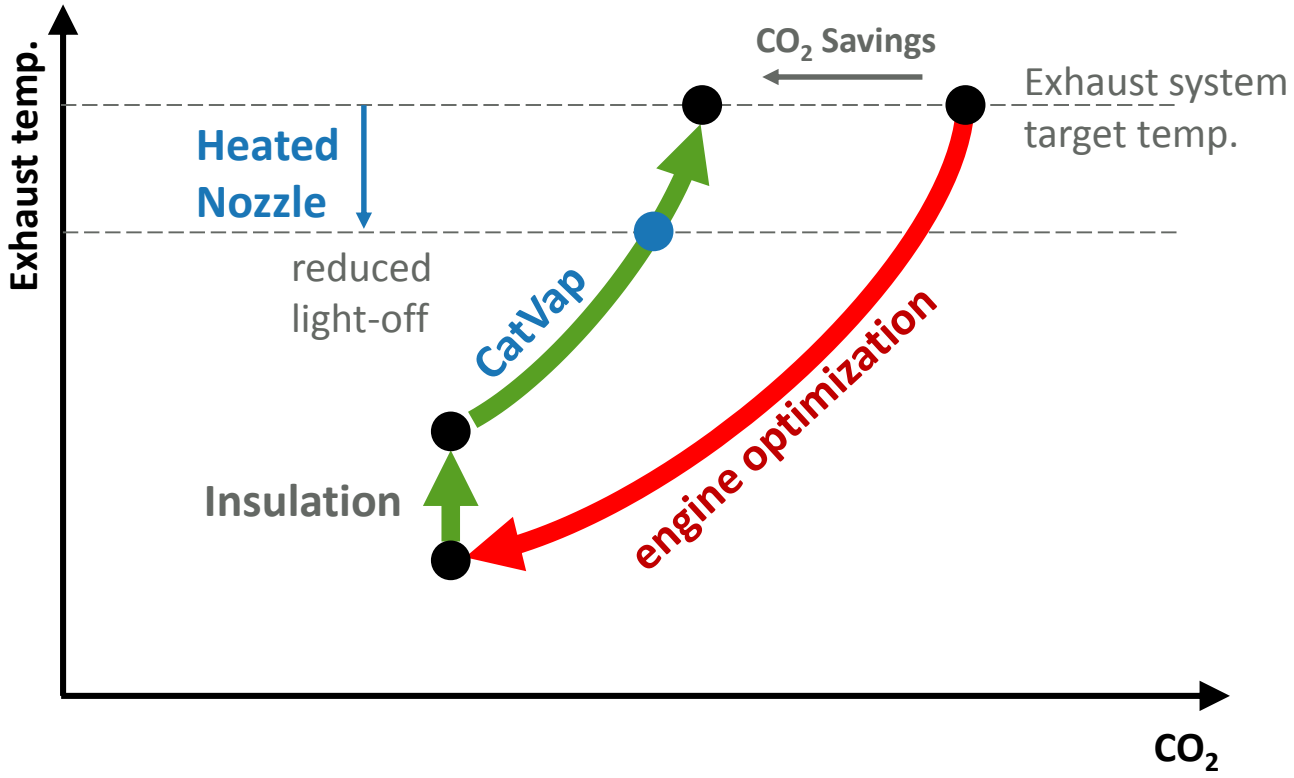
Exhaus Aftertreatment may Improve Engine Fuel consumption

- Proposal for EU CO_2 Fleet Emission will be a motivation to improve the efficiency of the EATS
- Fleet emission should be reduced by 45% until 2030 (former 30%) on the basis of 2019
- E-Trucks and H_2 trucks sales not be sufficient to achieve the target, there will be the need of additional measures to improve fuel consumption of diesel trucks



Source:
https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en

Albonair EU 7 Technologies lead to CO_2 Savings



➢ **Efficient Exhaust Heating will improve CO_2 Emission.**

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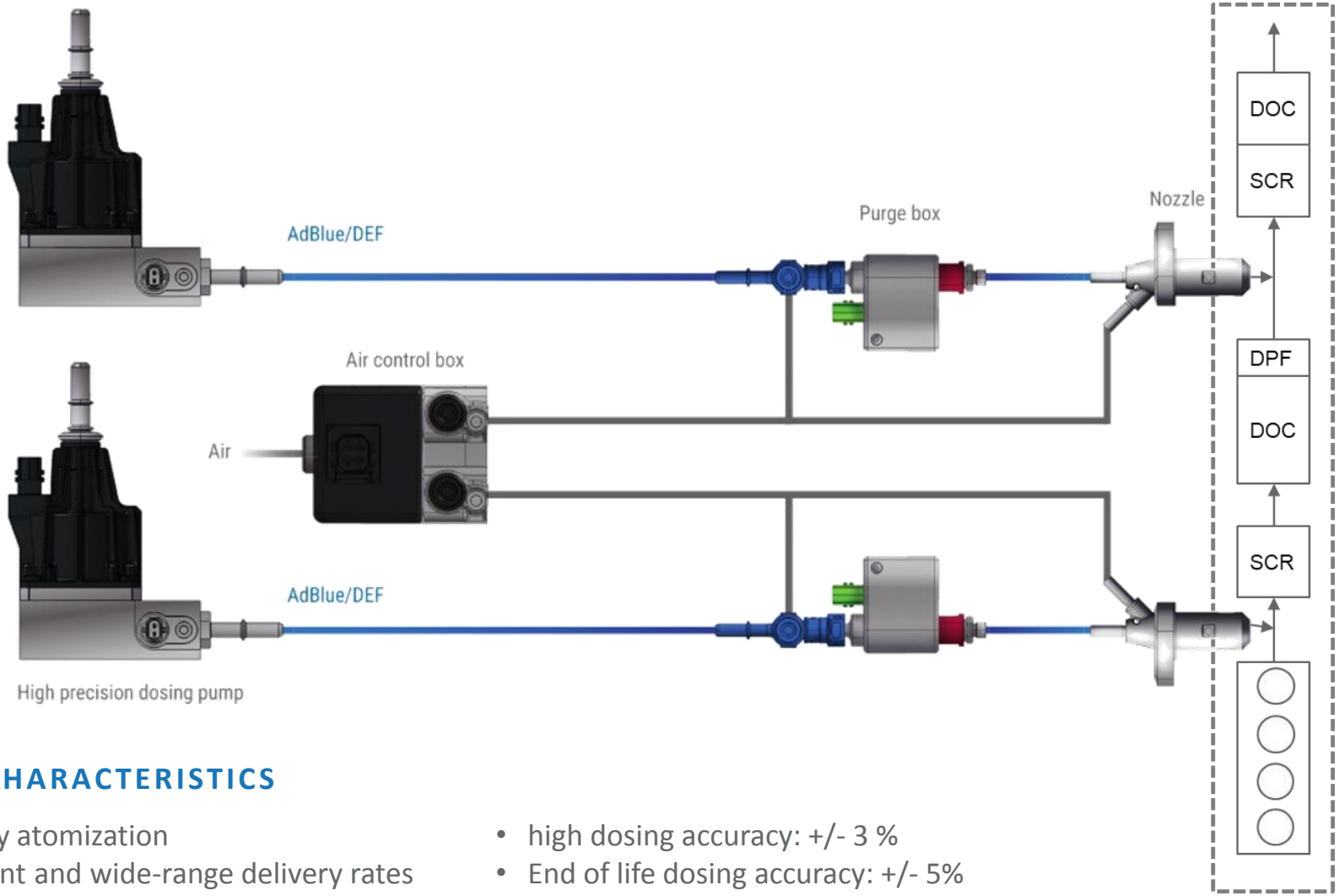
3 Heated Nozzle: close the gap

4 **Robust AdBlue Dosing Systems: reduce complexity and Cost**

5 Summary

Albonair Dual dosing system

Modular design for simple system installation and integration



System Characteristics

- finest spray atomization
- independent and wide-range delivery rates
- up to 11 kg/h dosing amount per dosing point
- high dosing accuracy: +/- 3 %
- End of life dosing accuracy: +/- 5%
- Lifetime: > 60.000 kg (each injector)

Albonair Airless Dual dosing system

Robust Urea Dosing System to reduce service demands and system costs

System Characteristics

- Airless urea injection
- Application for LD/MD,
  off Road application w/o air supply
- Smart and robust passive Airless Injector design
  - No electrical components
  - No moving mechanical components
  - sufficient spray & NOx performance
  - avoiding UREA crystallization

  ➔ ensuring high durability & reliable product
- significantly reduced costs
- No Aftercooling after engine shut off
- No limit on Nozzle Tip Temperature as there are no movable or electric parts in the nozzle

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5 **Summary**

Summary

- EU 7 emission regulation is still open. Decision is expected in Q1/2024
- Most stringent proposal of the EU commission is technical feasible; however, it has a high-cost impact on the vehicles
- The Albonair CatVap system shows capability to improve emissions close to EU 7 limits
- The Albonair Heated Nozzle may close the gap for very low emission targets by SCR conversion at low temperatures
- Future CO2 emission regulation will lead to reduced exhaust gas temperatures and force efficient exhaust gas heating in low load
- Dual Dosing may be an effective solution, if packaging requirements for two SCR systems can be met
- The new airless dosing system of Albonair is a robust solution with minimized components




German Engineering for Clean Air