Ultra-low PN10 emissions of a 48V mild-hybrid gasoline vehicle with advanced emission control technologies

Cambridge Particle Meeting • 25 June 2021

AECC
ASSOCIATION FOR EMISSIONS CONTROL BY CATALYST

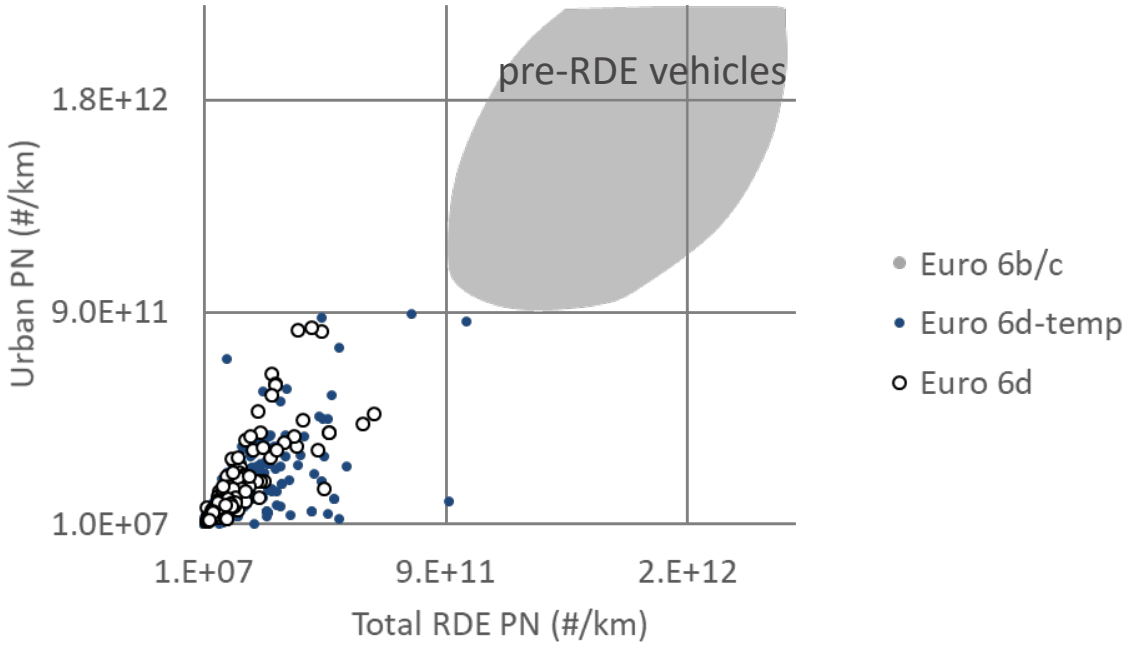
Association for Emissions Control by Catalyst (AECC AISBL)

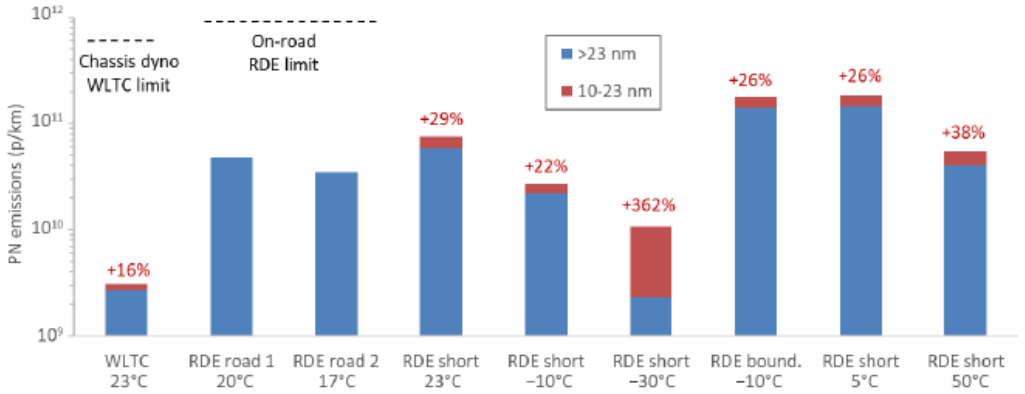
AECC members : European Emissions Control companies

- Exhaust emissions control technologies for original equipment, retrofit and aftermarket for all new cars, commercial vehicles, motorcycles, and non-road mobile machinery
  - AECC is # 78711786419-61 in EU Transparency Register and has consultative status with the UN Economic and Social Council (ECOSOC)

Pollutant emissions significantly reduced towards Euro 6d

- Including for gasoline PN emissions with the introduction of the Gasoline Particulate Filter



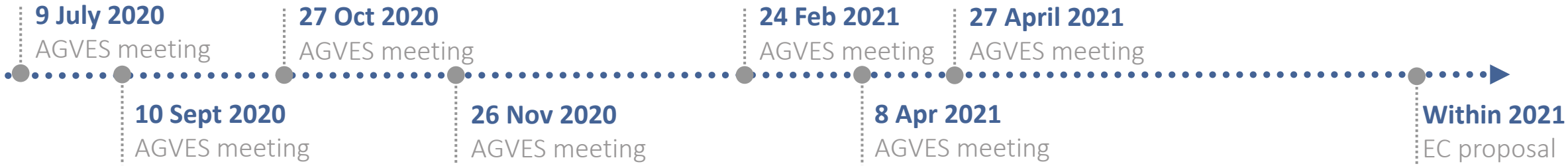


Sources: - ACEA/JAMA Euro 6d(-TEMP) PEMS data consulted 17 July 2020
- pre-RDE PN emissions factors from B. Giechaskiel, Int. J. Environ. Res. Public Health, 2018

Source: "Particle Number Emissions of a Euro 6d-Temp Gasoline Vehicle under Extreme Temperatures and Driving Conditions", B. Giechaskiel, et al.; Catalysts, Vol. 11, 607, 2021

Euro 7 will drive further emission control technology innovation

- The AGVES expert working group met until end of April 2021
- CLOVE consortium studies expected to finish by Q2/2021
  - Scenarios presented for light- and heavy-duty vehicles
  - Will provide further input for the European Commission impact assessment
- UNECE PMP IWG is preparing PN10 measurement procedure
- The actual European Commission proposal is expected within 2021 followed by trialogue negotiations with European Parliament and Council



Ongoing AECC demonstration test programmes

- Ultra-low emissions of light-duty and heavy-duty vehicles with state-of-the-art emission control technologies in an integrated powertrain approach
- Validation of renewable fuels for low CO_2 emissions
- This presentation focuses on PN emissions of the LD gasoline demonstrator vehicle

LD gasoline demonstrator concept

- Base vehicle
  - C-segment vehicle
  - Engine
    - 1.5l with 4 cylinders
    - Variable valve train with cylinder deactivation
  - 48V mild-hybrid (belt-driven, P0 configuration)
  - Euro 6d type-approval baseline with GPF + TWC
- Project partners

automotive engineering iav

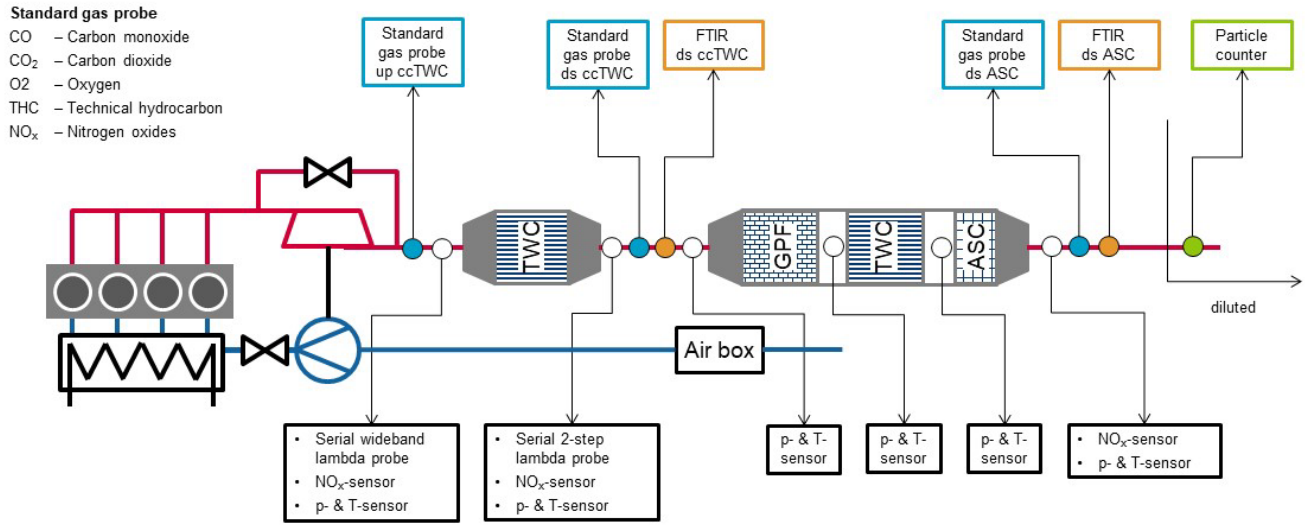
IPA INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

DENSO

LD gasoline demonstrator concept

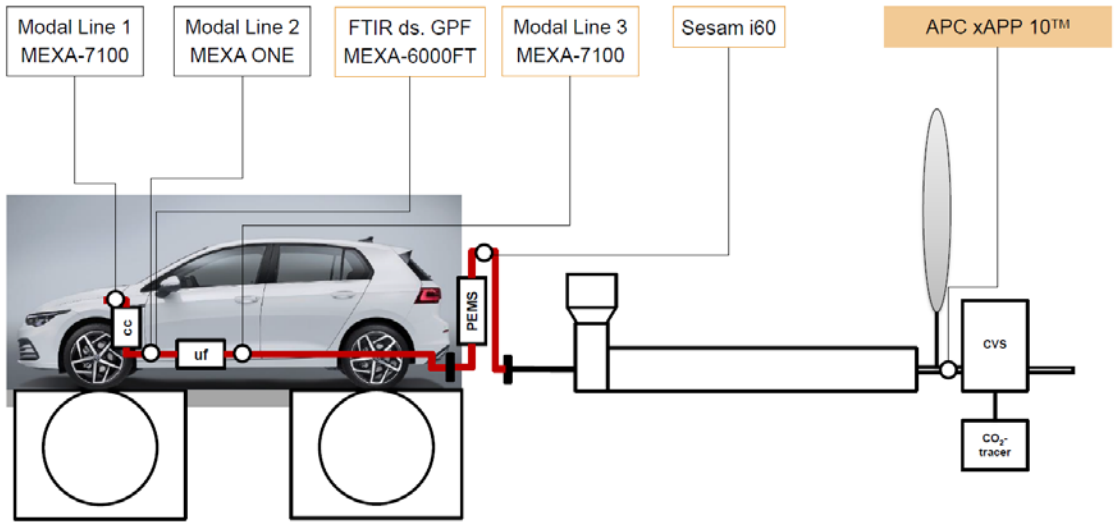
- Emission control system
  - ccTWC, ufGPF+TWC+ASC[1]

    [1] ASC operation strategy for gasoline under investigation in addition to improved lambda control
  - Bench aged components targeting 160k km
  - Lambda control of ccTWC
    - Wideband lambda probe upstream
    - 2-step lambda probe downstream



- Instrumentation
  - Chassis dyno: 3x sample points incl. 2x FTIR and PN10
  - Road: PEMS incl. prototype for NH_3, N_2O and PN10

Specifications of PEMS and lab PN equipment

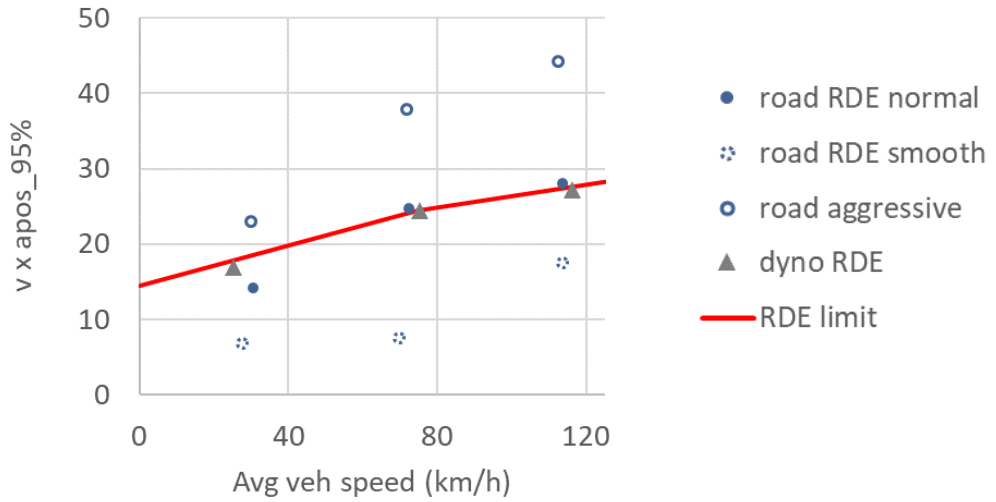


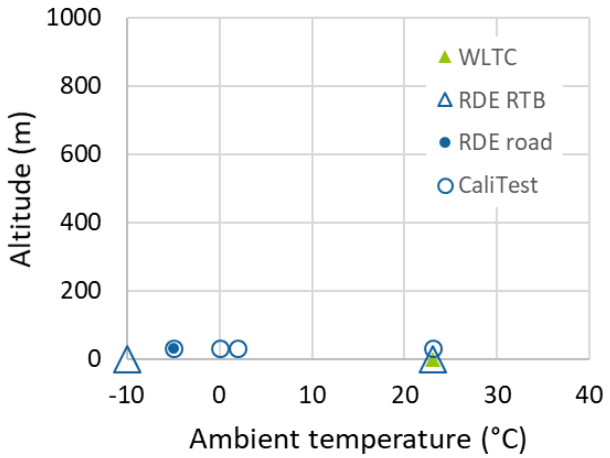
Model	APC xAPP 10™
Measurement principle	Laser dispersion condensation particle counter (CPC)
Measurement range	0 – 30000 p/cm³ (single counting mode), linear (R^2 > 0.95) to 50000 p/cm³
Signal processing	Single peak detection and counting
Control of counting efficiency	Peak pulse control
Lower particle limit diameter	10 nm (> 50%) 15 nm (> 90%)
Mean reaction time of measurement system T90	2,0 s
Mean reaction time of CPC sensor T90	4,5 s
CPC reading accuracy	0,1 p/cm³
CPC data acquisition	10 Hz
CPC butanol consumption	5 ml/h
Altitude range	Up to 3000 m (w/ cooling device)
Ambient temperature range	-30 °C – 45 °C
Rel. humidity	0 – 90% w/ optional cooling device
Exhaust temperature	≤600 °C
Exhaust back pressure (rel. to ambient pressure)	+200/-300 mbar
Sampling flow rate	5 l/min (diluted), 4 – 7 l/min (raw)
$PCRF_{TOT}$	100 – 20000 (compliant with PMP up to 1000)
Separation efficiency volatile particles	> 99% separation of tetracon particles with a electric mobility diameter of min. 30 nm at a concentration at inlet of ≥ 10000 p/cm³
Temperature evaporation tube	Adjustable 300 – 370 °C with additional catalytic stripper

Model	AIP PEMS Gen2
Measurement principle	Condensation particle counter (CPC)
Particle diameter	Dp: 10 nm ≤ Dp ≤ 2.5 µm
Dilution / PCRF	~100, relative to PMP protocol
Linearity	Gradient: 0.85 to 1.15 $R^2 \geq 0.95$ Standard deviation ≤ 10% FS Intercept ≤ 5% FS

LD gasoline demonstrator preliminary data

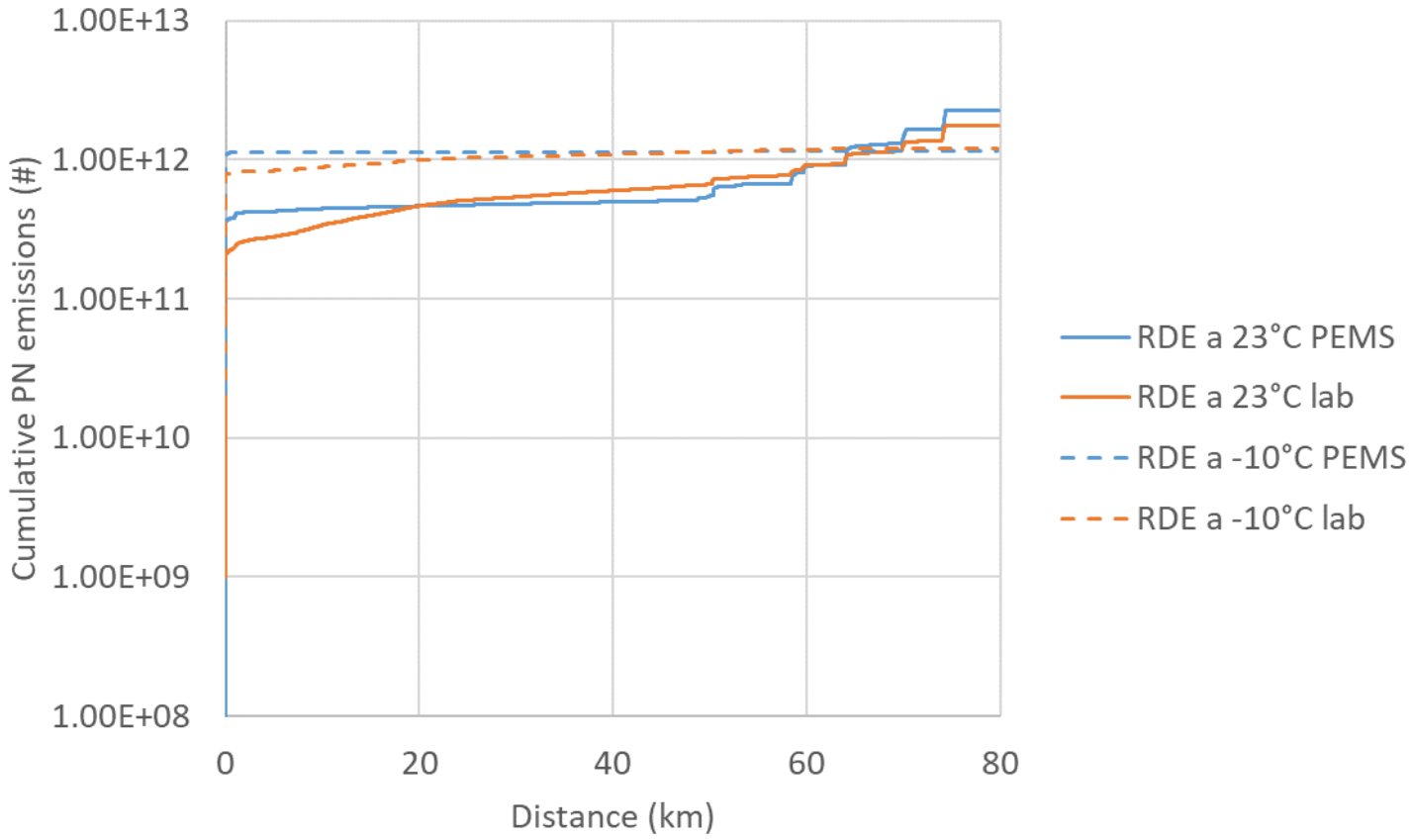
- Exploring beyond Euro 6 RDE boundary conditions
- On the chassis dyno
  - WLTC at 23°C
  - RDE aggressive at 23°C and -10°C
- On the road
  - RDE normal driving at -5°C
  - Short calibration test
    - Normal driving at 0°C and 23°C
    - Smooth driving at -5°C
    - Aggressive driving at 2°C





Preliminary comparison of PEMS and lab PN10 data

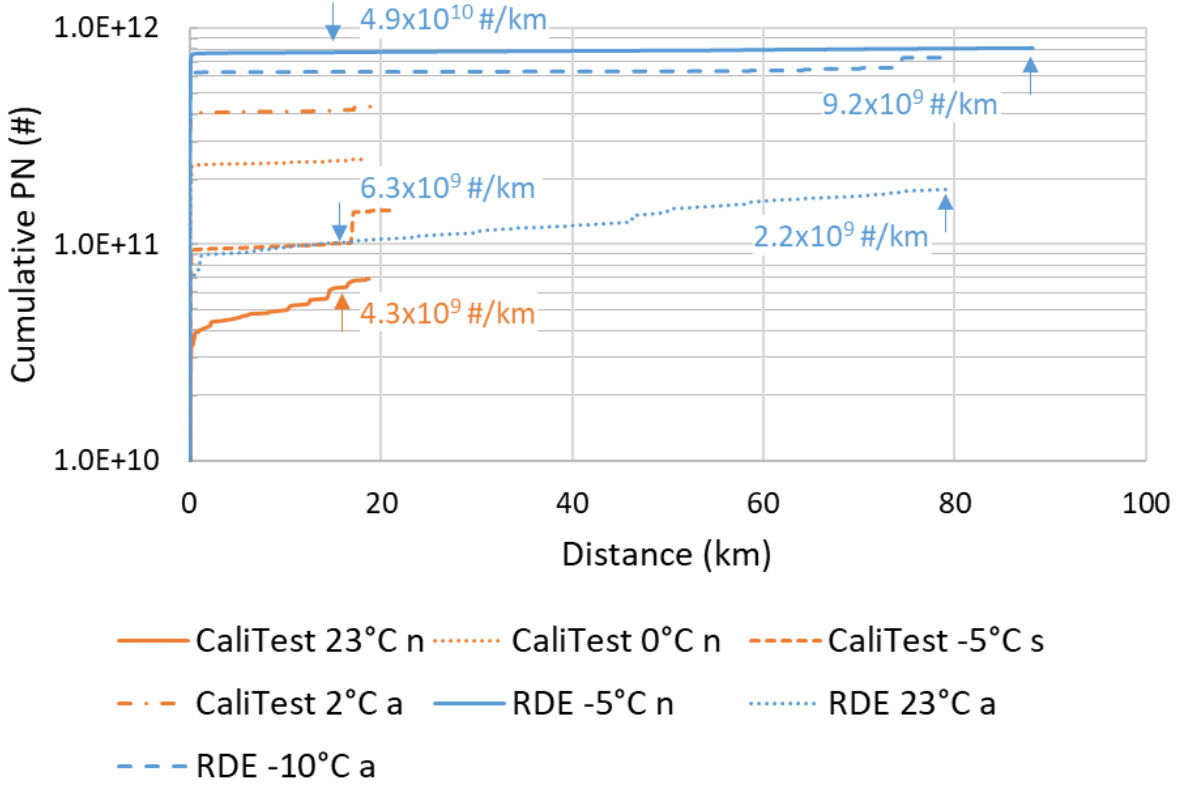
- Example of RDE aggressive test at 23°C and -10°C



[1] The results are reported as measured by the PEMS under the specified test routes and conditions

Ultra-low PN10 emissions over range of driving conditions

- Soot and ash accumulation during ageing of parts supports filtration efficiency
- Initial cold-start effect is observed
- Near-zero emissions during the rest of the tests



[1] The results are reported as measured by the PEMS under the specified test routes and conditions
[2] Urban values are evaluated at a trip length of 16 km

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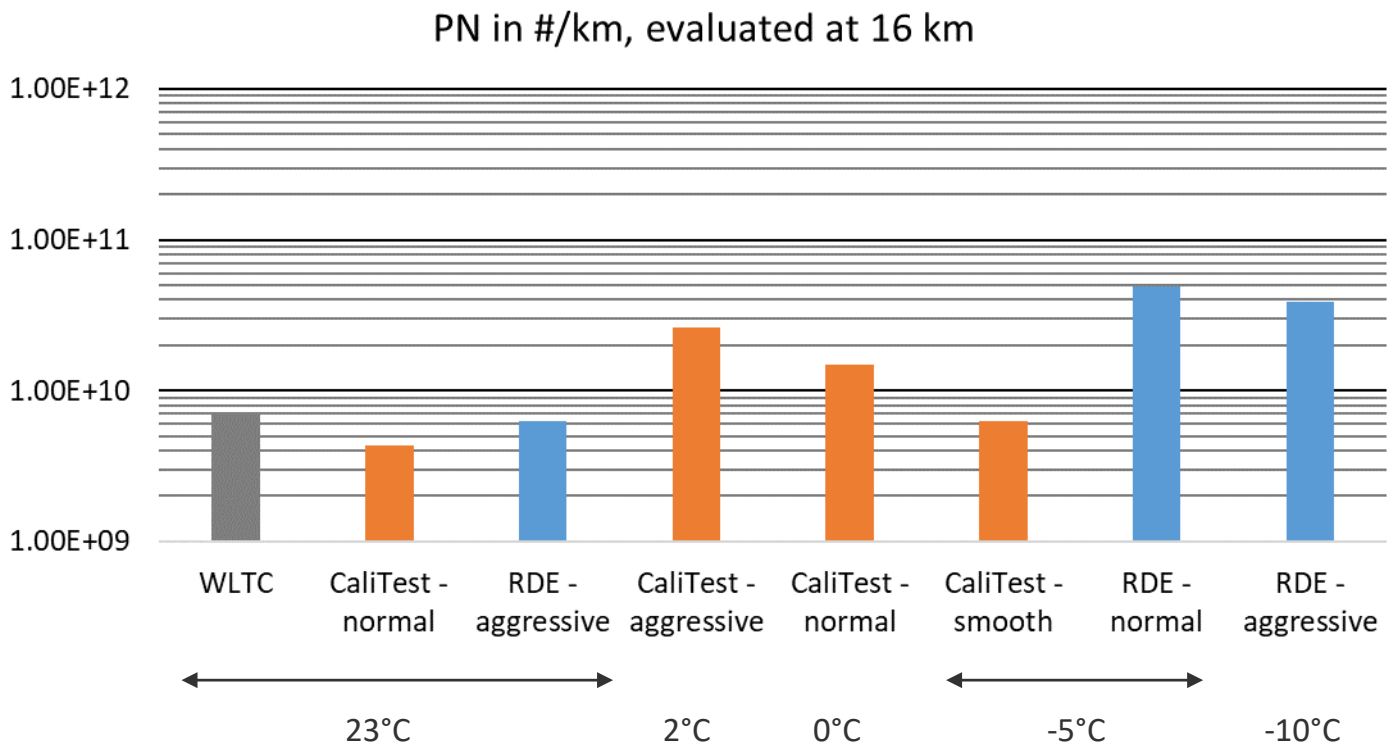
Ultra-low PN10 emissions over range of driving conditions

- Variation in #/km over 2 orders of magnitude, impacted by
  - Ambient temperature
  - Driving conditions
  - Engine-out emissions
  - Initial filter status



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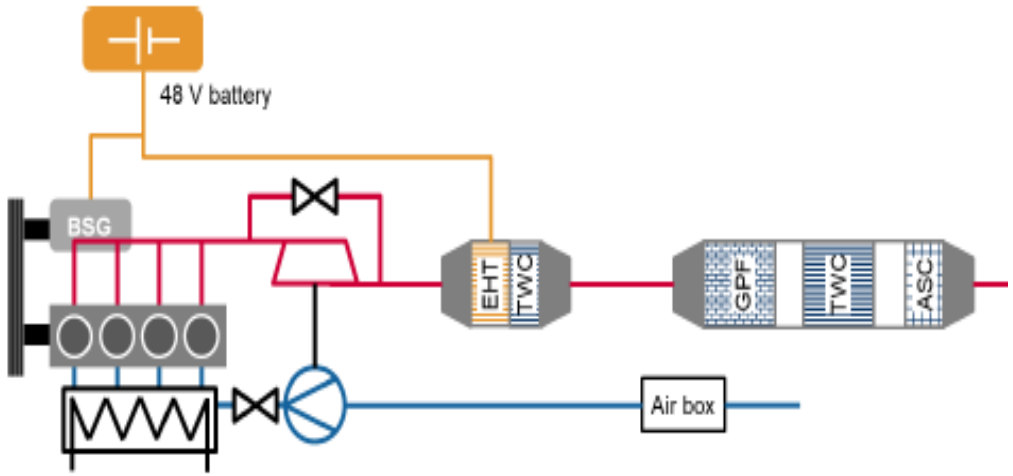
Summary and outlook

- Combination of close-coupled and underfloor components is used on a LD gasoline demonstrator vehicle to investigate early light-off for urban emission control in combination with consistent emissions reduction over the range of driving conditions
- PN10 emissions controlled to ultra-low levels
  - Initial cold-start effect observed
  - Near-zero emissions throughout rest of the tests
- Gaseous emissions will be covered in a paper at the SAE International Conference on Engines & Vehicles, Capri, 12-16 September 2021
- 2021 follow-up activities
  - Implementation of electrically heated catalyst to reduce the remaining initial cold-start emissions
  - Evaluation of a fresh GPF
  - Testing of renewable fuels with drop-in capabilities to investigate Well-to-Wheel CO_2 reductions



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