Insights for post-Euro 6, based on analysis of Euro 6d-TEMP PEMS data

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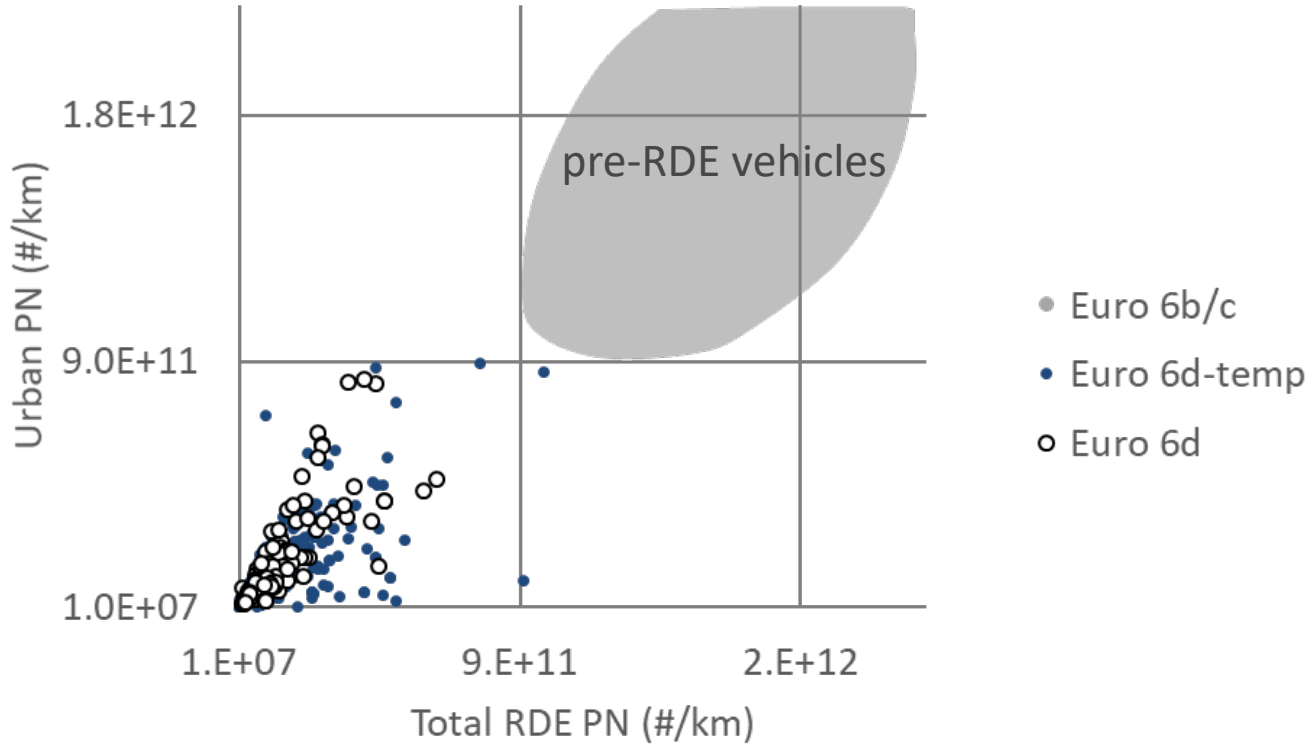
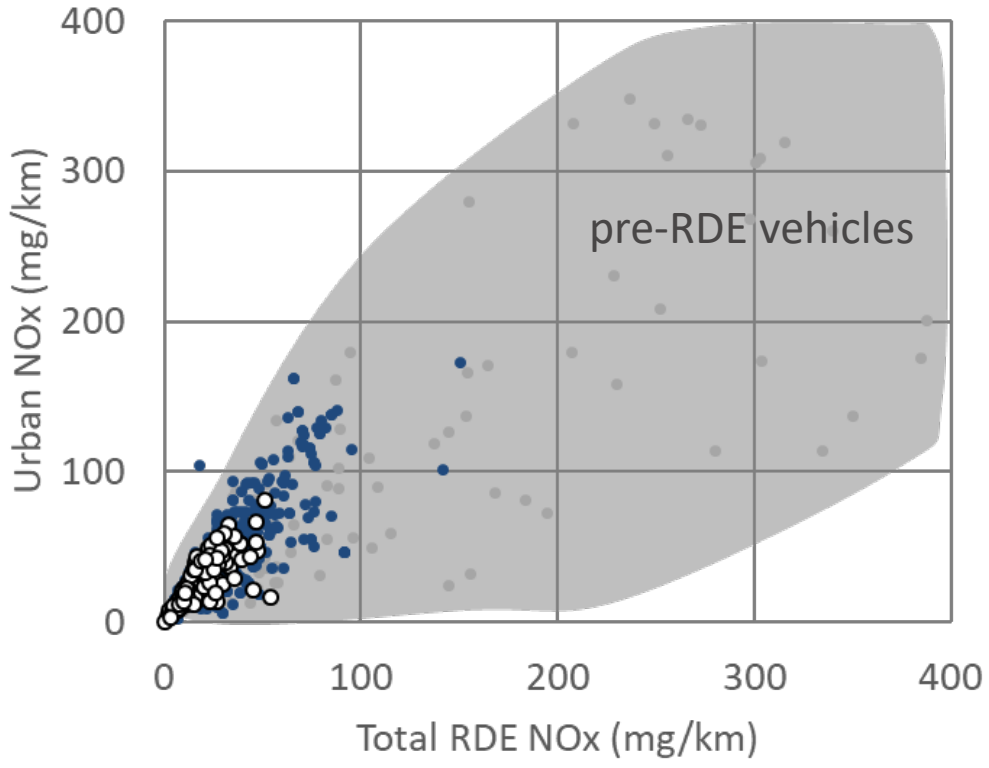
Pollutant emissions significantly reduced towards Euro 6d

- Light-duty gasoline PN emissions



- Light-duty diesel NOx emissions



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*

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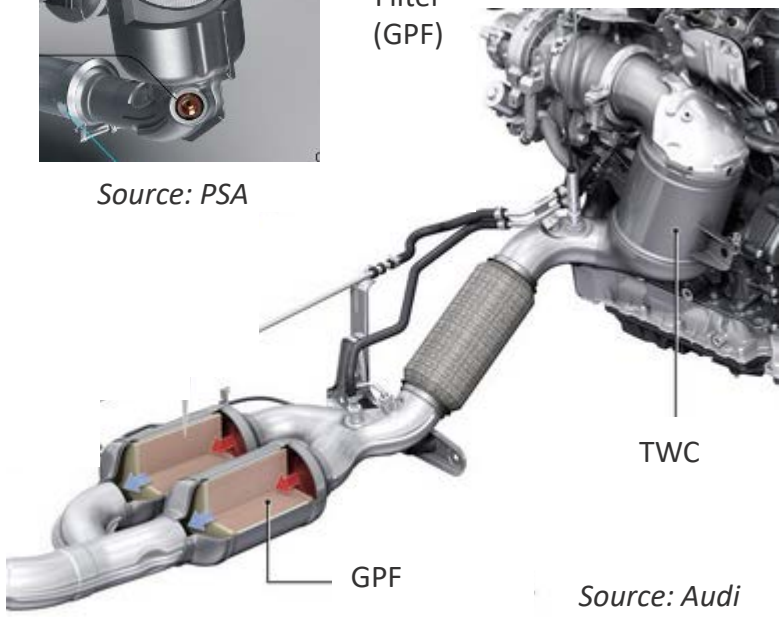
Advanced emission control systems towards Euro 6d

Gasoline – introduction of GPF

TWC

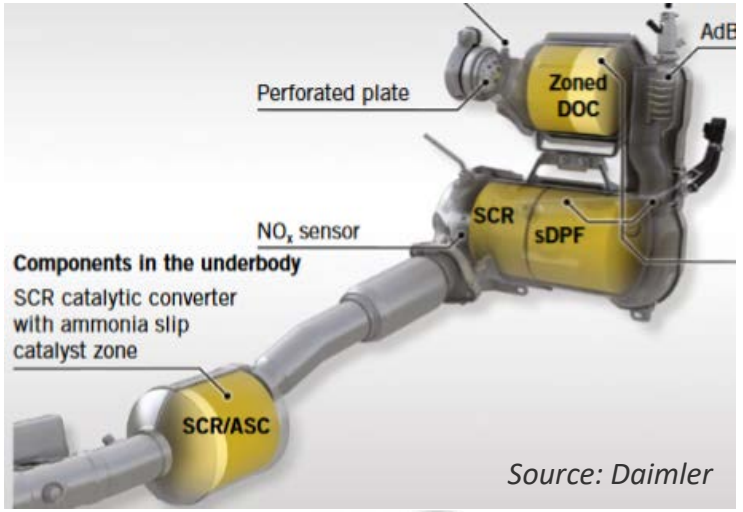
Gasoline Particulate Filter (GPF)

Source: PSA



Source: Audi

Diesel – combination of deNOx technologies



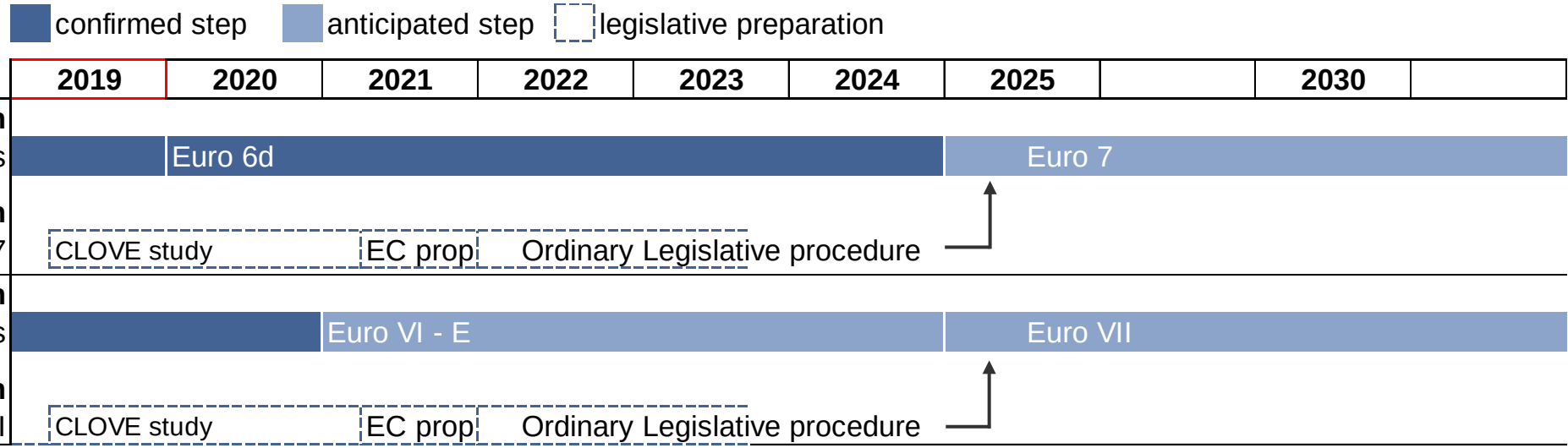
Source: Daimler

Source: VW

Further steps expected for Euro 7

Confirmed in EU Green Deal communication

- European Commission working group:
  Advisory Group on Vehicle Emission Standards (AGVES)
- Studies by CLOVE consortium until Mid of 2021
- European Commission proposal expected in 2021 followed by ordinary legislative procedure with European Parliament and Council



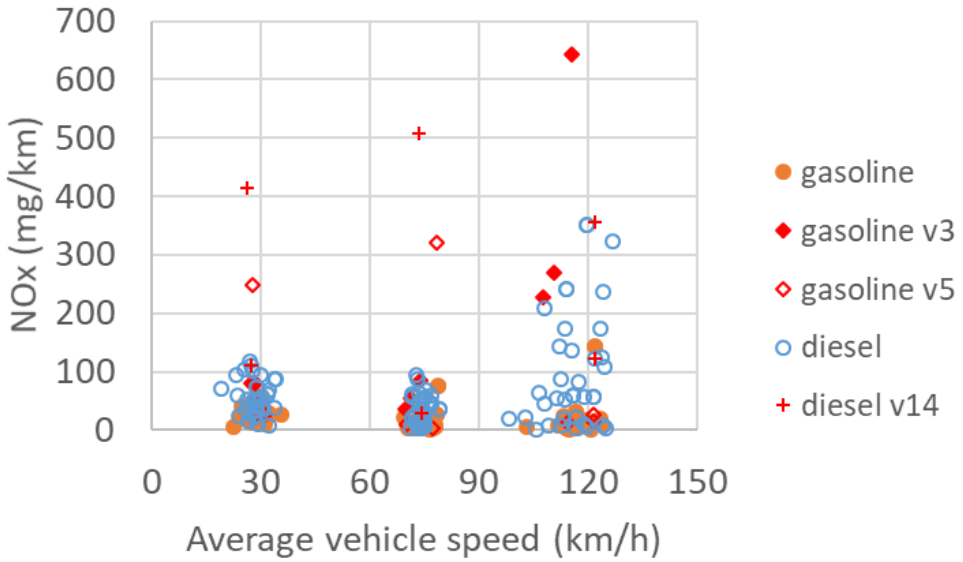
Euro 6d-TEMP PEMS data analysis

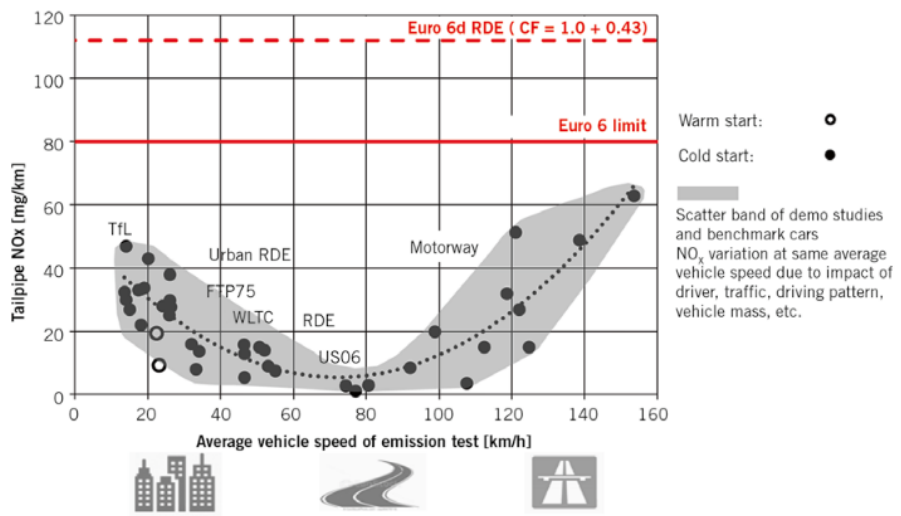
- Data Sources
  - Benchmark data obtained by AECC
  - Global RDE database (UBA, JRC)
  - JRC publications
- 7 gasoline and 13 diesel vehicles
- Objective is to investigate
  - Overall emissions performance
  - Remaining emission events
    - Initial cold-start
    - Outlier results
- Limited information about test conditions

VehicleID	Fuel_type	Type Approval	Technology
Vehicle 1	gasoline	Euro 6d-TEMP	GDI, TWC, GPF, 48V mild-hybrid
Vehicle 2	gasoline	Euro 6d-TEMP	GDI, TWC, GPF
Vehicle 3	gasoline	Euro 6d-TEMP	PFI, TWC
Vehicle 4	gasoline	Euro 6c	GDI, TWC
Vehicle 5	gasoline	Euro 6b	GDI, TWC, GPF
Vehicle 6	gasoline	Euro 6d-TEMP	PFI, TWC
Vehicle 7	gasoline	Euro 6d-TEMP	GDI, TWC, GPF
Vehicle 8	diesel	Euro 6c	DOC, EGR, DPF, SCR
Vehicle 9	diesel	Euro 6d-TEMP	DOC, EGR, DPF, SCR
Vehicle 10	diesel	Euro 6d-TEMP	DOC, EGR, DPF, LNT, SCR
Vehicle 11	diesel	Euro 6d-TEMP	DOC, EGR, LNT, DPF, LNT, pSCR
Vehicle 12	diesel	Euro 6d-TEMP	SCR, EGR, DPF
Vehicle 13	diesel	Euro 6d-TEMP	SCR, LNT, DPF
Vehicle 14	diesel	Euro 6d-TEMP	LNT, EGR, DPF
Vehicle 15	diesel	Euro 6d-TEMP	SCR, EGR, DPF
Vehicle 16	diesel	Euro 6c	SCR, EGR, DPF
Vehicle 17	diesel	Euro 6d-TEMP	SCR, EGR, DPF
Vehicle 18	diesel	Euro 6d-TEMP	SCR, EGR, DPF
Vehicle 19	diesel	Euro 6d-TEMP	SCR, EGR, DPF
Vehicle 20	diesel	Euro 6d-TEMP	SCR, EGR, DPF

Overall low NOx emissions are observed

- Gasoline NOx emissions
  - Low for all parts of RDE test
  - Vehicle 3 and 5 will be investigated as outlier
- Diesel NOx emissions
  - Similar to gasoline for urban and rural part of RDE test
  - Tend to be higher for motorway part of RDE test
    - Demonstrators show improvements through a combination of reduction in engine-out emissions and appropriate sizing of the emission control system [1-2]
  - Vehicle 14 will be investigated as outlier

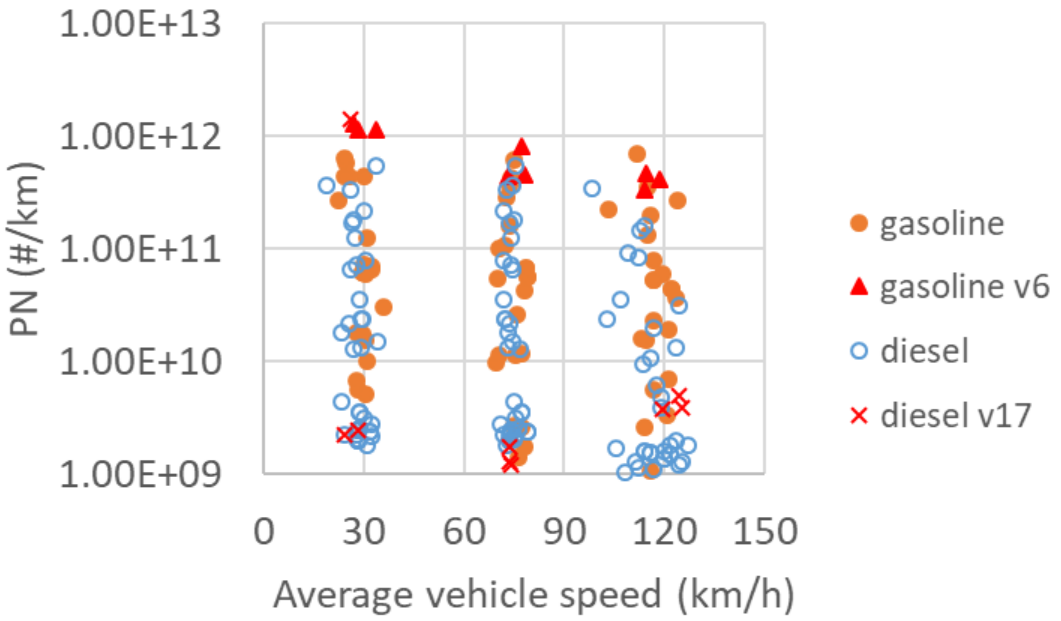




1) *Vienna Motor Symposium, 2019,* https://www.aecc.eu/wp-content/uploads/2020/07/190516-AECC-IAV-IPA-Integrated-Diesel-System-achieving-Ultra-Low-NOx-on-the-road-Vienna-Symposium.pdf
2) MTZ Worldwide 9/2020, https://www.aecc.eu/wp-content/uploads/2020/11/200901-modern-diesel-MTZ.pdf

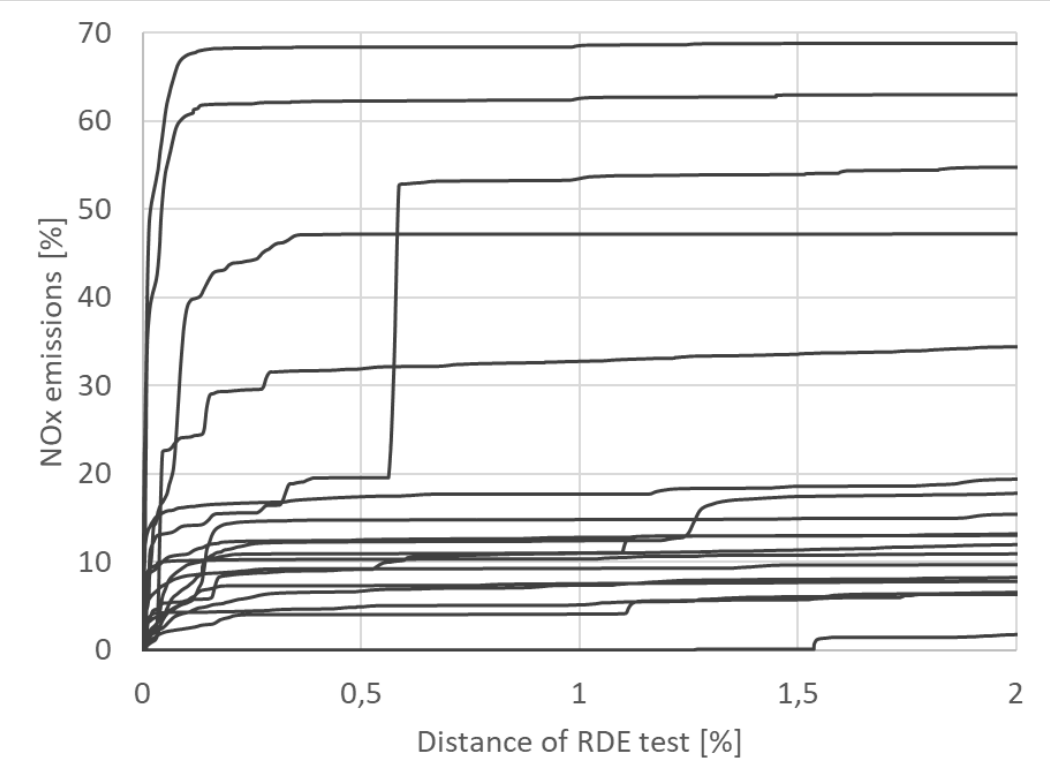
Overall low PN emissions are observed

- Diesel PN emissions
  - Low emissions for all parts of the RDE test
  - Vehicle 17 will be investigated as an outlier for the urban part
- Gasoline PN emissions
  - Similar to diesel for all parts of the RDE test
  - Vehicle 6 (Euro 6d-TEMP, PFI, TWC) is an outlier
    - PN emissions are at high end for all parts of the RDE test
    - There is no PN limit for PFI vehicles within Euro 6
    - Expected that Euro 7 will set fuel-neutral limits



Initial cold-start emissions gasoline vehicles

- TWC needs to reach operating temperature
- >40% of emissions can be emitted in <0.5% of test distance
- But majority of data still shows up to 80% of emissions in rest of test



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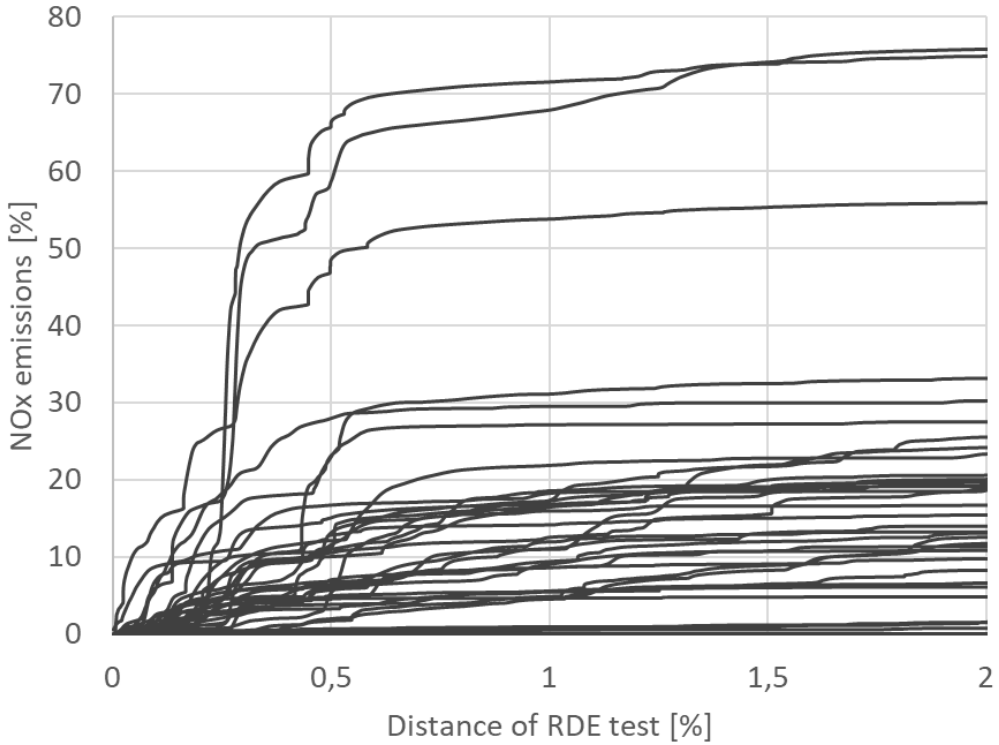
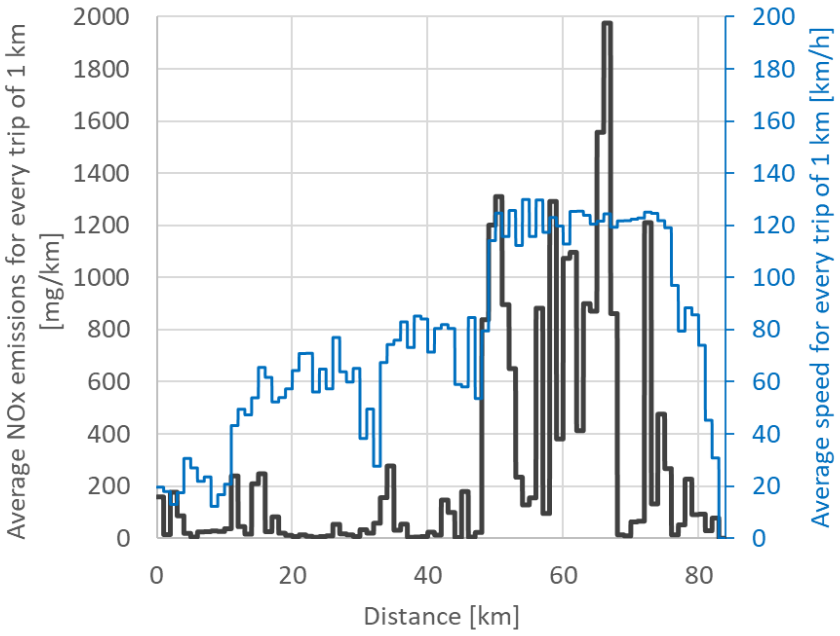
Initial cold-start emissions diesel vehicles

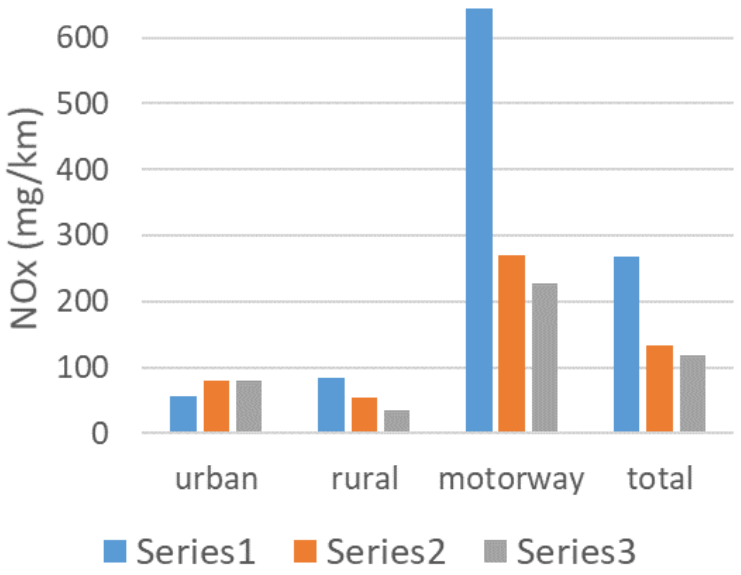
- Combination of deNOx technologies to reduce emissions
- Initial cold-start effect less pronounced compared to gasoline vehicles
- But best performing vehicles show >40% of emissions in <0.5% of distance

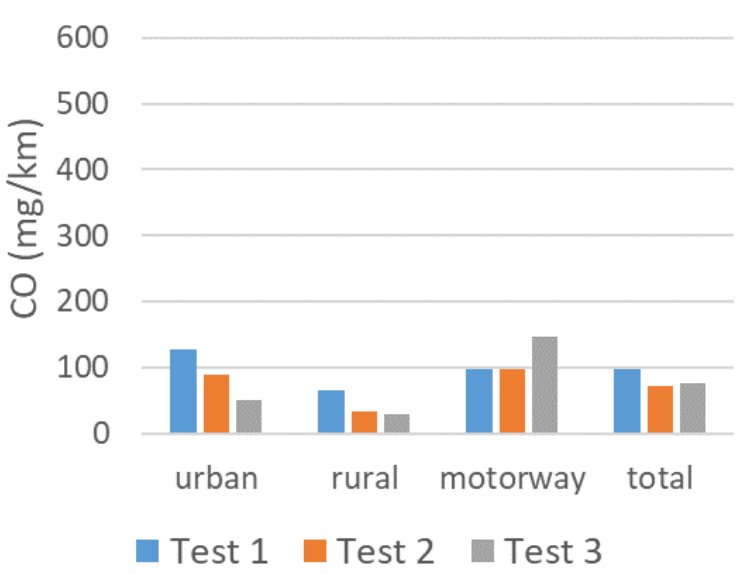


Outlier NOx result of gasoline vehicle 3

- Similar outlier result in all 3 PEMS tests
- High NOx emissions in motorway part of RDE test
- Effect not visible in CO emissions

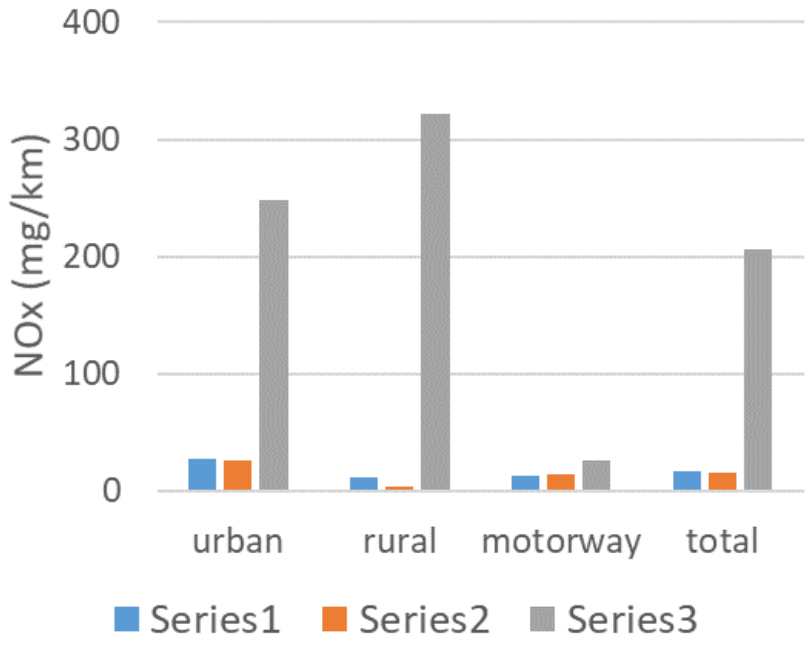


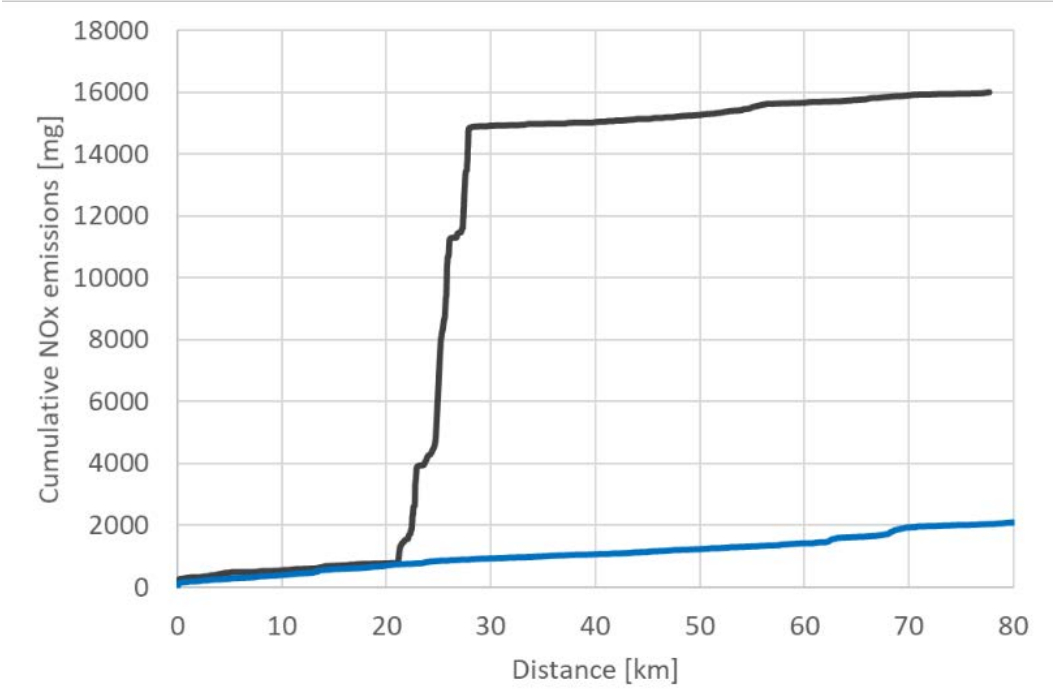




Outlier NOx result of gasoline vehicle 5

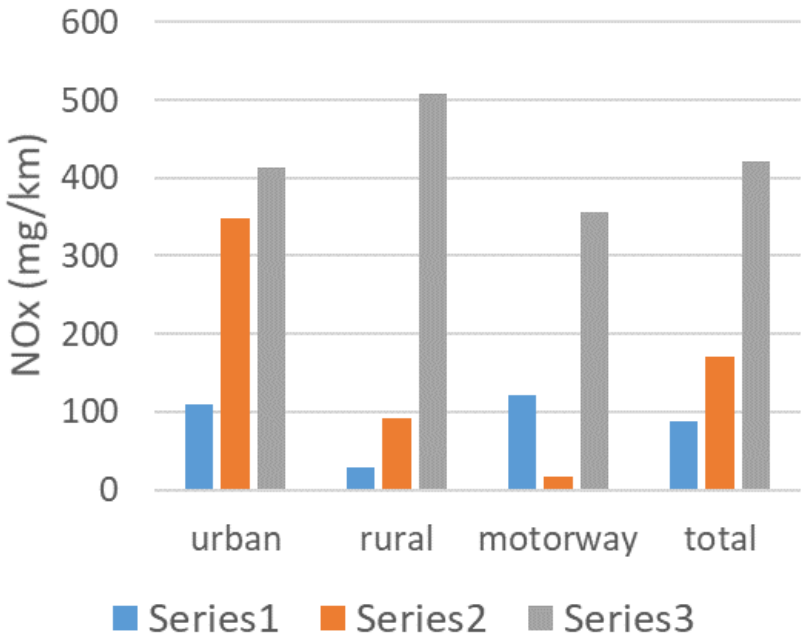
- Example of data without dominance by initial cold-start emissions
- Outlier result caused by event in the transition from urban to rural part of RDE test

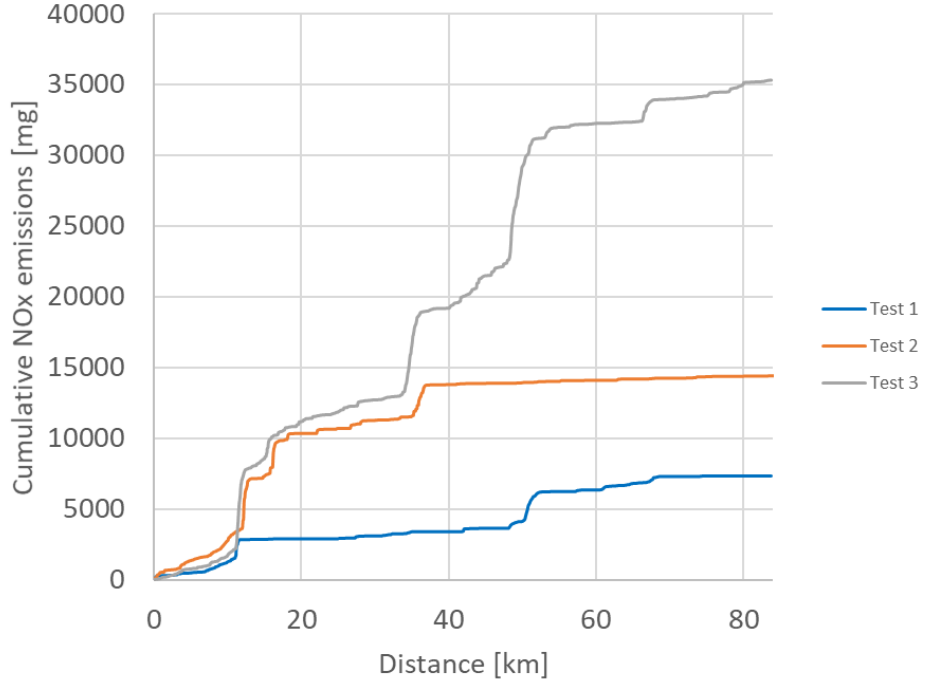




Outlier NOx result of diesel vehicle 14

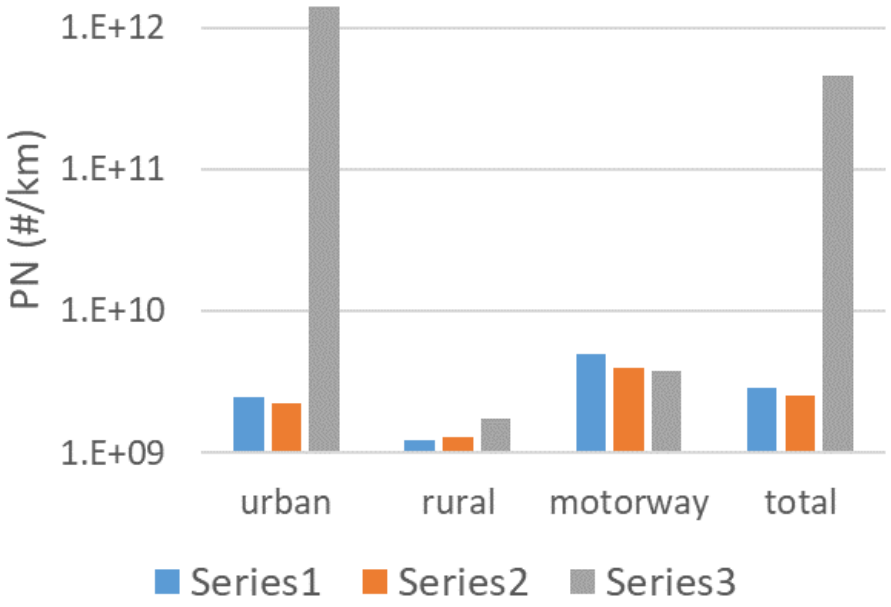
- Example of data without dominance by initial cold-start emissions
- Outlier result caused by different emission events
- Emission control system (EGR, LNT) limitations for wide range of driving conditions

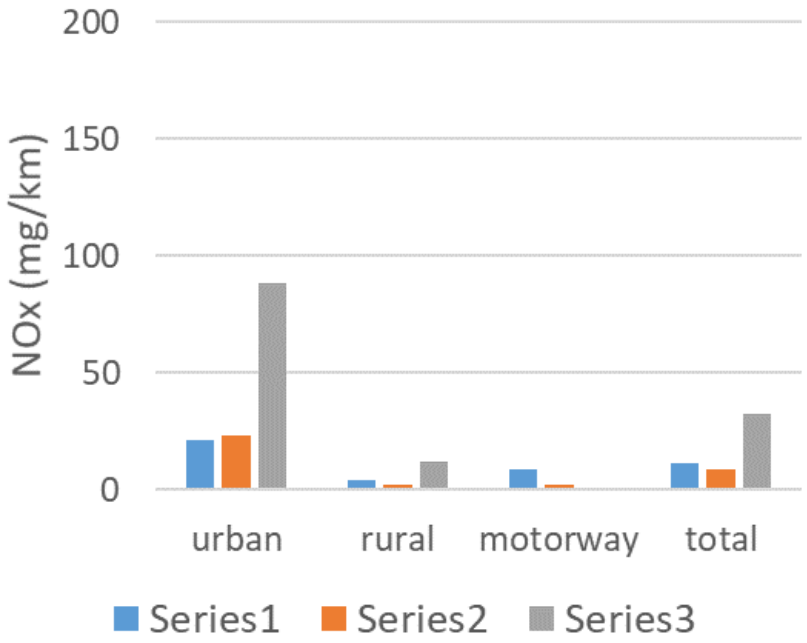




Outlier PN result of diesel vehicle 17

- Increased PN and NOx in urban part of RDE test 3
- Potentially due to DPF regeneration





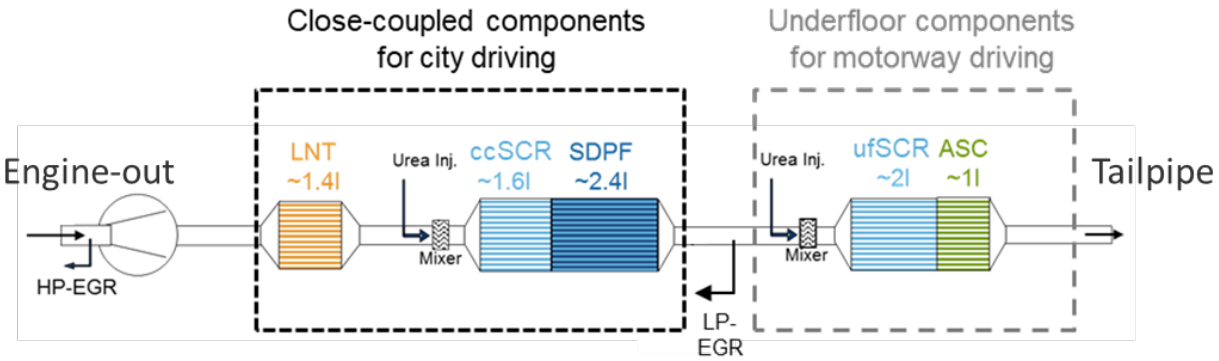
Conclusions and outlook

- PEMS data of diesel and gasoline vehicles investigated confirms significant reduction of NOx and PN emissions with introduction of RDE regulation
- Some outlier results were observed for both diesel and gasoline
  - Diesel NOx emissions tend to be higher in the motorway section
  - Other outlier results
    - Limitations of implemented emission control systems (no filter, no SCR)
    - Emission event that only occurs time to time (DPF regeneration)
- The initial cold-start emissions become increasingly important
- Effective legislation must ensure that remaining emission peaks are properly controlled by the testing protocol with appropriate averaging of emissions over the test, or part of it
- The effect of the initial cold-start on the report value in mg/km and #/km needs to be considered. But challenging conditions should not be overcompensated by the rest of the test

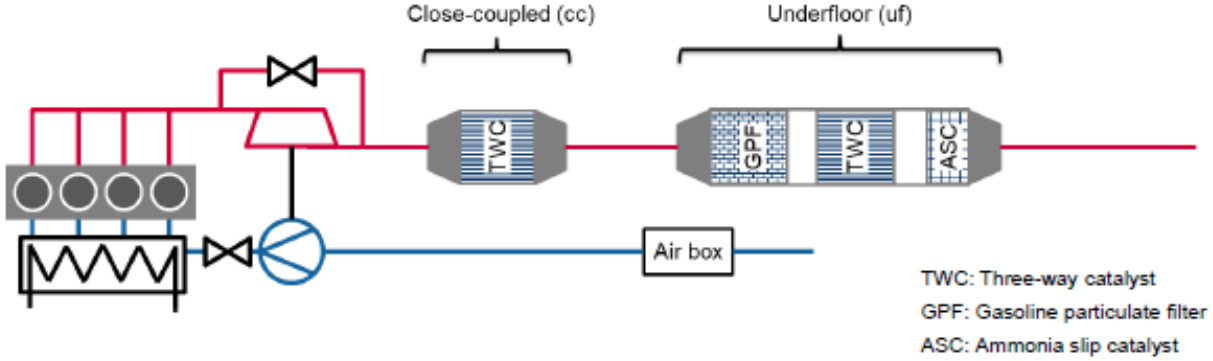
Conclusions and outlook

- AECC demonstration projects investigate ultra-low pollutant emissions in a broad range of driving conditions for light- and heavy-duty
- For light-duty diesel and gasoline emission control systems combine
  - Close-coupled catalysts for cold-start and low speed/load driving in the city
  - Underfloor catalysts for high speed/load area on the motorway
  - Total catalyst + filter volume to cope with peak engine pollutant flow

LD diesel demonstrator



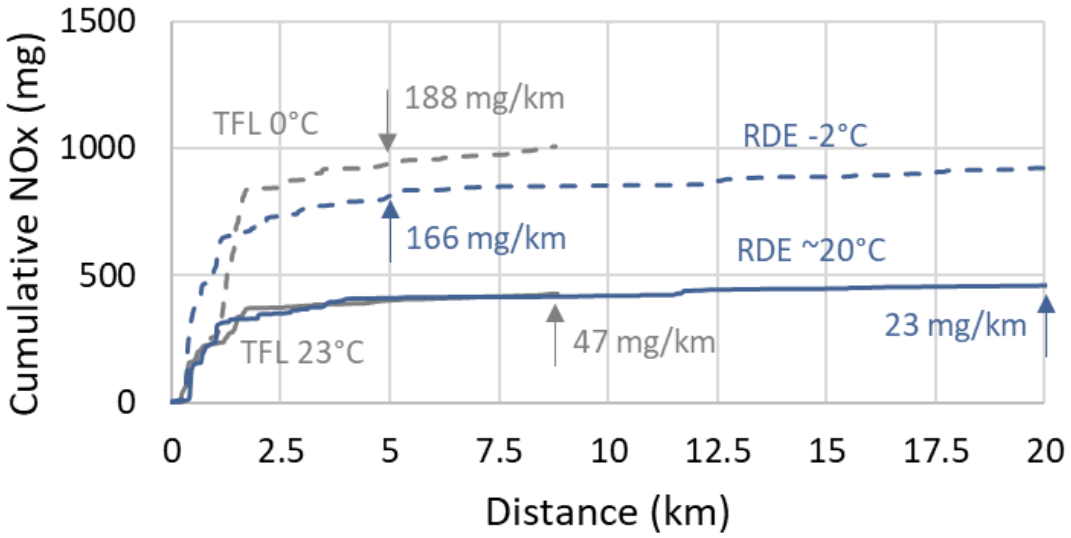
LD gasoline demonstrator



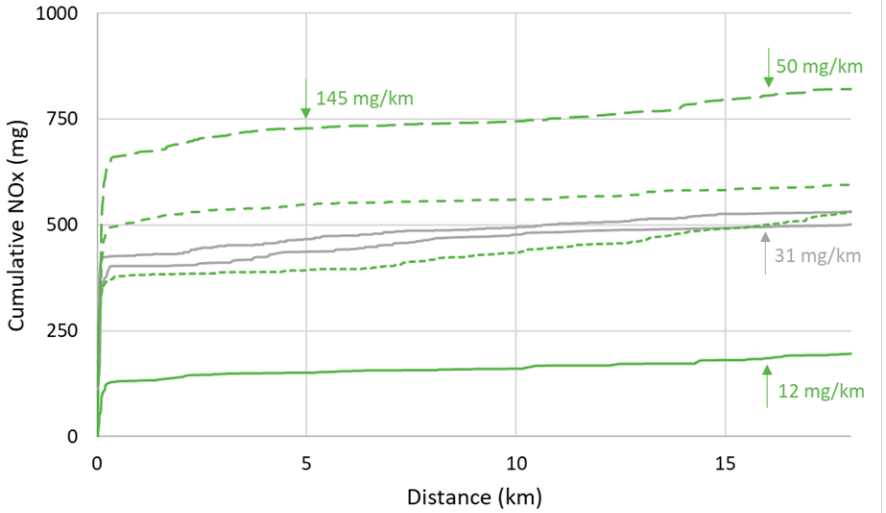
Conclusions and outlook

- AECC demonstration projects investigate ultra-low pollutant emissions in a broad range of driving conditions

LD diesel demonstrator



LD gasoline demonstrator



- Implementation of electrically heated catalyst will be investigated as active thermal management technology on light-duty gasoline vehicle to reduce the remaining initial cold-start emissions with minimal impact on CO_2 emissions

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