

# **Euro 6 Vehicles' RDE-PEMS Data Analysis with EMROAD and CLEAR**

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6<sup>th</sup> International MinNO<sub>x</sub> Conference  
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Association for Emissions Control by Catalyst AISBL

# Association for Emissions Control by Catalyst (AECC)

AECC members: European Emissions Control companies



Johnson Matthey

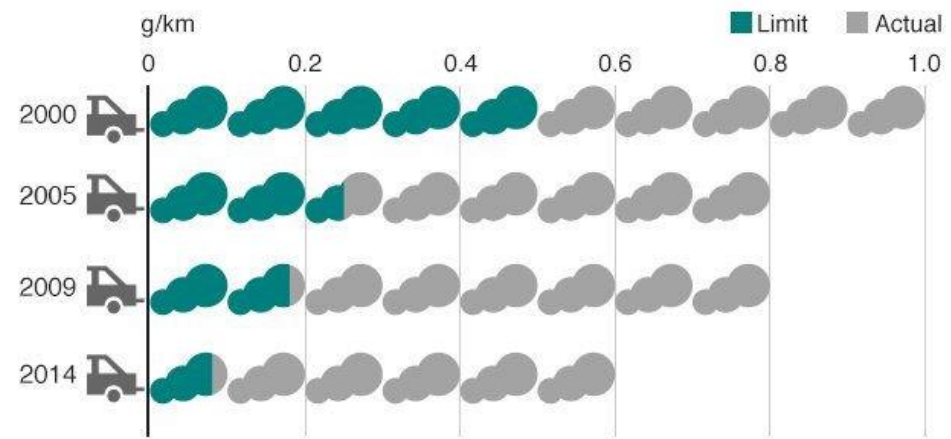


Technology for exhaust emissions control on cars, buses and commercial vehicles and an increasing number of non-road applications and motorcycles.

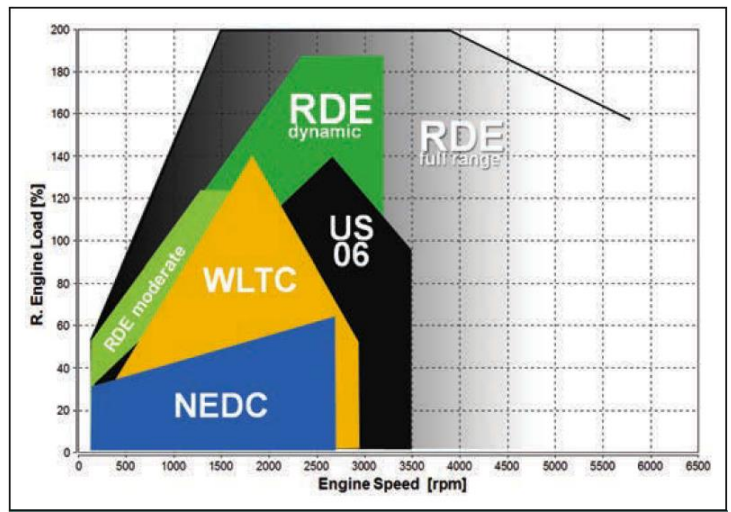


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# RDE legislation to close the gap between lab and real world emissions



Source: the ICCT



Source: AVL

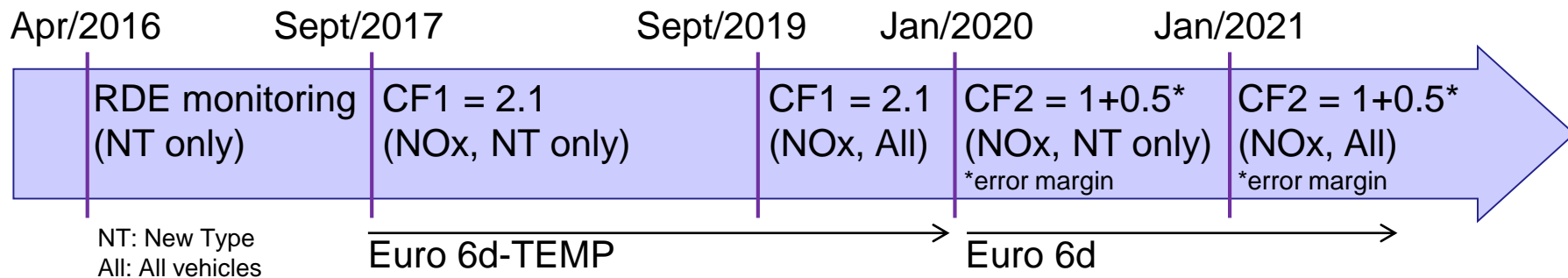
RDE: Real Driving Emissions



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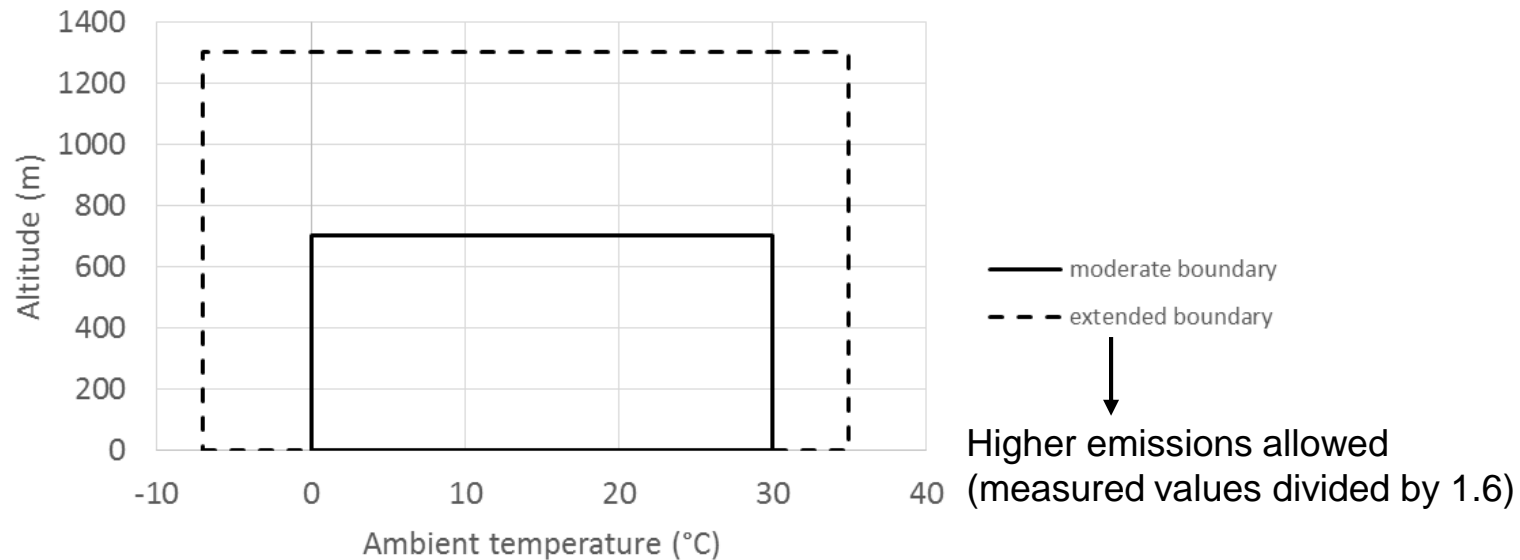
# RDE legislation to close the gap between lab and real world emissions

- Not-to-exceed (NTE) = Euro 6 limit x Conformity Factor (CF)
  - CF defined for NO<sub>x</sub>, PN expected
  - CF error margin to be reviewed annually
- CF applies to urban part and total trip
- Portable Emissions Measurement Systems (PEMS) are used



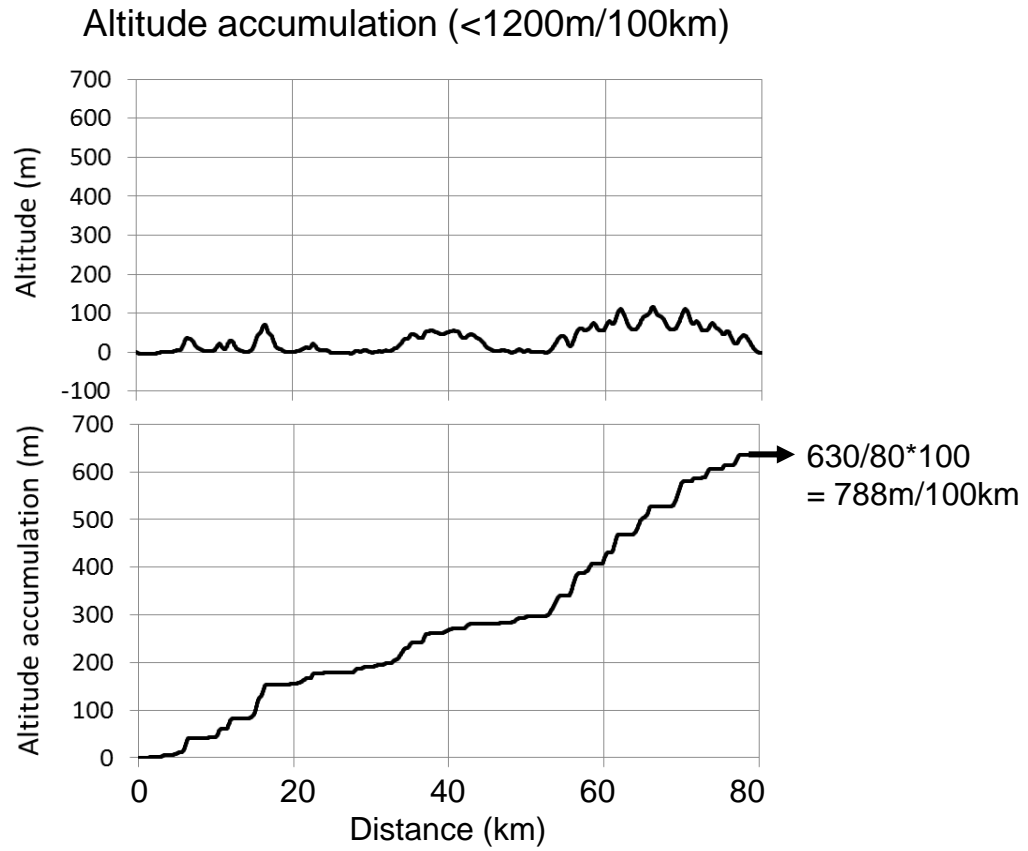
# RDE legislation to close the gap between lab and real world emissions

- Different boundary conditions define normal driving
  - Route criteria (duration, share urban/rural/motorway, ...)
  - Ambient conditions

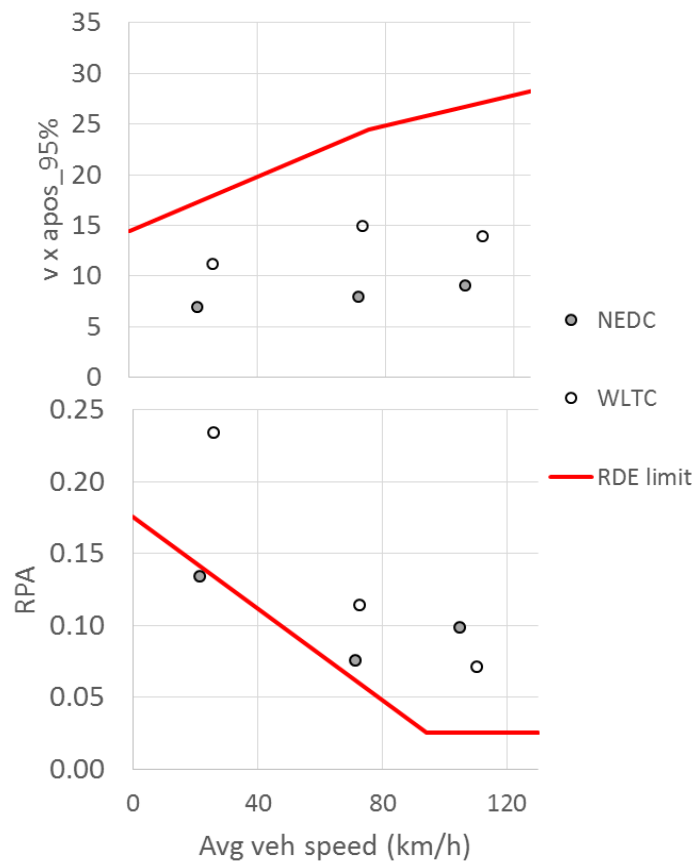


# RDE legislation to close the gap between lab and real world emissions

- Different boundary conditions define normal driving
  - Dynamic conditions

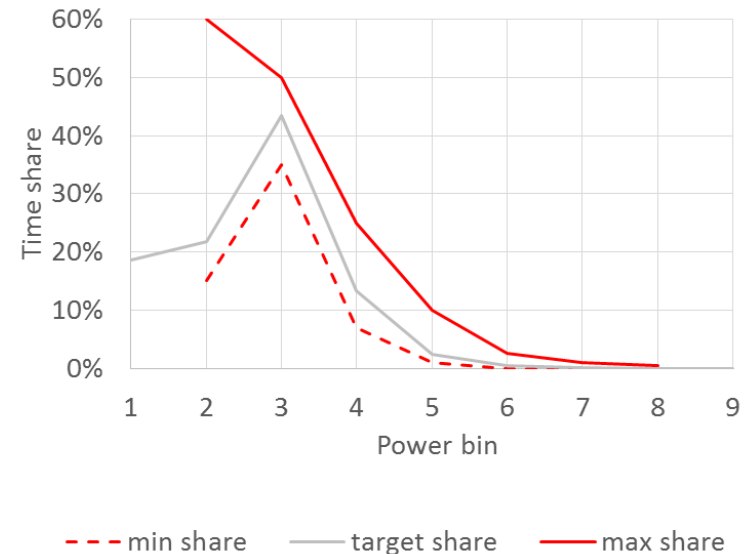
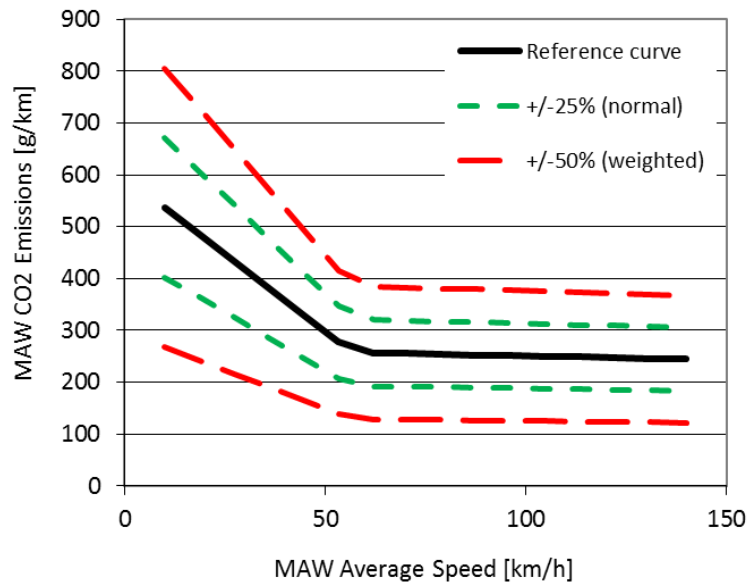


excess or absence of driving dynamics



# RDE legislation to close the gap between lab and real world emissions

- PEMS data is post-processed before CF is applied
  - RDE cold-start emissions are currently excluded
  - Tools further check & correct normality, based on WLTC reference
    - EMROAD (moving average window): 50% of windows in +/-25% range of CO<sub>2</sub> curve
    - CLEAR (power binning): limits defined for time share of each power bin



PEMS: Portable Emissions Measurement Equipment

CF: Conformity Factor

MAW: Moving Average Window



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# Content

- Overview of the AECC PEMS database
- Boundary conditions covered
- RDE NO<sub>x</sub> analysis with EMROAD and CLEAR
- Cold-start impact on RDE NO<sub>x</sub>



# Overview of AECC PEMS database

- Diesel vehicles → focus on NOx RDE
- Gasoline vehicles → focus on PN RDE

Vehicle	Year	Type	Series production/ demonstrator	Comment
1	2012	GDI-MPI	Series	Without GPF
2	2013	Diesel	Series	HP+LP EGR
3	2013	Diesel	Series	SCR
4	2013	Diesel	Series	LNT+SCR
✓ 5	2014	Diesel	Demonstrator NOx CF<1.5	SCR on DPF
✓ 6	2015	Diesel	Series NOx CF<1.5	SCR on DPF
7	2015	GDI	Series NOx and PN CF<1	With GPF
8	2016 ongoing	GDI	Series + Demonstrator	Without GPF With GPF



GDI: Gasoline Direct Injection  
 MPI: MultiPoint Injection  
 GPF: Gasoline Particulate Filter  
 HP: High Pressure  
 LP: Low Pressure  
 EGR: Exhaust Gas Recirculation  
 SCR: Selective Catalytic Reduction  
 LNT: Lean NOx Trap  
 DPF: Diesel Particulate Filter

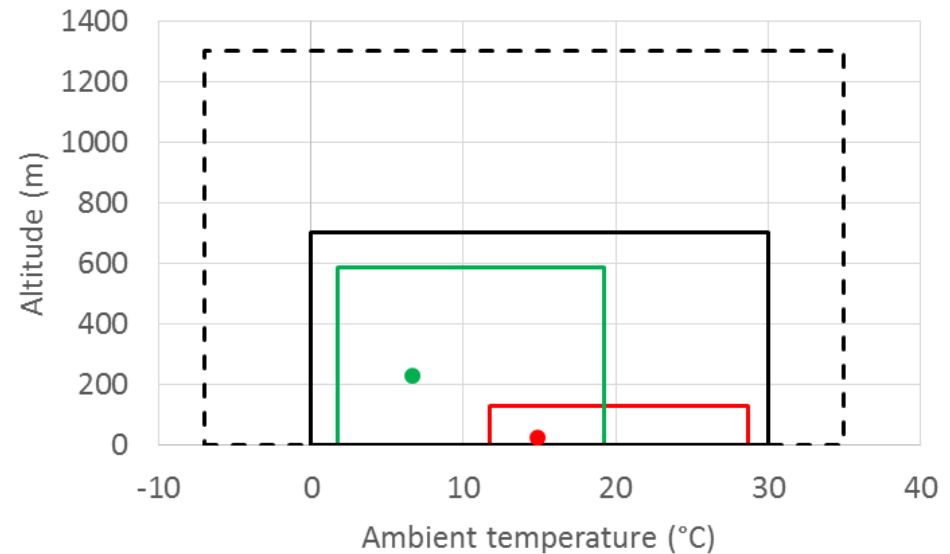
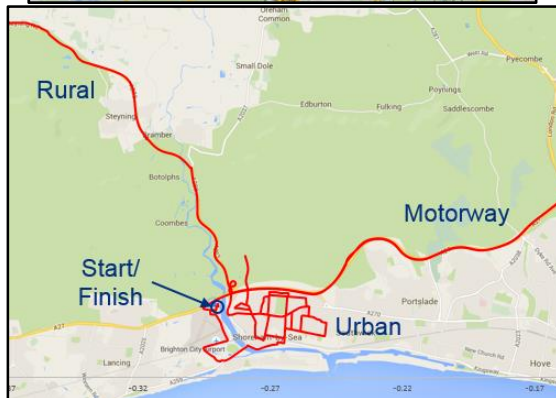
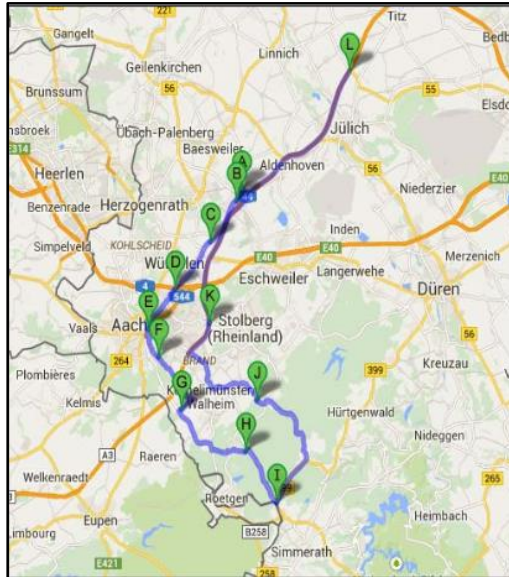
✓ Focus of this presentation



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# Boundary conditions covered

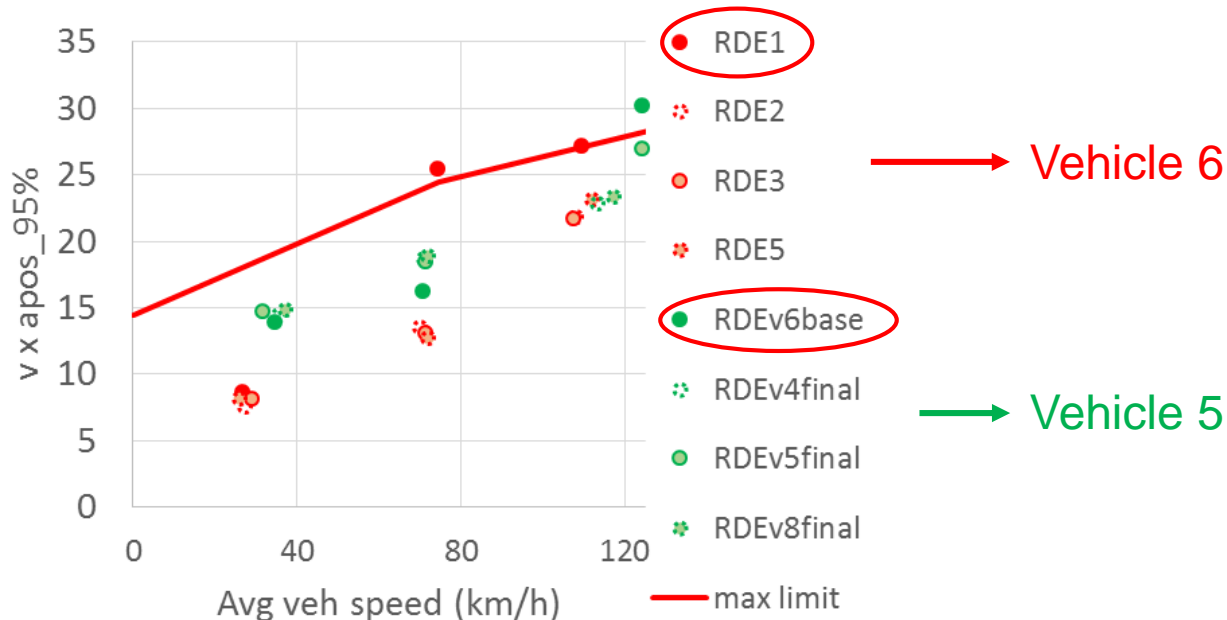
- RDE routes of vehicle 5 and 6 meet the requirements
- All data within the moderate environmental boundary conditions



- 2015 Veh6
- 2015 Veh6 avg
- 2014 Veh5
- 2014 Veh5 avg
- moderate boundary
- - - extended boundary

# Boundary conditions covered

- The dynamic boundary conditions exclude some data
  - altitude accumulation is  $\sim 800\text{m}/100\text{km}$ , all data within the limit
  - upper acceleration limit ( $v_{x_{\text{apos}}}$ ) excludes 2 trips



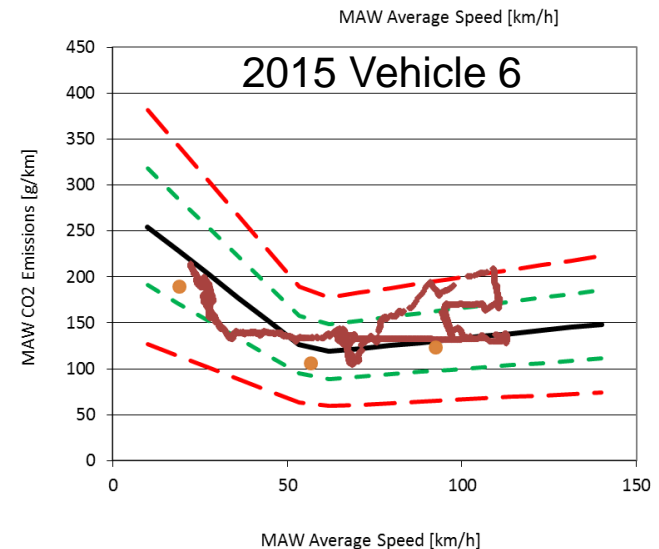
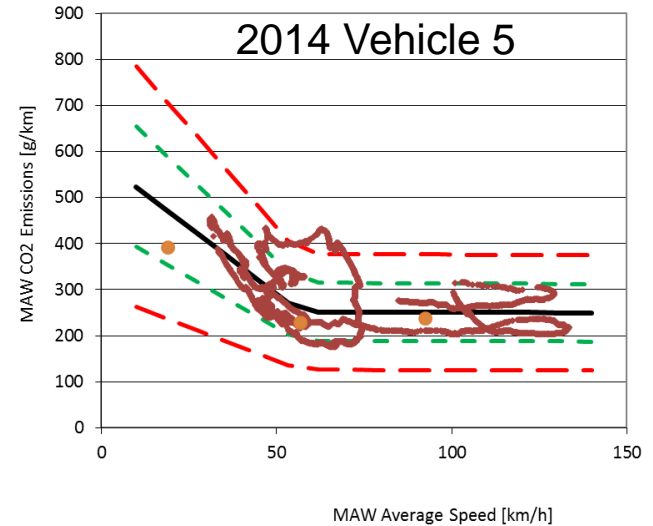
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- Overview of the AECC PEMS database
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- Cold-start impact on RDE NO<sub>x</sub>

# RDE NOx analysis with EMROAD and CLEAR

- all AECC data valid for EMROAD

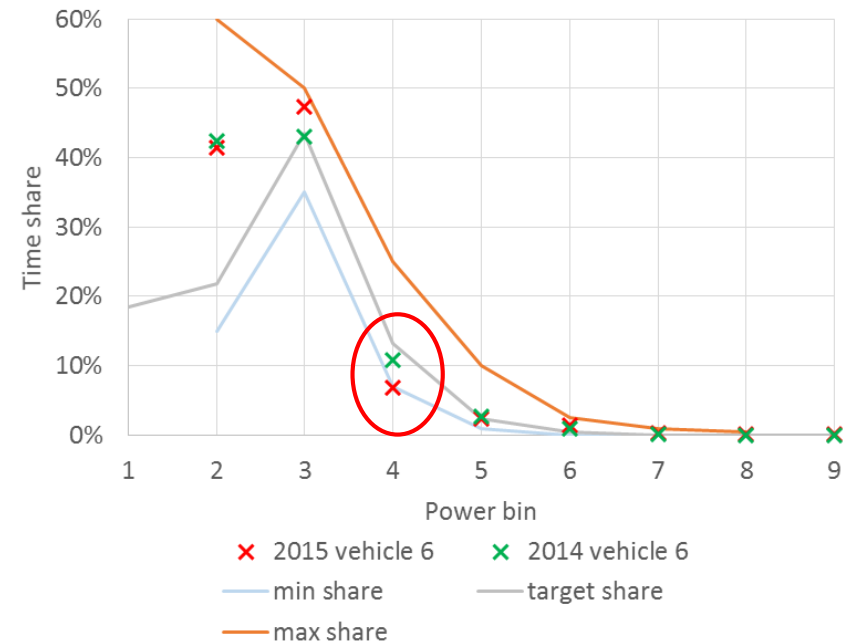
	Normality of windows
2014 Vehicle 5	✓ - Urban: ~90% - Rural: 60-70% (hilly) - Motorway: ~90%
2015 Vehicle 6	✓ - Urban: ~100% - Rural: ~100% - Motorway: ~70% (hilly)



# RDE NOx analysis with EMROAD and CLEAR

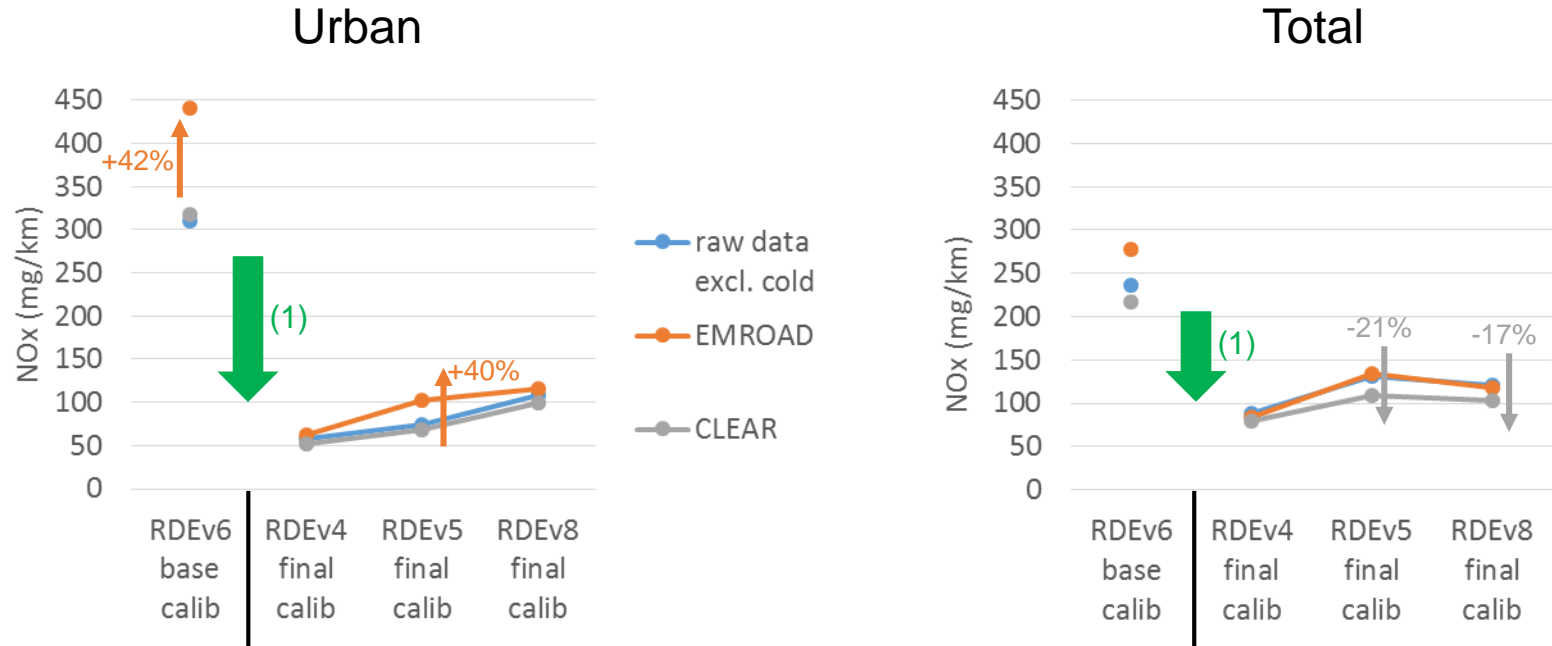
- Some data is just outside the minimum share for CLEAR, but all data is included in the analysis

		2014 Vehicle 5	2015 Vehicle 6
RDE 1	Urban Total	✓ ✓	✓ ✗
RDE 2	Urban Total	✓ ✓	✓ ✗
RDE 3	Urban Total	✓ ✓	✓ ✓



# RDE NOx analysis with EMROAD and CLEAR

- Vehicle 5 results compared to raw emission value
  - Project showed overall NOx reduction from base to final calibration (1)
  - The tools have a different normalisation impact
  - Corrections between -21% (-22.5mg/km) and +42% (+130mg/km)

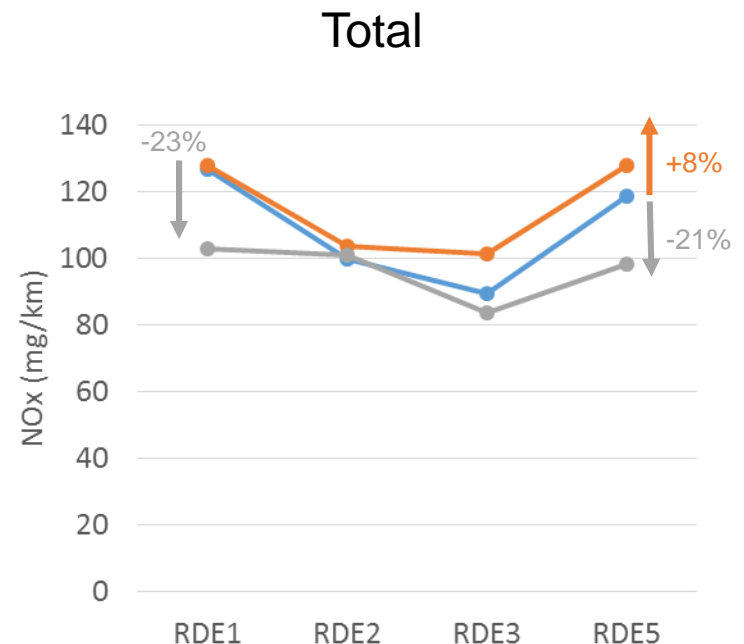
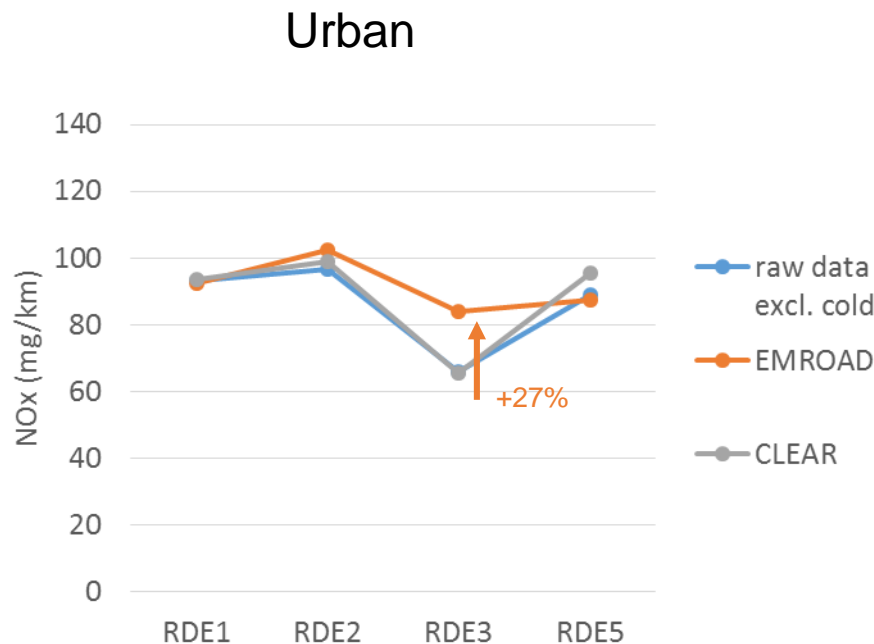


excluding cold start emissions; EMROAD v. 5.9B5; CLEAR v. 1.8.13



# RDE NOx analysis with EMROAD and CLEAR

- Vehicle 6 results compared to raw emission value
  - The tools have a different normalisation impact
  - Corrections between -23% (-23.7mg/km) and +27% (+17.9mg/km)



excluding cold start emissions; EMROAD v. 5.9B5; CLEAR v. 1.8.13

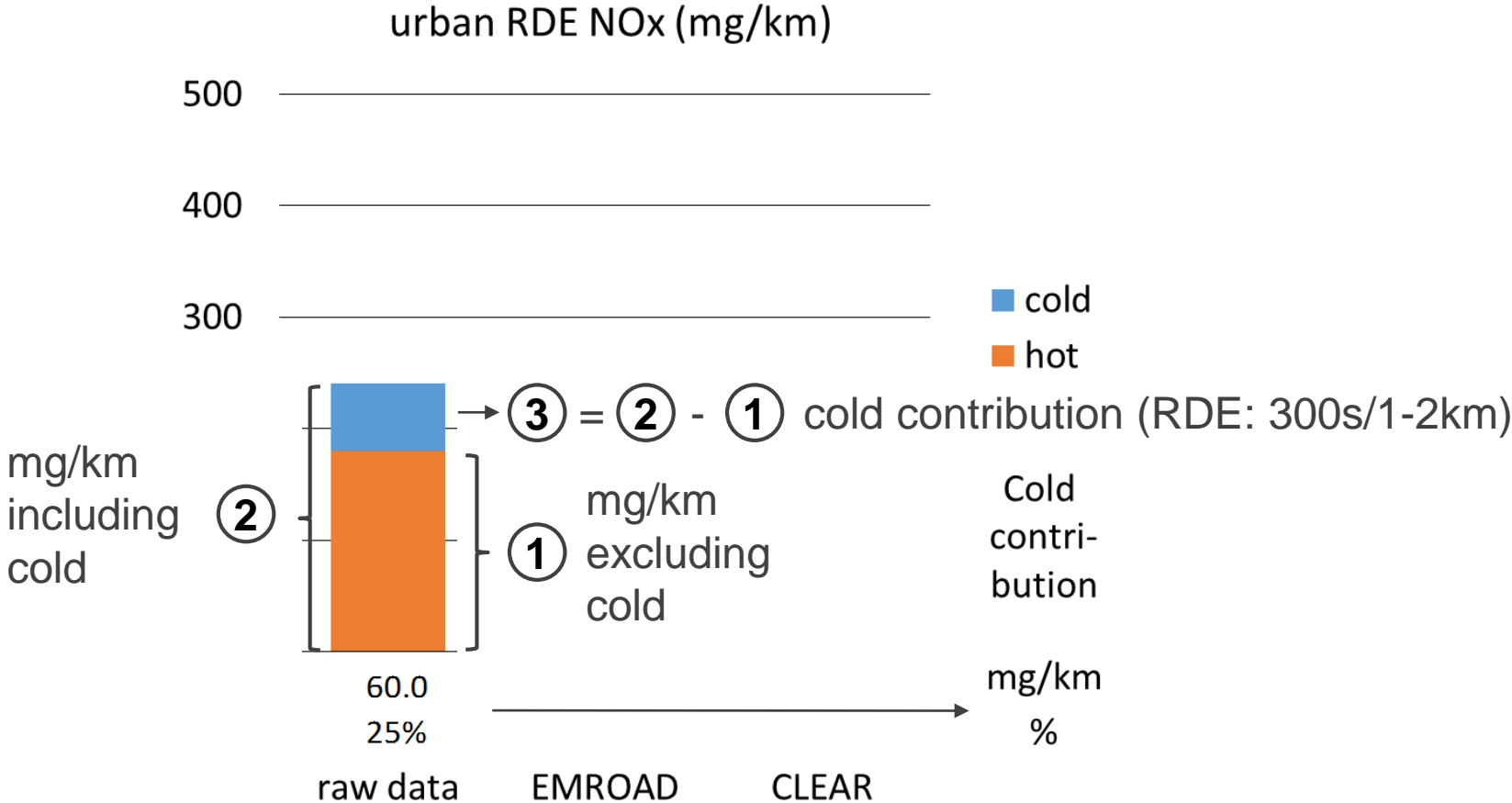


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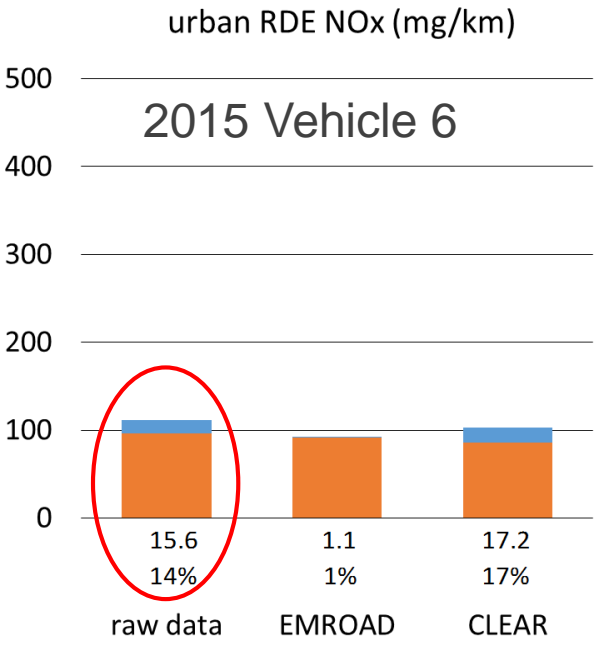
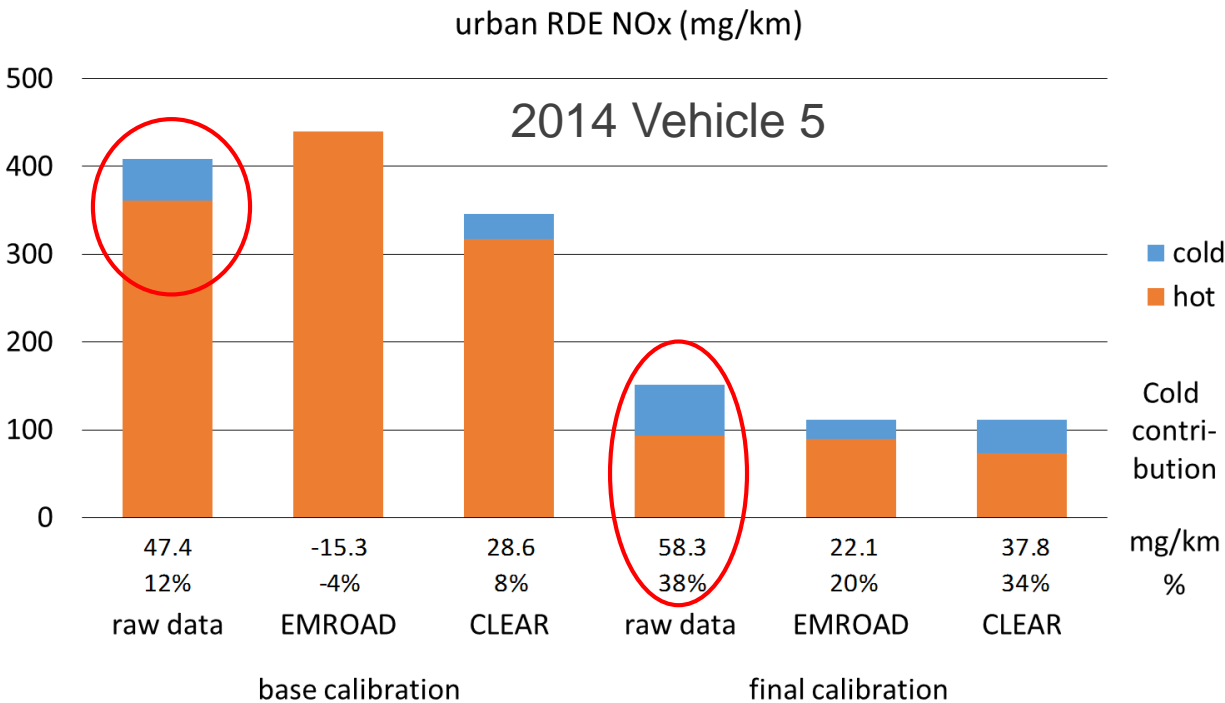
# Cold start RDE analysis

- Impact of currently excluded 5 minutes of cold start emissions on urban RDE data



# Cold start RDE analysis

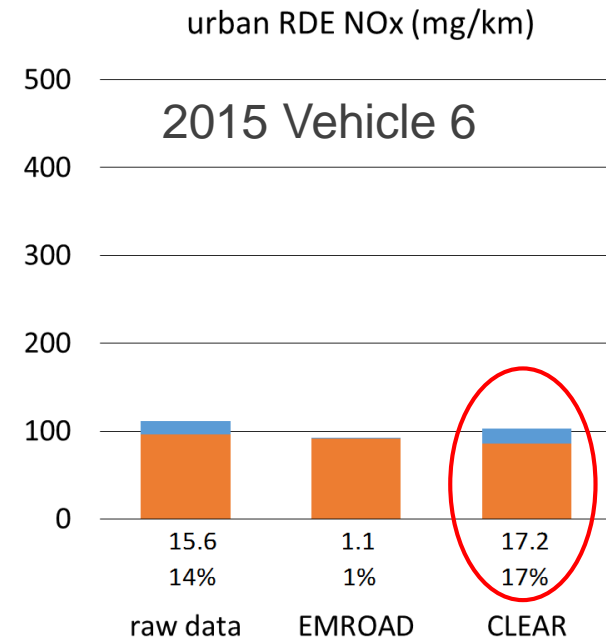
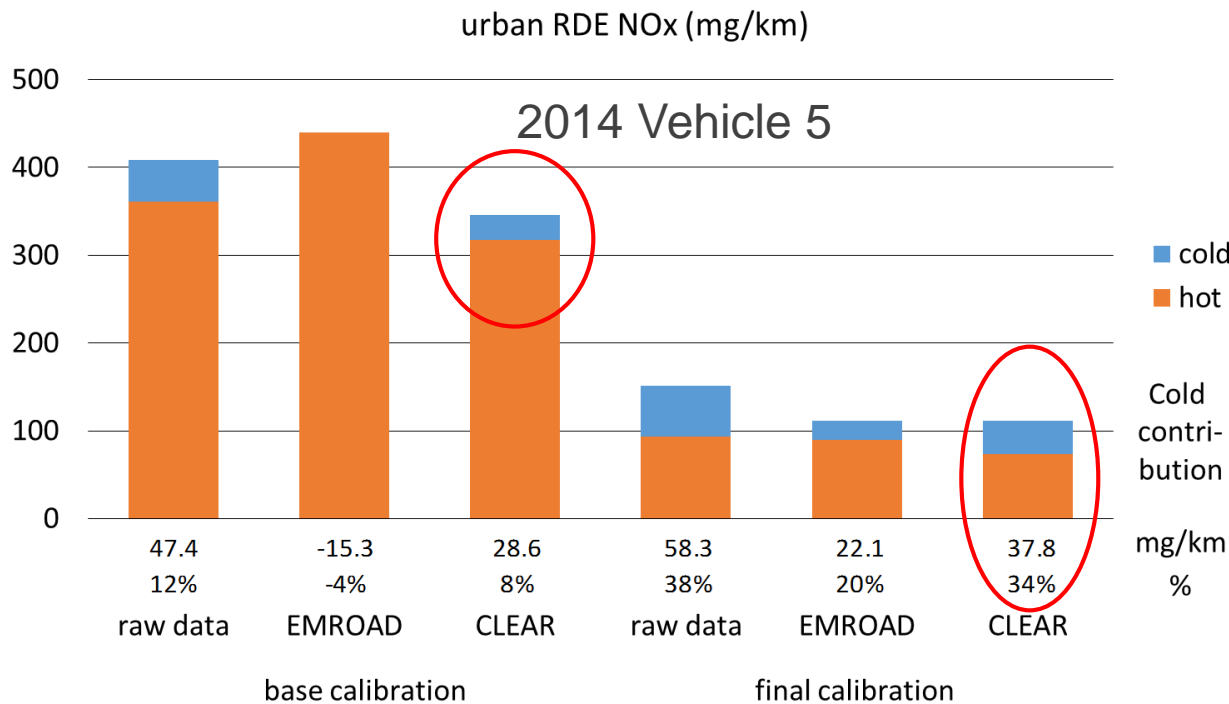
- Impact on diesel NOx
  - Significant cold start contribution in raw urban data (up to 38%)



# Cold start RDE analysis

- Impact on diesel NOx

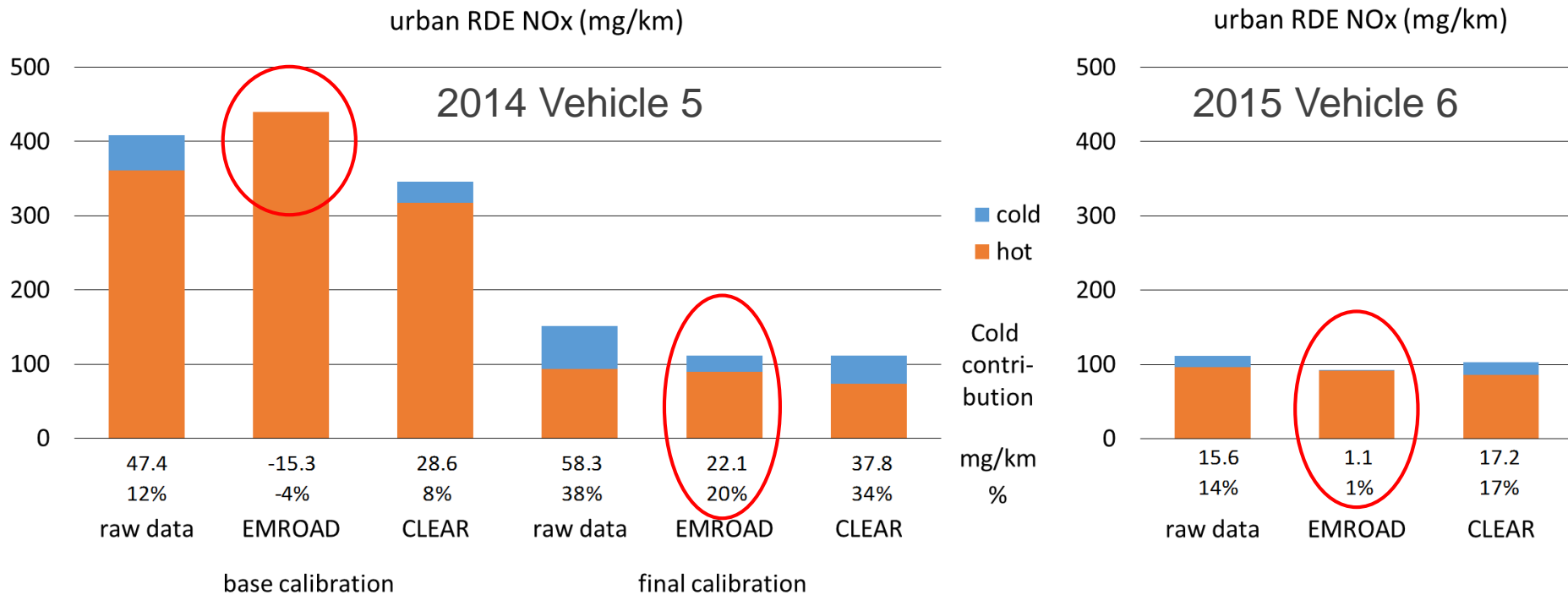
1. Significant cold start contribution in raw urban data (up to 38%)
2. Contribution CLEAR ~ raw data



# Cold start RDE analysis

- Impact on diesel NOx

1. Significant cold start contribution in raw urban data (up to 38%)
2. Contribution CLEAR ~ raw data
3. Only significant contribution in EMROAD for final calibration of vehicle 5

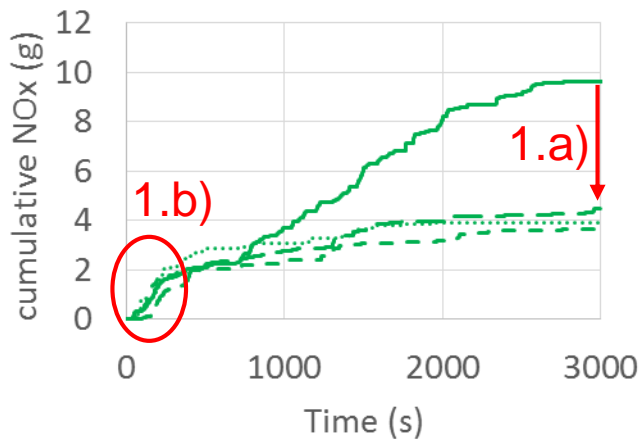


# Cold start RDE analysis

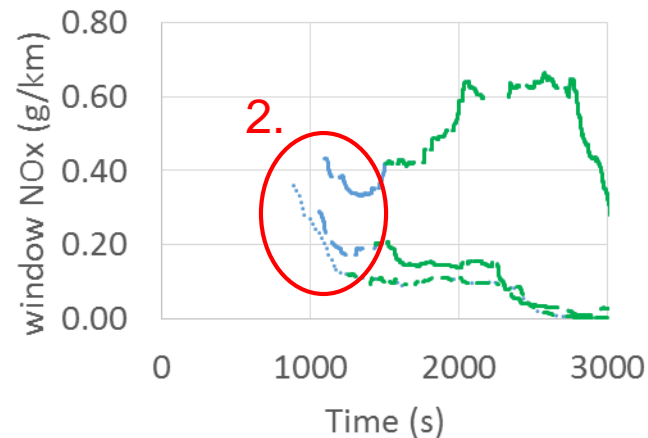
- Extra analysis on 2014 Vehicle 5 data
  1. Final calibration showcase of what could happen if cold start remains excluded
    - a) Overall emissions in urban reduced
    - b) But same NOx ramp during cold start → contribution increases
  2. Final value is average of moving average windows

Base calibration: NOx of extra cold windows < hot windows  
→ cold start not significant in EMROAD

Final calibration: NOx of extra cold windows > hot windows  
→ cold start significant in EMROAD



— RDEv6base  
... RDEv4final  
- - RDEv5final  
- . RDEv8final



— RDEv6base  
- - RDEv4final  
... RDEv5final  
- . RDEv8final

# Conclusions (1/2)

- RDE legislation is being introduced to reduce the gap between lab and real world emissions.
- Different boundary conditions are included to define normal driving. The analysis shows that the majority of the presented AECC PEMS data is valid, although the data was measured before the final set of boundary conditions was defined.
- The measured emissions are post-processed with one of the two normalisation tools (EMROAD and CLEAR). A comparison with the raw NO<sub>x</sub> emissions of two diesel vehicles shows that the two tools have a different normalisation impact with corrections that vary from -23% to +42%.

# Conclusions (2/2)

- The currently excluded 5 minutes of cold-start emissions have a significant impact. The NO<sub>x</sub> data of two diesel vehicles shows a cold start contribution of up to 38% in the raw urban data.
- Cold-start should be well controlled by the RDE legislation. This is expected to be part of the RDE package 3.
- Further analysis of the AECC PEMS database will be undertaken to better understand the normalisation impact of EMROAD and CLEAR.





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### Who are AECC and what do we do ?

**AECC** is an international non-profit scientific association of European companies making technologies for engine exhaust emissions control.

The members of AECC are companies operating worldwide in the research, development, testing and manufacture of key technologies for emissions control.

Their products are the ceramic and metallic substrates for catalysts and filters; autocatalysts (substrates with catalytic materials incorporated or coated); adsorbers; filter-based technologies to control particulate emissions from diesel and other lean burn engines; and speciality materials incorporated into the catalytic converter or filter.

Catalyst-equipped cars were first introduced in the USA in 1974 but only appeared on European roads in 1985 and in 1993 legislation forced their use on cars. Now more than 275 million of the world's 500 million cars and over 85% of all new cars produced worldwide are equipped with autocatalysts. Catalytic

### What are the emission control technologies?

Exhaust gas contains carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM). The main technologies used to treat exhaust to remove harmful gases and particles are:

- autocatalysts
- adsorbers (traps)
- filters

There are more details on the technology pages.



# Thank you for your attention

Dieselretrofit