

# **Real-driving emission results from GDI vehicles with and without a GPF**

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IQPC 4<sup>th</sup> International Conference  
Advanced Emission Control Concepts  
for Gasoline Engines

Bonn, 10-12 May 2016



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.



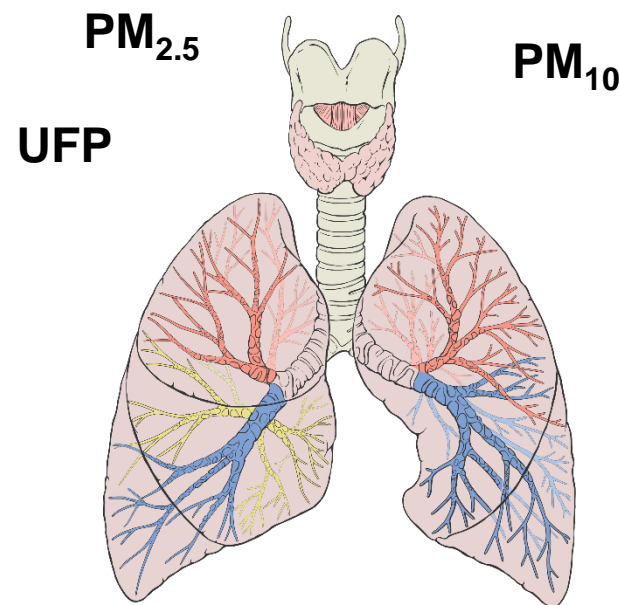
Association for Emissions Control by Catalyst AISBL

# Content

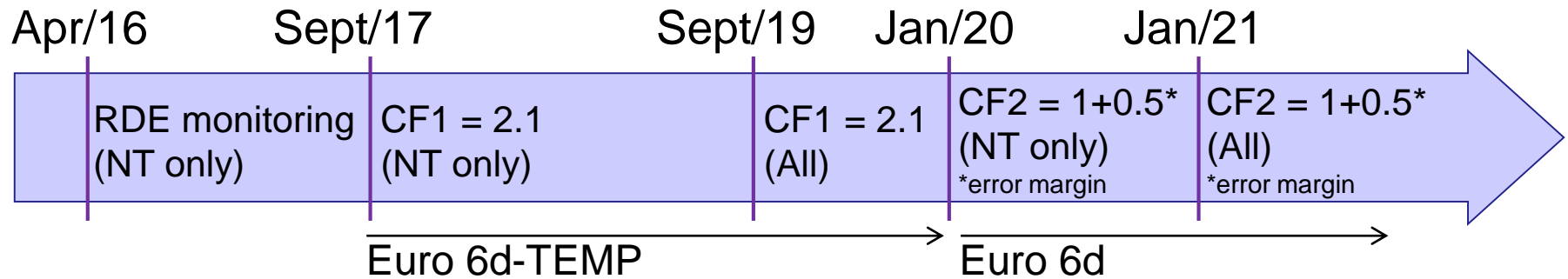
- Setting the scene
- 2016 GDI test programme
  - Set-up
  - NEDC and WLTC results
  - RDE results
- Cold start GDI PN emissions
- Conclusions

# Health impact of ultrafine particles

- Concerns reported because of the surface area of UFP and its translocation capability into the human body
- Conclusions of 2013 WHO Review of Evidence on Health Aspects of Air Pollution (REVIHAAP)
  - Indications for toxic effects of UFP
  - Not enough epidemiological evidence for UFP air quality guideline in addition to  $PM_{2.5}$  and  $PM_{10}$
  - Precautionary principle: WHO supports regulatory efforts to reduce the number of UFP (PN) in engine emissions



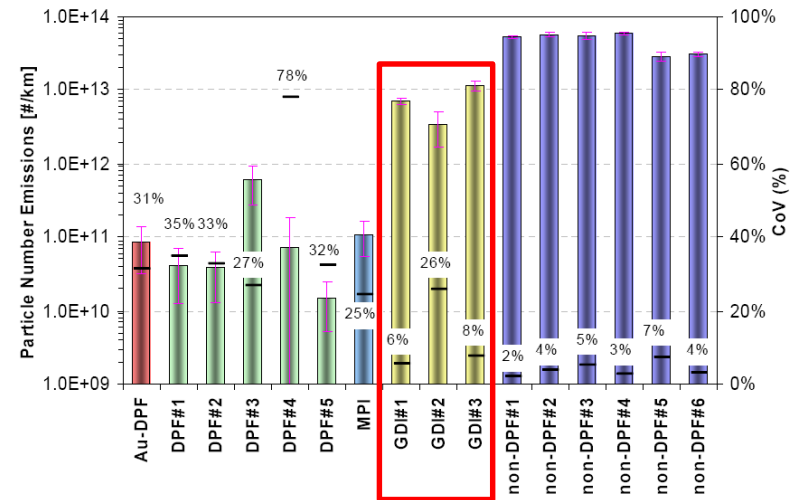
# RDE legislation to close the gap between lab and real world emissions



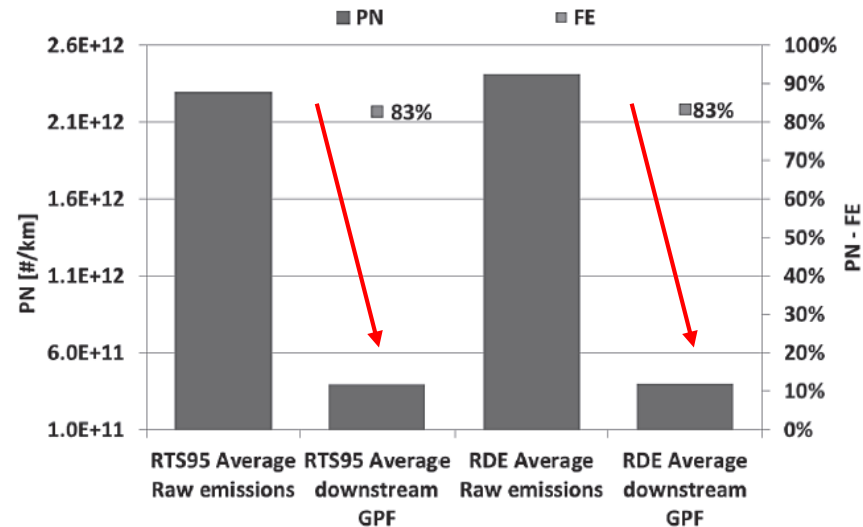
- NTE limit = Euro 6 limit x CF
  - CF defined for NO<sub>x</sub>, PN expected
  - Error margin to be reviewed annually
- CF applies to urban part and total trip
- PEMS data post-processed with normalisation tools
  - EMROAD (moving average window) and CLEAR (power binning)
  - Normalisation for dynamic driving conditions
  - Cold start emissions post-processing expected

# The GDI particle RDE issue

- CO<sub>2</sub> legislation promotes fuel-efficient Gasoline Direct Injection (GDI) in the EU
- Particles emitted by DI gasoline vehicles are higher than Euro 6c limit of  $6 \times 10^{11}$  #/km, especially under real driving conditions
- Gasoline Particulate Filters (GPF) are an effective route to reduce the number of ultrafine particles under a range of driving conditions

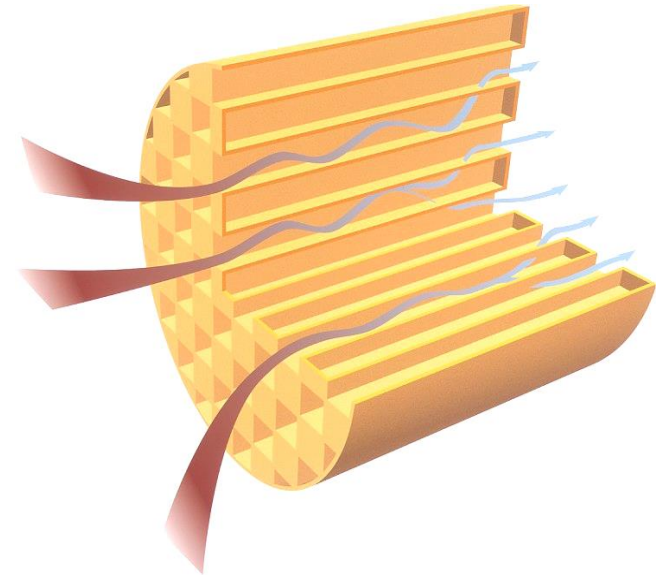
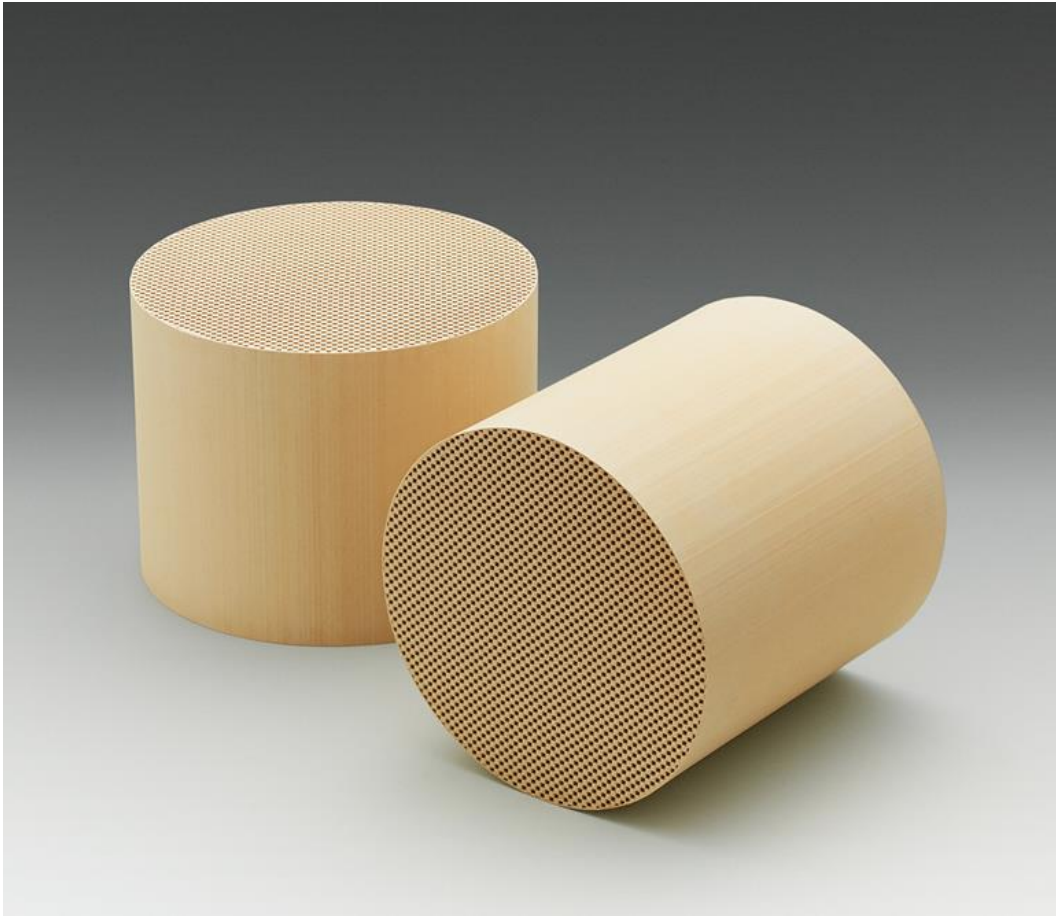


Source: PMP Inter-Laboratory Correlation Exercise Final Report



Source: AECC member

# Gasoline Particulate Filter (GPF)



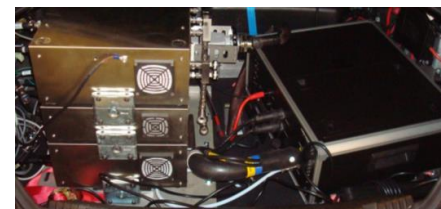
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# 2016 GDI test programme within the AECC PEMS database

- Diesel vehicles → focus on NO<sub>x</sub> RDE
  1. 2013: HP+LP EGR, on market
  2. 2013: SCR, on market
  3. 2013: LNT + SCR, on market
  4. 2014: SCR on DPF, clean diesel demonstrator, CF<1.5
  5. 2015: SCR on DPF, on market, CF<1.5
- Gasoline vehicles → focus on PN RDE
  1. 2012: GDI-MPI w/o GPF, on market
  2. 2015: 1<sup>st</sup> GDI w GPF on market  
NO<sub>x</sub> and PN CF <1
  3. 2016: GDI w/o GPF on market + GPF demonstrator; ongoing



# 2016 GDI test programme set-up

- Objective: investigate NO<sub>x</sub> & PN RDE without and with GPF
- At Ricardo in cooperation with Concawe
- Vehicle
  - Medium size, 1.4l engine
  - Market representative GDI technology targeting Euro 6c → only Euro 6b available
  - Original configuration w/o GPF
  - Add coated GPF demonstrator underfloor
- HORIBA PEMS equipment
  - Gaseous PEMS (CO<sub>2</sub>, CO, NO<sub>x</sub>)
  - PEMS-PN demo unit



# 2016 GDI test programme set-up

- Identified parameters to evaluate
  - fuel type & quality
  - cold start PN
  - driving dynamics (RDE on dyno)
  - cold ambient temperature
  - <23nm PN

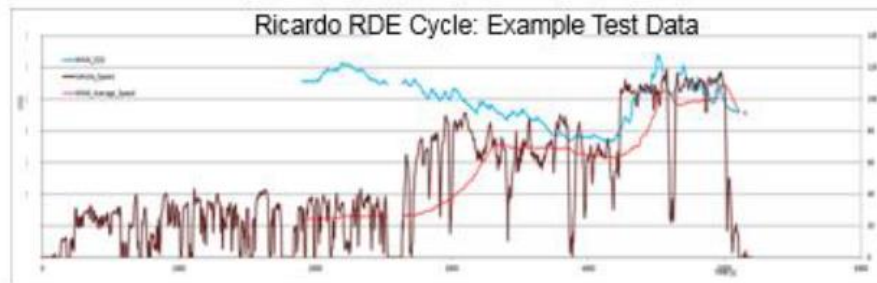
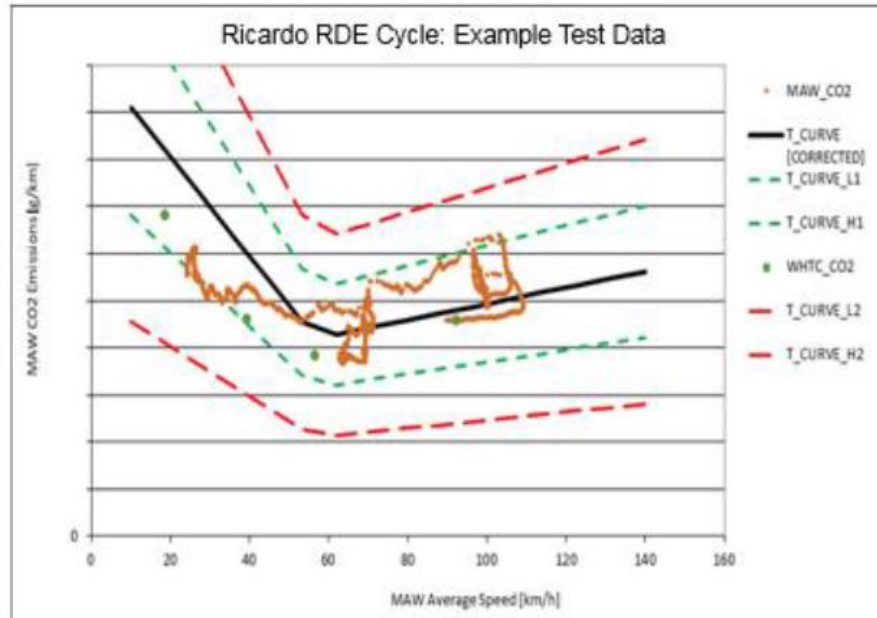
- Test matrix

- Focus of today

- Market E5
- NEDC + WLTC
- RDE on road
- no exclusions/  
normalisation

Exhaust	Fuel	NEDC + WLTC	RDE on road	RDE on dyno
Original (without GPF)	Ref E5	1x	-	-
	Ref E10	1x	3x	-
	Market E5	1x	3x	6x
With coated GPF	Ref E10	1x	3x	-
	Market E5	1x	3x	6x

# 2016 GDI test programme RDE route



Label	Route Validity			EMROAD Processing		
	% Distance by phase			Valid MAW>15%		
	Urban <60	Rural >90	MW >90	Urban <60	Rural >90	MW >90
Ricardo RDE Cycle	30%	36%	33%	35%	43%	22%

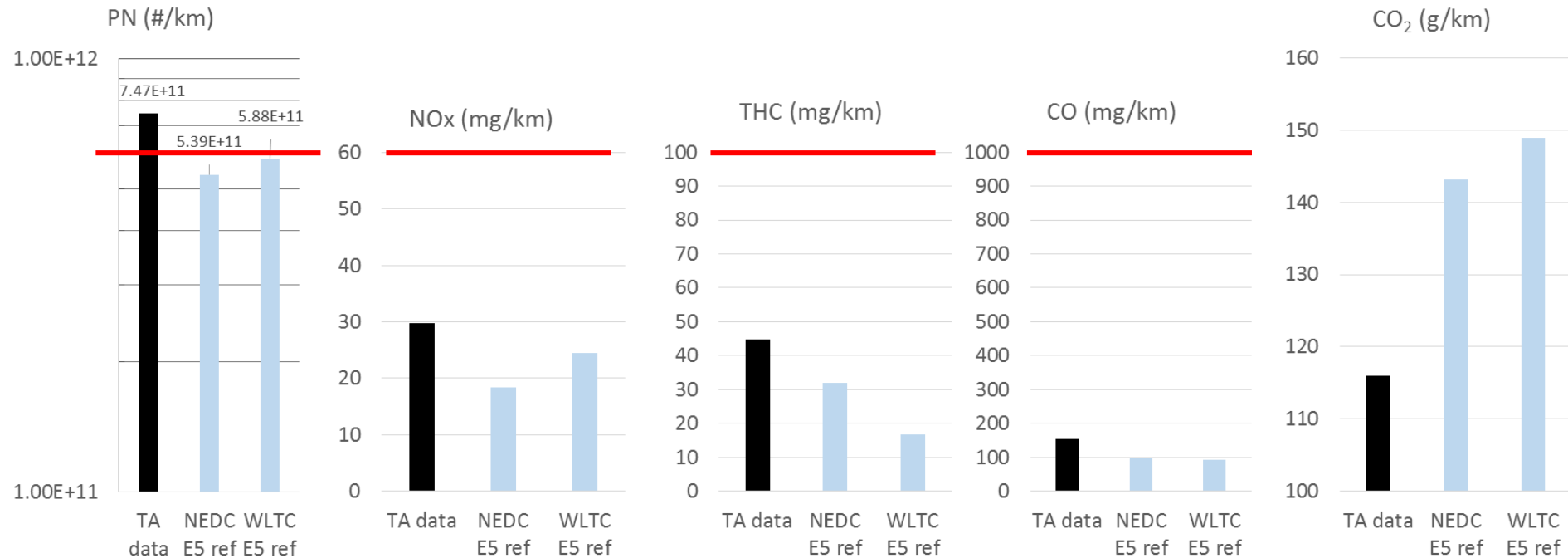
EMROAD Driving Style

>= 50% valid MAW "Normal" each phase.

Yes (67%U, 100%R, 96%M)

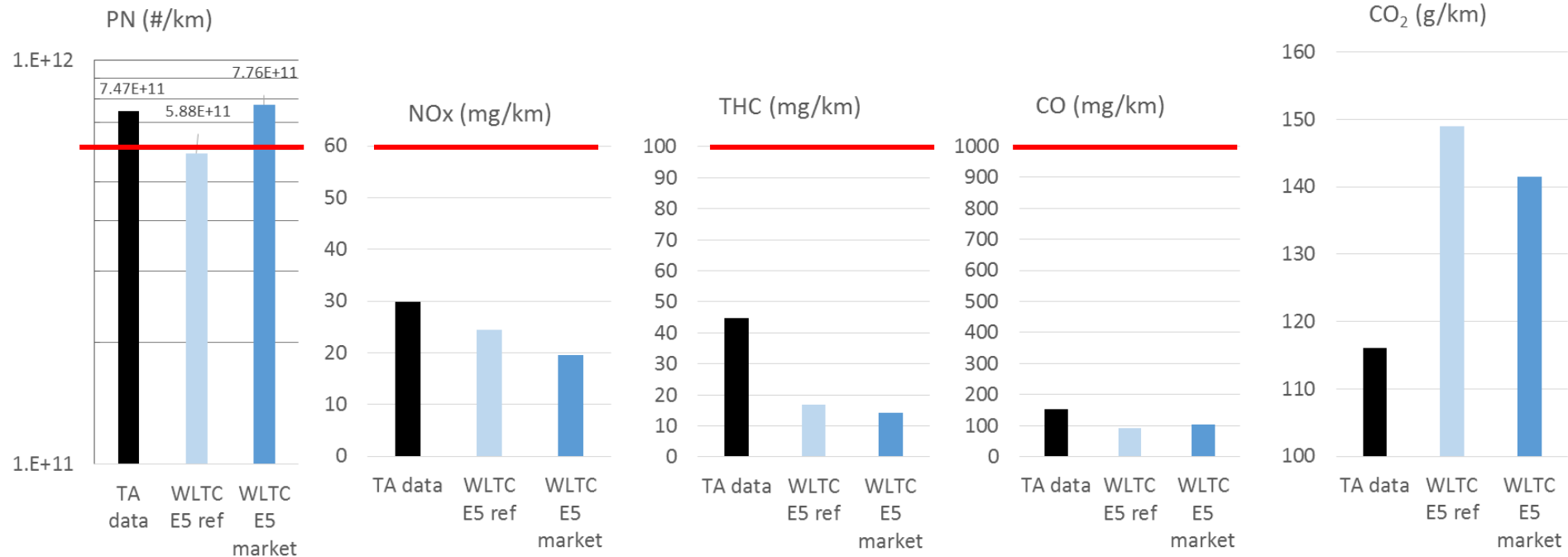
# NEDC + WLTC results w/o GPF on E5 ref fuel are below Euro 6c limits

- Data demonstrates that the vehicle is a state of the art GDI



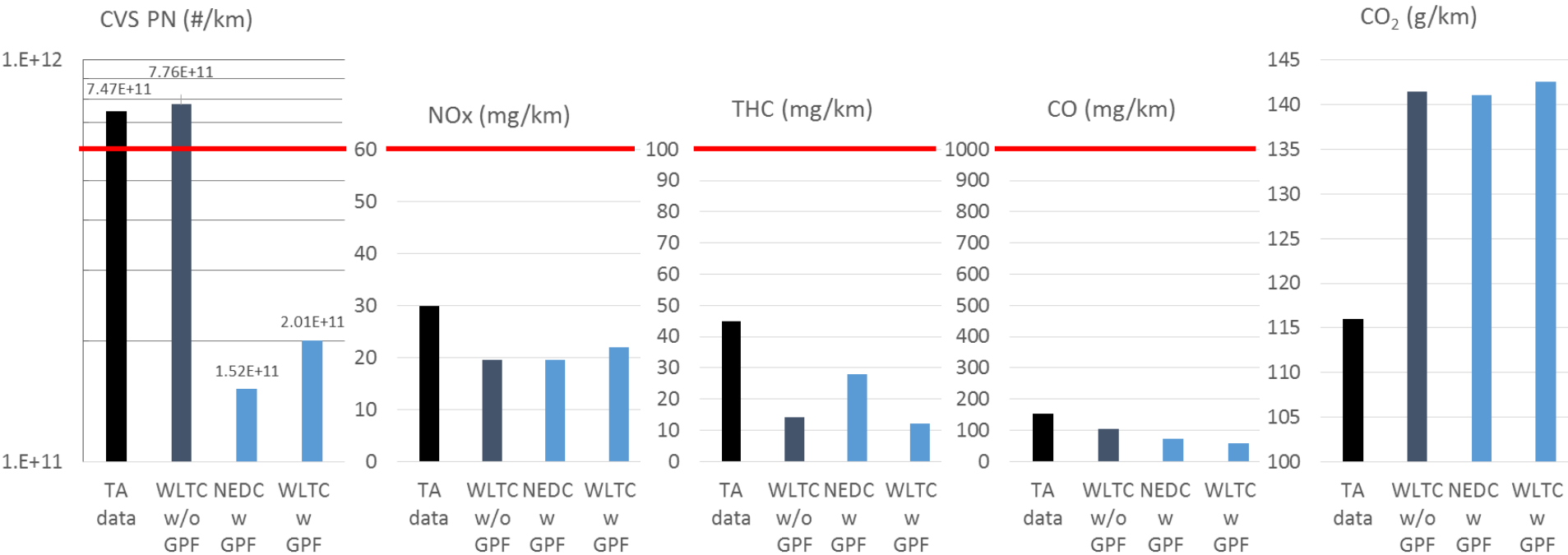
— Euro 6c limit

# WLTC results w/o GPF on market fuel are within Euro 6c limits, except PN



— Euro 6c limit

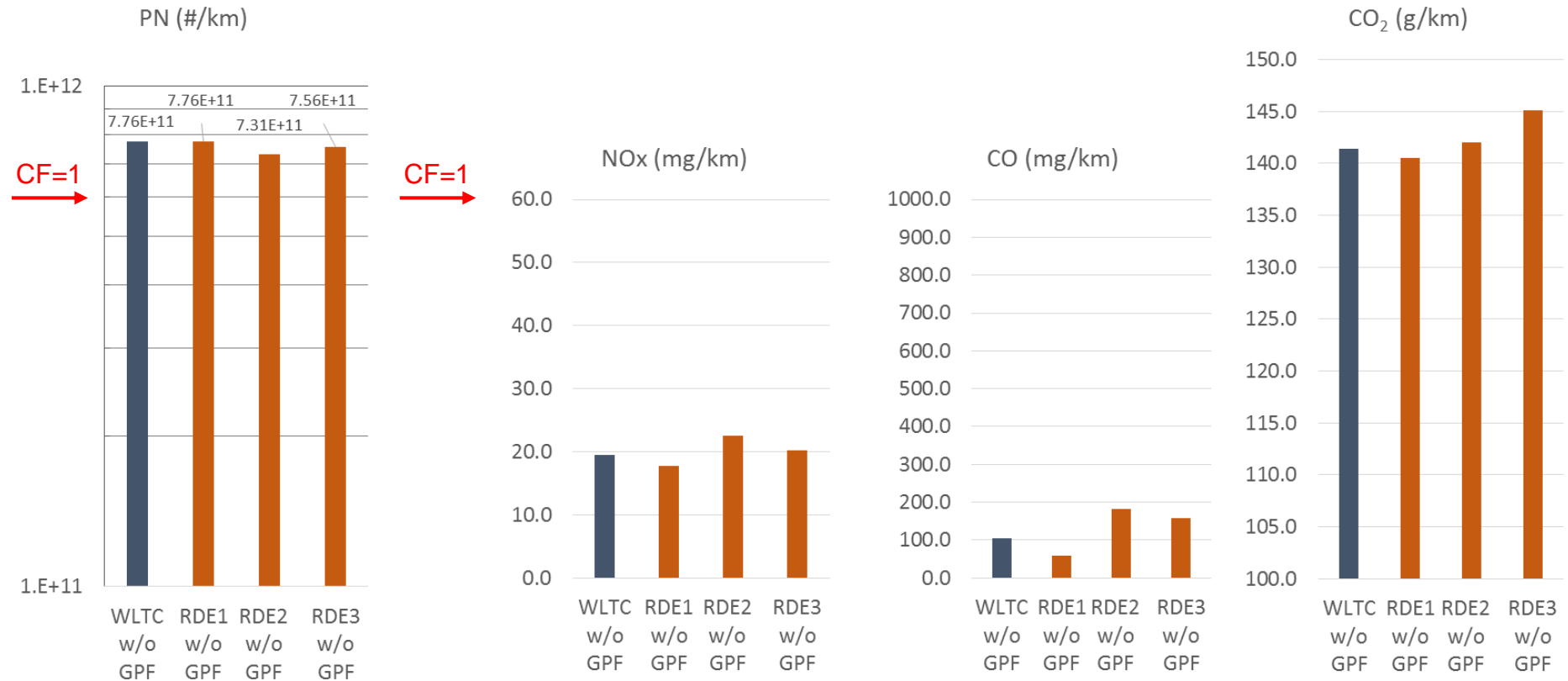
# NEDC and WLTC results with GPF on market fuel are within Euro 6c limits



— Euro 6c limit

# Total RDE results w/o GPF

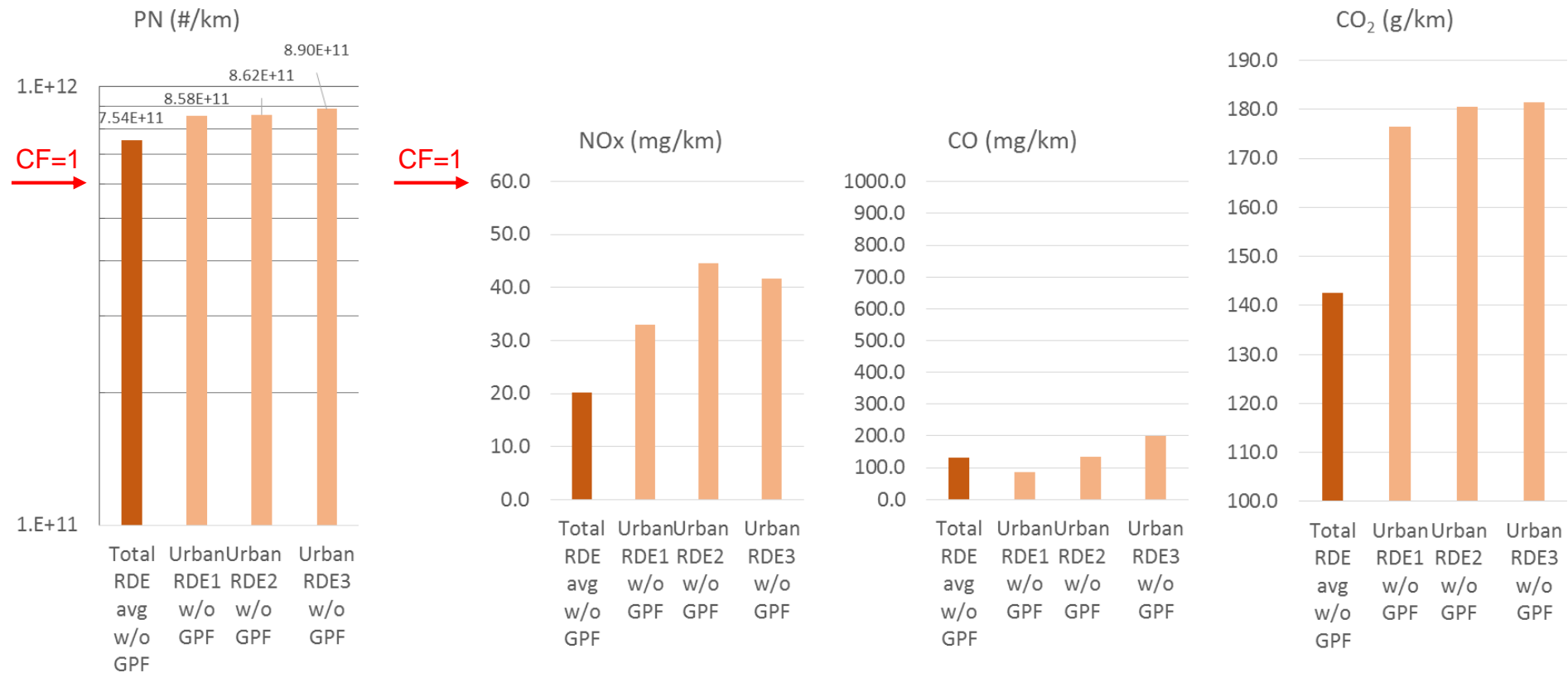
- Preliminary data, without exclusions/normalisation





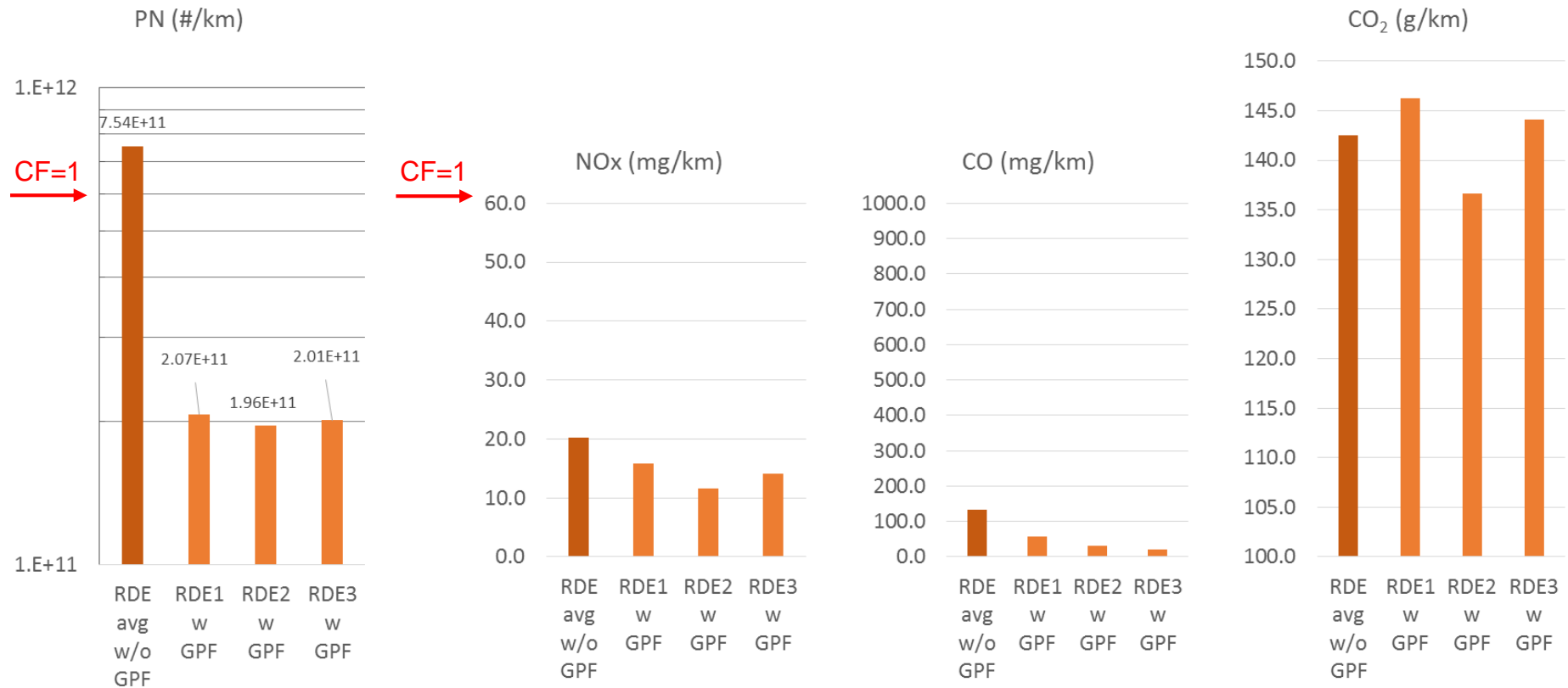
# Urban RDE results w/o GPF

- Preliminary data, without exclusions/normalisation



# Total RDE results with GPF

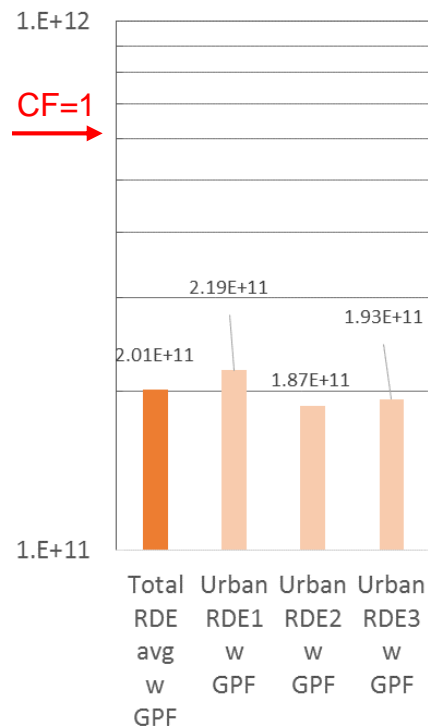
- Preliminary data, without exclusions/normalisation



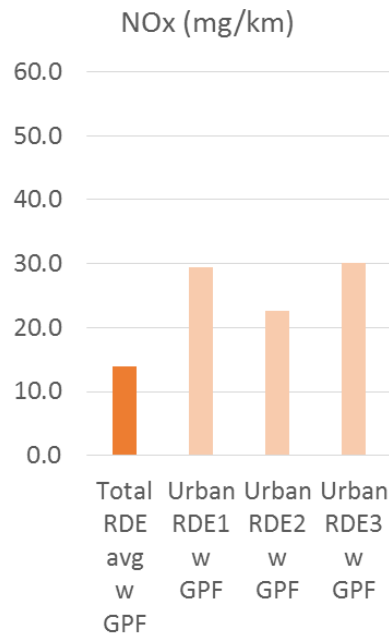
# Urban RDE results with GPF

- Preliminary data, without exclusions/normalisation

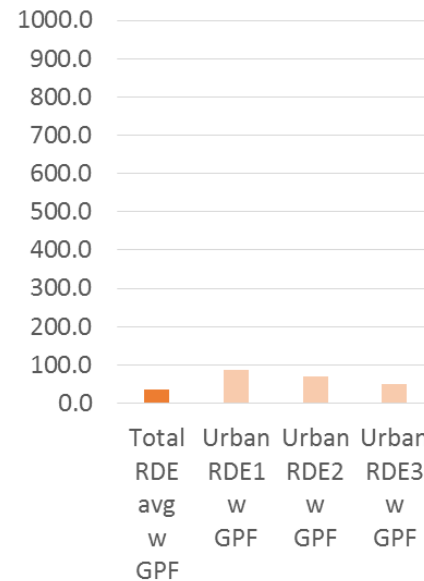
PN (#/km)



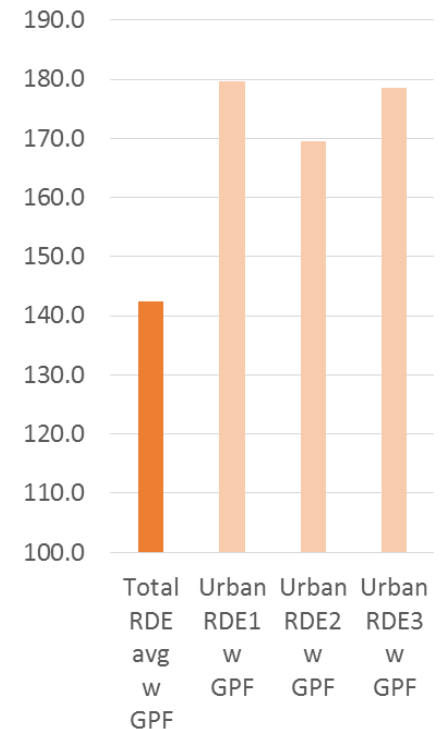
CF=1 →



CO (mg/km)



CO<sub>2</sub> (g/km)



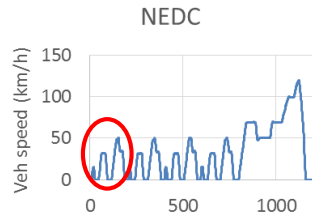
# 2016 GDI programme next steps

- Investigate impact of normalisation tools
- Investigate fuel impact (reference E10 vs. market E5)
- Investigate impact of boundary conditions
- Investigate <23nm PN

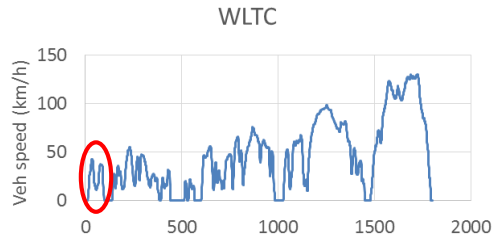
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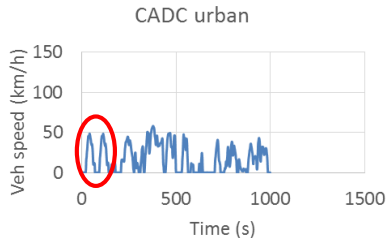
# Impact of cold start on urban RDE is compared to that in test cycles



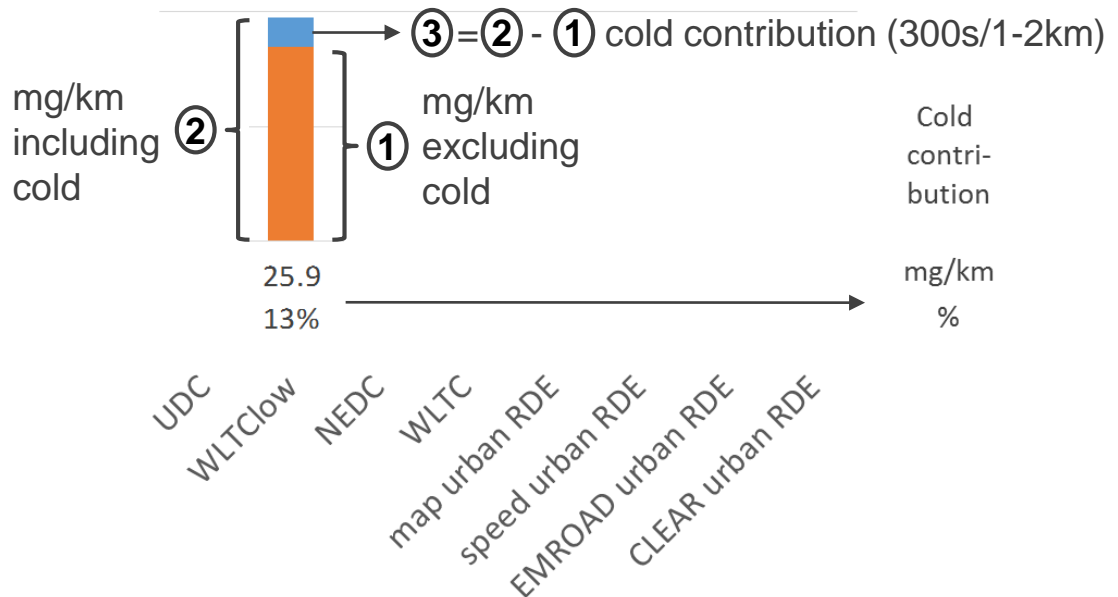
Cold: UDC1 (200s/1km)



Cold: first short trip (120s/0.61km)

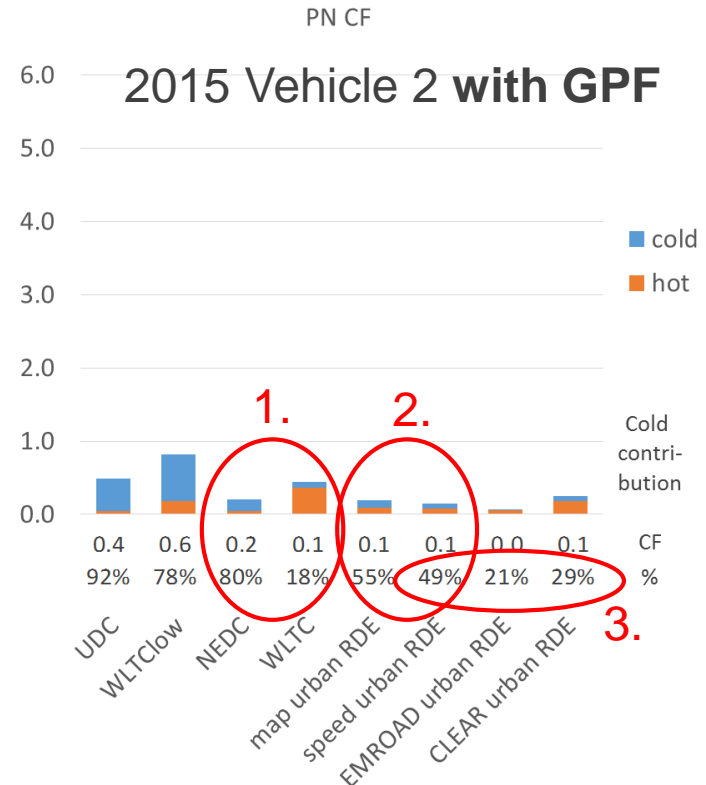
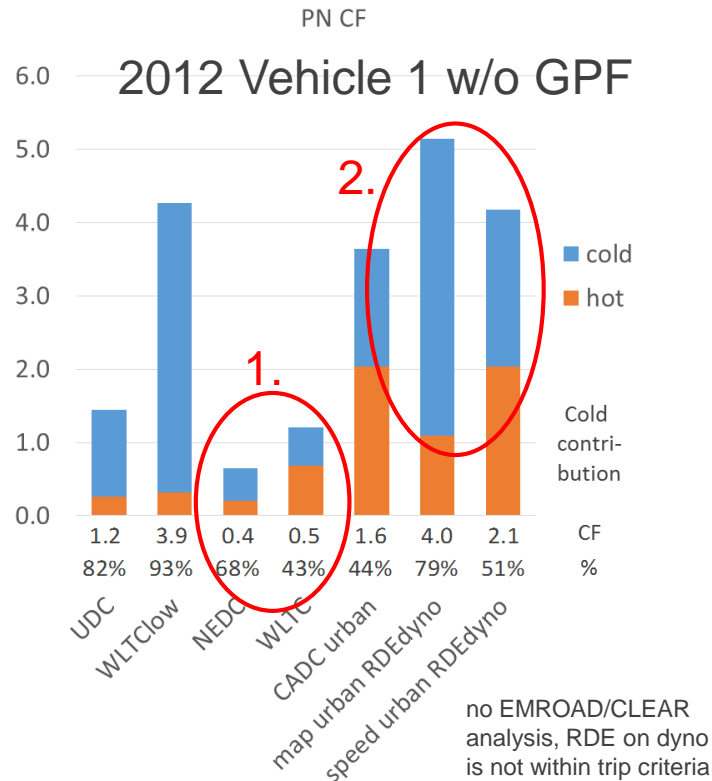


Cold: first 2 short trips (151s/0.81km)



# Impact of cold start on urban RDE is compared to that in test cycles

1. WLTC < NEDC
2. RDE: up to 80% from cold start
3. RDE raw > CLEAR > EMROAD



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# Conclusions

- Engine-out RDE PN emissions of GDIs are higher than on the regulatory test cycles
- GPF technology is available and demonstrates PN reduction under all driving conditions
- The currently excluded 5 minutes of cold start PN emissions are significant and should be well controlled by RDE legislation
- Further work is undertaken in the current AECC 2016 GDI test programme
- Further evaluation of the AECC PEMS database is ongoing



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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

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