Particles Emissions from a Euro 6 Gasoline Direct Injection (GDI) Passenger Car

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Association for Emissions Control by Catalyst AISBL

Association for Emissions Control by Catalyst (AECC)

AECC members: European Emissions Control companies

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

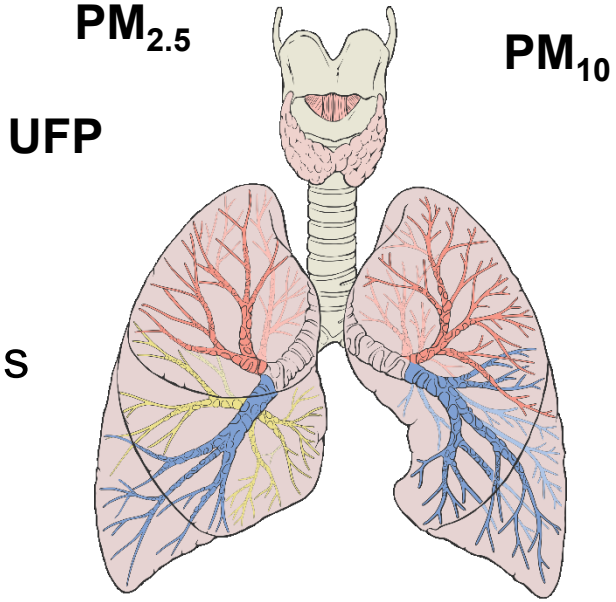
Content

- Context
- AECC GDI emissions test programme
  - Programme set-up
  - Emissions on regulatory test cycles (NEDC and WLTC)
  - Real-Driving Emissions (RDE)
- Focus on cold start GDI PN emissions
- Conclusions

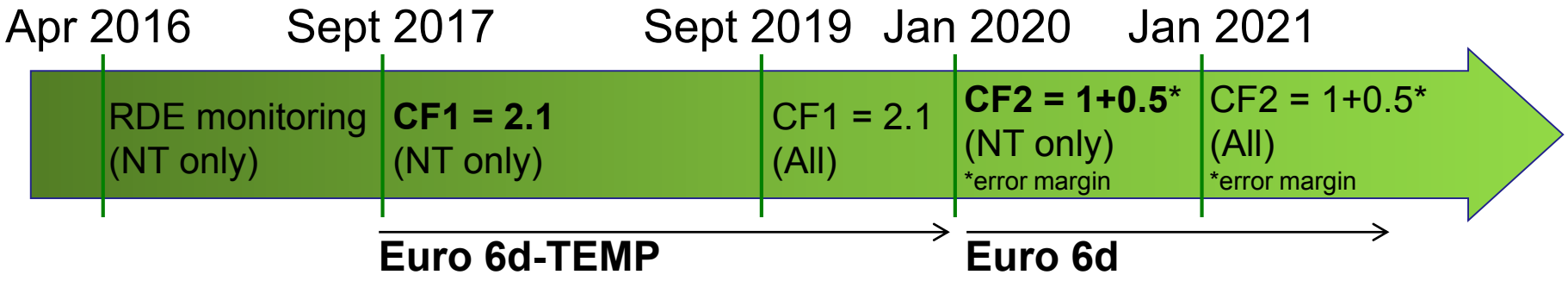
Health impact of ultrafine particles

- 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

World Health Organization
REGIONAL OFFICE FOR Europe



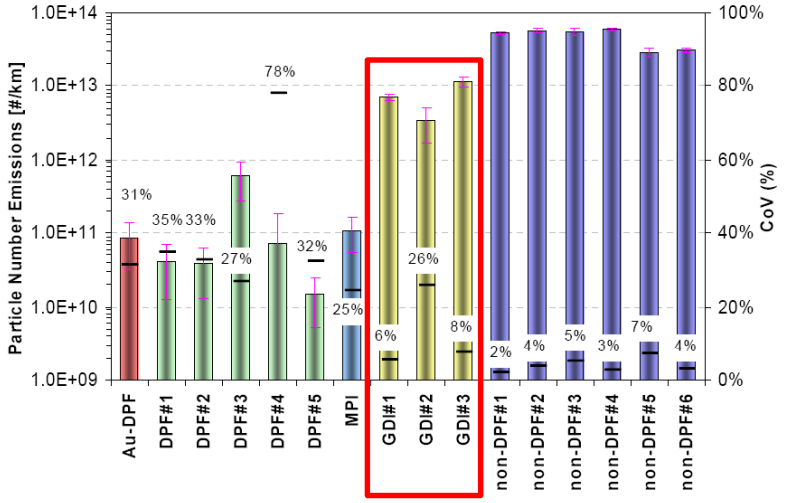
RDE legislation to close the gap between lab and real world emissions



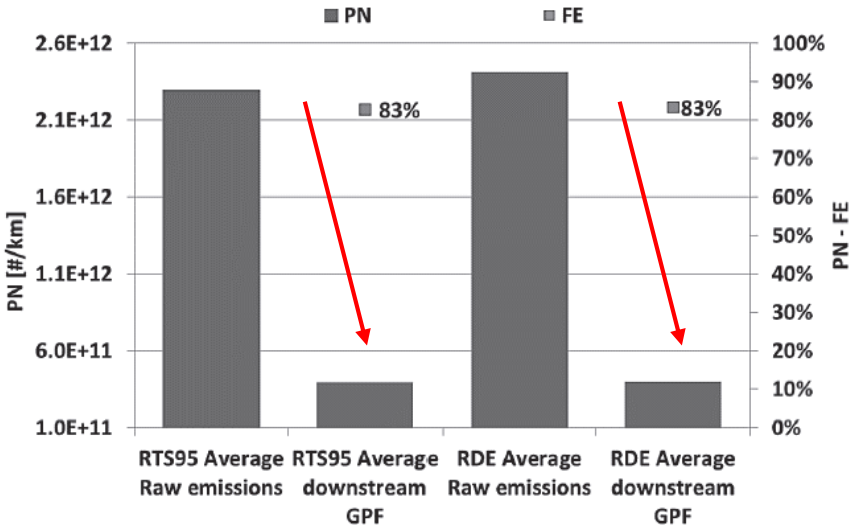
- Not-To-Exceed limit = Euro 6 limit x Conformity Factor (CF)
  - CF defined for NOx
  - Particle Number CF to be defined in 3rd RDE package (in fall 2016)
  - Error margin to be reviewed annually from 2017 onwards
- CF applies to both urban part and total trip
- PEMS data post-processed with normalisation tools
  - EMROAD (moving average window) and CLEAR (power binning)
  - Normalisation for dynamic driving conditions
- Cold start emissions to be addressed in 3rd RDE package

The GDI particle RDE issue

- CO_2 legislation promotes fuel-efficient Gasoline Direct Injection (GDI) in the EU
- Particles emitted by DI gasoline vehicles are higher than Euro 6c limit of 6×10^{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

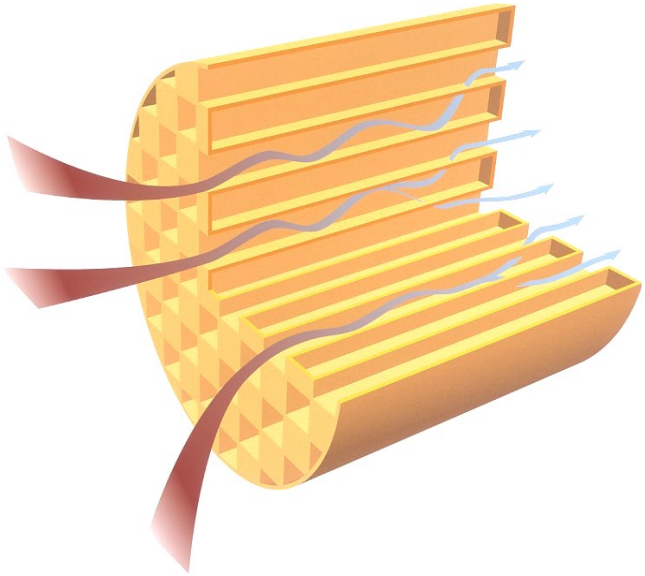


Source: PMP Inter-Laboratory Correlation Exercise Final Report



Source: AECC member

Gasoline Particulate Filter (GPF)



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AECC GDI test programme

- Objective: investigate NOx & PN RDE without and with GPF
- At Ricardo, UK in cooperation with Concawe
- GDI car
  - 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_2, CO, NOx)
  - PEMS-PN demo unit

GDI test programme matrix

- Parameters evaluated
  - Chassis-dyno regulatory tests vs. on-road
  - Fuel type & quality: E5 reference vs. market, E10 reference
  - Cold start PN

Exhaust	Fuel	NEDC & WLTC	RDE
Original (without GPF)	Ref E5	1x	-
	Ref E10	1x	3x
	Market E5	1x	3x
With coated GPF	Ref E10	1x	3x
	Market E5	1x	3x

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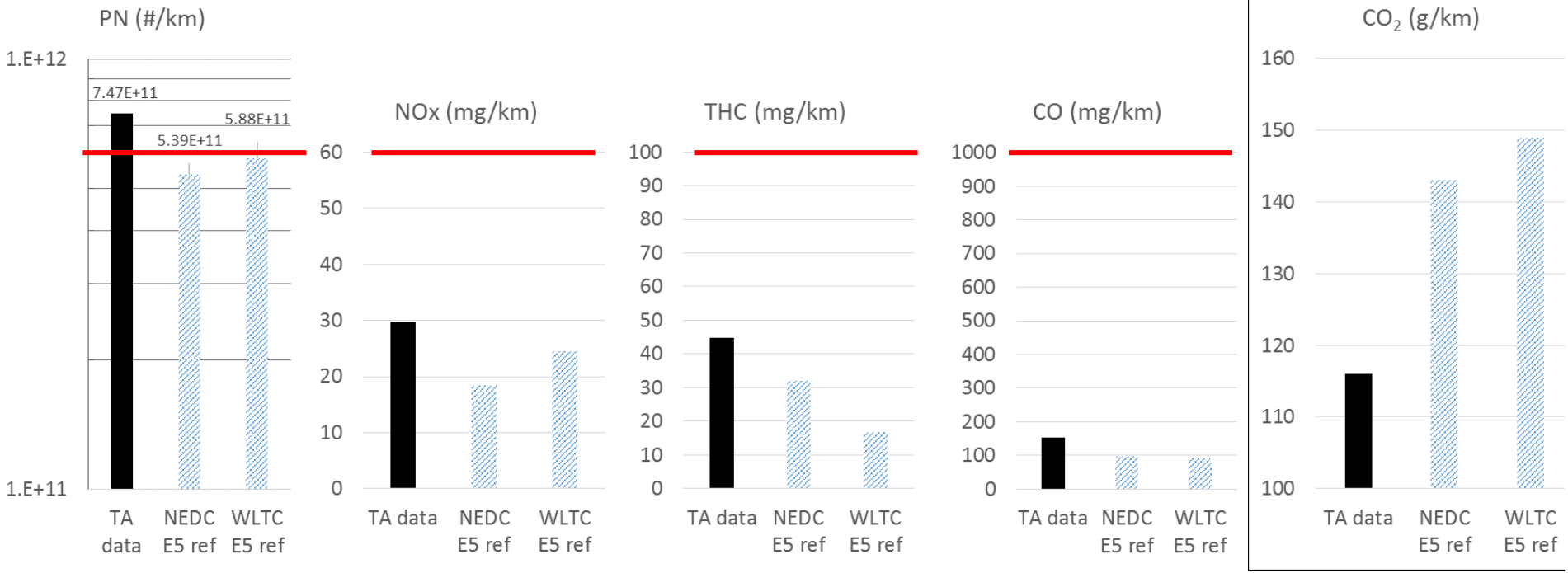
Emissions on NEDC & WLTC meet Euro 6c limits w/o GPF

- Vehicle is a state of the art GDI

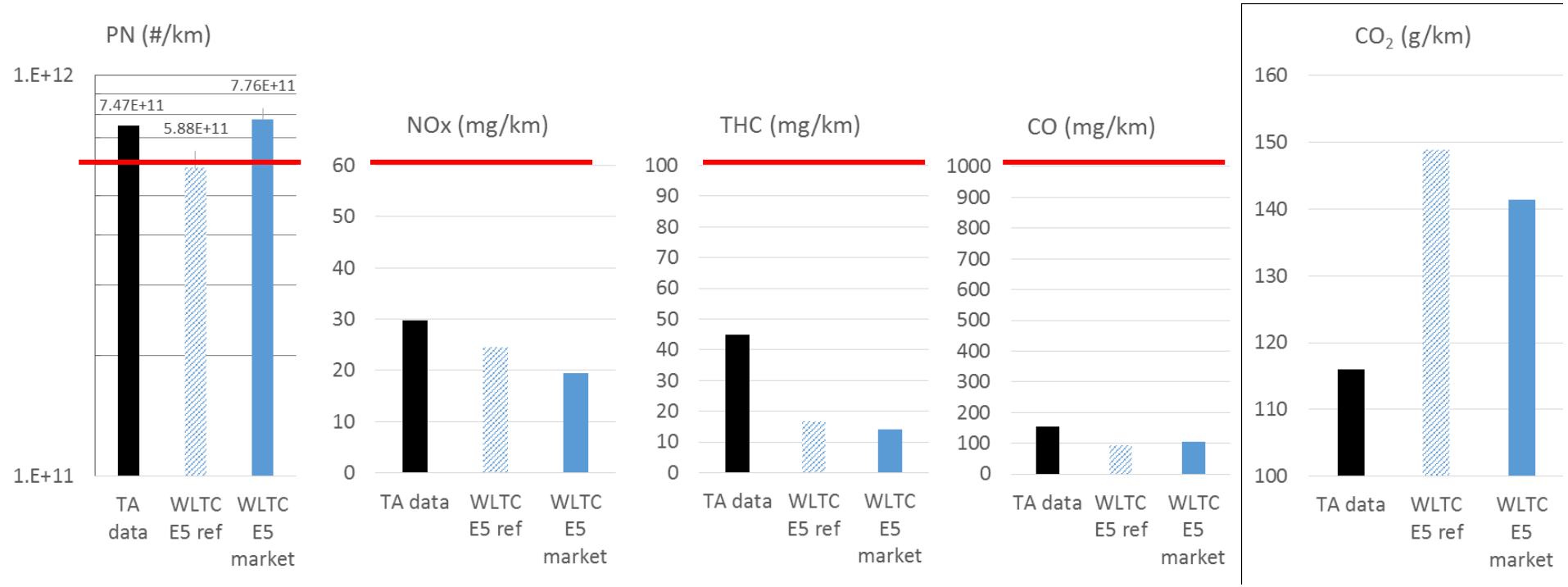


Euro 6c limit

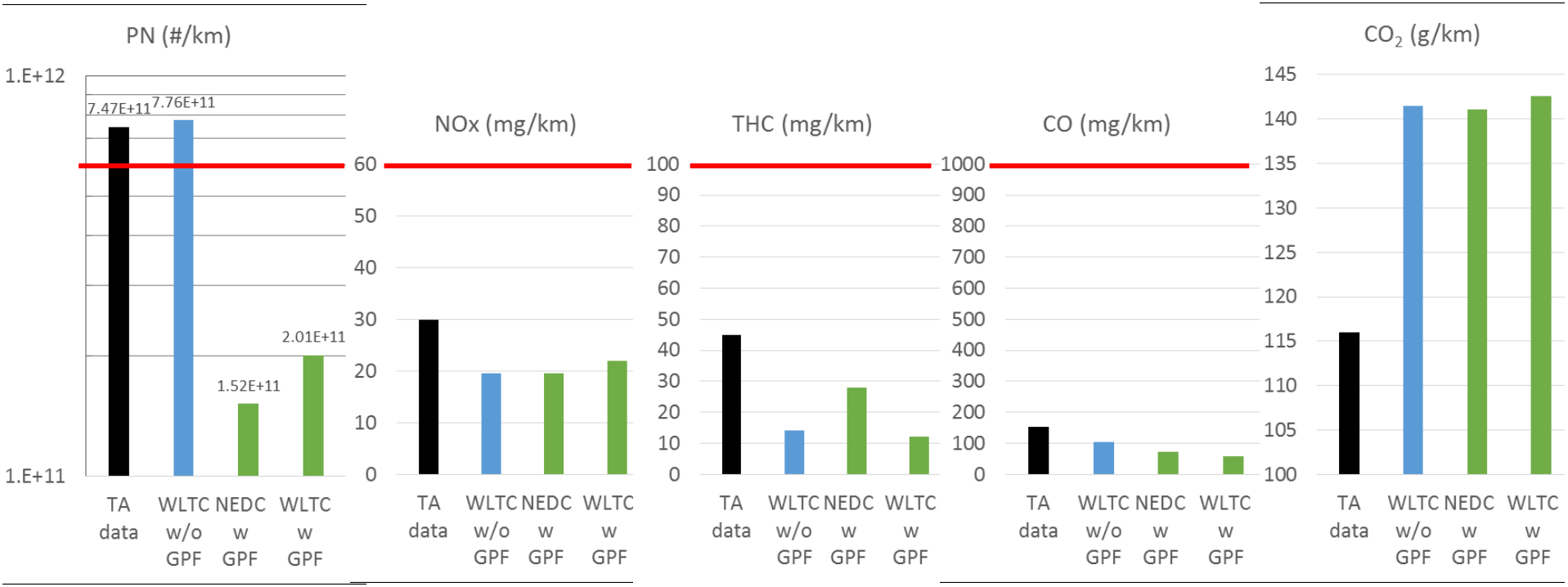
All data measured with E5 reference fuel

Market fuel effect: WLTC emissions still meet Euro 6c limits, except PN

- PN emissions are sensitive to fuel quality



With a GPF, NEDC and WLTC emissions all meet Euro 6c limits



Euro 6c limit

All data measured with E5 market fuel

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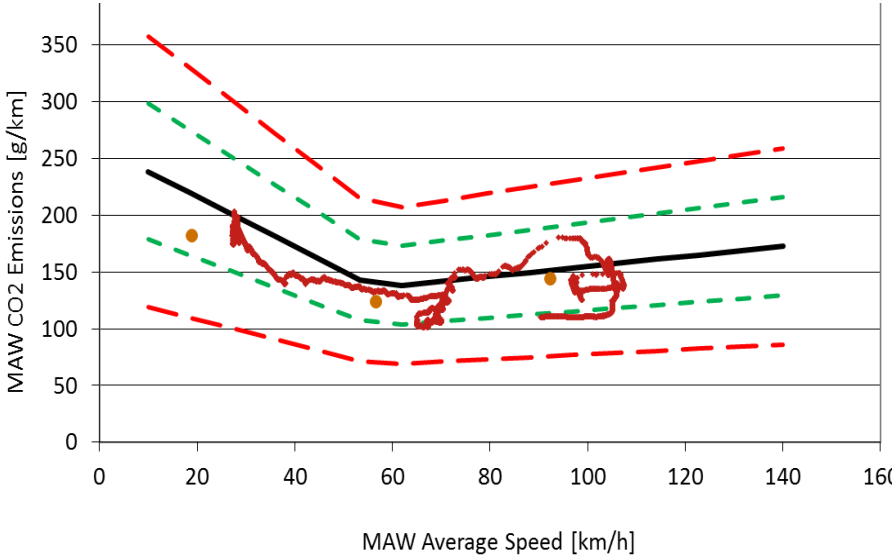
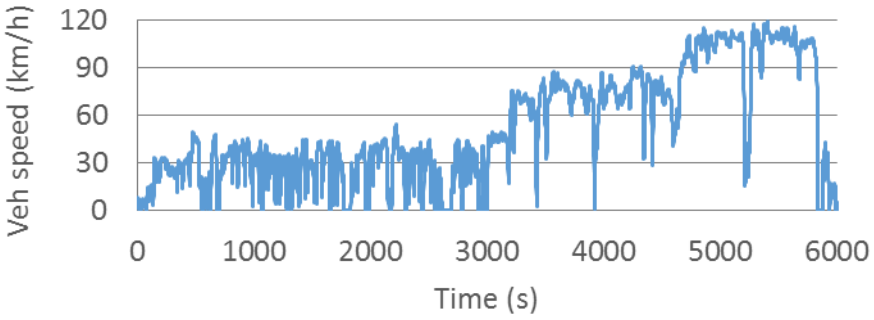
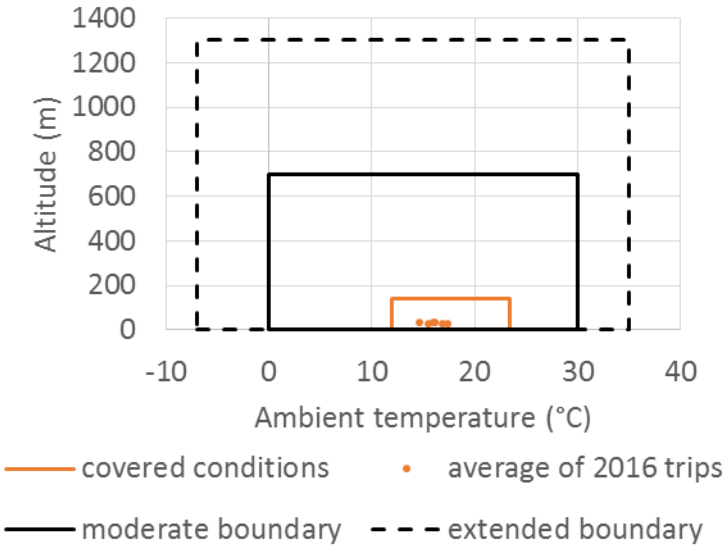
RDE route

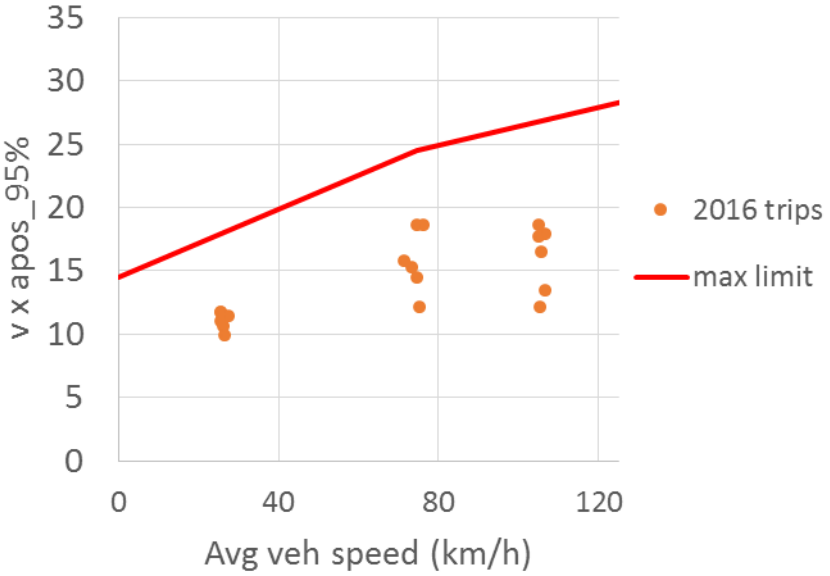

RDE Cycle Route from GPS
Rural
Motorway
Urban
Start/
Finish
Oreham Common
Small Dole
Pyecombe
Poynings
Edburton
Fulking
Saddlescombe
Steyning
Botolphs
Coombes
Portslade
Lancing
Hove
Brighton City Airport

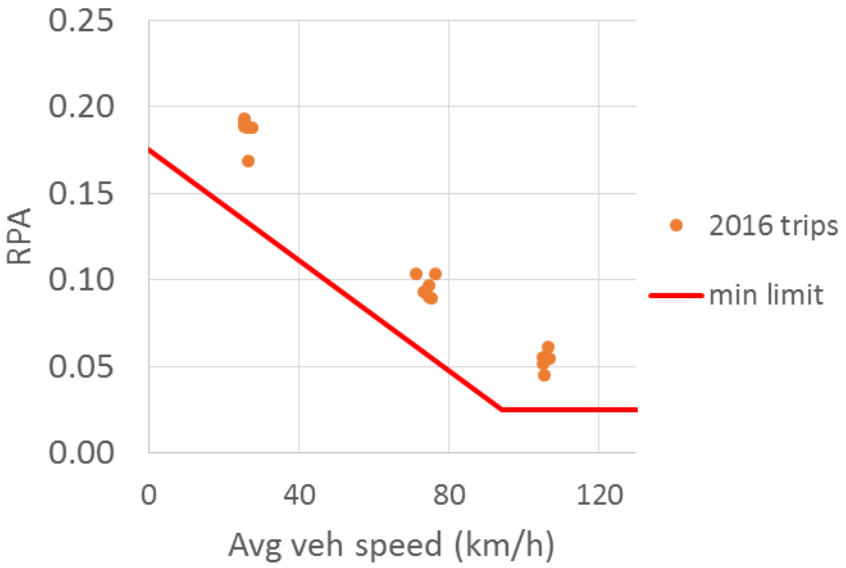

MAW CO2 Emissions [g/km]
0
50
100
150
200
250
300
350
0
20
40
60
80
100
120
140
160
MAW Average Speed [km/h]


Veh speed (km/h)
0
30
60
90
120
0
1000
2000
3000
4000
5000
6000
Time (s)


Altitude (m)
0
200
400
600
800
1000
1200
1400
-10
0
10
20
30
40
Ambient temperature (°C)
covered conditions
average of 2016 trips
moderate boundary
extended boundary

Dynamic boundary conditions covered

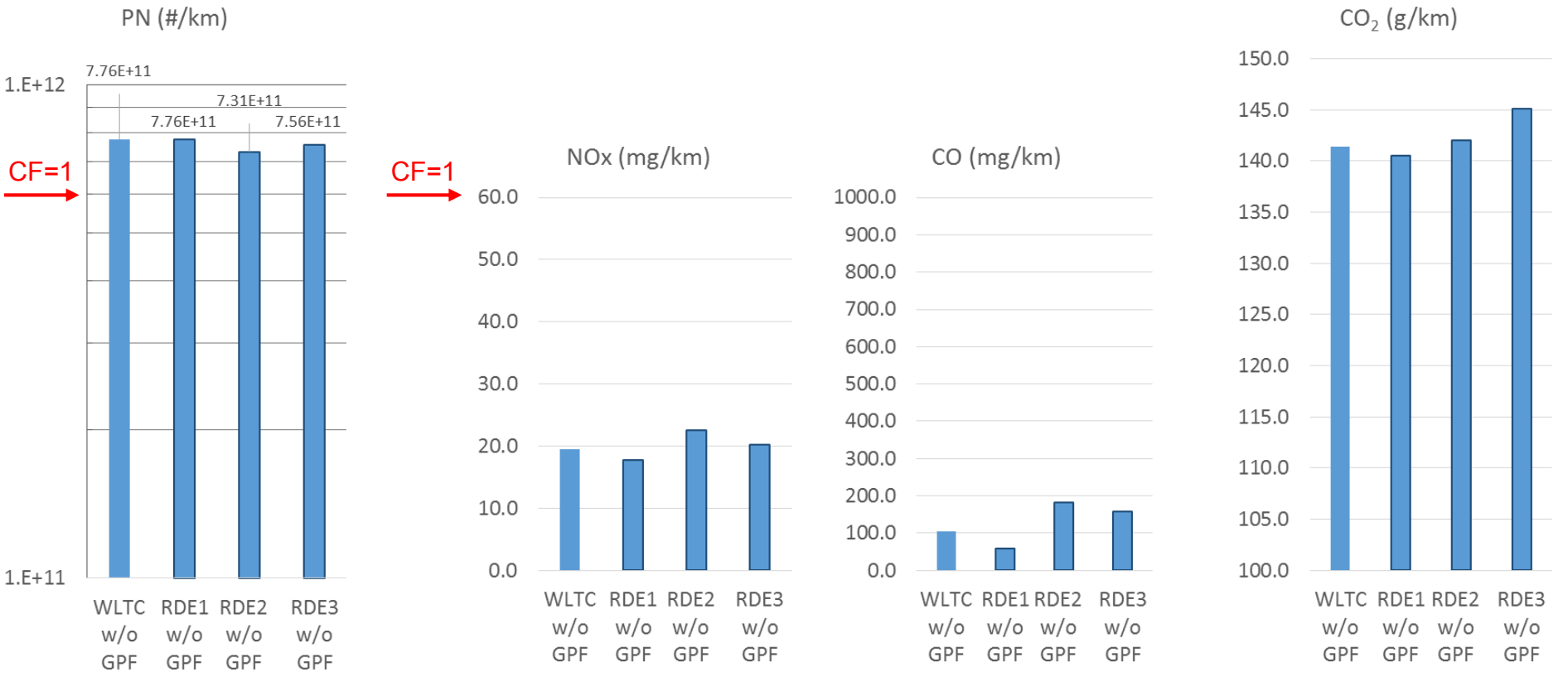




Altitude gain: ~ 850m/100km

RDE results w/o GPF are comparable to WLTC performance

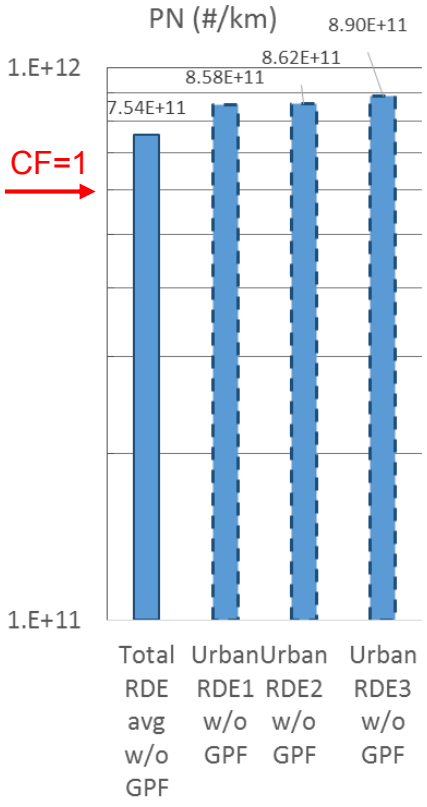
- No data exclusions/normalisation

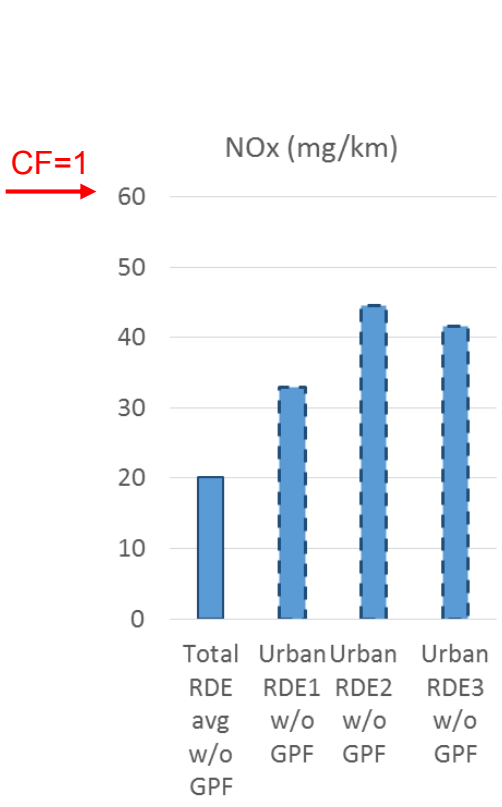


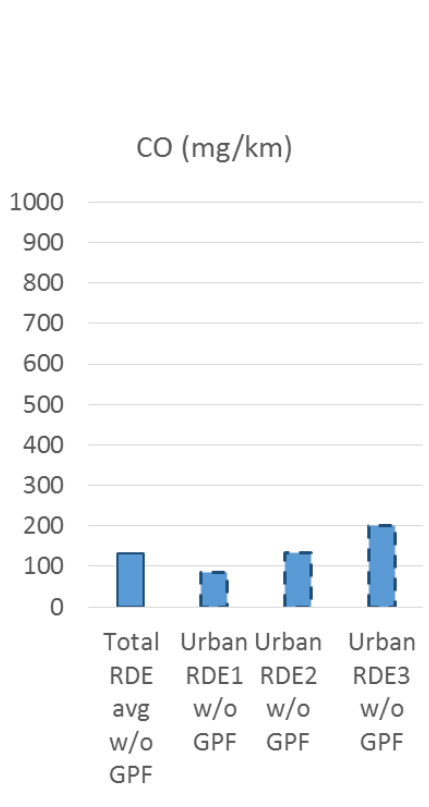
All data measured with E5 market fuel

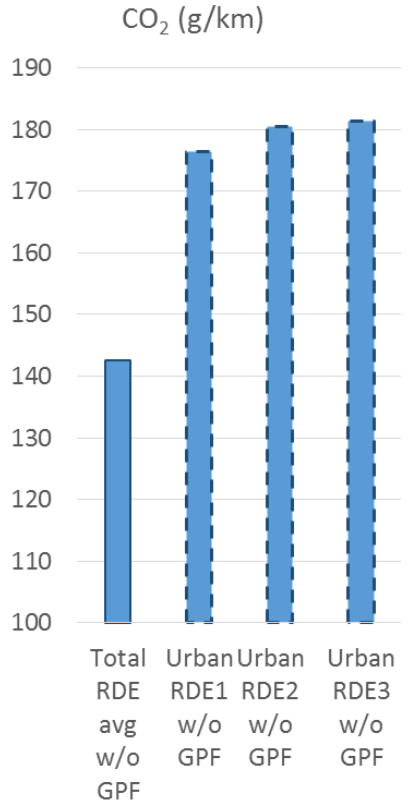
Urban RDE results w/o GPF are higher than total RDE

- No data exclusions/normalisation





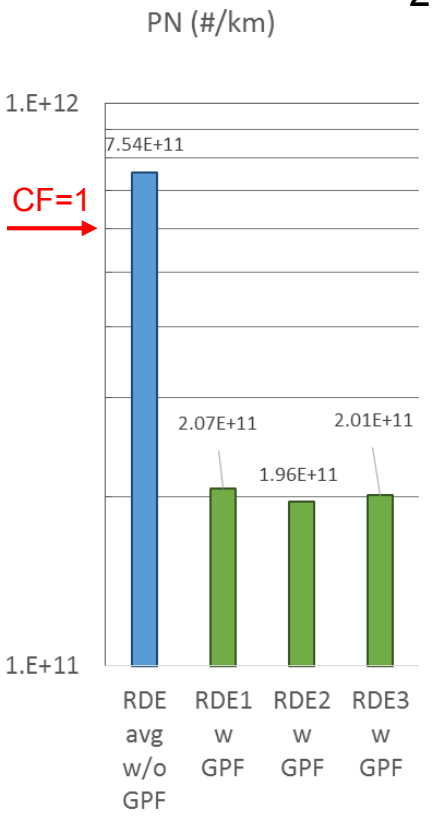


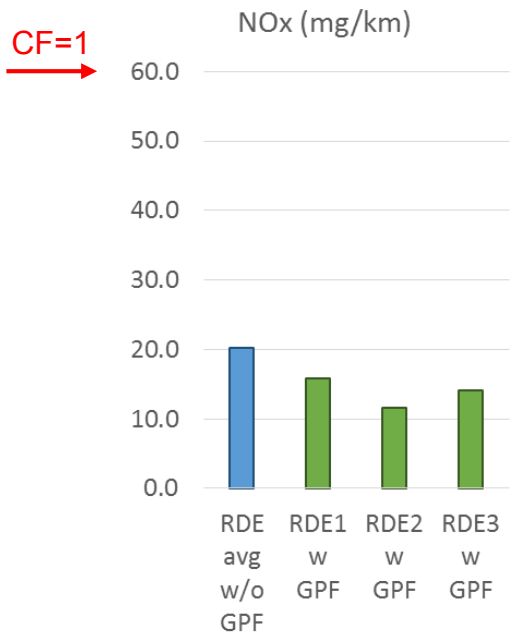


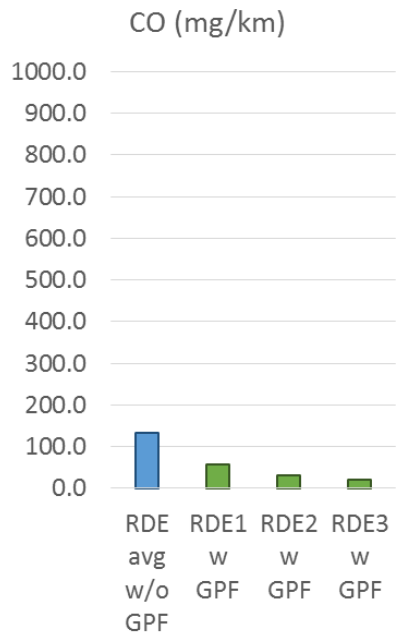
All data measured with E5 market fuel

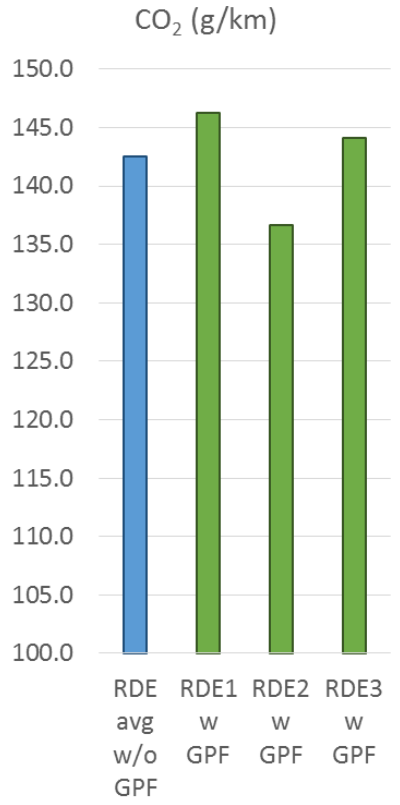
GPF ensures RDE PN well below a CF of 1.0

- No data exclusions/normalisation
- No CO_2 penalty was measured with GPF









All data measured with E5 market fuel

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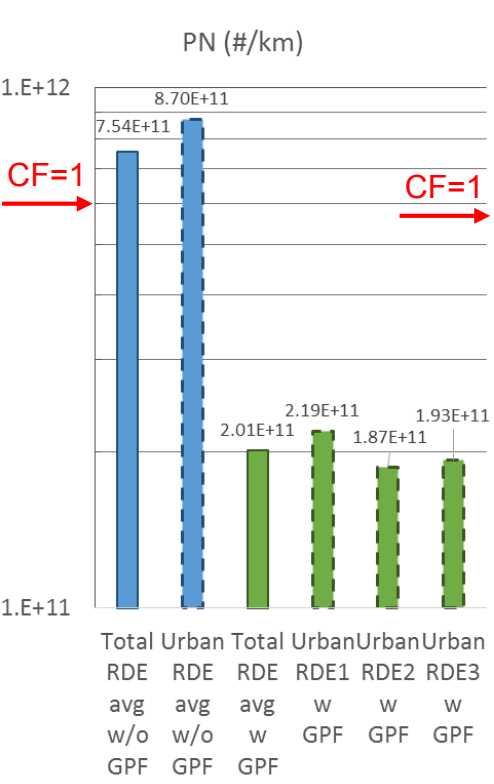
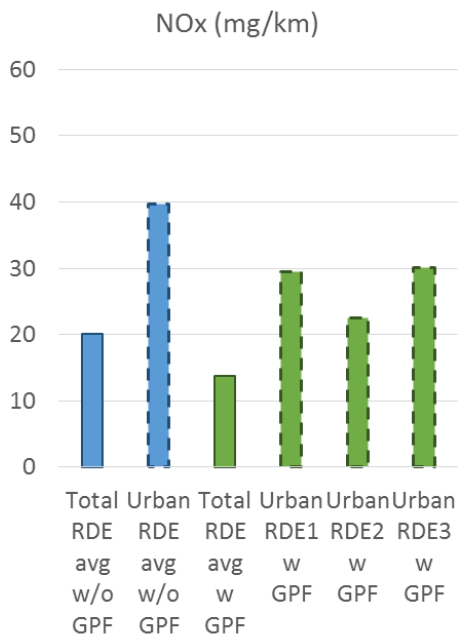
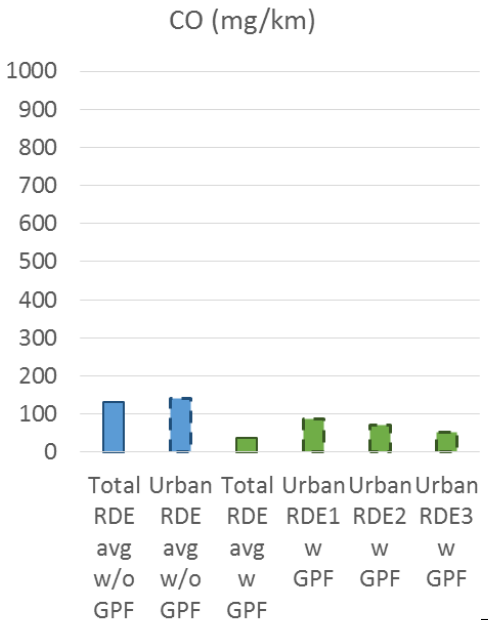
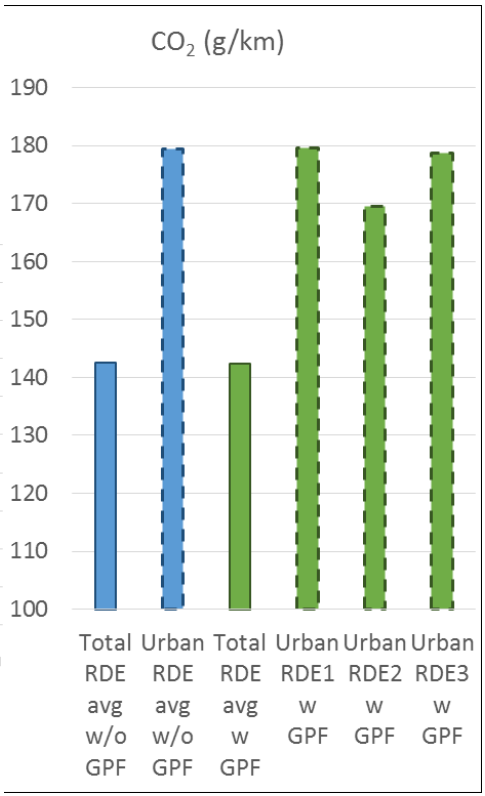
GPF ensures PN control below a CF of 1.0 also in the urban part of RDE

- No data exclusions/normalisation
- No CO_2 penalty was measured with GPF









All data measured with E5 market fuel

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Next steps of the GDI programme

- Investigate
  - impact of normalisation tools (EMROAD and CLEAR)
  - fuel impact (reference E10 vs. market E5)
  - “severitized” RDE dynamic conditions
  - impact of ambient temperature
  - sub-23nm PN

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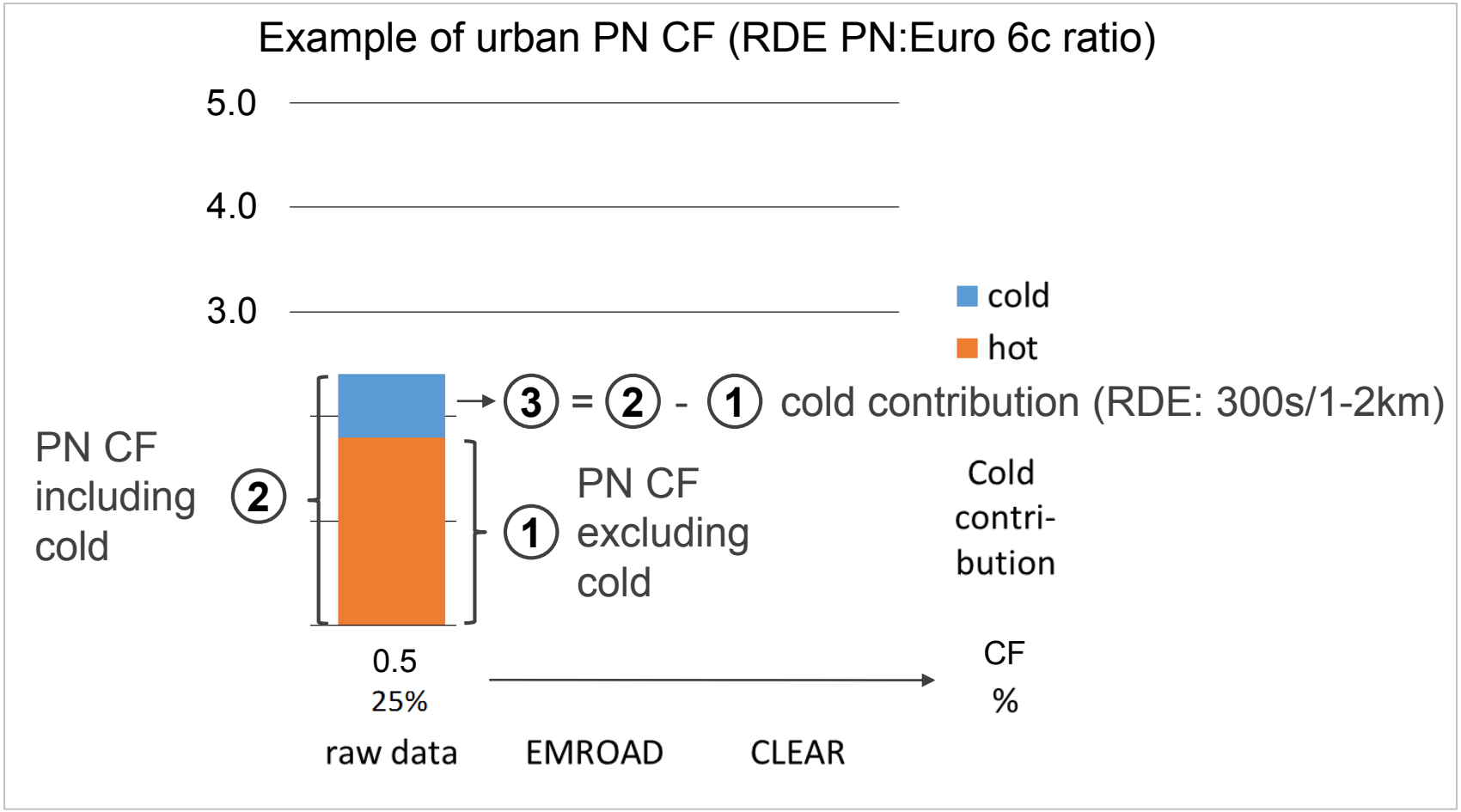
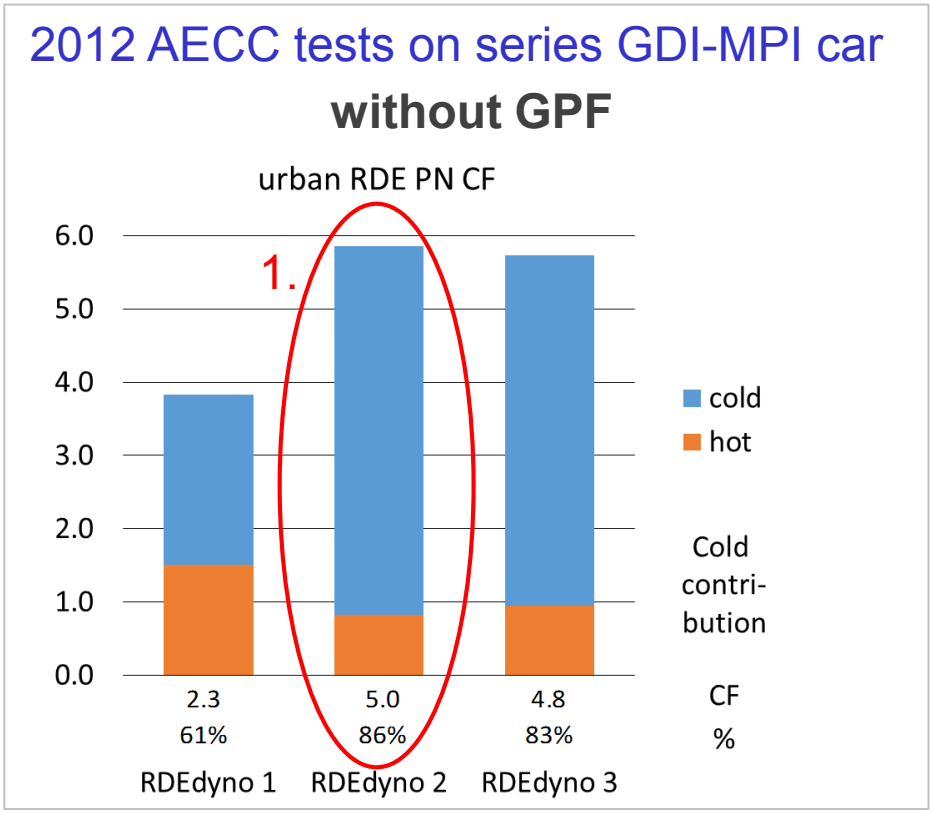
Impact of cold start on urban RDE

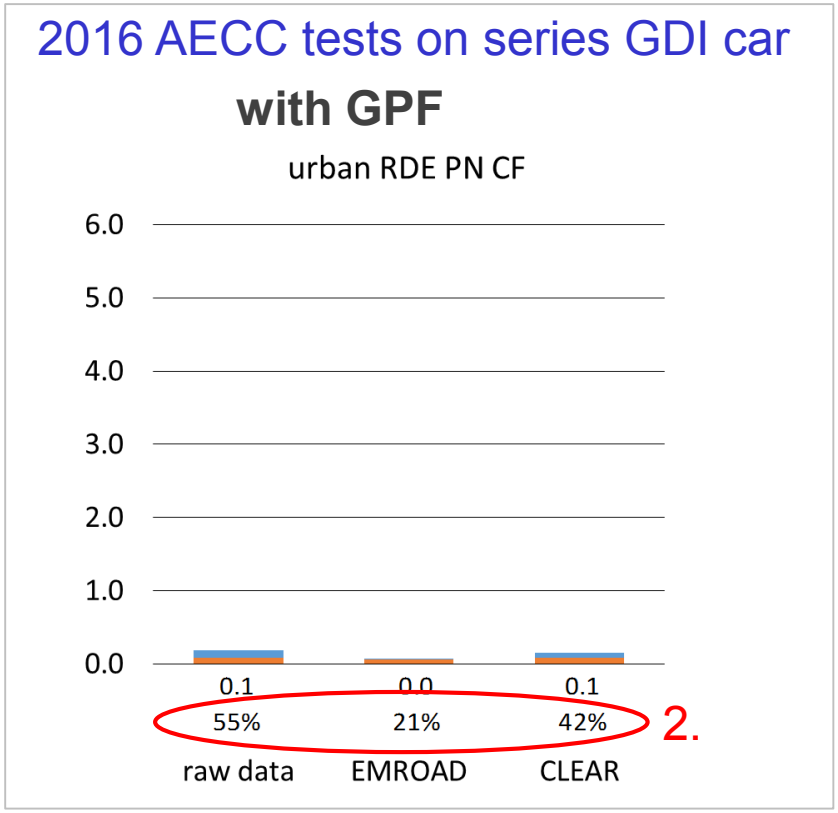
- The RDE test procedure currently excludes the first 5 minutes after engine start.
- We evaluated the contribution of these first 5 minutes.



Cold start impact on urban RDE PN can be large

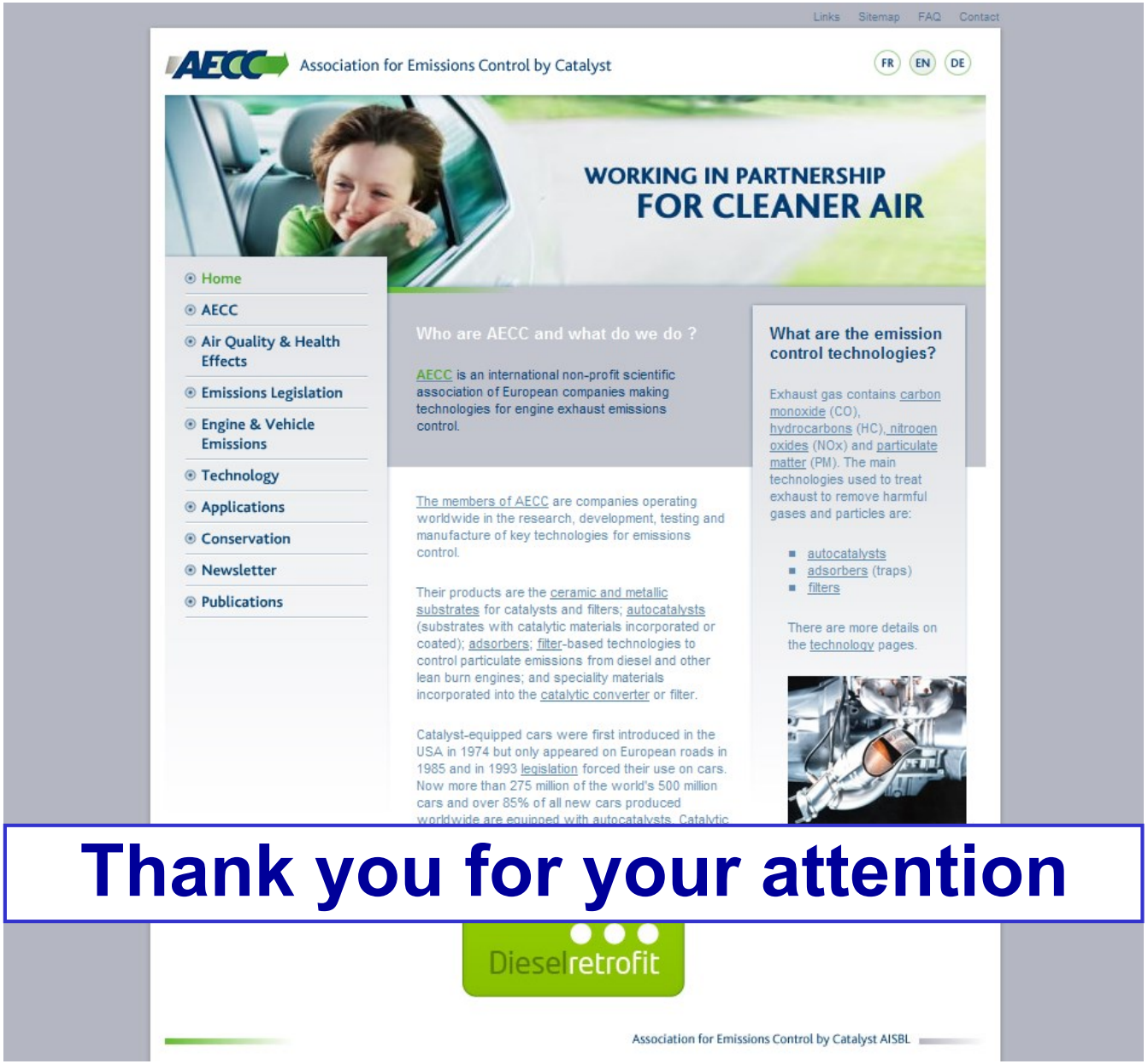
1. RDE: up to 80% from cold start
2. RDE raw > CLEAR > EMROAD





Conclusions

- Engine-out PN emissions of GDIs are higher in real-life than on the regulatory test cycles.
- The GPF technology is available and demonstrates PN control under all driving conditions.
- Cold start (first 5 min excluded from RDE procedure) is significant for GDI PN emissions; it needs to be well controlled by the RDE legislation.



Thank you for your attention