

# Real-Driving Emissions from a Gasoline PHEV with and without a GPF

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# Association for Emissions Control by Catalyst (AECC AISBL)

AECC members : European Emissions Control companies



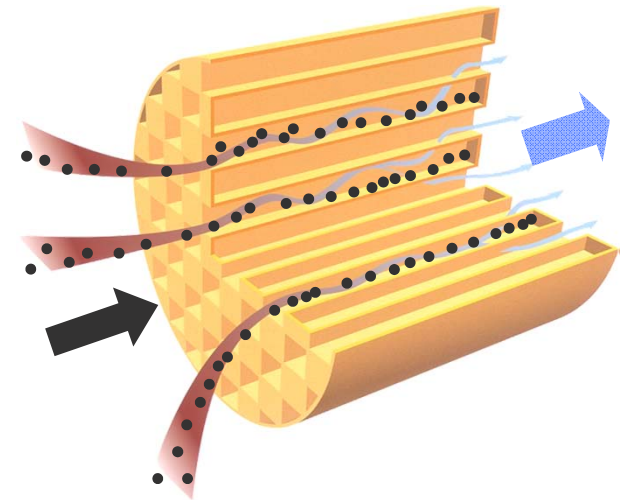
- Exhaust emissions control technologies for original equipment, retrofit and aftermarket for all new cars, commercial vehicles, motorcycles, and non-road mobile machinery

# Content

- PHEV test programme set-up
  - Real-Driving Emissions (RDE) testing on the road
  - RDE testing on the chassis dyno towards the RDE boundary conditions
- PN RDE results without and with a GPF
- NOx RDE results and impact of ICE cold-start peak
- Summary

# Test programme set-up

- Objective: measure the real-world behaviour of a market-representative Plug-in Hybrid Electric Vehicle (PHEV)
- Vehicle: C-segment, 1.5l class GDI engine, Euro 6b, E5 market fuel
- Test Matrix
  - All 4 driving modes: Electric, Hybrid, Charge and Sport
  - Variation in initial battery State of Charge (SOC)
  - RDE on-road and on the chassis dyno
  - 2 tests repeated with a coated Gasoline Particulate Filter (GPF) replacing the second (underfloor) Three-Way Catalyst (TWC)
- Emissions are compared to similar GDI vehicle tested in 2016 AECC test programme\*

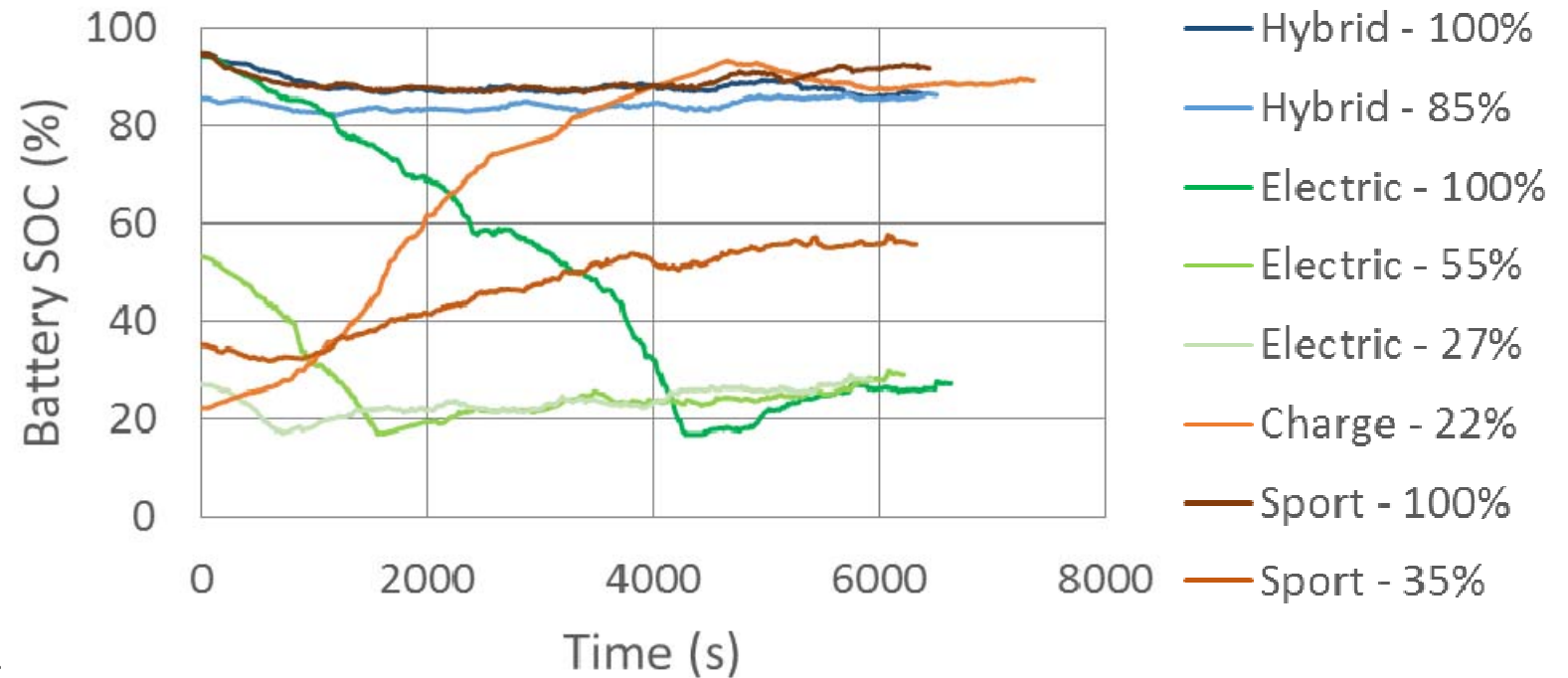


\* Real-World Emissions Measurements of a GDI Vehicle without and with a GPF, Demuyneck, et al., SAE 2017-01-0985

# 8 combinations of mode and initial battery SOC tested

Change in battery SOC (State of Charge) during on-road RDE tests

SOC	Electric	Hybrid	Charge	Sport
100%	1x	1x	-	1x
85%		1x		
55%	1x			
25%	1x		1x	1x

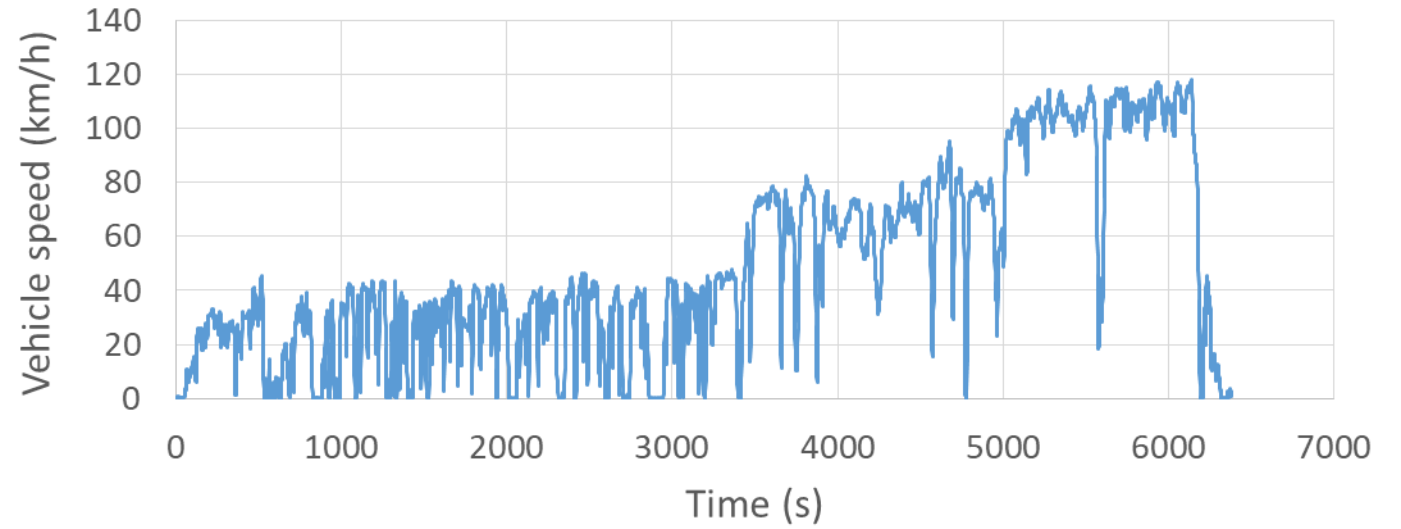
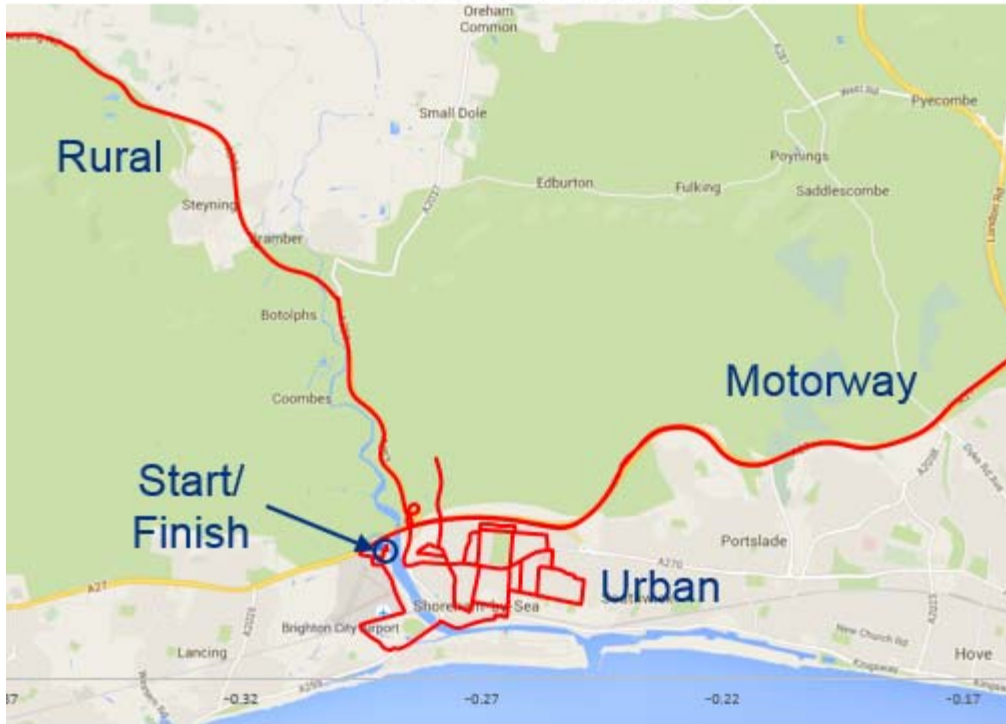


## ➤ Comparison to WLTP definitions

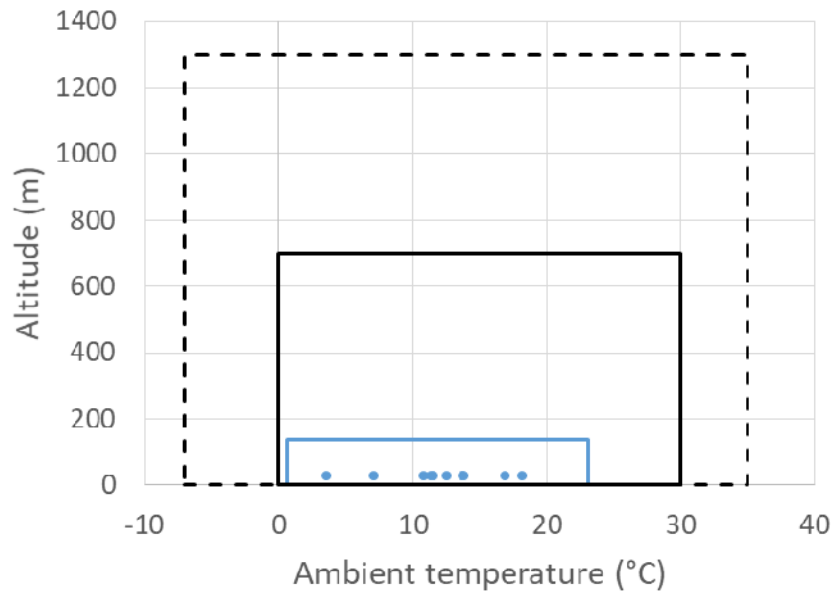
- Charge depleting: **Electric – 100%**
- Charge sustaining: **Hybrid – 85%** and **Electric – 25%**

# RDE route and speed profile

RDE Cycle Route from GPS

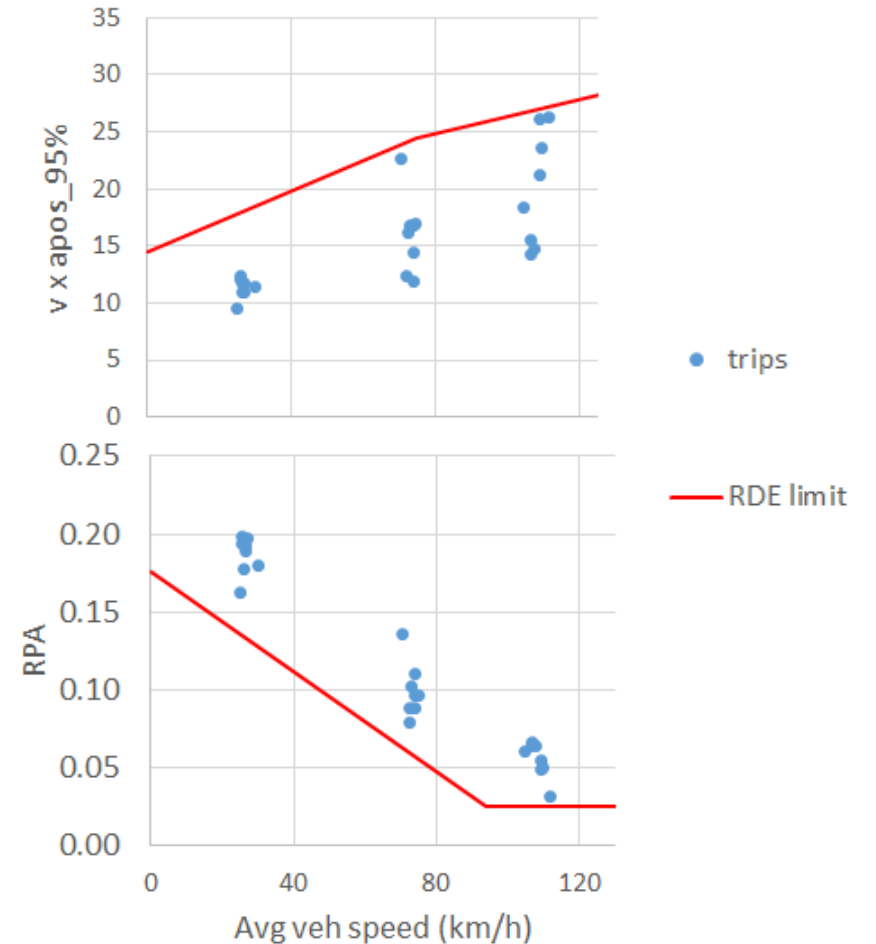


# On-road data within RDE boundary conditions



- covered
- trip average
- moderate boundary
- - - extended boundary

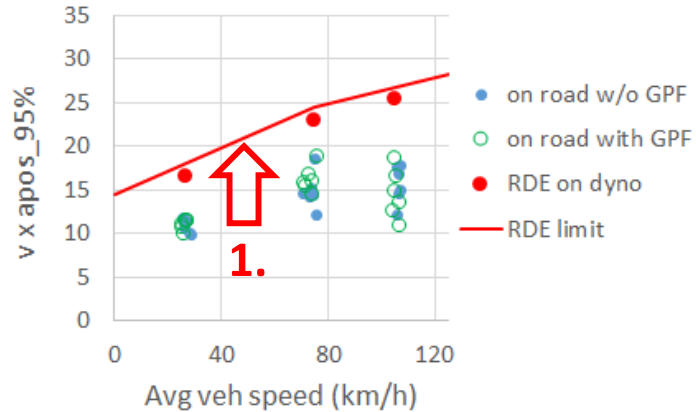
Excess or absence of driving dynamics



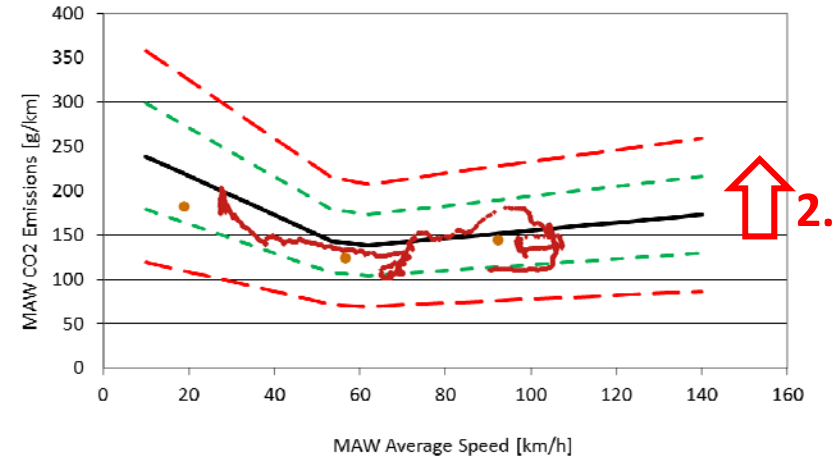
# Impact of RDE boundary conditions tested on the chassis dyno

Severitised RDE (SRDE) visualised with 2016 GDI data; PHEV tests with combination of step 1-3

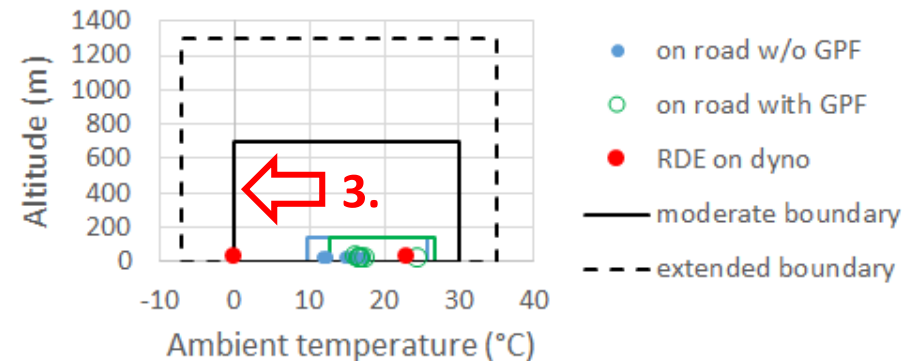
## 1. Change accelerations



## 2. Change dyno load

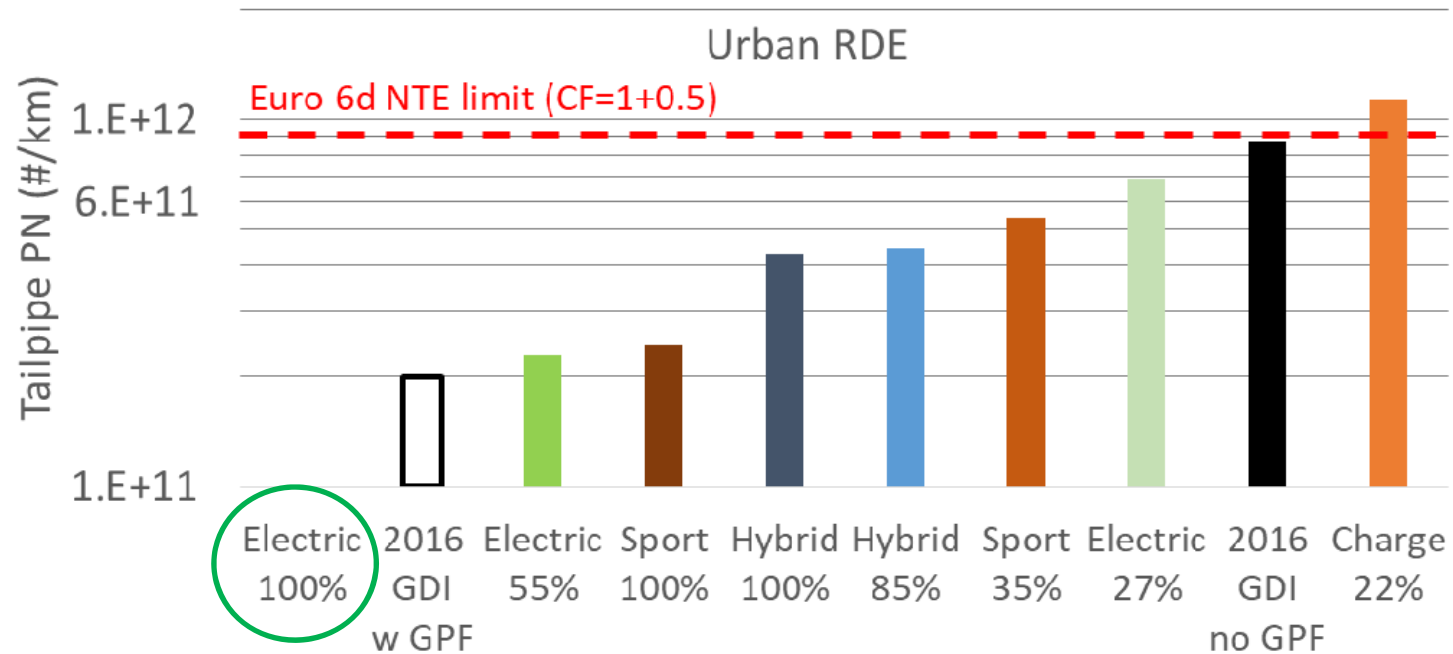


## 3. Change ambient temperature





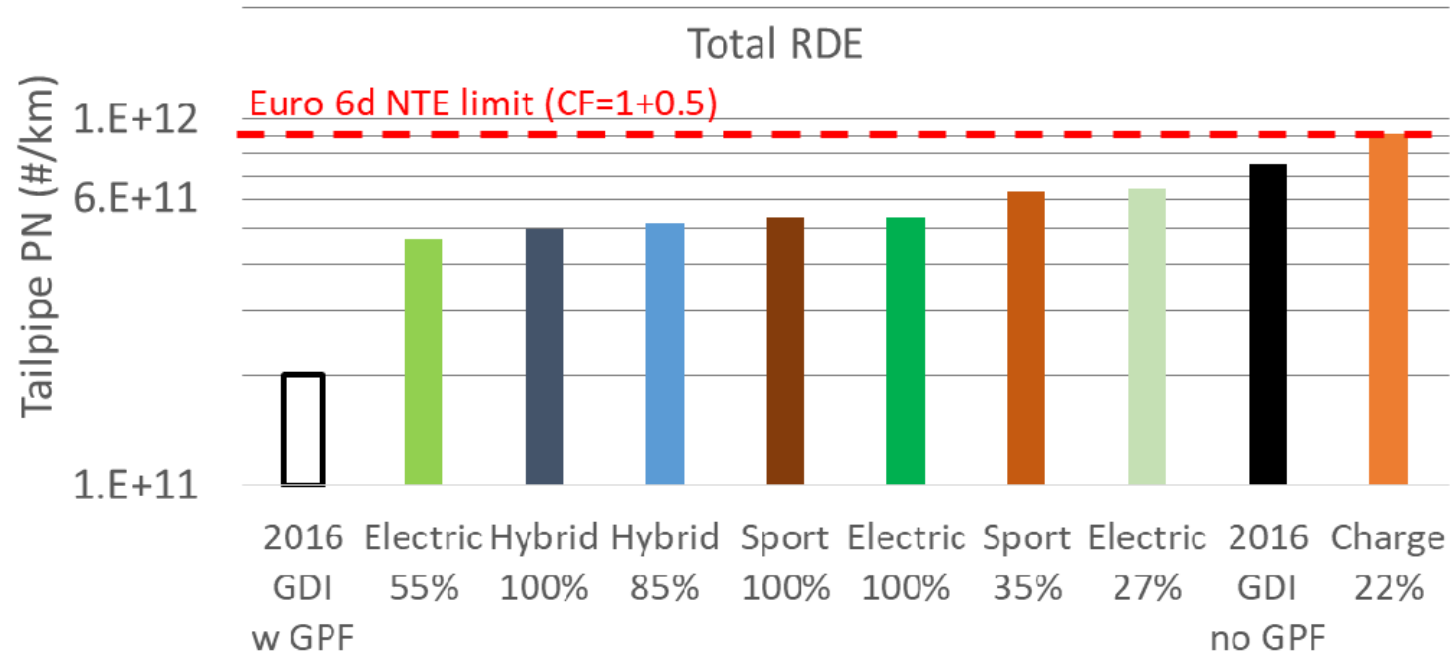
# Most urban PN emissions higher than GDI with GPF



- **Electric mode – full battery:** urban part entirely run electric → zero urban tailpipe PN emissions
- **Charge mode – empty battery:** high power demand on ICE → highest PN emissions

ICE: Internal Combustion Engine

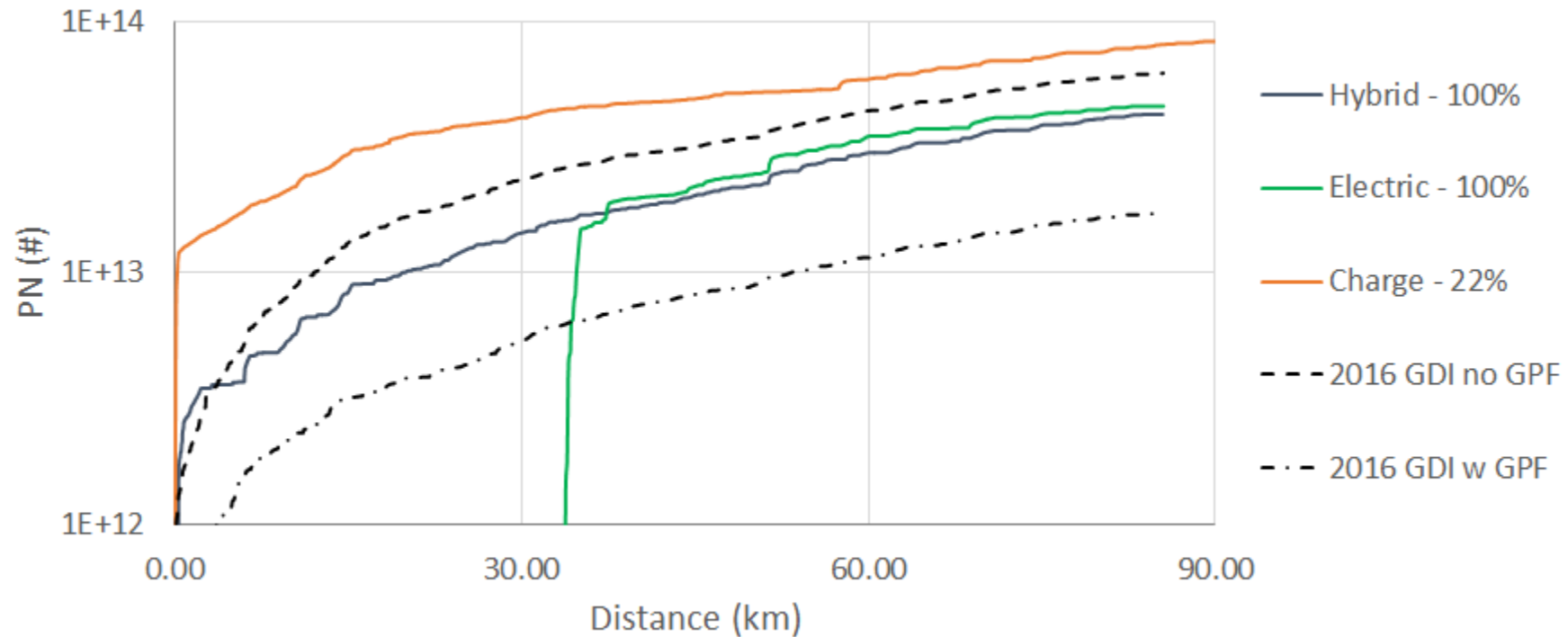
# All total RDE PN emissions higher than GDI with GPF



- **Electric mode – full battery:** ICE operates for 2/3 of trip, but PN emissions as high as other modes
- **Charge mode – empty battery:** high power demand on ICE → highest PN emissions

ICE: Internal Combustion Engine

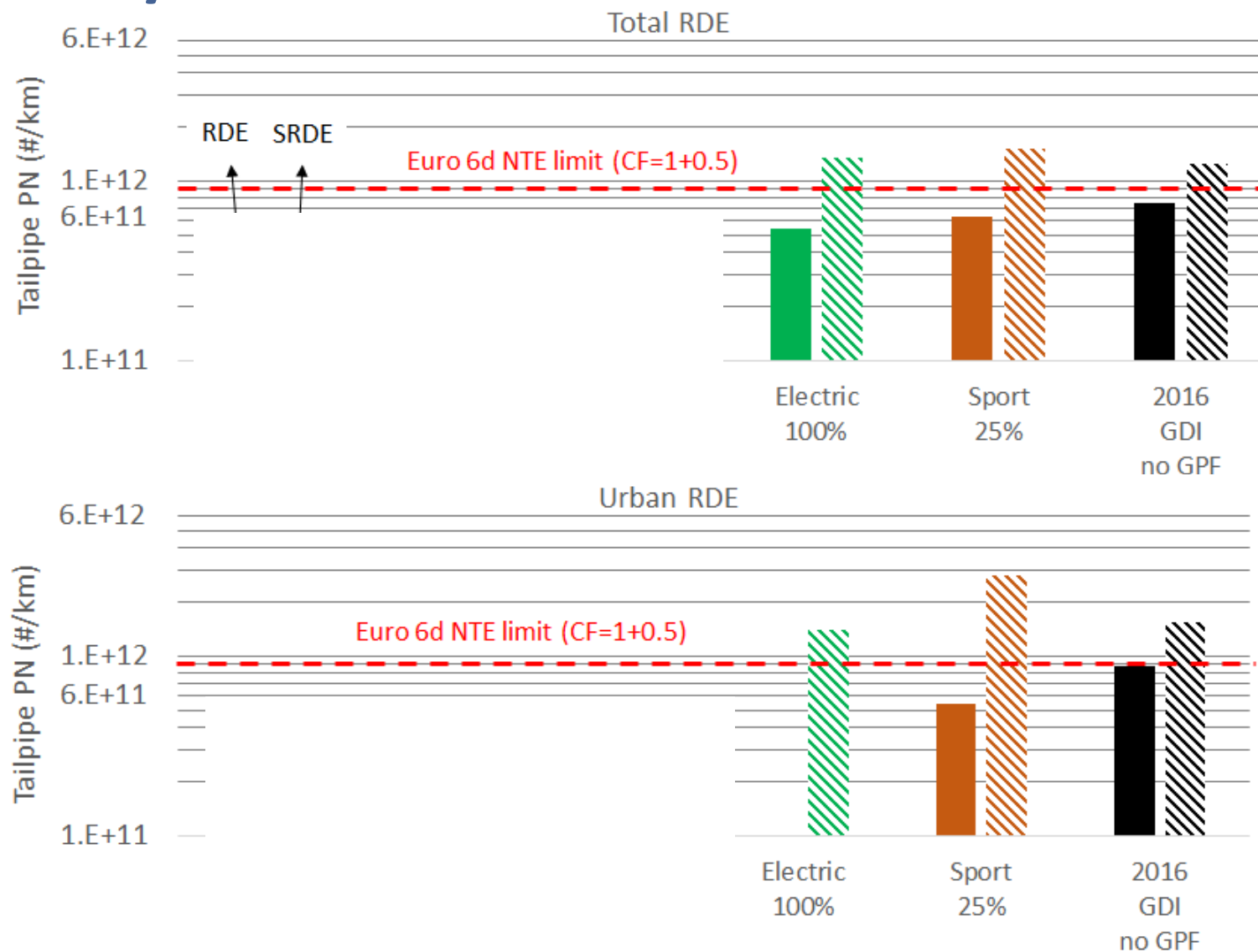
# PN spikes at cold ICE start during high power demand



- **Charge mode – empty battery:** PN peak at start of trip → highest PN level
- **Electric mode – full battery:** PN peak in middle of trip → overall same PN level as other modes

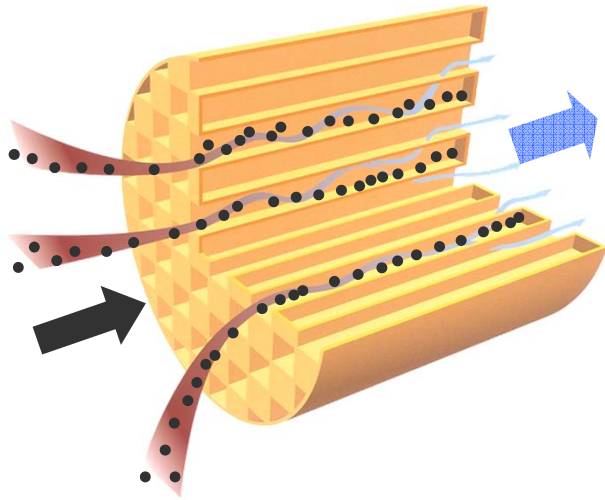
ICE: Internal Combustion Engine

# All Severitized RDE PN w/o GPF above Euro 6d NTE limit

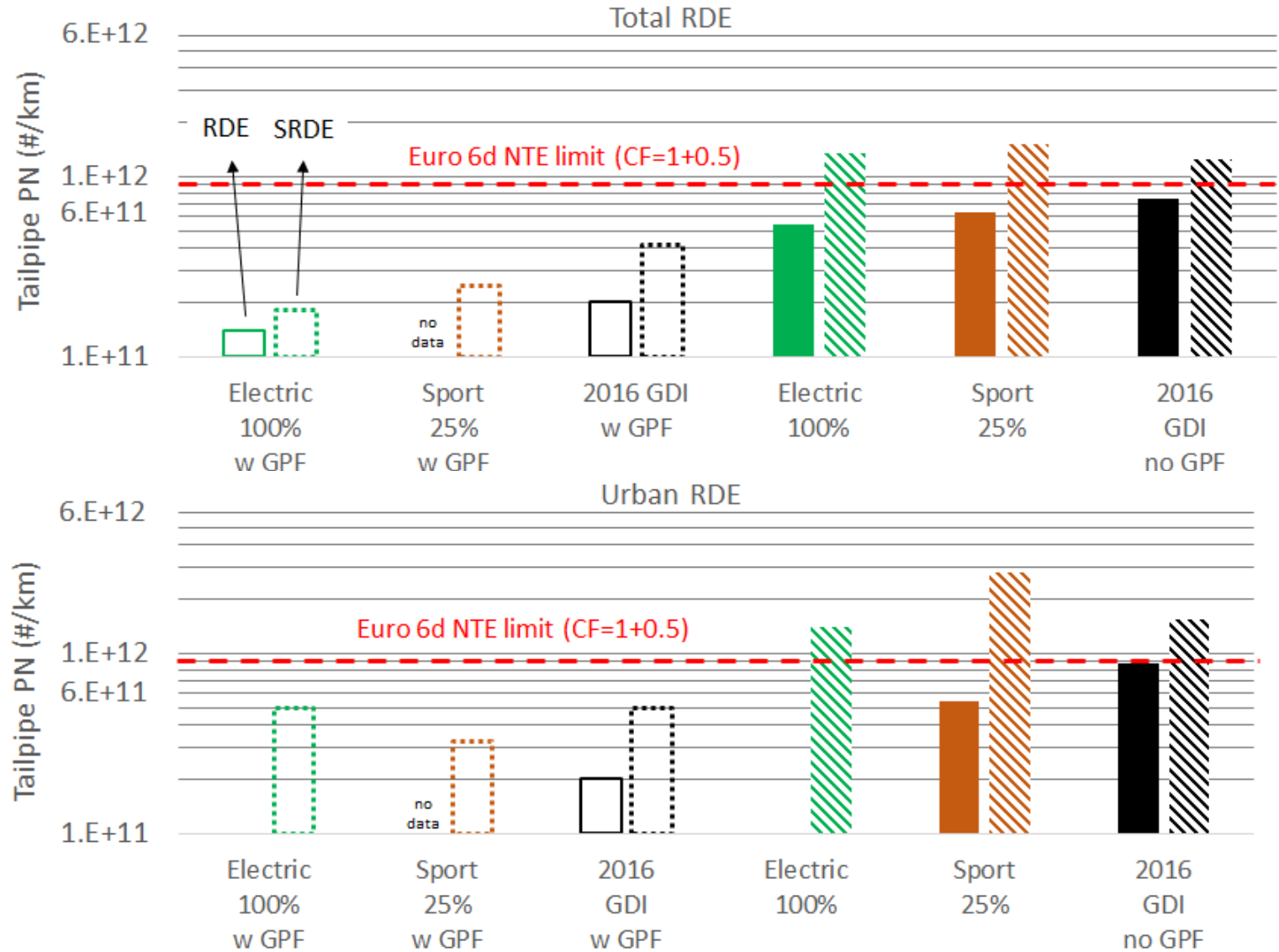


Note: 1.6 factor for extended ambient temperature included where applicable

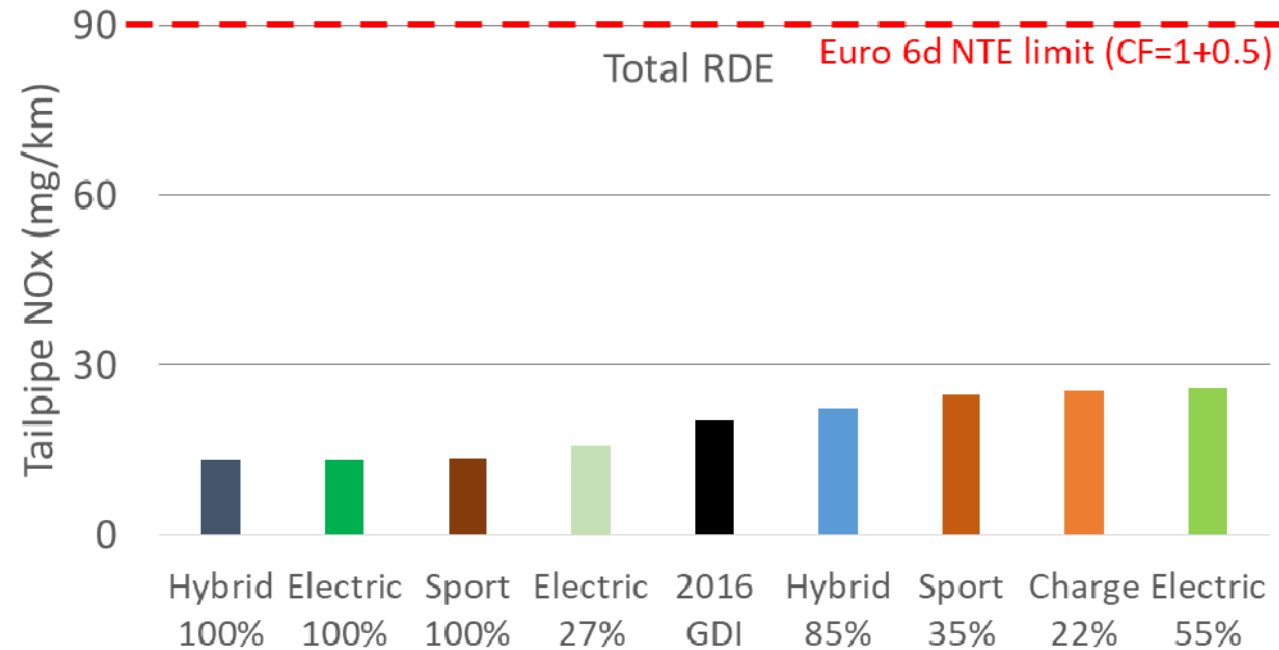
# All PN results with GPF are below Euro 6d NTE limit



Note: 1.6 factor for extended ambient temperature included where applicable

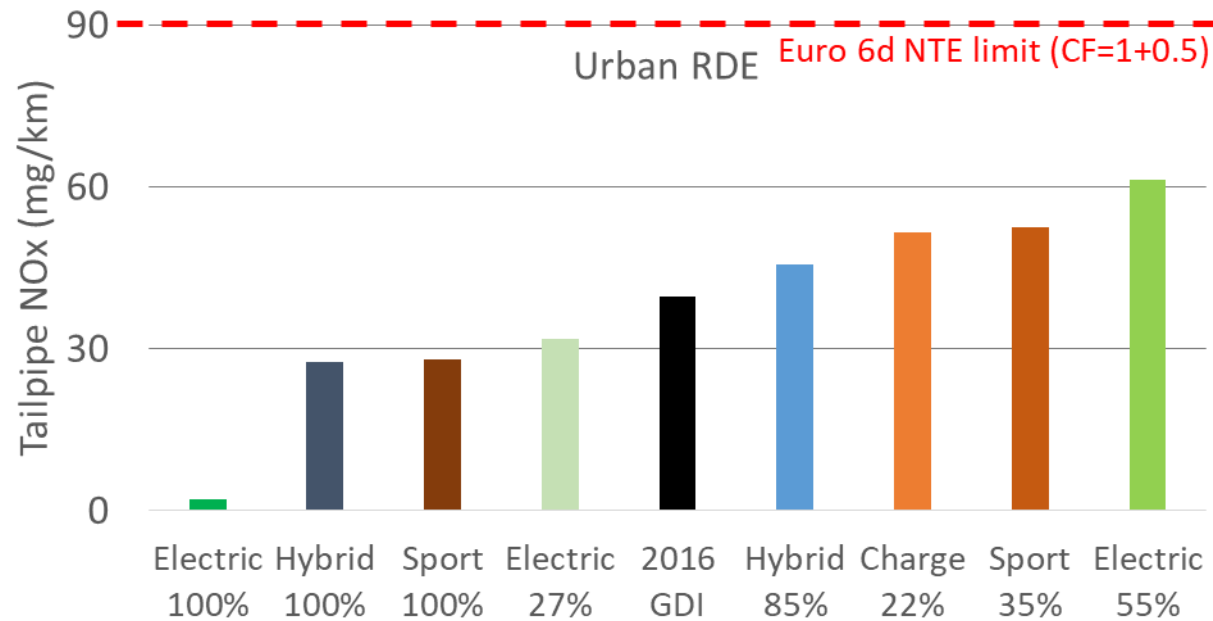


# All total RDE NOx emissions below Euro 6d NTE limit



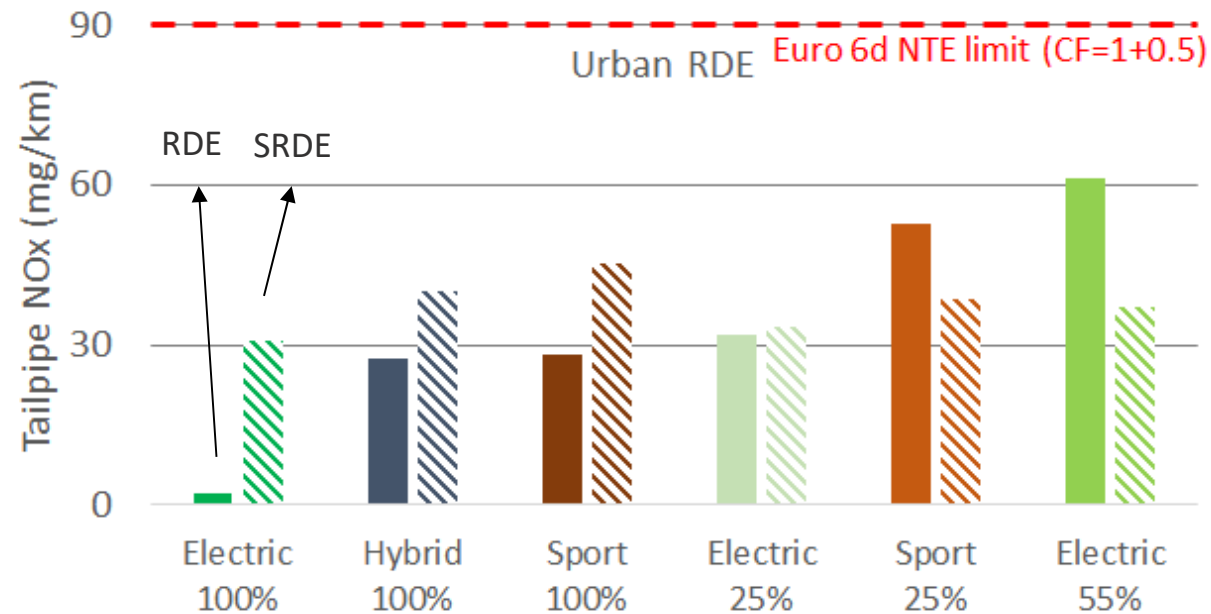
- Reference GDI result is in the middle of PHEV total NOx range
- Total NOx emissions of PHEV with fully-charged battery are consistently the lowest

# All urban RDE NOx emissions below Euro 6d NTE limit



- Reference GDI result is in the middle of PHEV urban NOx range
- NOx emissions of PHEV with fully-charged battery are consistently the lowest
- **Electric mode – full battery:** urban part entirely run electric → zero urban tailpipe NOx emissions
- **Electric mode – 55% battery SOC:** highest NOx emissions

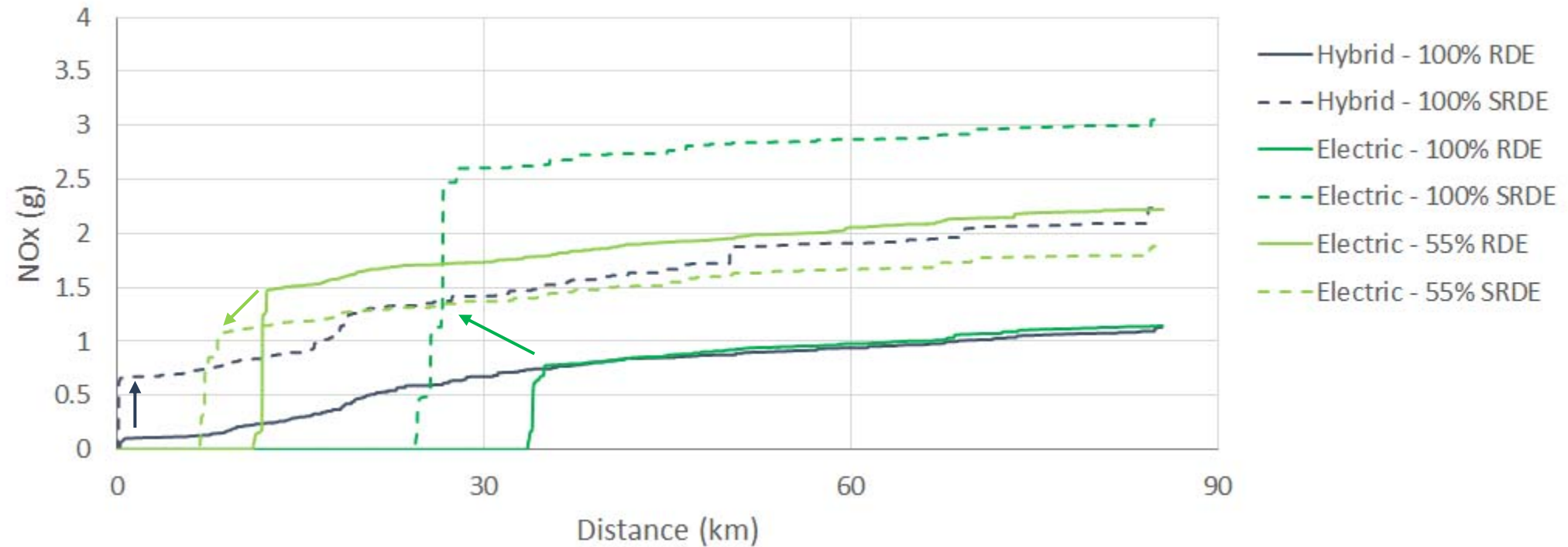
# All Severitized RDE NOx emissions below Euro 6d NTE limit



Note: 1.6 factor for extended ambient temperature included where applicable



# NOx peak at cold ICE start impacts overall NOx level



- Electric mode – full battery: higher peak in SRDE test → highest SRDE NOx level
- Electric mode – 55% battery SOC: lower peak in SRDE test → lower SRDE NOx level
- Hybrid mode – full battery: higher peak at start of trip → higher SRDE NOx level

ICE: Internal Combustion Engine

# Summary

## ➤ AECC PHEV test programme

- Tested 1 Euro 6b C-segment vehicle
- Raw data is shown, without RDE post-processing

## ➤ PN and NOx Real-Driving Emissions

- Zero tailpipe emission capability at point of use
  - in electric mode when battery has been fully charged
  - trip distance within electric range
- Higher emissions than reference GDI observed under other conditions
  - NOx results are all below Euro 6d NTE limit
  - timing of cold ICE start during RDE trip strongly impacts NOx and PN emissions
- High PN spikes observed at cold ICE start are well controlled by GPF

# THANK YOU!

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