Portable Emissions Monitoring System (PEMS) on-vehicle emission testing and its role in Euro 6

Dr Robin North — Transport Systems Catapult
Aravinth Thiyagarajah — Imperial College London
Nick Molden — Emissions Analytics Ltd.

Investigation of Air Pollution Standing Conference (IAPSC) 2014, 3rd December 2014, Austin Court, Birmingham

Background

- Emissions Analytics are building international real-world emissions inventories using PEMS on-vehicle testing
  - To improve understanding of true in-use performance
  - Transforming the economics of obtaining emissions data
  - To provide intelligence for OEMs, consumers and policy

  ➢ 800+ new vehicles so far tested in 3 years since Aug 2011

- Data can also support the investigations of the research community
- Partnership with Imperial College London to explore the use of the existing datasets for analysis of transport and environmental impacts

- **TODAY: overview of PEMS and early results for Euro 5 and Euro 6 diesels**

PEMS Equipment

- SEMTECH-DS and Ecostar-FEM
- Portable Emissions Measurement System connects to tailpipe
  - Captures emissions for CO_2, CO, NO, NO_2, total hydrocarbons
  - At 1 Hertz
- Air temperature, pressure, humidity
- GPS for speed and altitude
- Engine data via CANBUS
- DS weighs approximately 95kg including auxiliary batteries
- Proven robust over potholes, speed bumps

Imperial College London

CATAPULT Transport Systems

EMISSIONS ANALYTICS

PEMS in action (1)

Imperial College London

CATAPULT Transport Systems

EMISSIONS ANALYTICS

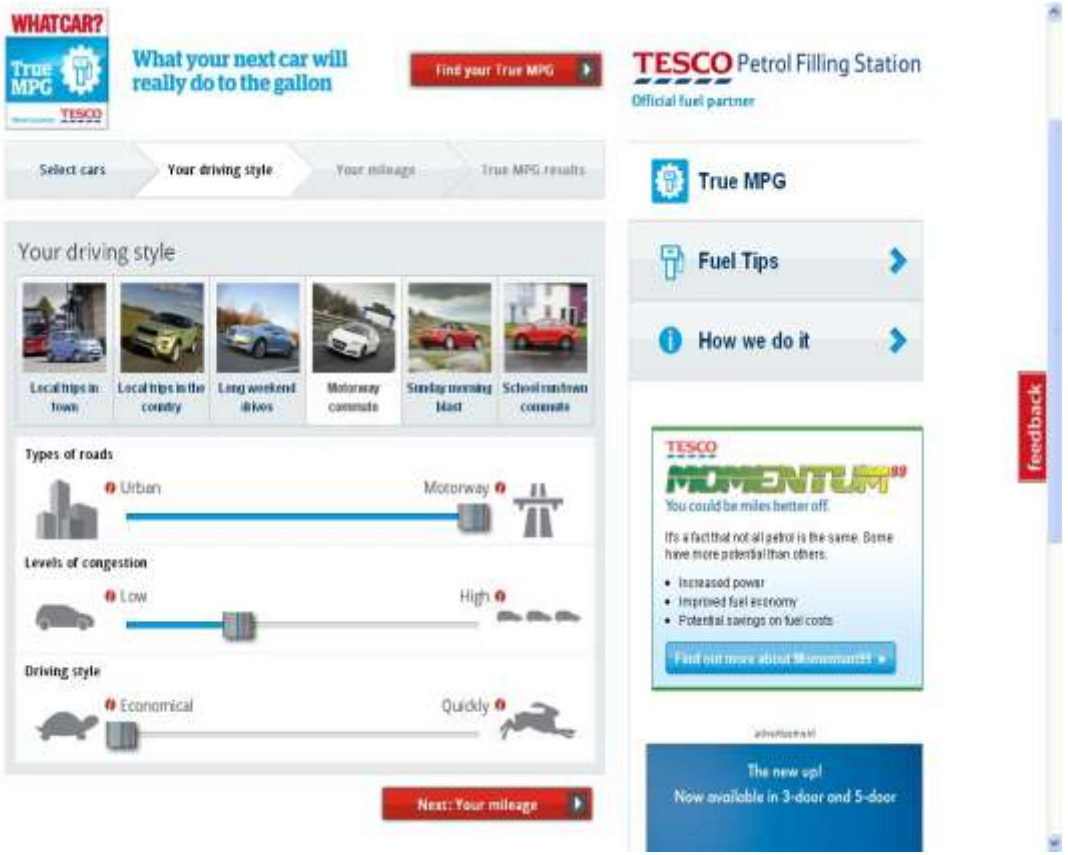
PEMS in action (2)

“True MPG”

- Test every car road tested
- >350 models and >700 variants currently live
- 1m++ users since launch

- Gaining profile
  - Prime time BBC1
  - BBC Radio 4
  - Sunday Times
  - Daily Mail

- **SEMTECH DS data also include NO and NO_2**



Imperial College London

CATAPULT Transport Systems

EMISSIONS ANALYTICS

Aims of this analysis

- Examining the use of TrueMPG data for investigation of NO_x emissions from modern light-duty diesel vehicles

  1. Comparison of PEMS data to COPERT 4v10 and to Euro 5/6 regulatory limits

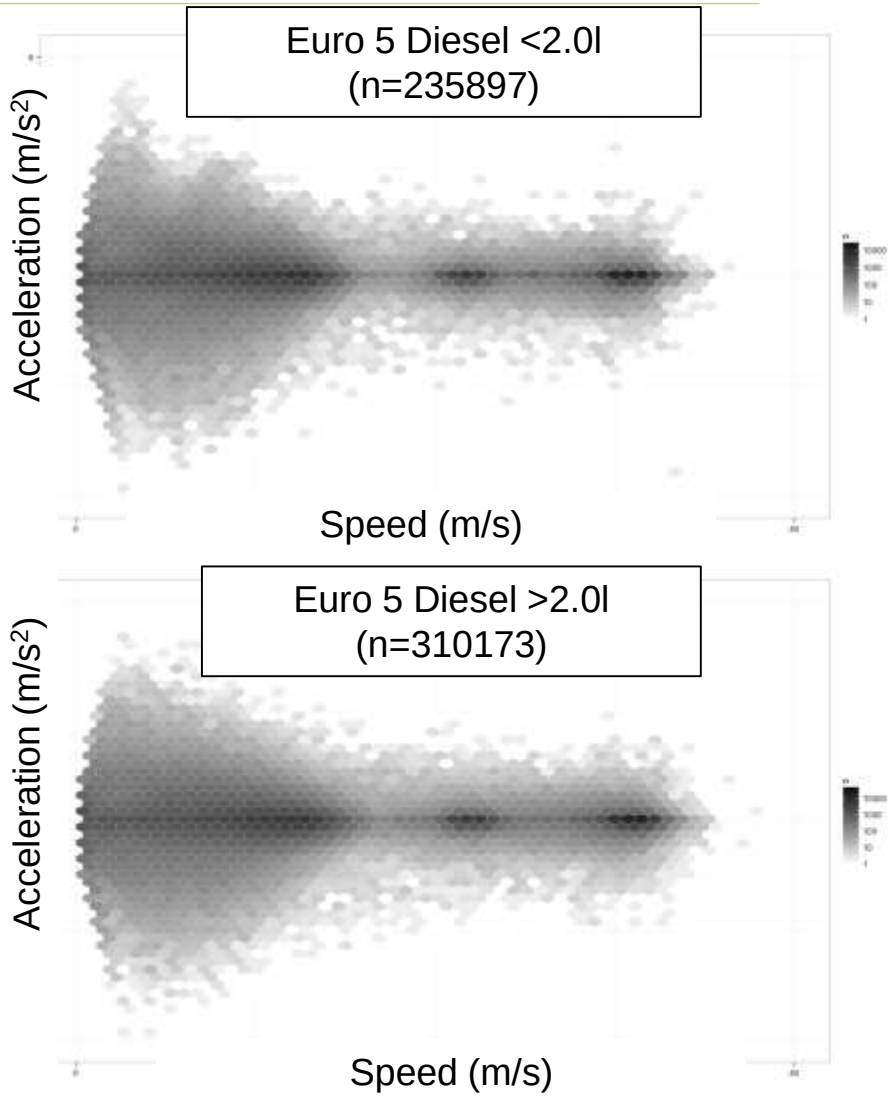
  2. Examination of fNO_2 and variation with vehicle class, average speed and VSP

  3. Examination of fuel-specific NO_x emission rates across the VSP range

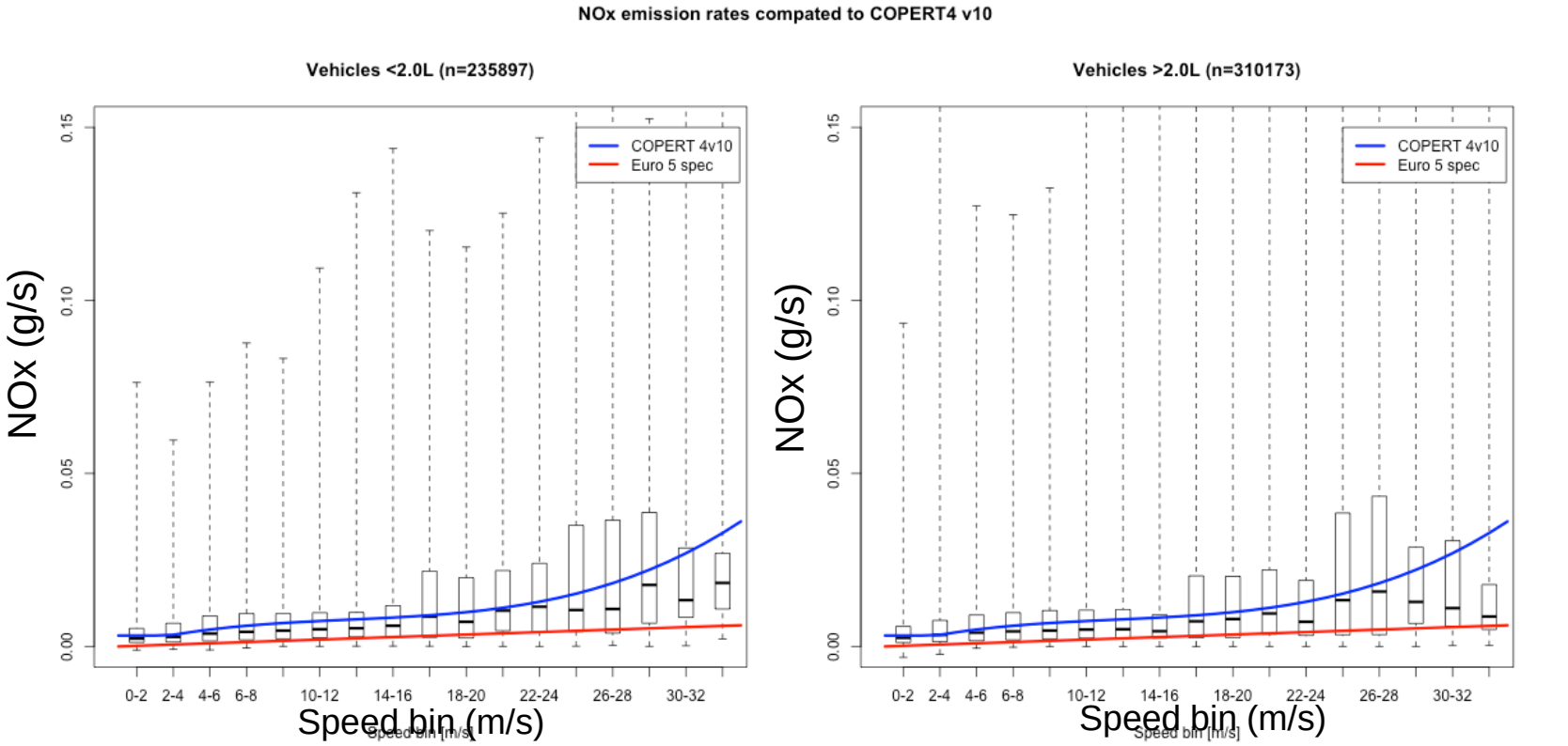
- Provide a starting point for further investigation of large PEMS datasets

Data characterisation

- Consistent London area test routes covering urban and extra-urban cycles.
- Quality assurance:
  - Trained drivers and data filtered to ensure segment average-speeds within bounds.
  - Additional filters to remove tests with abnormal ‘events’
- Leaves **82 Euro 5** and **12 Euro 6** vehicles , each has > 2.5hrs test time.
  - Vehicle activity data derived from 1Hz GPS giving ~600,000 data points.
- COPERT classifications used:
  - Diesel <2.0l gives 36+4 vehicles
  - Diesel >=2.0l capacity 46+8 vehicles.

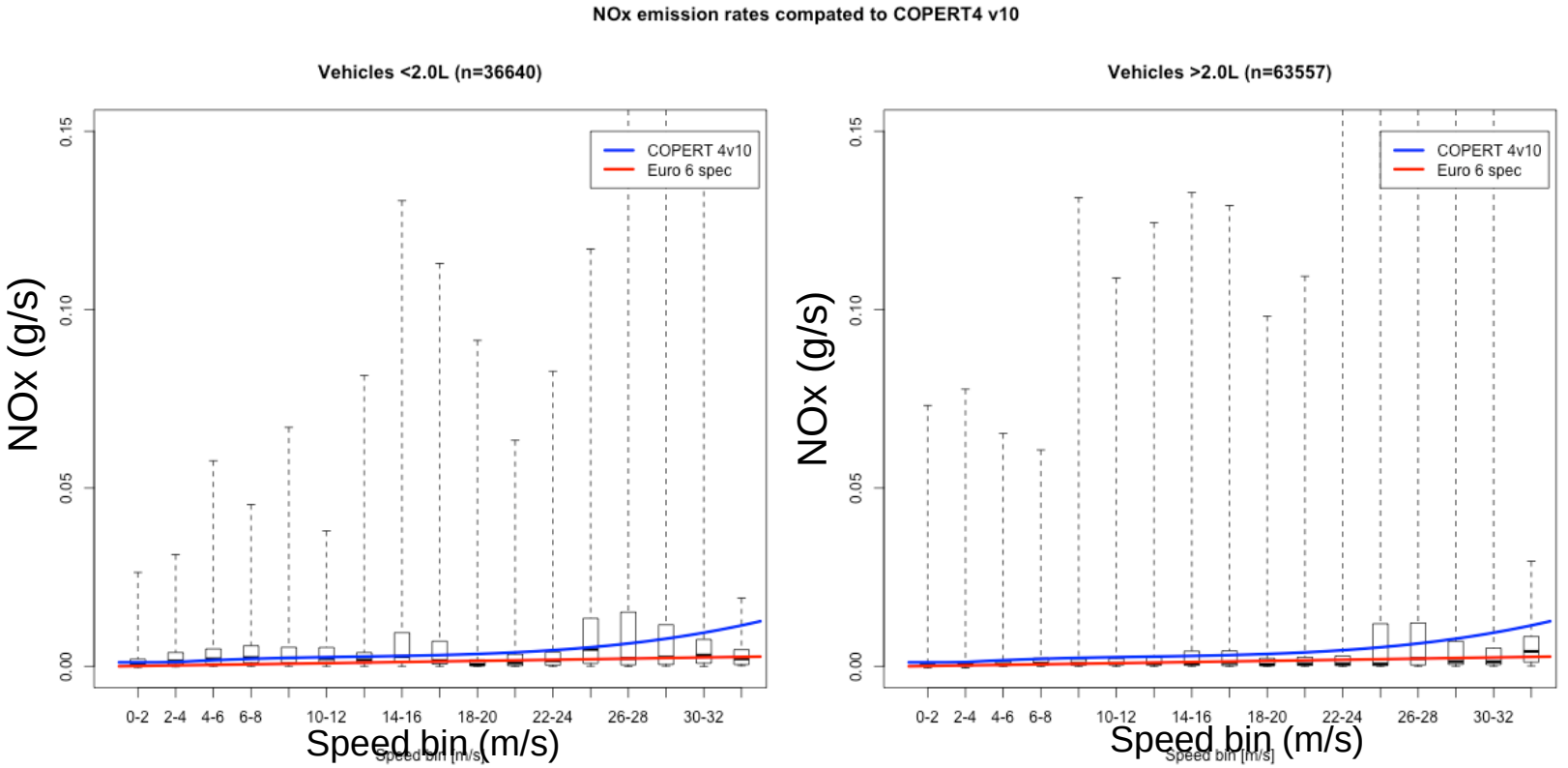


Real world v **Euro 5** specification & COPERT 4v10



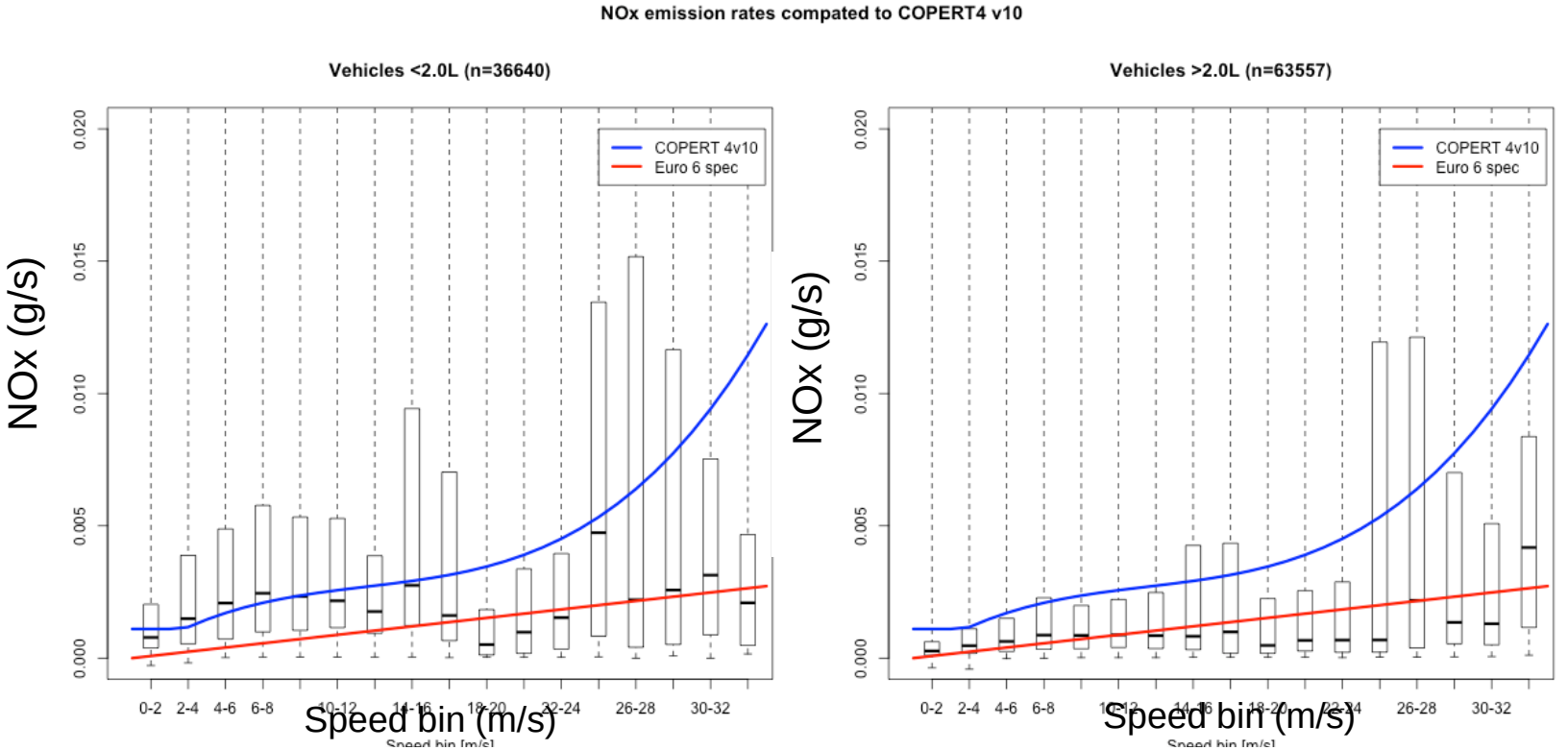
- Box and whisker plots show real world emissions from EA collected data
- For every speed bin, real world emissions greater than Euro 5 specification values
- COPERT 4v10 overestimates median NO_x emissions for every speed bin – difference is greater for higher speed bins (effects of 2013-14 PEMS data vs COPERT tests?)

Real world v **Euro 6** specification & COPERT 4v10



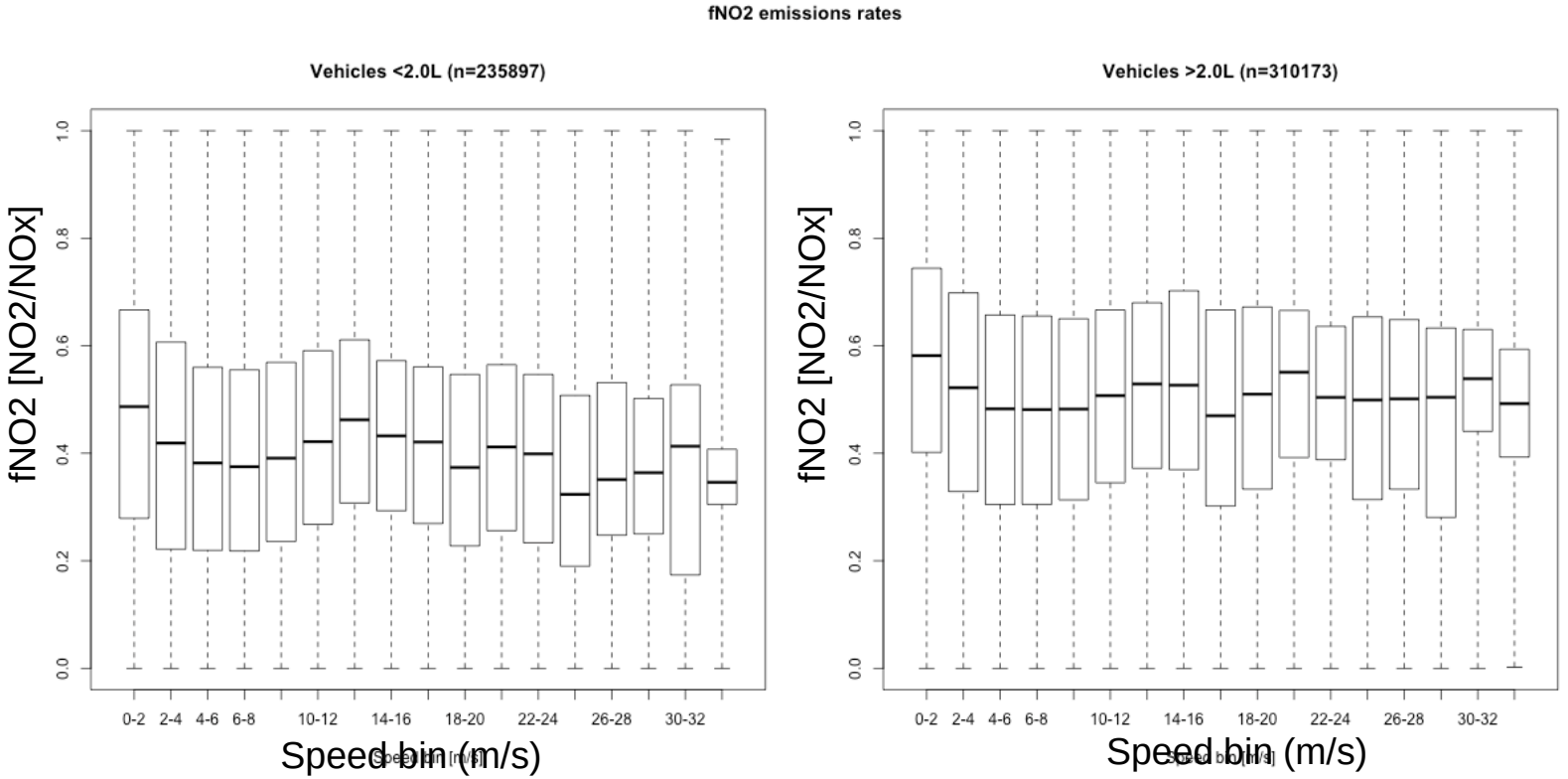
- Euro 6 emissions reduced compared to Euro 5
- Some deviation above Euro 6 COPERT curve, especially at higher speed
- Small sample sizes, so conclusions limited

Real world v **Euro 6** specification & COPERT 4v10



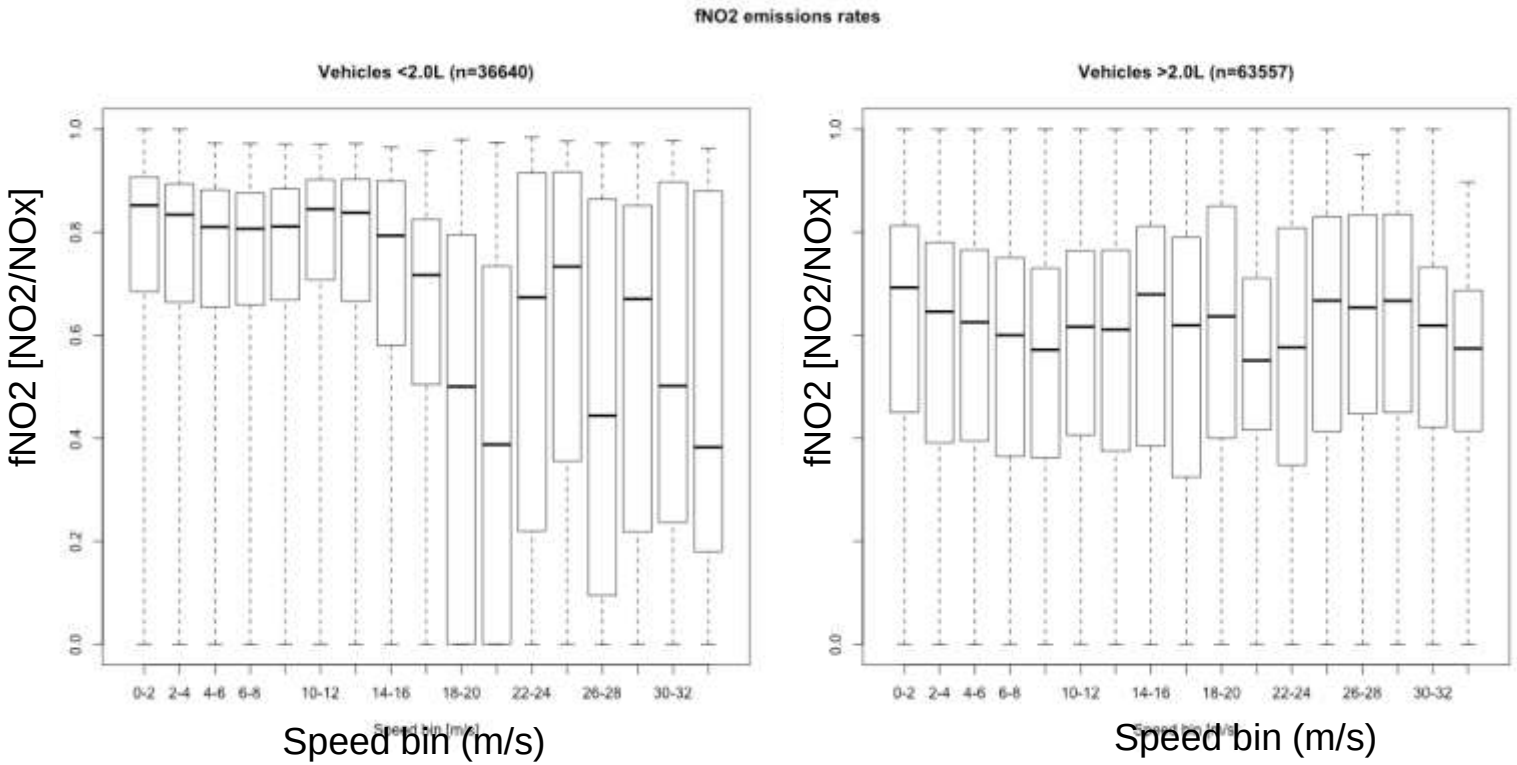
- [‘zoom’ of previous plots]

Euro 5 - fNO_2 emissions rates by speed bin



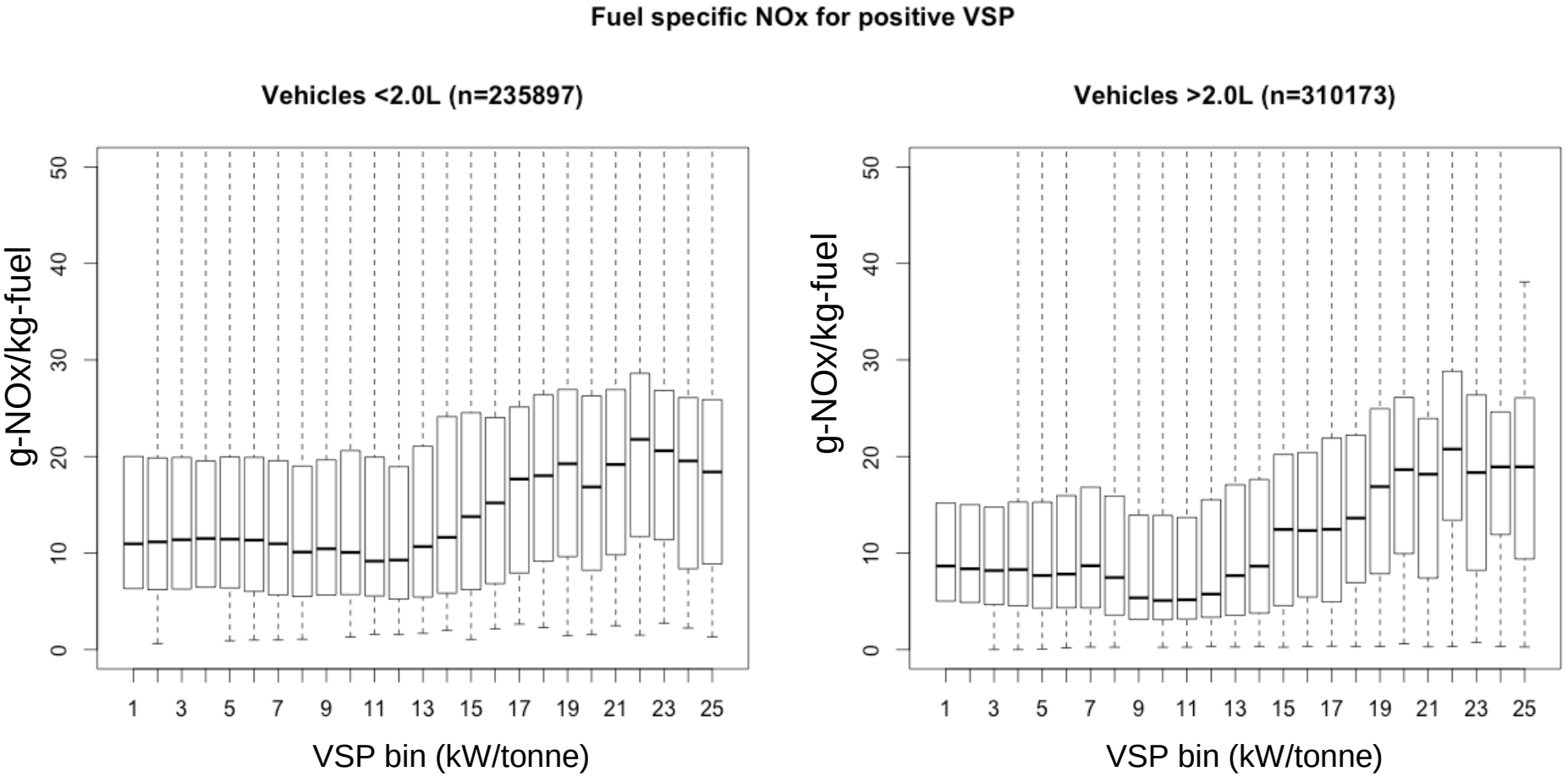
- Vehicles with a larger engine capacity have higher fNO_2 emission rates across all speed bins
- Consistent with other real world studies – e.g. Carslaw's remote sensing studying in London where larger engine capacity vehicles (>2L) had up to 60% higher NO_2 emissions

Euro 6 - fNO_2 emissions rates by speed bin



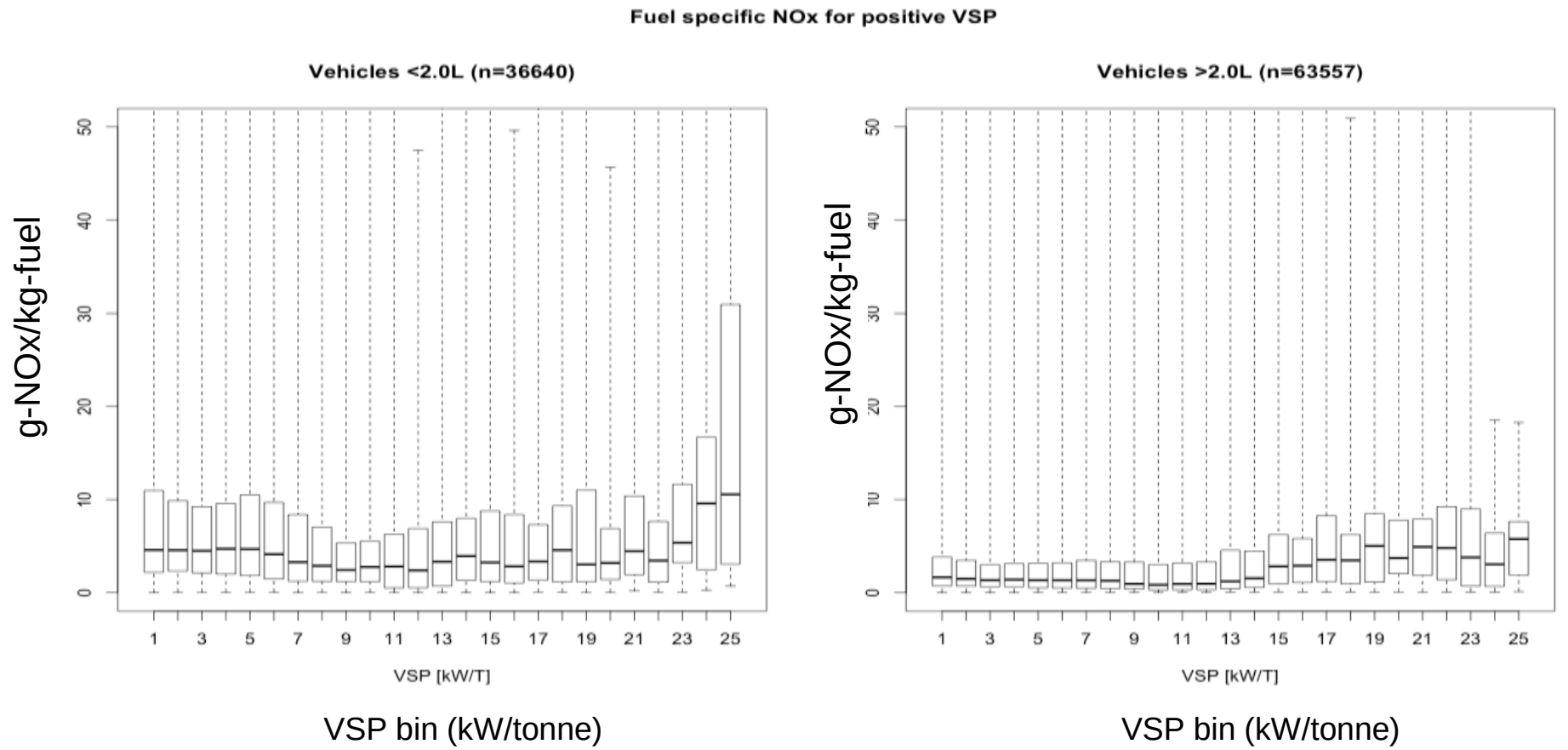
- Euro 6 fNO2 generally higher than Euro 5
- Variability for smaller engines at higher speed bins – effect of loading?
- Small sample size…

Euro 5 - Fuel-specific NO_x (positive VSP only)



- CO_2 used as a proxy for fuel usage, VSP calculated from road gradient
- Generally slightly lower NO_x/kg-fuel for larger engines (for 2013MY and 2014MY)
- Flat ratio at low VSP, increasing above ~12 kW/t (<2.0l) and ~14kW/t (>2.0l)

Euro 6 - Fuel-specific NO_x (positive VSP only)



VSP bin (kW/tonne)

VSP bin (kW/tonne)

- CO_2 used as a proxy for fuel usage, VSP calculated from road gradient
- Fuel-specific NO_x reduced for Euro 6 and potentially lower for larger-engine vehicles

Imperial College London

CATAPULT Transport Systems

EMISSIONS ANALYTICS

Summary and conclusions

- PEMS data collected for TrueMPG is a very rich source of information about NO_x emission rates
- For 82 Euro 5 diesel vehicles of 2013MY and 2014MY examined over urban and extra-urban cycles:
  - Median emission rates were slightly lower than COPERT 4v10 across the average speed range (up to ~75mph).
  - More significant differences at high speeds, and a wider spread in 30mph-50mph range
  - NO_2 fraction was increased for the larger engines, little variation with speed
  - DPF regeneration events increased link emissions substantially for the 3 cases studied
  - Fuel-specific NO_x rates suggest reduced interesting differences between large- and small-engined vehicles
- For 12 Euro 6 vehicles initial observations that median emission rates reduced compared to Euro 5, fNO_2 increased and g-NO_x/kg-fuel substantially reduced
- Further data collection and further analysis is needed (e.g. per-km values)

Dr. Robin North

robin.north@ts.catapult.org.uk

+44 (0) 7971 226590

http://ts.catapult.org.uk/

Aravinth Thiyagarajah

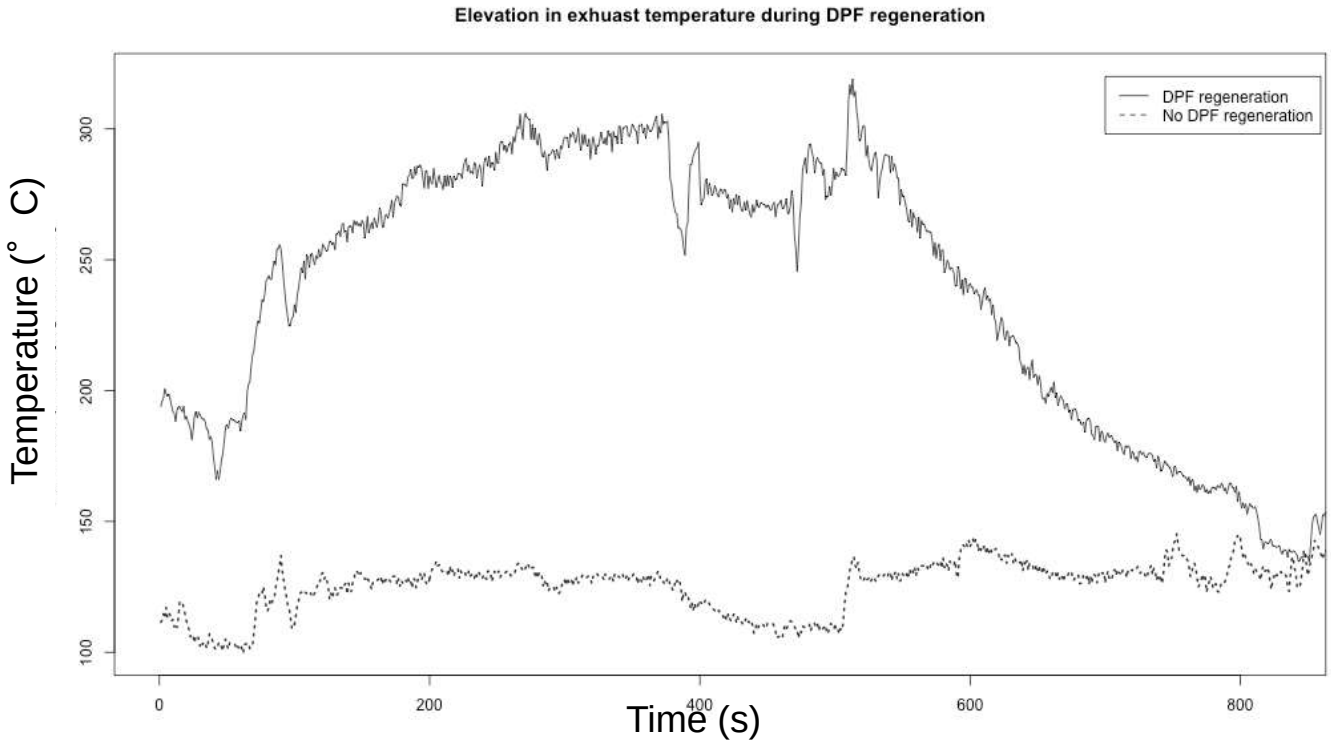
aravinth.thiyagarajah07@imperial.ac.uk

Nick Molden

nick@emissionsanalytics.com

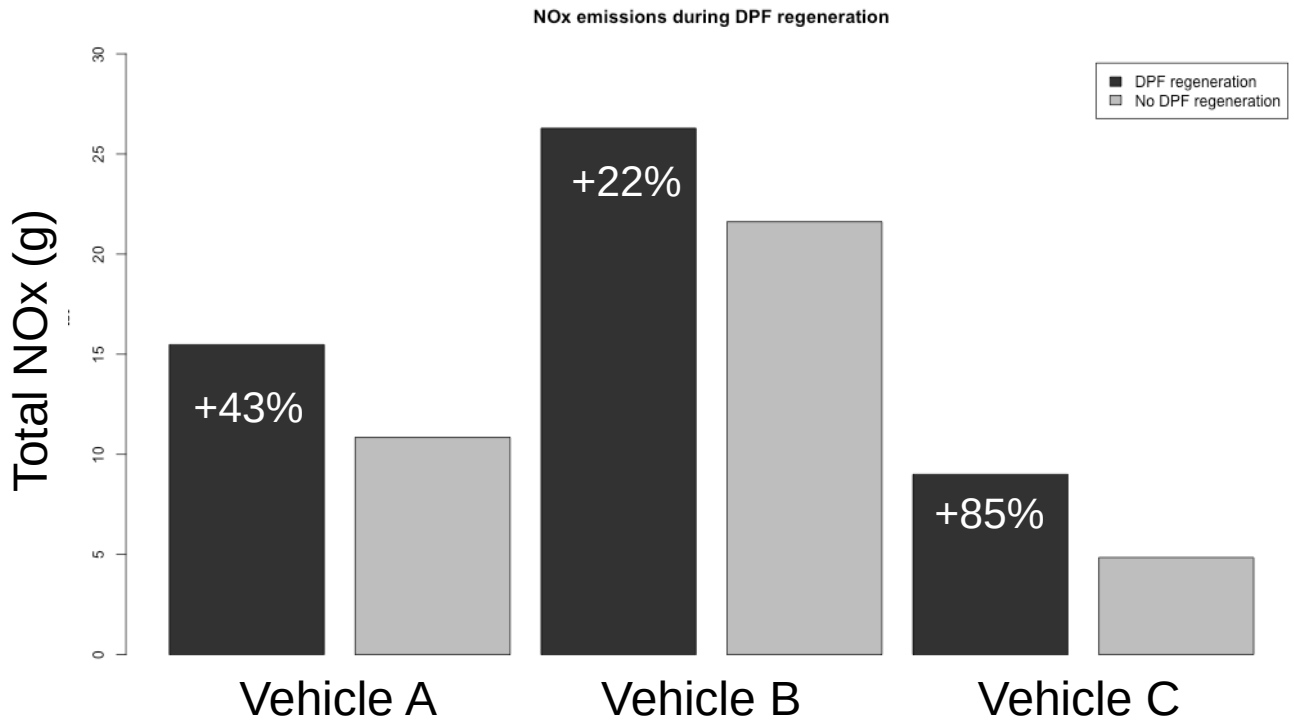
Sign up to receive our monthly newsletter featuring the latest emissions insights at www.emissionsanalytics.com

Effects of DPF regeneration



- Episodes of DPF regeneration are identified by sudden and extended periods of elevated exhaust temperature
- For some vehicles, tests with DPF and non-DPF are available
- Graph shows the same vehicle travelling on the same road segment at similar operating conditions with a clear difference in exhaust temperature

Effects of DPF regeneration



- 3 vehicles where DPF regeneration and non-DPF cycles were recorded were selected from the EA test database
- Comparisons made for the whole of a ~30 minute motorway link on which a DPF event occurred (not just during the period of raised temperature)
- For all 3 vehicles, elevated NO_x emissions during DPF regeneration and reduced fNO_2