Ricardo
Energy & Environment

Real World Driving Emissions – Supporting Effective Air Quality Management in the UK

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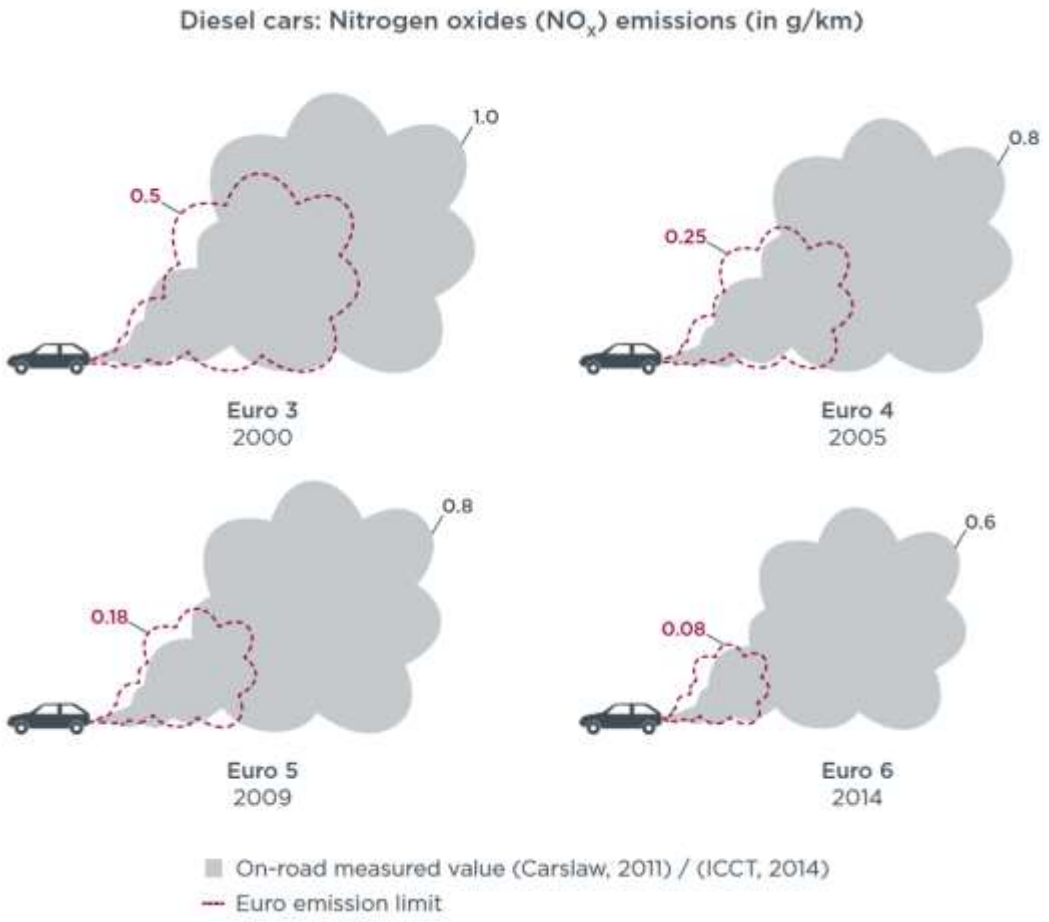
IAPSC, December 2019

Real World v Lab-based type approval emissions

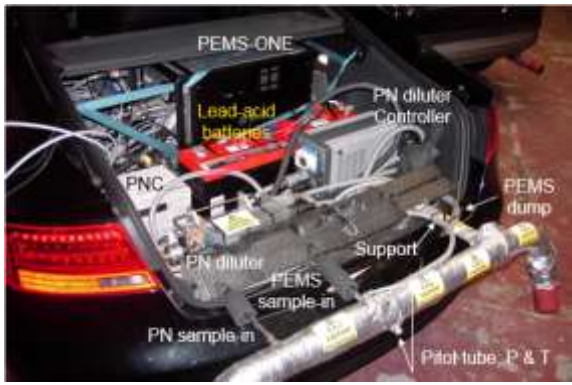


Most AQ management strategies are based on lab-based emission factors ...

... Yet significant discrepancies between emissions detected in diesel vehicle exhaust during type-approval tests and those observed during “real-world” operation (ICCT)

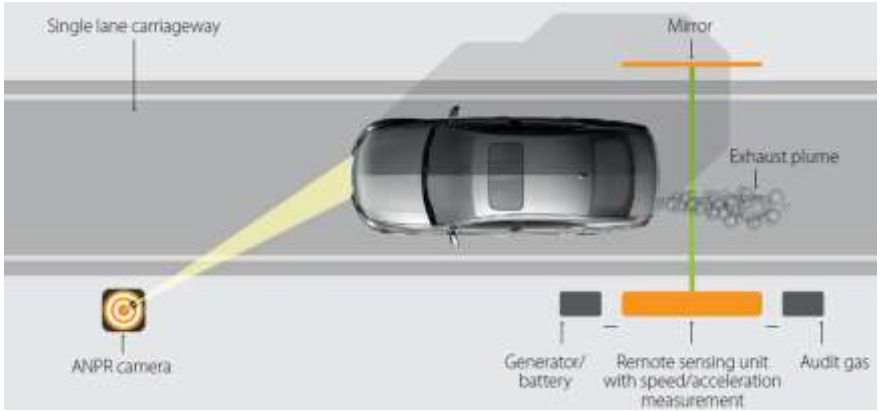
Vehicle Emission Measurements

- Three main ways of measuring vehicles emissions
  - In the laboratory (like the Ricardo Vehicle Emission Research Centre, VERC)
    - Used for type approval of emission standards
    - Conducted on a rolling road (dynamometer)
    - Good for consistency and reproducibility
  - Portable emission measurement systems (PEMS) (we have five)
    - Instrument individual vehicles
    - Provides real-world driving emissions
    - Limited to relatively few vehicles
  - Vehicle emission remote sensing
- The three techniques are highly complementary, but:
  - Remote sensing provides data that is closely aligned to air quality problems
  - Measures the whole vehicle fleet
  - Can be used to derive emission factors for use in emission inventories



Real World Emissions ... Vehicle Emission Remote Sensing

- The technique:
  - UV/Infrared beam measures emissions – different gases absorb in different wavelength regions
  - Measures NO, NO_2 (hence NO_x), CO, HC, PM and NH_3
  - 100 scans in 0.5 seconds of exhaust plume
  - **Emissions expressed as ratios to CO_2** and through combustion equations, grammes of pollutant per unit fuel (mostly commonly g/kg)
  - Measure speed and acceleration of each vehicle
- Captures each vehicle number plate
  - Detailed cross reference with SMMT derived databases, more than 80 vehicle characteristics ... even down to the colour of the vehicle!

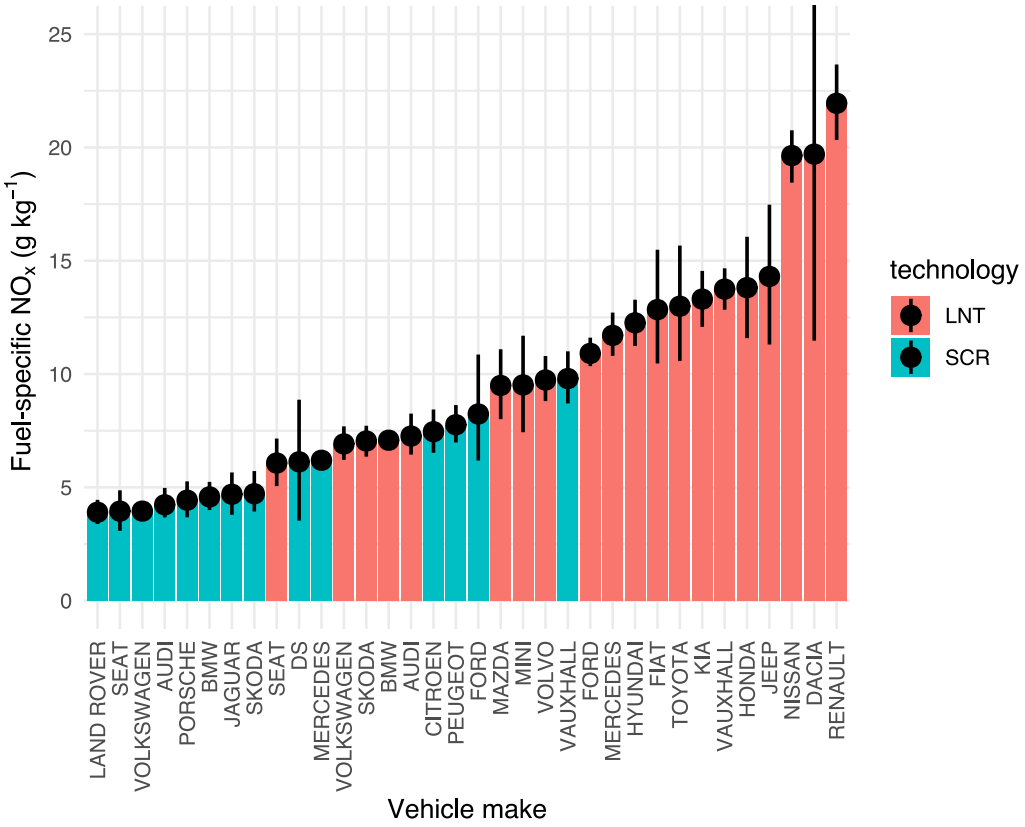


Overview of the Ricardo Remote Sensing Programme

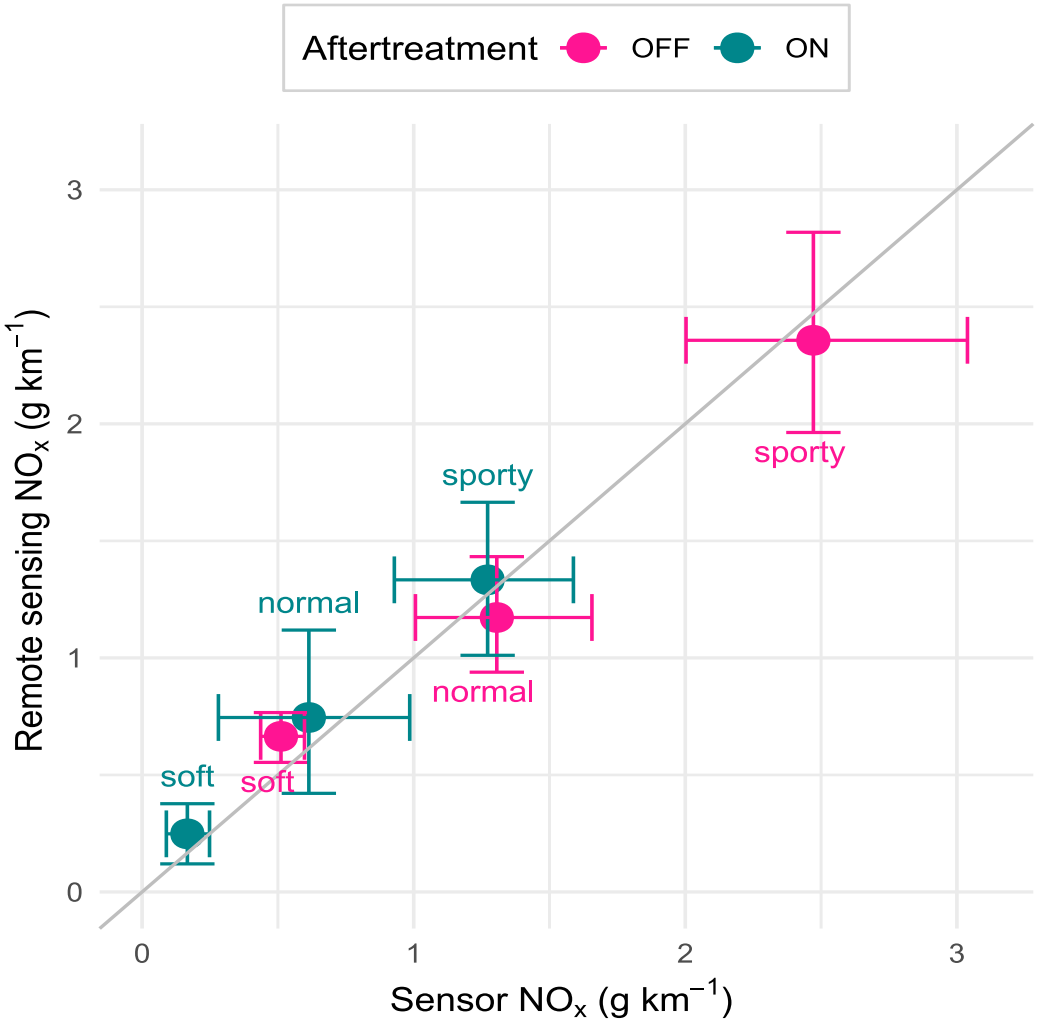
- Working with our Technology Partner OPUS RSE
- Measurements started in March 2017 and have continued since
- >400,000 measurements across UK (and growing)
- 100,000 in London as part of work for ICCT, feeds into the TRUE real-world emissions rating
- Measurements are representative of the UK fleet
- Cover a wide range of conditions
  - All seasons, wide range of temperatures
  - Many speeds and accelerations typical of urban driving

Some benefits of Remote Sensing

- RS is complementary to PEMS
- Remote sensing typically is presented with **uncertainties in emission estimates**
  - Sample size and representivity
- Provides a way of telling whether emissions are statistically different from one another
  - Of use in ranking of vehicles and emission indices
- Provides a consistent basis for comparison
  - On average, the vehicles tested **experience the same driving and ambient conditions**
  - Difficult or impossible to achieve using PEMS



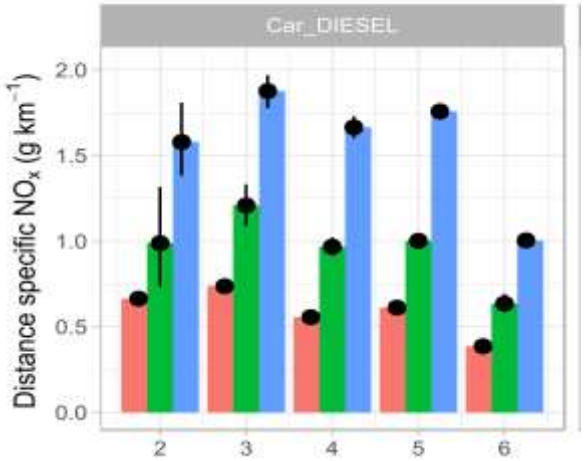
Comparison of VERS with PEMS



- Euro 6d-temp passenger car with Lean NO_x Trap
- Even with few measurements, remote sensing:
  - Agrees well with PEMS overall
  - Could clearly distinguish vehicle aftertreatment being on / off
  - Distinguish between driving conditions of ‘soft’, ‘normal’ and ‘sporty’

Vehicle Emissions Remote Sensing – Enhanced Evidence Base

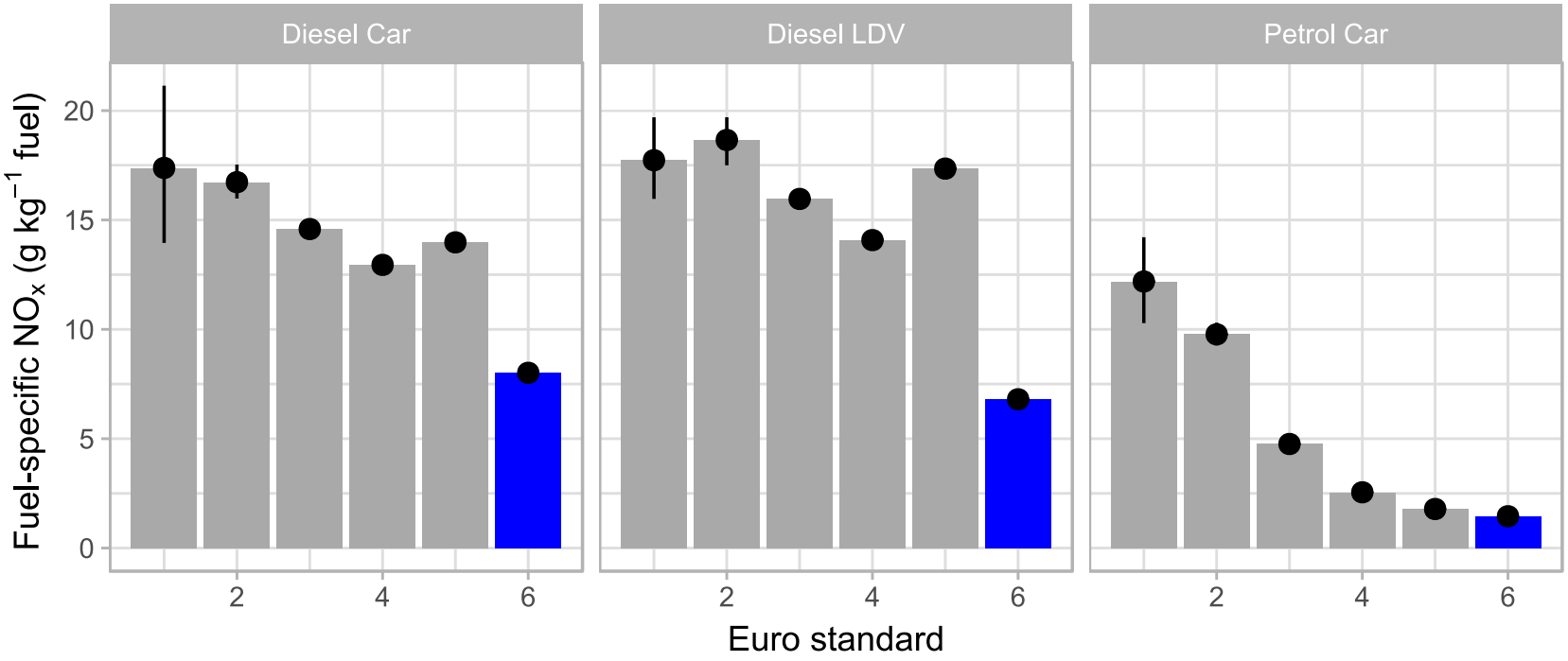
- **Improves air quality emissions inventories and modelling**
  - Characterise real-world emissions of vehicles in fleet
  - Enhance inventories by providing emission factor temperature dependence
  - Significantly reduced modelling uncertainty by replacing assumptions with evidence-based real-world driving emissions information



- **Supports the design of cost effective, evidence-based, Clean Air and Low Emission Zone strategy and schemes**

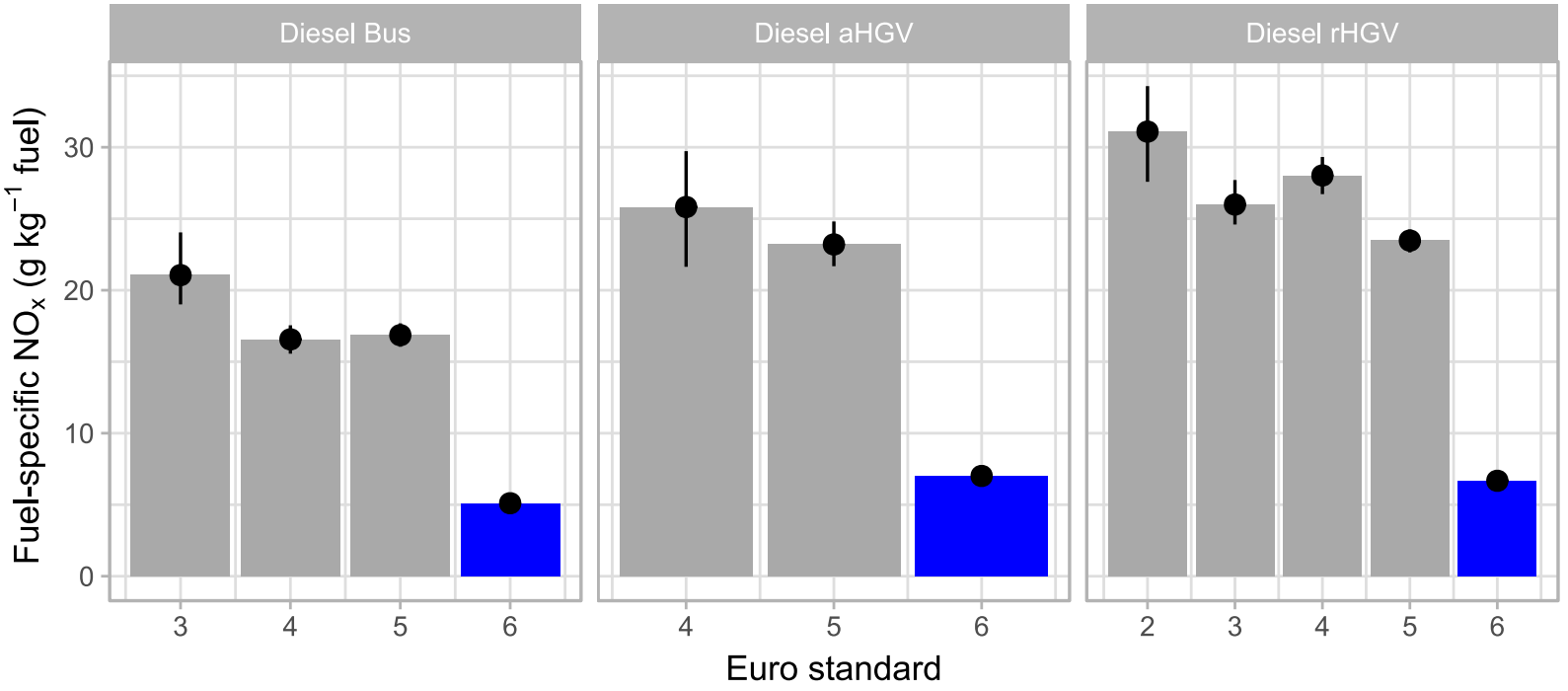
- **Surveillance to track and assess the effectiveness of policy measures and understand the performance of new vehicles**

Surveillance of new vehicles: how effective is Euro 6?



- Little change in NOx emissions pre-Euro 6
- But significant improvement for Euro 6

Surveillance of new vehicles: how effective is Euro 6?



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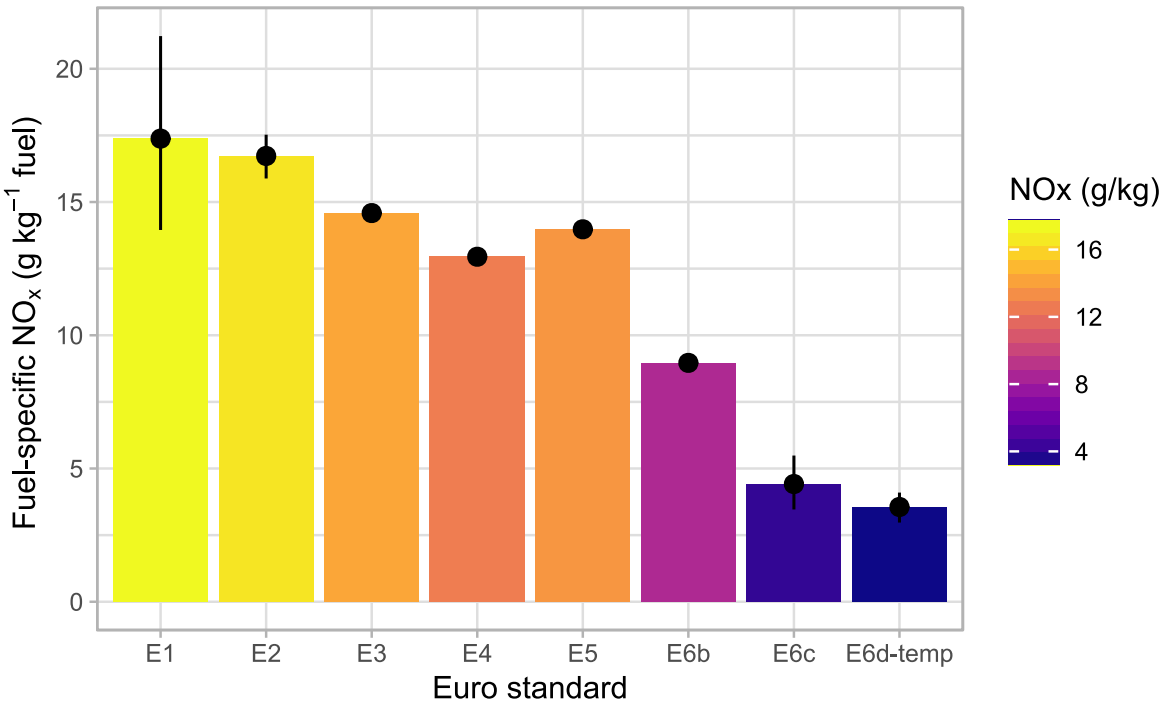
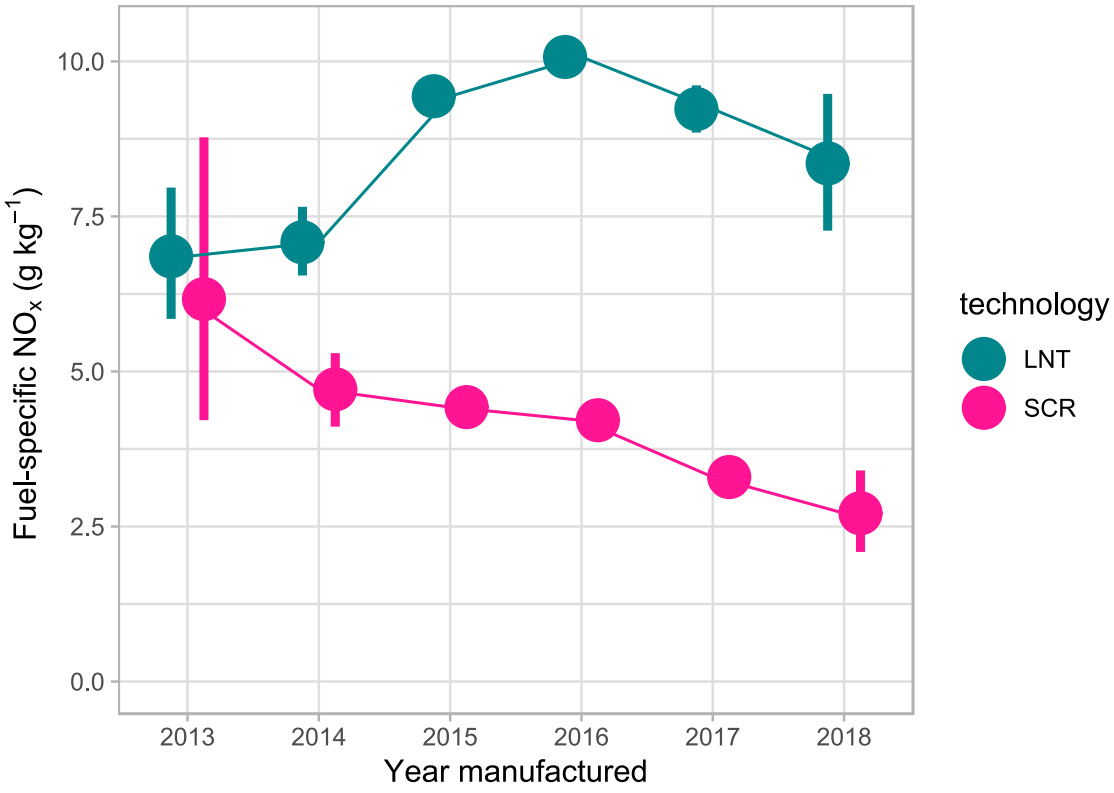
Euro 6 Diesel Cars – Impacts of RDE regulations

- Euro 6 is not one thing – staged introduction of 'real-world' driving component to the testing
  - Euro 6c (09/2017): Lab drive cycle changed to WLTP, more representative of real-world driving
  - Euro 6d-TEMP (09/2019): RDE on-road PEMS test, conformity factor 2.1
  - Euro 6d (2020): RDE with conformity factor 1.43
- Manufacturers are using a range of after treatment technologies to meet Euro 6 emission standard and this has an impact…



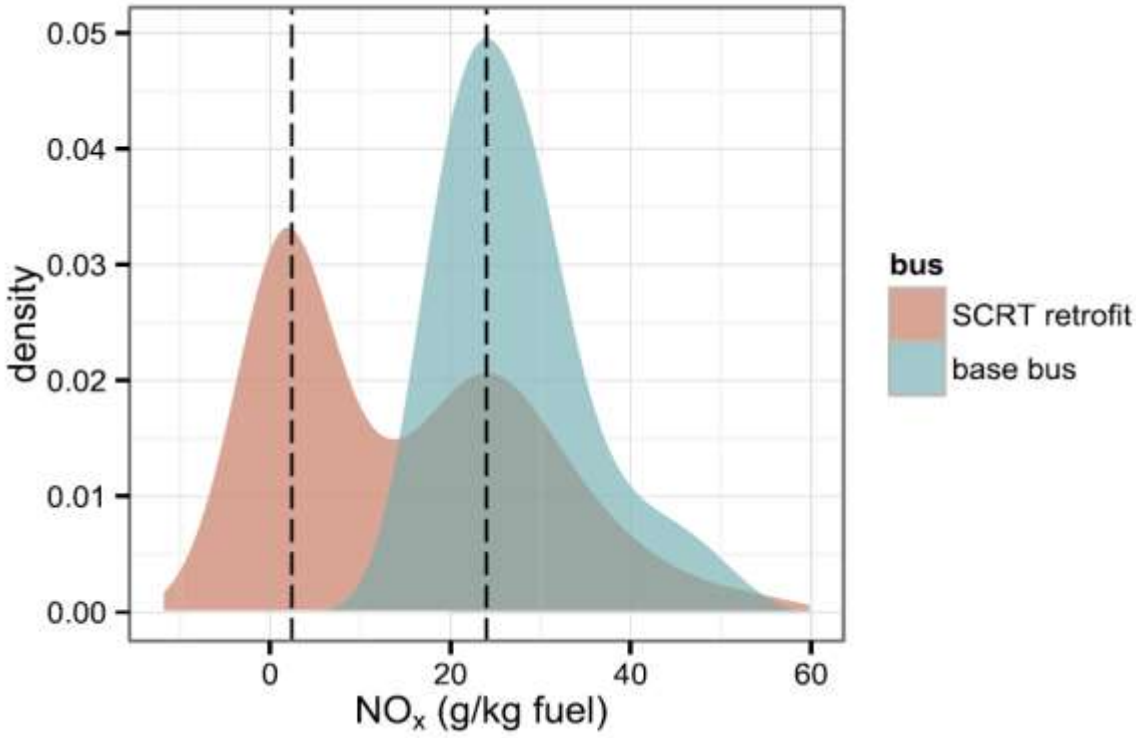
Emissions of NOx from Euro 6 diesel cars – technology dependence

- Have identified whether Lean NOx Trap (LNT) or Selective Catalytic Reduction (SCR) used on Euro 6 vehicles
- On average SCR vehicles emit much less NOx than LNT
- Perhaps more of an indication of decreases year on year for SCR than LNT
- Useful to see how Euro 6 improves in future – especially RDE-compliant vehicles



Bus retrofit programs

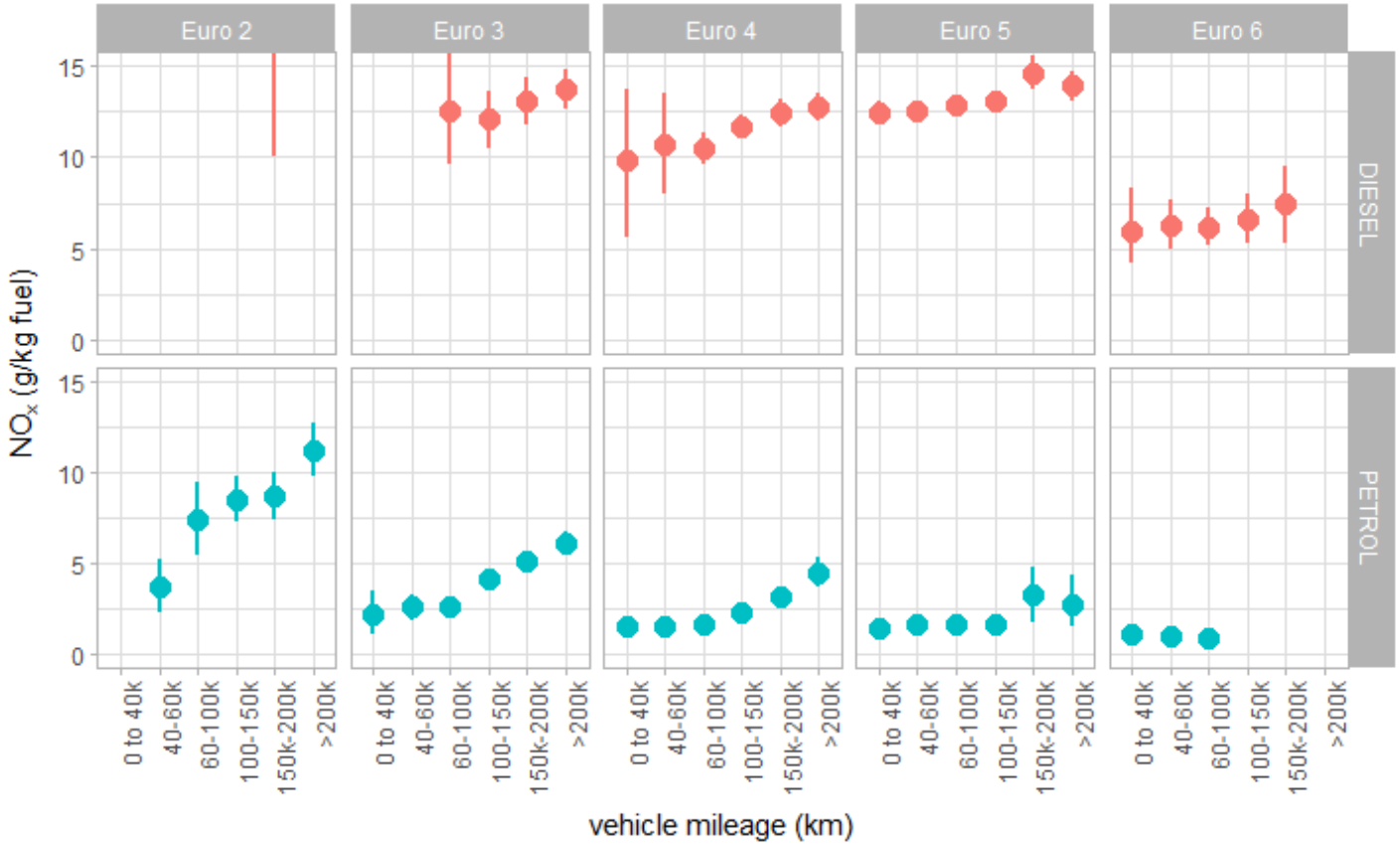
- Retrofit technologies aim to achieve Euro VI emissions standards
- Previous work using RS to measure bus emissions in London and Oxford demonstrated*:
  - Variation in NOx emissions between buses was large.
  - SCR retrofits to Euro III buses were effective under some, but not all conditions.
- Emerging evidence from recent measurements suggests that current retrofits continue to show mixed performance



Bus measurements in London: TfL Euro III with and without SCRT retrofit system

*Carslaw et al., Atmospheric Environment 105 (2015) 70-77

Effect of vehicle mileage on NOx

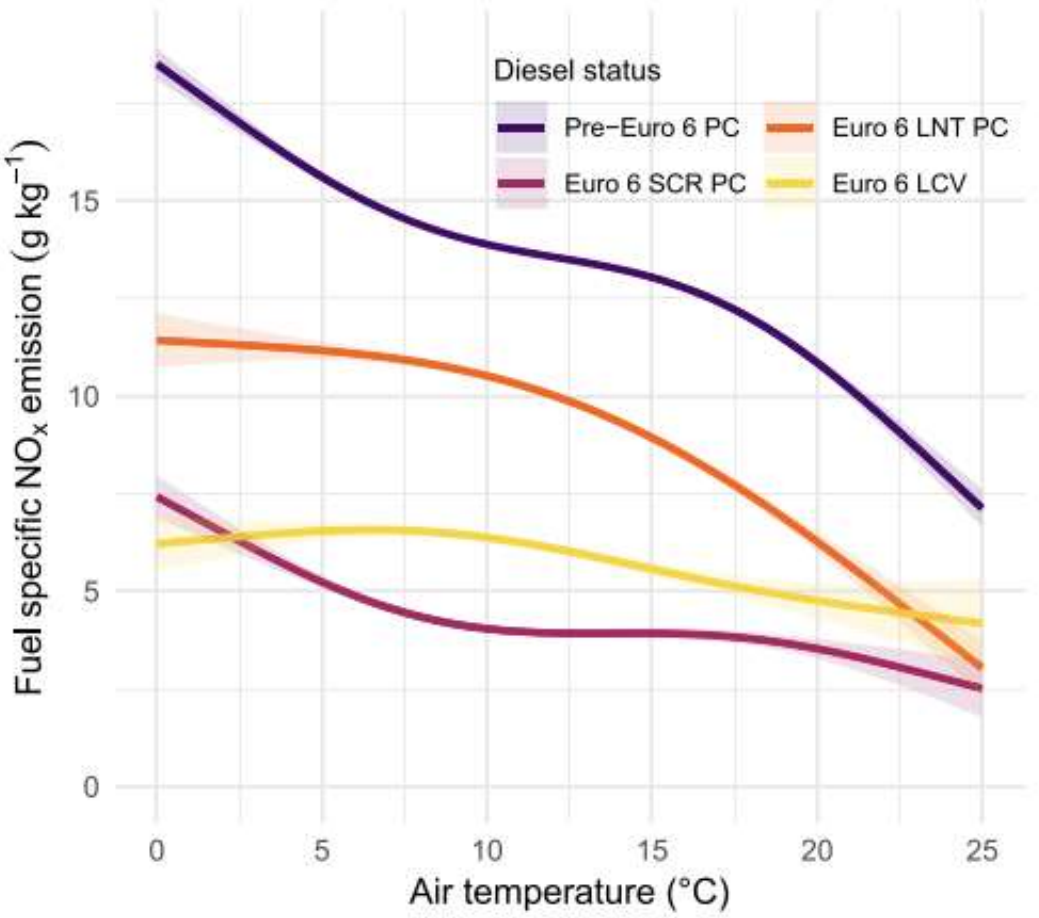


- Implications for scrappage schemes and other actions to improve air quality
- Continue to track the performance of the latest Euro 6 vehicles with increasingly complex aftertreatment technologies

https://ee.ricardo.com/news/emissions-deterioration-%E2%80%93-the-cinderella-of-vehicl

Effect of ambient temperature

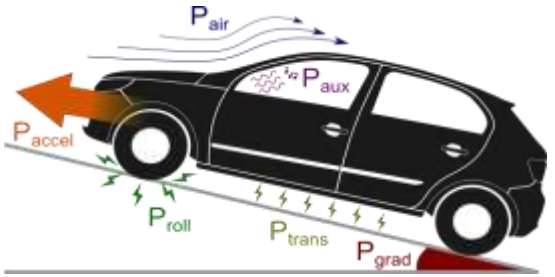
- Strong temperature dependence for pre-Euro 6 light duty diesel vehicles
- Stronger temperature dependence for LNT Euro 6 cars than SCR
- Important implications for air quality
  - Low temperatures can lead to less efficient dispersion (stable atmosphere)
  - Increased emissions and less efficient dispersion = increased concentrations
  - Increased use of Euro 6 SCR diesels should lead to a decrease in NO_x emissions, especially under winter episode conditions



Grange et al., Temperature Dependance for Light-Duty Vehicle NOx, Environ. Sci. Technol. 2019, 53, 6587−6596

Real-World Emission Factors to improve inventories

- Remote sensing provides **ratios of pollutants to CO_2** → easy to derive fuel-specific emissions (e.g. grams of NO_X per kg fuel)
- To calculate g/km emissions need to estimate CO_2 in g/km i.e. the fuel consumption of the vehicle at the time of measurement
- A couple of possible options
  - Simplest would be to use common emission factors such as COPERT to estimate vehicle CO_2 in g/km
    - Multiply CO_2 in g/km with remote sensing ratio to CO_2 e.g. NO_x/CO_2
    - Assumes emissions factors for CO_2 are good …
  - Calculate fuel consumption based on vehicle specific power (VSP)
    - A physics-based approach
    - We have all the information we need to do this



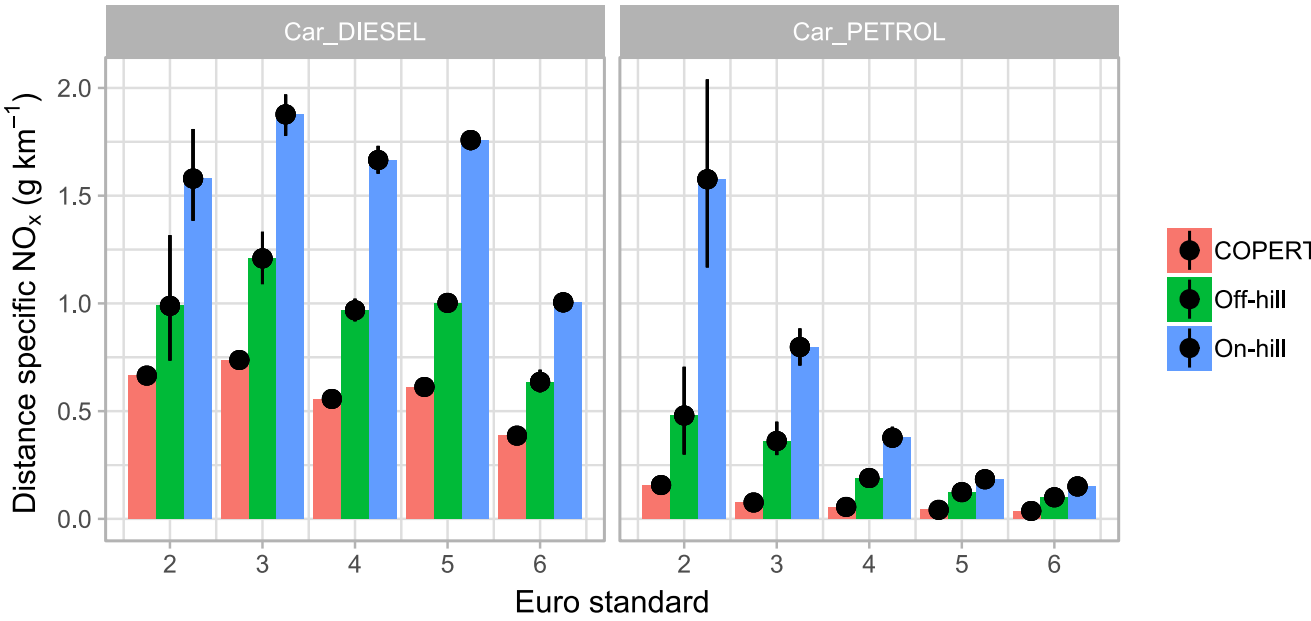
Real-World Emission Factors to improve inventories

- Remote sensing data can be directly aligned with COPERT emission factor categories
  - Vehicle type
  - Euro standard
  - Vehicle weight / engine size

- Can go ***beyond*** COPERT emission factor categories
  - Road gradient
  - Acceleration
  - Ambient temperature
  - Vehicle mileage
  - Vehicle manufacturer and model
  - Specific vehicle technologies

- Can develop ***local*** and ***national*** emission factors

Remote sensing improves model performance



- AQ problems linked to congestion, road gradient and street canyon
- 4 week monitoring campaign at two locations
- Measure emissions from vehicles across the local fleet
- Calculate **local** emission factors
- Real-world emissions from vehicles are significantly higher than inventory emission factors

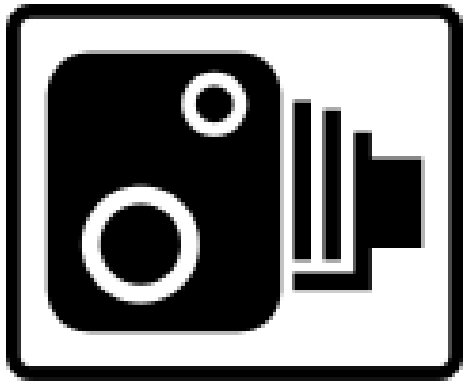
Remote sensing improves model performance

- Real-world emission factors provide input into AQ models
  - Air quality modelling using real-world emission factors showed significant improvement in capability predict of NOx and NO_2 concentrations

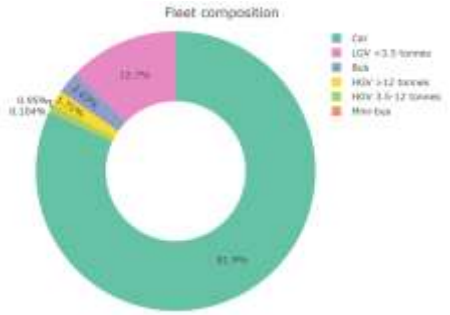
⇒ RS provides improved evidence base to inform policy strategies to improve air quality

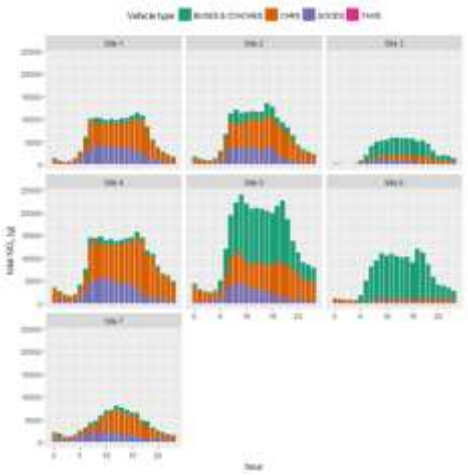
Linking ANPR cameras with Ricardo's Real World Emissions Database & Emissions Processor

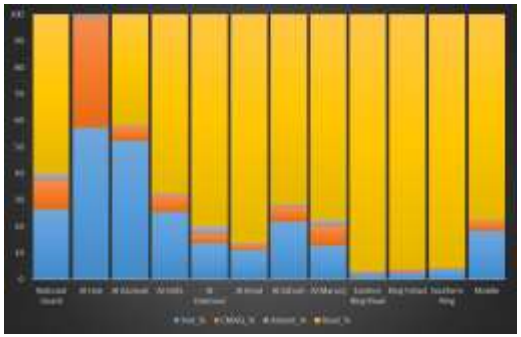
ANPR Data



Ricardo's Real World Emissions Database & Emissions Processor







Better Policy making and tracking

Real time?

Summary

- Remote sensing provides comprehensive real-world emissions measurements
  - Measures the full fleet over a wide range of conditions
  - Capable of measuring regulated (NOx, PM, CO, HC) and unregulated pollutants (NO_2, NH_3)
  - Provides understanding of emissions by vehicle, type fuel type, vehicle model, aftertreatment technology…
  - Assess the effectiveness of retrofits and new abatement technologies
  - Understand deterioration with vehicle mileage and impact of ambient temperature
- Capability to develop full fleet emission factors in g/km to improve emission inventories and to improve the evidence base for AQ modelling of policy scenarios
- Support Clean Air / Low Emission Zone strategies and other policy options
  - At modelling stage to provide robust evidence to inform decision making
  - Surveillance data to support Clean Air and Low Emission Zone compliance

Thank you for your attention

Find out more @
https://ee.ricardo.com/air-quality/case-studies/remote-sensing-blog-2

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