Alternative Road Transport Emissions Modelling Approach for the UK NAEI

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TFEIP

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Introduction & Background

- UK road transport emissions model uses a Tier 3 approach with Guidebook emission factors and methods (COPERT 5.6) combined with detailed road transport activity data from UK Department for Transport.

- A modelling approach that serves the needs of the UK National Atmospheric Inventory (NAEI): Consistent time series of emissions 1990 – current inventory year & projections for international inventory reporting (NECR, CLRTAP)

- NAEI serves the needs of Defra and DA policies and air quality models and a national and a local level
  - National compliance assessment under UK Air Quality Standards Regulations
  - PM target setting, NO_2 plans, etc.

- The evidence base on vehicle emission factors and their dependencies is continuously evolving – inventories need to respond to this, serving the needs of the inventory and modelling and policy tools

A Review of Alternative Emission Factors and Modelling Approach for the NAEI

- Ongoing program of continuous improvement and verification of the inventory

- Commissioned by Defra to investigate alternative sets of emission factors and modelling approaches:

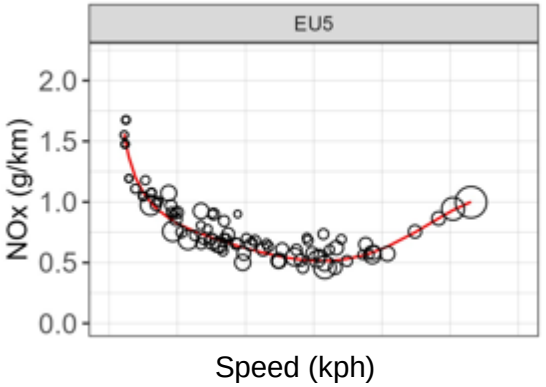
- Review of **Handbook Emission Factors for Road Transport (HBEFA)** – developed in Austria, Germany, Switzerland and used by several European countries for national inventory reporting
  - Comparing emission factors and consideration of using HBEFA for the UK inventory

- Emission factors from **roadside remote sensing**
  - Latest dataset held by Ricardo – comparison with COPERT and HBEFA

- TFEIP 2023 – Tim Murrells (Ricardo) and Daniel Mehlig (Imperial College London) presented work to investigate the use of vehicle emissions remote sensing data for emission inventories and modelling NO_x and NO_2 concentrations

Approach to review HBEFA

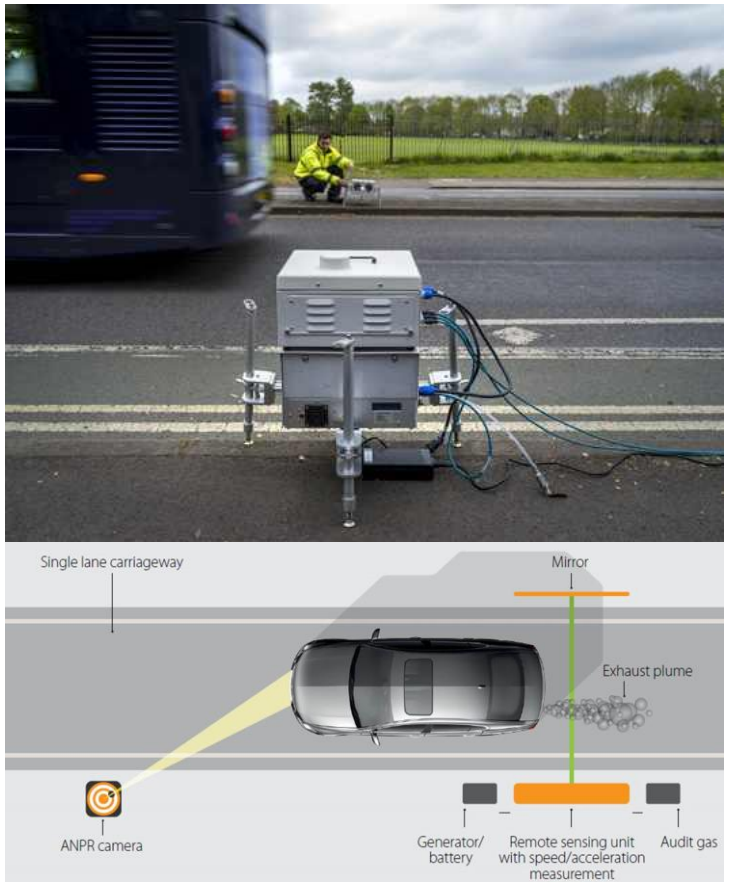
- Provides emission factors and methods to calculate road transport emissions for national inventory reporting and modelling – offers an alternative to the COPERT emission factors that are currently used in the UK inventory
- Emission factors are for a large set of 'traffic situations', in contrast to the average speed-based emission factors available from COPERT
  - Total of 365 traffic situations defined by four characteristics: Urban/rural area, road type, speed limit and level of service (measure of congestion)
- Disaggregation of UK activity data to traffic situations is a challenge! Start by developing speed emission curves from the HBEFA emission factors comparable to COPERT.
- Focus on exhaust emissions of NO_x and PM, and non-exhaust emissions of PM
- Comparisons between HBEFA 4.2 and COPERT 5.6
  - Derived speed emission curves, degradation of emissions, ambient temperature dependence of emissions
- Impact of using HBEFA model on UK emissions trends from 2005-2050
- Consider how to assign traffic-situation based emission factors with UK activity data.



Engaged with TU Graz during the project. Data from HBEFA provided directly by TU Graz.

Remote Sensing – Approach to Emission Factor Development

- Use of extensive remote sensing measurements available
  - Over 60 locations and > 750,000 measurements since 2017
  - Mostly urban measurements and do not include motorway driving (derived emission factors for high-speed driving are less certain)
- Use of methods to calculate g/km emissions that can be expressed as speed-emission curves for comparison with COPERT and HBEFA – vehicle power-based approach*
- Express the speed-emission curves at a fixed temperature and mileage for consistency with emission factor models
- Derive degradation adjustment factors where appropriate
- Derive ambient temperature adjustment factors where appropriate
- Focus on NO_x and NH_3
- Compare to COPERT and HBEFA
- Impact of using RS data on UK emissions trends from 2005-2050

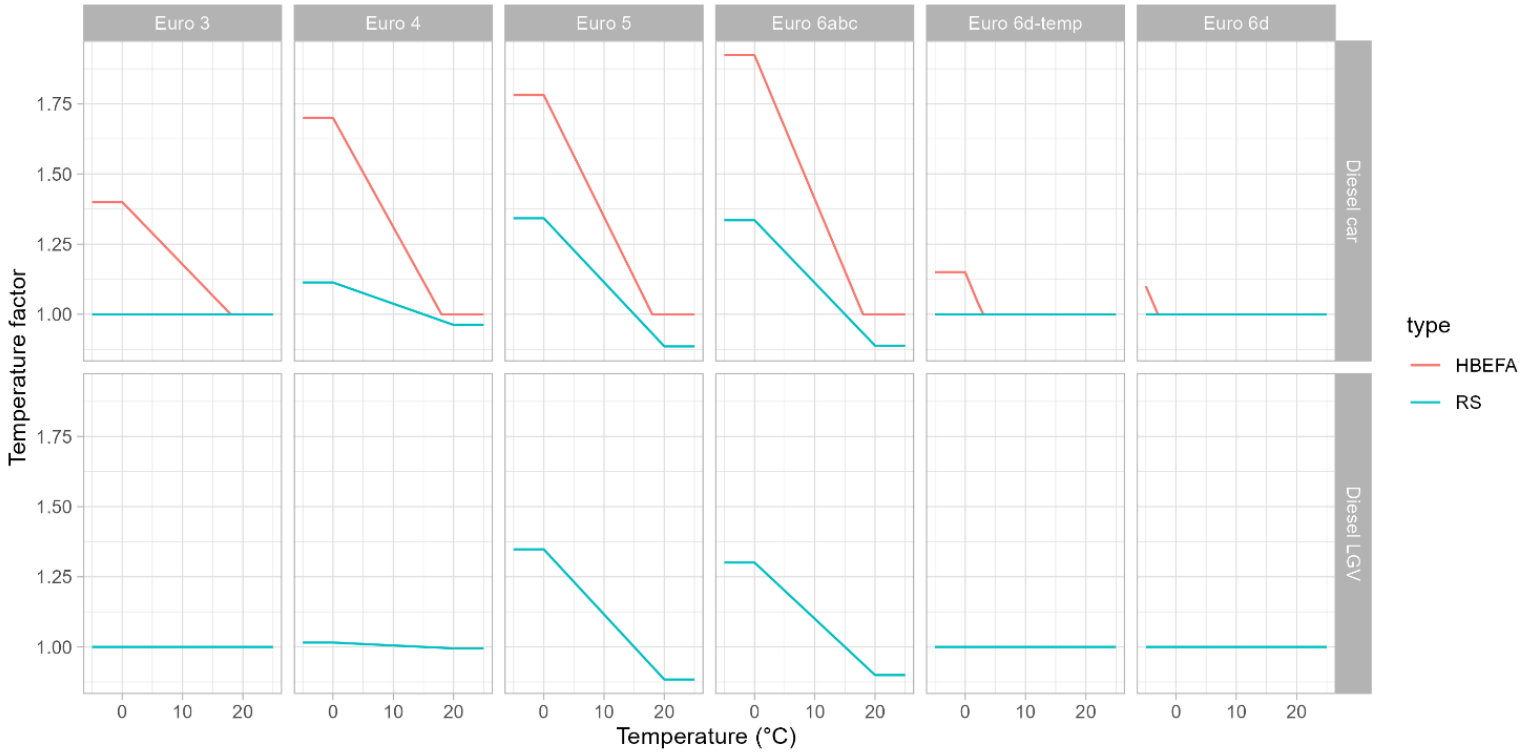


*Davison, J., et al. (2020). Calculation of Distance-Based Emission Factors from Vehicle Emission Remote Sensing Measurements. *Science of the Total Environment*. 739 (2020) 139688.
*Davison, J. et al., (2021). Verification of a National Emission Inventory and Influence of On-road Vehicle Manufacturer-Level Emissions, *Environmental Science & Technology*, 55, 4452−4461

Overview of the Main Results

- Overall, NO_x speed emission curves from COPERT and HBEFA show quite good agreement
- Speed emission curves from RS often also show quite good agreement
- Overall, degradation functions for light duty vehicles from COPERT, HBEFA and RS that account for the increase in emissions as mileage as vehicles age are reasonably well aligned and show similar trends with Euro standard & fuel type
- BUT there are some differences:
  - Temperature dependence of NO_x emissions
  - NO_x emissions from heavy duty vehicles
  - NH_3 emissions from petrol cars
  - PM emissions

Evidence of Ambient Temperature Dependence of NO_x Emission – Diesel Cars and LGVs



- HBEFA provides temperature correction functions for diesel cars
- Temperature correction derived from RS data for diesel cars and LGVs
- Dependence on ambient temperature not currently accounted for in Guidebook methodology
- Accounts for the increase in emissions at temperatures lower than those required under regulatory emissions tests.
- The effect is more significant in HBEFA than RS.

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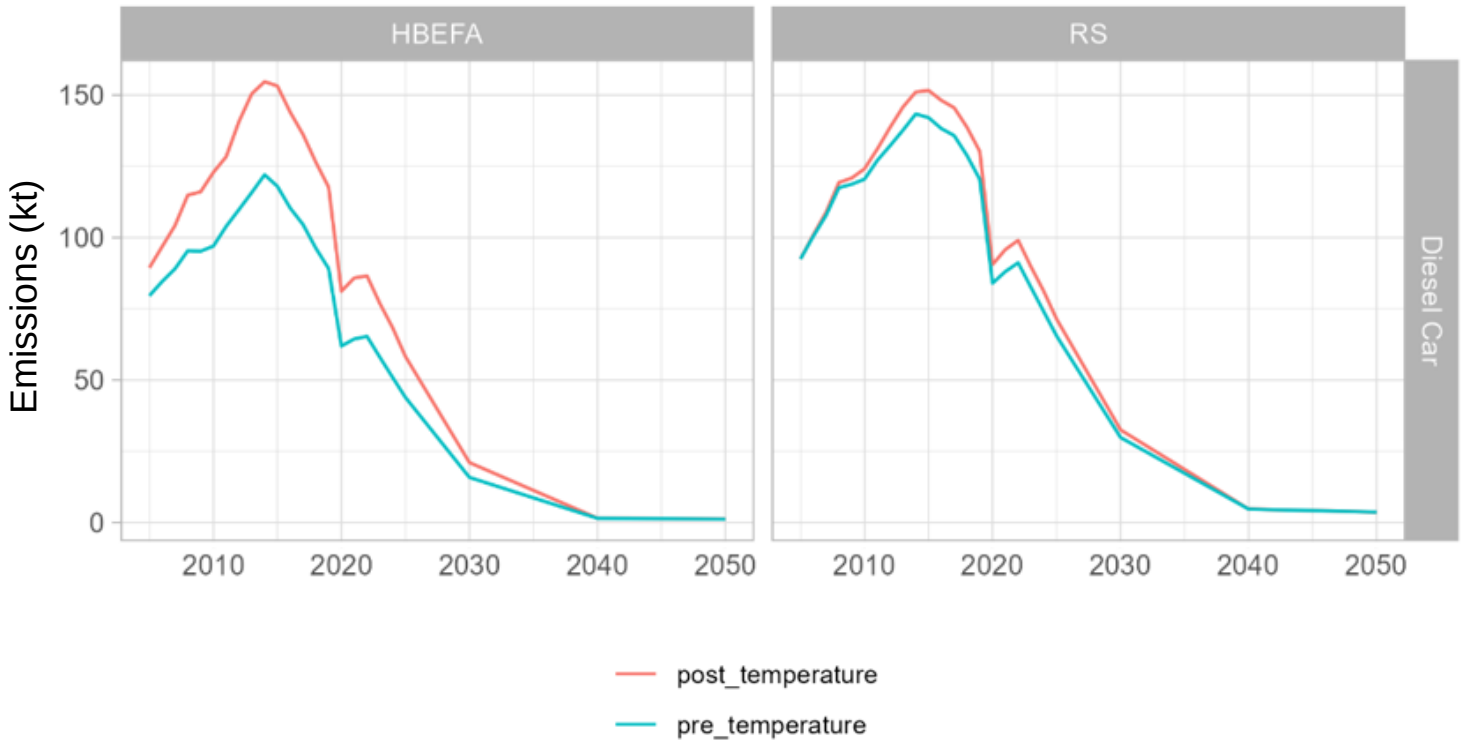

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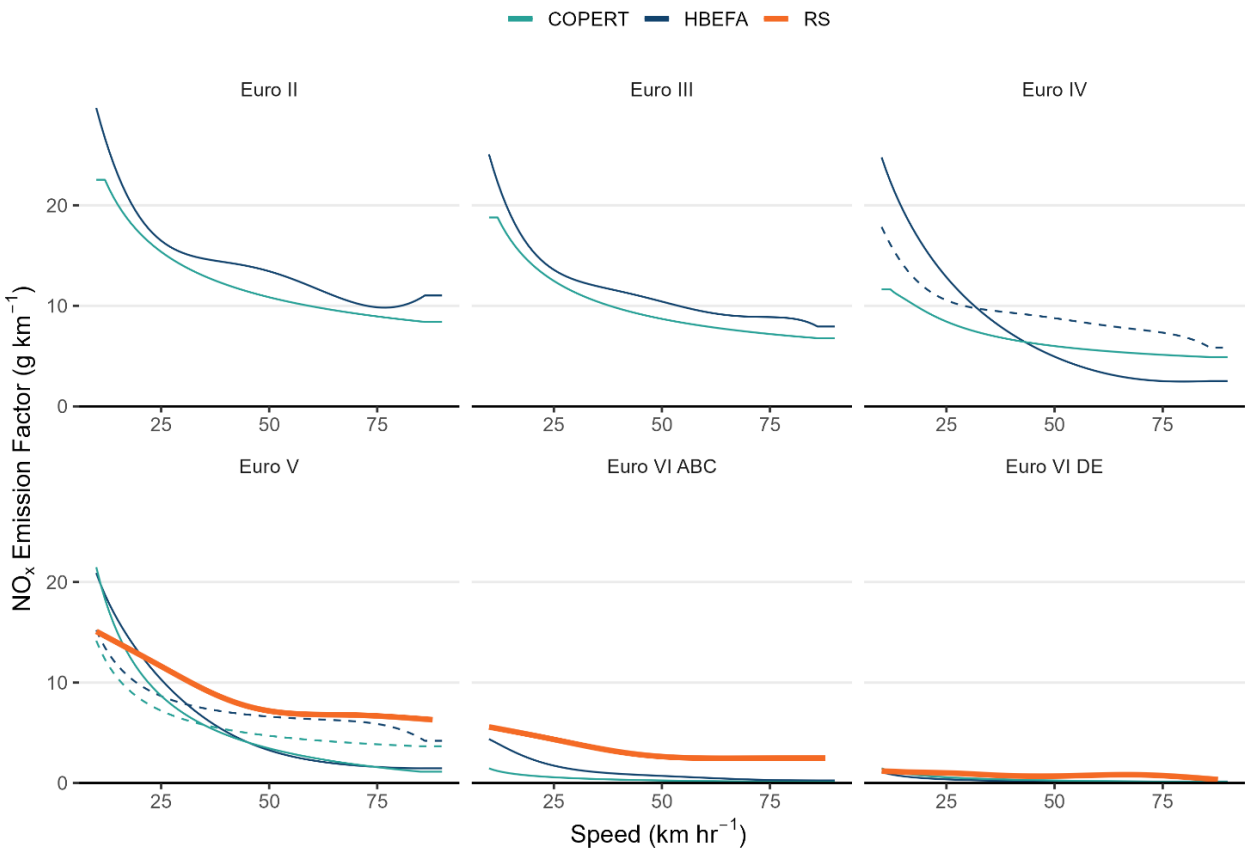
- The effect is more significant in HBEFA than RS.
- Increase in emissions from diesel cars most significant in 2010 – 2025
  - Up to 35 kt HBEFA
  - Up to 10 kt RS

NO_x Emissions from Heavy Duty Vehicles

Articulated HGVs (50% load, 0 gradient)

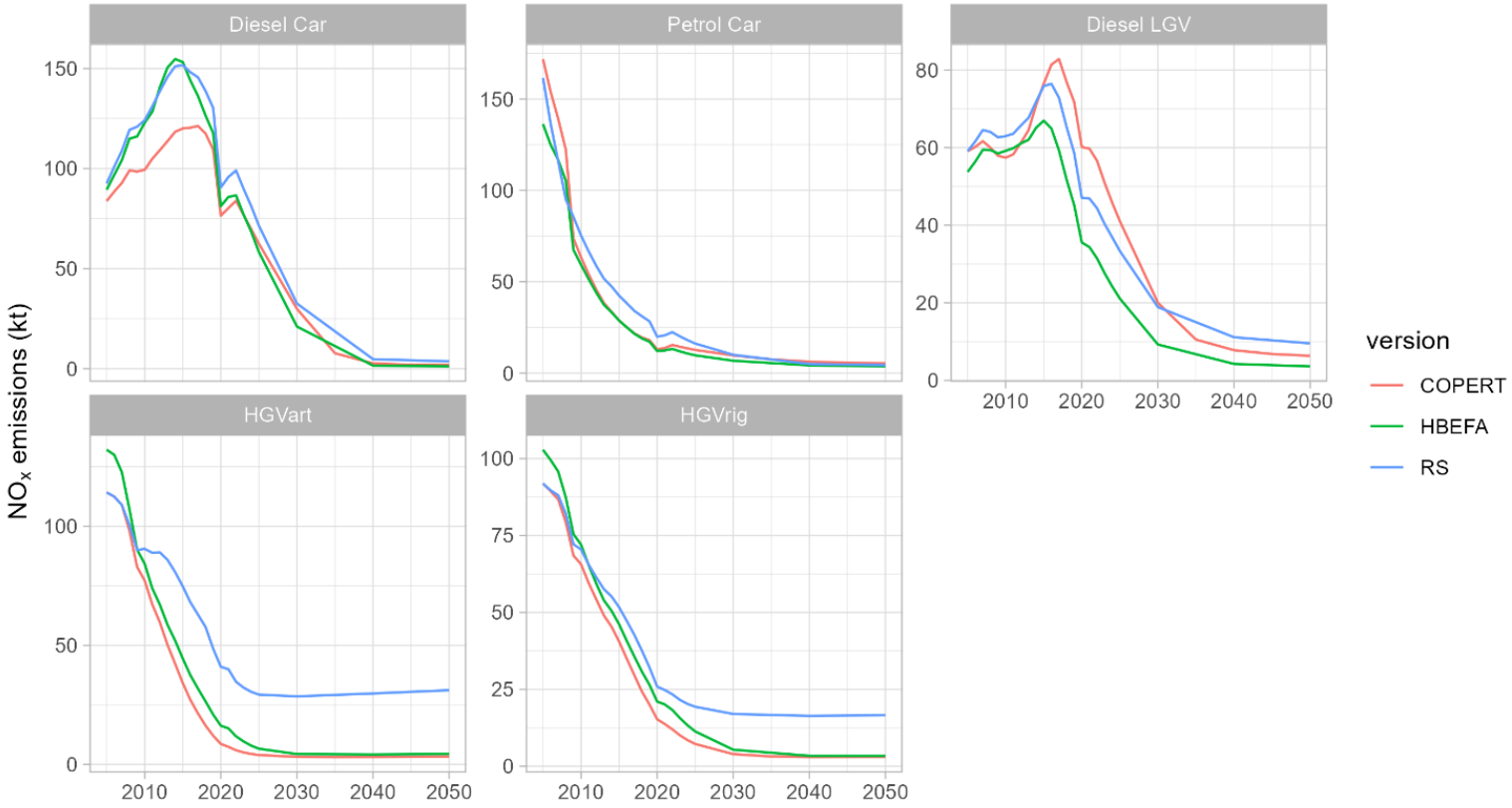


Euro IV & Euro V
Dashed – EGR; solid - SCR

- Evidence that NOx emissions decrease between pre-2019 Euro VI ABC and 2019+ Euro VI DE
  - HBEFA provides separate emission factors Euro VI ABC and Euro VI DE
  - RS confirms a decrease in emissions between Euro VI ABC and Euro VI DE
  - COPERT provides a single speed-emission curve for Euro VI HGVs, emission factors are ~mid-way between the HBEFA Euro VI ABC Euro VI DE factors
- RS data suggests that HGV emission factors may be underestimated in inventories, particularly Euro VI ABC
- HBEFA includes functions to account for the degradation of emissions with vehicle mileage for Euro V and VI heavy duty vehicles – but this does not fully account for the difference between inventory emission factors and RS
- Less certainty around RS emissions on motorways – more real-world evidence required?

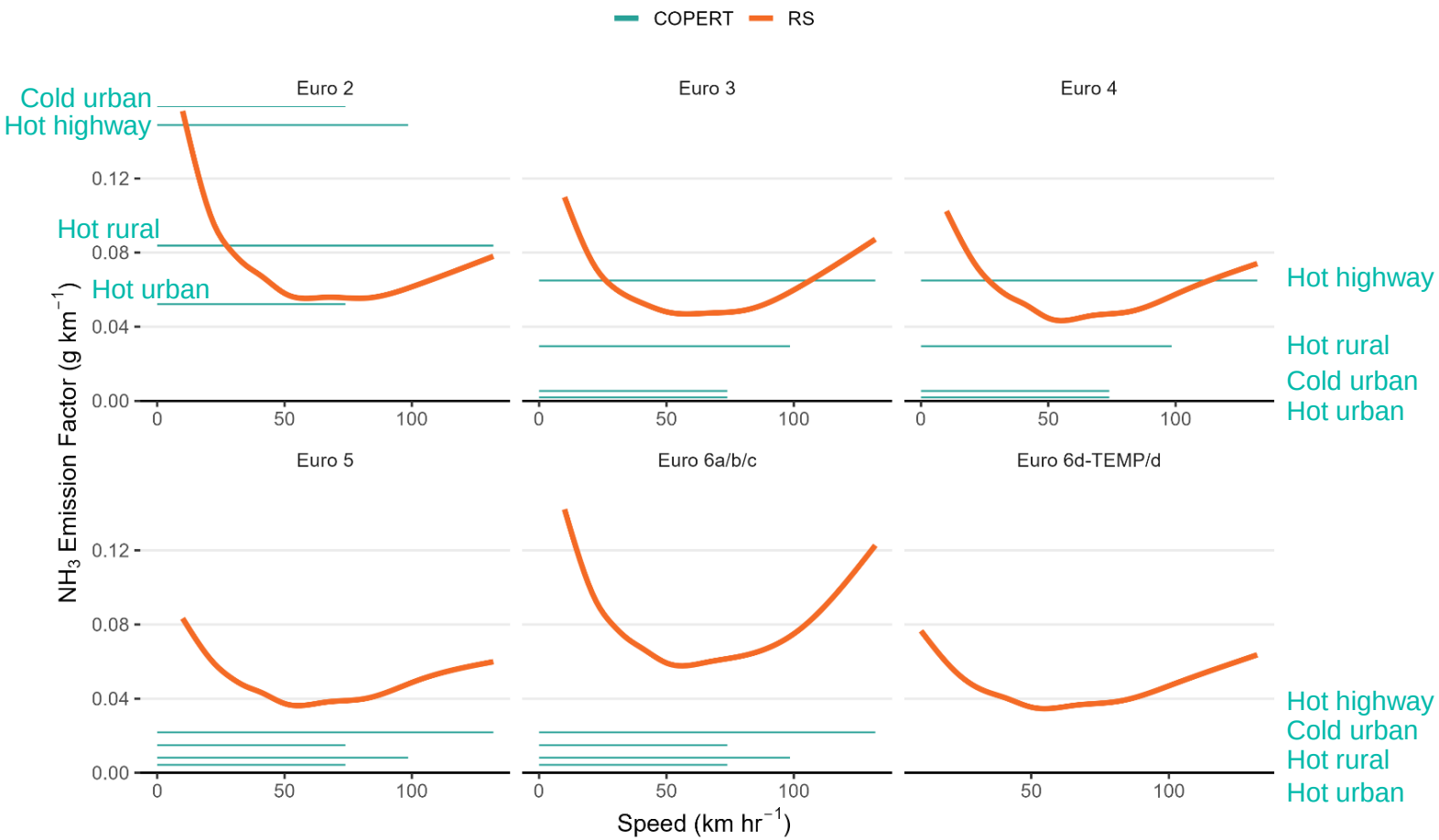
Overall Impact on NO_x Emission Trends

UK hot exhaust NO_x emissions 2005-2050 by vehicle type



- Combined impact of using different speed emission curves, degradation functions and temperature functions

Emissions of NH_3 from Petrol Cars



- Speed emission curves developed from RS data
- Guidebook provides fixed values for cold/hot urban, rural and highway driving
- RS data suggests there is little change in NH_3 speed emission curves progressing from Euro 2 through to Euro 6
- Greatest difference between Guidebook and RS emission factors are for Euro 3+ petrol cars under lower speed urban driving conditions
- The impact on NH_3 emissions from road transport is significant – more than doubles RT emissions of NH_3 from ~2020 onwards and the impact is most significant in urban areas.
- Total UK NH_3 emissions remain dominated by emissions from agriculture sector
- But increases in NH_3 emissions in urban areas could be significant in the context of understanding secondary $PM_{2.5}$ formation in urban areas, nitrogen deposition.

PM Emissions

- **Higher exhaust emission of PM in HBEFA**: PM exhaust emission factors are higher in HBEFA than COPERT for most vehicle classes and Euro standards. The origin of the differences is unclear.

- **Lower non-exhaust emission factors in HBEFA**: Non-exhaust emission factors for PM from brake and tyre wear and road abrasion are significantly lower in HBEFA than in COPERT.

- **Evidence of non-exhaust emission factors continues to develop**: NEE remain quite uncertain, but as PM exhaust emissions have declined NEE have increased in priority. New measurement studies should provide more evidence over the next couple of years.

Summary

- Two sources of alternative sources of road transport emission factors, HBEFA 4.2 and UK roadside remote sensing, were investigated and compared to the current UK road transport modelling methodology based on the Guidebook approach and emission factors (COPERT 5.6)

- HBEFA and RS showed evidence that **NO_x emissions from diesel cars and LGVs increase at lower ambient temperatures,** and this is not currently factored into the Guidebook approach

- HBEFA accounts for a **decrease in NO_x emissions from heavy duty vehicles between Euro VI ABC and Euro VI DE**, and RS provides support. However, RS data suggests **NO_x emissions from Euro VI ABC HDVs may be underestimated.**

- RS data suggests that **NH_3 emissions from petrol cars are underestimated**, particularly in urban areas

- There are differences between PM exhaust and non-exhaust emission factors in COPERT and HBEFA

- Evidence from RS data is strongest in urban areas where monitoring campaigns are undertaken and RS is perhaps best suited to provide adjustment to inventory emission factors, or UK specific (temperature and degradation) functions.

Next Steps Under Consideration

- Updates to the UK inventory methodology to incorporate UK specific data and new evidence:
  - Temperature correction function, UK specific degradation functions, update to NH_3 emission factors

- Should the UK move towards the HBEFA traffic situation-based methodology?
  - Can we allocate HBEFA traffic situations to UK roads? Daniel Mehlig and Helen ApSimon have already made good progress & ongoing engagement with Department for Transport.
  - Local case study – does the use of traffic situation-based emission factors that account for congestion levels improve the geographic allocation of NO_x emissions to UK towns and cities, and improve the agreement between modelled and measured concentrations of NO_2? Does the use of evidence from RS to adjust emission factors result in further improvements?
  - There is a need to understand the impact of any change in approach on existing UK policy tools and decisions

- We are interested in hearing the thoughts and experiences from the audience!
  - HBEFA users
  - real-world emissions evidence

Thank you for your attention!

Acknowledgements

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Daniel Mehlig and Helen ApSimon (Imperial College London)

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Degradation of NO_x from Cars and Vans

- COPERT and HBEFA provided functions to account for the increase in NO_x emissions as vehicle mileage increases, derived from separate analyses of European RS data
- UK RS data provides UK specific degradation functions
- Overall, degradation functions generally show similar trends with Euro standard & fuel type