Atmosphere and Local Environment

Trends in NO_X/NO_2 emissions and ambient measurements in the UK

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Presentation Overview

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- Research Project Background
- Analysis of ambient measurement data
- Analysis of remote sensing data
- Comparison of Emissions Factors
- Recalculation of Emissions Inventories
- Ongoing Work
- Summary

Research Project Background

- A Defra and Devolved Administrations funded consortium research project.
- To answer: why have recent concentrations of NO_X and NO_2 in the UK not decreased as anticipated?
- To consider: implications of evidence for emissions inventories, emissions factors and policy development to meet NO_2 Limit Values.
- **Steering Group:** Tim Barlow (TRL), Dr Paul Boulter (TRL), Finn Coyle (TfL), Professor Dick Derwent (RD Scientific), Iain Forbes (DfT), Dr Sarah Honour (Defra) and Chris Parkin (DfT).
- **Research Team:**
  - King's College, London: David Carslaw, Sean Beevers, Martin Williams, Emily Westmoreland.
  - AEA Technology: Tim Murrells, Yvonne Li, John Stedman, Susannah Grice, Andrew Kent, Ioannis Tsagatakis
  - Leeds University: James Tate
- Project completed May 2011.

Trends in NO_X concentrations

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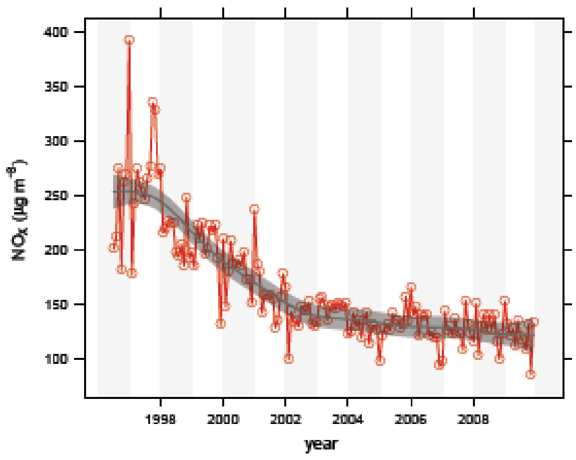
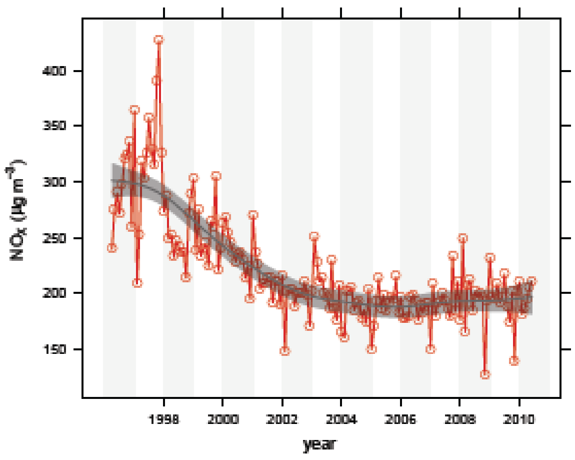
- Two characteristics in NO_X trends:
  - a decrease in concentration from 1996 to 2002–2004.
  - a period of more stable concentrations from 2002/2004–2009, best described as being weakly downward.

12 UK sites



10 Inner London sites



NO_X Trends by Site Type

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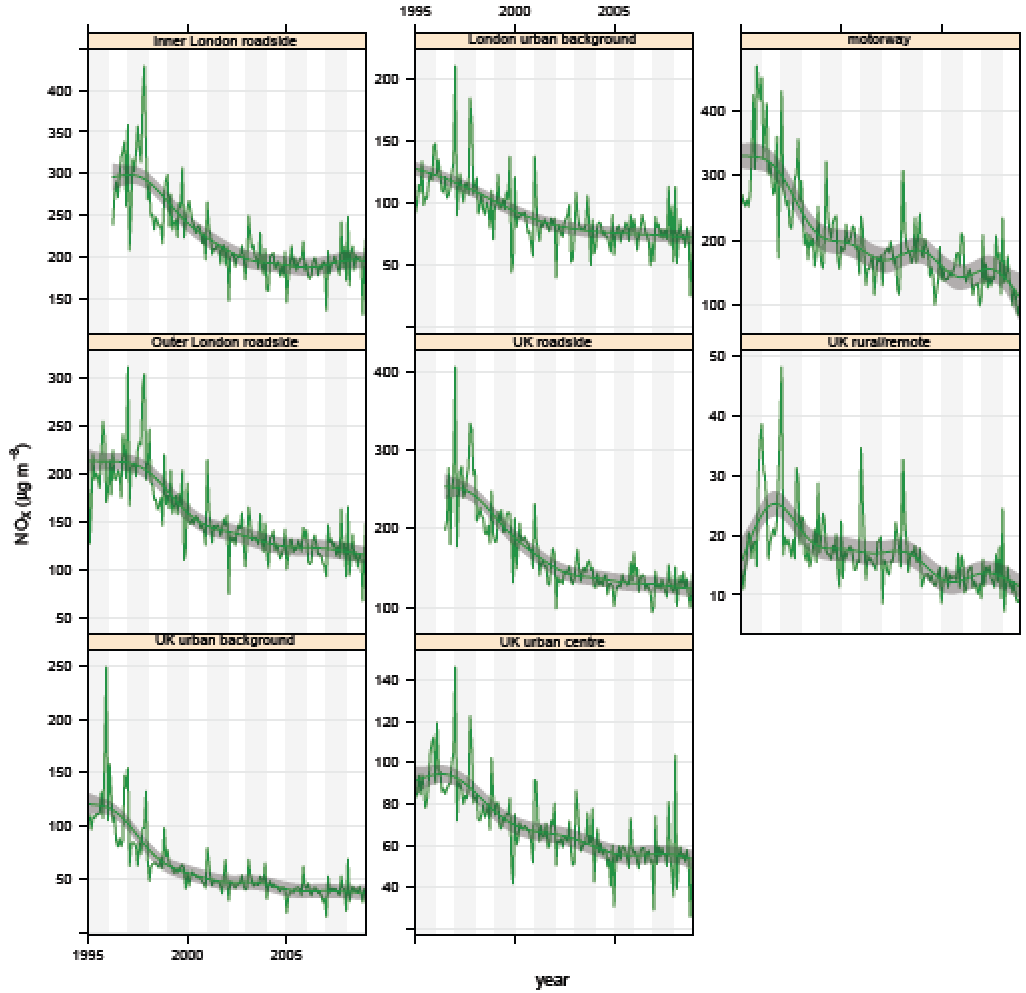
- Weakly downward trend observed for all sites types and the two locations considered.
- Monthly data from each location type averaged and de-seasonalised.
- 95% confidence intervals in the fit calculated as shown by the shading.



Inter-site Variation

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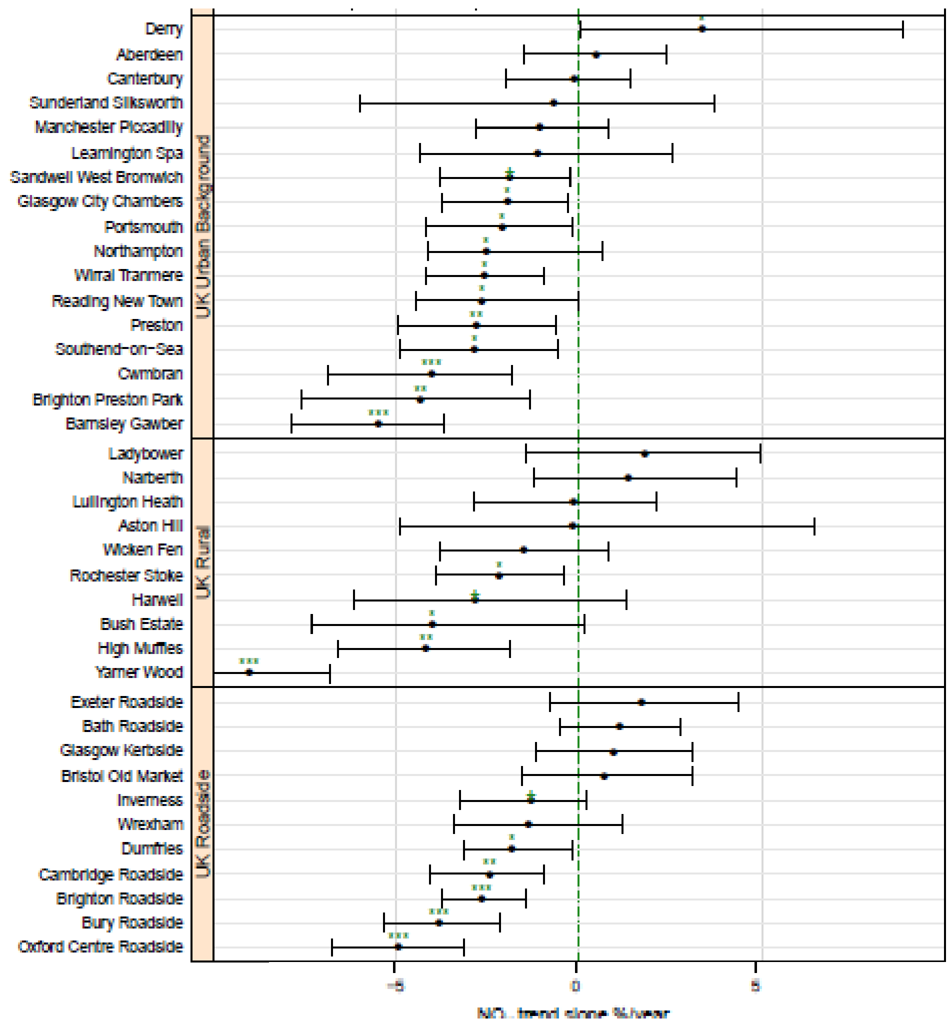
- Important to consider inter-site variation in NO_X trends for 2004 to 2009.
- A mix of sites showing upward and downward trends.
- Overall effect is that there is little evidence of a consistent downward trend in NO_X concentrations.



NO_X/NO_2 Trend Summary 2004-09

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NO_X: annual percentage reduction in concentrations of - 1–2%.

- Typical site values (median) shown below.
- Urban Centre and Inner London weaker trend and motorways stronger.
- Trends in emissions over same period are- 5 to 6% from UK Emission Factors (EFs).

NO_2: Corresponding trends of decreases in the range - 0.5 to 1% per year although rural sites have shown a greater decrease 1.4% per year.

- Weaker trends than for NO_X, primary NO_2 is important here.

Measurement trends by site type 2004–2009 (% per year)

Location	trend (2004–2009)
Inner London	−0.6
Motorway	−3.4
Outer London	−1.7
UK roadside	−1.4
UK rural	−1.9
UK urban background	−2.1
UK urban centre	−0.8

Location	trend (2004–2009)
Inner London	−0.5
Motorway	−0.8
Outer London	−0.8
UK roadside	−0.6
UK rural	−1.4
UK urban background	−0.8
UK urban centre	−0.4

Trends in primary NO_2 (f-NO_2)

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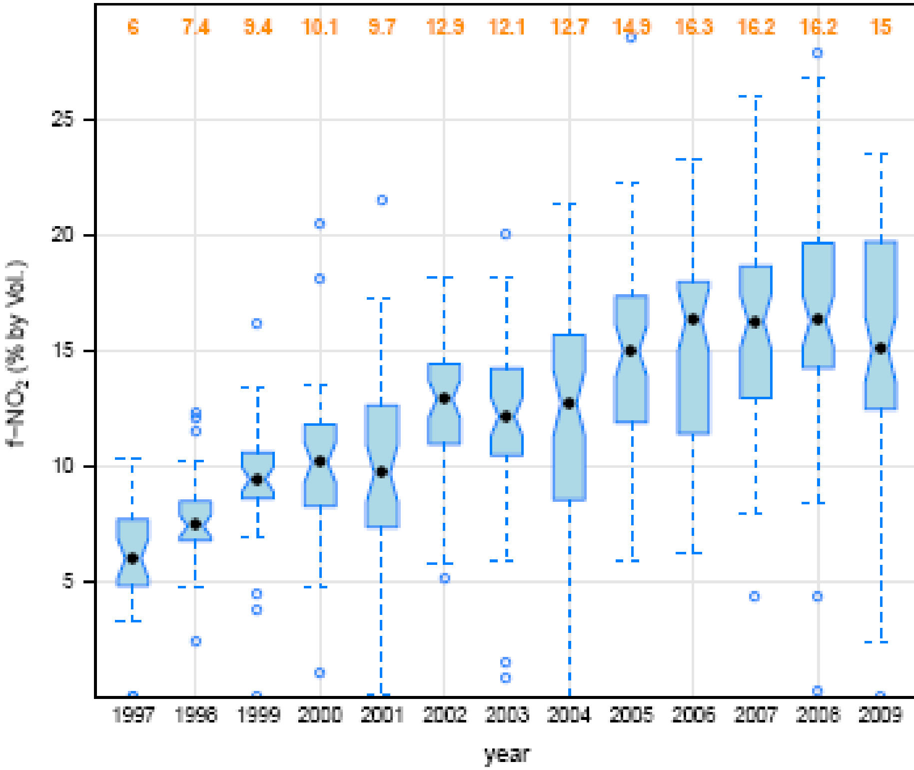
- Key to understand trends and implications for EFs.
- Strong increase in the UK and in particular London.
- UK f-NO_2 has increased from 5–7% in 96 to 15–16% in 09.
- London from 5% in 1998 to about 21% in 2009.
- Principal causes: increased use of oxidation catalysts and particle filters. (AQEG, 2008).
- Evidence suggests levelling off post 2008.



- Monthly estimates of f-NO_2 at roadside AURN sites.

Methodology: Carslaw and Beevers 2005.

Monitored NO_2 – European Picture

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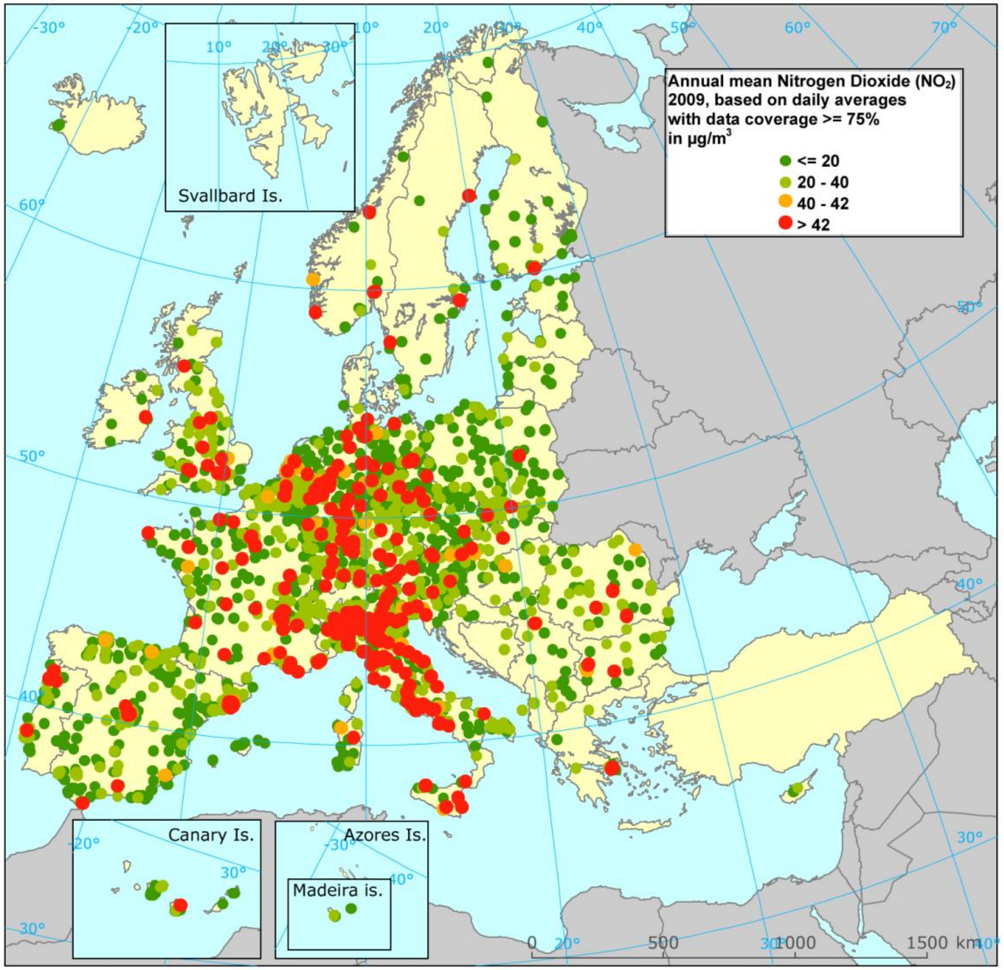
- Monitored annual mean NO_2 Concentrations in 2009.
- Vast majority of member states have exceedences of limit value.



NO_2 Concentrations across Europe

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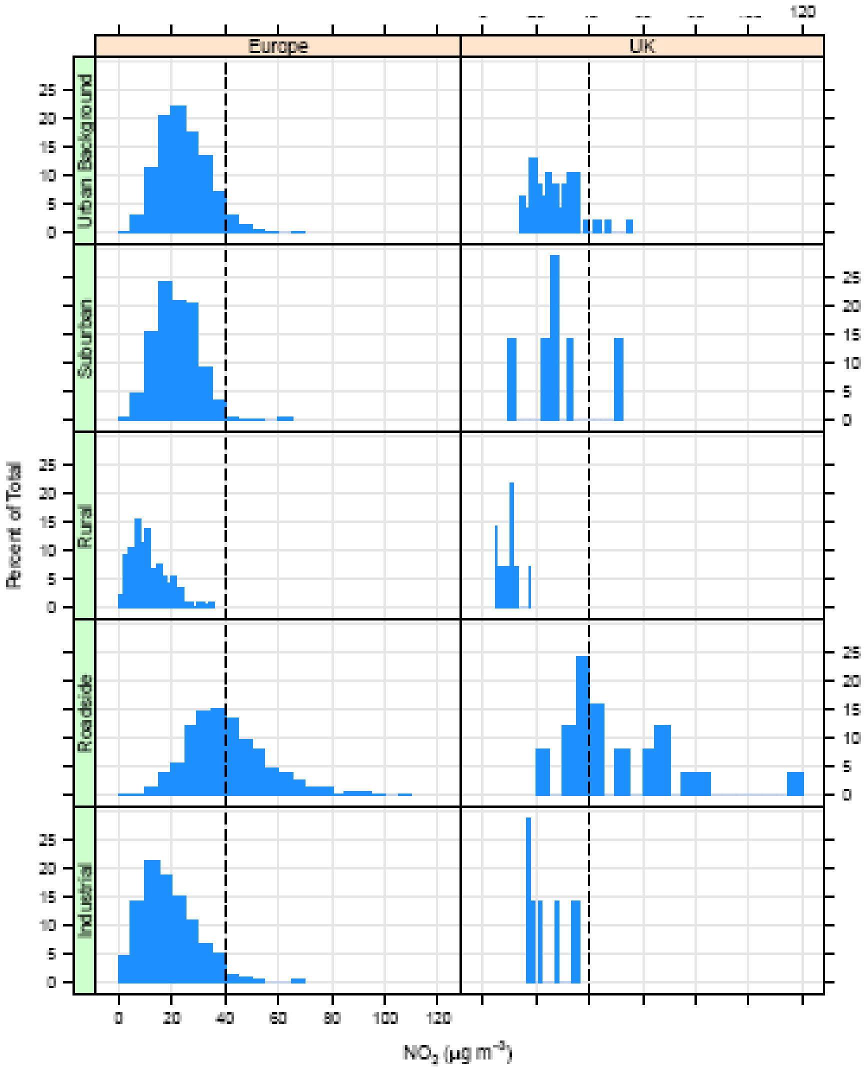
- Data analysed from 2700 stations using EEA's Airbase for 2008.
- 18.9% of all sites across Europe exceeded annual mean NO_2 Limit Value.
- 18% of UK sites exceeded Limit Value – very similar figure.

NO₂ concentrations in 2008 split by site type



Trends Across Europe

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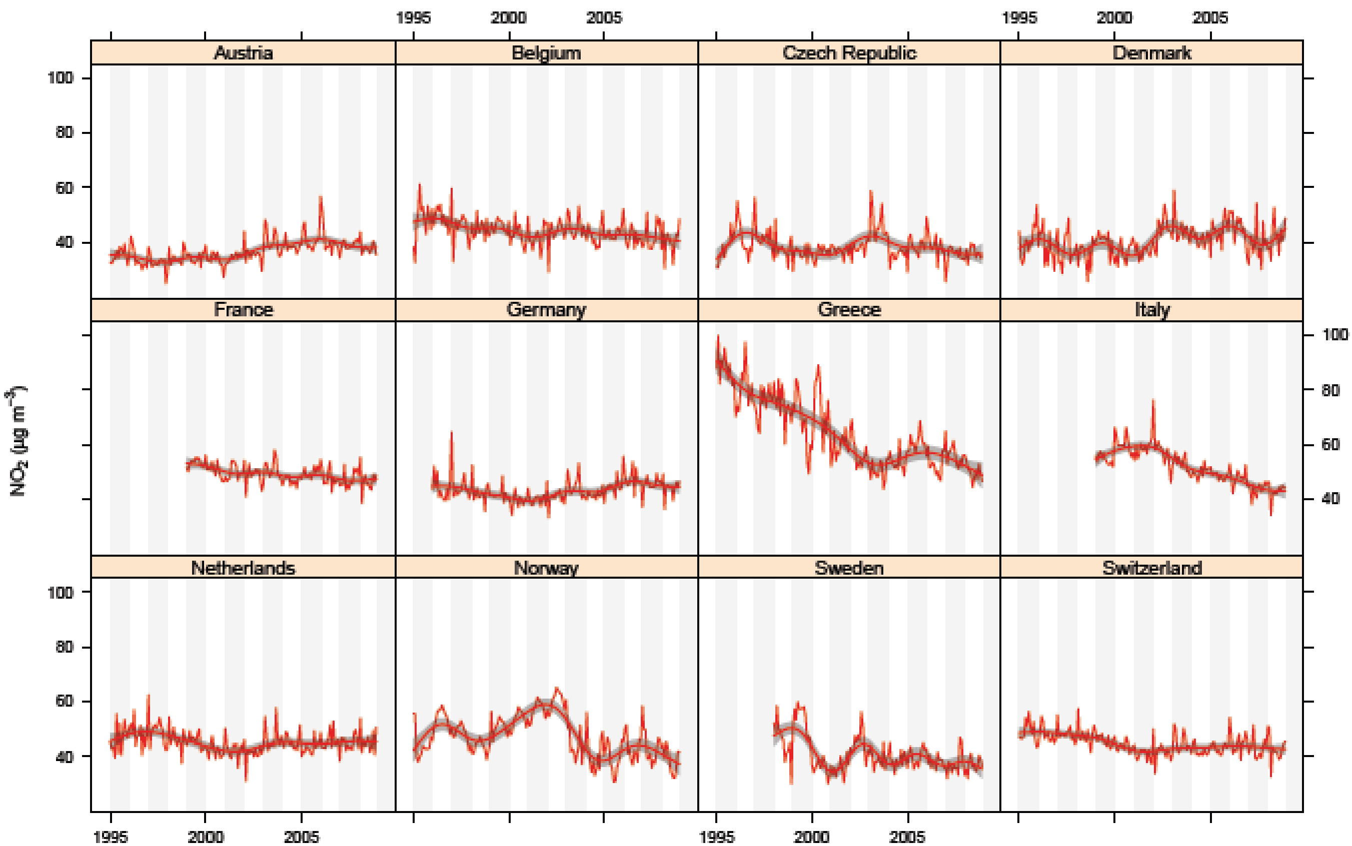

Monthly de-seasonalised trends in NO_2 concs at roadside sites for selected European Countries.

- In recent years, all countries show a levelling off of NO_2 concentrations despite some differences in initial trends.

Euro Standards and Emissions

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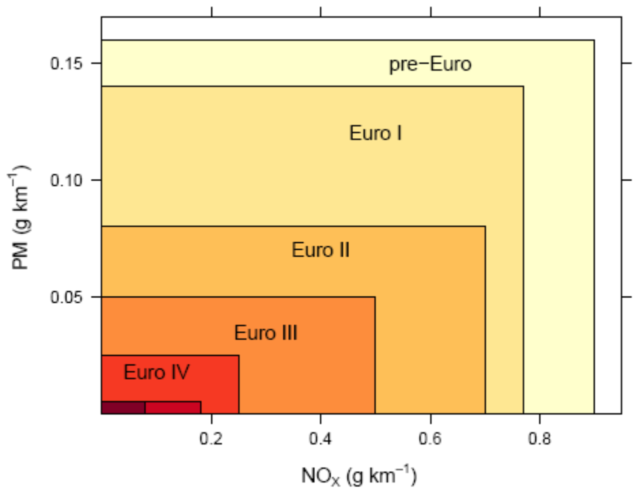
- UK emissions projections are downward in line with the Euro Standards.
- Monitored NO_X and NO_2 trends – weakly downward in recent years.
- Why is there a mismatch?
- What's wrong with the emissions projections and EFs?
- Data from real world driving conditions provides new and important information on vehicle emissions.

For diesel car NO_X and PM_{10} from pre Euro to Euro VI



Plot indicates approximate reduction in NO_X and PM_{10} vehicle emissions expected due to tightening vehicle emissions legislation

Remote Sensing Data (RSD)

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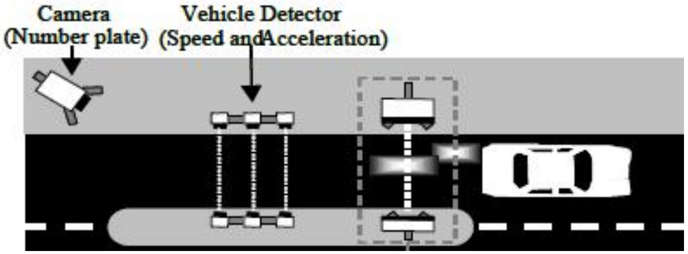
- IR/UV beam to measure individual exhausts.
- Measure ratio of NO, CO, HC to CO_2.
- Sampled 72,000 vehicles under real world driving conditions.
- Vehicles identified by ANPR/ CarWeb.
- EFs calculated for NO_X and classified by Euro Standard based on vehicle age.
- Limitations: representative of urban areas, units are ratios of pollutants, engines under load, no large HGVs.



Thanks to James Tate (Leeds Uni.). and Enviro Technology for data provision.

Remote Sensing: Cars and LGVs

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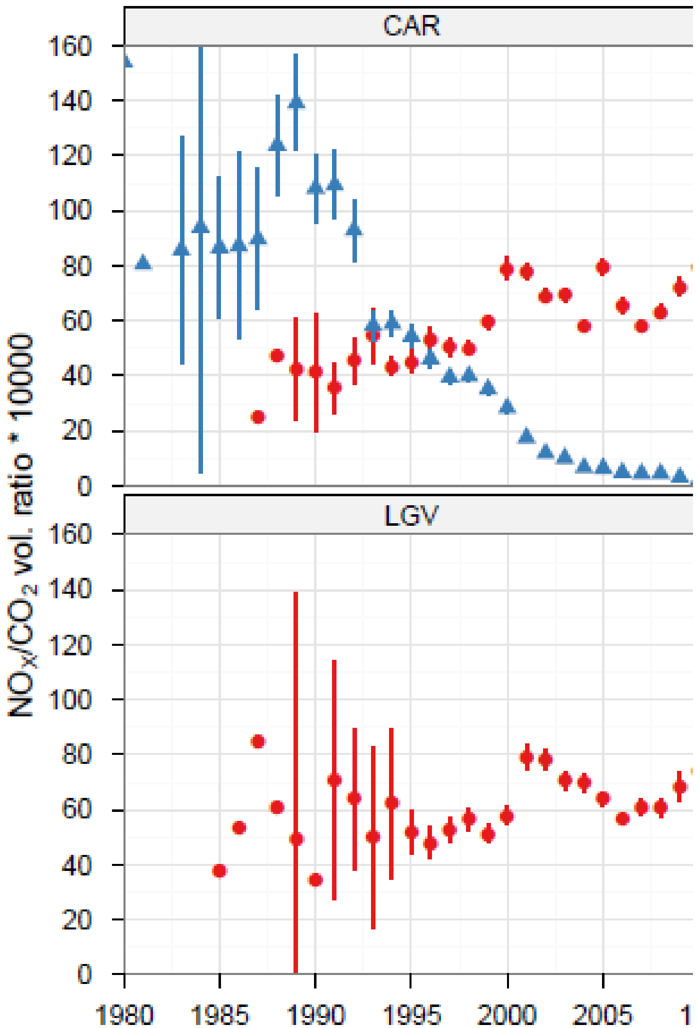
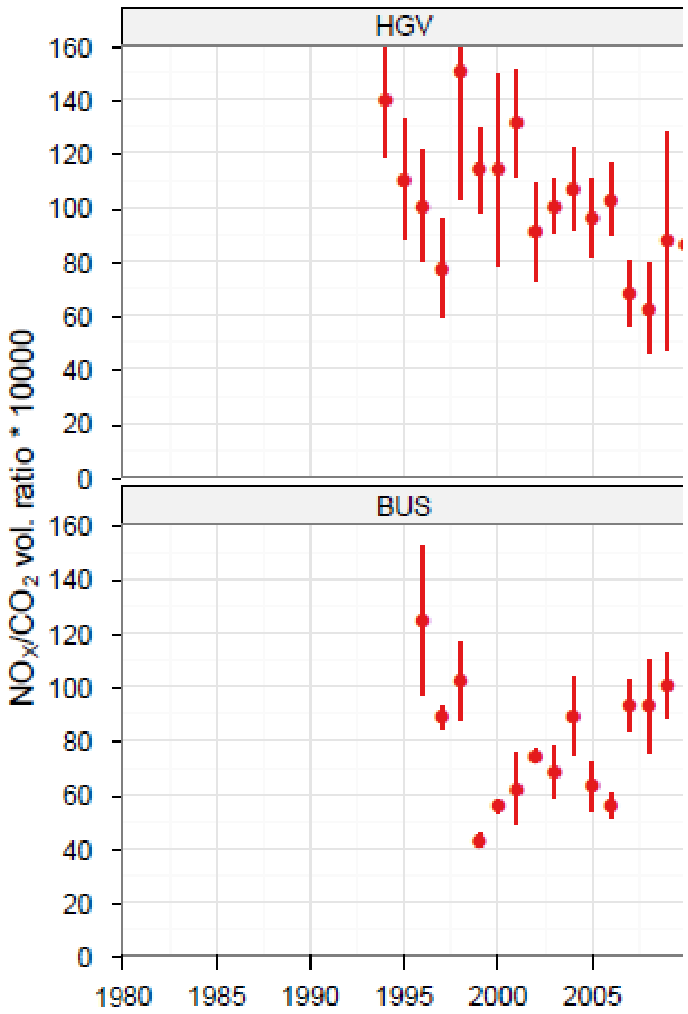
- The effect of introducing various Euro standards is very apparent for petrol vehicles (blue) and a steep reduction in emissions in seen.
- In contrast, NO_X emissions from diesel cars have changed little over a period of about 15-20 years.
- The trend for LGVs is similar to diesel cars.



Remote Sensing: HGVs and Buses

- The HGV trend is relatively flat but there is evidence of a decrease in emissions from 2006–2007.
- The timing of this decrease is consistent with emissions legislation for Euro IV.
- The trend for buses is again different to other vehicles types.
- Remote Sensing (RSD) bus emissions data affected by local factors from the specific fleets used in urban areas. Not considered further here.



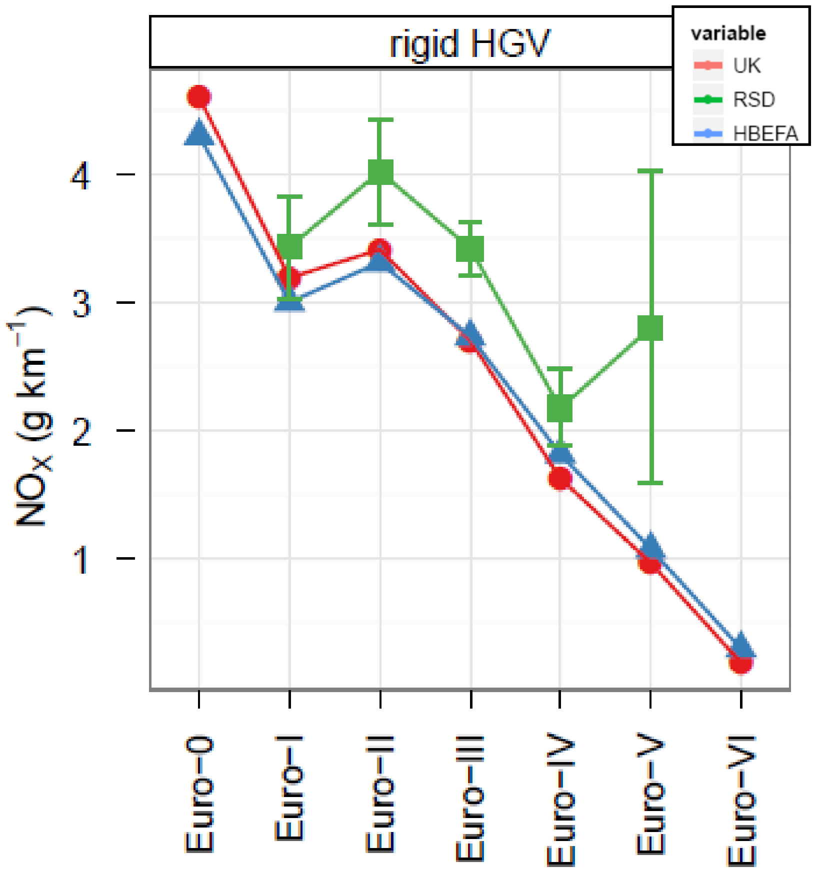
Comparison of RSD with Emission Factors

- Remote Sensing Data (RSD) compared with Swiss- German Handbook (HBEFA*) and current UK Emission Factors (UKEFs).
- HBEFA represents an alternative approach to UK emissions inventories (NAEI/LAEI) and is based on traffic situations rather than speed related EFs.
- The RSD used to provide a clear indication of where there may be issues with the currently used UK EFs.

- *HBEFA, 2010. Handbook emission factors for road transport. http://www.hbefa.net/e/index.html

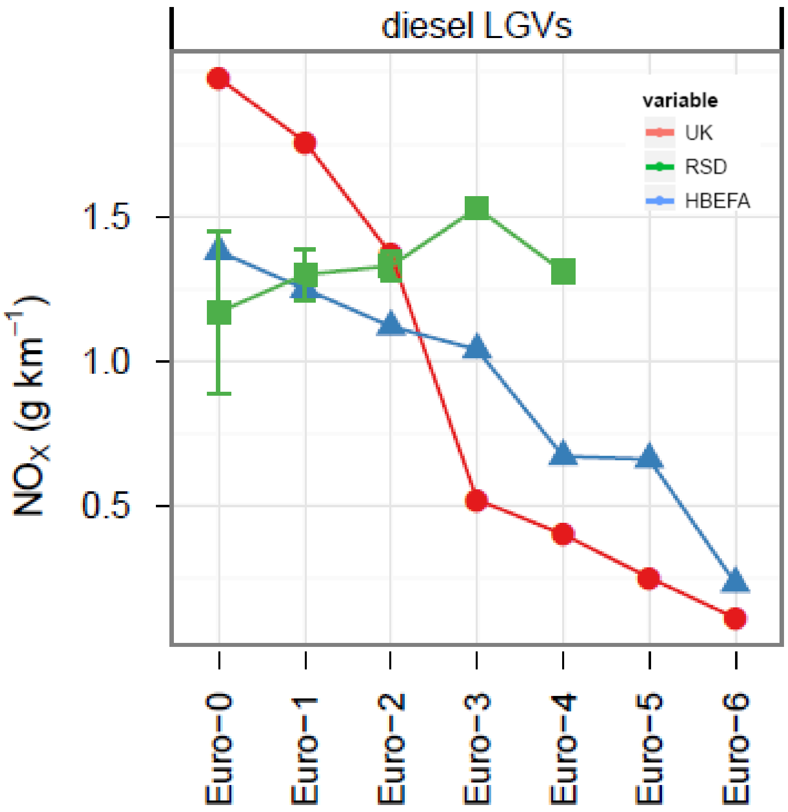
Comparison of Emissions – Rigid HGVS

- Good agreement across all three sources.
- HBEFA and UK have the same input data (ARTEMIS)
- RSD supports the data in both trends and magnitude.
- NO_X emissions static until Euro III.
- To also consider: an important issue to emerge recently is that selective catalytic reduction (SCR) on HGVs is currently ineffective under urban-type (slow speed, low engine temperature) conditions.



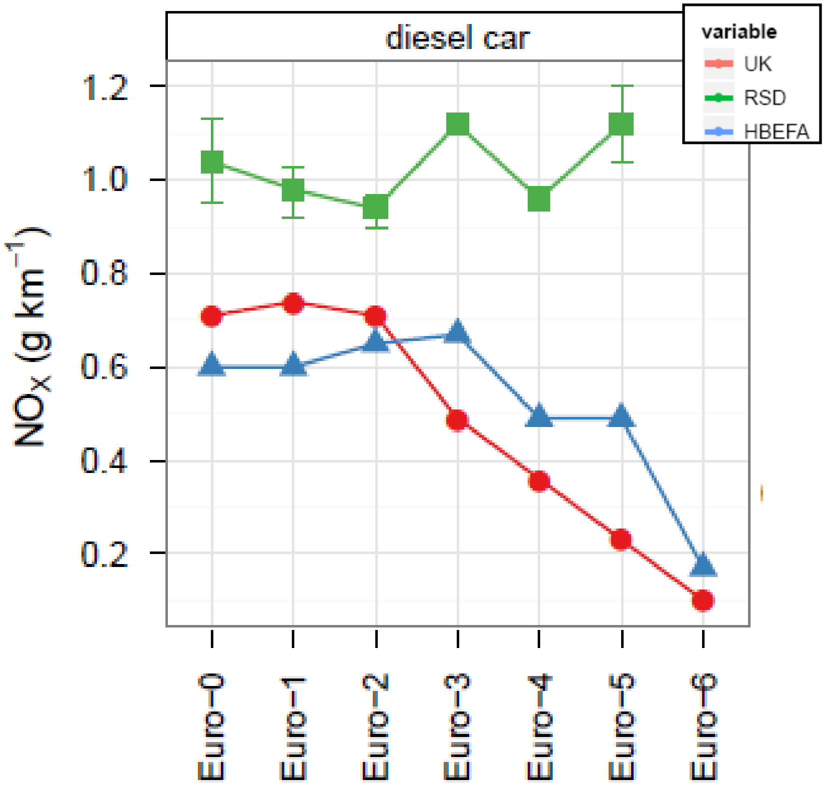
Comparison of Emissions – Diesel LGVS

- Significant disagreement between all the datasets.
- RSD suggests that there has been little change in total NO_X emissions over the past 15 years.
- UK EFs suggest that NOx emissions should have fallen by approx 80% from pre-Euro to Euro 4.
- HBEFA suggests emissions should have fallen by 40% , half that suggested by the UK EFs and in disagreement with the RSD.



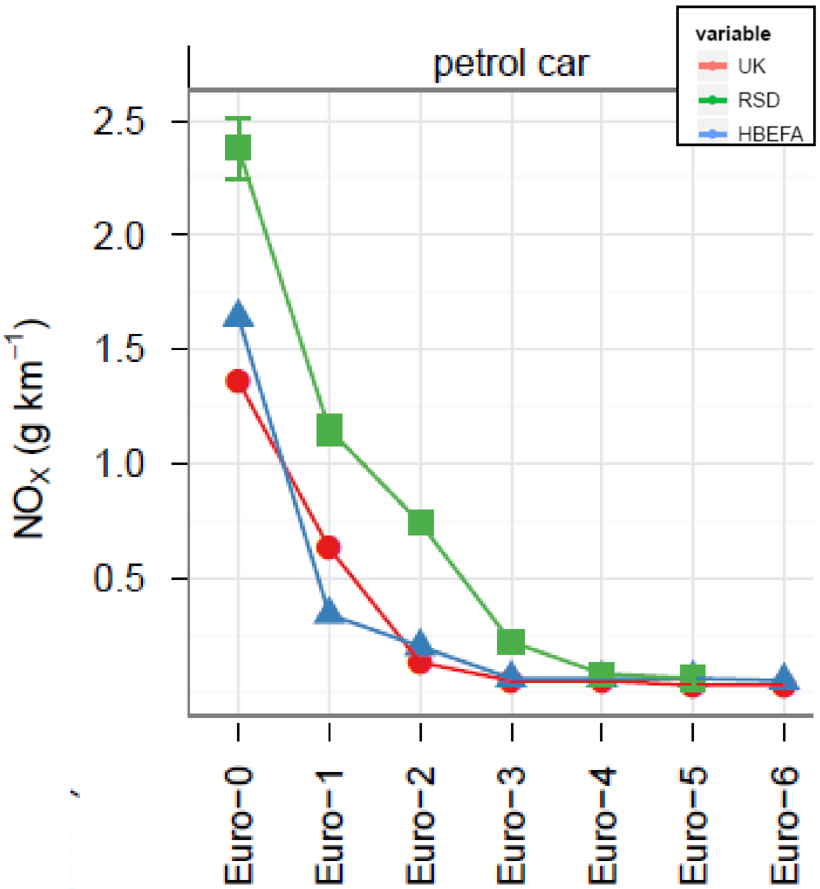
Comparison of Emissions - Diesel Cars

- Disagreement between all data sources, particularly RSD and the other two.
- The pattern of emission changes is most similar for HBEFA and the RSD with UK EFs showing linear decrease after Euro II.
- RSD shows little change in emissions over 15 years.
- If RSD assumed to be correct, the net effect would mean diesel cars are more important for NO_X emissions than previously thought.



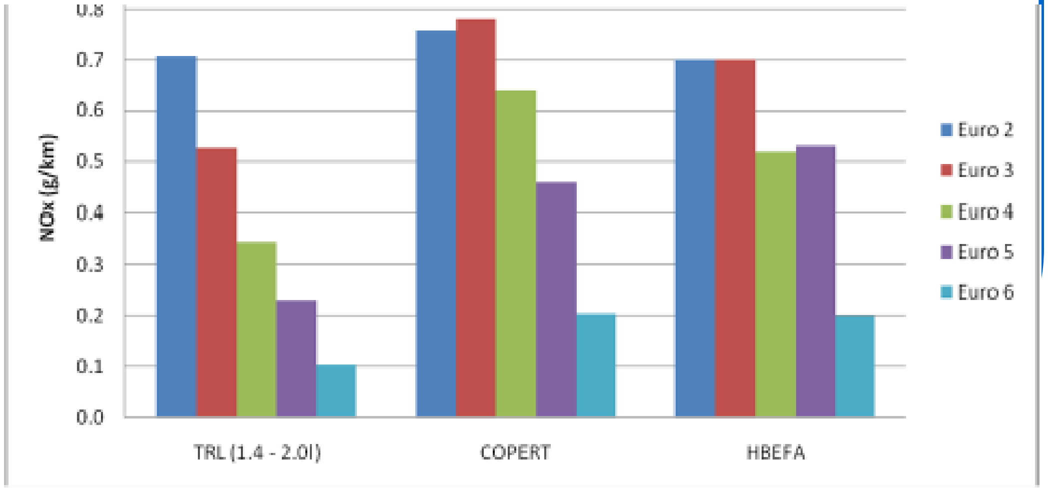
Comparison of Emissions - Petrol Cars

- A very large reduction in NO_X (>95%) from pre-Euro vehicles to Euro 4/5 in all cases.
- Key difference is between the RSD and the UK/HBEFA emissions for pre-Euro 4 vehicles.
- RSD suggests petrol car emissions of NO_X are much higher for Euro 2/3 vehicles compared with the other data.
- Reason – likely to be emission system degradation for Euro 2/3 catalyst-equipped vehicles.



Comparison of UKEFs with COPERT 4

- Comparison of UKEFs (TRL 2009) COPERT 4 (EEA funded EF compilation) and HBEFA. UKEF and COPERT4 used with other assumptions within inventories.
- EFs for diesel cars and LGVs in COPERT 4 and HBEFA are markedly higher compared with those in the UKEF for Euro 3 vehicles onwards.
- Possible reason: -treatment of effects of emission degradation on diesel cars - UKEFs assume a negative emission degradation for Euro 3 diesel cars and LGVs whereas COPERT 4 assumes no degradation.



Recalculation of Emissions Factors

- The UKEFs were scaled based on data implied from RSD and fed into the inventory. (Note: this exercise is not the same as re-developing the emissions inventories and EFs. Far more complex than this and this would not be fit for purpose.)
- COPERT 4 and the RSD EFs slow down the rate of decrease in emissions of NO_X compared with the NAEI trend **but still not enough to bring consistency with the roadside measurements**.
- Data for on-road vehicle stock: the RSD indicates a much lower proportion of Euro 4/5 petrol vehicles than the inventories assume. Important because the downward trend in NO_X is strongly influenced by Euro 4/5 petrol vehicles.
- **Conclusion: likely that issues exist not only with the emission factors used in inventories but also their underlying assumptions and other data used to compile emission inventories.**

Improving the NAEI and EFs…

- Where possible, take into account and then correct inventory in terms of the EFs and the input assumptions and underlying data.
- RSD is a snapshot in time with severe limitations. Not suitable for use in the UK Emissions Inventory.
- HBEFA – structured in a very different way to NAEI, based on traffic situations. Unmodified HBEFA data of limited use as would require a complete structural change from bottom up to the UK's emissions inventories.
- To improve emission inventory calculation methodology with confidence more info needed on: extent of SCR use in HGV fleet; changing emissions performance of petrol vehicles over time and the vehicle stock age profile and distance travelled.

Work Ongoing….

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- Better understanding of issues with the inventory, particularly NO_2 emissions from diesel vehicles. Looking into how best to address these but no decisions made yet.
- The inventories have many purposes. Need to coordinate with wide range of activities such as fulfilling international reporting requirements, inputting into ambient AQ assessments and providing tools for LAQM.
- Looking to update the inventory as soon as robust alternative methodology available with work to provide EFs and background maps to follow after.
- Published advice note/FAQ for LAQM setting out the issues. Will update as useful new information is available.
- Research project report to be updated having now received technical comments. Will be published as a final version in August.

Summary

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- Older petrol vehicles (Euro 1-3) emit higher emissions than previously thought due to emissions system degradation.
- RSD data suggest that diesel cars and LGV emissions of NO_X have decreased little in the past 15–20 years. The Euro Standards have failed to deliver the expected improvements for these vehicles.
- SCR thought to be ineffective for HGVs in urban conditions due to low operating temperatures. Extent of this within the UK fleet is uncertain.
- Issues with diesel vehicle degradation factors and vehicle stock assumptions in emissions inventories are also significant findings.
- Findings to date and RSD still do not address the mismatch between emissions and concentrations. Further investigation is needed.
- Work underway to address as many findings as possible, but need to ensure NAEI is still fit purpose.

Research report available at: http://uk-air.defra.gov.uk/reports/cat05/1103041401_110303_Draft_NOx_NO2_trends_report.pdf

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