Trends in NO_x and NO_2 Emissions and Ambient Measurements in the UK

AEA

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SCOTTISH AIR QUALITY DATABASE AND WEBSITE ANNUAL SEMINAR
Stirling
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Outline: A Consortium-Research Study

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- Trends in ambient NO_x concentrations and road traffic emissions
- Review of existing road transport emission factors
- Remote sensing of traffic emissions – what does this tell us?
- Emissions modelling with illustrative emission factor scenarios
- Conclusions

Recent Trends in Roadside NO_x Concentrations

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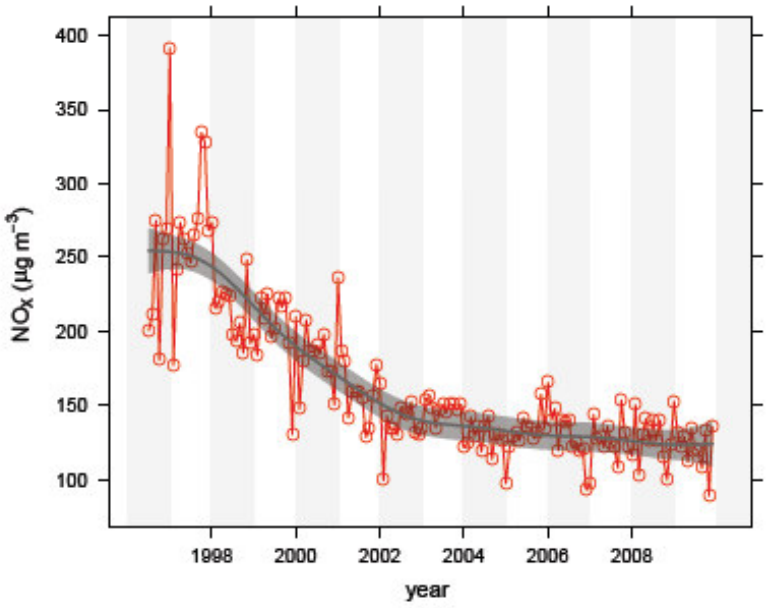
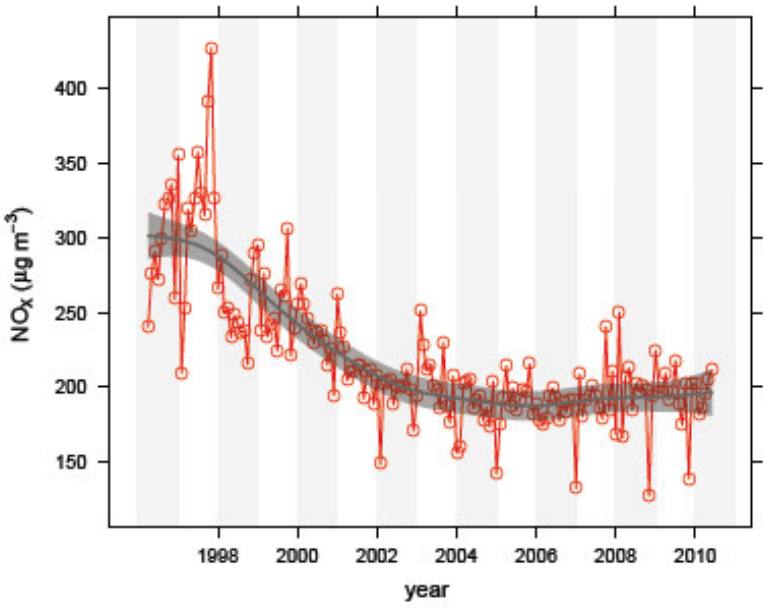
12 UK sites



10 Inner London sites



- Concentrations have been flat or weakly downward over the past 6-8 years

Recent Trends in Roadside NO_x Concentrations

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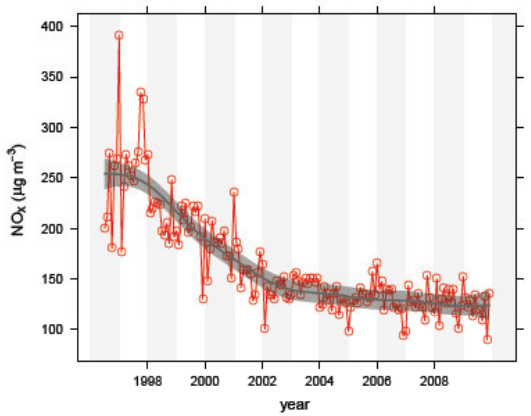

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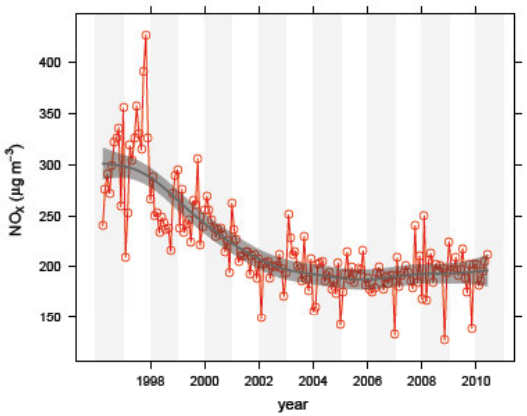
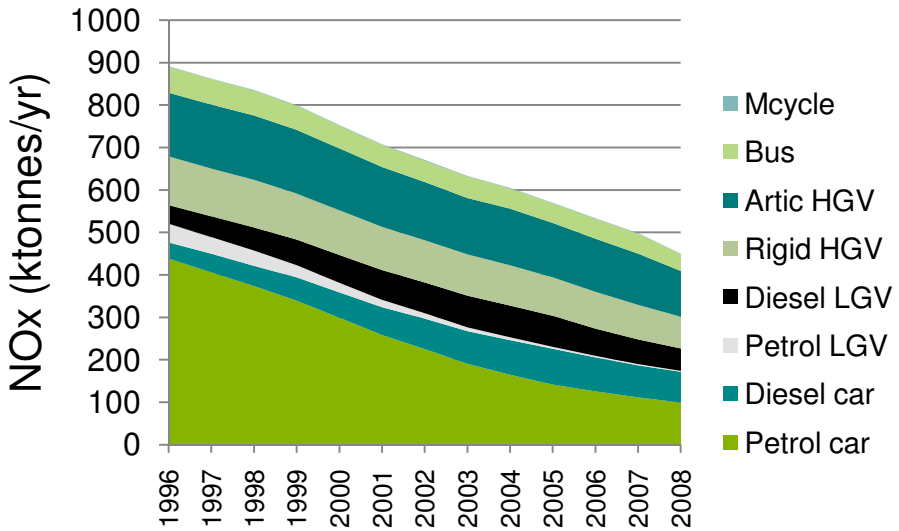


Trend in conc.:
-0.5% to -2%/year



Trends implied by UK inventory are not consistent with observations

Trend in emissions:
-6%/year

Trends in NO_x Concentrations: 2004 - 2009

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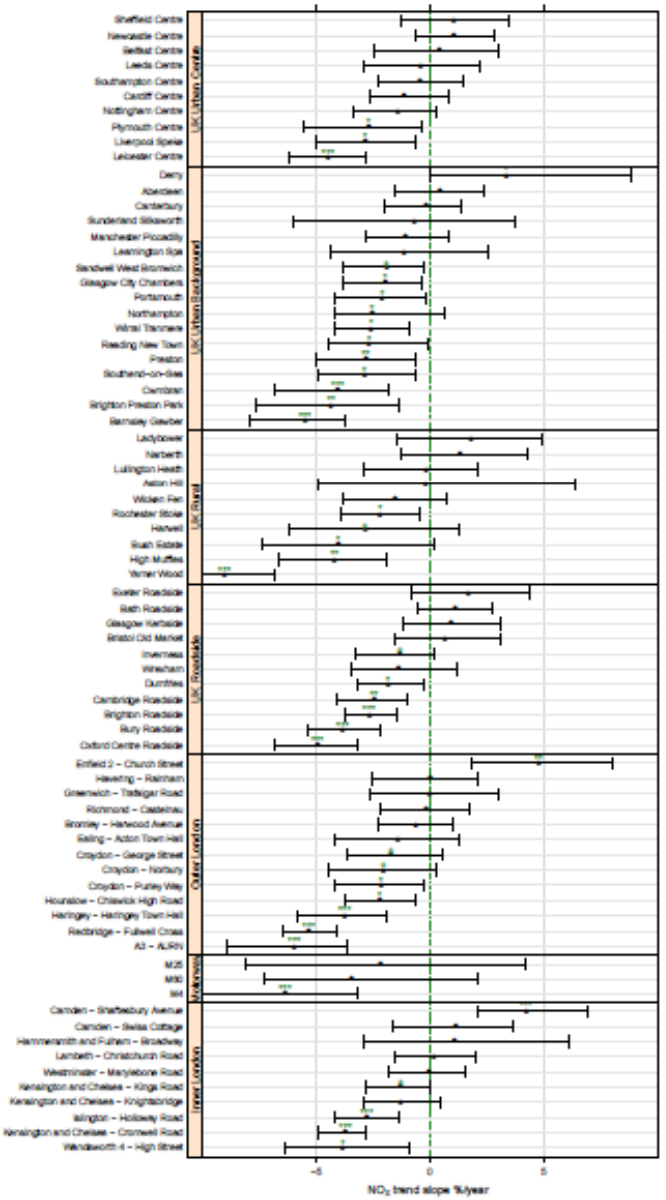
	%/yr
Dumfries roadside	-1.8%
Inverness roadside	-1.3%
Glasgow kerbside	+1.0%
Glasgow urban background	-2.0%
Aberdeen urban background	+0.4%



NO_x Trends at Roadside Sites in European Cities

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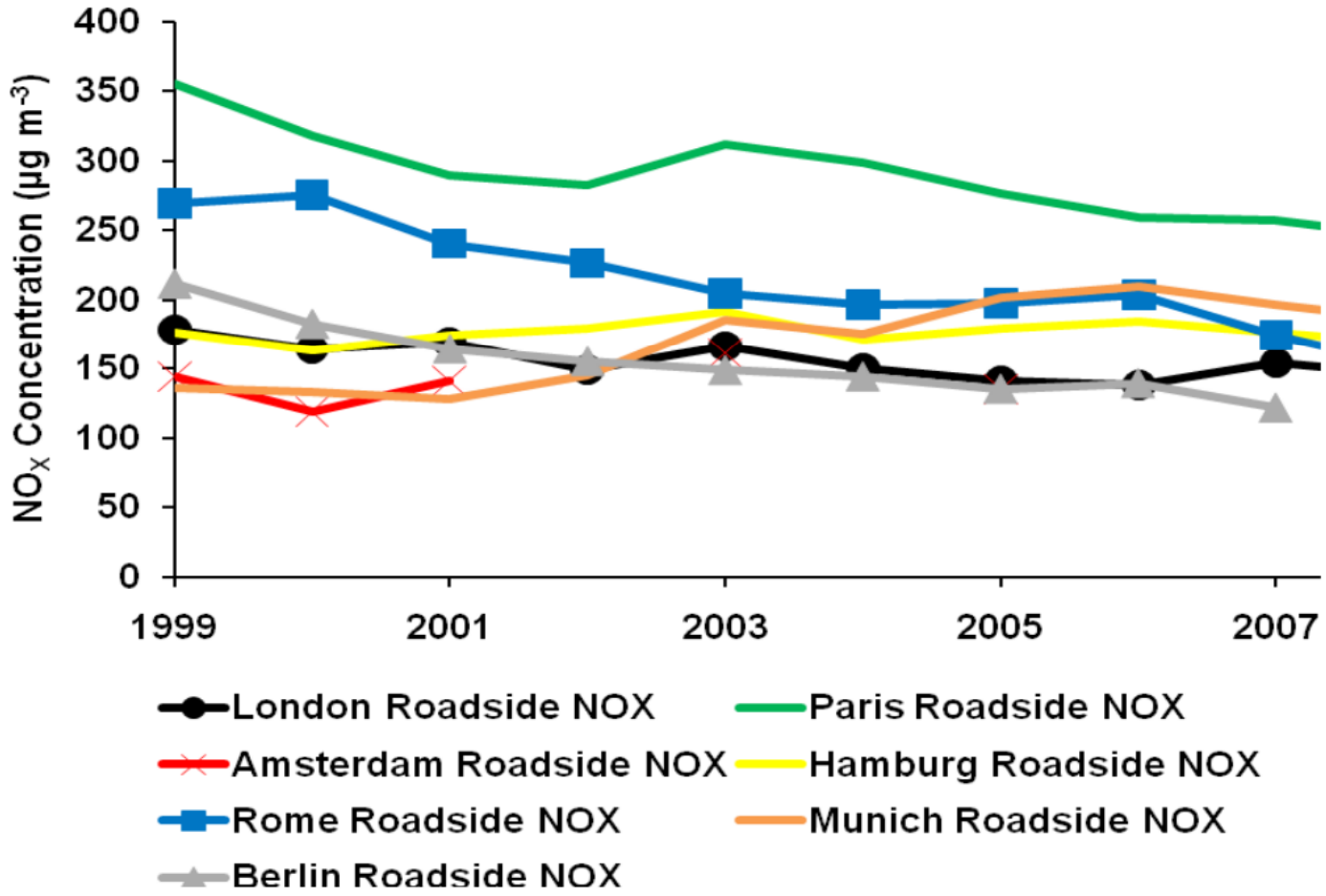

Trends in NO_x and NO_2 Emissions and Ambient Measurements

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- A consortium-based project supported by Defra, the Scottish Executive, Welsh Assembly and Department of the Environment in Northern Ireland.

- King's College, London
  - David Carslaw, Sean Beevers, Emily Westmoreland, Martin Williams
- AEA
  - Tim Murrells, John Stedman, Yvonne Pang, Susannah Grice, Andrew Kent
- University of Leeds
  - James Tate

- Steering Group
  - Defra (Sarah Honour)
  - DfT (Chris Parkin, Iain Forbes)
  - TfL (Finn Coyle)
  - Dick Derwent
  - TRL (Tim Barlow, Paul Boulter)

Why cannot emissions inventories explain trends in NO_x concentrations ?

Estimating Emissions from Road Transport

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Emissions from each vehicle type (tonnes/yr) = emission factor (g/km, g/kg fuel) * activity (vehicle km travelled, kg fuel)

Emission factor determinants:
- pollutant type
- vehicle type
- vehicle size (cc/weight)
- vehicle age
- retrofit technology
- fuel type
- fuel quality
- fuel volatility
- speed
- temperature
- degradation

Emission factors
- hot exhaust
- cold start
- evaporative

Activity data
- km travelled/yr
- fuel consumption/yr
- trip length

EMISSIONS
- tonnes/yr (UK)
- 1x1 km maps

UK Emission Factors (2009)

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EF (g/km) = $y=k*(a+bx+cx^2+dx^3+ex^4+fx^5+gx^6)/x$ where x = average speed in kph

Vehicle category					Average Emission Factors (g/km)									
Code	Vehicle type	Fuel type	Engine capacity (cc) or weight limit (tonnes)	Emission standard	Coefficients							Adjustment factor (k)	Valid speed range	
					a	b	c	d	e	f	g		Minimum (km/h)	Maximum (km/h)
R001	Car <2.5 t	Petrol	<1400 cc	Pre-Euro 1	10.961	0.2456	0.0212	0	0	0	0	1	5	140
R002	Car <2.5 t	Petrol	<1400 cc	Euro 1	2.877243	0.218052	0.001296	2.85E-06	2.51E-08	0	0	1	5	120
R003	Car <2.5 t	Petrol	<1400 cc	Euro 2	2.818032	0.021812	-0.0001	9.47E-06	-7.3E-08	4.42E-10	0	1	5	140
R004	Car <2.5 t	Petrol	<1400 cc	Euro 3	0.606757	0.021434	0.000338	-9.3E-07	1.83E-08	0	0	1	5	140
R005	Car <2.5 t	Petrol	<1400 cc	Euro 4	0.88707	0.009761	9.91E-05	1.84E-07	0	0	0	1	5	120
R006	Car <2.5 t	Petrol	<1400 cc	Euro 5	0.88707	0.009761	9.91E-05	1.84E-07	0	0	0	0.594	5	120
R007	Car <2.5 t	Petrol	<1400 cc	Euro 6	0.88707	0.009761	9.91E-05	1.84E-07	0	0	0	0.594	5	120
R008	Car <2.5 t	Petrol	1400-2000 cc	Pre-Euro 1	5.8816	0.6836	0.0139	0	0	0	0	1	5	140
R009	Car <2.5 t	Petrol	1400-2000 cc	Euro 1	2.365838	0.199261	0.000647	3.22E-06	0	0	0	1	5	120
R010	Car <2.5 t	Petrol	1400-2000 cc	Euro 2	1.095261	0.120124	0.000613	1.17E-06	8.78E-09	0	0	1	5	140
R011	Car <2.5 t	Petrol	1400-2000 cc	Euro 3	0.437044	0.06136	8.02E-05	8.83E-08	0	0	0	1	5	140
R012	Car <2.5 t	Petrol	1400-2000 cc	Euro 4	0.516914	0.034502	5.49E-05	4.08E-07	0	0	0	1	5	120
R013	Car <2.5 t	Petrol	1400-2000 cc	Euro 5	0.516914	0.034502	5.49E-05	4.08E-07	0	0	0	0.594	5	120
R014	Car <2.5 t	Petrol	1400-2000 cc	Euro 6	0.516914	0.034502	5.49E-05	4.08E-07	0	0	0	0.594	5	120
R015	Car <2.5 t	Petrol	>2000 cc	Pre-Euro 1	20.29168	0.911359	0.013899	-3.6E-05	7.36E-07	0	0	1	5	140
R016	Car <2.5 t	Petrol	>2000 cc	Euro 1	4.923703	0.07351	0.000743	2.95E-07	3.33E-08	0	0	1	5	120
R017	Car <2.5 t	Petrol	>2000 cc	Euro 2	1.9784	0.0564	0.0015	0	0	0	0	1	5	140
R018	Car <2.5 t	Petrol	>2000 cc	Euro 3	2.430651	-0.00258	0.000626	-1.7E-05	3.03E-07	-2.3E-09	8.59E-12	1	5	140
R019	Car <2.5 t	Petrol	>2000 cc	Euro 4	2.634692	0.003709	0.000289	3.11E-07	0	0	0	1	5	120
R020	Car <2.5 t	Petrol	>2000 cc	Euro 5	2.634692	0.003709	0.000289	3.11E-07	0	0	0	0.594	5	120
R021	Car <2.5 t	Petrol	>2000 cc	Euro 6	2.634692	0.003709	0.000289	3.11E-07	0	0	0	0.594	5	120

www.dft.gov.uk/pgr/roads/environment/emissions/report-3.pdf

NO_x Emission Factor for Small Euro 3 Diesel Car: <2.0l

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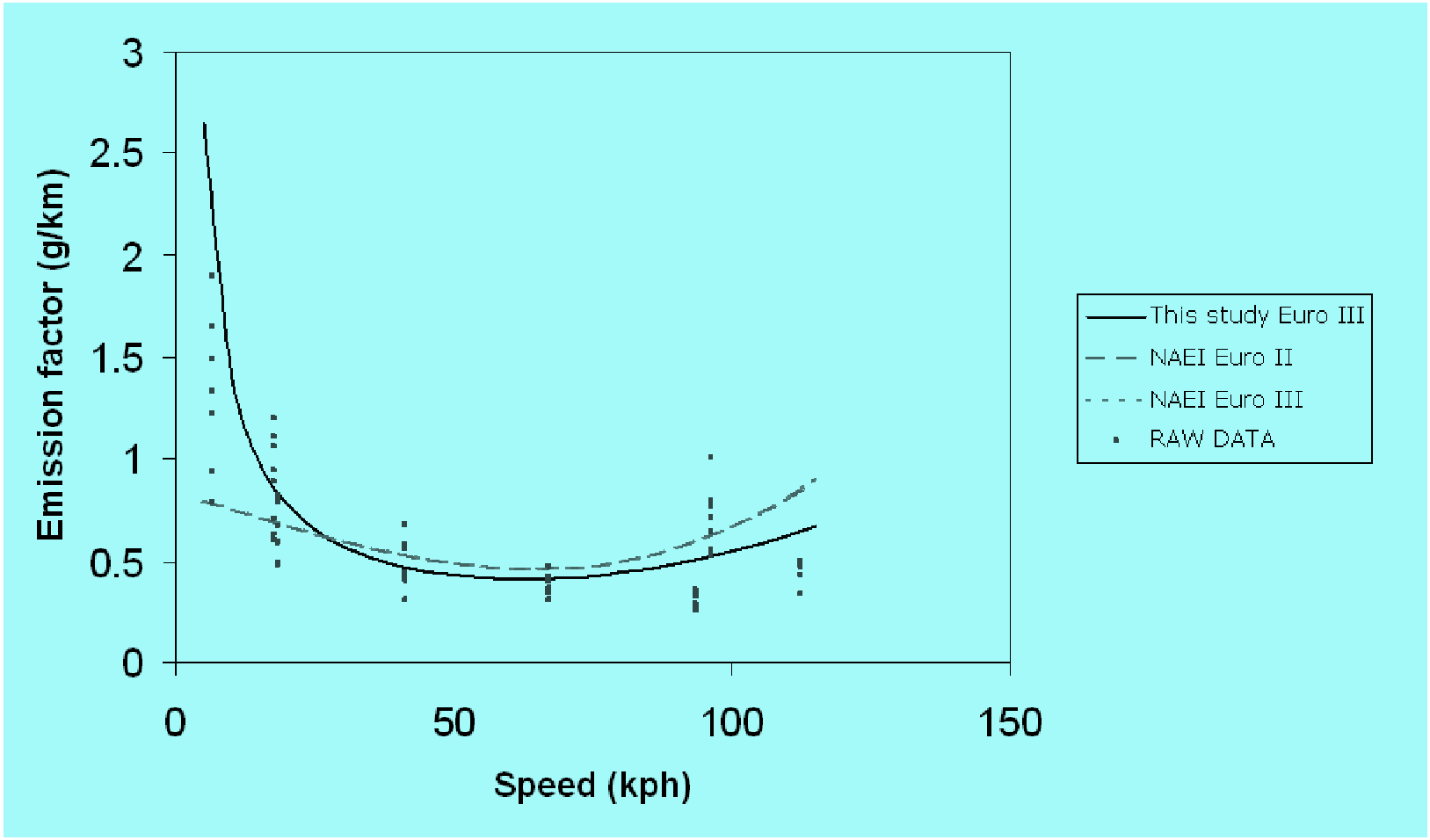

Road traffic by vehicle type and road class Scotland: 2009

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Road traffic by vehicle type and road class, Scotland: 2009 [1]

Million vehicle kilometres

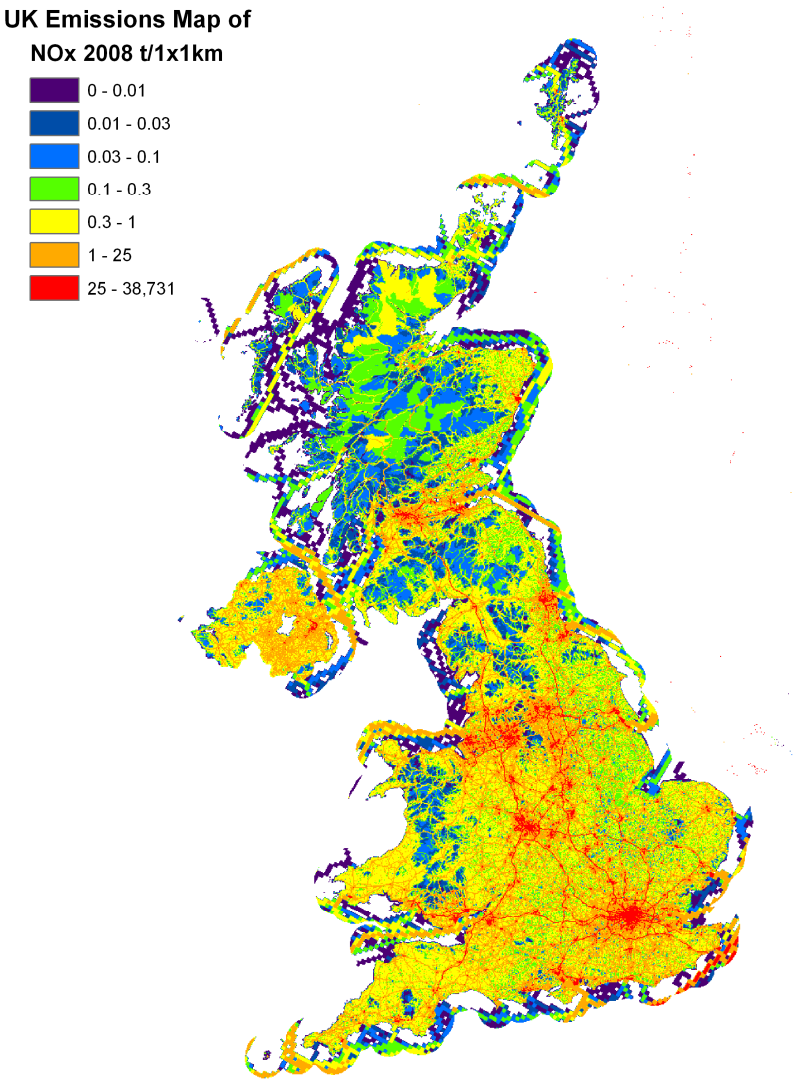
					Heavy Goods Vehicle								
					Rigid by number of axles			Artic by number of axles					
	Cars and taxis	Motor cycles	Buses & coaches	Light vans	2	3	4 or more	3 or 4	5	6 or more	All HGVs	All motor vehicles	Pedal cycles
Motorways [2]	4,954	25	52	837	218	41	44	50	197	215	765	6,633	-
Rural 'A' roads:													
Trunk [3]	6,866	72	85	1,147	283	57	48	56	150	190	784	8,955	6
Principal	6,184	74	99	1,068	214	52	45	31	42	59	443	7,868	17
All rural 'A' roads	13,050	146	184	2,215	497	109	93	88	191	249	1,227	16,822	23
Urban 'A' roads:													
Trunk [3]	746	4	7	129	29	5	5	4	10	12	65	951	1
Principal	3,747	21	86	503	94	16	14	7	10	12	153	4,510	21
All urban 'A' roads	4,493	25	93	632	123	21	19	11	21	24	218	5,461	22
All major roads [4]	22,496	196	329	3,684	837	172	156	148	409	488	2,210	28,916	45
Minor roads:													
Minor rural roads	5,233	59	90	1,319	123	44	16	8	8	16	215	6,916	117
Minor urban roads	6,662	66	216	1,024	94	16	6	4	3	9	132	8,100	125
All minor roads	11,895	125	306	2,343	218	60	22	12	11	25	347	15,016	243
All roads	34,391	322	635	6,027	1,055	232	177	160	420	513	2,557	43,932	287

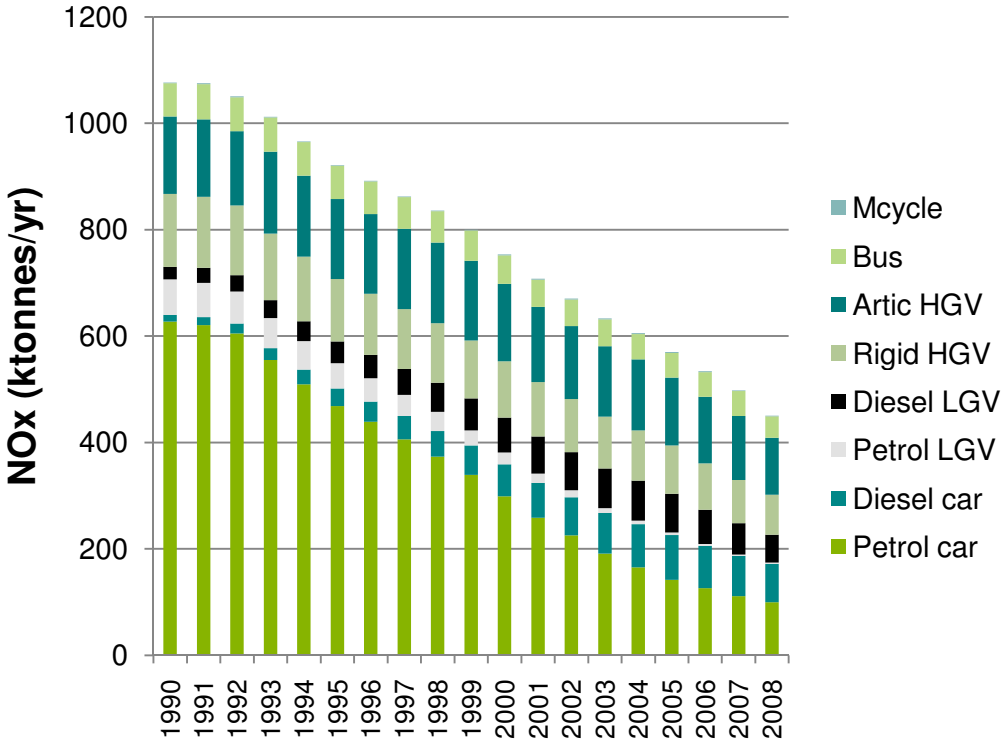
1. Urban roads: Major and minor roads within an urban area with a population of 10,000 or more. These are based on the 2001 urban settlements. The definition for 'urban settlement' is in *Urban and rural area definitions: a user guide* which can be found on the CLG web site at: http://www.communities.gov.uk/planningandbuilding/planningbuilding/planningstatistics/urbanrural/
2. Includes trunk motorways and principal motorways.
3. Figures for trunk and principal roads in England since 2001 are affected by the detrunking programme.
4. Includes motorways, urban and rural 'A' roads.

Source: National Road Traffic Survey, DfT.

- Fleet information based on Vehicle Licensing Statistics (DfT):
  - Vehicle age
  - Euro standard
  - Petrol/diesel mix

UK Emissions of NO_x





Alternative Sources of Emission Factors for Road Transport in Europe

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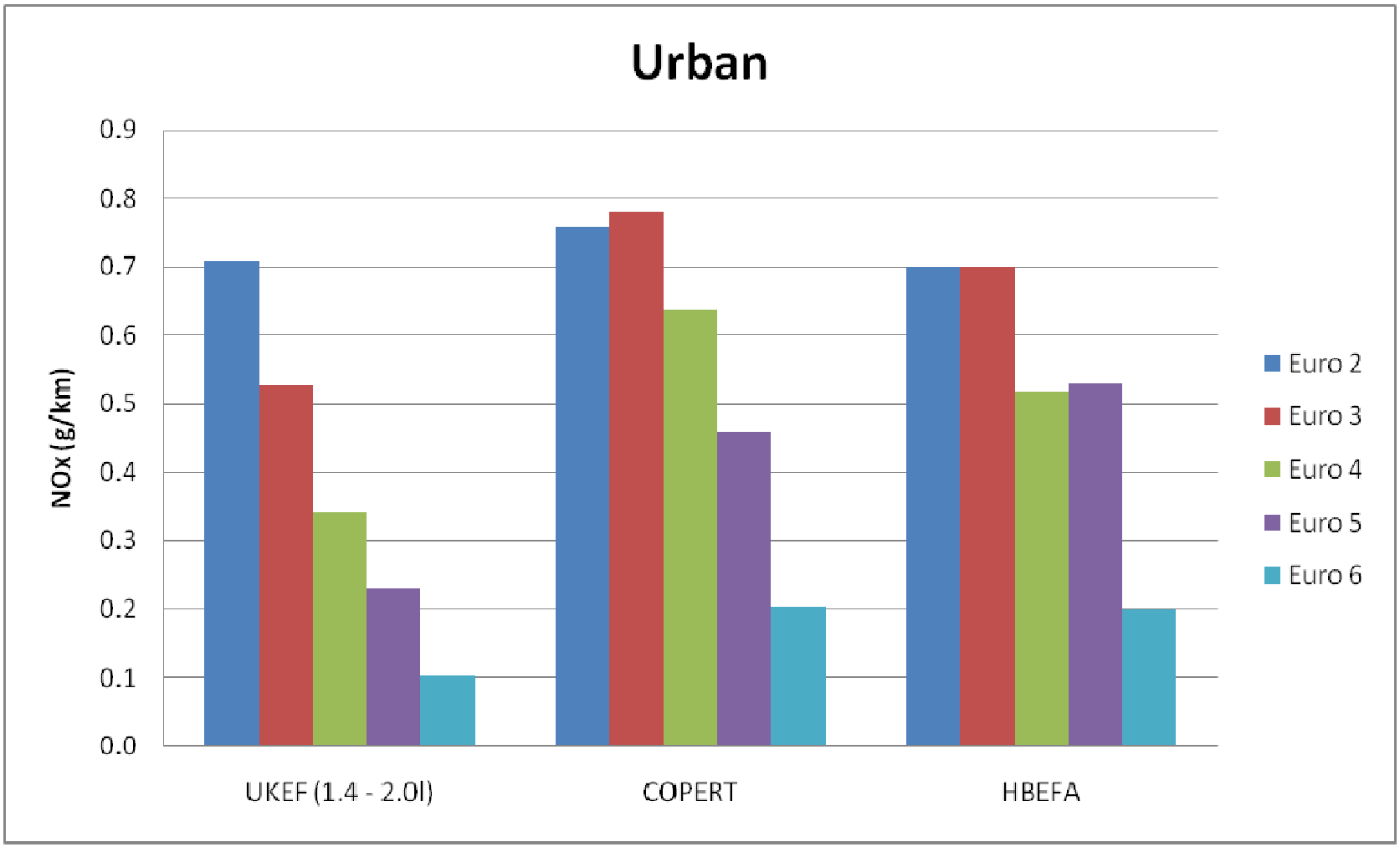
- COPERT 4
  - Supported by European Environment Agency for national inventory reporting under CLRTAP
  - EMEP/CORINAIR Emissions Inventory Guidebook
    www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-road-transport.pdf
  - Recently updated
  - Average speed-related emission factors similar in style to UKEF

- HBEFA v3.1
  - Swiss/German Handbook of Emission Factors (January 2010)
  - Factors for many different “traffic situations”

NO_x Emission Factors: Diesel Cars



Remote Sensing of Vehicle Emissions

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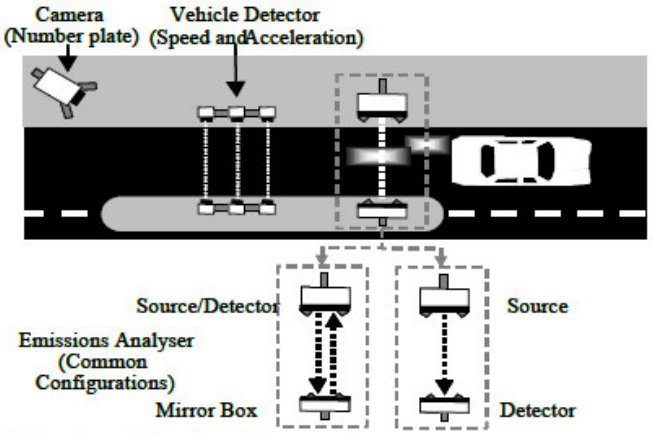
- Remote sensing
  - Infrared/UV beam across road using ESP Remote Sensing Detector (RSD-4600)
  - Individual vehicle exhausts measured
  - Measures **ratios** of NO, CO, HC, "smoke" to CO_2 i.e fuel-based emission factors
  - Some practical limitations
- Several campaigns from 2008–2010 in 5 urban areas
  - About 72,000 vehicles sampled
  - Number plates matched by CarweB (`http://www.carwebuk.co.uk/`)



Thanks to Dr James Tate, ITS, University of Leeds and Enviro Technology plc

Remote Sensing of Vehicle Emissions

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- Independent research campaigns during 2008-2010
  - ITS University of Leeds (Dr James Tate)
  - Enviro Technology plc
- Urban sites at:
  - York (2007)
  - Halifax (2009)
  - Shropshire (2010)
  - London (2008)
  - Devon (2008)
- Automatic Number Plate Recognition
  - matches number plate to Euro standard for each vehicle sampled.
- Limitations:
  - Restricted to single lanes
  - Vehicle speed < 60kph
  - Measures only NO, so necessary to make assumptions about primary NO_2 emissions to convert to NO_x

NO_x/CO_2 for Petrol Cars by Year-of-Registration from Remote Sensing

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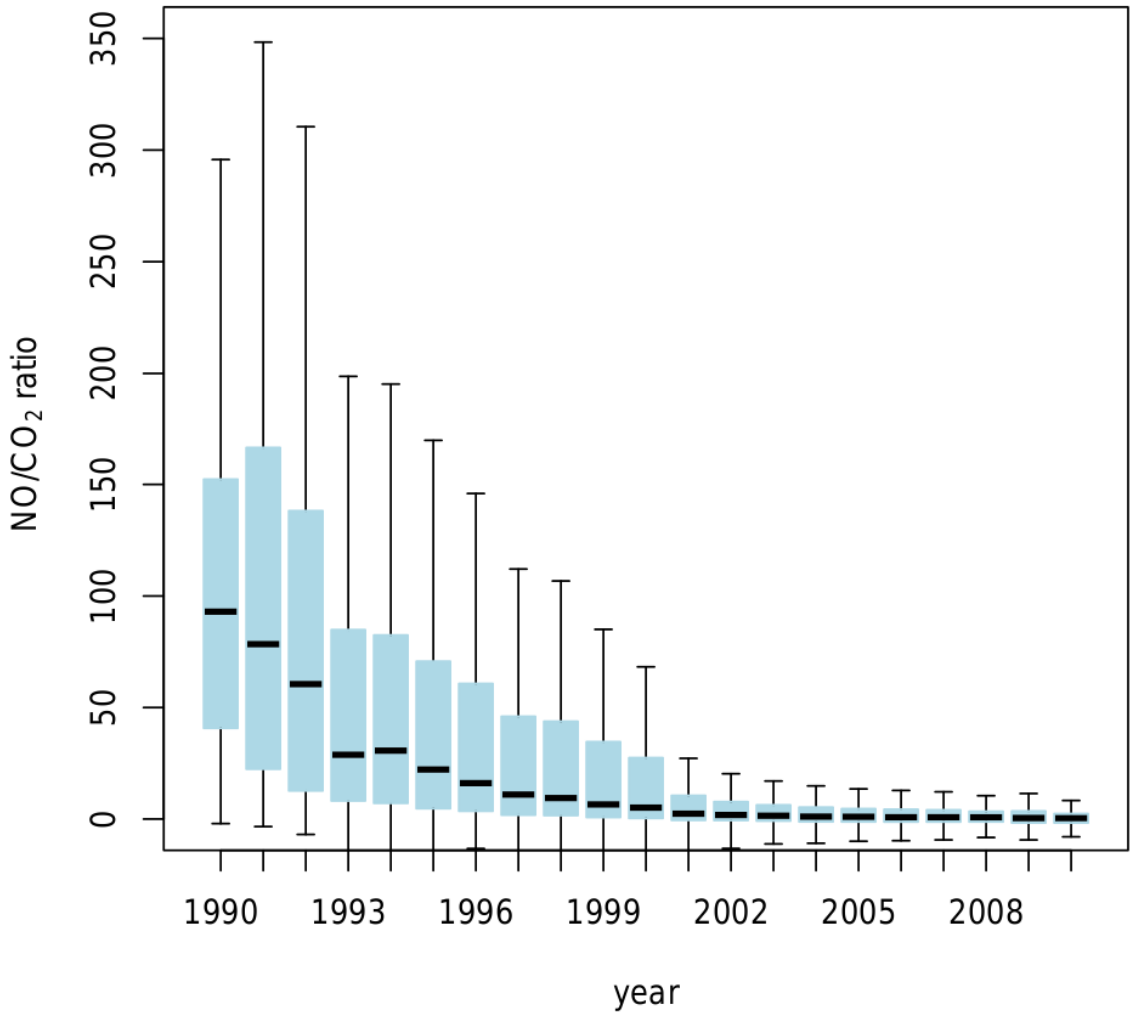
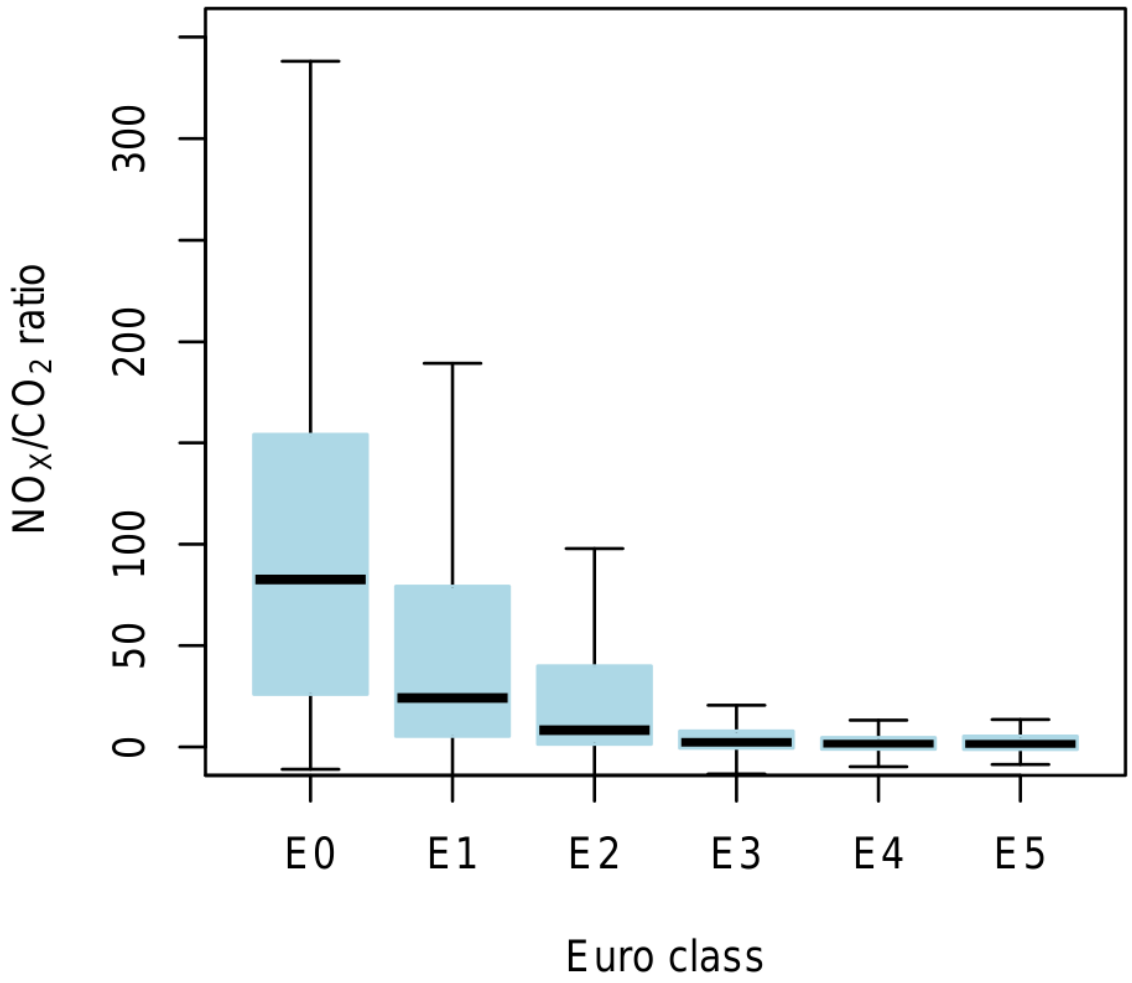


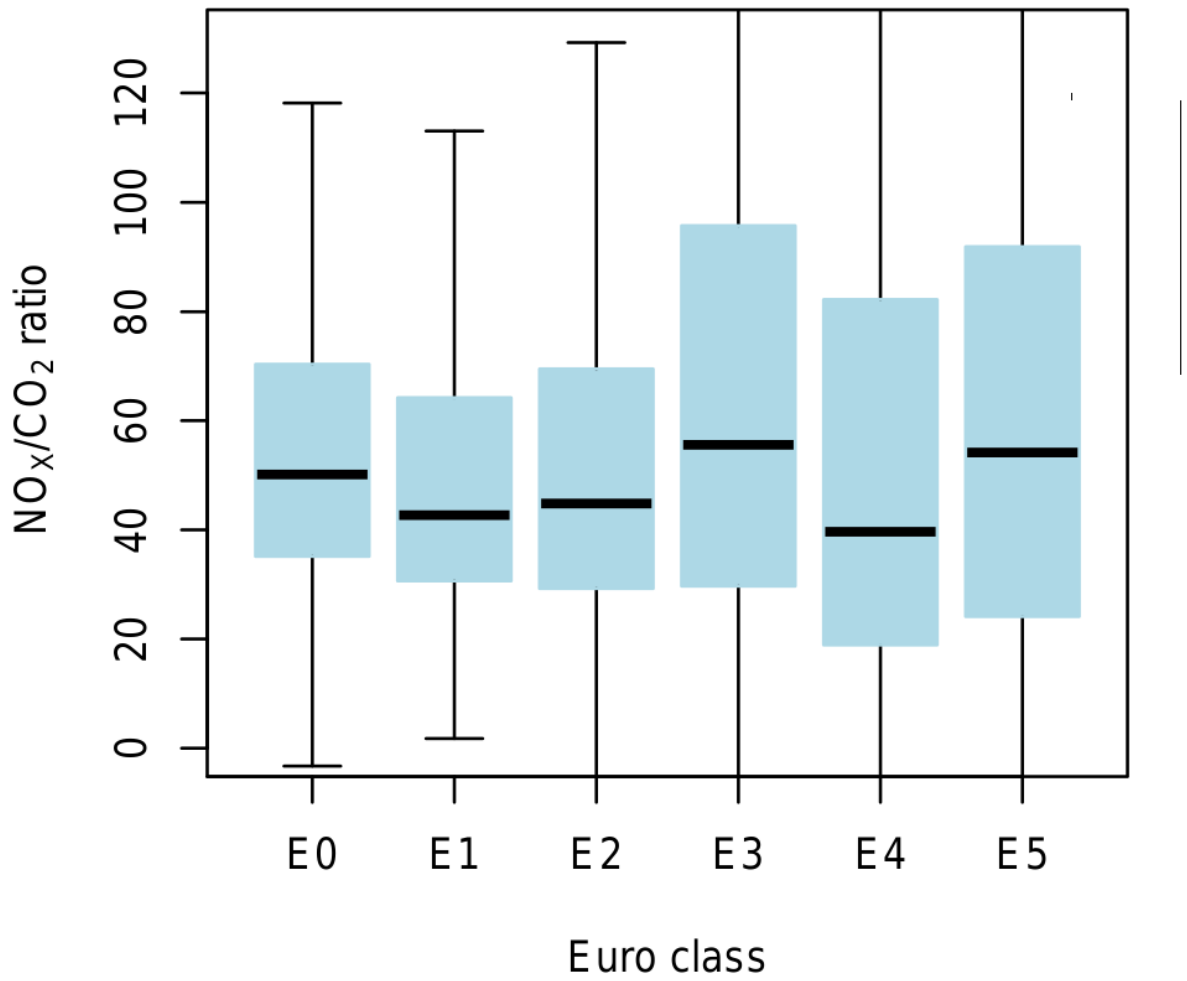
NO_x/CO_2 for Petrol Cars by Euro Class from Remote Sensing

AEA



NO_x/CO_2 for Diesel Cars by Euro Class from Remote Sensing

AEA



Comparison Between UK Emission Factors, HBEFA and Factors from Remote Sensing

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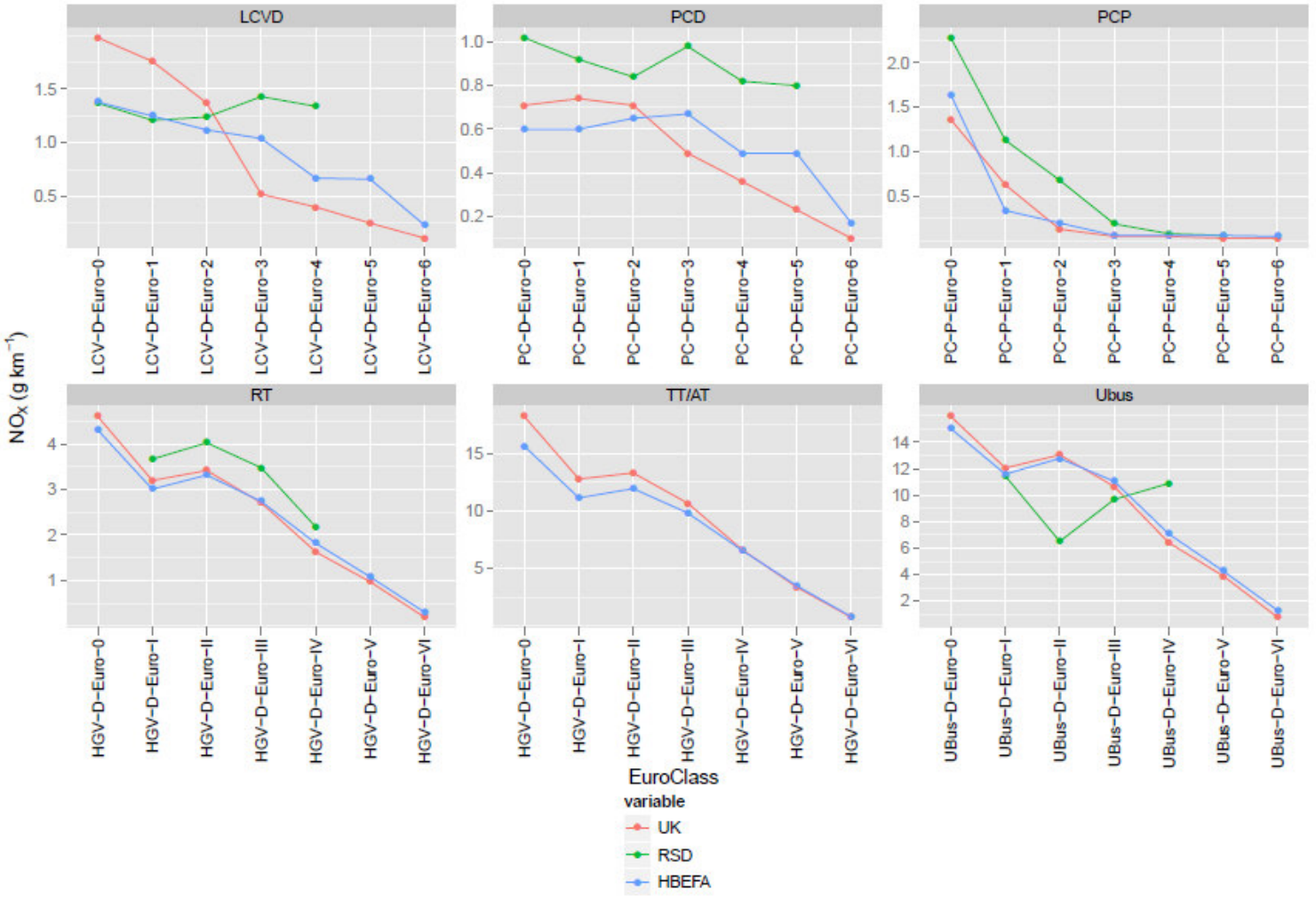
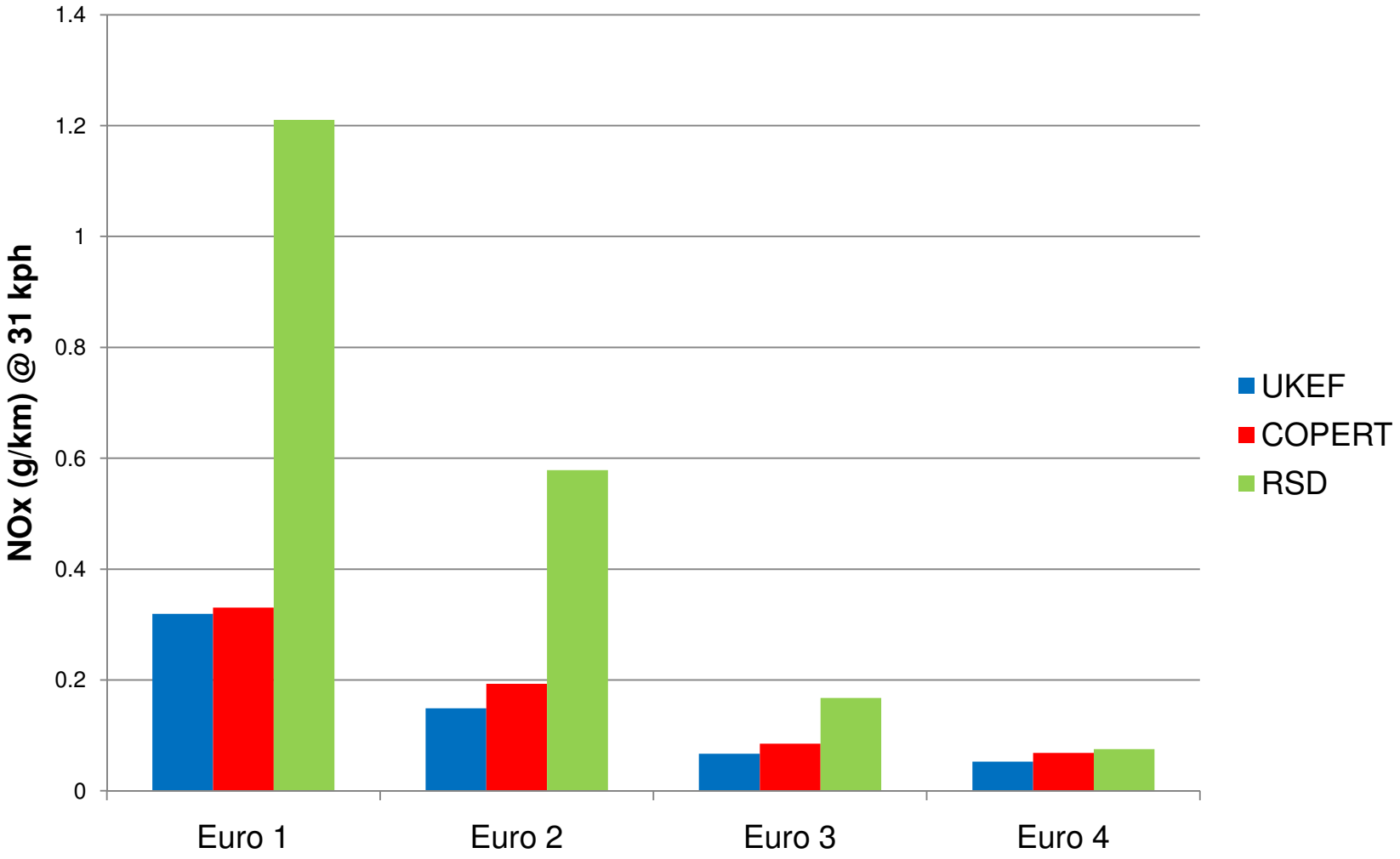
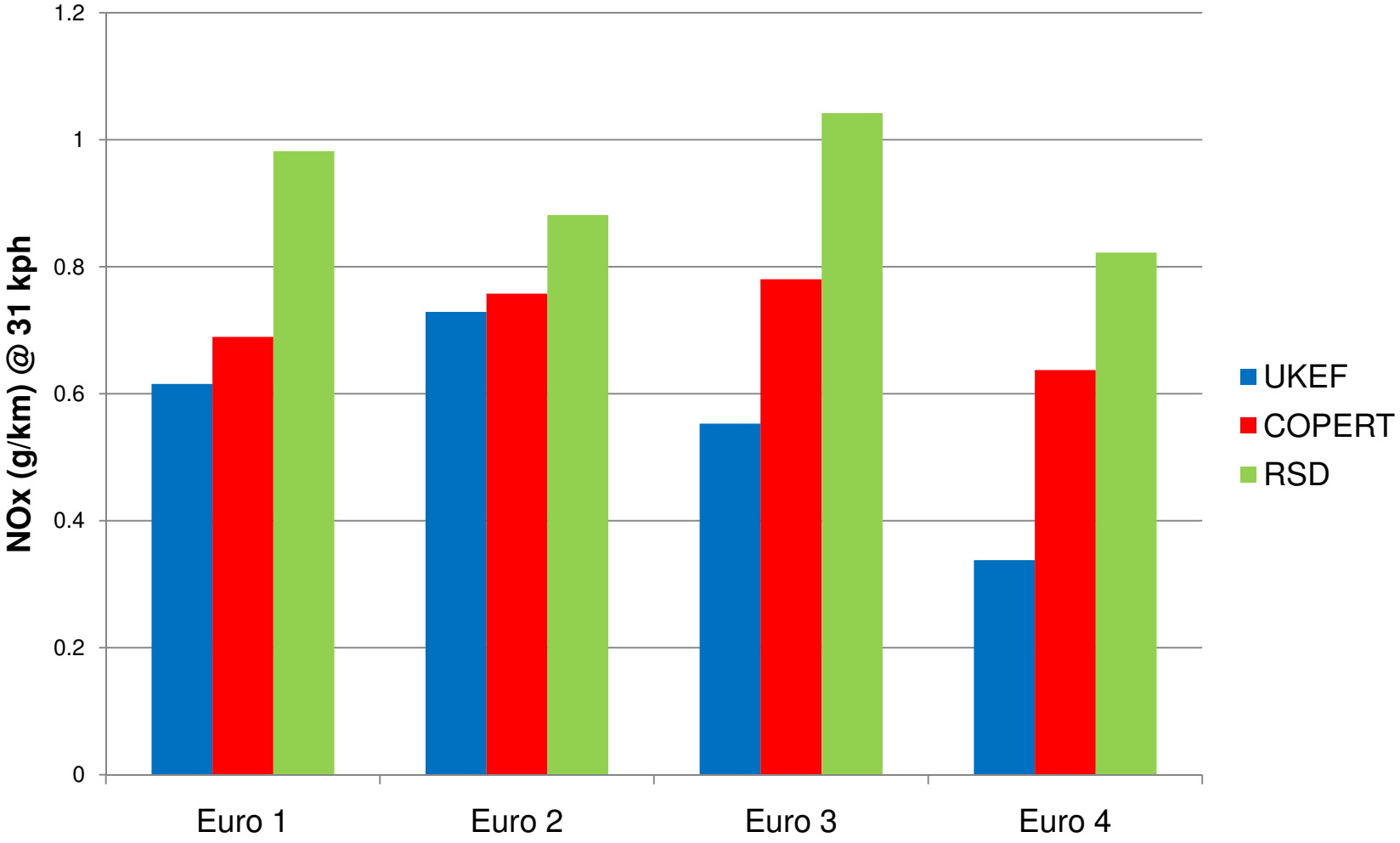


Urban NO_x Emission Factor: Petrol Cars



Urban NO_x Emission Factor: Diesel Cars



Urban NO_x Emission Factor: Rigid HGVs (<7.5t)

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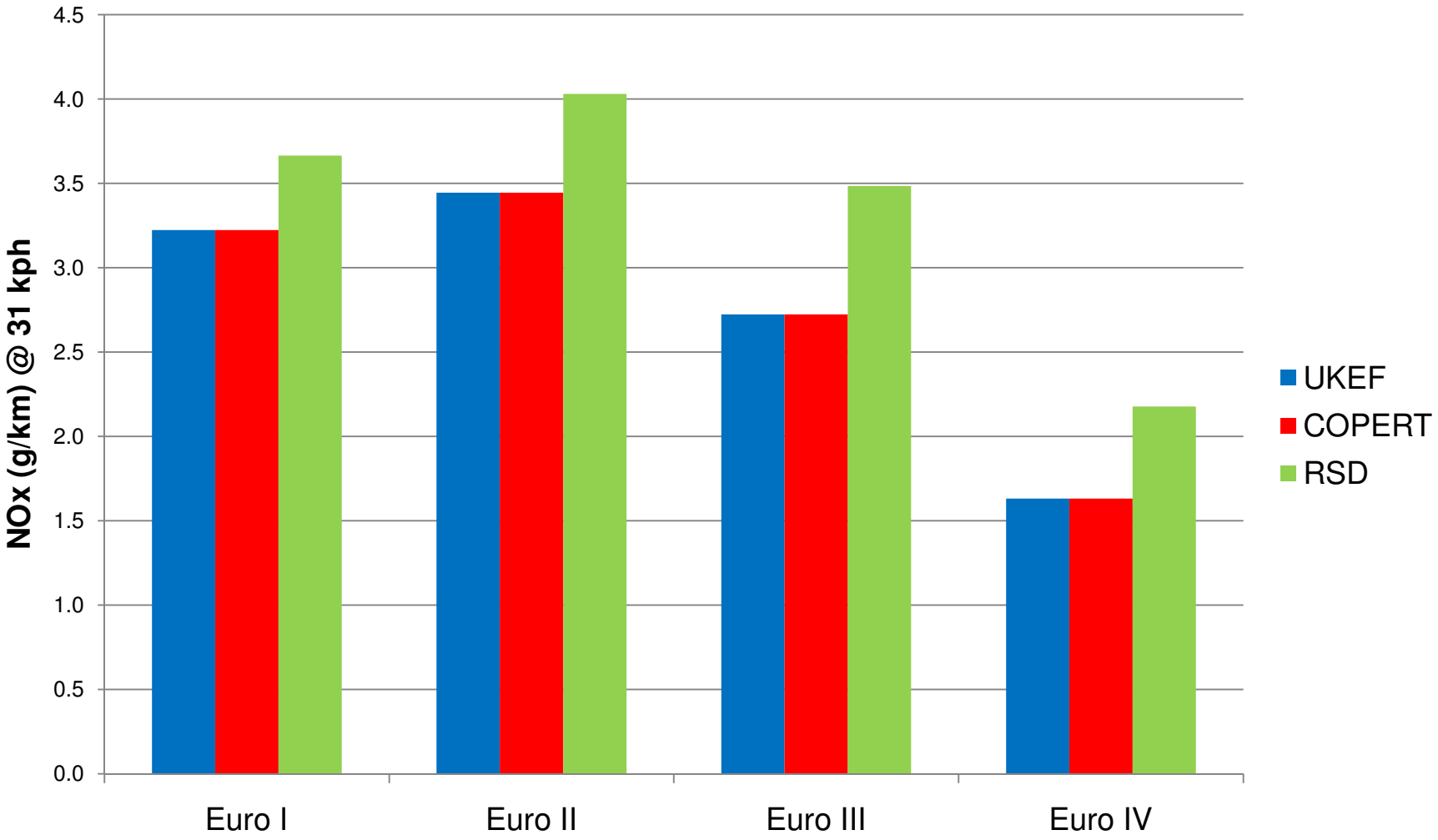

Importance of Emission Degradation

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- The remote sensing data gives us a “snapshot” of current emission performance of cars
- RSD suggest high emission factors for Euro 1 and 2 petrol cars, but have they always been high during the lifetime of the car?
- Emission degradation/failure - a feature taken into account in both UK inventory and COPERT methodologies
- Emission trends are sensitive to assumptions about degradation
- Complicates interpretation of RSD

UK NO_x Emissions from Road Transport: Illustrative Emission Factor Scenarios

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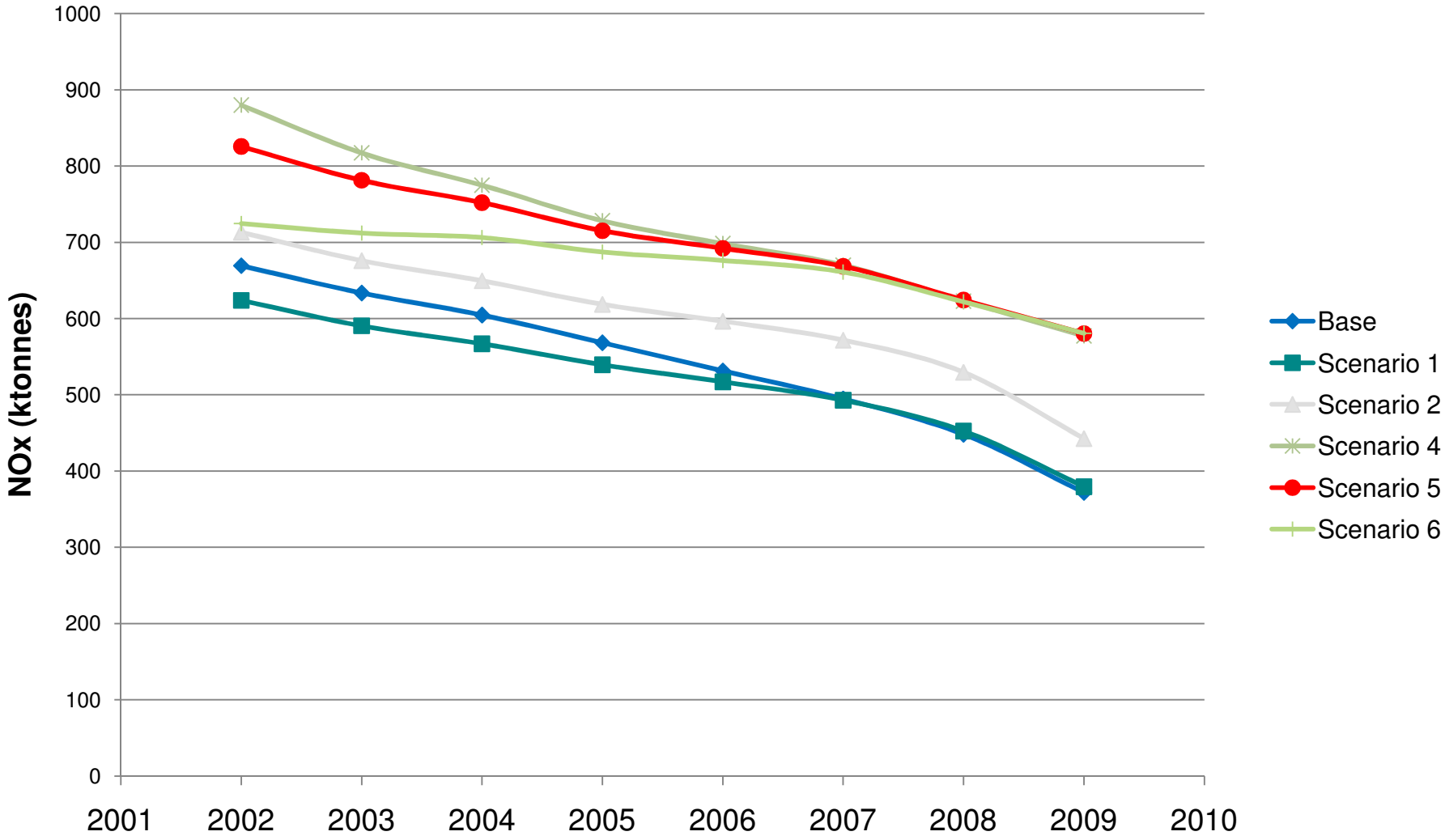

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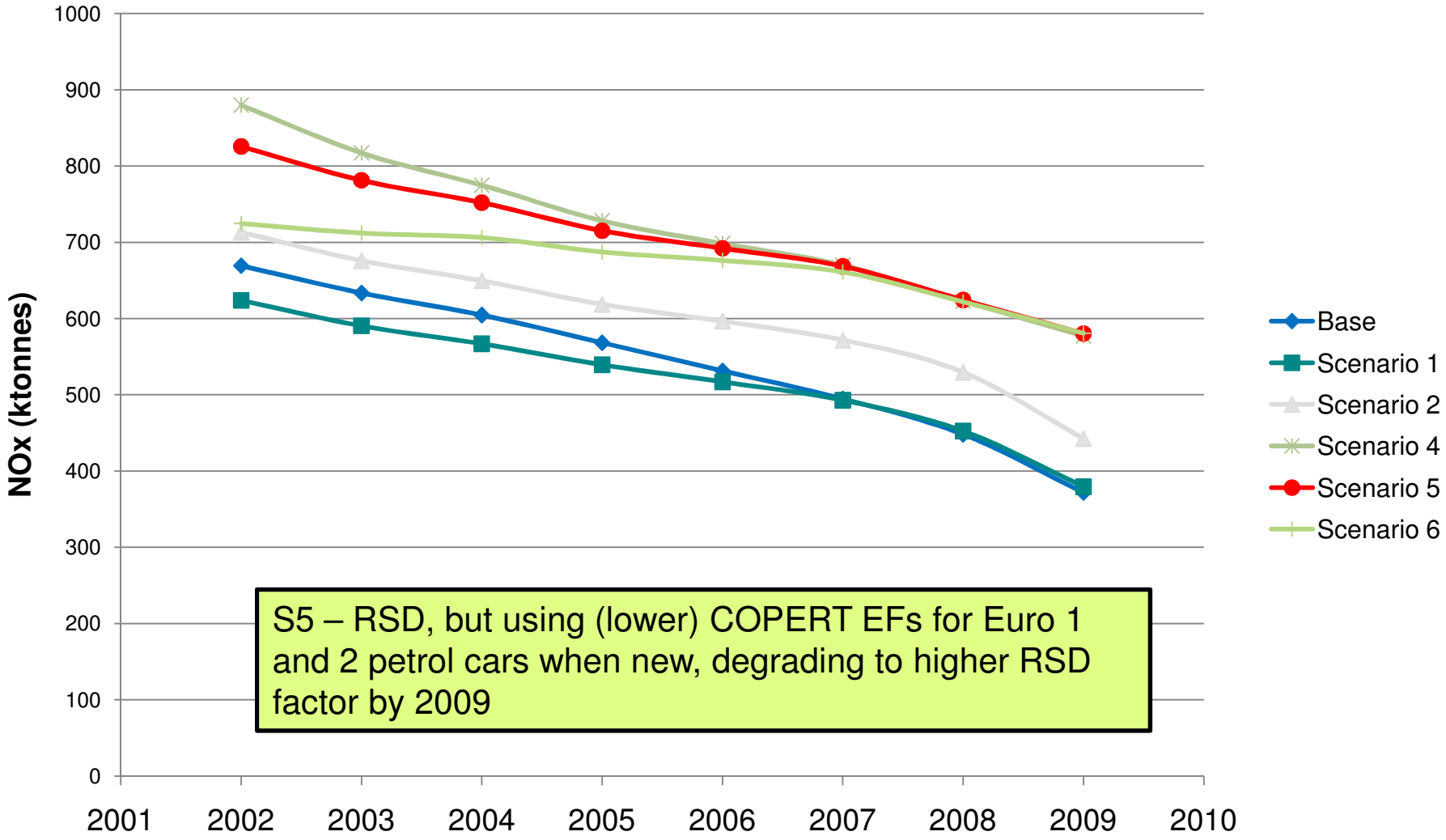

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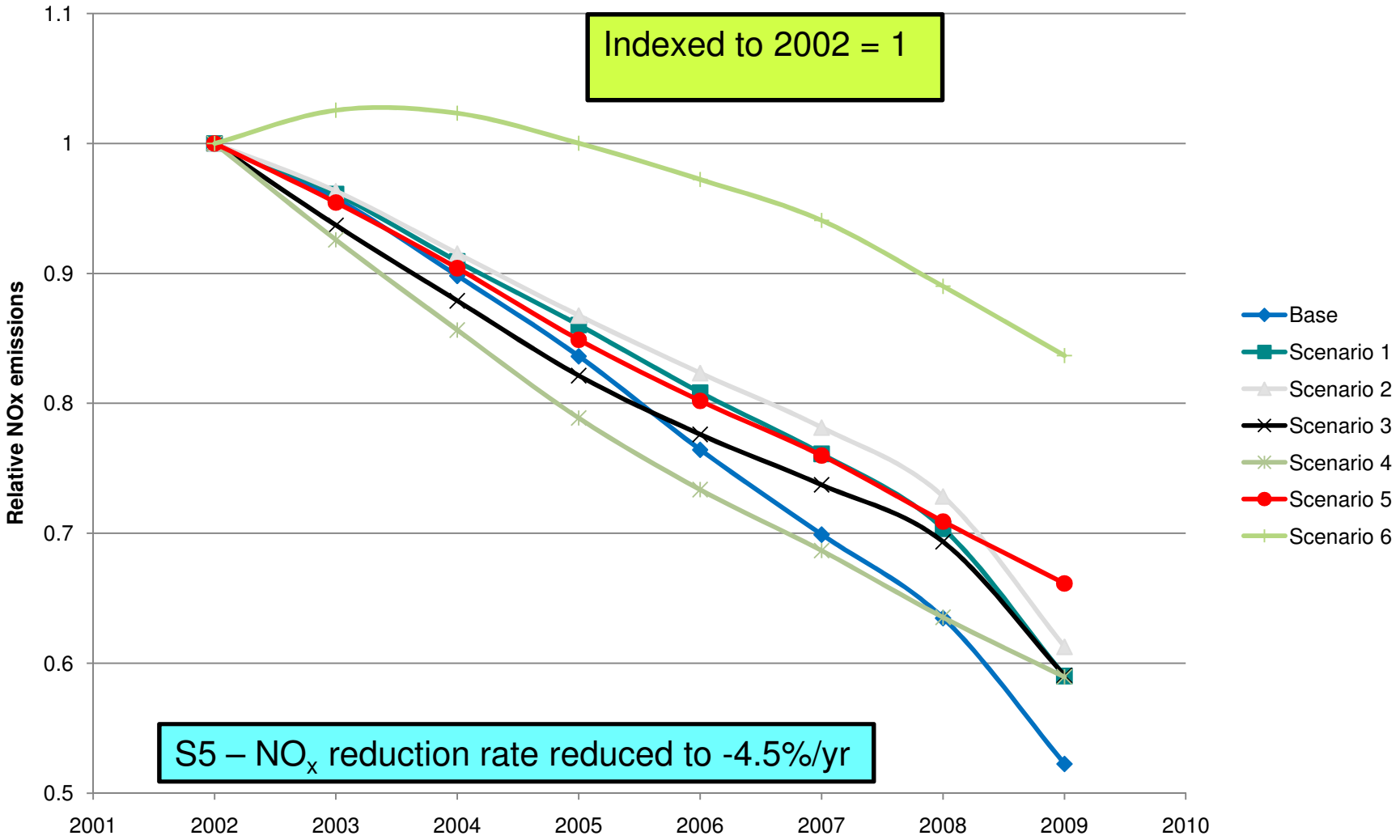

Further Illustrative Modelling

- Illustrative scenarios based on emission factors from remote sensing combined with COPERT 4 slows rate of NO_x emission reduction from -6%/year to -4.5%/year over 2002-2008 period
- Not enough to explain flat trends in roadside NO_x concentrations: <2%/year
- Similar analysis and conclusions with London Atmospheric Emissions Inventory
- Pollution Climate Modelling
  - Using emissions inventory to model NO_x concentrations at roadside sites
  - Illustrative emission scenario improves agreement, but not enough

Other Considerations

- How reliable is the national fleet information applied to local situations?
- Local and road type variations in age of fleet
- Not just about Euro standard, but technologies as well
  - A separate investigation on HGVs with SCR for NO_x control:
  - Evidence for poor performance under urban cycles
  - Probably few HGVs in urban environments currently equipped with SCR

Conclusions

- Roadside concentrations of NO_x in the UK and much of Europe have been flat or only weakly downward over the past 6-8 years
- This is in contrast to current emissions inventory trends which suggest a decline in traffic emissions of around 6% per yr
- New European emission factor compilations suggest NO_x factors for diesel cars and vans have not been declining as quickly as UK emission factors suggest since the introduction of Euro 3 in 2000
- New data from roadside remote sensing suggests
  - 'real-world' NO_x emissions from diesel cars and vans have not changed at all and may even have increased since Euro 1.
  - Emissions from old (Euro 1, 2) petrol cars are also be higher than published factors suggest
  - This could indicate emissions from old catalyst cars have been degrading faster than previously thought and catalysts failing at a higher rate.
- Using **illustrative** emission factors based on these data in inventory calculations does slow down trends in NO_x emissions but does not close the gap sufficiently to explain trends in ambient concentrations
- Questions on fleet composition

What next?

- Draft report released for comment on 3rd March 2011
  - http://uk-air.defra.gov.uk/reports/cat05/1103041401_110303_Draft_NOx_NO2_trends_report.pdf
- Project consortium will be re-convening to consider what changes should be made to UKEF in light of current evidence
- Implications for:
  - National inventory and international commitments
  - Assessing NO_2 air quality exceedences: now and future
  - Local inventories
  - Local Air Quality Management

Acknowledgements

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- Grateful to all members of the consortium team and steering group, especially David Carslaw (King's College) who led the work and provided some of the figures presented

- Thanks to James Tate (ITS Leeds) and Enviro Technology plc for providing remote sensing data