Roadside remote sensing of vehicle exhaust emissions: The London 2012 surveys

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APRIL Transport sub-group, November 7th 2013

Conclusions from 2011 APRIL presentation

- Euro 2 diesel cars were observed to emit higher levels of nitric oxide than either Euro 1 or Euro 3 diesel cars.
- Euro 3 London taxis (as built) were observed to emit higher levels of smoke (particulates) than Euro 1 or Euro 2 London taxis retro-fitted with emissions control equipment.
- (Some) Euro 3 buses were observed to emit higher levels of nitric oxide than Euro 2 buses.
- Therefore, policies of excluding certain vehicle types based simply on the age / Euro class of the vehicle *may* not in all cases necessarily deliver the required air quality improvements (because some emissions do not decrease monotonically).
- Mean NO emissions from Euro 4 diesel cars were observed to be 6 times higher than from Euro 4 petrol cars.
- **What about primary NO_2? Increasing problem in new diesels. Would be very useful to collect data on NO and NO_2 explicitly in future surveys.**

Project partners

Department
for Environment
Food & Rural Affairs

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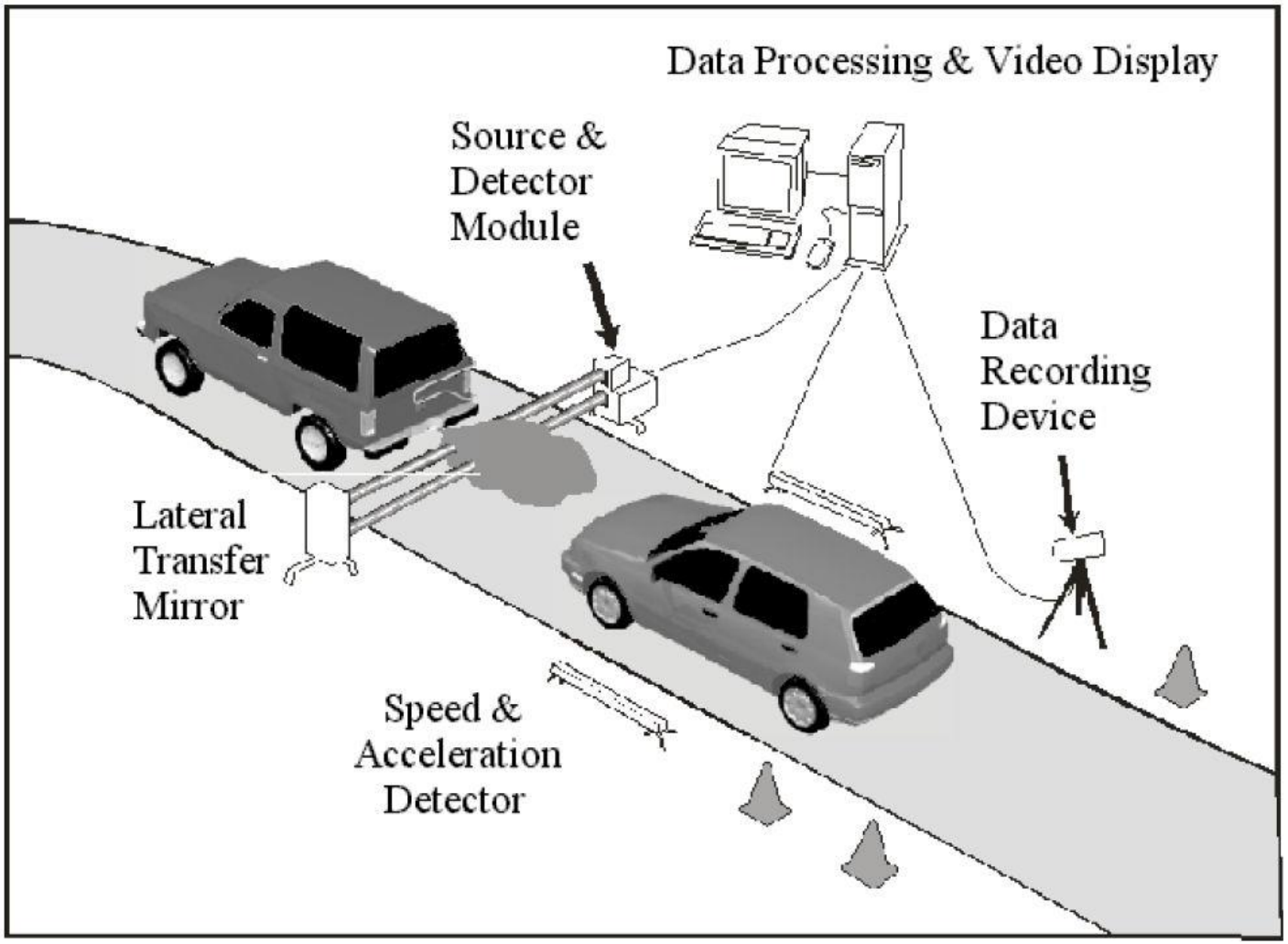
Remote Sensing of Exhaust Emissions

Project objectives

- To quantify emissions of NO_2 and NO_x in road vehicle exhaust gases in an urban area;
- To quantify the variation in NO_2 and NO_x emissions across the urban road vehicle fleet by vehicle type (e.g. car, LGV, HGV, bus, taxi), fuel type, Euro standard, engine size and vehicle age;
- Where practicable, characterise the emissions by driving conditions;
- To determine the NO/NO_2 ratio in vehicle exhaust gases (by vehicle category) from direct measurement, and;
- Develop emission factor information that can be used in the NAEI and other inventories, which will directly help to validate them.

Remote Sensing of Exhaust Emissions



Source: ESP / Southeast Michigan

Non-dispersive infrared (NDIR) component for detecting CO, CO_2, and HC, and a dispersive ultraviolet (UV) spectrometer for measuring oxides of nitrogen (NO and NO_2), SO_2 and NH_3.

Remote Sensing of Exhaust Emissions

Important

The instrumentation measures '**ratios**' of pollutant to carbon dioxide (CO_2) in the exhaust plume by mole, not absolute values.

Results are typically reported in terms of:

- Raw ratio (e.g. NO_2/CO_2, NO/CO_2 etc); or
- Rate per unit of fuel consumed (e.g. gNO_2 per kg of fuel consumed, or gNO_2 per litre of fuel consumed).

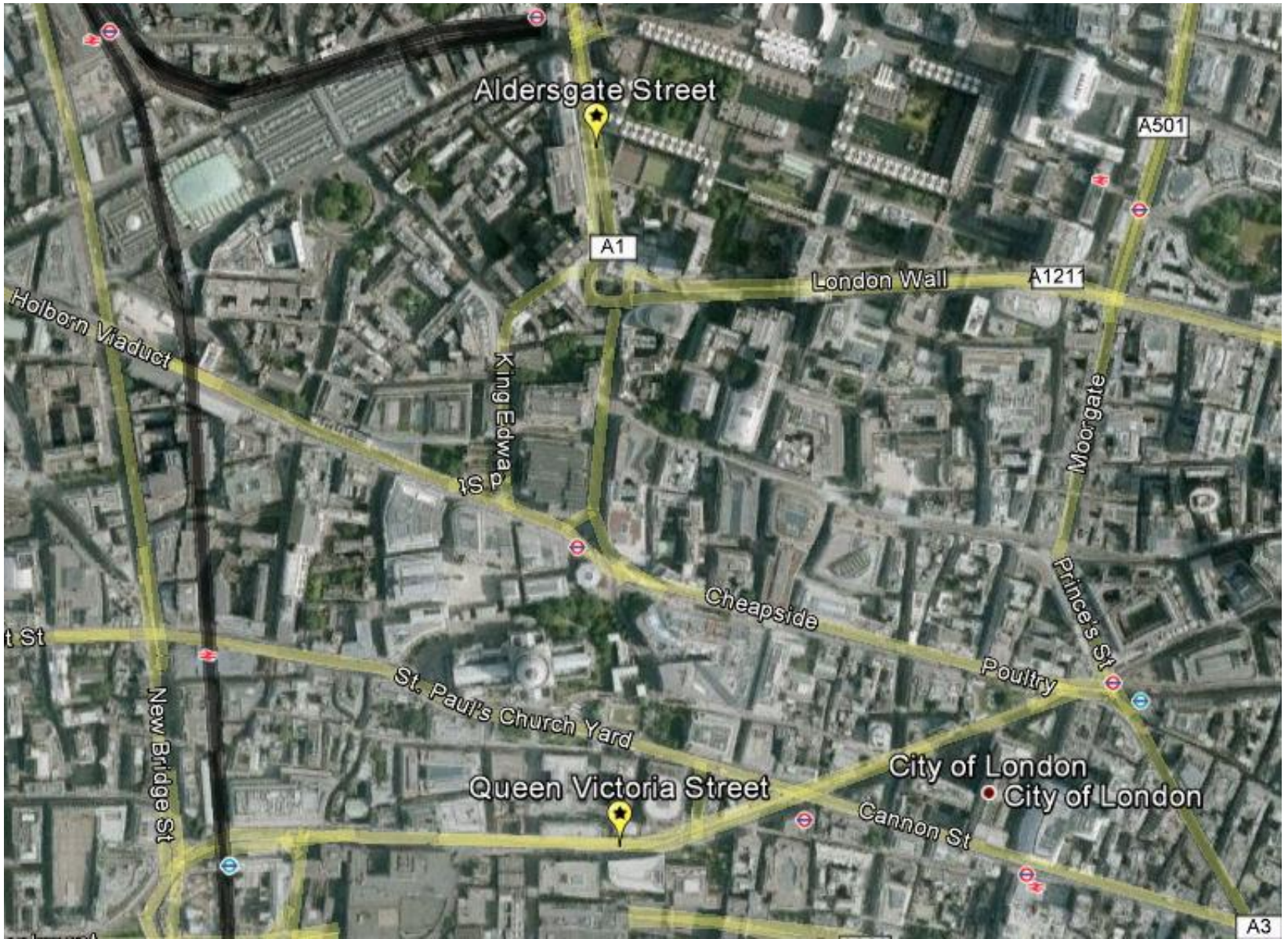
Denver University instrumentation

Photograph:

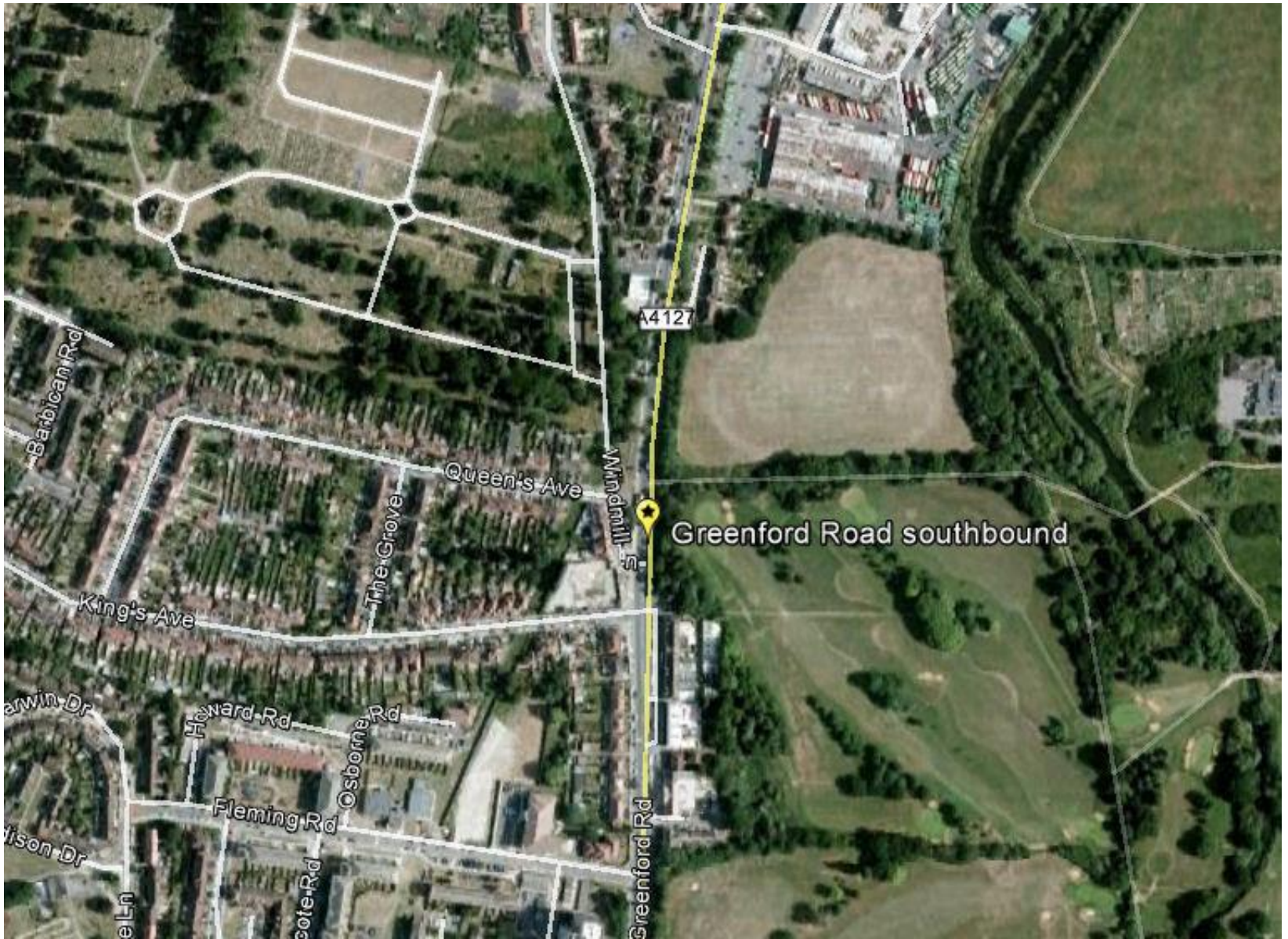
Glyn Rhys-Tyler.

DEFRA 2012 surveys.

City of London survey sites



Ealing survey sites



Ealing survey sites

Survey implementation

Photographs: Glyn Rhys-Tyler. DEFRA 2012 surveys.

Survey implementation

Surveys implemented in the period May 21st to July 2nd 2012

Aldersgate Street	4 survey days	17,170 observations
Queen Victoria Street	8 survey days	31,297 observations
Greenford Road	8 survey days	32,282 observations
A40 slip road	6 survey days	12,588 observations
Total	**26 survey days**	**93,337 observations**

76,180 valid emissions (NO_2) measurements

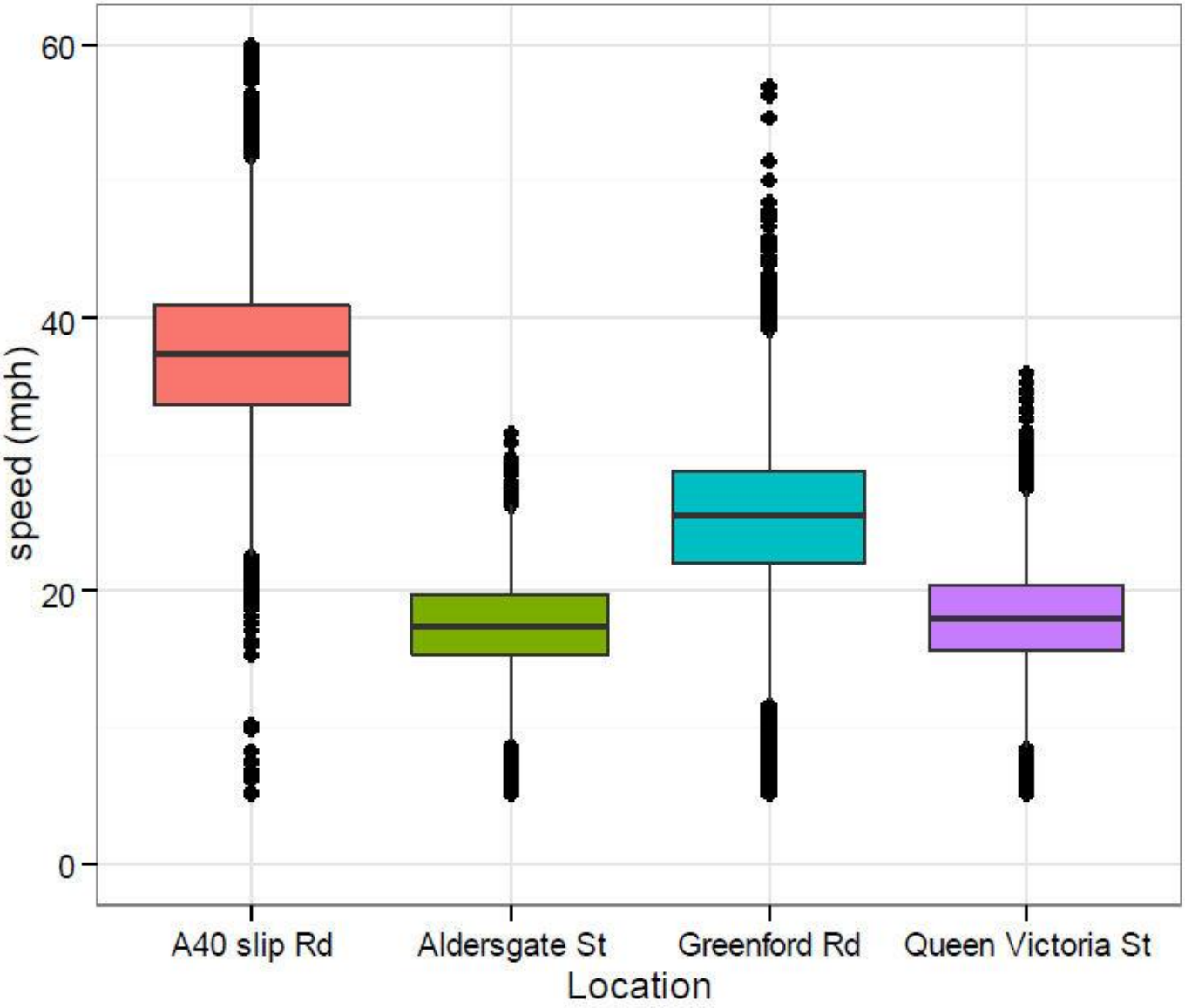
72,712 vehicles identified from licence plates

68,068 usable records for analysis (compared to circa 55,000 usable records (NO, CO, HC, smoke) from the 2008 surveys).

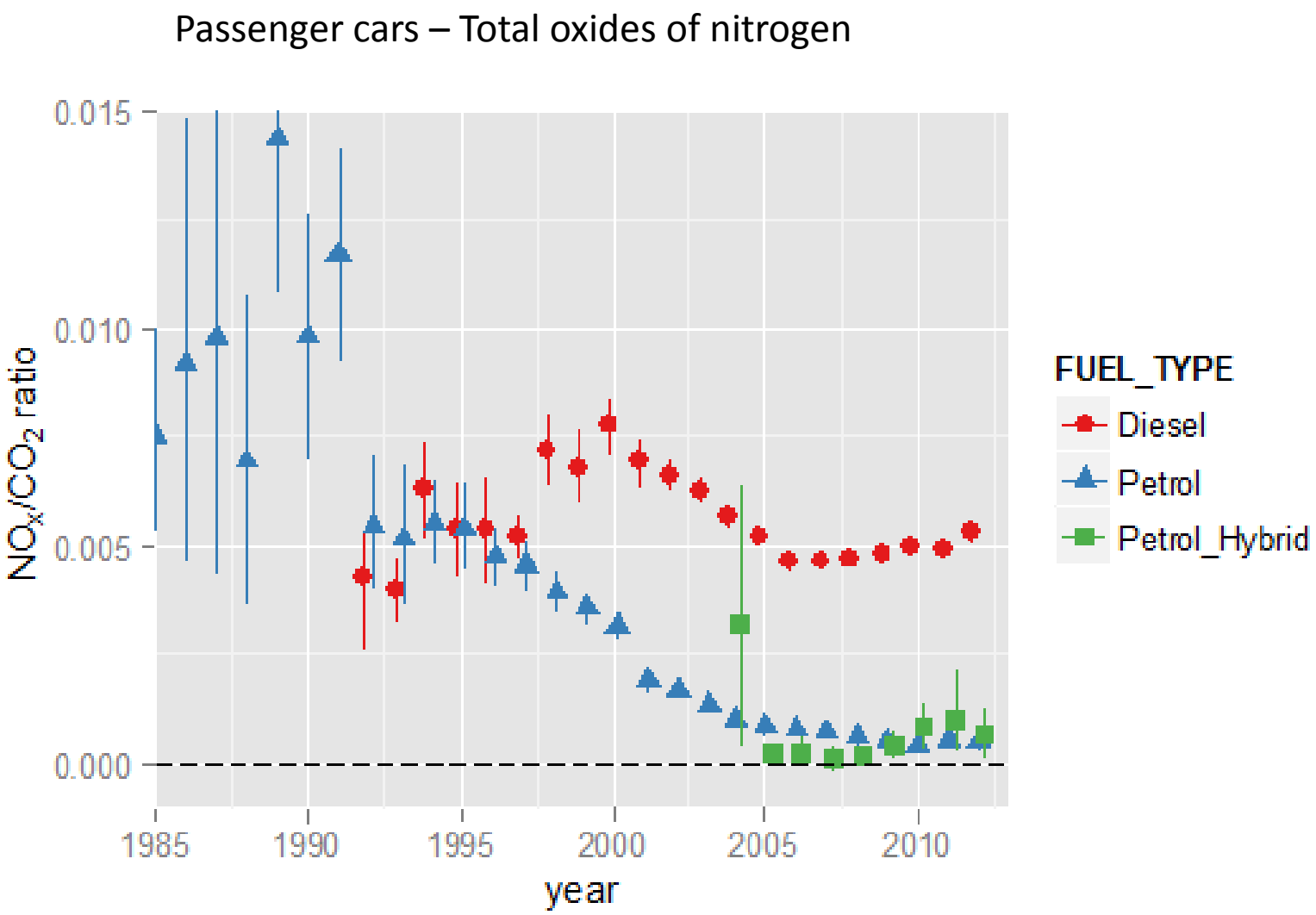
Observed vehicles by fuel type

Vehicle type	Diesel	Petrol	Petrol / Gas	Petrol / Hybrid	Total
Car (M1)	13582	20030	127	769	34508
Minibus (M2)	142	4	0	0	146
Bus (M3)	2583	0	0	0	2583
Van (N1)	12631	471	325	0	13427
HGV (N2)	791	0	0	0	791
HGV (N3)	568	0	0	0	568
Moped (L1)	0	66	0	0	66
Motorcycle (L3)	0	848	0	0	848
Three wheeler (L5)	0	5	0	0	5
Plant	12	0	0	0	12
Taxi (M1)					
LTI FX4	877	0	0	0	877
LTI TX1	4132	0	0	0	4132
LTI TXII	4050	0	0	0	4050
LTI TX4	4904	0	0	0	4904
Carbodies Metrocab	228	0	0	0	228
Mercedes Vito 111	594	0	0	0	594
Mercedes Vito 113	329	0	0	0	329
Total	45423	21424	452	769	68068

Variation in vehicle dynamics by location

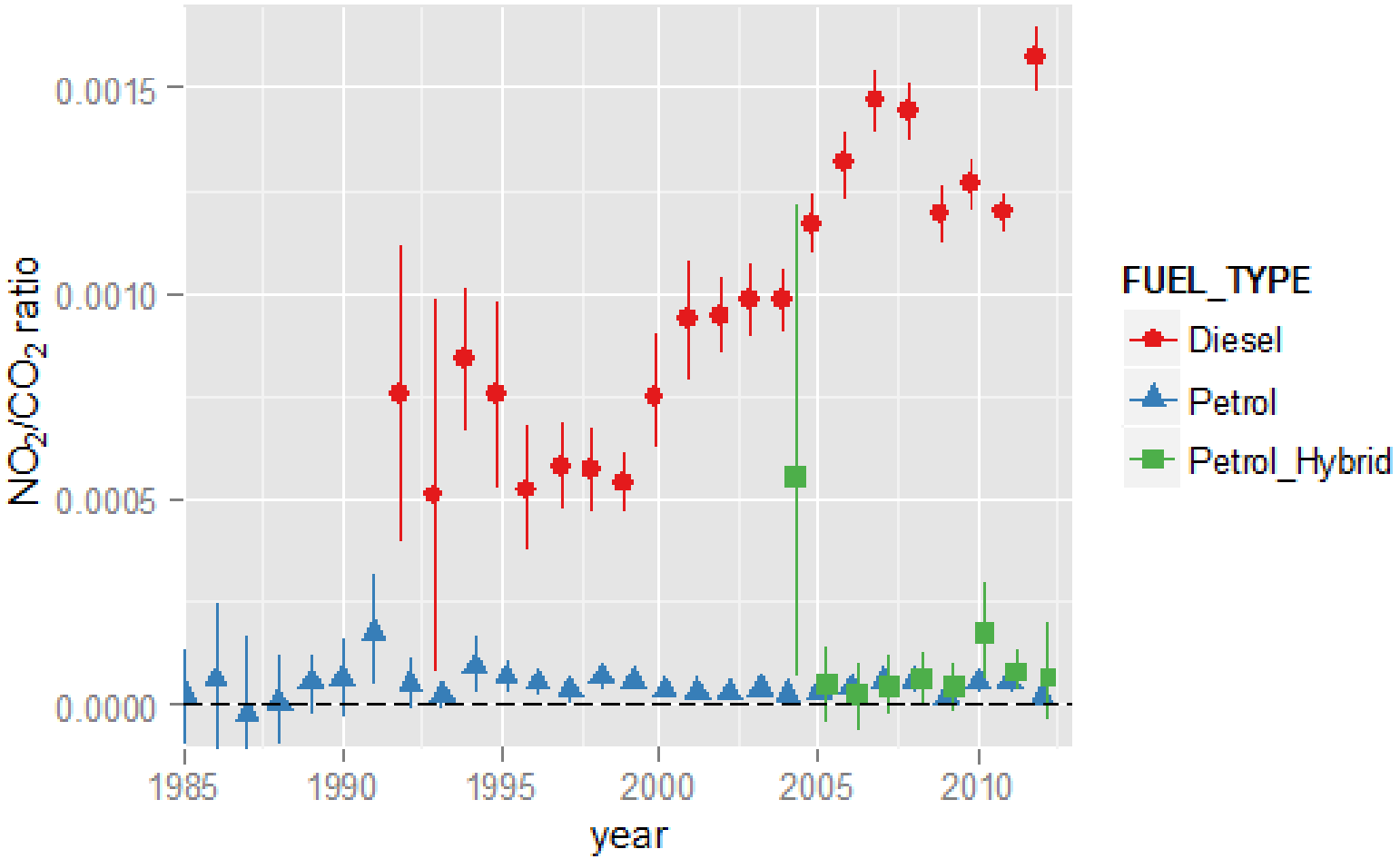


Passenger cars



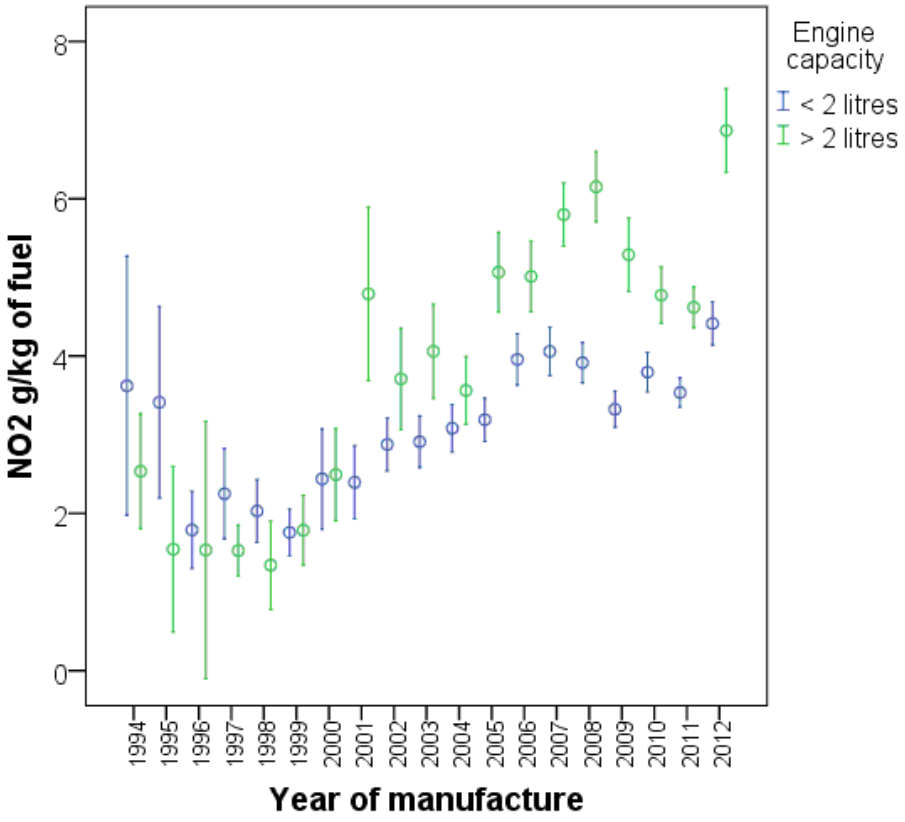
Passenger cars

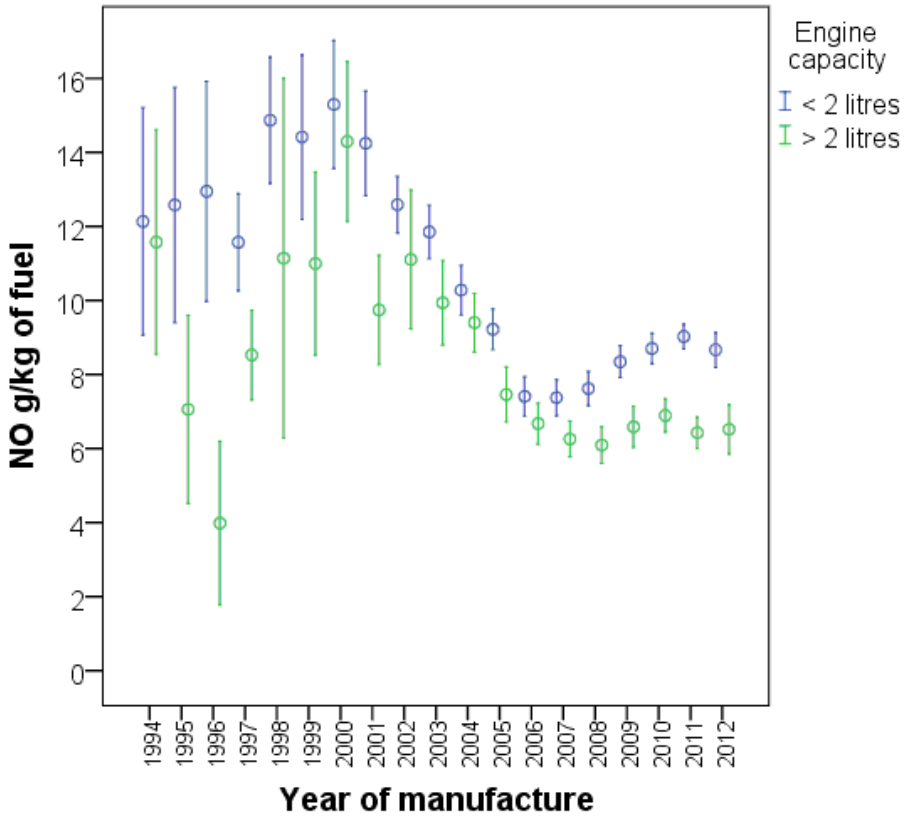
Passenger cars – Nitrogen dioxide emissions



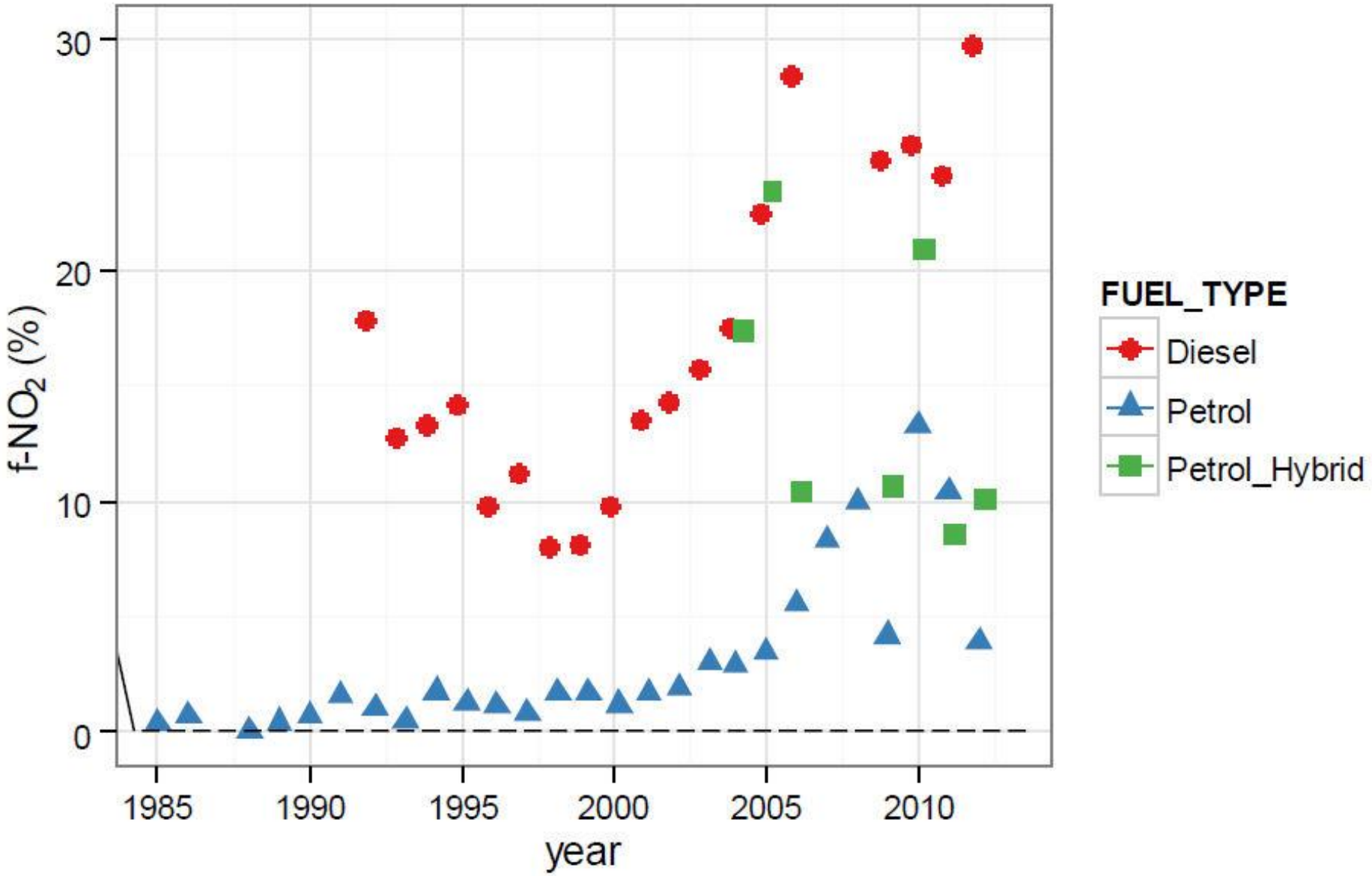
Passenger cars

Diesel passenger cars – Nitrogen dioxide and Nitric oxide emissions

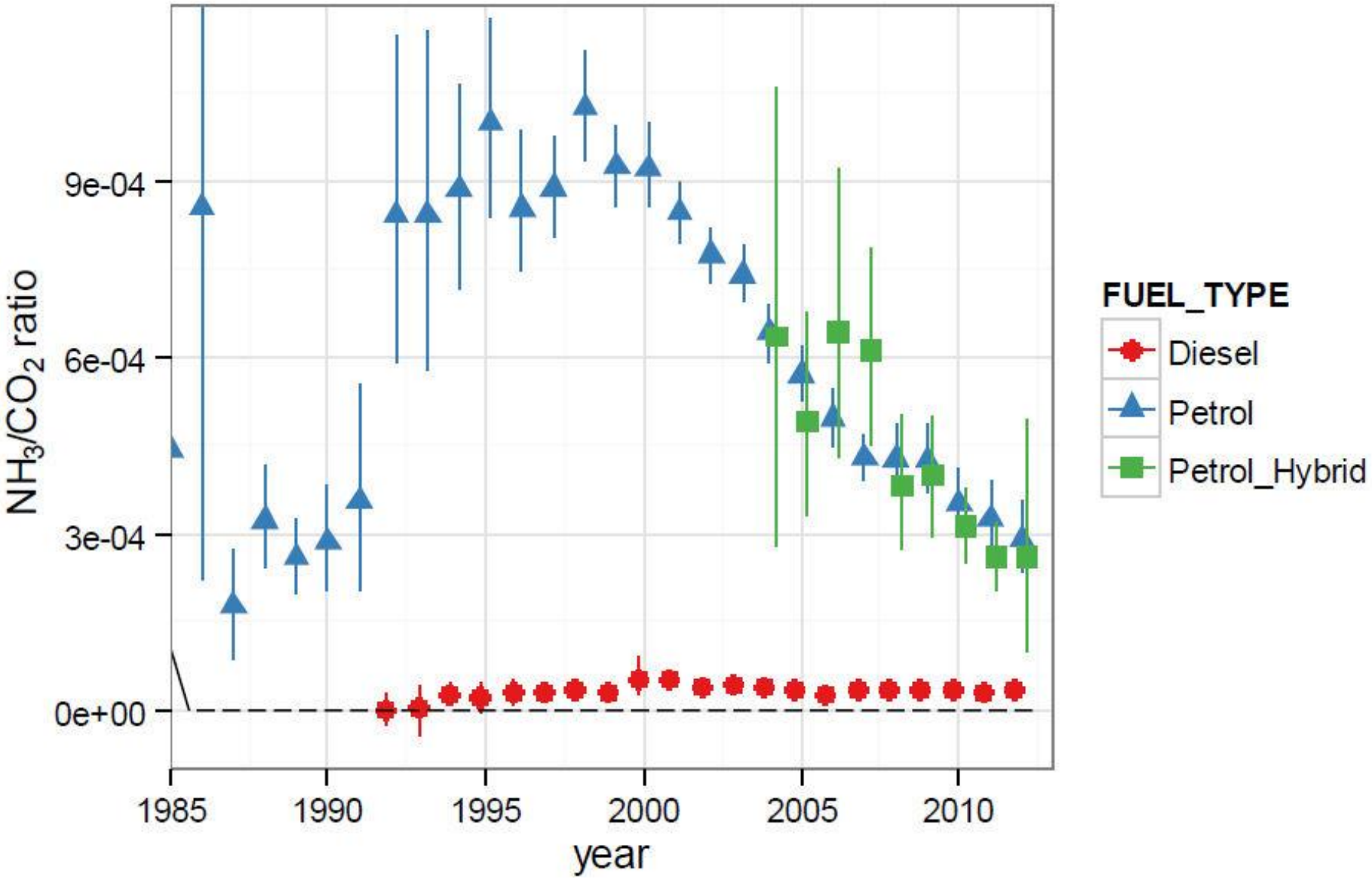




Passenger cars

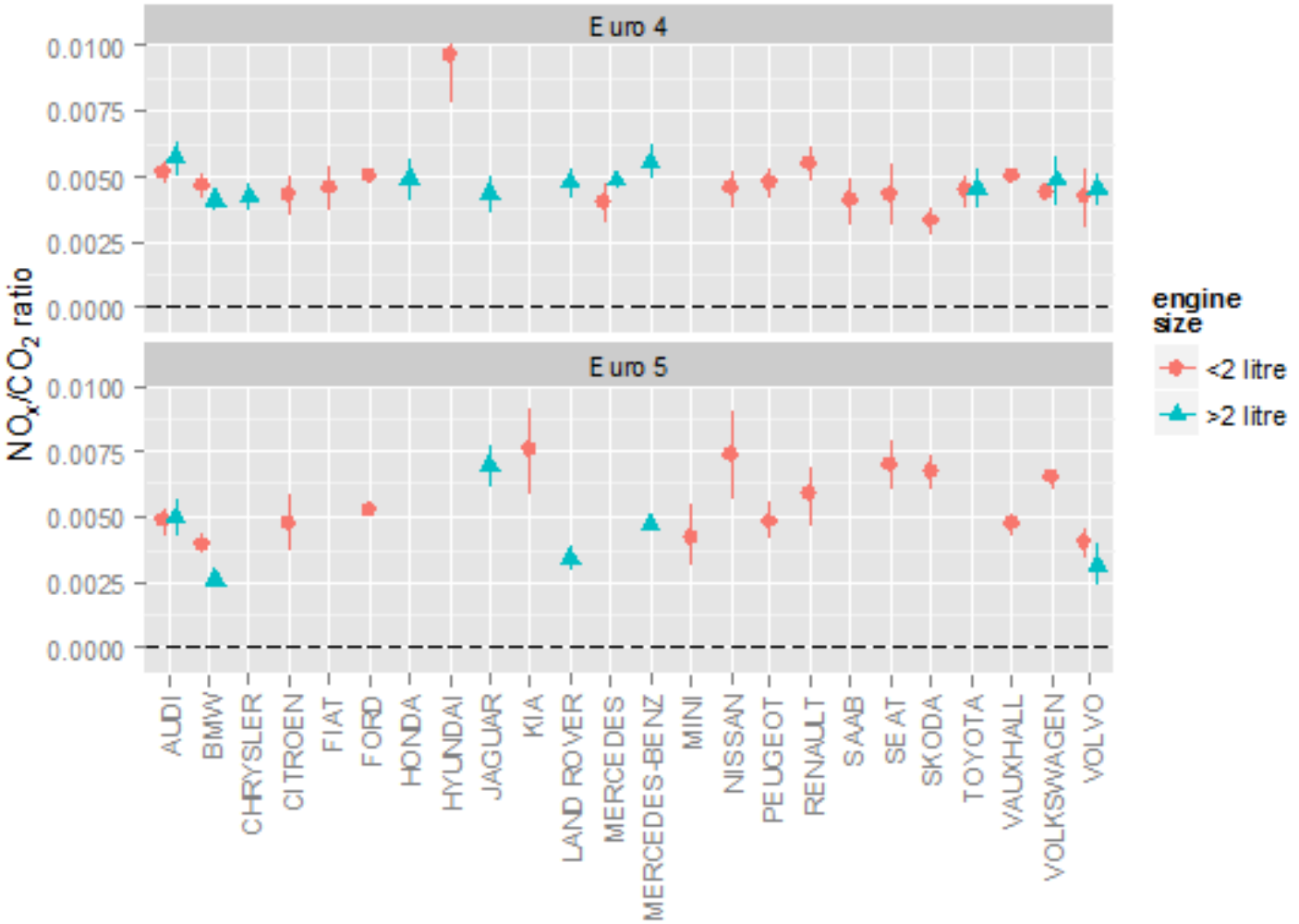


Passenger cars



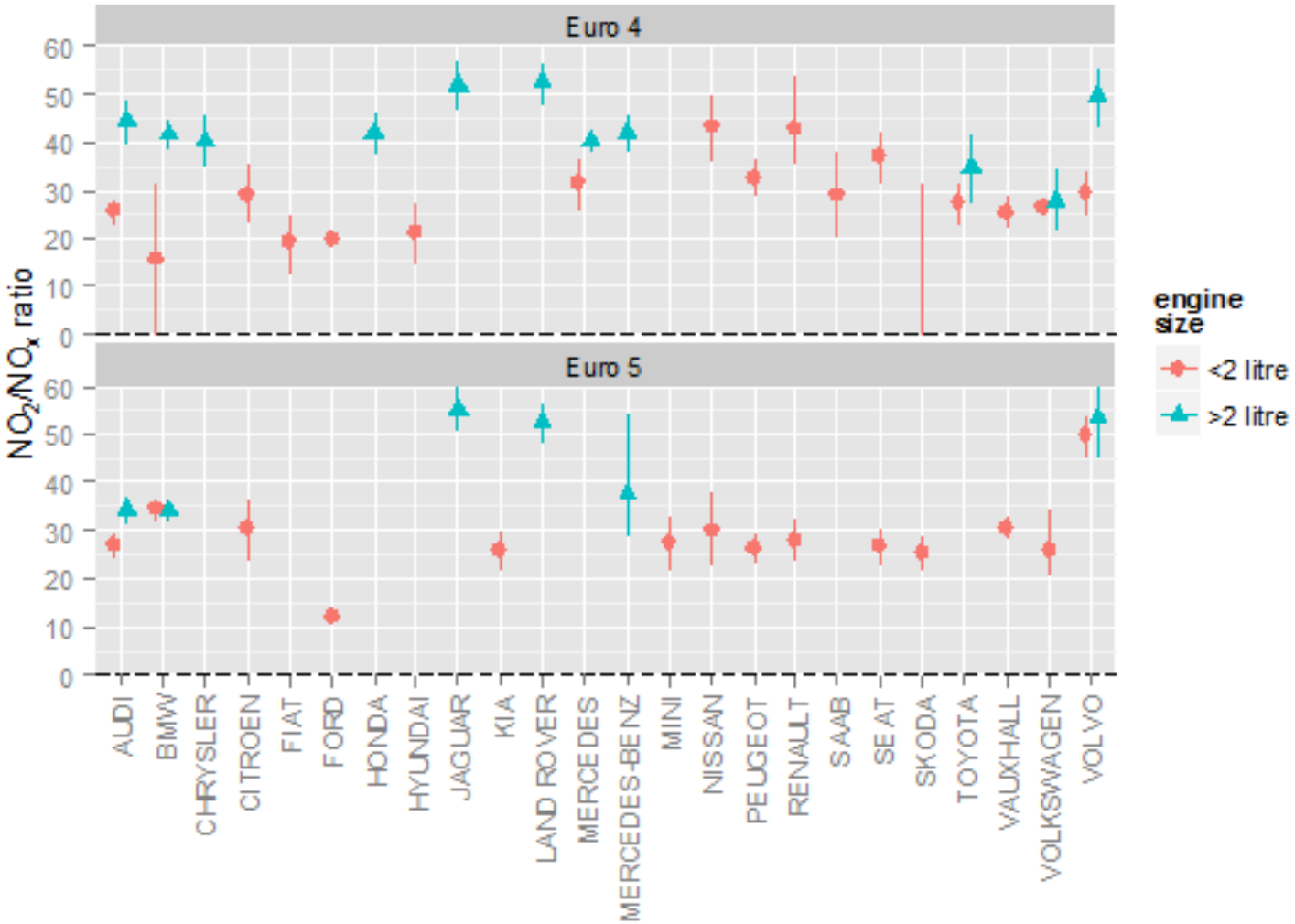
Passenger cars

Diesel passenger cars – Total oxides of nitrogen



Passenger cars

Diesel passenger cars – NO_2 / NO_x ratio

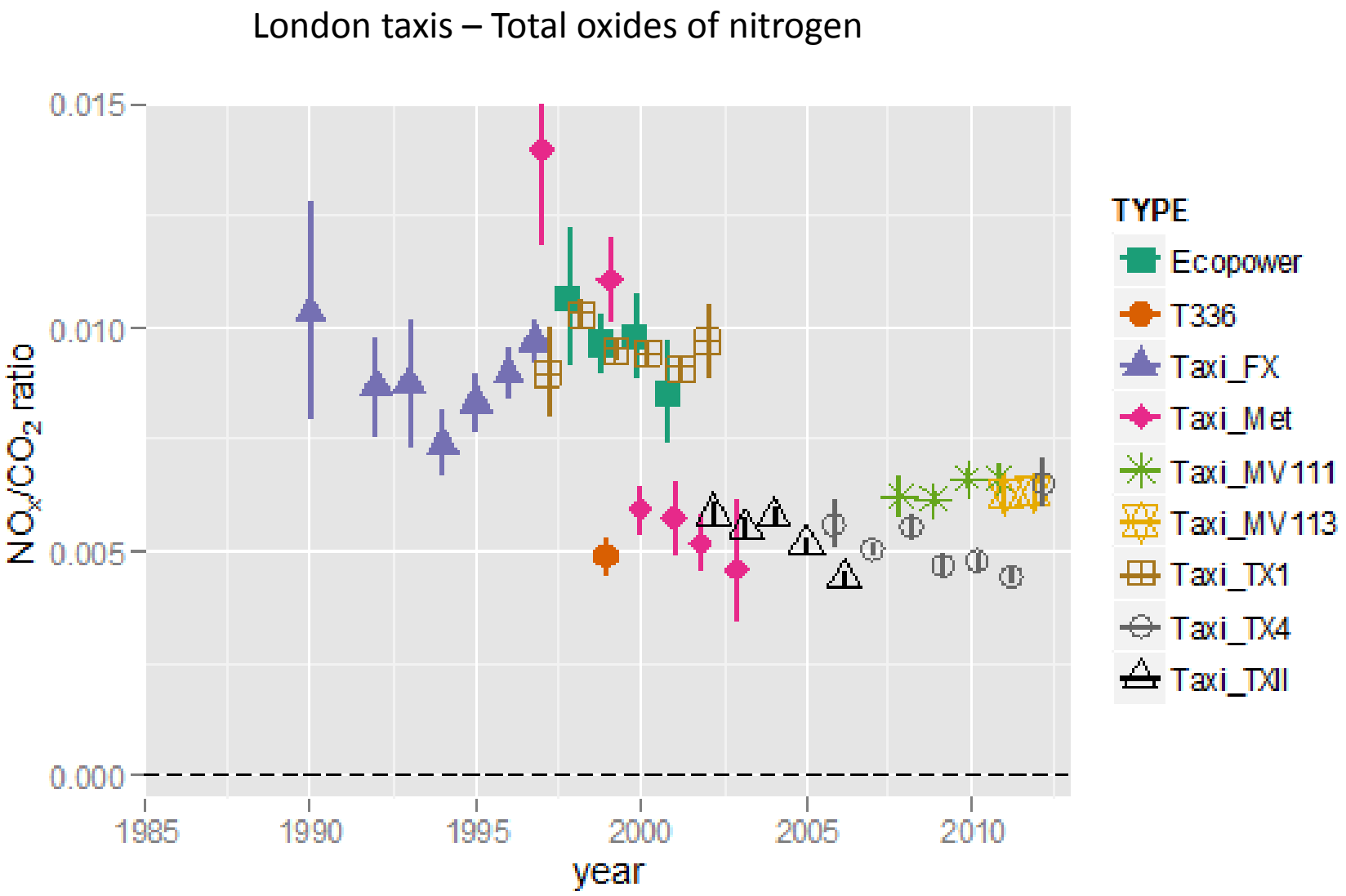


London taxis

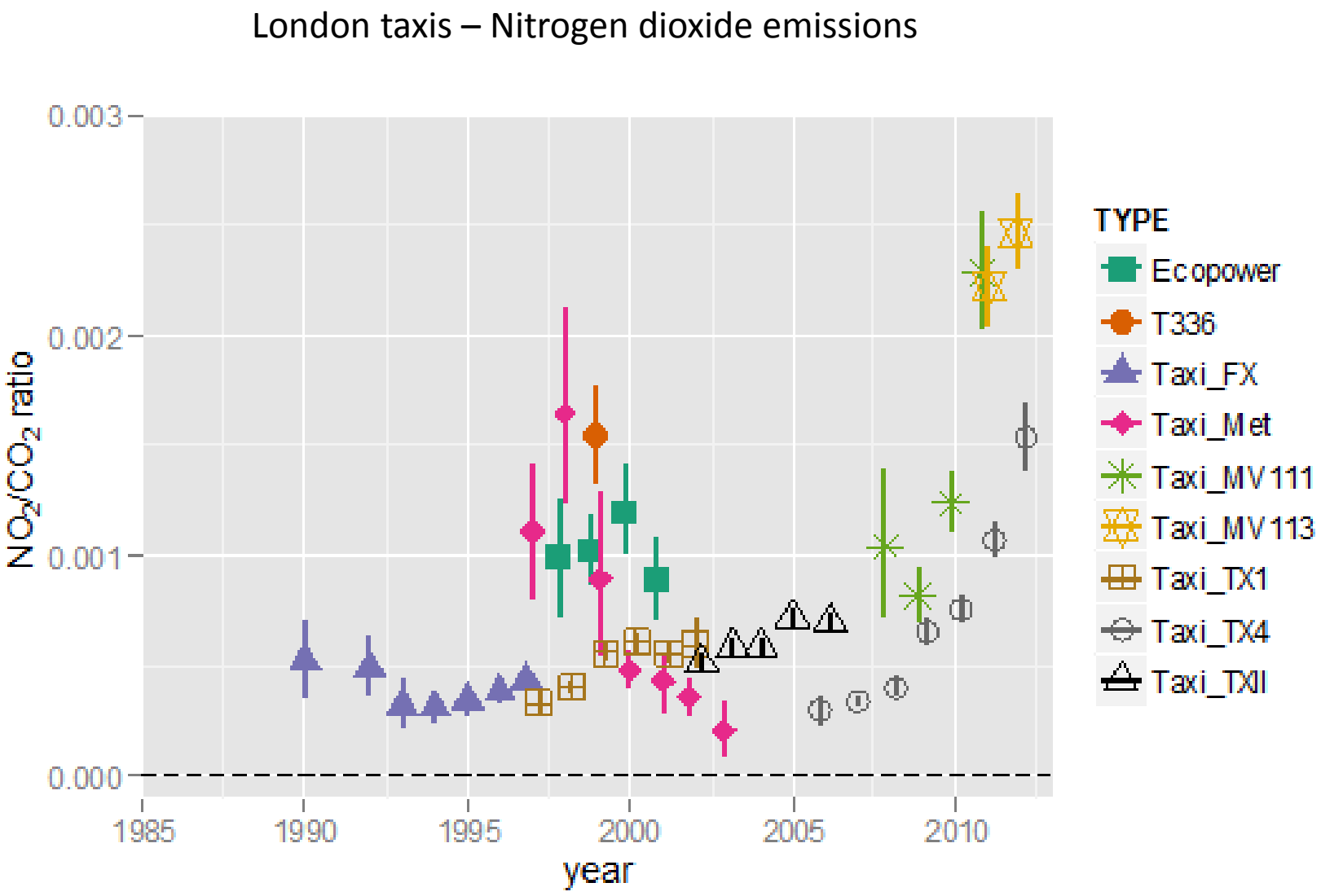
London Taxis (Black cabs)

Already required to be Euro 3 compliant for NO_x and particulates, either as built, or by retro-fitting of emissions control equipment

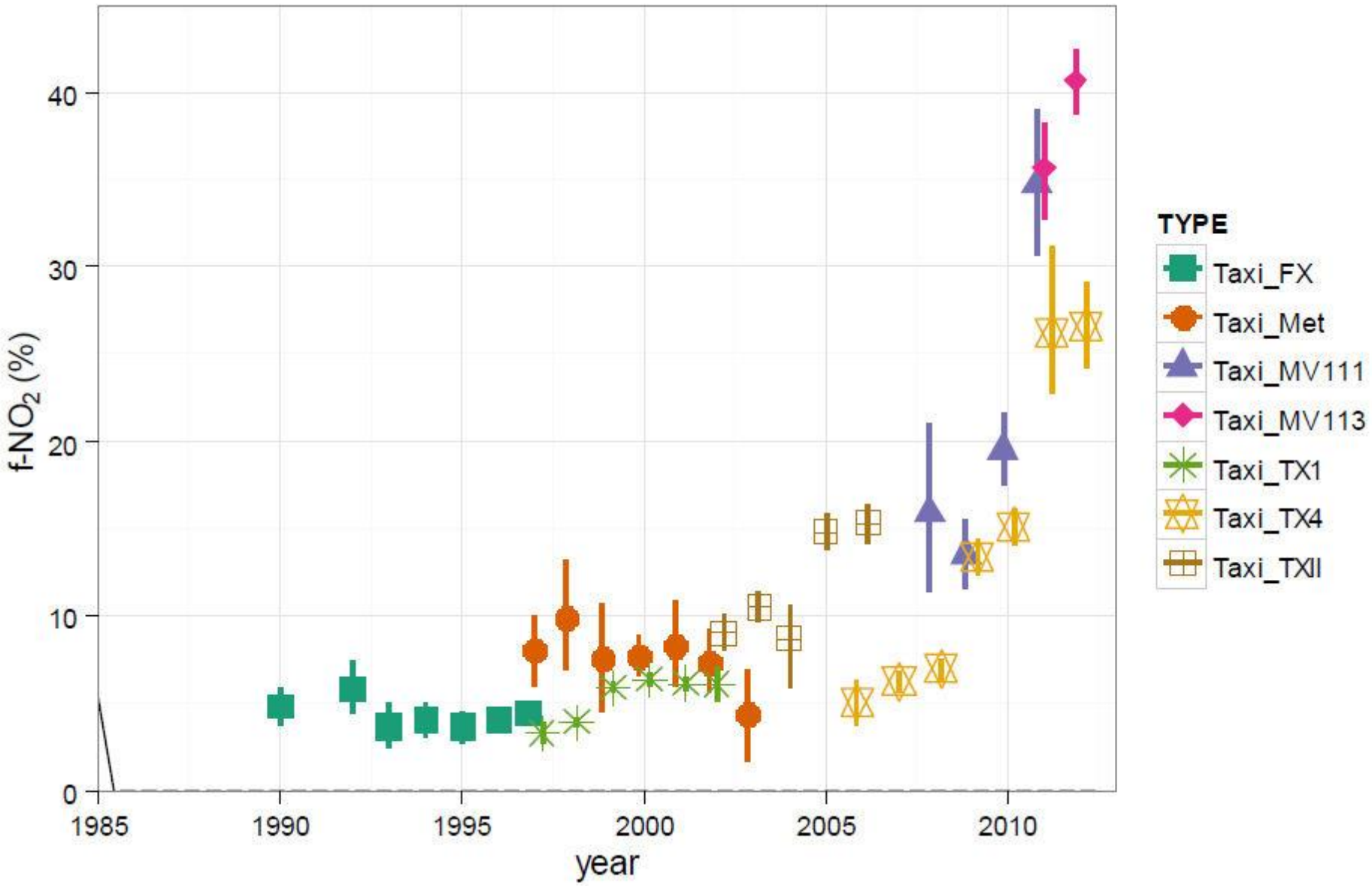
London taxis



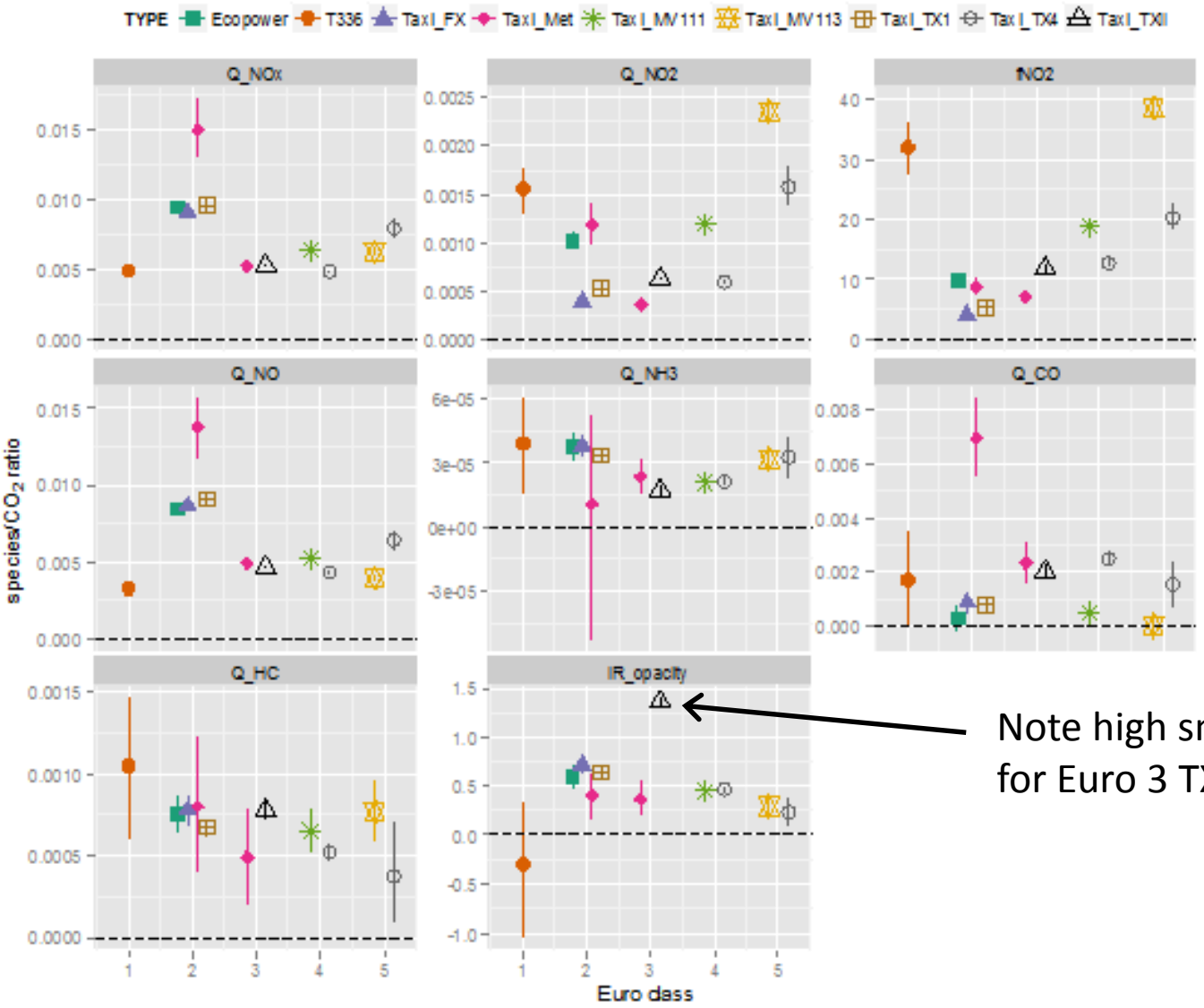
London taxis



London taxis – Observed f-NO2 (%)

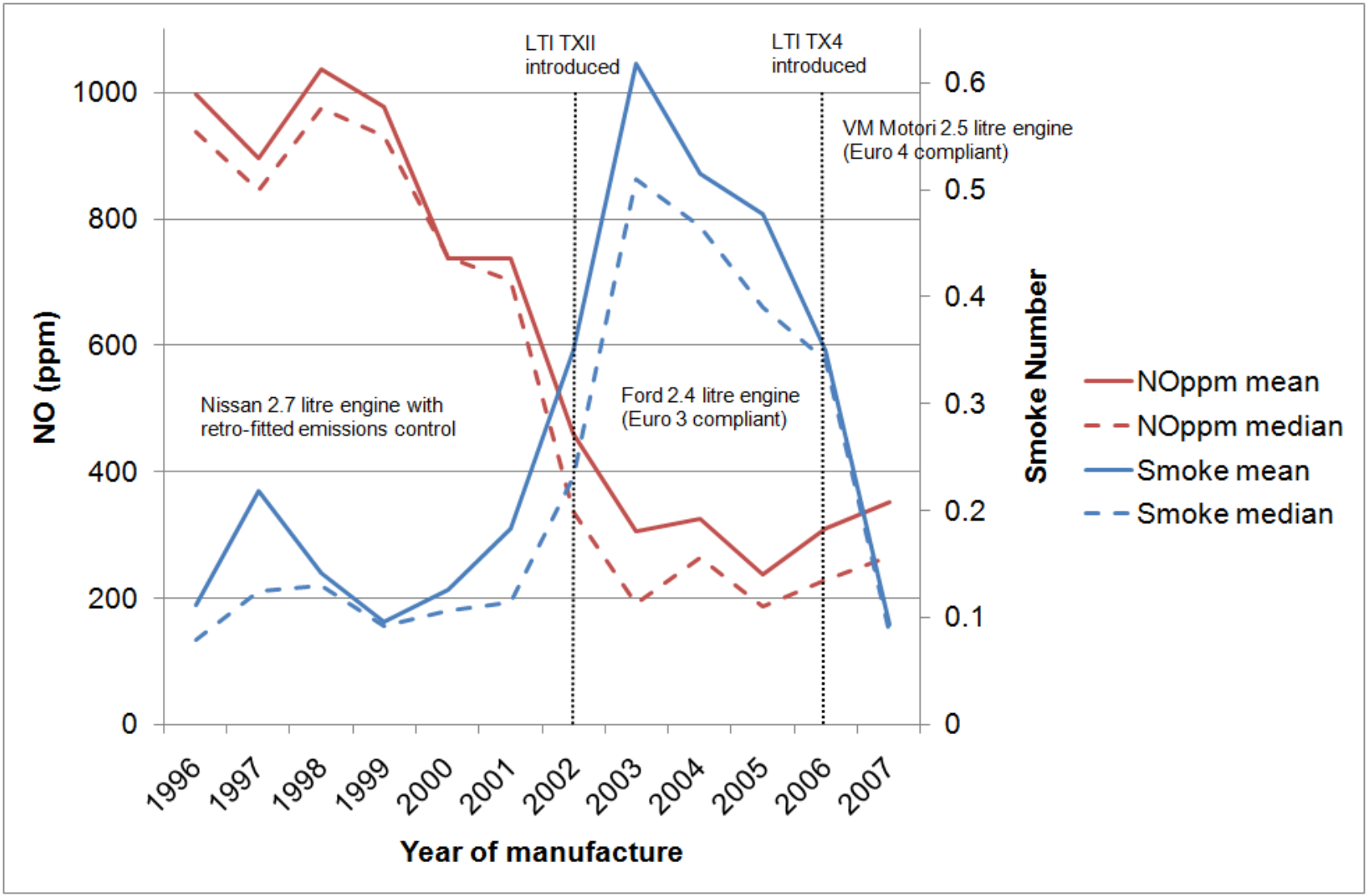


London taxis

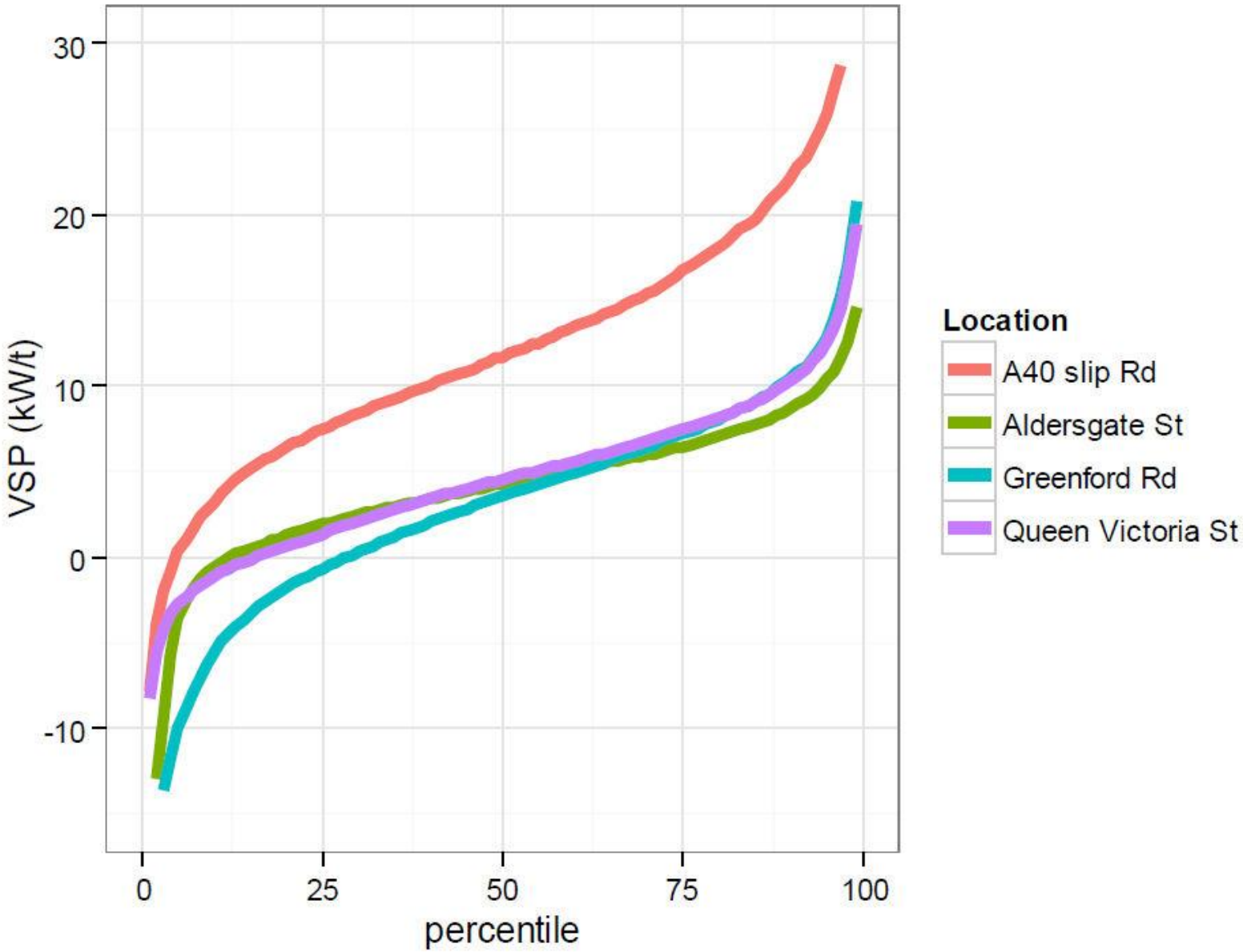


Note high smoke (IR opacity) for Euro 3 TXII taxi.

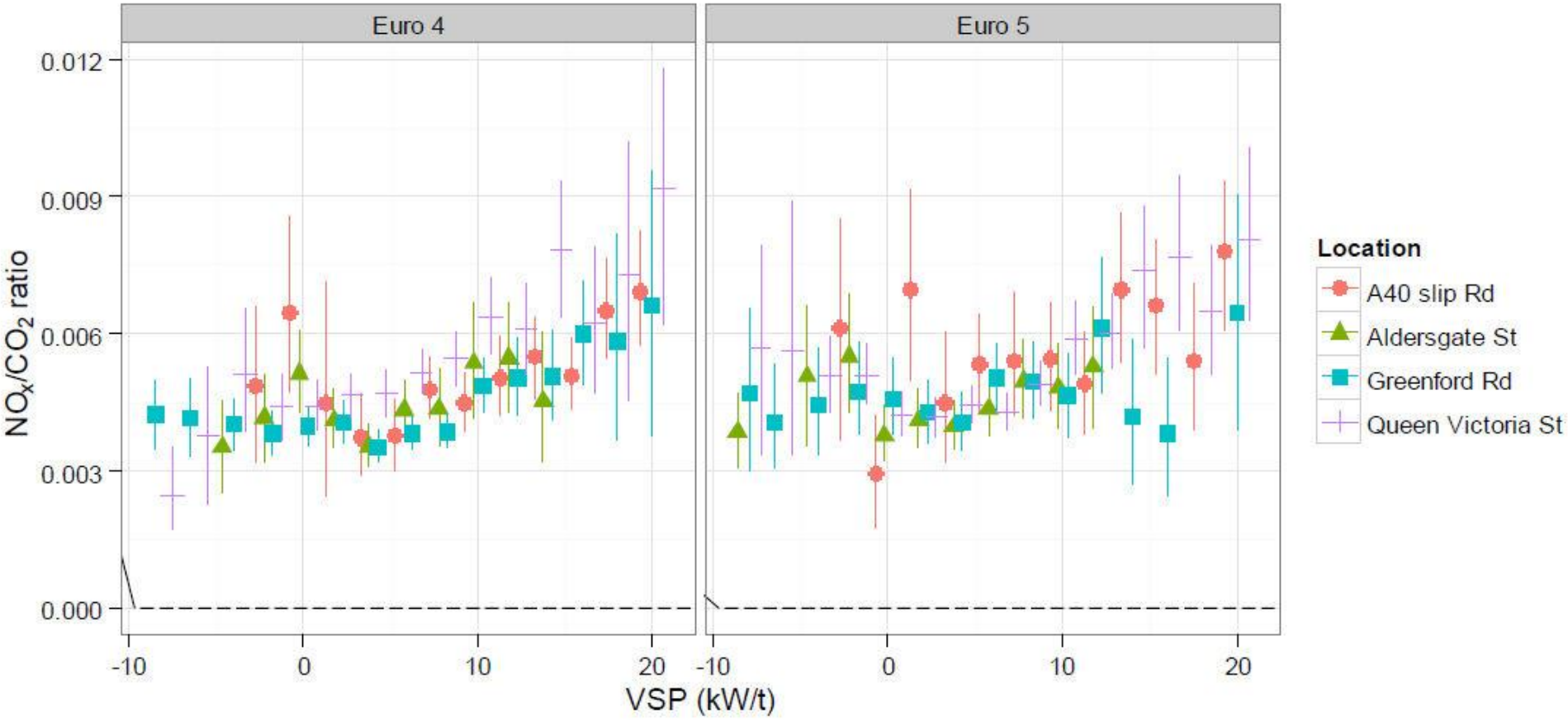
London taxis – Nitric oxide / smoke emissions (2008 data)



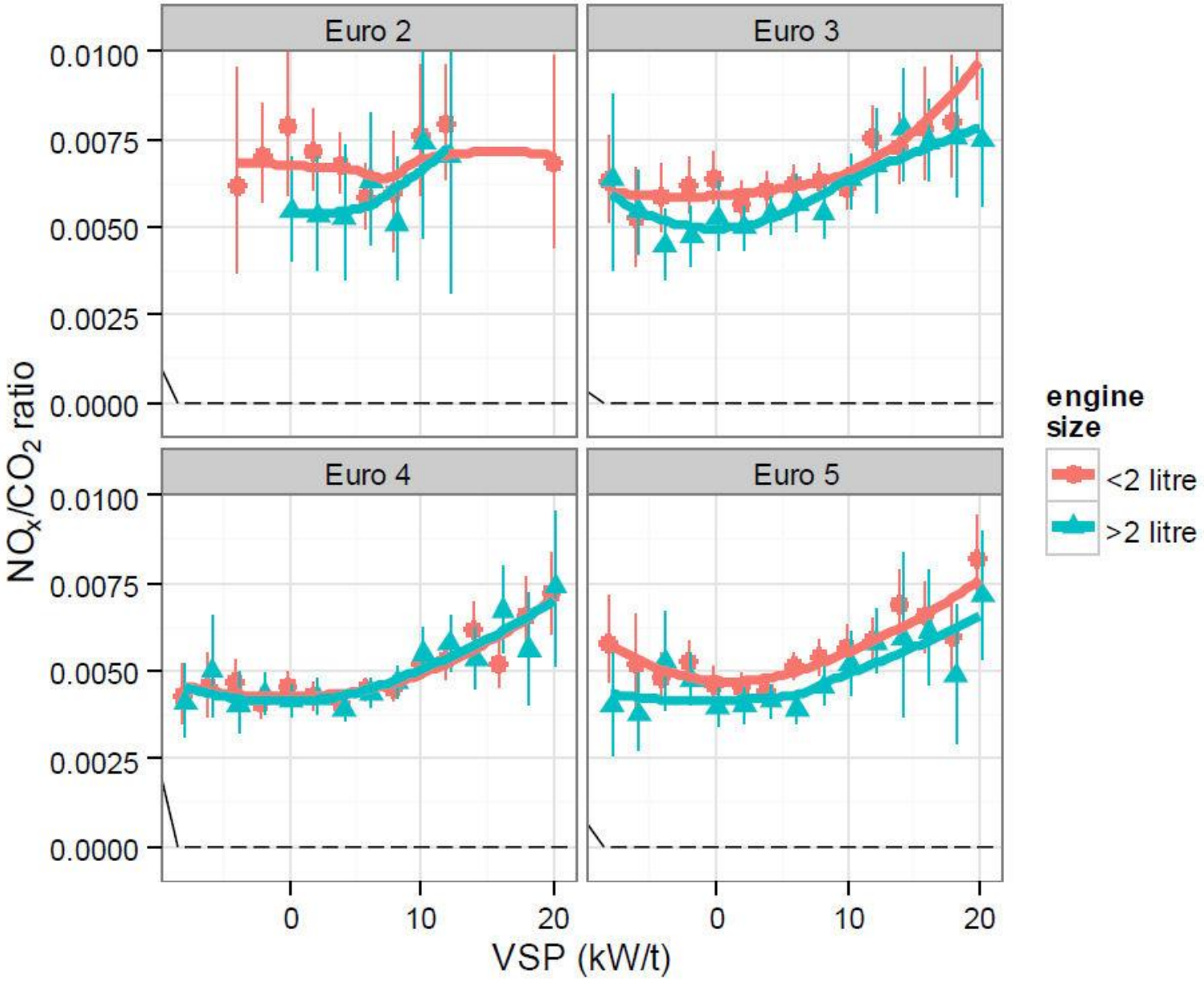
Variation in Vehicle Specific Power



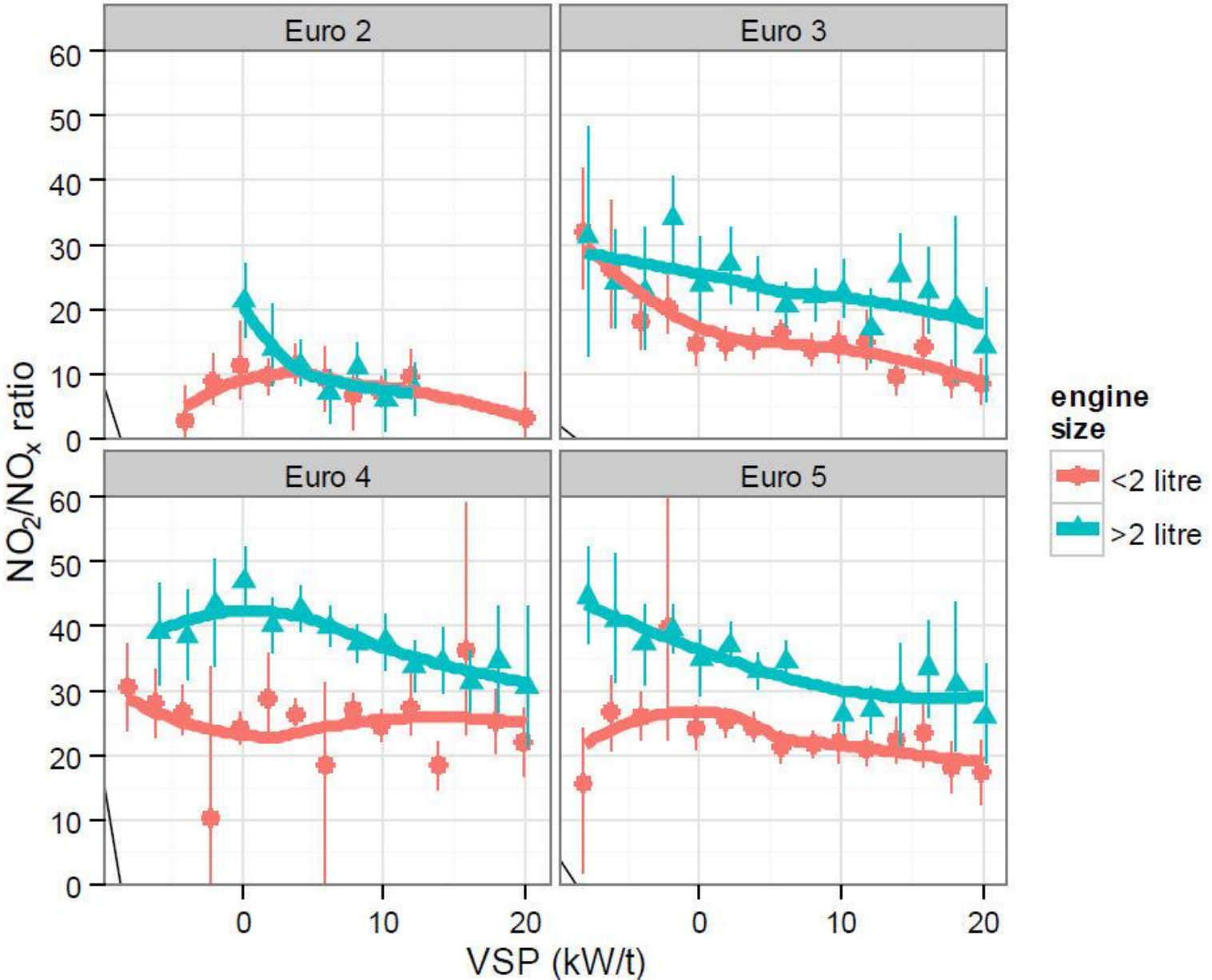
NO_x/CO_2 ratio by VSP by location



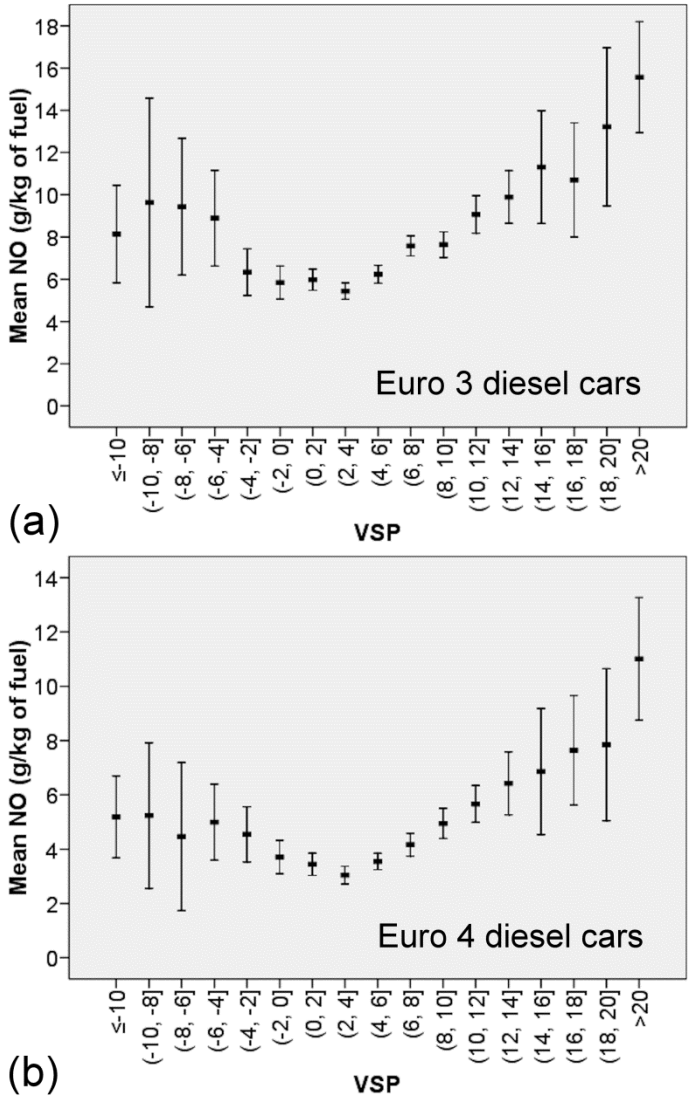
Diesel car – NO_x vs VSP



Diesel car – NO_2 vs VSP



Diesel car NO vs VSP



Nitric oxide (NO) emissions from Euro 3 and Euro 4 diesel cars, by VSP bin.

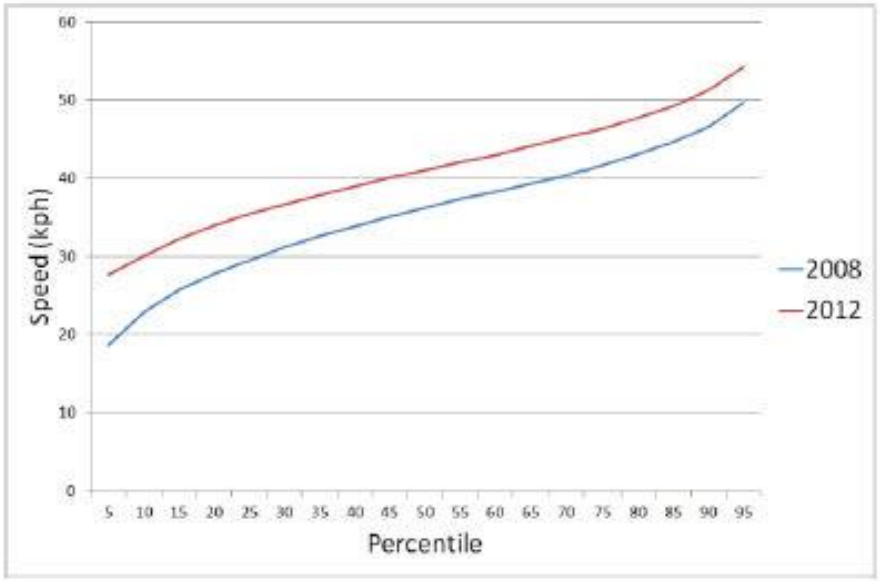
Data from remote sensing surveys carried out in London in 2008.

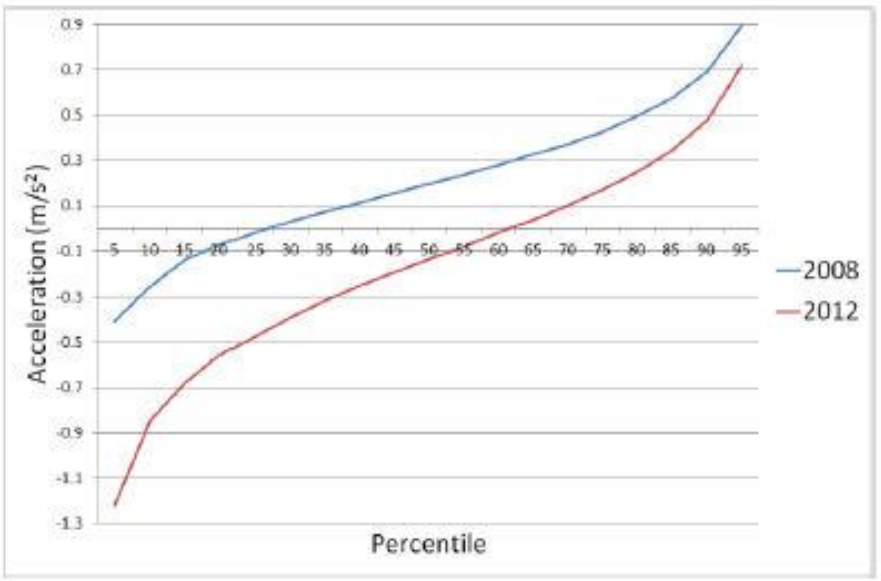
Clear relationship between VSP (kW/ton) and NO emissions for both groups of vehicles, but note difference in magnitude on 'y' axis.

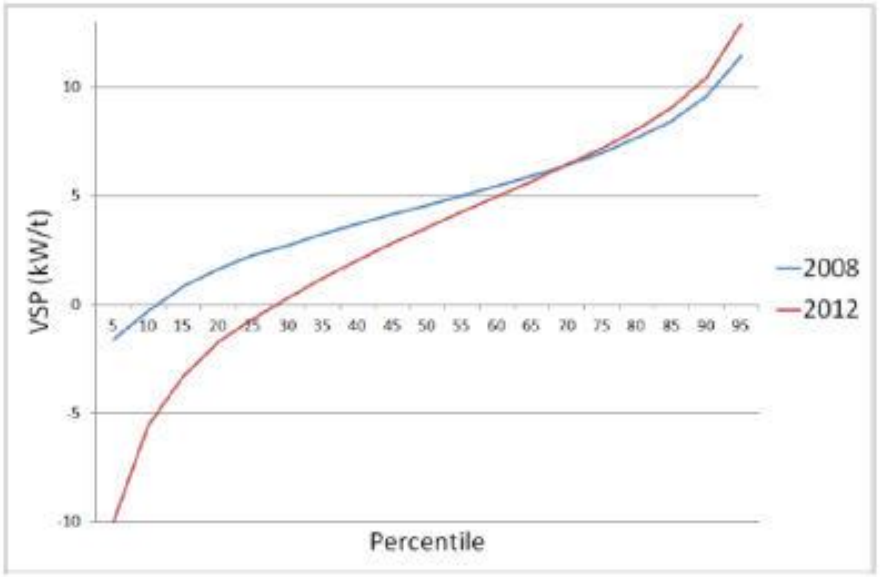
Implications for local traffic management? Opportunity to influence vehicle operation?

Source: Rhys-Tyler G.A., Bell M.C. Toward reconciling instantaneous roadside measurements of light duty vehicle exhaust emissions with type approval driving cycles. Environmental Science & Technology 2012, 46(19), 10532-10538

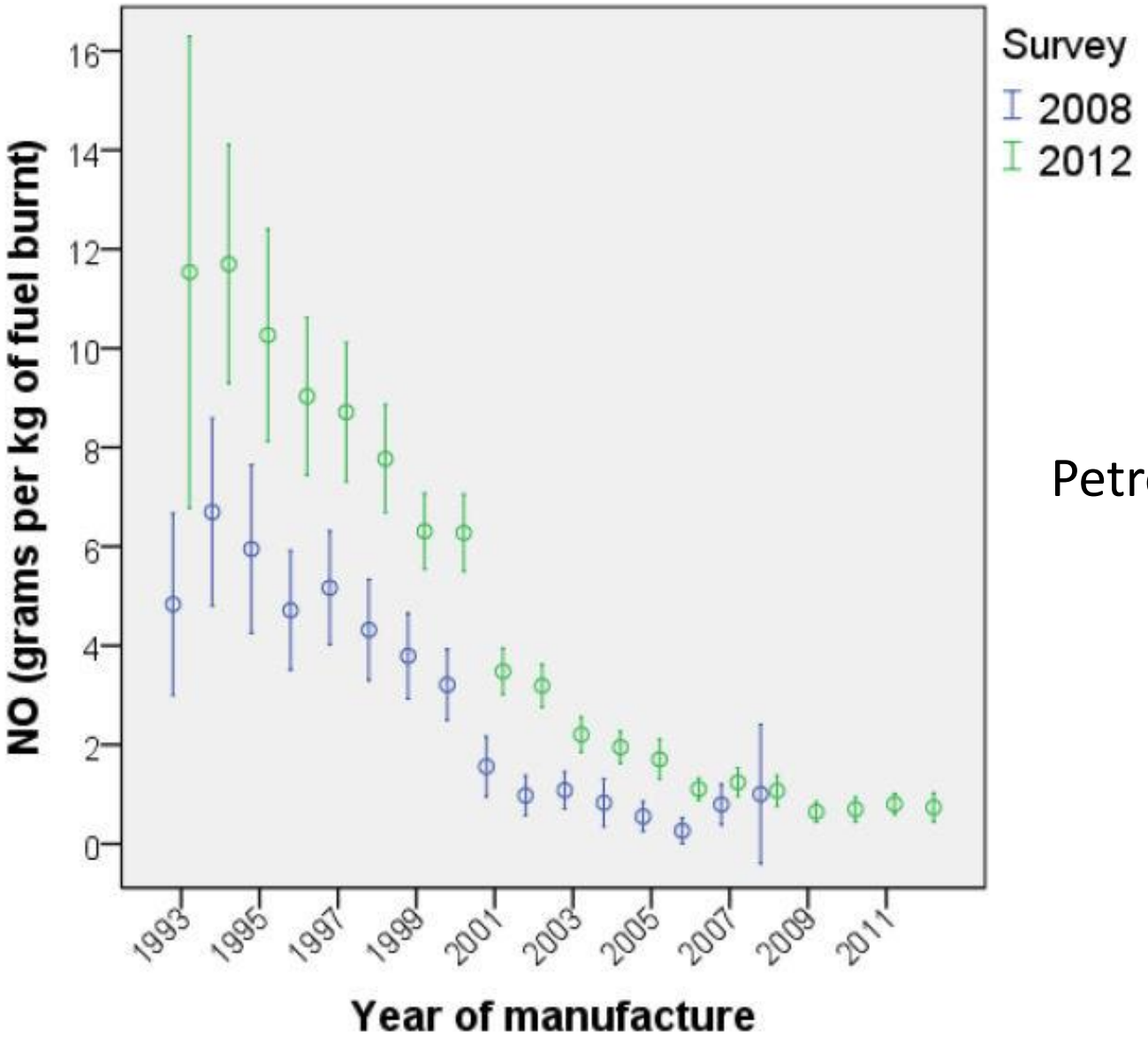
Inter-survey comparisons – Greenford Rd





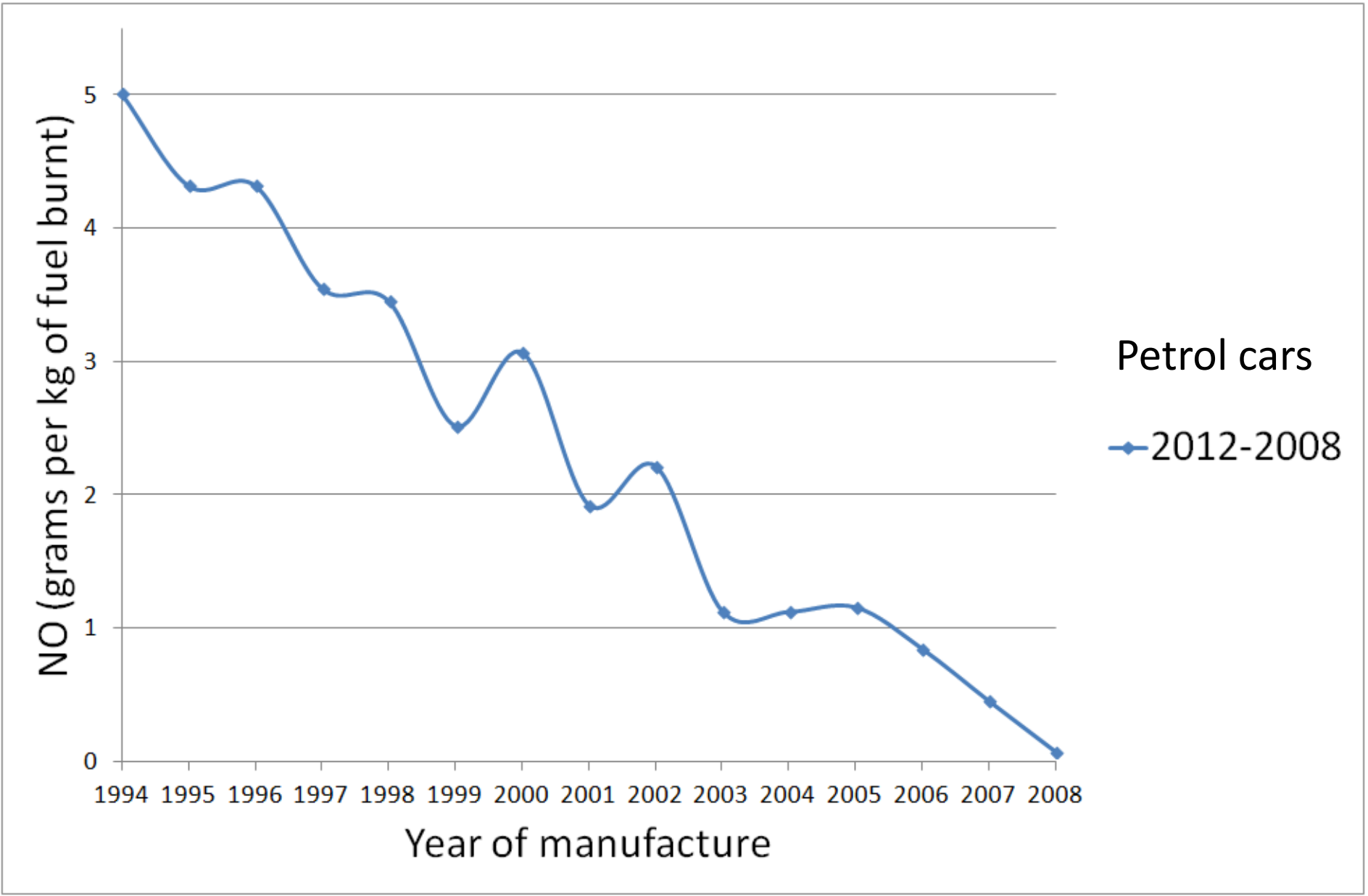


Inter-survey comparisons – Greenford Rd

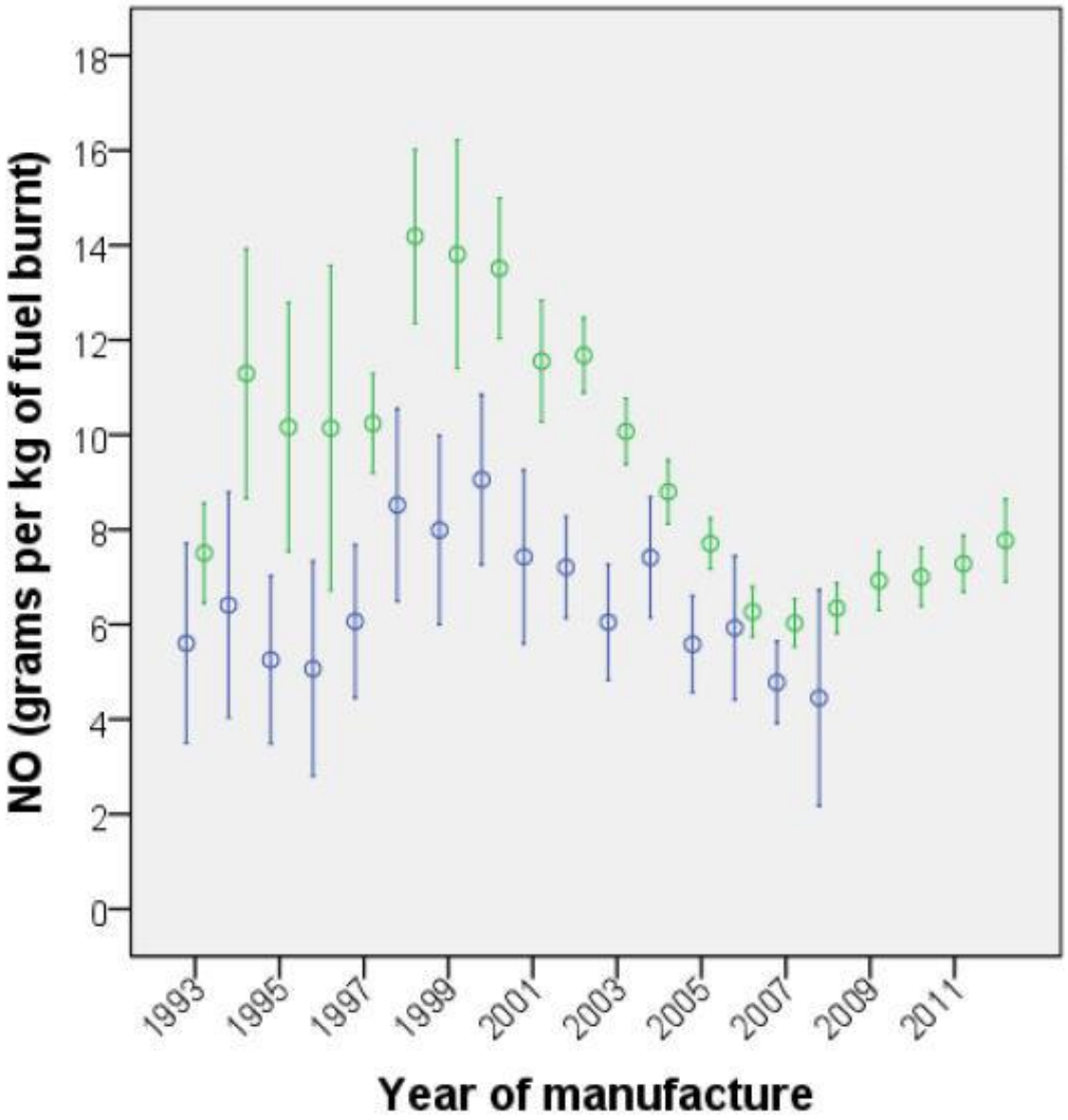


Petrol cars

Inter-survey comparisons – Greenford Rd

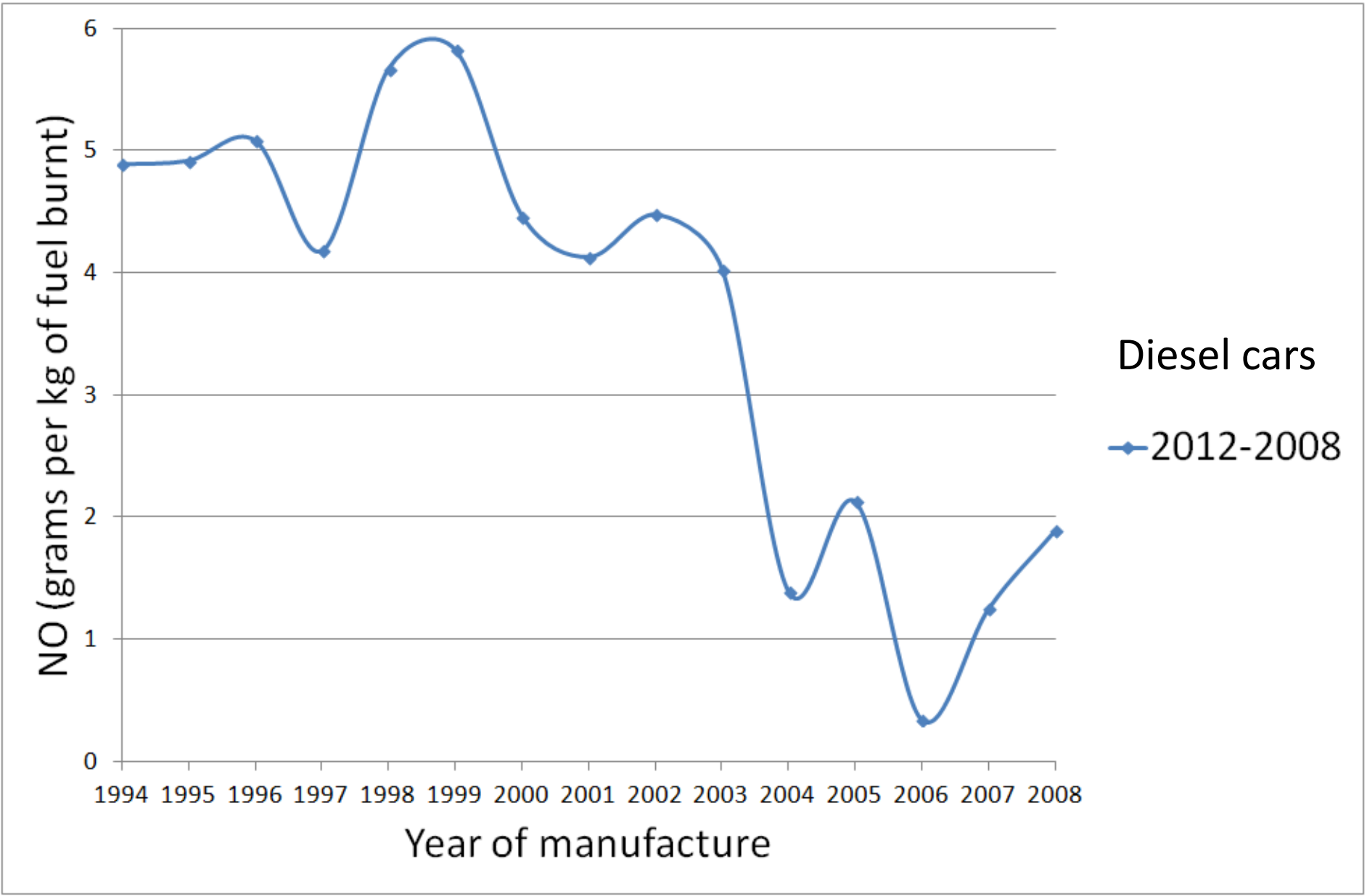


Inter-survey comparisons – Greenford Rd

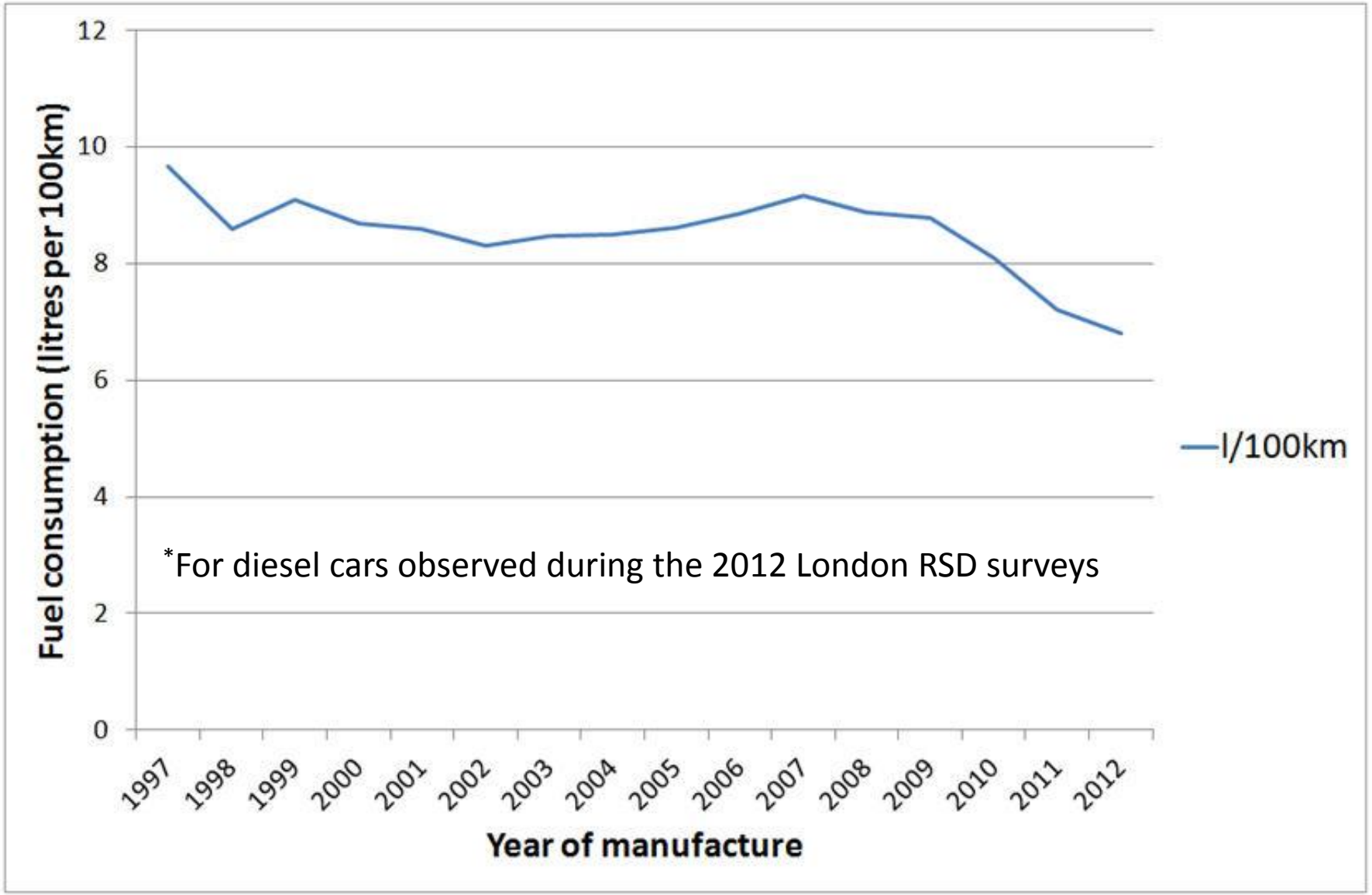


Diesel cars

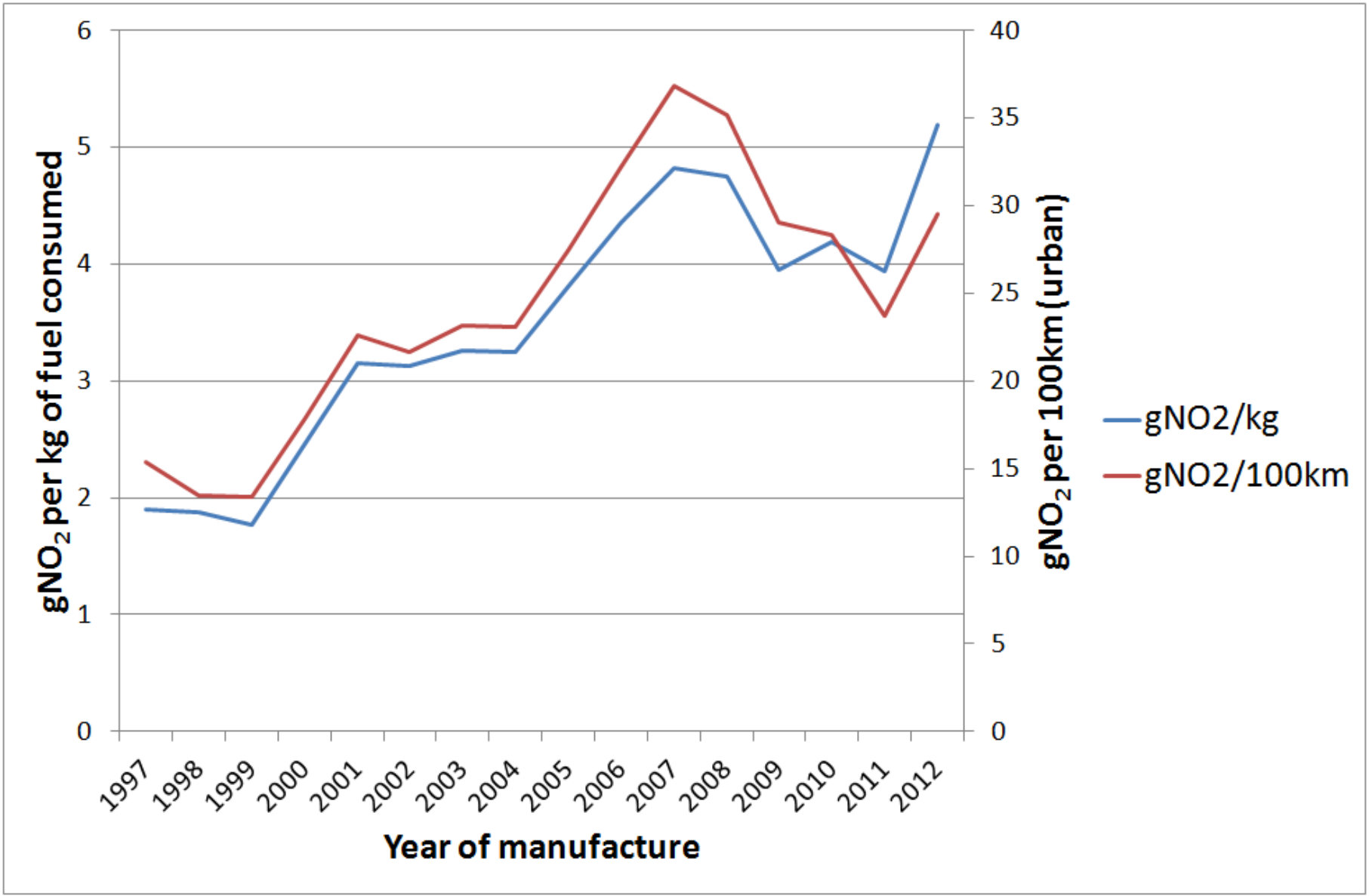
Inter-survey comparisons – Greenford Rd



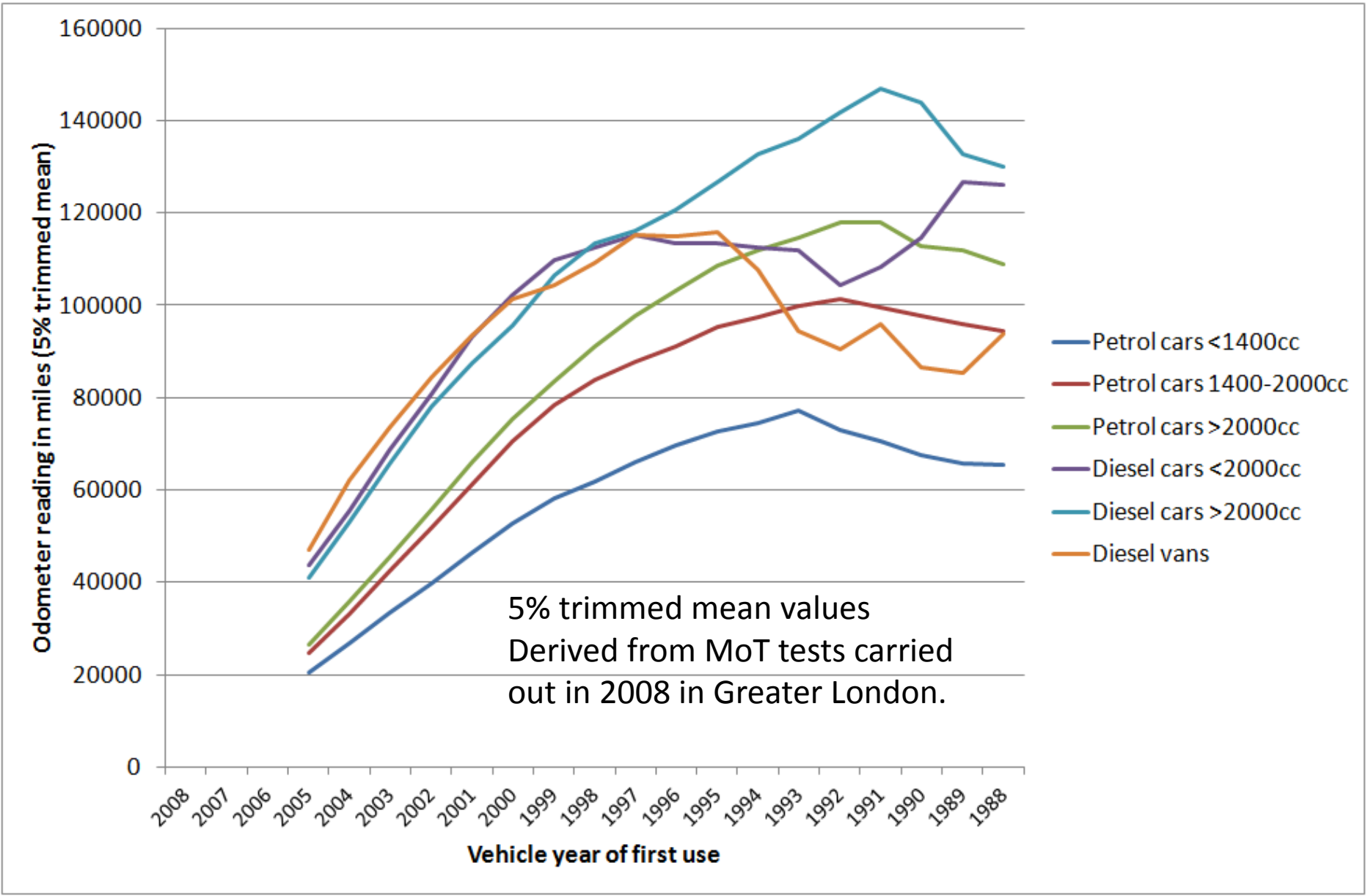
Diesel car urban fuel consumption (VCA data from NEDC tests)*



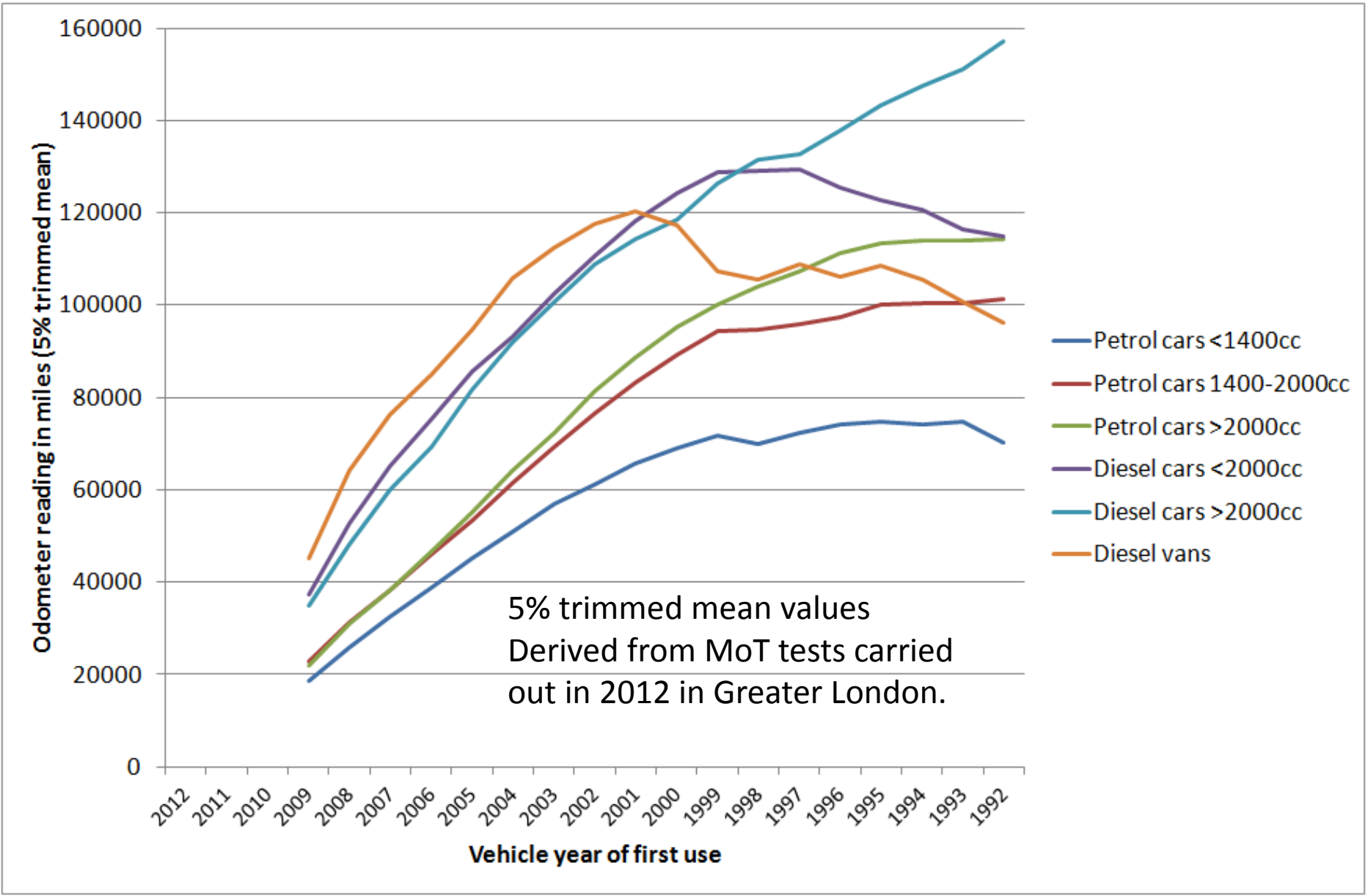
Diesel car primary NO_2 emissions adjusted for NEDC fuel consumption



Vehicle odometer data 2008



Vehicle odometer data 2012



Publications

Newcastle University

KING'S College LONDON

Remote sensing of NO_2 exhaust emissions from road vehicles

A report to the City of London Corporation and London Borough of Ealing

David Carslaw, King's College London

Glyn Rhys-Tyler, Newcastle University

Version: 16th July 2013

DEFRA Project Reference:

332c2011 (City of London Corporation)

334c2011 (London Borough of Ealing)

Ealing www.ealing.gov.uk

CITY OF LONDON

Atmospheric Environment 81 (2013) 339–347

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journal homepage: www.elsevier.com/locate/atmosenv

New insights from comprehensive on-road measurements of NO_X, NO_2 and NH_3 from vehicle emission remote sensing in London, UK☆

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HIGHLIGHTS

- First direct measurements of NO_2 and NH_3 using remote sensing in the UK.
- Selective catalytic reduction no better than non-SCR technology in reducing NO_x.
- Variations in NO_2 by vehicle technology, engine size and vehicle manufacturer.
- Comprehensive emission factor for NO_x, NO_2 and NH_3 for others to use.
- Important implications at a European level for meeting NO_2 limits.

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ABSTRACT

In this paper we report the first direct measurements of nitrogen dioxide (NO_2) in the UK using a vehicle emission remote sensing technique. Measurements of NO, NO_2 and ammonia (NH_3) from almost 70,000

More in preparation.....

Some challenges and opportunities

- Emissions of total NO_x from diesel cars are shown to peak for cars manufactured in 2000, decrease by about a third to 2005, but then gradually increase to 2012 (***currently on upward trajectory***);
- f-NO_2 from diesel cars has increased from around 10-15% for Euro 3 and older technologies up to an average of almost 30% for Euro 4/5 technologies (but less than the 55% previously estimated). However, this hides significant variability by manufacturer and engine size / technology (***opportunity?***);
- Diesel light goods vehicles (N1) were observed to emit between 4% and 9% more total NO_x than the equivalent diesel passenger cars. They emit similar proportions of f-NO_2;
- Newer London taxis (2011 & 2012) emit higher levels of f-NO2 (25% to 40+%) than older taxis (5% to 15%);
- Results for TfL buses are variable. Ideally, need to resurvey post TfL SCR retrofit campaign to assess impact.

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- Colin Oates (lead RSD technician) and Enviro Technology who organised use of RSD in the UK
- Camilla Ghiassee (now at Public Health England)
- Transport for London – for permission to survey on the A40
- Finn Coyle (TfL) for bus information

Thank you

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References

- Rhys-Tyler G.A., Legassick W., Bell M.C. (2011). The significance of vehicle emissions standards for levels of exhaust pollution from light vehicles in an urban area, Atmospheric Environment, Volume 45, Issue 19, June 2011, Pages 3286-3293, http://dx.doi.org/10.1016/j.atmosenv.2011.03.035
- Rhys-Tyler G.A. and Bell M.C. (2012). Toward reconciling instantaneous roadside measurements of light duty vehicle exhaust emissions with type approval driving cycles. Environmental Science & Technology, 46(19), 10532-10538. http://pubs.acs.org/doi/abs/10.1021/es3006817. To view the full paper see http://pubs.acs.org/articlesonrequest/AOR-Dwwp8izvGJF8vx9TY7y5 (registration required).
- Carslaw D. and Rhys-Tyler G. (2013). Remote sensing of NO_2 exhaust emissions from road vehicles. Department for Environment Food and Rural Affairs (DEFRA). http://uk-air.defra.gov.uk/library/reports?report_id=754
- Carslaw, D.C., Rhys-Tyler, G. (2013). New insights from comprehensive on road measurements of NO_x, NO_2 and NH_3 from vehicle emission remote sensing in London, UK, Atmospheric Environment, Volume 81, Pages 339–347, http://dx.doi.org/10.1016/j.atmosenv.2013.09.026 (open access)
- Presentation to APRIL (Transport sub-group), July 2011. http://www.april-network.org/transport_and_noise/documents/050711_Rhys_Tyler_Presentation.pdf