# Talk title: The London Low Emission Zone
Author; Sean Beevers

**Summary**

The London Low Emission Zone (LEZ) covers the whole of Greater London and was introduced by the Greater London Authority (GLA) in February 2008 (phase 1 of the scheme). Phase 2 began in July 2008. The first 2 steps required all Heavy Goods vehicles (HGVs) and Buses to comply with EURO 3 emissions standard for $PM_{10}$. As such it is too early to report on the actual changes in air quality and so this summary is limited to looking at the methods used to assess the LEZ prior to its introduction, outlining the monitoring strategy for the LEZ and summarising the additional research being undertaken in support of the LEZ.

The motivation for the LEZ was the widespread exceedences of EU limit values and UK National Air Quality Objectives, including the annual mean $NO_2$ standard (40 $\mu g\ m^{-3}$) as well as exceedences of the annual mean $PM_{10}$ standards of (40 $\mu g\ m^{-3}$ and 23 $\mu g\ m^{-3}$), although the latter standard no longer exists. Finally there is also widespread exceedence of daily $PM_{10}$ standard of 50 $\mu g\ m^{-3}$ not to be exceeded for more than 35 days in a calendar year. As such $PM_{10}$ air quality was the focus of the scheme, although benefits were also sought for $NO_2$ as well as avoiding increases in $CO_2$ emissions.

The key aim of the LEZ is to improve air quality and public health by encouraging improvements to the emissions performance of heavier vehicles (goods vehicles, buses and coaches) travelling in London, and is a key part of wider policies being pursued by the Mayor of London as set out in his Air Quality Strategy[1].

To ensure that the impact of the LEZ is well understood a monitoring strategy has also been put in place with the aim of:

- Characterising the LEZ impacts;
- Understanding the impacts rather than simply measuring them;Contributing to wider scientific understanding of the air quality science associated with the scheme.

The assessment of the scheme was undertaken using emissions/dispersion modelling techniques, the results of which were used to assess population exposure and health damage costs. The basis of the assessment was the London Atmospheric Emissions Inventory (LAEI)[2]. Predictions were made for future years 2008, 2010 and 2012 looking at numerous strategies for reducing emissions from ‘in-scope’, heavy goods vehicles, large vans and buses. Compliance with the scheme could result in the adoption of various strategies from the vehicle operators included fitting vehicles with new engines, buying newer vehicles, swapping vehicles within existing fleets across the UK and fitting exhaust technology. As such the effects of the LEZ are predicted to go well beyond Greater London and into the whole of the UK.

[1] http://www.london.gov.uk/mayor/strategies/air_quality/air_quality_strategy.jsp
[2] http://www.london.gov.uk/mayor/environment/air_quality/research/emissions-inventory.jsp

Results from the LAEI showed that especially for PM emissions 'in-scope' vehicles, i.e. those affected by the introduction of the LEZ represented approximately 20-30% of HGVs and approaching 40% of coaches in 2007/08 and that these vehicles had a significant contribution to total vehicle emissions. Forecast emissions changes varied by year and resulted in reductions of 3-10% of $PM_{10}$ and $NO_X$ without increasing $CO_2$ to any significant degree. From these results, population exposures to concentrations above EU limit values were reduced significantly. Reductions of approximately 10% for annual mean $NO_2$ and 7% for annual mean $PM_{10}$ were typical in 2008.

Two approaches were used to calculate the health damage costs of the LEZ scheme and these were based upon the UK method (proposed by the Department for Environement, Food and Rural Affairs, DEFRA[3]) and that proposed for the EC as part of the CAFÉ programme, the latter accounting for a wider range of health impacts. The benefits of the scheme were calculated at between £200 - 420 million, for the UK and EC methods, respectively. It is notable that the benefits were not solely associated with London but also in the rest of the UK and also that air pollution benefits far outweighed other impacts such as SocioEconomic, noise and road safety.

A number of important features of air quality in London limit the impact that any traffic management project can have and this includes the contribution of 'other' sources, mainly long range transport of secondary PM aerosol into London, which dominates the annual mean $PM_{10}$ concentrations. Its notable that for $NO_X$ the opposite is true and that the vast majority is from London itself. However it is also notable that trends in $PM_{10}$ since 2000 have shown no obvious downward trajectory (Fuller and Green, 2006) and that this is at odds with the emissions inventories which show a gradual decline. The reason for this is not immediately apparent. Some of the methods used to tackle the LEZ were associated with fitting particle filters on vehicles and in doing so the potential to increase the emissions of primary $NO_2$ were apparent. Primary $NO_2$ has been the subject of a number of publications (AQEG 2007, Carsalw and Beevers 2004 and 2005) and this knowledge has lead to the creation of the first primary $NO_2$ emissions inventory ($NO_2$p) in London.

The monitoring programmes have begun and are based upon the measurement sites of the London Air Quality Network (LAQN) but especially 7 LEZ 'Supersites' some of which belong to the LAQN and others which were established for the LEZ. Each site was upgraded with additional monitoring equipment and included species such as particle counts, black carbon measurements, roadside $O_3$ (for estimating NO2p), $PM_{2.5}$ and FDMS $PM_{10}$. From these data new source apportionment techniques are being used, including 'Polar plots' to identify the source characteristics of the measurements but also the examination of a number of measurement time series. These include Elemental Carbon from aethalometer measurements, speciation of PM including EC/OC, ions and metals as well as statistical analysis of the 'Supersite' measurement time series. The latter work is aimed at removing the meteorological signal from the measurements using Generalised Additive Modelling (GAM) techniques and in doing so to identify more clearly the LEZ signal.

[3] http://www.tfl.gov.uk/assets/downloads/roadusers/lez/LEZ-Health-Impact-Assessment-November-2006.pdf

In addition use will be made of Automatic Number Plate Recognition (ANPR) data to measure the 'on-road' vehicle stock and use these data within the emissions modelling work to more accurately assess the LEZ impacts. Finally, measurements of Oxidative Potential are being undertaken to look at spatial and temporal differences in the toxicity of PM samples taken during the campaign. To maximise our potential to observe the anticipated decreases in the oxidative potential of ambient $PM_{10}$ and $PM_{2.5}$, in association with altered traffic densities and vehicle mix following the introduction of the LEZ, we established a detailed pre-implementation measurement campaign. This entailed an assessment of the intrinsic oxidizing properties of London PM, with a specific focus on the contribution of traffic derived components. By using a synthetic RTLF model (Mudway et al, 2004) we obtained an integrative summary of the activity of the redox-active components associated with PM, whilst use of a simplified ascorbate only model, with or without metal chelators, enabled us to dissect out the relative contributions of metals and organic radicals to the oxidative signal.

Finally the work undertaken in the LEZ study has opened up a number of opportunities for analysing, not only the impacts of the LEZ in London, but also the benefits of other policies affecting exposure of the population to vehicle emissions. London resembles many international cities in terms of its, population demographics and health status, as well as its ambient PM concentrations. The results arising from this accountability research are therefore of relevance to international public health, and may provide a model for the implementation and analysis other such schemes that will undoubtedly follow.

References

Fuller GW, Green D. 2006. Evidence for increasing primary $PM_{10}$ in London. Atmos Environ 40:6134-6145.

Air Quality Expert Group (AQEG). 2007. Trends in primary Nitrogen Dioxide in the United Kingdom. Report prepared for Department for Environment, Food and Rural Affairs, Scottish Executive, Welsh Assembly Government and Department of the Environment in Northern Ireland.

Carslaw DC, Beevers SD. 2004. Investigating the potential importance of primary $NO_2$ emissions in the street canyon. Atmos Environ 38:3585-3594.

Carslaw DC, Beevers SD. 2005. Estimates of road vehicle primary $NO_2$ exhaust emission fractions using monitoring data in London. Atmos Environ 39:167-177.

Mudway IS, Stenfors N, Duggan ST, Roxborough H, Zielinski H, Marklund SL, Blomberg A, Frew AJ, Sandstrom T, Kelly FJ. 2004. An in vitro and in vivo investigation of the effects of diesel exhaust on human airway lining fluid antioxidants. Arch Biochem Biophys 423:200-212.




# The London Low Emission Zone

Sean Beevers, ERG, King's College, London




# Talk summary

Methods employed to assess the LEZ;

Monitoring of the LEZ;

Additional research in support of the LEZ.


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# Motivation for the LEZ

Widespread exceedences of the annual $NO_2$ standard in London;

$PM_{10}$: Central London roadside > 40 μg $m^{-3}$ but widespread exceedence of the 23 μg $m^{-3}$ (R.I.P);

Number of days > 50 μg $m^{-3}$ ?? (VCM) (very year dependent)




# Key aims of the LEZ

The first phase of which was introduced successfully on 4 February 2008 (second phase in July 2008);

The LEZ is intended to improve air quality and public health by encouraging improvements to the emissions performance of heavier vehicles (goods vehicles, buses and coaches) travelling in London;

The LEZ is a key part of wider policies being pursued by the Mayor of London as set out in his Air Quality Strategy.

## The aims of monitoring

The monitoring work is aimed at characterising the LEZ impacts;

The monitoring should seek to understand as well as simply measure;

The scope of the monitoring should contribute to wider scientific understanding of the air quality science associated with the scheme.




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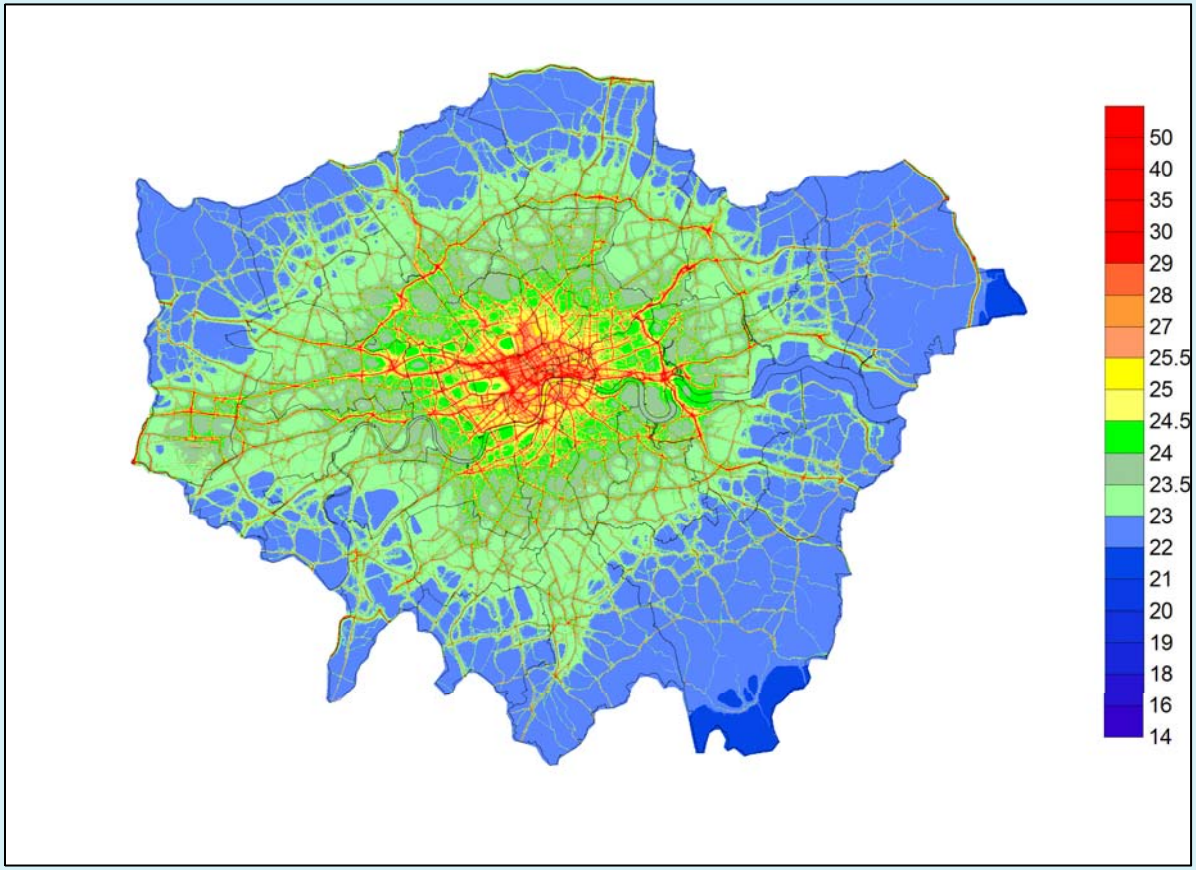
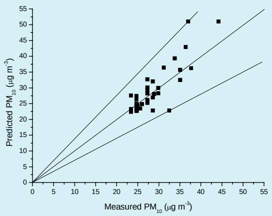
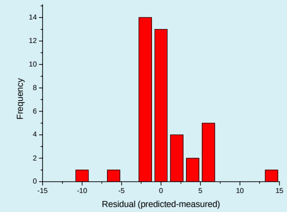
# London $PM_{10}$ concentrations and LEZ area.

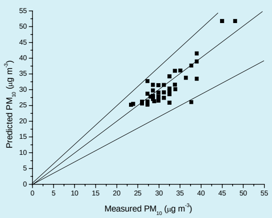


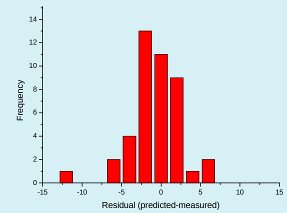




Annual Mean $PM_{10}$ 2003 ($\mu g\ m^{-3}$)

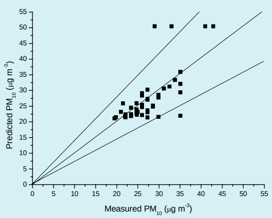
$PM_{10}$ residuals (predicted-measured) ($\mu g\ m^{-3}$)

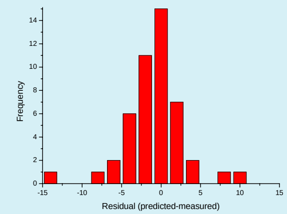



Annual Mean $PM_{10}$ 2004 ($\mu g\ m^{-3}$)

$PM_{10}$ residuals (predicted-measured) ($\mu g\ m^{-3}$)



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# Key implementation dates


**From February 2008**, a standard of **Euro III** for particulate matter (PM) for Heavy Goods Vehicles (HGVs) over 12 tonnes in weight;

**From July 2008**, a standard of **Euro III** for PM for goods vehicles between 3.5 and 12 tonnes in weight, and for buses and coaches;

**From October 2010**, a standard of **Euro III** for PM for heavier Light Goods Vehicles (LGVs) and minibuses; and

**From January 2012**, the standard will be tightened to **Euro IV** for PM for goods vehicles over 3.5 tonnes, buses and coaches

**Penality:**

£200, (£500 (14days) up to £1000) – HGV's/Buses

£100, (£250 (14days) up to £500) – LGV's




# Pollutants to be tackled

$PM_{10}$ but also $NO_X/NO_2$ and $CO_2$; $PM_{2.5}$?

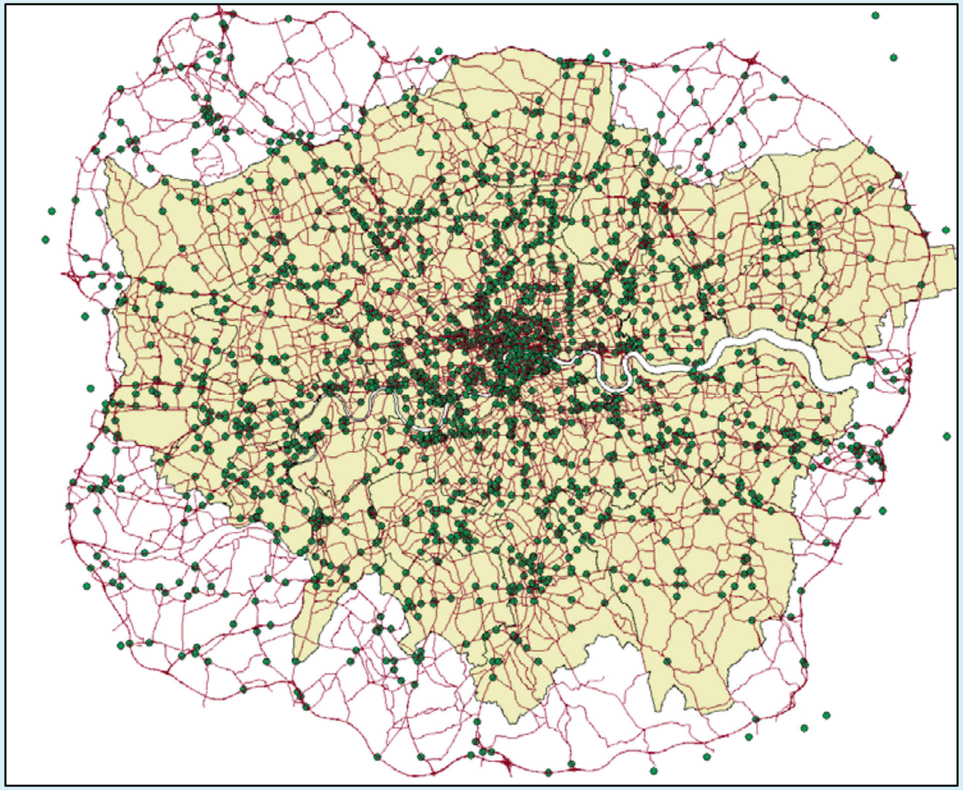
Vehicle fleets are expected to change in different ways:

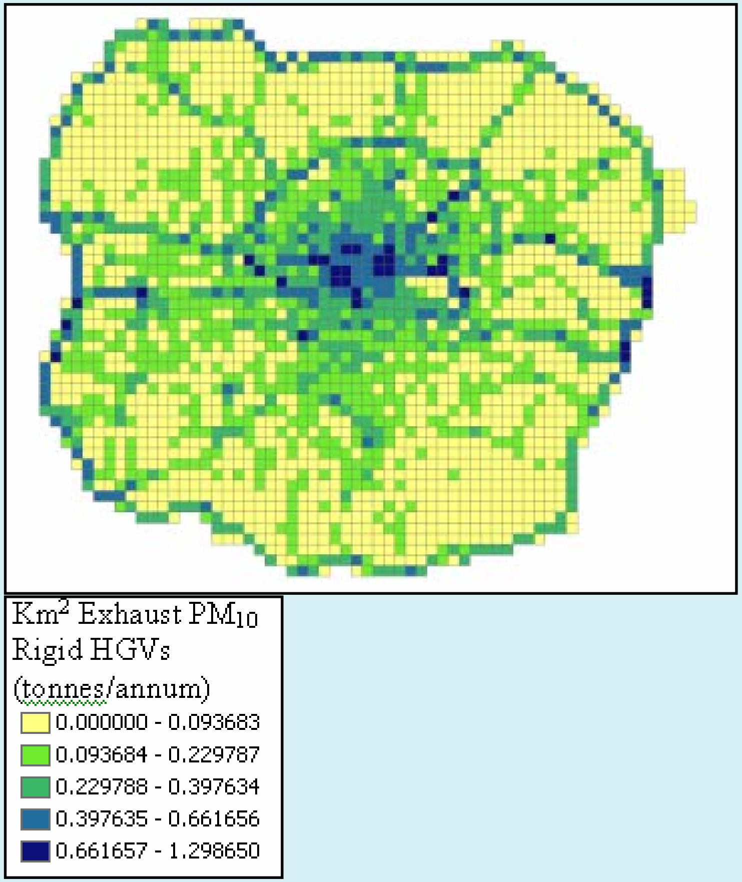
New engines, replacement with newer vehicles, swapping vehicles within a large fleet across the UK, exhaust technology.

Effects outside London.




# London Atmospheric Emissions Inventory (LAEI) area








# Features of the road traffic emissions Inventory LAEI

Bottom-up, based upon a large number of traffic counts (11 vehicles types) and speed estimates (floating car);

National and London vehicle stock (bus and taxi);

Speed related emissions factors (Barlow et al., 2001);

16 pollutants: $NO_X$, $PM_{10}$, $PM_{T\&B}$, $CO_2$, Primary $NO_2$;

Road scale emissions up to M25 plus 1 x 1 km annual totals, cold starts;

Diesel car penetration: 42% of total car sales by 2010;

SRC – 50% $NO_X$ reduction, DPF – 95% PM reduction, 0.8% increase in $CO_2$ .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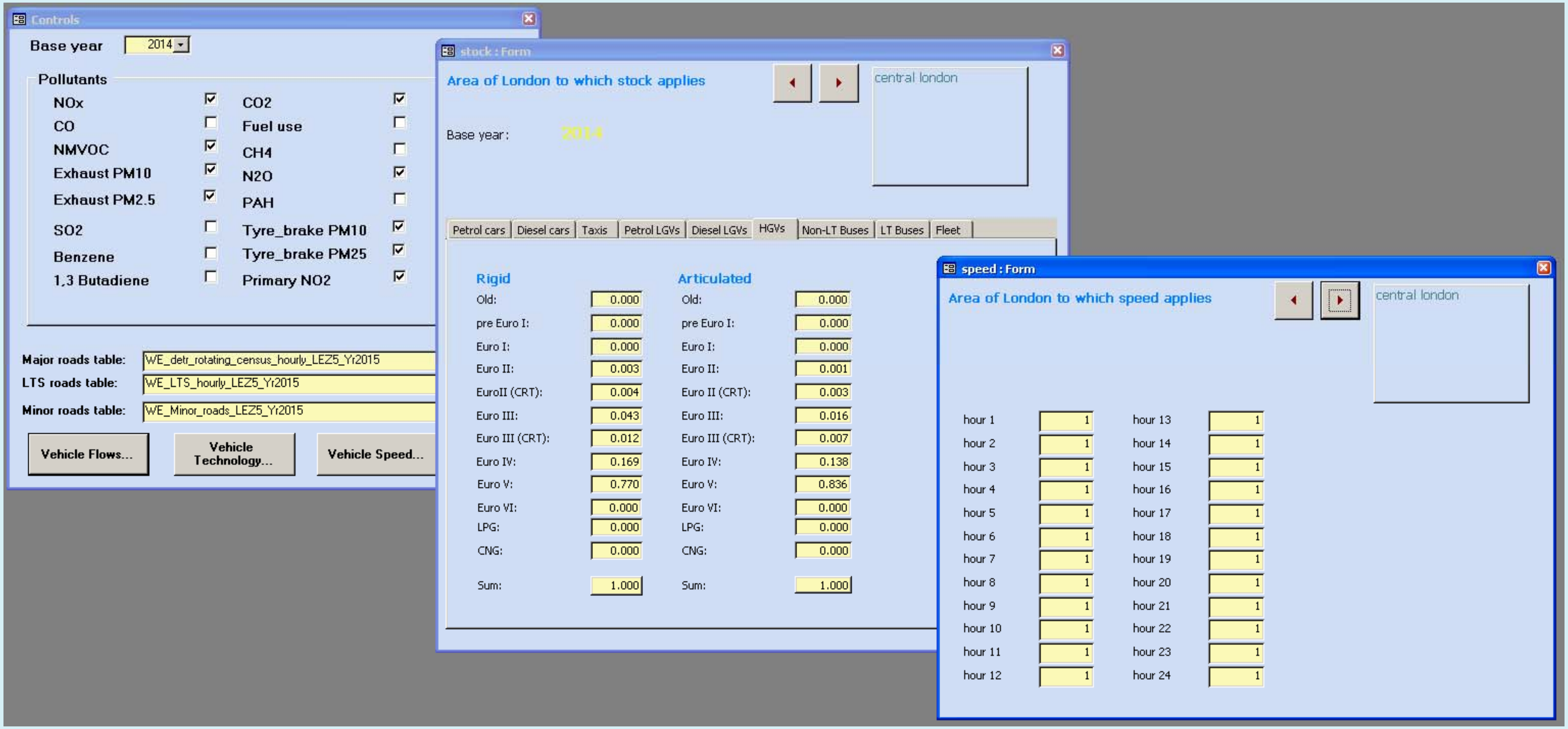
# Emissions toolkit – source of LAEI road traffic data

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# LAEI 2004/08/10 emissions results

**Mobile sources** – railways, aircraft, ships, motor vehicles;

**Stationary sources** – domestic and commercial gas combustion, boilers, large industrial plant, smaller part B industrial processes etc;

**Other sources** – agriculture/natural, sewage treatment, solvents.

| Tonnes/annum | $NO_X$ | $PM_{10}$ (T&B) | $NO_X$ | $PM_{10}$ (T&B) | $NO_X$ | $PM_{10}$ (T&B) |
|---|---|---|---|---|---|---|
| year | 2004 | 2004 | 2008 | 2008 | 2010 | 2010 |
| Vehicle Emissions | 43804 | 2824 (1025) | 33851 | 2462 (1053) | 27054 | 2184 (1074) |
| All other sources* (includes Industrial processes and Gas combustion) | 44247 | 1132 | small changes | small changes | small changes | small changes |

| % contribution | Year | motorcycles | cars | taxis | Bus and coaches | LGV | Rigid | Artic |
|---|---|---|---|---|---|---|---|---|
| $NO_X$ | 2004 | 0.3 | 29.8 | 2.0 | 9.4 | 10.1 | 21.8 | 26.6 |
| $PM_{10}$ | 2004 | 3.3 | 40.7 | 4.4 | 3.7 | 20.6 | 13.4 | 13.8 |
| $CO_2$ | 2004 | 0.8 | 59.1 | 1.9 | 4.2 | 11.0 | 9.4 | 13.6 |

| In-Scope | 2007 | 2008 |
|---|---|---|
| Rigid HGVs | 35 | 27 |
| Artic HGVs | 24 | 17 |
| Coaches | 42 | 35 |




# Previous LEZ input data processing (source: TfL)

Impact sheet processed to calculate final vehicle stock for every scenario and vehicle type affected by LEZ

| 2008<br>EIII for PM10 | On Scheme Commencement, Vehicle Becomes: | | | | | | |
|---|---|---|---|---|---|---|---|
| Vehicle Standard Prior to Jan 2008 | E0 | EI | EII | EIII | EII + RPC | EIII + RPC | EIV |
| **HGV (Artic)** | | | | | | | |
| E0 | **10.52%** | 0.00% | 0.00% | **50.76%** | **9.58%** | 0.00% | **29.13%** |
| EI | - | **10.52%** | 0.00% | **50.76%** | **9.58%** | 0.00% | **29.13%** |
| EII | - | - | **10.52%** | **46.21%** | **18.69%** | 0.00% | **24.58%** |
| EIII | - | - | - | **100%** | 0% | 0.00% | 0.00% |
| EII + RPC | - | - | - | **-** | **100%** | 0.00% | 0.00% |
| EIII + RPC | - | - | - | - | - | **100%** | 0.00% |
| EIV | - | - | - | - | - | - | **100%** |




# Forecast LEZ emissions effects $NO_X$

| Area* | 2008 | 2010 | 2012 | 2015 |
|---|---|---|---|---|
| CCS | 24 | 17 | 49 | 21 |
| Inner | 210 | 135 | 414 | 166 |
| Outer | 491 | 285 | 964 | 380 |
| External | 564 | 228 | 1047 | 391 |
| **Total** | **1289** | **664** | **2474** | **957** |
| % emission reduction | 3.8% | 2.5% | 9.8% | 4.4% |

# Forecast LEZ emissions effects $PM_{10}$

| Area* | 2008 | 2010 | 2012 | 2015 |
|---|---|---|---|---|
| CCS | 1 | 2 | 3 | 1 |
| Inner | 12 | 14 | 26 | 9 |
| Outer | 25 | 29 | 57 | 19 |
| External | 25 | 20 | 54 | 18 |
| **Total** | **64** | **64** | **141** | **47** |
| % emission reduction | 2.6% | 2.9% | 6.6% | 2.3% |

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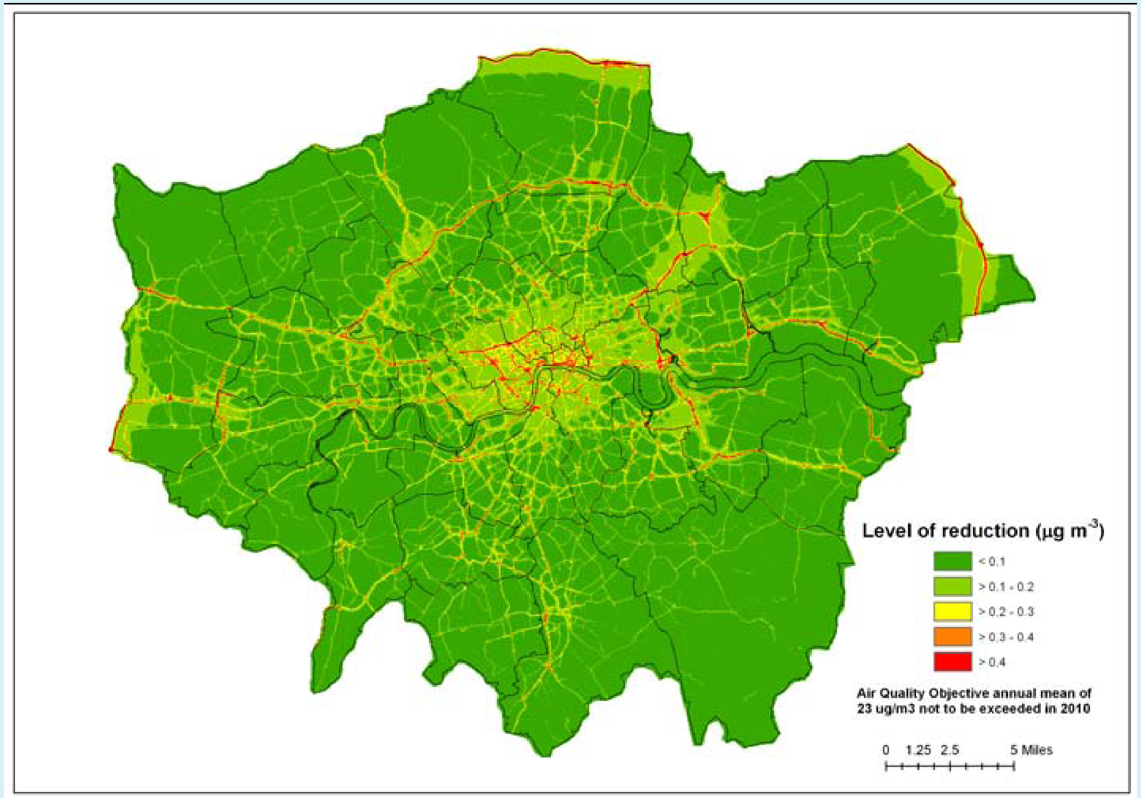
# Reductions in $PM_{10}$ concentrations in 2012 as a result of the introduction of the LEZ

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# Proportion of Borough population in exceedence areas (pre-LEZ), and reduction in population in exceedence areas post possible LEZ implementation in 2008 (AEA, 2006)

| Borough | Annual mean NO2 > 40 ug/m3 | | | Annual mean PM10 > 23 ug/m3 | | | No. of days > 50 ug/m3 daily mean PM10 | | |
|---|---|---|---|---|---|---|---|---|---|
| | % popn exc. 40 ug/m3 | Popn exc. 40 ug/m3 | % reduction in exc. popn | % popn exc. 23 ug/m3 | Popn exc. 23 ug/m3 | % reduction in exc. popn | % popn exc. 10 days | Popn exc. 10 days | % reduction in exc. popn |
| Barking and Dagenham | 1.2% | 2,116 | 18.7% | 1.6% | 2,705 | 10.8% | 0.9% | 1,576 | 4.9% |
| Barnet | 5.5% | 18,025 | 10.2% | 4.3% | 13,925 | 5.1% | 2.8% | 9,174 | 5.0% |
| Bexley | 1.5% | 3,355 | 10.5% | 1.6% | 3,652 | 7.7% | 0.9% | 1,959 | 15.3% |
| Brent | 10.4% | 28,610 | 10.7% | 4.4% | 11,938 | 8.7% | 2.4% | 6,646 | 10.4% |
| Bromley | 0.3% | 829 | 17.4% | 0.5% | 1,646 | 3.7% | 0.3% | 790 | 11.6% |
| Camden | 53.5% | 110,124 | 7.3% | 20.6% | 42,512 | 5.4% | 10.8% | 22,337 | 3.3% |
| City of London | 100.0% | 7,448 | 0.0% | 49.8% | 3,712 | 4.0% | 34.6% | 2,581 | 10.5% |
| Croydon | 4.4% | 15,028 | 10.1% | 3.1% | 10,659 | 9.7% | 1.6% | 5,595 | 13.8% |
| Ealing | 11.7% | 36,500 | 7.8% | 6.9% | 21,640 | 4.8% | 4.2% | 13,207 | 7.5% |
| Enfield | 3.7% | 10,654 | 10.0% | 4.2% | 12,036 | 6.6% | 3.1% | 8,957 | 2.6% |
| Greenwich | 6.8% | 15,161 | 10.3% | 4.8% | 10,794 | 5.9% | 3.1% | 6,863 | 7.3% |
| Hackney | 23.3% | 49,221 | 11.6% | 7.4% | 15,622 | 9.7% | 3.9% | 8,151 | 12.1% |
| Hammersmith and Fulham | 32.2% | 55,372 | 8.7% | 10.5% | 17,988 | 6.5% | 6.3% | 10,824 | 7.1% |
| Haringey | 8.4% | 18,909 | 11.5% | 4.1% | 9,257 | 8.3% | 2.2% | 4,984 | 9.8% |
| Harrow | 0.4% | 911 | 19.0% | 0.8% | 1,724 | 12.3% | 0.3% | 540 | 13.2% |
| Havering | 0.5% | 1,137 | 12.5% | 0.9% | 2,124 | 6.6% | 0.5% | 1,059 | 4.3% |
| Hillingdon | 3.3% | 8,376 | 8.9% | 2.5% | 6,199 | 5.9% | 1.4% | 3,573 | 6.3% |
| Hounslow | 5.3% | 11,746 | 10.8% | 5.6% | 12,328 | 5.4% | 3.6% | 7,997 | 7.7% |
| Islington | 50.7% | 92,775 | 9.5% | 11.3% | 20,700 | 7.0% | 6.1% | 11,242 | 5.2% |
| Kensington and Chelsea | 89.9% | 148,648 | 4.9% | 23.3% | 38,490 | 3.7% | 15.7% | 26,010 | 2.6% |
| Kingston upon Thames | 2.4% | 3,696 | 5.8% | 3.6% | 5,462 | 6.8% | 2.4% | 3,665 | 6.2% |
| Lambeth | 30.7% | 85,111 | 12.1% | 9.8% | 27,115 | 6.7% | 5.7% | 15,746 | 7.6% |
| Lewisham | 9.6% | 24,740 | 10.1% | 5.0% | 12,936 | 9.3% | 2.9% | 7,500 | 11.6% |
| Merton | 6.5% | 12,753 | 13.5% | 2.9% | 5,707 | 10.6% | 1.7% | 3,272 | 4.0% |
| Newham | 10.3% | 26,197 | 12.2% | 3.8% | 9,569 | 11.4% | 2.0% | 5,086 | 3.7% |
| Redbridge | 4.3% | 10,777 | 10.6% | 3.7% | 9,074 | 4.1% | 2.1% | 5,330 | 5.0% |
| Richmond upon Thames | 2.4% | 4,329 | 9.1% | 3.5% | 6,206 | 7.1% | 2.4% | 4,352 | 5.4% |
| Southwark | 35.3% | 89,936 | 9.0% | 12.6% | 32,111 | 6.0% | 6.9% | 17,508 | 4.2% |
| Sutton | 0.5% | 947 | 31.5% | 1.4% | 2,538 | 12.7% | 0.6% | 1,146 | 13.2% |
| Tower Hamlets | 23.4% | 47,668 | 12.3% | 12.1% | 24,689 | 5.1% | 8.8% | 17,859 | 5.7% |
| Waltham Forest | 20.6% | 46,832 | 8.4% | 4.4% | 9,963 | 6.0% | 2.7% | 6,048 | 9.1% |
| Wandsworth | 25.2% | 68,307 | 11.1% | 6.3% | 17,107 | 5.9% | 3.8% | 10,264 | 8.3% |
| Westminster | 93.4% | 176,042 | 2.2% | 38.7% | 72,939 | 5.7% | 20.9% | 39,394 | 6.4% |




# Health Impacts ($NO_2$ and $PM_{10}$)*

Two approaches were used for quantifying health effects :

New Defra methodology, as developed for the Defra UK Air Quality Strategy Review (AQSR), and published by the IGCB (the Inter-Department Group on Costs and Benefits) in April (IGCB 2006, COMEAP).

An alternative, the European Commission part of the Clean Air for Europe (CAFE) programme, a much wider range of health impacts (morbidity).

DEFRA – 5200 years of life gained, 43 respiratory and cardiovascular hospital admissions avoided.

EU – additionally: 310,000 cases of lower respiratory symptoms, 30,000 cases of respiratory medication and 231,000 restricted activity days avoided.

DEFRA discounted benefits: £200 million.

EC Café CBA analysis: £420 million.

Not just in London (central London saw greatest benefits).

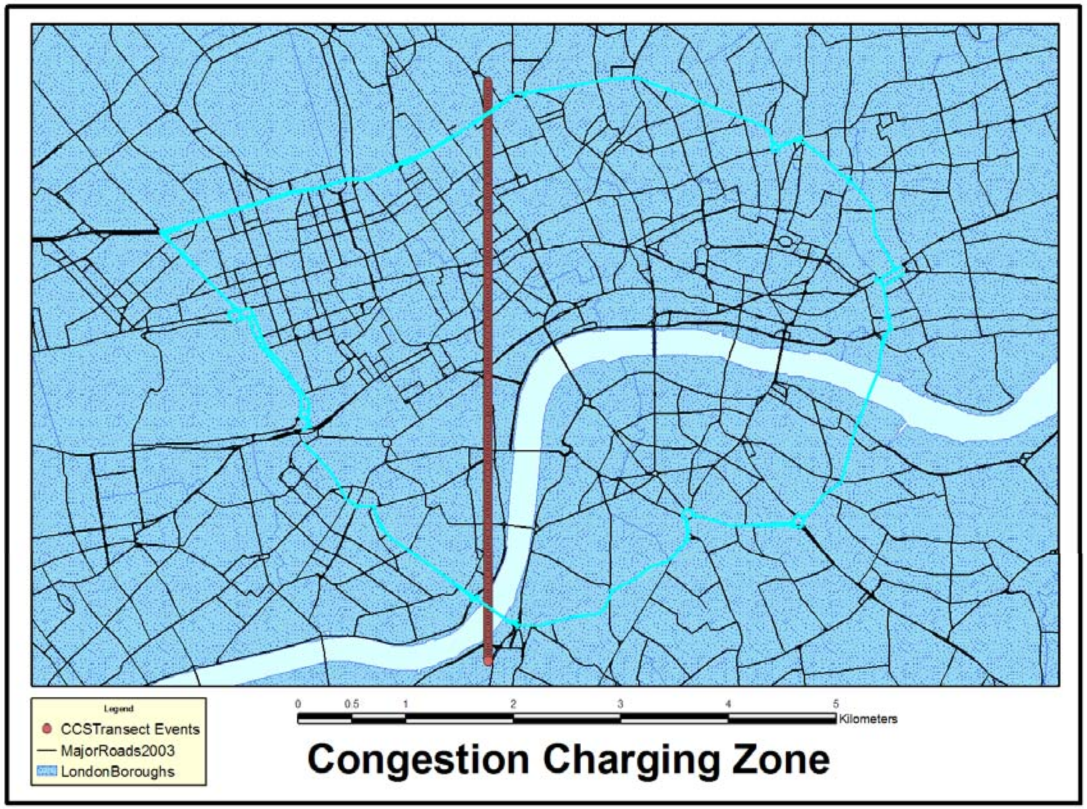
SocioEconomic, Environmental perception, Noise and road safety.

AEA, 2006, London Low Emission Zone. Health Impact assessment, final report.

Report for Transport for London. www.tfl.gov.uk



# Transect location

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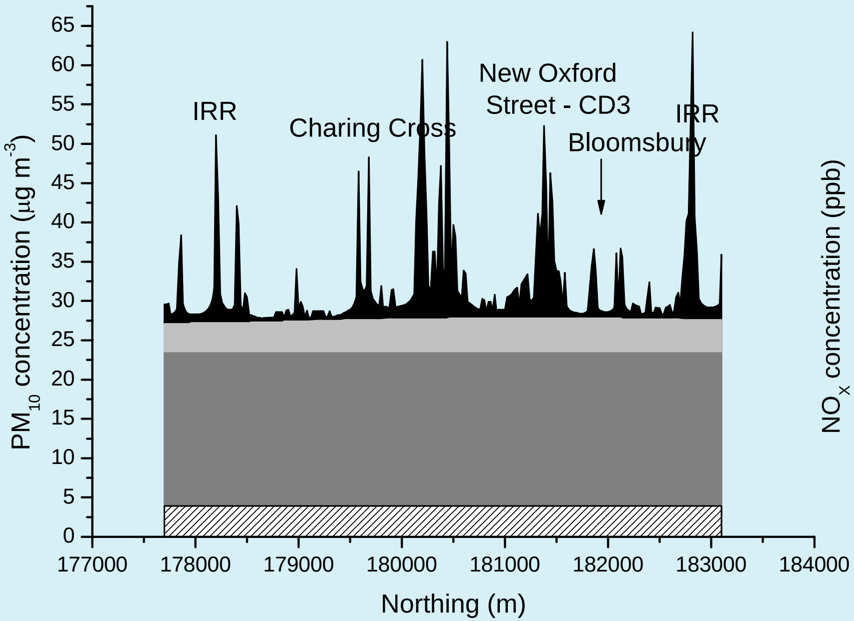
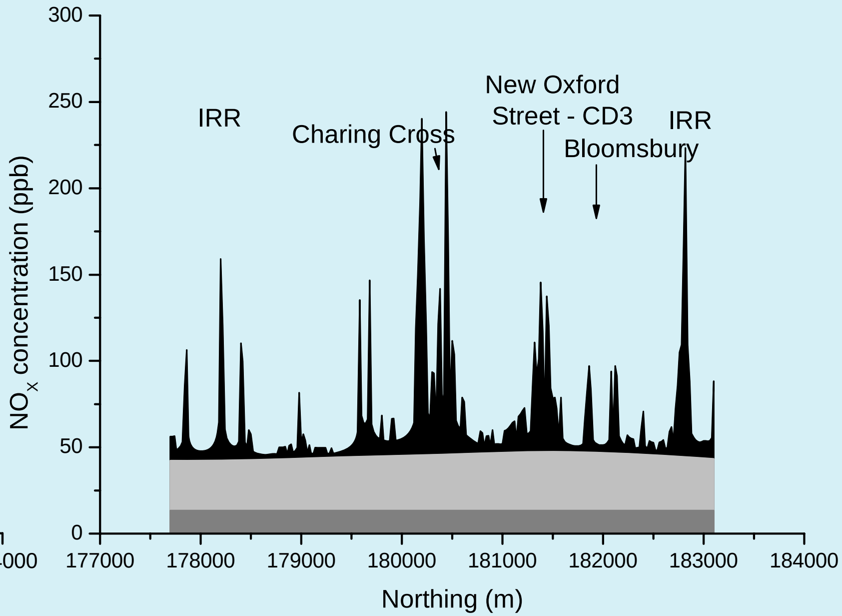
# Model output $PM_{10}$ and $NO_X$ – by source type




Dark grey – rural, light grey – London background sources, black – roadside.

Fuller, G., Carslaw, D.C., Lodge, H.W., 2002. An empirical approach for the prediction of daily mean $PM_{10}$ concentrations. Atmospheric Environment 36, 1431-1441.

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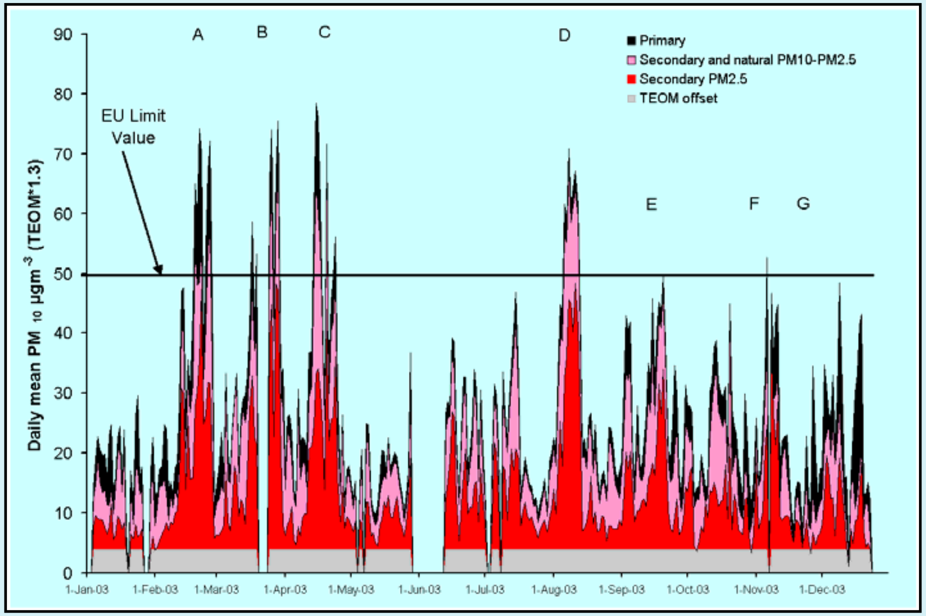
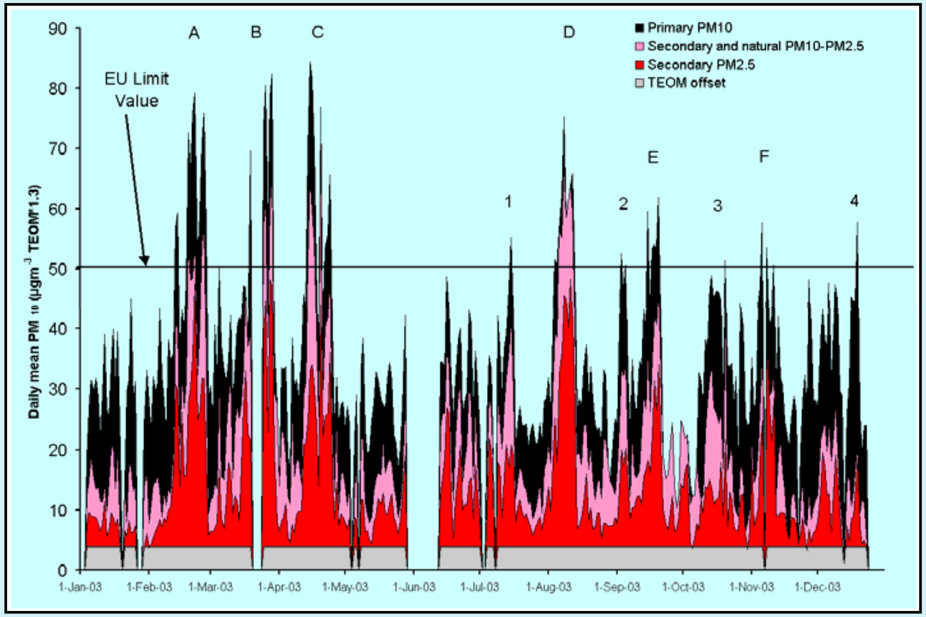
# $PM_{10}$ Source Apportionment

## Inner London Background




## Inner London Roadside




Using $PM_{2.5}$ and $PM_{10}$ measurements divided into three source components: *primary emissions* (associated with $NO_X$), *secondary aerosol* (mainly the $PM_{2.5}$ not associated with $NO_X$) and *natural particles* (the $PM_{10}$-$PM_{2.5}$ component not associated with $NO_X$).

References

Fuller, G., Carslaw, D.C., Lodge, H.W., 2002.

Fuller, G., Green, D., 2006.

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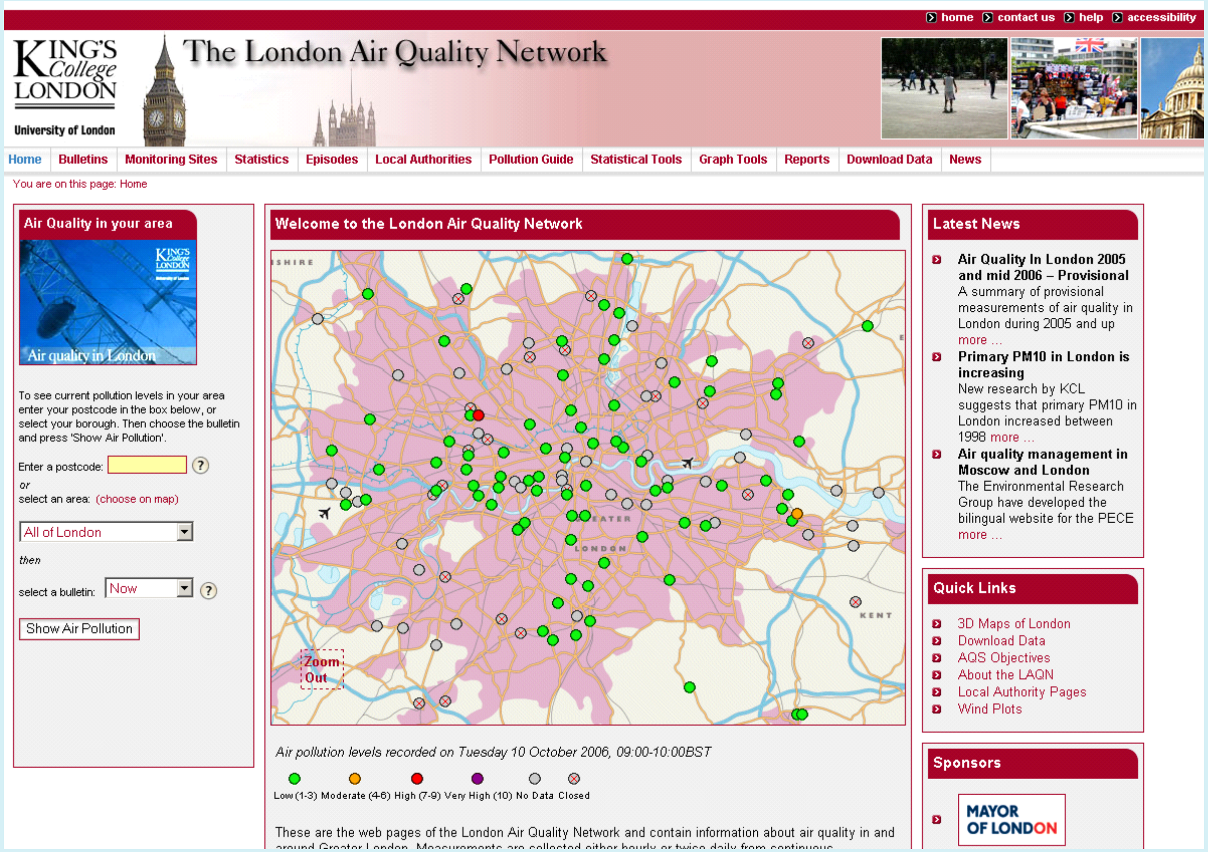
# The London Air Quality Network (LAQN)




The LondonAir website www.londonair.org.uk

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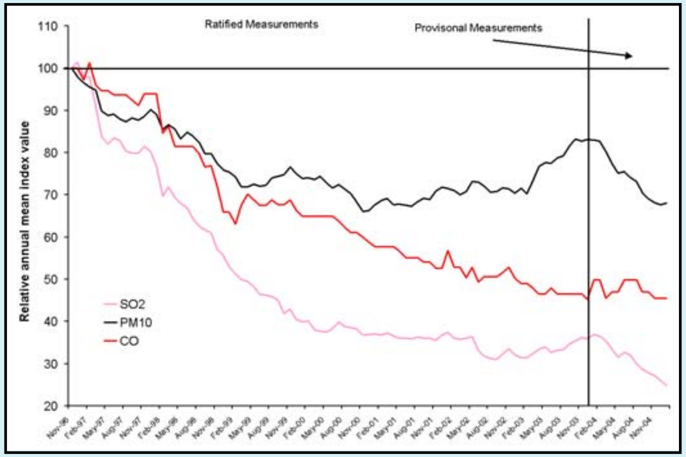
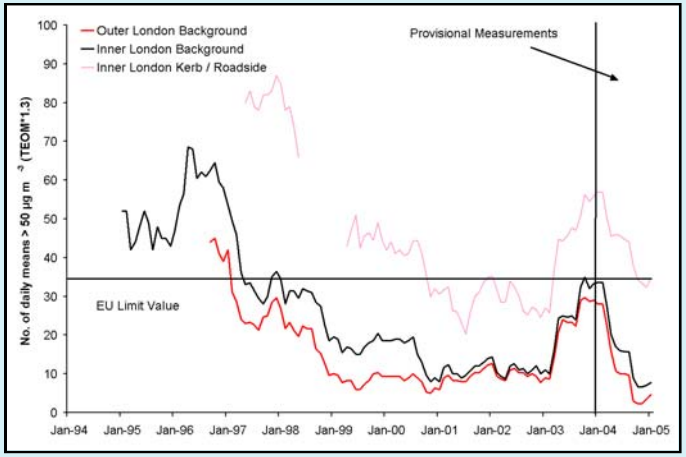
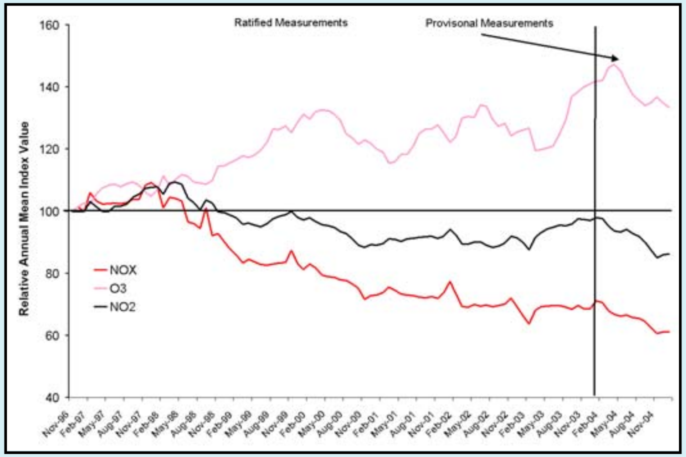
# Air Quality trends in London

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# $NO_2$ primary trends in London (AQEG, $NO_2$)

Table 1 $NO_2$ : $NO_x$ ratios (%) for different vehicle classes

| Vehicle category | Motorcycles | Petrol Cars | Diesel Cars | HGV | Bus | Petrol LGVs | Diesel LGVs |
|---|---|---|---|---|---|---|---|
| Pre Euro 1 | 0.04 | 0.04[1] | 0.105[2] | 0.14[1] | 0.175[1] | 0.04 | 0.22[1] |
| Euro 1 | 0.04 | 0.04 | 0.105 | 0.14 | 0.175 | 0.04 | 0.22 |
| Euro 2 | 0.04 | 0.04 | 0.105 | 0.14 | 0.175 | 0.04 | 0.22 |
| Euro 3 | 0.04 | 0.04 | speed related (0.2 to 0.4)[3] | 0.14 | 0.175 | 0.04 | speed related (0.2 to 0.4)[3] |
| Euro 4+ | 0.04 | 0.04 | speed related (0.2 to 0.4) | 0.14 | 0.175 | 0.04 | speed related (0.2 to 0.4)[3] |
| Oxidation Catalyst | - | - | speed related (0.2 to 0.4) | - | 0.35[3] | - | - |
| Particle trap | - | - | 0.23 | 0.48[3] | 0.4[3] | - | 0.23 |
| Selective catalytic reduction | - | - | - | - | 0.4[3] | - | - |

1 (Latham et.al, 2001), 2 (Richards et. al, 2002), 3 (D Carslaw, personal comm.)




# Validation using LAQN measurements

Based on individual data from 37 measurements sites, a multiple regression has been used to estimate the mean primary $NO_2$ for different vehicle types.

The regression links the estimated $NO_2$ concentration due to primary $NO_2$ with the estimated concentration of $NO_X$ due to different vehicle types. The latter has been estimated using the $NO_X$ emission estimates provided by ERG expressed as a fraction of the $NO_X$ concentration estimate above background.
The following model was obtained:

$[NO_2]$primary = 0.39 (± 0.02)$[NO_X]$buses + 0.12 (± 0.05)$[NO_X]$HGVs + 0.18 (± 0.05)$[NO_X]$cars+LGVs – 1.35 (± 0.76)

This suggests primary $NO_2$ values of around 39% for buses, 12% for HGVs and 18% for cars and LGVs considered together.

*Reference:* Carslaw, D. C., Beevers, S. D., Bell, M. C. 2006. Risks of exceeding the hourly EU limit value for nitrogen dioxide resulting from increased road transport emissions primary nitrogen dioxide, Atmospheric Environment "*in press*"

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# $NO_2$ primary trends in London

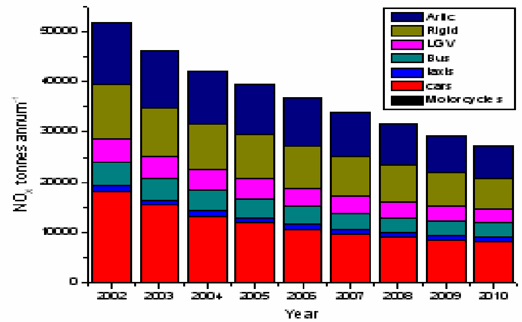



Figure 1 Total $NO_X$ emissions in London by vehicle type

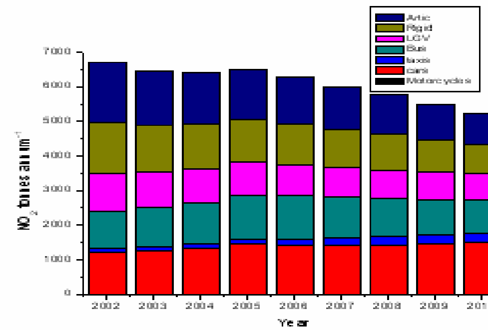



Figure 2 Total $NO_2$ emissions in London by vehicle type

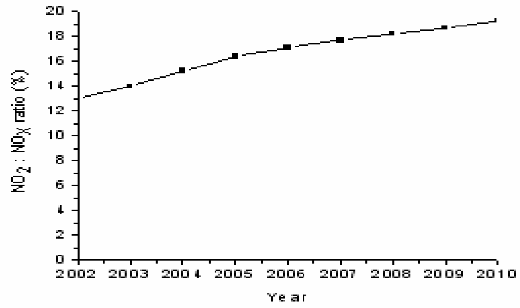



Figure 3 The percentage $NO_2$ to $NO_X$ ratio for all vehicle types.

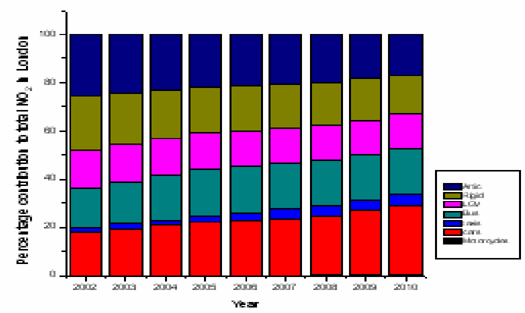



Figure 4 The percentage contribution to total London $NO_2$ emissions by vehicle type



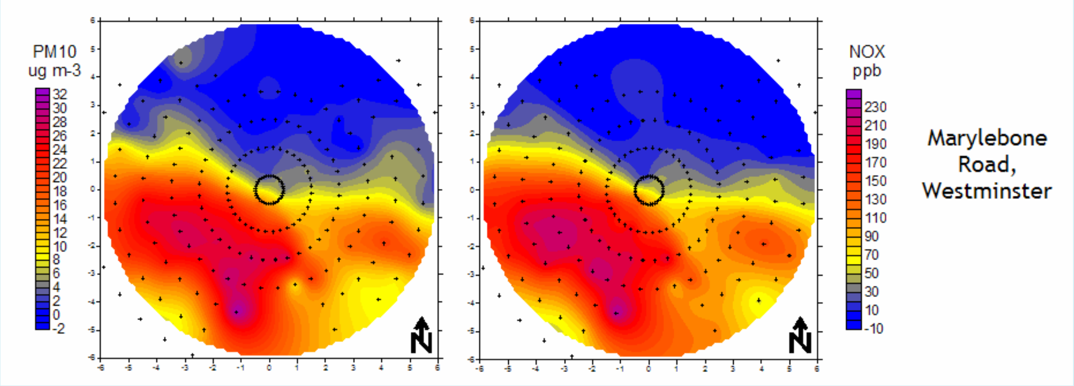

# New LEZ supersites

| Site code | Site name, borough and location | Parameters monitored |
|---|---|---|
| MY1 | Marylebone Road, Westminster, Central London | TEOM $PM_{10}$, FDMS $PM_{10}$, $PM_{2.5}$, $P_{NUM}$, BC, $NO_X$, $O_3$, Hydrocarbons, meteorology |
| HK6 | Old Street, Hackney, Central London | TEOM $PM_{10}$, $NO_X$, $O_3$, $PM_{2.5}$ |
| BX8 | A206 Cray, Bexley, East London | FDMS $PM_{10}$, $PM_{2.5}$, $NO_X$, $O_3$, meteorology |
| GR8 | Westhorne Avenue (A2 / South Circular Interchange), Greenwich, South East London | FDMS $PM_{10}$, $PM_{2.5}$, $NO_X$, $O_3$, meteorology |
| GR9 | Woolwich Flyover (A2), Greenwich, South East London | TEOM $PM_{10}$, $PM_{2.5}$, $NO_X$, $O_3$ |
| BT4 | North Circular (Ikea), Brent, North West London | TEOM $PM_{10}$, $PM_{2.5}$, $NO_X$, $O_3$, $P_{NUM}$, BC, meteorology |
| TH4 | Blackwall Tunnel Northern Approach, Tower Hamlets, East London | FDMS $PM_{10}$, $PM_{2.5}$, $P_{NUM}$, BC, $NO_X$, $O_3$, meteorology |

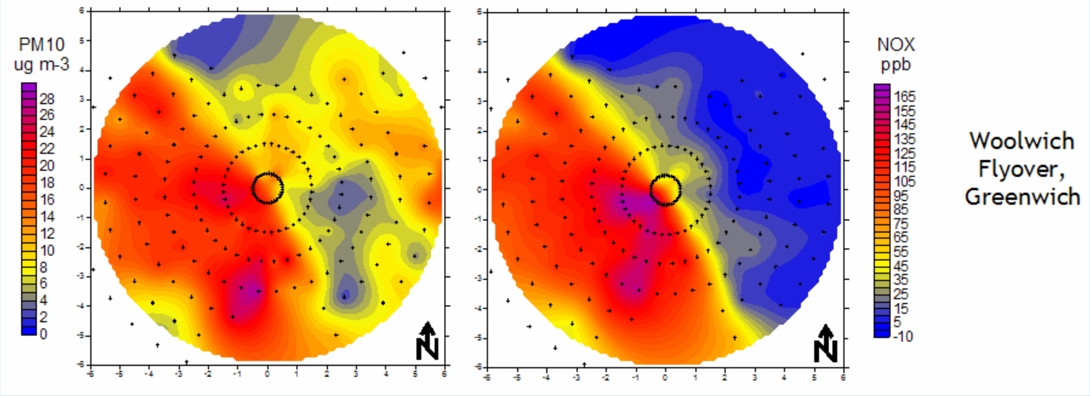
Note that all sites also have continuous automatic traffic counters, periodic manual classified traffic counts and ANPR camera sampling of Euro Class profiles.

# LEZ supersite details – polar plots

## Marylebone Rd, Westminster




## Woolwich flyover, Greenwich

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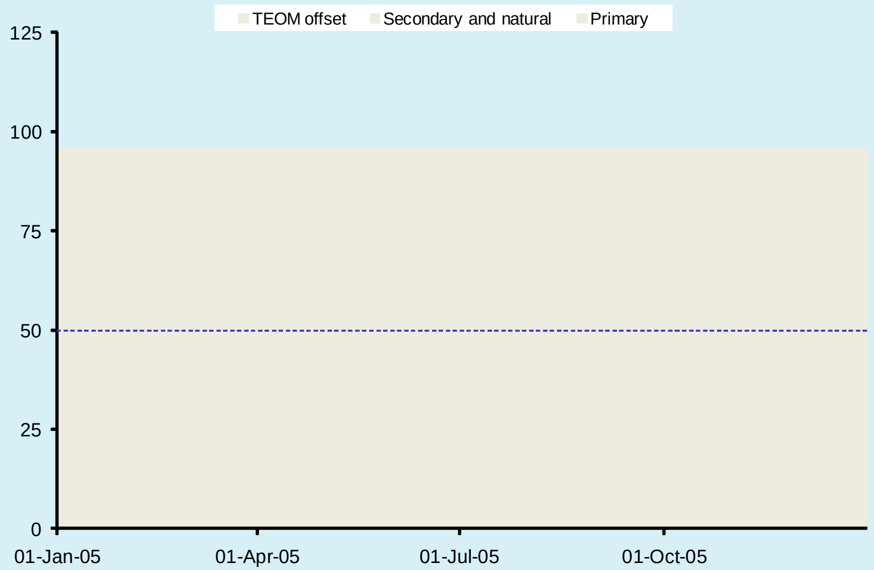
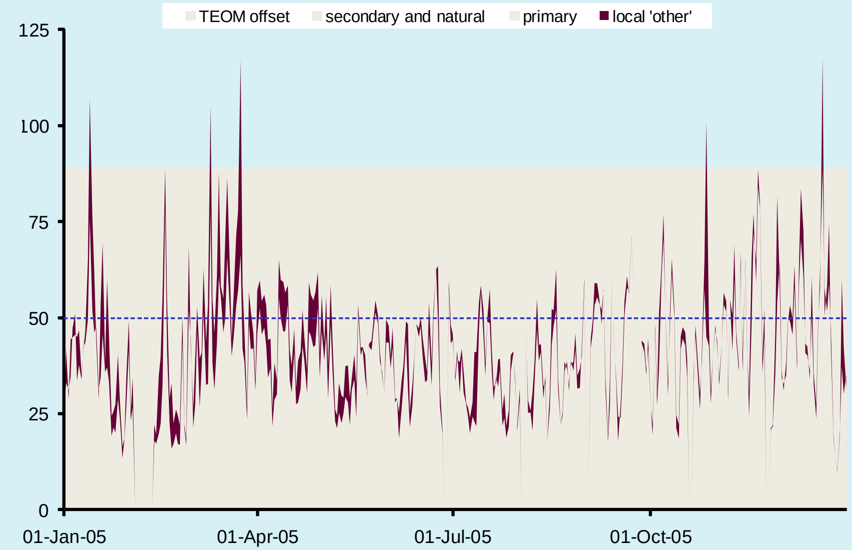
# LEZ supersite details

## Marylebone Rd, Westminster




## Woolwich flyover, Greenwich




References


Fuller, G., Carslaw, D.C., Lodge, H.W., 2002.

Fuller, G., Green, D., 2006.






# Monitoring and future work

1. Examining the historical concentration of Elemental Carbon in London
Studies such as Fuller and Green (2004) and Harrison et al (2008) have highlighted that PM concentrations are not reducing as forecast by emission inventories and there is evidence that PM from primary sources is increasing. However, there is a lack of historic speciation measurements with which to identify the causes, although the situation has improved somewhat in the last year. King's are accessing the archive of $PM_{10}$ and $PM_{2.5}$ samples from a kerbside and a background site from 2000 onwards for analysis using a lab based aethalometer. This will provide a measurement of the changes in elemental carbon over time to help to identify the sources of $PM_{10}$ in London. This will allow reductions in PM from the LEZ to be placed in context of other changes in PM source and composition.

2. Chemical Speciation at LEZ Supersites
Daily samples of $PM_{10}$ will be made for 2 30 day campaigns (summer and winter) at Tower Hamlets 4 and Brent 4. Chemical components will be measured (EC/OC, ions, metals). Harrison's method of pragmatic mass closure (2003, 2008) will be used to assess the chemical components of $PM_{10}$.

3. Removing the met. signal from time series measurements using GAM modelling methods to remove the inter annual variability and potentially other non-LEZ signals.




# Automatic Number Plate Recognition (ANPR) data

100 sites across a range of road types

Data taken at monthly intervals

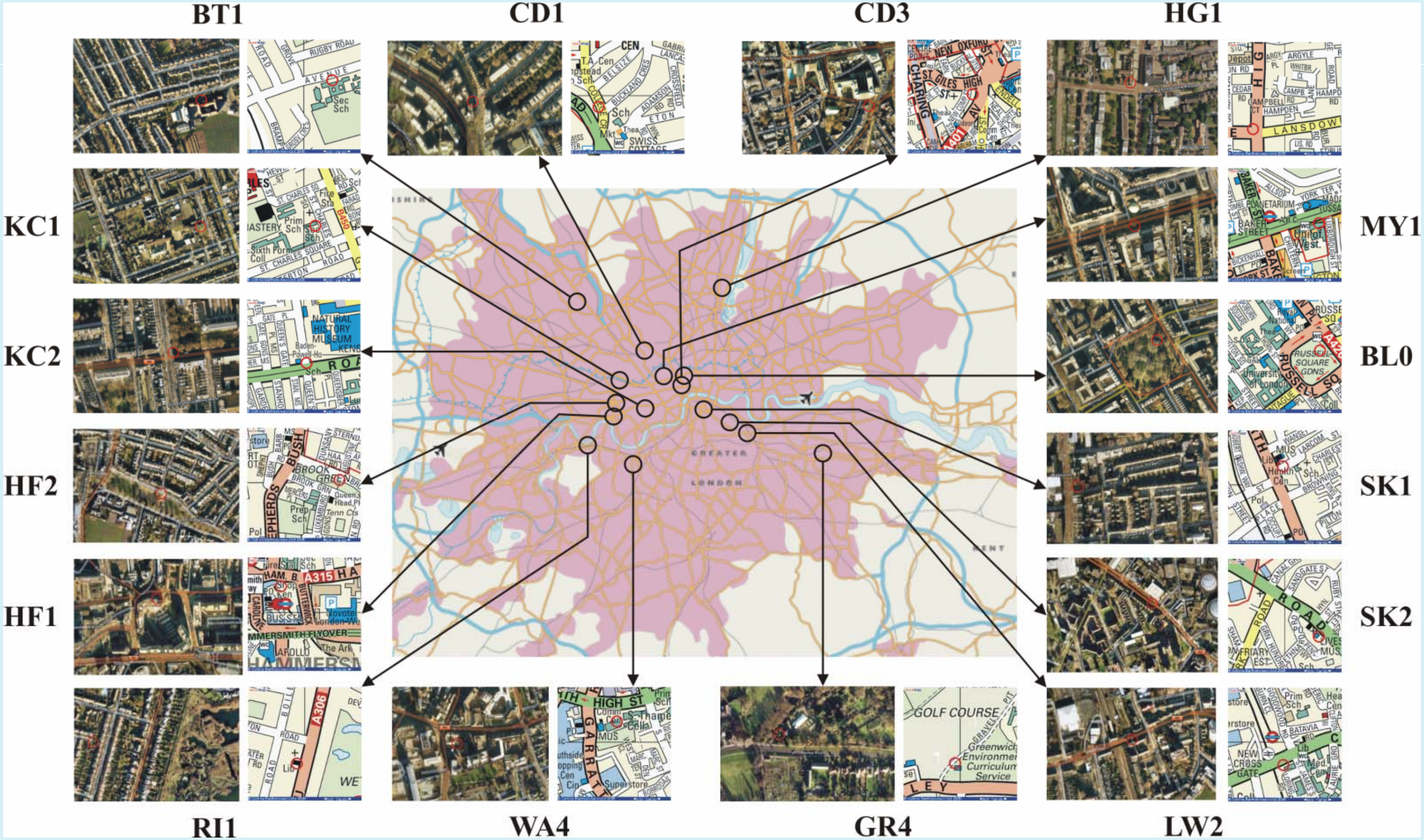
High capture rates

Compare with the DVLA (SMMT) database

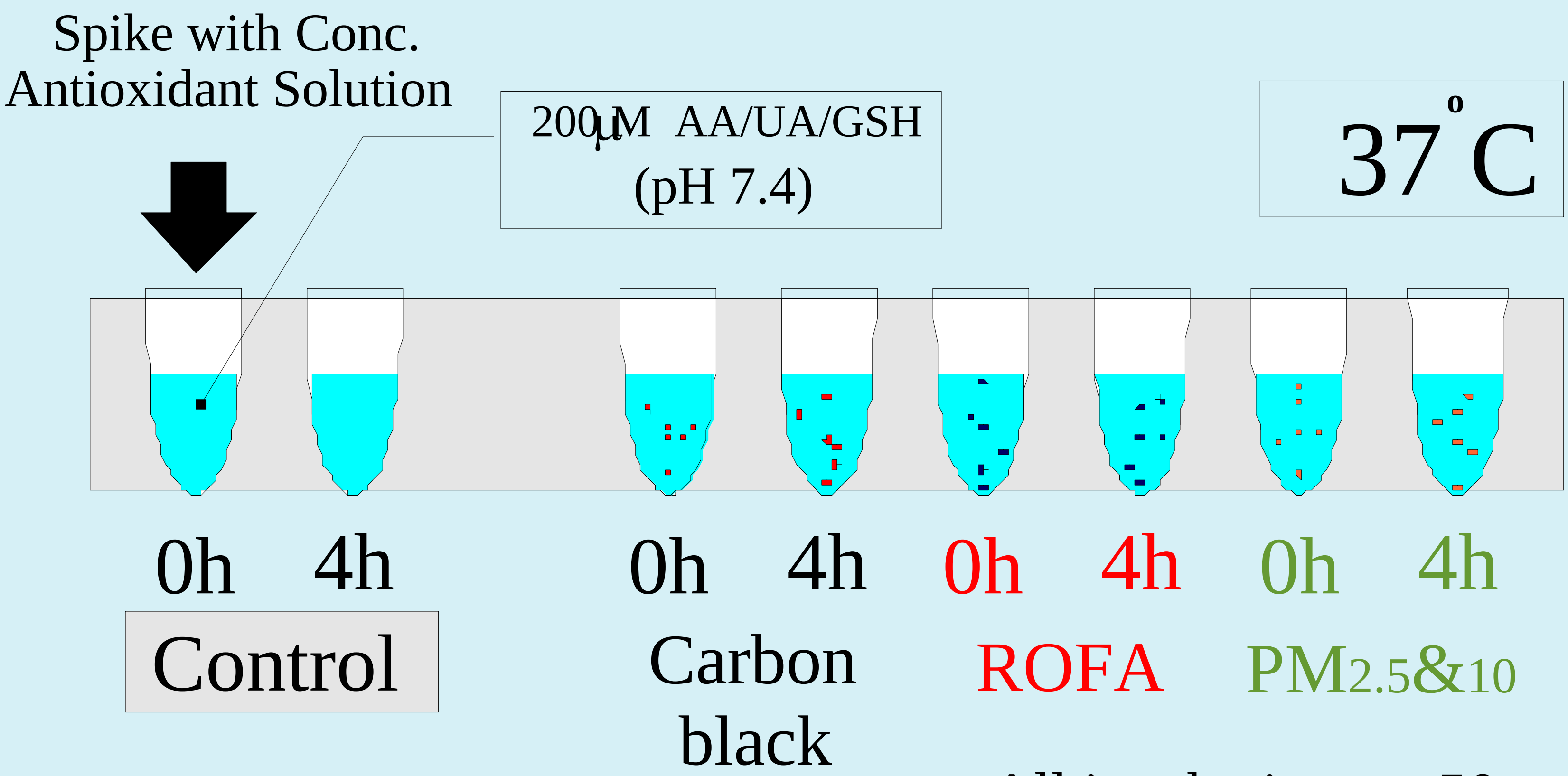
To find:

Scheme compliance via background stock change and acceleration of the change closer to the LEZ start date.

# Within-City Spatial Variation in OP



# Particle Exposure Model




All incubations at 50μg/ml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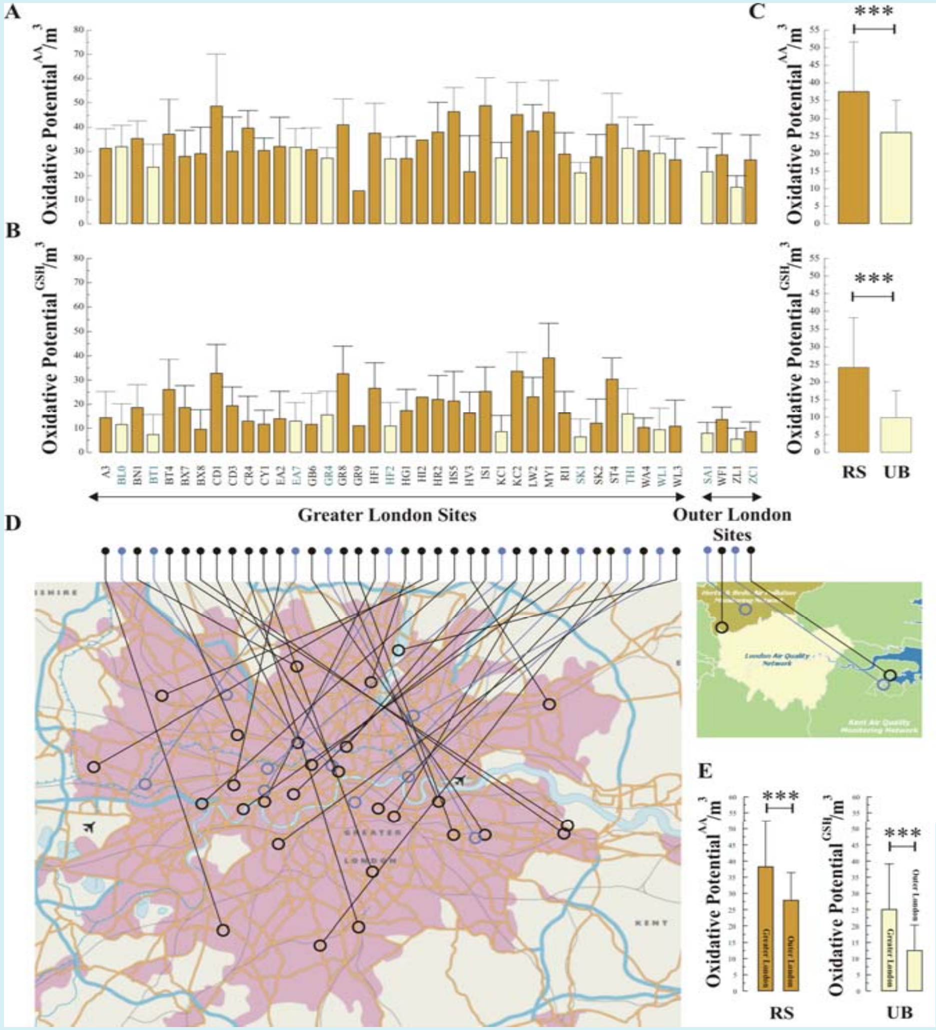


# Toxicity (traffic):

# Quinones and Metals




# Thanks for your attention…

Thanks to:

Transport for London (TfL)/Greater London Authority and HEI

Frank Kelly, Ian Mudway, Ben Barratt, David Green, Gary Fuller and David Carslaw.




# Future air pollution predictions

Future $NO_X$ contributions from outside London were scaled from the 2003 base using (NAEI). These show that $NO_X$ emissions will decrease between 2000 and 2010 by 25% and 2000 and 2020 by 34% (AQEG $NO_2$, 2004).

The future concentration of $PM_{10}$ from secondary sources is expected to reduce due to the reduction in the emissions of precursor pollutants under the Gothenburg Protocol. Factors for future concentrations of nitrate and sulphate $PM_{10}$ were reported in Stedman et al. (2000) for 1997 to 2010 and were weighted for both the relative ambient concentration of each component and for the TEOM sensitivity to nitrate aerosols (Allen et al 1997). Weighted factors indicate a reduction of approximately 30 % in the concentration of secondary $PM_{10}$ between 2002 and 2010. $PM_{10}$ from natural sources is not expected to change.

Direct $NO_2$ from emissions inventory.