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Air Quality Plans for the achievement of EU air quality limit values for nitrogen dioxide (NO_2) in the UK

Technical Report

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AIR QUALITY PLANS FOR THE ACHIEVEMENT OF EU AIR QUALITY LIMIT VALUES FOR NITROGEN DIOXIDE (NO_2) IN THE UK: TECHNICAL REPORT

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AIR QUALITY PLANS FOR THE ACHIEVEMENT OF EU AIR QUALITY LIMIT VALUES FOR NITROGEN DIOXIDE (NO_2) IN THE UK: TECHNICAL REPORT

1. Introduction

This document describes the air quality modelling that has been undertaken to support the development of air quality plans for the achievement of EU air quality limit values for nitrogen dioxide (NO_2). Emissions to air are regulated in terms of oxides of nitrogen (NO_X), which is the term used to describe the sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2). The limit values for the protection of human health relate to NO_2. NO_X and NO_2 concentrations have been calculated at background and roadside locations across the UK.

This document supports and should be read alongside the separate UK overview document, the list of UK and National measures and the air quality plans for each of the 40 UK zones all of which are available on the UK Air website[1].

The reference year for the NO_2 plans is 2008. This is the year recommended in the EU Communication on time extension notifications[2] and is also the most recent year for which a full dataset was available at the time of assessment. The reference year is the year for which the assessment of compliance has been carried out and the year from which projections are made. The air quality modelling assessments carried out to support the notification are all based on the modelling methods and base year modelling carried out for the 2008 air quality assessment reported to the European Commission in the 'Questionnaire' in September 2009[3]. Thus the projections of future air quality are consistent with the annual air quality assessment carried out for 2008.

[1] http://uk-air.defra.gov.uk/library/no2ten/
[2] http://ec.europa.eu/environment/air/quality/legislation/time_extensions.htm
[3] Available on the EU Central Data Repository: http://cdr.eionet.europa.eu/gb/eu/annualair

2. Assessment methodologies for NO_2

The UK is required to report the results of an annual ambient air quality assessment to the Commission by the end of September each year for the previous year's data. This report, known as the Questionnaire, includes a comparison of ambient air quality for the previous calendar year with the limit values, target values and long term objectives set within the Ambient Air Quality Directive (2008/50/EC)[4] (hereafter called "the Directive") and 4th Daughter Directive (2004/107/EC)[5]. The assessment for the UK is based on a combination of information from the UK national monitoring networks and the results of modelling assessments, currently carried out using the Pollution Climate Mapping (PCM) models. Where both measurements and model results are available the assessment of compliance for each zone is based on the higher concentration of the two.

2.1. Air quality monitoring

The NO_2 monitoring assessment for the UK is delivered through the Automatic Urban and Rural Monitoring Network (AURN). Automatic measurements of the concentrations of NO_X on an hour-by-hour basis are made using the reference method (the standard measurement method laid out in the Directive), which is chemiluminescence. The number of NO_X monitoring stations required is defined by consideration of the following as specified in the Directive:

- Upper and Lower Assessment Thresholds (Annex II) together with;
- Population of zones and agglomerations (Annex V).
- Reduction in the number of monitoring points allowed due to supplementary annual modelling (Article 7, paragraph 3).

Hourly NO_X measurements and statistics for all AURN sites, together with those for the separated NO and NO_2 components, can be downloaded in either near-real-time provisional or finally ratified form from the UK-AIR website[6].

Annex VI of the Directive defines the reference method for NO_X monitoring, and the procedure for demonstration of equivalence with the reference methods. The reference method specified is that developed by CEN (European Committee for Standardization) and published in the UK through the British Standard BS EN14211: 2005 (NO_X).

In compliance with Annex VI, D of the Directive all new equipment introduced into the network complies with the reference method or has been demonstrated to be equivalent. The UK has a rolling programme to replace all non type-tested or non-equivalent equipment in the AURN with type tested or equivalent analysers by the due date of 11 June 2013.

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[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF
[5] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:023:0003:0016:EN:PDF
[6] http://uk-air.defra.gov.uk/data/

The AURN is required to have an established and well-defined quality assurance and quality control (QA/QC) programme to ensure that it achieves the data quality objectives as defined in Annex I of the Directive. Details of this QA/QC programme are published in the network QA/QC manual[7]. The programme includes full traceability of all measurements through the use of reference calibration standards, and the participation of the appointed QA/QC institution in the related EU-wide quality assurance programmes.

2.2. Modelling for compliance assessment

In addition to providing information to supplement the annual monitoring assessment, the use of modelling also provides the additional information on source apportionment and projections required for the development and implementation of air quality plans. Thus the source apportionment and projections will be consistent with the annual air quality assessments because the same models are used throughout.

The PCM models have been designed to assess compliance with the limit values at locations defined within the directives. The models are used to calculate urban (and rural) background concentrations for all pollutants on a 1 km x 1 km grid.

A single representative value is calculated for the roadside concentration adjacent to each of approximately 9000 major road links (A roads and motorways) in urban areas. In this instance a road link is defined as the stretch of road between junctions with other major roads. A traffic count is available for each of the road links. The requirement not to assess compliance in the vicinity of major junctions (within 25 m) is addressed by using this single value for each road link and thus any additive effect of the contributions to the micro environment at a junction from more than one road is not included.

Roadside concentrations should be assessed at no more than 10 m from the kerbside. The PCM model for roadside concentrations provides a concentration estimate for a receptor at approximately 4 m from the kerbside. This is the average distance from the kerbside for roadside and kerbside sites within the AURN. These are the sites that have been used to calibrate the PCM model for roadside locations and thus the model has been calibrated in such a way as to provide estimates of concentration at this distance from the kerb.

[7] http://uk-air.defra.gov.uk/reports/cat13/0910081142_AURN_QA_QC_Manual_Sep_09_FINAL.pdf

3. Annual mean NO_X and NO_2 modelling for 2008

3.1. Introduction

A full description of the base year NO_X and NO_2 model for 2008 has been provided in the technical report that accompanies the 2008 air quality assessment Questionnaire[8]. Key information is summarised in this section. The GIS-based Pollution Climate Mapping (PCM) air dispersion model has been used to estimate annual mean NO_X concentrations at background and roadside locations using emissions estimates from the UK National Atmospheric Emissions Inventory (NAEI). Annual mean NO_2 concentrations were then calculated from the modelled NO_X concentrations. The models have been calibrated using data from the UK AURN.

3.2. Oxides of nitrogen emissions

The NO_X modelling for 2008 has been based on the 2007 NAEI NO_X emissions estimates[9] and mapped emissions projected forward by one year. This was done because 2007 was the most recent year for which estimates were available when the air quality assessment for 2008 was carried out. The largest contributions to total UK emissions in 2007 were from road transport exhaust emissions and combustion in energy production and transformation (See Figure 5.1).

Emissions in 2007 and projections for future years have been made using existing vehicle emissions factors from the National Atmospheric Emissions Inventory as these represented the best available evidence. However, emerging evidence from different sources suggests that there are still uncertainties in emission estimates for some current vehicle types and Euro standards. Understanding of the issues is not yet sufficiently advanced to allow a comprehensive update of our road transport emissions inventory based on the emerging evidence. Further information on the approach to vehicle emission factors is provided in Chapter 3 of the UK overview document[10].

Emissions maps for area sources within the 2007 NAEI at a resolution of 1 km x 1 km have been calculated for each combination of source (such as domestic combustion, railways or road traffic) and activity (typically fuel, such as diesel, gas or coal) using distribution grids that have been generated using appropriate surrogate statistics. The distribution grids for road traffic include a component for the emission from vehicles on major roads that has been calculated from traffic count data for individual road links. The distribution grids for other sources include a wide range of data on population, employment and land use amongst others. These individual emissions grids are then added together to give sector area source emission grids.

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[8] http://uk-air.defra.gov.uk/reports/cat09/1101250943_dd122008mapsrep_v4.pdf
[9] http://uk-air.defra.gov.uk/reports/cat07/1010140907_2007_Report_Final_9.pdf
[10] http://uk-air.defra.gov.uk/library/no2ten/

The full emissions method is described in UK Emission Mapping Methodology 2007 report[11]

3.3. The PCM model for NO_X

Based on the NAEI emissions estimates, a 1 km x 1 km annual mean background NO_X concentration map for 2008 has been calculated by summing the contributions from:

- Large point sources, modelled explicitly using an air dispersion model
- Small point sources, modelled using a generalised model using dispersion kernels generated using an air dispersion model
- Distant sources, characterised by the rural background concentration
- Local area sources, modelled using dispersion kernels generated using an air dispersion model and calibrated using measurement data from the national monitoring network.

At locations close to busy roads an additional roadside contribution has been added to account for contributions to total NO_X from road traffic sources. Full details of the modelling method have been provided by Grice et al, 2010[12].

3.4. The PCM model for NO_2

Maps of annual mean NO_2 concentrations have been calculated from our modelled NO_X concentrations using a calibrated version of the updated oxidant-partitioning model[13 14]. This model uses representative equations to account for the chemical coupling of ozone (O_3), NO and NO_2 within the atmosphere. A key advantage of this approach for modelling NO_2 concentrations is that emission scenarios can be directly addressed by varying regional oxidant levels and/or primary NO_2 emissions. The primary NO_2 emission fraction (f-NO_2) for each individual road link has been calculated from a combination of traffic counts for each vehicle type and fleet weighted f-NO_2 values for each vehicle type. Full details of the modelling method have been provided by Grice et al, 2010[15].

3.5. Source apportionment

3.5.1. Source apportionment for NO_X

The PCM models for NO_X explicitly include detailed information on the source apportionment for annual mean NO_X concentrations. This includes the following splits:

- Regional

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[11] http://uk-air.defra.gov.uk/reports/cat07/1010011332_UKMappingMethodReport2007.pdf
[12] http://uk-air.defra.gov.uk/reports/cat09/1101250943_dd122008mapsrep_v4.pdf
[13] Jenkin, M.E. (2004). Analysis of sources and partitioning of oxidant in the UK-Part 1: the NO_X-dependence of annual mean concentrations of nitrogen dioxide and ozone. Atmospheric Environment, **38**, 5117–5129. doi:10.1016/j.atmosenv.2004.05.056
[14] http://uk-air.defra.gov.uk/reports/cat07/0804291542_ED48749_Ann_Rep1_2007_tropospheric_ozone_final_AQ03508.pdf
[15] http://uk-air.defra.gov.uk/reports/cat09/1101250943_dd122008mapsrep_v4.pdf

- Within member state
  - Transboundary
  - Shipping
- Urban
  - Sectors such as road traffic, industry domestic and others
- Local
  - Including a split into different vehicle classes, such as cars, buses, HGVs

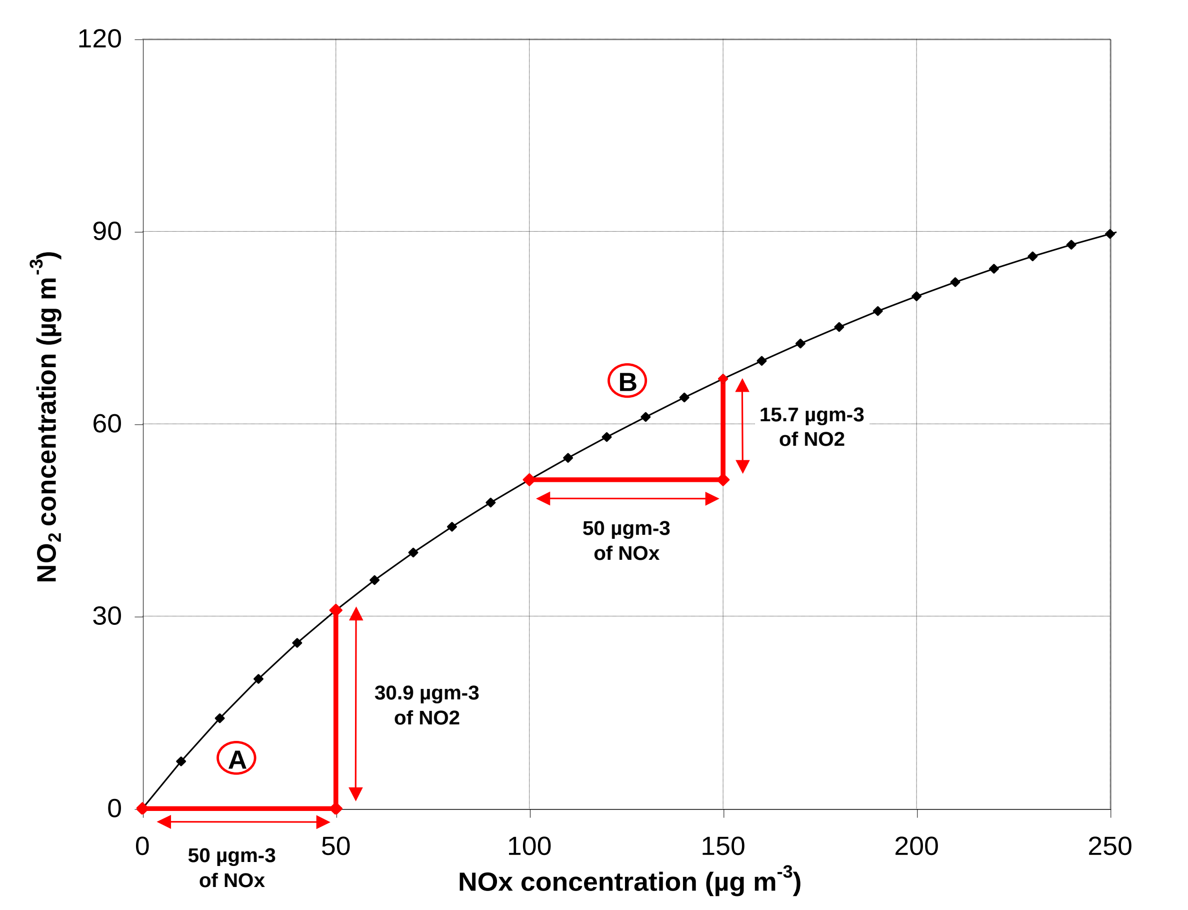
Source apportionment for NO_X is presented in the UK overview document and air quality plans for each zone[16].

3.5.2. Source apportionment for NO_2

It is not possible to calculate an unambiguous source apportionment for annual mean NO_2 concentrations because ambient NO_2 concentrations include contributions from both directly emitted primary NO_2 and secondary NO_2 formed in the atmosphere by the oxidation of NO. There is no simple linear relationship between NO_2 concentrations and NO_X emissions or concentrations. Figure 2.1 illustrates why this is so. The magnitude of the reduction in NO_2 concentration associated with a reduction in NO_X concentration depends on the initial NO_X concentration. Thus, the same reduction in NO_X emissions will have a lower impact on NO_2 concentrations where those concentrations are already high. This is illustrated in Figure 2.1 where a reduction of 50µg m^{-3} NO_X results in a reduction of nearly 40 µg m^{-3} at location A whereas the same NO_X emission reduction at location B only results in a reduction of just under 16 µg m^{-3} in the NO_2 concentration. Likewise, an equal reduction in NO_2 concentrations will require a larger reduction in NO_X emissions where the starting concentration is already high. The complexity is further increase by the variation in primary NO_2 emissions from one location to another, thus the curves are different for different locations.

[16] UK overview document and plans are available at: http://uk-air.defra.gov.uk/library/no2ten/

Figure 2.1. Relationship between NO_X and NO_2 concentrations for a hypothetical site using realistic variables



A method has however been developed to provide an indicative source apportionment for annual mean NO_2 concentrations for the air quality plans for each zone. This method involves calculating the maximum and minimum possible contribution from each source to the NO_2 concentration using curves similar to the curve illustrated in Figure 2.1. The final source apportionment has been calculated as the average of the minimum and maximum contributions for each source, with the results normalised so that the contributions sum to the total modelled NO_2 concentration.

Overall, the source apportionment for NO_2 was found to be very similar to the source apportionment for NO_X. The exceptions were for sources such as buses in London and light good vehicles, for which high primary NO_2 emission fractions are expected due to the widespread use of oxidation catalysts. The percentage contribution to NO_2 concentrations from these vehicle types is greater than the percentage contribution to NO_X.

3.6. NO_2 maps for 2008

The annual mean NO_2 maps for 2008 for background and roadside locations are shown in Figures 2.2 and 2.3. The model results for 2008 in terms of the extent of exceedance of the annual mean limit value for NO_2 are presented in the air quality plans for each zone.

Figure 2.2. Annual mean background NO_2 concentration, 2008 ($\mu g\ m^{-3}$)

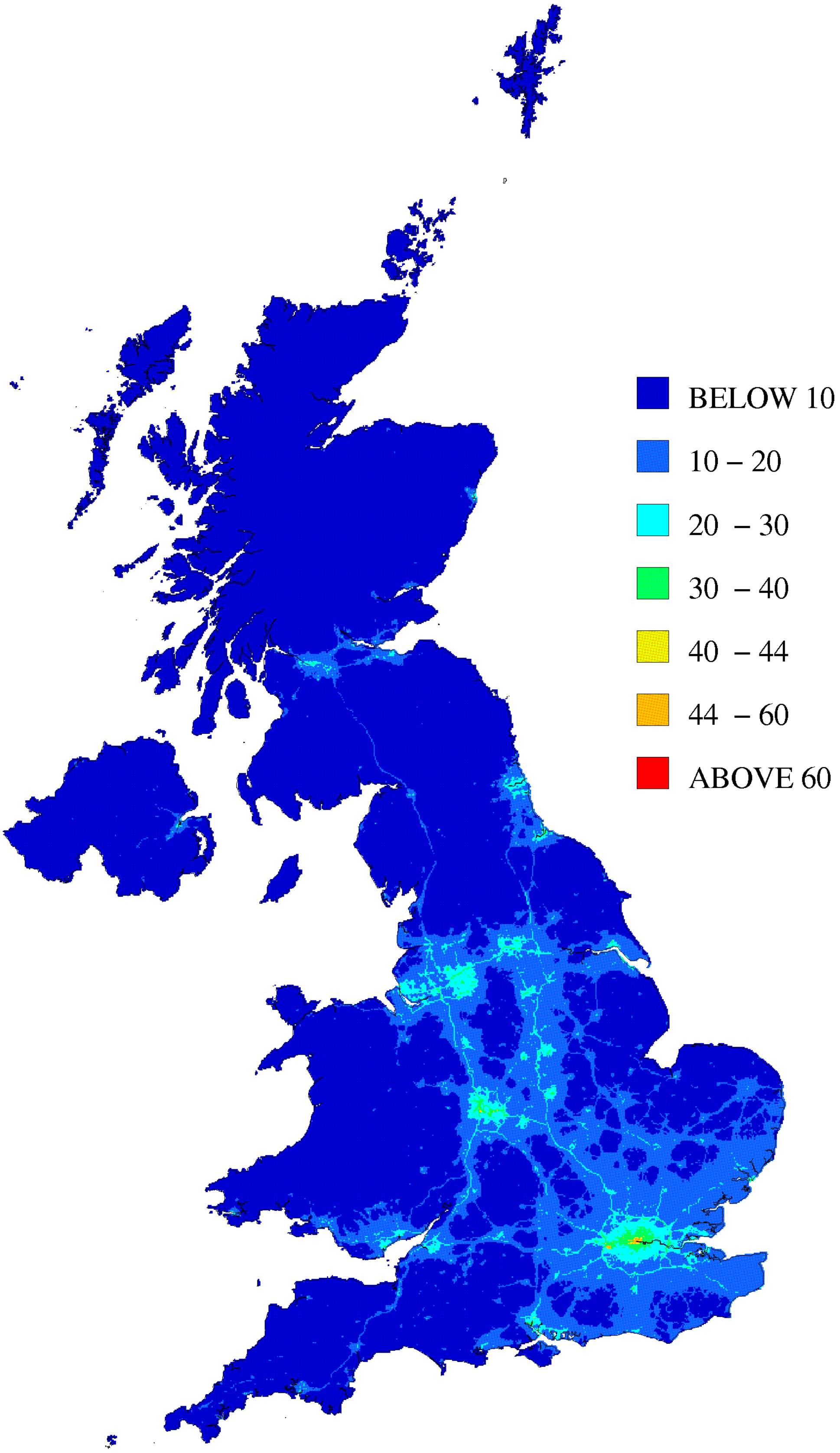
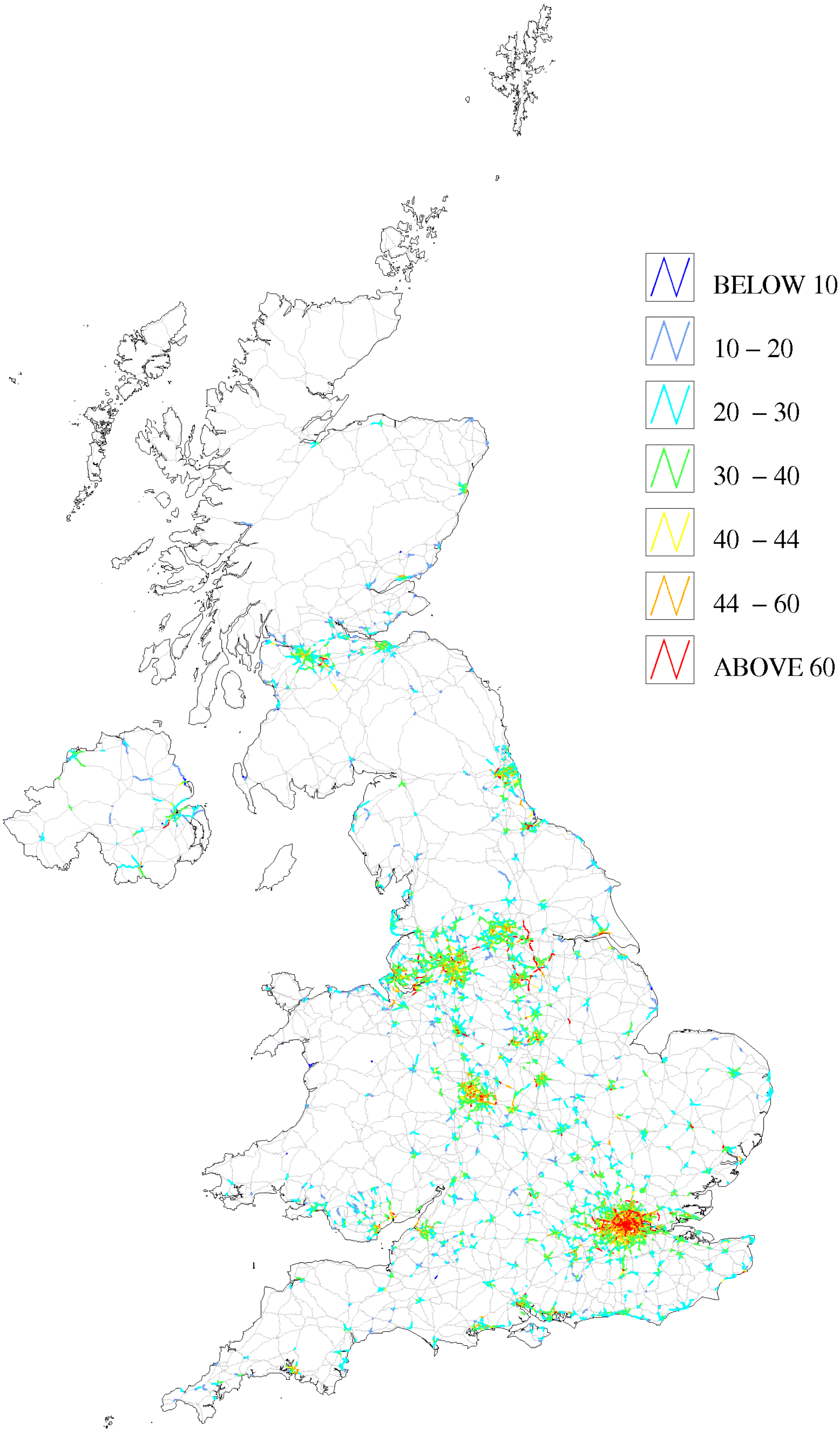


Figure 2.3 Urban major roads, annual mean roadside NO_2 concentration, 2008 ($\mu g\ m^{-3}$)



4. Assessment of the 1-hour limit value in 2008

Modelling of 1-hour NO_2 concentrations for comparison with the 1-hour limit value has not been carried out because of the very large additional uncertainties that would be associated with attempting to model concentrations on an hourly basis using the currently available techniques. The assessment of compliance with this limit value in 2008 has been based on monitoring data only. A model has been developed to calculate projections of 1-hour NO_2 concentrations for 2010 and 2015 at monitoring site locations. This model is described in Section 6 of this report.

5. Baseline NO_X and NO_2 projections for 2010, 2015 and 2020

5.1. NO_X emissions

5.1.1. Introduction

Emissions projections are available from the NAEI for 2010, 2015 and 2020. These projections have been calculated from an emission inventory base year of 2007. The projections split by emission source sector are illustrated in Figure 5.1. The values for intermediate years shown in this figure have been calculated by interpolation i.e. by extending the trend between the years explicitly modelled (2007, 2010, 2015 and 2020).

Projections are required in order to determine the compliance picture for 2010, the year the limit values came into force. 2010 projections have been used because a full assessment of monitored and modelled air quality data for 2010 will not be completed until the end of September 2011. Projections for 2015 and 2020 are required to support the development of the air quality plans.

5.1.2. Road traffic sources

The projections for road traffic incorporate information on:

- Vehicle activity derived from the UK Department for Transport National Transport Model published in March 2010[17] and for London provided by Transport for London in December 2010.
- Vehicle fleet characteristics and turnover, including assumptions about the proportion of new cars sold that are diesel cars (43% for 2010 and subsequent years).
- Changes in emissions as a result of the Euro standards for new vehicles and changes in fuel standards (legislation up to and including Euro 5 & 6 for light duty vehicles and Euro VI for heavy duty vehicles).

The measures influencing vehicle emissions that have been included in these baseline projections are in the list of UK and National Measures document[18].

The impact of the group of local measures known as 'smarter choices' has also been included in the evaluation. This group of measures includes actions by local authorities to manage demand for mobility through the implementation of travel management options including institutional and individual travel planning to provide alternatives to car journeys. These measures are expected to result in a reduction in the distance travelled by cars in urban areas of 2% and, because they are not currently included in the national traffic activity projections, have been added to the baseline projections for this evaluation.

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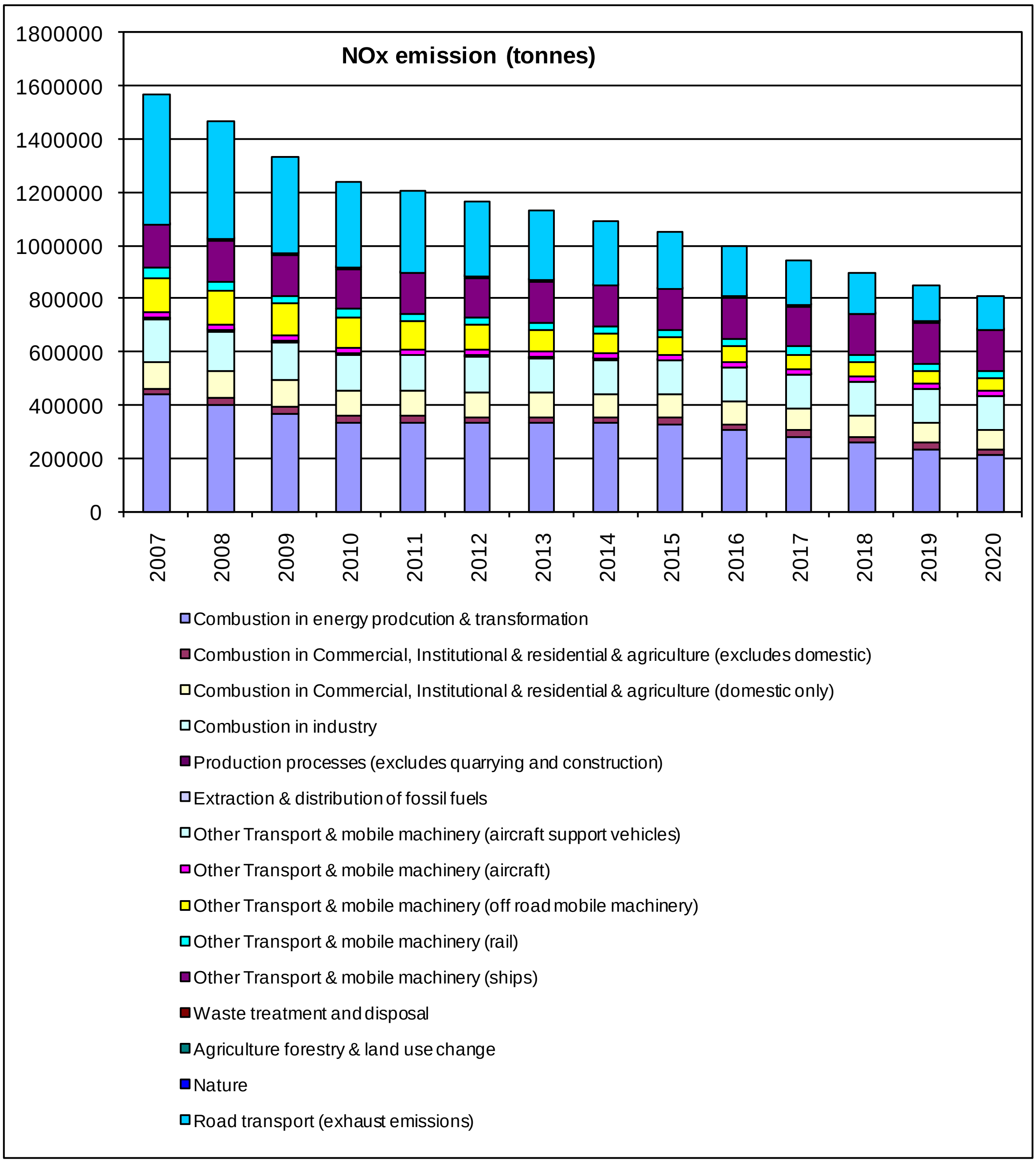
[17] http://www.dft.gov.uk/pgr/economics/ntm/forecasts2009/
[18] http://uk-air.defra.gov.uk/library/no2ten/

Figure 5.1. Total UK NO_X emissions for 2007 and emissions projections up to 2020 by source sector from NAEI 2007



5.1.3. Non-road traffic sources

The projections for non-road traffic sources have been calculated by the NAEI based on the Updated Energy Projections 37 from the Department of Energy and Climate Change[19]. The activity projections include the impact of the 2007 Energy White Paper and the estimated net impact of the European Commission proposals on the EU Emission Trading System. They do not include policies that were still under consideration at the time of compilation (June 2009) including:

[19] http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx

- The Carbon Capture and Storage demonstration project
- The Renewable Heat Incentive
- Feed in tariffs for renewable electricity
- Domestic energy efficiency measures including the Carbon Emissions Reduction Target extension, Heat and Energy Saving Strategy and the re-launch of Home Front
- The Carbon Reduction Commitment
- Smart meters to be installed in all homes and SMEs by 2020, better billing to be implemented
- Community Energy Saving Programme

In addition to changes in activity influencing emissions, improvements in abatement measures will also reduce emissions. The implementation of more stringent abatement measures, often the result of established legal requirements, must be considered when estimating future emissions. Therefore the emission factors where relevant have been varied to account for this. The projections do not include the impact of additional policies and measures that are subject to review and had not yet been implemented into UK law at the time of compilation, including the Industrial Emission Directive. Regulations that have been taken into account include:

- The Large Combustion Plant Directive
- The IPPC Directive
- The Solvent Emissions Directive
- Marpol VI
- Sulphur Content of Liquid Fuels Regulations 2007
- European Directives & UK Regulations on Non Road Mobile Machinery

Further details of the emissions projections are available from the NAEI[20].

5.2. The PCM models for baseline NO_X projections

5.2.1. Introduction

The 2008 base year model used to carry out the air quality assessment for 2008 has been used to calculate the baseline NO_X concentration projections for 2010, 2015 and 2020 to provide the information required to develop the air quality plans. Meteorological data for 2008 was used along with emission projections for the relevant year.

5.2.2. Road traffic sources

The emissions from road traffic sources have been mapped in detail for each projection year. These projections incorporate activity projections for each vehicle type in each of nine former Government Office Regions in England and projections

[20] http://uk-air.defra.gov.uk/reports/cat07/1011100847_2007_Emission_Projections_Report_June09_v1.pdf

for Scotland, Wales and Northern Ireland. The emissions for each of the individual major road links have been recalculated for the projection years based on the:

- 2007 traffic counts for each vehicle type
- Traffic activity projections in the projection year for each vehicle type for the relevant region
- The fleet weighted emission factor in the projection year for the vehicle type.

The contributions from emissions from traffic on minor roads and from cold starts were then added in order to calculate the total road traffic emissions for each of the 1 km x 1 km grid squares across the UK.

5.2.3. Non-road traffic area sources

The emissions for non-road area sources have been projected forwards from the 2007 emissions maps for each sector. Scaling factors for each sector were derived by summing the emissions estimates for each source for 2007 and for the projection year. Thus the spatial distribution for each sector the projection year is assumed to be the same as for that sector in 2007. This is in contrast to the emissions projection maps for road traffic sources, which have been recalculated in detail for each projection year.

5.2.4. Point sources

The emissions estimates for each point source for the projection years were estimated by scaling the 2007 emission estimates. Scaling factors were derived for each individual source code. Thus the proportional change in emissions for each plant within the same source code (such as iron and steel - combustion plant or incineration) were assumed to be the same. Plant that are expected to close were not included in the point source projections for the projection years.

5.2.5. Regional background

The maps of regional NO_X concentrations for the projection years have been calculated from the 2008 map of regional background concentration. The 2008 map has been split into three components:

- Regional NO_X concentration from UK sources
- Regional NO_X concentration from non-UK European sources
- Regional NO_X concentration from maritime sources

This source apportionment has been carried out using projected 2010 from EMEP grids (Tim Oxley pers. comm., 2006) for these sources. The contribution from UK and EU sources has been scaled forward according to the NAEI projections of total UK NO_X emissions. The contribution from maritime sources has been scaled forwards using emission projections from EMEP[21].

5.3. *The PCM models for baseline NO_2 projections*

The 2008 base year model used to carry out the air quality assessment for 2008 was used to calculate the baseline NO_2 concentration projections for 2010, 2015 and 2020. The primary NO_2 emission fraction, f-NO_2 has been recalculated for each road

[21] *Webdab, accessed May 2009* http://www.ceip.at/emission-data-webdab/emissions-as-used-in-emep-models/

link for the projection years based on the NO_X emission and a fleet weighted f-NO_2 value for the relevant year for each vehicle type. The regional oxidant concentration has been assumed to remain unchanged from the 2008 value in the projection years on the basis of projections presented by Derwent et al[22]. An analysis of recent trends in background ozone concentrations at Mace Head in Ireland also suggests that there has been little change in concentration since about 2000[23].

5.4. *NO_2 maps for 2010 and 2015*

Annual mean NO_2 maps for 2010 and 2015 for background and roadside locations are shown in Figures 5.2 to 5.5. The model results showing the extent of exceedance of the annual mean limit value for NO_2 are presented in the air quality plans for each zone.

[22] Derwent, R.G., Simmonds, P.G., O‟Doherty, S., Stevenson, D.S., Collins, W.J., Sanderson, M.G., Johnson, C.E., Dentener, F., Cofala, J., Mechler, R. and Amann, M. (2005). External influences on Europe‟s air quality: baseline methane, carbon monoxide and ozone from 1999 to 2030 at Mace Head, Ireland. Atmospheric Environment, 40, 844-855. doi:10.1016/j.atmosenv.2005.09.077

[23] Air Quality Expert Group. Ozone in the United Kingdom (2009): http://archive.defra.gov.uk/environment/quality/air/airquality/publications/ozone/documents/aqeg-ozone-report.pdf

Figure 5.2. Annual mean background NO_2 concentration, 2010 ($\mu g\ m^{-3}$)

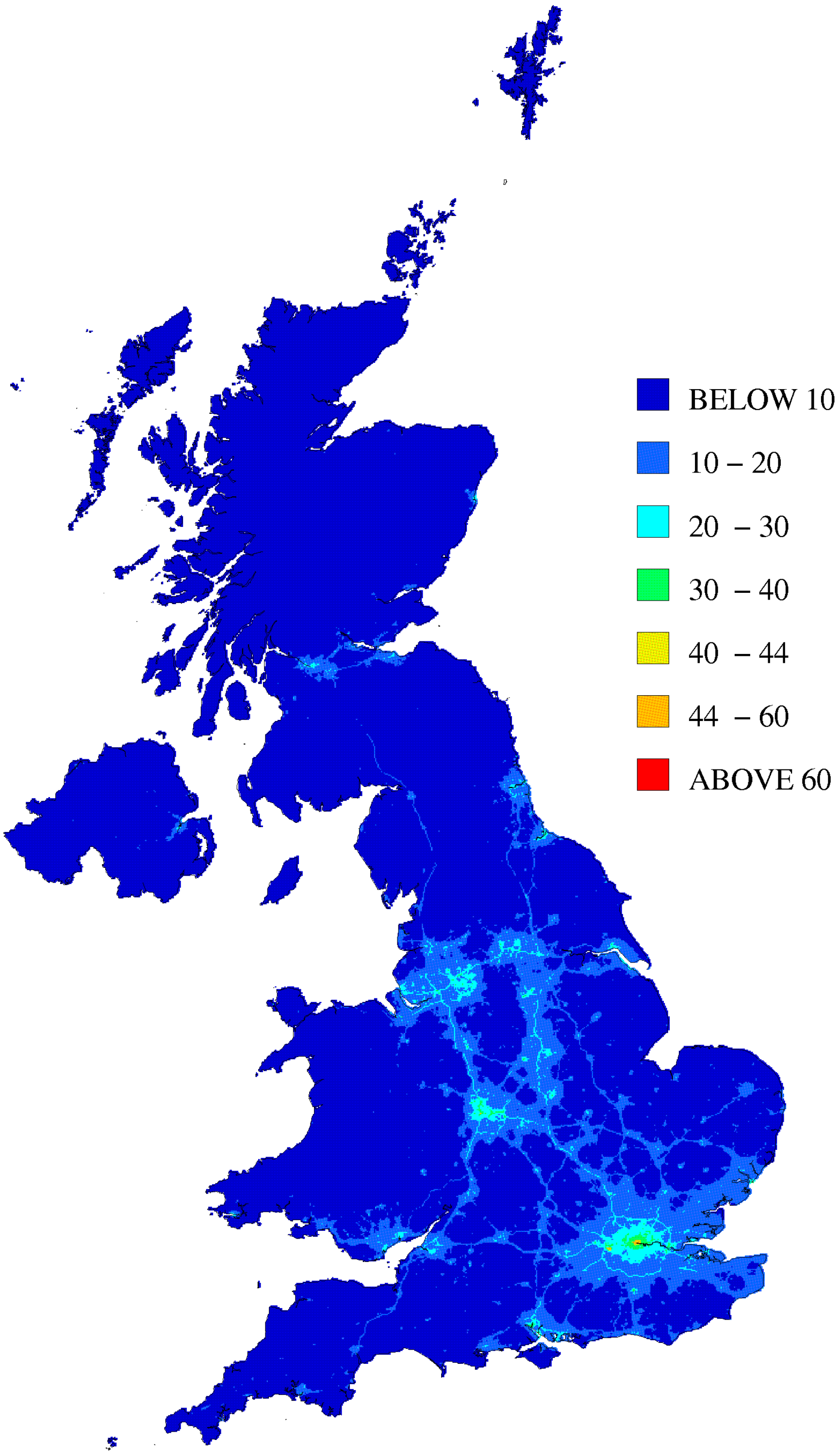


Figure 5.3 Urban major roads, annual mean roadside NO_2 concentration, 2010 ($\mu g\ m^{-3}$)

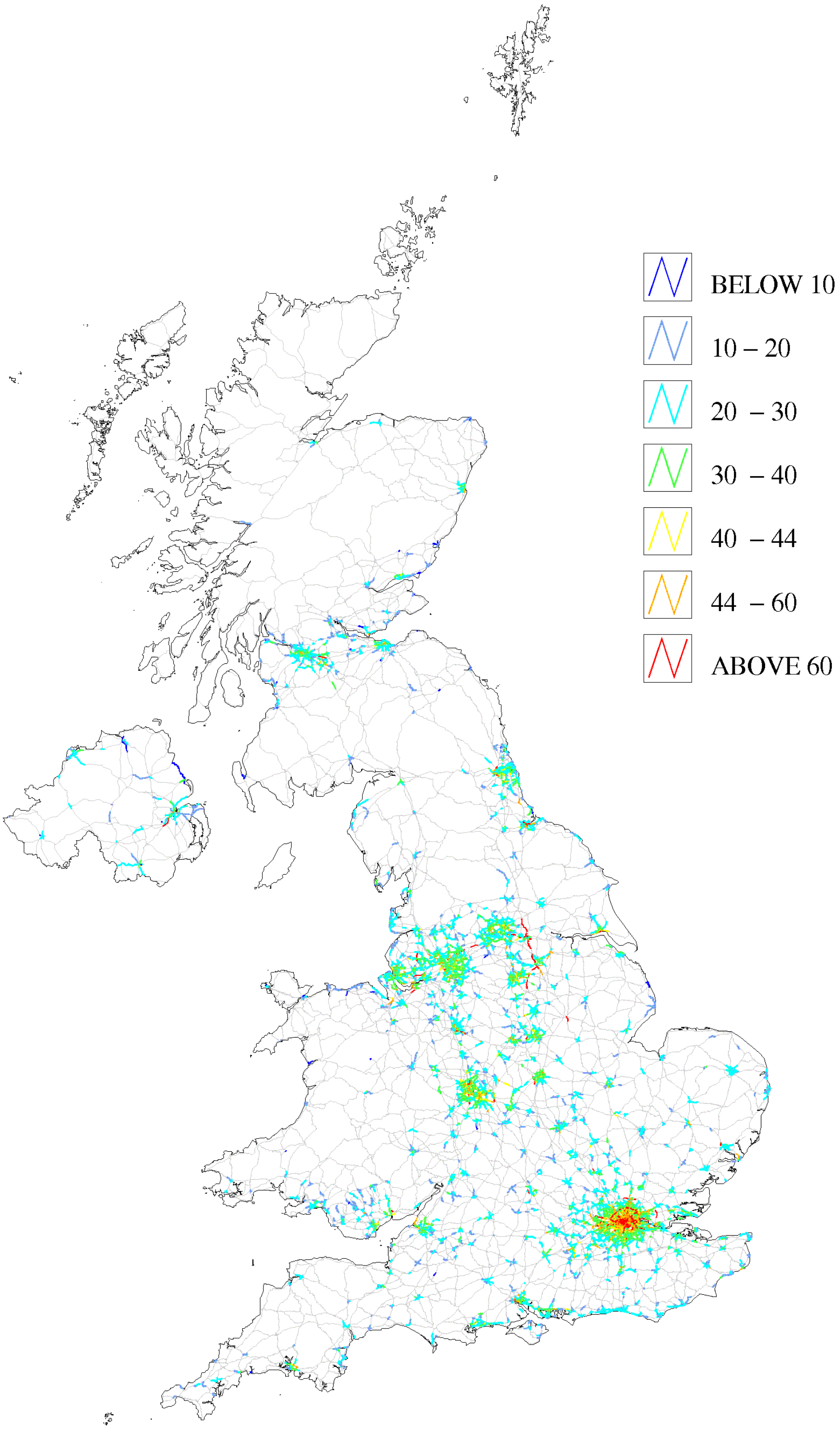


Figure 5.4. Annual mean background NO_2 concentration, 2015 ($\mu g\ m^{-3}$)

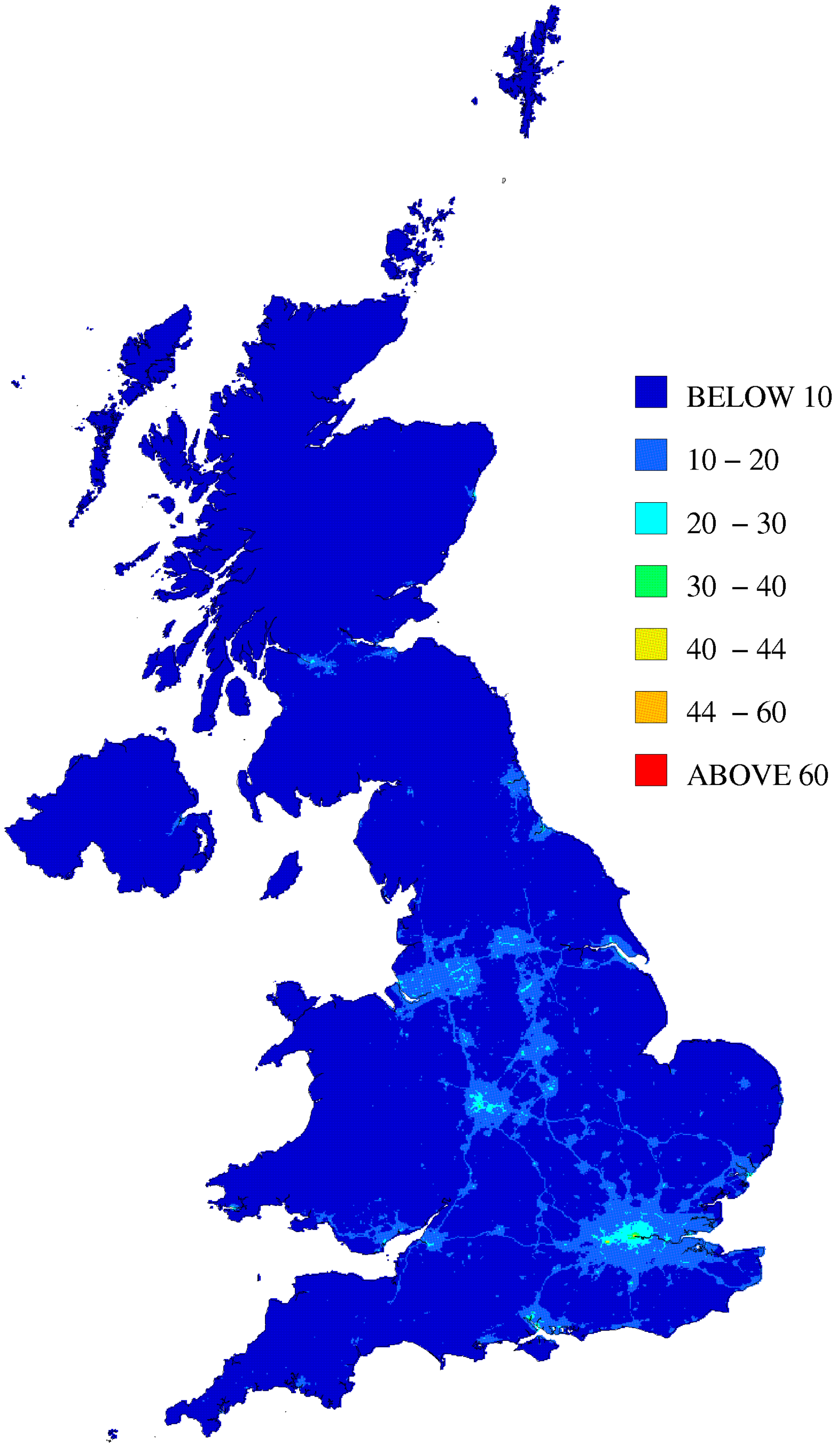
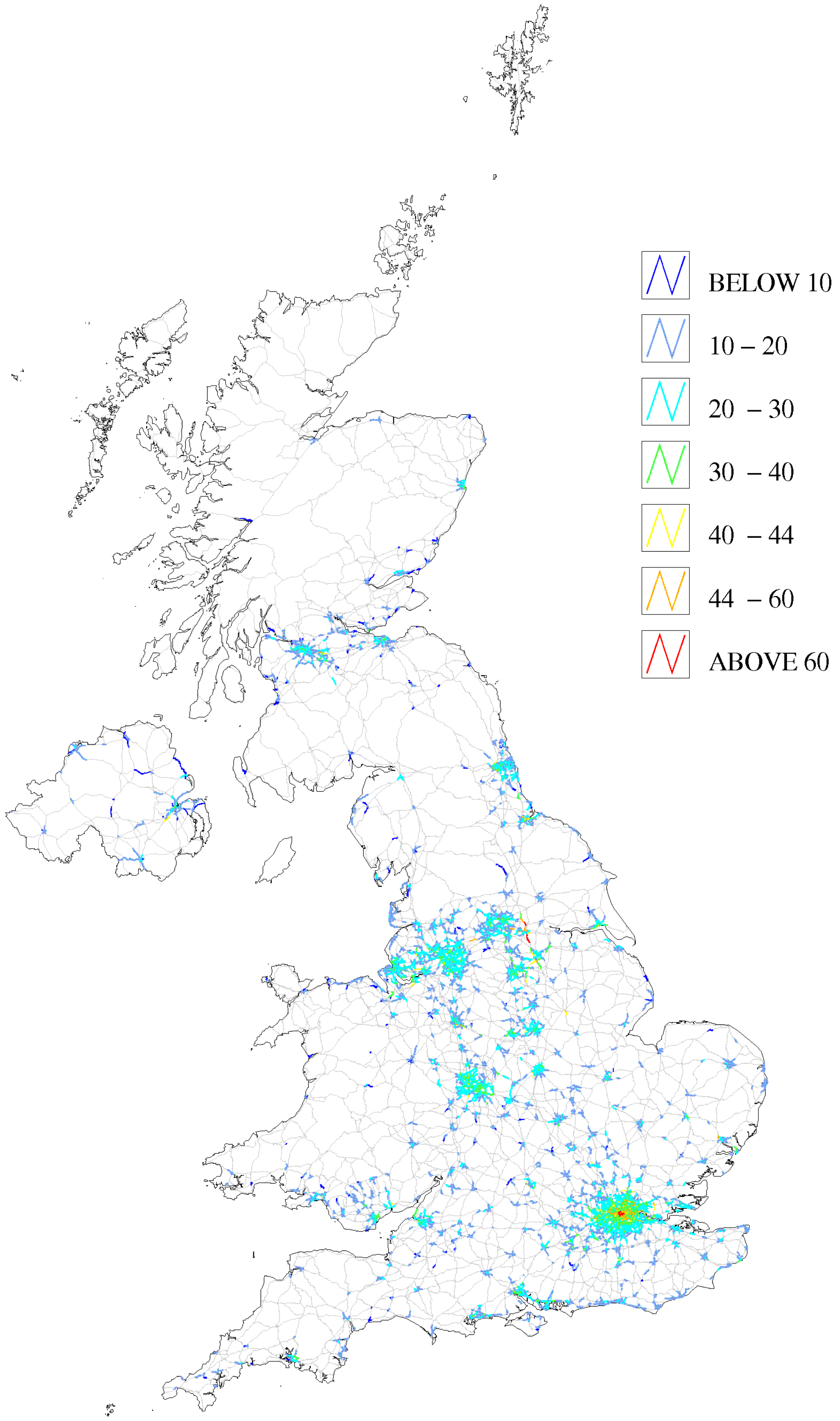


Figure 5.5 Urban major roads, annual mean roadside NO_2 concentration, 2015 ($\mu g\ m^{-3}$)



6. Baseline projections for comparison with the 1-hour limit value for 2010 and 2015

6.1. Introduction

Modelling of 1-hour NO_2 concentrations for comparison with the 1-hour limit value has not been carried out for the reference year. The assessment of compliance with this limit value in 2008 has been based on monitoring data only. The projection module of the Netcen primary NO_2 model has been used to calculate the projections of 1-hour NO_2 concentrations for 2010 and 2015 for comparison with the 1-hour limit value at monitoring site locations included in the air quality plans for each zone.

6.2. The Netcen primary NO_2 model

The Netcen primary NO_2 model is a one-dimensional representation of the interaction between NO, NO_2 and O_3 concentrations and f-NO_2 at roadside locations. The model has been described by Grice et al (2009)[24]. The model is underpinned by the basic assumption that an appropriate background site can be paired with each roadside monitoring site such that the NO, NO_2 and O_3 measured at the background site are representative of the background concentrations at the roadside site. The model has three modules:

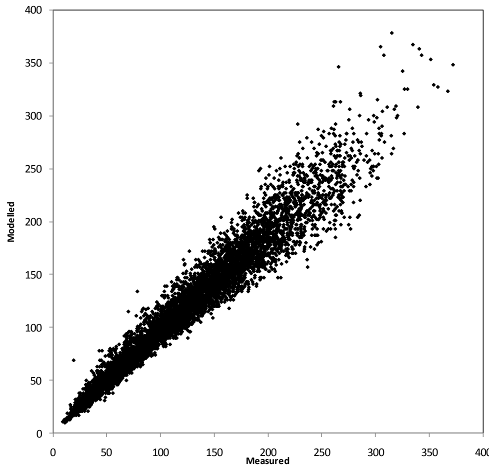
- The analysis module is used to determine f-NO_2 from ambient monitoring data. The NO_2 concentration at the roadside is apportioned into secondary NO_2 formed by the oxidation of NO by O_3 and the contribution from NO_2 emitted directly from local road vehicles, the primary NO_2.
- The O_3 concentration at the roadside must be known in order to estimate f-NO_2. The ozone module is therefore used to predict hourly ozone concentrations at the roadside where measurements are not available.
- The equations within the analysis module have been rearranged within the prediction module in order to predict roadside NO_2 concentrations with the value of f-NO_2 set as one of the model inputs.

Full details of the model are presented in Grice et al (2009). Figure 6.1 shows a comparison of the predictions of 1-hour NO_2 concentrations for 2008 calculated using the model with measured concentrations at the monitoring sites with a measured exceedance of the limit value in 2008. It is clear that the model provides a reasonably robust estimate of the concentration for 2008 and is therefore suitable for providing projections for other years.

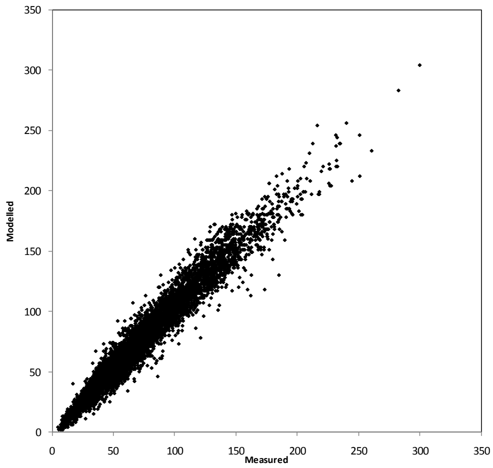
[24] Grice, S, Stedman, J, Kent, A, Hobson, M, Norris, J, Abbott, J, Cooke, S. (2009) Recent trends and projections of primary NO2 emissions in Europe. Atmospheric Environment 43, 2154–2167. doi:10.1016/j.atmosenv.2009.01.019

Figure 6.1 Comparison of modelled and measured 1-hour NO_2 concentration in 2008 ($\mu g\ m^{-3}$)

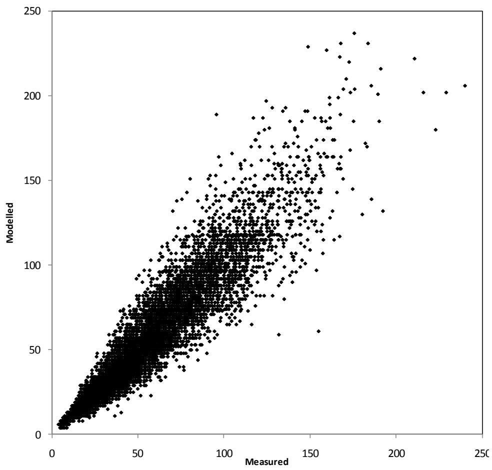
a) London Marylebone Road



b) Glasgow Kerbside



c) Aberdeen Union Street Roadside



6.3. Input assumptions for projections to 2010 and 2015

The projected numbers of 1-hour concentrations greater than the limit value have been calculated from the projections of 1-hour concentrations at the monitoring sites. These projections have been calculated using slightly different projections of NO_X emissions to those used for the annual mean projections described above.

The baseline emissions projections used within the 1-hour modelling have been derived from earlier traffic activity projections from the UK Department for Transport National Transport Model published in December 2008[25]. The impacts of the smarter choices measures and many of the measures from the Mayor's Air Quality Strategy for London[26] have not been included in these emissions projections, which were calculated early on in the assessment process.

[25] http://www.dft.gov.uk/pgr/economics/ntm/roadtransportforcasts08/
[26] http://www.london.gov.uk/publication/mayors-air-quality-strategy

A further difference in input assumptions compared with the annual mean projections is that the primary NO_2 emission fraction (f-NO_2) for the projection years has been assumed to be unchanged from the value derived from measurement data for 2008. The annual mean projections used link specific estimates of f-NO_2 derived from the emission inventory calculations for the relevant year. Primary NO_2 emissions are influenced by the local fleet and traffic conditions on each road and it was therefore considered that the use of measurement based estimates of f-NO_2 specific to the individual monitoring sites to be modelled for comparison with the 1-hr limit value is the more robust approach. Projections of the number of exceedances of the 1-hour limit value are particularly sensitive to the value of f-NO_2 and it was considered more important to incorporate this local measurement based information than to vary the f-NO_2 estimate for the projection years. Estimates of f-NO_2 derived from monitoring data are not available for the more than 9000 road links for which modelled assessments of the annual mean concentration have been calculated.

7. NO_2 projections for 2015 and 2020 including the Low Emission Zone (LEZ) scenario

7.1. Introduction

Projections of annual mean NO_X and NO_2 concentrations in 2015 and 2020 including the impact of a targeted Low Emission Zone (LEZ) measure have also been calculated to inform the development of the air quality plans. The scenario modelled here is to illustrate the NO_2 emission reductions a LEZ could bring. As explained in the UK overview document and air quality plan for relevant zones, further work is currently underway to investigate the feasibility, practicality and effectiveness of a national framework for low emission zones: the modelled scenario does not include an assessment of these issues. The LEZ scenario would require all buses and HGVs to meet at least EURO IV standards for both NO_X and particulate matter (PM_{10}) emissions by 2015. For modelling purposes, a number of assumptions have been made concerning the geographic extent of the LEZs and the actual impacts of the LEZ on emissions of NO_X; these are detailed below. The modelling of the impact of an equivalent LEZ scenario for the existing London LEZ area is described in Section 8.

Summary results from the modelling assessment in terms of extent of exceedance and maximum modelled concentration in each zone are provided in the air quality plans for the individual zones.

7.2. Geographical extent

A total of 41 local authorities outside London have been included in the modelling assessment for the LEZ scenario. These local authorities have been selected following a detailed analysis of the PCM model results for the baseline and a hypothetical scenario in which the LEZ applied everywhere. The selected local authorities fulfil one or more of the following criteria:

- The LEZ scenario enables compliance to be achieved within the zone by 2015 in a zone where compliance is not projected to be achieved under baseline conditions.
- The compliance gap is reduced but not completely closed (either because the compliance gap is too big, or there are one or more non-compliant strategic roads in the zone, for which an LEZ measure would not be practicable).
- Inclusion of the local authority results in a more coherent geographical area for the LEZ.

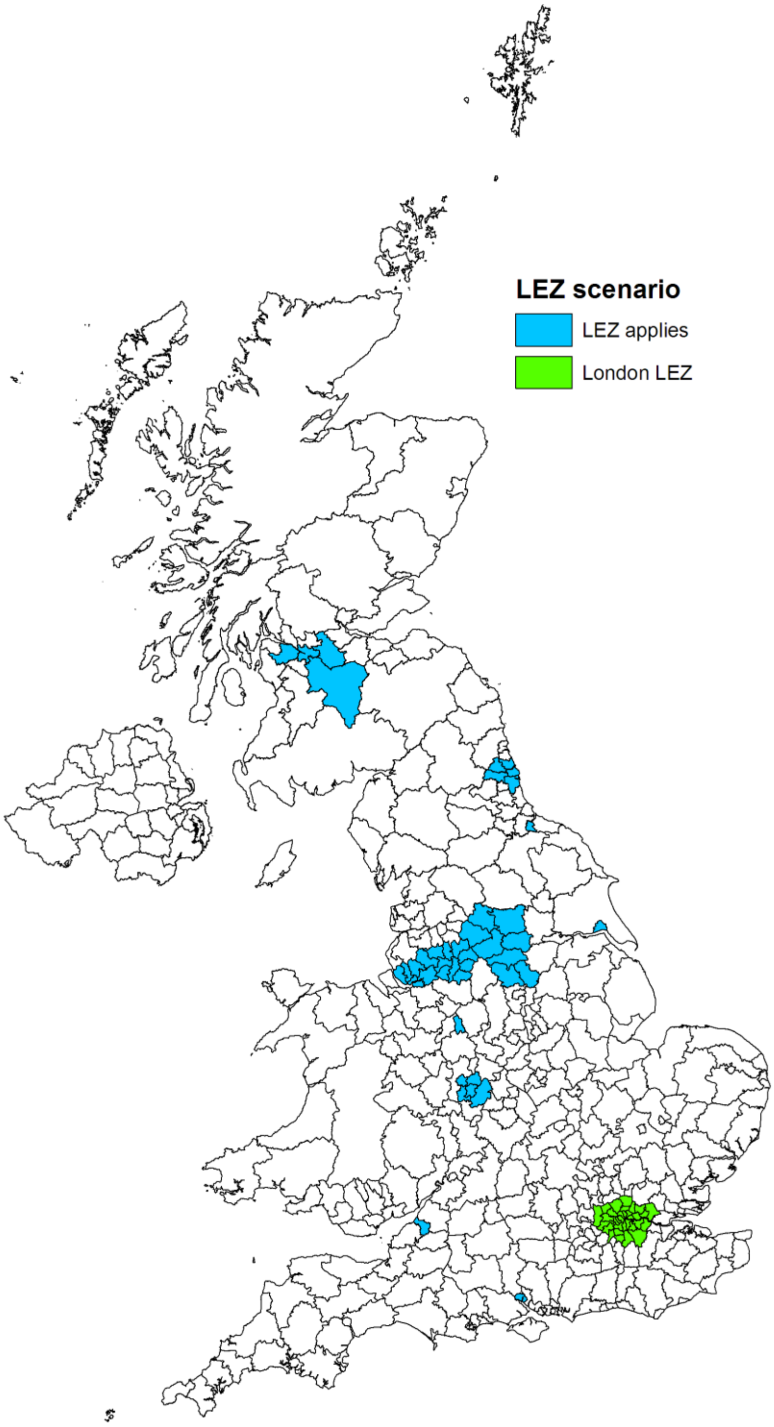
The inclusion of Glasgow was at the request of the Scottish Government.

The LEZ requirements have been assumed to apply to all buses and HGVs on roads within the selected local authorities that are not part of the strategic road network. It would not be practicable or reasonable to apply an LEZ to individual stretches of the main long distance routes that connect different parts of the country. The traffic fleet on all other roads across the UK is also assumed to be modified as a result of the implementation of this measure in the selected local authorities (see Section 7.3.1

for further details). The local authorities included in the analysis for the LEZ scenario and the existing London LEZ area are shown in Figure 7.1. The local authorities outside London included in the scenario analysis are:

- Barnsley Metropolitan Borough Council
- Birmingham City Council
- Bolton Metropolitan Borough Council
- Bradford Metropolitan District Council
- Bristol City Council
- Bury Metropolitan Borough Council
- Calderdale Metropolitan Borough Council
- Dudley Metropolitan Borough Council
- Gateshead Metropolitan Borough Council
- Halton Borough Council
- Kingston upon Hull City Council
- Kirklees Council
- Knowsley Metropolitan Borough Council
- Leeds City Council
- Liverpool City Council
- Manchester City Council
- Middlesbrough Council
- Newcastle upon Tyne City Council
- North Tyneside Metropolitan Borough Council
- Oldham Metropolitan Borough Council
- Rochdale Metropolitan Borough Council
- Rotherham Metropolitan Borough Council
- Salford City Council
- Sandwell Metropolitan Borough Council
- Sheffield City Council
- South Tyneside Metropolitan Borough Council
- Southampton City Council
- St Helens Metropolitan Borough Council
- Stockport Metropolitan Borough Council
- Stoke on Trent City Council
- Sunderland City Council
- Tameside Metropolitan Borough Council
- Trafford Metropolitan Borough
- Wakefield Council
- Walsall Metropolitan Borough Council
- Warrington Borough Council
- Wigan Metropolitan Borough Council
- Wolverhampton City Council
- Glasgow City Council
- North Lanarkshire Council
- Renfrewshire Council
- South Lanarkshire Council

Figure 7.1 The local authorities included in the LEZ scenario.



7.3. *Emissions assumptions*

The key determinants of emission changes are the behaviour of vehicle owners and the effectiveness of emission reduction measures. For modelling purposes a number of assumptions have been made, however, these will be subject to further investigation as part of the work underway exploring the feasibility of a national framework for low emission zones (see Chapter 5 of the UK overview document).

7.3.1. Behavioural responses

Owners of non-compliant vehicles could respond to the introduction of LEZs in one of three ways:

- Redeploy: Some Euro I, II and III vehicles will be redeployed to other routes and replaced with Euro IV or Euro V vehicles. This can occur both within large organisations and across organisations, through the second-hand market.
- Retrofitment: Some Euro I, II and III vehicle owners will retrofit their vehicles with emissions abatement technology to bring their emissions standards up to (at least) a Euro IV standard.
- Replacement: Some Euro I, II and III vehicle owners will replace their vehicles with new Euro VI vehicles.

Assumptions about the responses of vehicle owners have been based on expert judgement and estimates of the relative costs of different assumptions and include:

- Buses = buses and coaches.
- No buses are redeployed - it has been assumed that redeployment is an option for HGVs but not for buses due to the localised nature of bus journeys.
- Retrofit is only assumed for Euro III buses and HGVs based on costs. Costs for Euro II and I are assumed favourable for replacement.
- Retrofit assumed to be NO_X and PM, i.e. a combined diesel particulate filter (DPF) and selective catalytic reduction (SCR) system.
- Where vehicles are replaced, the replacement vehicles will be new e.g. Euro VI
- Where vehicles are redeployed, the incoming vehicles will be current fleet mix.

Table 7.1 shows the proportions of redeployment, retrofitment and replacement for each vehicle class used in the modelling of the LEZ scenario.

It has been assumed that changes to the national fleet resulting from the implementation of LEZs will have impacts on emissions outside the LEZ, leading to a slightly larger proportion of the HGVs being compliant with Euro IV than in the baseline. The assumptions for this change are listed in Table 7.1. It has been assumed that the impacts outside the LEZ will be uniform across the UK which will lead to a slight overestimate of the impacts in areas remote from likely LEZ locations where air quality will already be good.

Table 7.1 Uptake assumptions for LEZ scenario

	% Redeploy	% uptake of retrofitment inside an LEZ	% uptake of replacement inside an LEZ	% uptake of retrofitment outside an LEZ	% uptake of replacement outside an LEZ
Buses - Euro I	0%	0%	100%	0%	0%
Buses - Euro II	0%	0%	100%	0%	0%
Buses - Euro III	0%	50%	50%	0%	0%
Rigid HGVs - Euro I	18%	0%	82%	0%	25%
Rigid HGVs - Euro II	18%	0%	82%	0%	25%
Rigid HGVs - Euro III	18%	82%	0%	25%	0%
Artic HGVs - Euro I	18%	0%	82%	0%	25%
Artic HGVs - Euro II	18%	0%	82%	0%	25%
Artic HGVs - Euro III	18%	68%	14%	20%	4%

7.3.2. Emission changes

The scenario includes the option to replace old vehicles with newer ones. This move to a higher Euro standard is expected to reduce emissions of both NO_X and PM. However, it is known that the real world performance of the Euro standards has not delivered the expected emissions reductions in some cases. As explained in Section 3.2 of this document, understanding of these issues is not sufficiently advanced to allow these uncertainties to be quantified and included in the modelling: the model assumes that the Euro standards deliver the emissions reductions laid out in the National Atmospheric Emissions Inventory (NAEI) as these represented the best available evidence. The uncertainty around real world performance of the Euro standards is one of many uncertainties in future emissions from road transport and adds to uncertainties inherent in projections of future emissions.

Retrofitment is an emerging technology, thus the effectiveness of the technology is not certain and there is limited on-road test data. The effectiveness assumptions used in the modelling were derived from the published literature and from discussions with industry experts and are shown in Table 7.2. The primary NO_2 emission fraction for selective catalytic reduction and diesel particulate filter (DPF) retrofits are assumed to be the same as for EURO VI.

Table 7.2 Emissions reduction assumptions for retrofit

Selective catalytic reduction and DPF trap applied to Euro III	% reduction in pollutant achieved through retrofit technology to Euro IV (relative to Euro III)	
	NO_X	**PM_{10} and $PM_{2.5}$**
Buses	70%	90%
HGVs (Rigid and Articulated)	50%	90%

8. NO_2 projections for 2015 and 2020 for London with additional measures from the Mayor's Air Quality Strategy

8.1. Baseline projections for 2015 for London including fully committed additional measures from the Mayor's Air Quality Strategy for London

Baseline projections of NO_X and NO_2 concentrations in 2015 for the Greater London Urban Area zone were calculated using the PCM model in the same way as for all of the other zones in the UK. The baseline NAEI emissions projections for London includes the LEZ phases 1,2,3 and 4 measure from the Mayor's Air Quality Strategy for London (MAQS) published in December 2010.

The following London specific existing or fully committed quantifiable measures from the MAQS have also been included in the baseline projections for London within the Air Quality Plan for the Greater London Urban Area zone:

- Taxi age policy
- Taxi no idling
- Private Hire Vehicle (PHV) age policy
- Transport for London (TfL) bus strategy
- Electric vehicles
- Eco-driving
- Freight
- Energy efficiency for residential properties
- Energy efficiency for public buildings

These projections for 2015 were calculated using the PCM model.

The impact of these measures on emissions has been presented in the MAQS published in December 2010 along with the results of air quality modelling carried out to support the development of the MAQS. These emission reductions have been used within the PCM model to calculate the impact of these measures on concentrations in such a way as to be consistent with the modelling carried for the whole of the UK to support the time extension notification. Although based on similar assumptions, the modelling undertaken for the MAQS is different from the PCM modelling and the two are not directly comparable. The emissions calculations within the MAQS were carried out using the London Atmospheric Emission Inventory. The changes in emissions relative to the baseline calculated within the MAQS for each measure were applied to the baseline NAEI emissions to calculate emissions projections for these additional measures for use within the PCM model.

Further details of these measures and other measures, for which quantitative estimates of the impact are not available, can be found in the air quality plan for the Greater London Urban Area[27] and the MAQS published in December 2010.

8.2. Baseline projections for 2020 for London including fully committed additional measures from the Mayor's Air Quality Strategy for London

The impacts of the measures within the MAQS on emissions in 2020 are not given in the Strategy itself. An estimate has therefore been calculated of the impact of these measures on emissions in 2020 based on the assumptions listed in Table 8.1. It has not been possible to include an estimate of the impact of all of the MAQS measures in 2020 because relevant data are not available. These measures would be expected to have only a small impact in 2020.

Table 8.1 Assumptions for assessing the impact of MAQS measures in 2020

Measure	**Assumption for 2020**
LEZ phases 1,2,3 and 4	Included in NAEI baseline
Taxi age policy	Impact not in included in 2020 analysis
Taxi no idling	Assume same percentage impact as in 2015
PHV age policy	Impact not in included in 2020 analysis
TfL bus strategy	Impact not in included in 2020 analysis
Electric vehicles	Impact extrapolated from impact in 2011 and 2015
Eco-driving	Assume same percentage impact as in 2015
Freight	Assume same percentage impact as in 2015
Energy efficiency: residential	Assume same percentage impact as in 2015
Energy efficiency: public	Assume same percentage impact as in 2015

In order to estimate compliance with the annual limit value beyond 2020, baseline concentration projections for the location with the highest concentration were extrapolated to 2020 and then out to 2025.

8.3. Projections for 2015 including additional measures from the Mayor's Air Quality Strategy for London

Projections of NO_X and NO_2 concentrations in 2015 for the Greater London Urban Area zone including the impact of the additional quantifiable measures from the MAQS equivalent to the LEZ scenario have also been calculated using the PCM model. The London LEZ phase 4 has been included in the baseline assessment for London because this is a fully committed measure. Phase 4 will require all HGVs and buses to meet Euro IV standards in 2012 for PM_{10} emissions but not for NO_X. The following additional measures from the MAQS are equivalent to the national LEZ scenario:

- TfL Bus SCR strategy

[27] http://uk-air.defra.gov.uk/library/no2ten/

- LEZ phase 5

The TfL Bus SCR strategy is the means by which TfL buses would meet the NO_X emissions standards required to meet LEZ phase 5. The emissions assumptions for LEZ phase 5 in 2015 within the MAQS are slightly different from the assumptions for the national LEZ scenario outside London. Retrofit of SCR to TfL buses has been assumed to reduce NO_X emissions by 50% relative to Euro III. For HGVs and non-TfL buses all vehicles Euro III or earlier in the baseline have been assumed to meet Euro IV standards in order to comply with LEZ phase 5. Further details of these additional measures can be found in air quality plan for the Greater London Urban Area zone and the MAQS published in December 2010.

8.4. Projections for 2020 including additional measures from the Mayor's Air Quality Strategy for London.

The impacts of the additional measures within the Mayor's Air Quality Strategy on emissions in 2020 are not available from MAQS. An estimate has therefore calculated of the impact of the measures equivalent to the national LEZ scenario in London in 2020 based on the emission calculations completed for the national LEZ scenario. The baseline bus and HGV emissions in London have been multiplied by scaling factors derived from a comparison of the fleet-weighted emission factors for urban UK emissions from these vehicle types for the baseline and for locations with the LEZ applied. It is currently projected that a small compliance gap will remain in London beyond 2020, which is why full compliance is expected in the period 2020-2025.