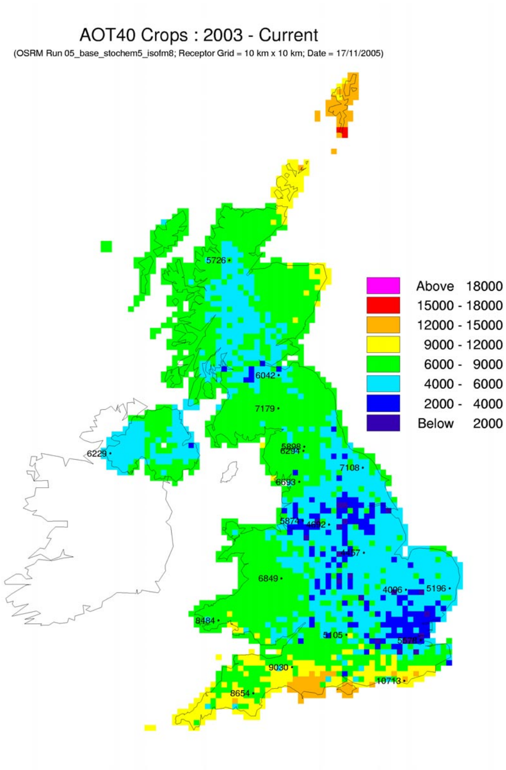
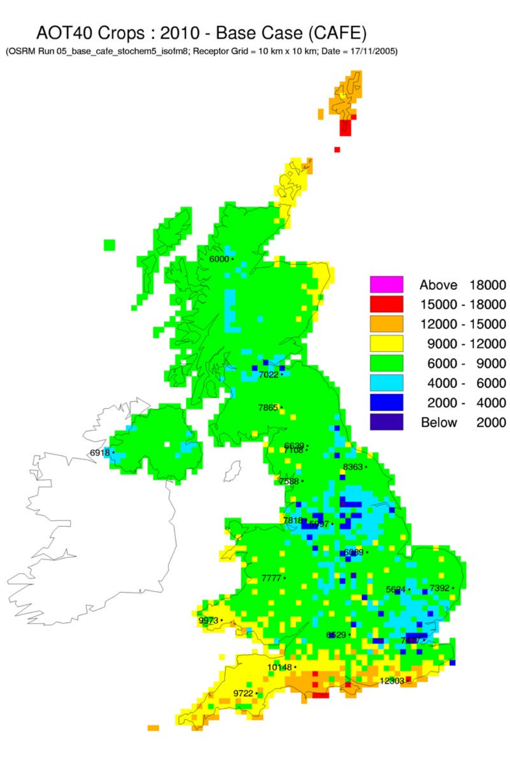
REPORT

Ozone Modelling for the Review of the Air Quality Strategy

A report produced for the Department for Environment, Food and Rural Affairs, the Scottish Executive, Welsh Assembly Government and the Department of the Environment Northern Ireland





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Executive Summary

The UK Government and the Devolved Administrations (the Scottish Executive, Welsh Assembly Government and the Department of the Environment Northern Ireland) published an Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland in January 2000. The strategy established air quality standards and objectives for eight key pollutants to be achieved between 2003 and 2008. The standards and objectives are subject to regular review to take account of the latest information on the health effects of air pollution and technical and policy developments. The AQS objectives for particles (PM_{10}), benzene and carbon monoxide were reviewed in 2000/01. An Addendum was published in 2003 and incorporated tighter objectives for these pollutants and introduced an objective for polycyclic aromatic hydrocarbons.

The UK Government and the devolved administrations are currently undertaking a review of the Air Quality Strategy. This review will assess progress towards the achievement of the AQS objectives and assess the costs and benefits of possible additional measures to improve air quality in the UK. The focus of this review of possible measures will be on the impact of measures on concentrations of particles, nitrogen dioxide and ozone, the pollutants for which the achievement of the objectives is likely to be the most challenging.

The non-linear nature of ground-level ozone production requires the use of sophisticated chemical transport models to understand its production and subsequent control. The Ozone Source-receptor model has been used to determine ozone air quality for future years and to assess the effectiveness of control measures on ozone precursor emissions (NO_x and VOC emissions) being considered for the Review of the Air Quality Strategy. This report describes the ozone modelling undertaken using the OSRM, the model runs that have been undertaken and the results obtained. Separate reports describe the modelling of the other pollutants and the subsequent cost-benefit analysis.

The following OSRM model runs were undertaken:

Year/Scenario Model Run	2003	1999	2000	2001	2002	2010	2015	2020	Sensitivity to Meteorology - 2000	Sensitivity to Meteorology - 2002	With Changing Atmospheric Composition	Without Changing Atmospheric Composition
Current Year	✓	✓	✓	✓	✓						✓	
Base Case -NECD						✓	✓	✓			✓	
Base Case -CAFE						✓	✓	✓			✓	✓
Measure A						✓	✓	✓			✓	
Measure B						✓	✓	✓			✓	
Measure B*						(1)	✓	✓	✓	✓	✓	
Measure C						✓	✓	✓			✓	
Measure E						✓	✓	✓			✓	
Measure J						✓	✓	✓			✓	
Measures K and L						✓	✓	✓			✓	
Measure L						(2)	✓	✓			✓	
Measure M						✓	✓	✓	✓	✓	✓	
Measure O						✓	✓	✓			✓	
Measure P						(3)	✓	✓			✓	
Measure Q						(4)	✓	✓			✓	
Measures M and Q						✓	✓	✓			✓	

Notes (1) Equivalent to the Scenario B 2010 run; (2) Equivalent to the 2010 base case run; (3) Equivalent to the Scenario C 2010 run; (4) Equivalent to the Scenario O 2010 run.

The analysis of the various base case and scenario runs considered seven ozone and one nitrogen dioxide metrics:

Health-based Metrics:

(a) Annual Mean of the Maximum Daily Running 8-hour Average Ozone concentration (*i.e.*, with no cutoff)

(b) Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 35 ppb (or 70 $\mu g\ m^{-3}$) cutoff

(c) Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 $\mu g\ m^{-3}$) cutoff

(d) Number of Days when the maximum of the 24 possible 8-hour running mean concentrations in each day exceeds 100 $\mu g\ m^{-3}$ (metric in the UK Air Quality Strategy)

(e) Annual Mean NO_2 concentration

Non Health-based Metrics:

(f) Annual Mean O_3 concentration

(g) Ozone AOT40 for crops

(h) Ozone AOT40 for forests

Population-weighted means were derived for the metrics associated with impacts on human health. Area-weighted means were derived for the non-health effects metrics. The population- and area-weighted means have been determined for the following regions: All UK, Scotland, Wales, Northern Ireland, Inner London, Outer London and the Rest of England.

The key points to note from the model runs are that:

- The base case runs show a progressive worsening of ozone air quality for all metrics from 2003 to 2010 and beyond;
- There is however an improvement in nitrogen dioxide air quality as annual mean concentrations fall, especially for the NO_x control measures;
- The use of population-weighted means focuses the analysis on ozone in urban areas. In addition to the role of NO_x emissions in photochemical ozone production, lower NO_x emissions reduce the chemical titration effect, most notably in urban areas. This causes ozone concentrations to move towards the higher concentrations in surrounding rural areas. The reduced chemical titration is a major factor in the increase in the ozone metrics and the deterioration of ozone air quality;
- A second major factor leading to higher ozone concentrations is changing atmospheric composition arising from climate change. In the absence of such a change, the base case runs would have shown an improvement in ozone air quality for some metrics (AOT40 – Crops and AOT40 – Forests);
- The NO_x control measures generally increase ozone concentrations, although there are instances for some of the measures that ozone air quality is improved in 2020, as evidenced by a lower value of the ozone metric;
- The VOC control measures, on the other hand, lead to an improvement in ozone air quality for all ozone metrics;
- Meteorological effects and year-to-year variability in meteorology can have a larger effect on ozone air quality than some of the emission control measures considered.

As a result of the above, there will be widespread exceedences of ozone air quality standards and objectives in 2010 and beyond.

The model outputs - population- and area-weighted means of seven ozone metrics - were passed to the teams involved in the cost-benefit analysis being carried out for the Review of the Air Quality

Strategy. These are reported separately. Three of the ozone metrics [metric (a), (b) and (c)] were used to assess the benefits/disbenefits to human health of the measures modelled by the OSRM. Another three of the metrics [metrics (f), (g) and (h)] were used to assess the non-health benefits/disbenefits for materials, crops and vegetation.

Contents

Appendices

1 Introduction

1.1 REVIEW OF THE AIR QUALITY STRATEGY

The UK Government and the devolved administrations (the Scottish Executive, Welsh Assembly Government and the Department of the Environment Northern Ireland) published an Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland in January 2000 [DETR, 2000]. The strategy established air quality standards and objectives for eight key pollutants to be achieved between 2003 and 2008. For seven of these pollutants, local authorities were charged with the task of working towards the objectives in a cost effective way. The standards and objectives are subject to regular review to take account of the latest information on the health effects of air pollution and technical and policy developments.

The Air Quality Strategy aims to:

- map out as far as possible future ambient air quality policy in the UK in the medium term;
- provide best practicable protection to human health by setting health-based objectives for air pollutants;
- contribute to the protection the natural environment through objectives for the protection of vegetation and ecosystems
- describe current and future levels of air pollution
- provide a framework to help identify what we can all do to improve air quality.

The AQS objectives for particles (PM_{10}), benzene and carbon monoxide were reviewed in 2000/01. An Addendum [Defra, 2003] was published in 2003 and incorporated tighter objectives for these pollutants and introduced an objective for polycyclic aromatic hydrocarbons.

The UK Government and the devolved administrations are currently undertaking a review of the Air Quality Strategy [Defra, 2006a, 2006b]. This review will assess progress towards the achievement of the AQS objectives and assess the costs and benefits of possible additional measures to improve air quality in the UK. The focus of this review of possible measures will be on the impact of measures on concentrations of particulate matter, nitrogen dioxide and ozone, the pollutants for which the achievement of the objectives is likely to be the most challenging.

1.2 OZONE MODELLING

The Department for Environment, Food and Rural Affairs (Defra) and the Devolved Administrations have awarded a contract **Modelling of Tropospheric Ozone** (EPG 1/3/200) to a consortium led by **netcen** (part of AEA Technology). The contract addresses ground-level ozone, its formation, impacts and control.

The concentrations of ground-level ozone, a pollutant that affects human health, ecosystems and materials, widely exceed environmental quality standards across the UK and Europe. Ozone is not emitted directly into the atmosphere, but is a secondary photochemical pollutant formed in the lower atmosphere from the sunlight-initiated oxidation of volatile organic compounds (VOCs) in the presence of nitrogen oxides (NO_x). Elevated concentrations of ozone over the UK are especially generated when slow-moving or stagnant high pressure (anticyclonic) weather systems occurring in the spring or summer bring in photochemically reacting air masses from mainland Europe. Under such conditions, the formation and transport of ozone can thus occur over hundreds of kilometres, with concentrations at a given location influenced by the history of the airmass over a period of up to several days. In addition to this, the increasing levels of ozone in the free troposphere on a global scale, driven by climate change, also influence regional scale photochemical processes by providing an increasing background ozone level upon which the regional and national scale formation is superimposed. This effect now has to be considered when assessing whether proposed air quality standards for ozone are likely to be achieved.

The non-linear nature of ground-level ozone production requires the use of sophisticated chemical transport models to understand the factors affecting its production and subsequent control. The Department and the Devolved Administrations (DAs) require a modelling capability to treat ozone formation (a) on all spatial scales from urban areas at high spatial resolution to the global scale so that ozone production on the regional and global scales is linked and (b) from timescales of hours to reproduce the diurnal behaviour of ozone to decades so that the influence of climate change can be assessed. The Ozone Source-receptor Model (OSRM), developed during the project **Modelling of Tropospheric Ozone Formation** (EPG 1/3/143), is the principal tool being used to address these requirements [Hayman *et al.*, 2002, 2006].

1.3 THIS REPORT

The Ozone Source-receptor model has been used to determine ozone air quality for future years and to assess the effectiveness of control measures on ozone precursor emissions (NO_x and VOC emissions) being considered for the Review of the Air Quality Strategy. This report describes the OSRM, the model runs that have been undertaken and the results obtained.

Modelled changes in ozone concentrations and metrics are one of the inputs to the cost-benefit analysis that has been undertaken for the Review of the Air Quality Strategy [Defra, 2006a, 2006b]. Three of the ozone metrics [metric (a), (b) and (c) below] were used to assess the benefits/disbenefits to human health of the measures modelled by the OSRM. Another three of the metrics [metrics (f), (g) and (h) below] were used to assess the non-health benefits/disbenefits for materials, crops and vegetation. Modelling of the other pollutants considered in the strategy, including nitrogen dioxide and particulate matter as PM_{10} and $PM_{2.5}$, has been described elsewhere [Grice *et al.*, 2006; Stedman *et al.*, 2006].

This report has been prepared as one of the technical supporting document to the consultation paper and is structured as follows:

Section:	**Contents:**
Section 2 – UK Ozone	Brief review of ozone measurements and trends.
Section 3 – The Ozone Source-Receptor Model	Description of the Ozone Source-Receptor Model, the OSRM Post-processor, the Surface-Conversion algorithm and the performance of the OSRM compared to measurements and other models.
Section 4 - Model Scenarios, Inputs and Assumptions	Description of the OSRM scenario runs, the input and emission assumptions.
Section 5 - OSRM Model Results	Results and Discussion of the Model Runs.
Section 6 - References	
Section 7 - Acknowledgements	

2 UK Ozone

2.1 INTRODUCTION

Ozone is a secondary pollutant formed in the lower atmosphere from the sunlight-initiated oxidation of volatile organic compounds (VOCs) in the presence of nitrogen oxides (NO_x). In common with the other key pollutants (nitrogen dioxide and particulate matter) being considered in the review of the Air Quality Strategy, ozone concentrations do not respond in a simple manner to precursor emission control. Ozone is also present in the unperturbed atmosphere and ground-level concentrations are influenced by input from the stratosphere and by changes occurring at the hemispheric scale (*e.g.*, as a result of climate change).

While the control of VOCs emissions generally improves ozone air quality, the position is more complex for the emissions of oxides of nitrogen (*i.e.*, nitric oxide and nitrogen dioxide). Oxides of nitrogen are involved in both the production of ozone and, at higher concentrations, the loss of ozone. This results in a strong coupling between the concentrations of ozone and oxides of nitrogen (NO_x), as illustrated in Figure 2.1 (adapted from Clapp and Jenkin, 2001).

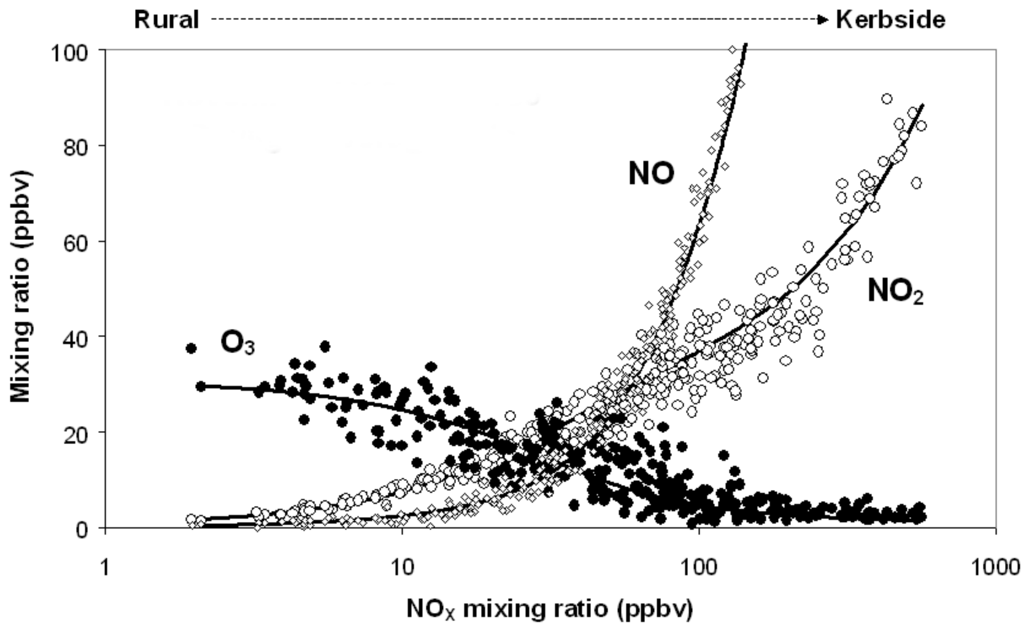


Figure 2.1: Dependence of the Observed Daylight Average Mixing Ratios of O_3, NO and NO_2 on the Concentration of NO_X at Six Southern UK Sites (Note that the NO_X axis is logarithmic). The Solid Lines were calculated with the Assumption of the Photostationary State.

Figure 2.1 shows that concentrations of ozone are generally higher in rural locations compared to urban and, at the extreme, roadside locations, where the emissions and hence concentrations of oxides of nitrogen are higher. The concentrations of ozone are suppressed through the reaction of ozone with nitric oxide. As the emissions and hence concentrations of oxides of nitrogen are reduced at these locations, ozone concentrations will rise and tend towards the concentrations observed at surrounding rural sites.

2.2 UK OZONE TRENDS

There are a number of drivers that have affected ozone concentrations and the distribution of ozone concentrations over the last 15 years:

- regional controls on NO_x and VOC emissions, reducing peak ozone concentrations (*i.e.*, **reduced photochemical ozone production**)

- a **reduction in the NO_x titration effect**, especially in urban areas, as a result of the control of local NO_x emissions, leading to increased ozone concentrations at lower percentiles
- an **increasing background concentration** arising from global changes in atmospheric composition and hemispheric circulation

As a result of the above drivers, the frequency distributions of the hourly mean ozone concentrations observed at rural UK ozone monitoring sites, during each year, have changed throughout the period over which monitoring has been carried out. Some years show a greater frequency and intensity of summertime ozone episodes and wintertime depletion events, compared with others. Despite this variability, episodic peak ozone levels have been decreasing at rural sites at about 2-3 ppb (4-6 µg m^{-3}) per year during the 1990s, and by about 50-150 ppb (100-300 µg m^{-3}) from the early 1970s to the late 1990s. The decreasing intensity of the regional ozone pollution episodes can be illustrated using the annual trends in the maximum 8-hour mean ozone concentrations monitored during each year at a selection of long-running rural UK ozone monitoring sites (see Figure 2.2). The majority of the rural sites show downwards trends in maximum 8-hour mean ozone concentrations that are statistically significant, reflecting the influence of the Europe-wide controls on the ozone precursor emissions of volatile organic compounds and oxides of nitrogen through the introduction during the 1990s of three-way exhaust gas catalysts to petrol-engined motor vehicles and of canisters to reduce petrol evaporation emissions.

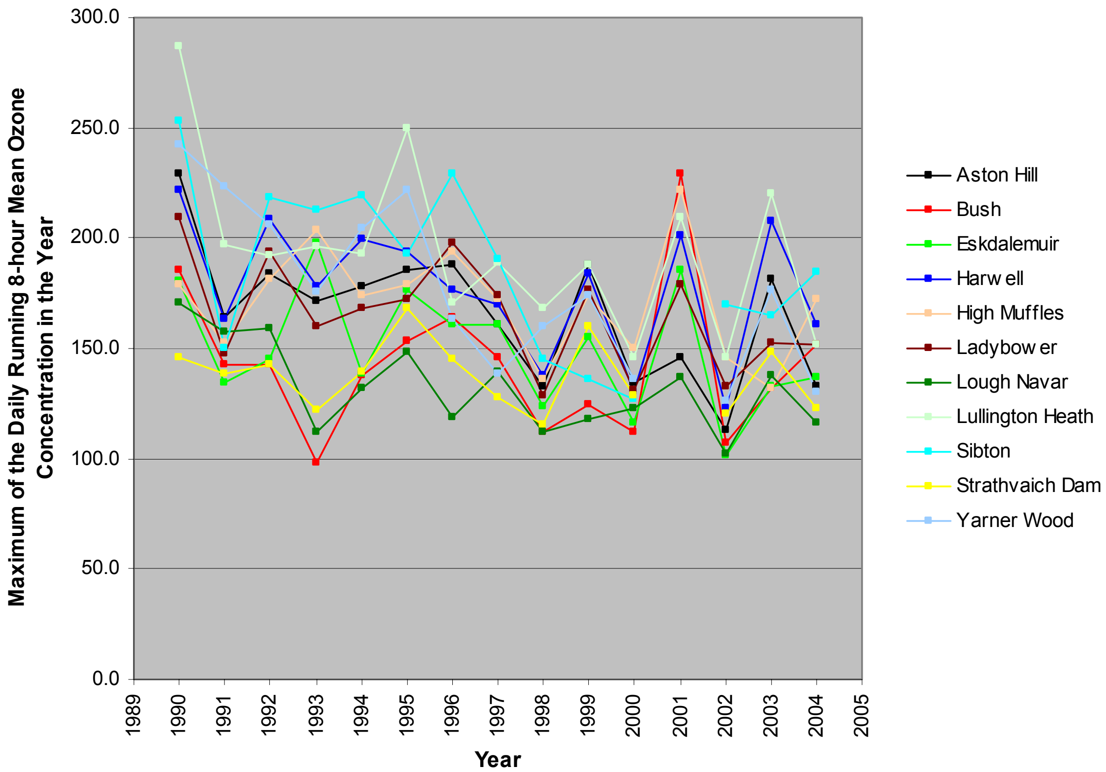


Figure 2.2: Time Series of the Maximum of the Daily Running 8-hour Mean Ozone Concentrations Determined at a Selection of Long-running Rural UK Ozone Monitoring Sites between 1990 and 2004.

Three-way exhaust gas catalysts and measures to reduce NO_x emissions from diesel traffic have also reduced the extent of ozone scavenging by the NO_x emissions from road traffic. As a result, ozone levels in towns and cities have begun to rise back towards the levels found in the surrounding countryside. Wintertime ozone depletion events have become less severe. There has been a tendency, therefore, for levels to rise during much of the year whilst episodic peak levels during summertime have fallen.

There have also been more subtle influences at work on the ozone distribution across north west Europe because of hemispheric scale changes in ozone air quality. For most urban pollutants, the location of major European population and industrial centres on the east of the UK has been an air quality advantage because clean Atlantic Ocean air masses generally bring low pollution levels. However, ozone production from both natural and man-made ozone precursors on the hemispheric scale ensures that these otherwise clean air masses always contain some background or baseline levels of ozone. This is why ozone is almost invariably present in most towns and cities across Europe on almost all days. Over the period from 1987 onwards, ozone levels in these Atlantic Ocean air masses has been observed to be steadily rising, by about 5 ppb (10 $\mu g\ m^{-3}$) per decade. Winter and spring levels have been rising somewhat faster than summertime levels. A similar trend has been observed in clean Pacific Ocean air masses entering the North American continent.

To illustrate some of these trends, Figure 2.3 presents a histogram of the 8760 hourly ozone mean concentrations measured at an urban background site in central London during 1991 and 1998. There has been a marked shift in the frequency distribution of ozone concentrations between these years bringing a much reduced frequency of low ozone concentrations (<10 ppb <20 $\mu g\ m^{-3}$) and a much increased frequency of ozone concentrations in the 10-40 ppb (20-80 $\mu g\ m^{-3}$) range. This is likely to be due mainly to reduced NO_x emissions from petrol-engined vehicles, which deplete urban ozone, but will also reflect the steadily increasing ozone background, especially during wintertime. Similar behaviour is anticipated in most towns and cities in north west Europe.

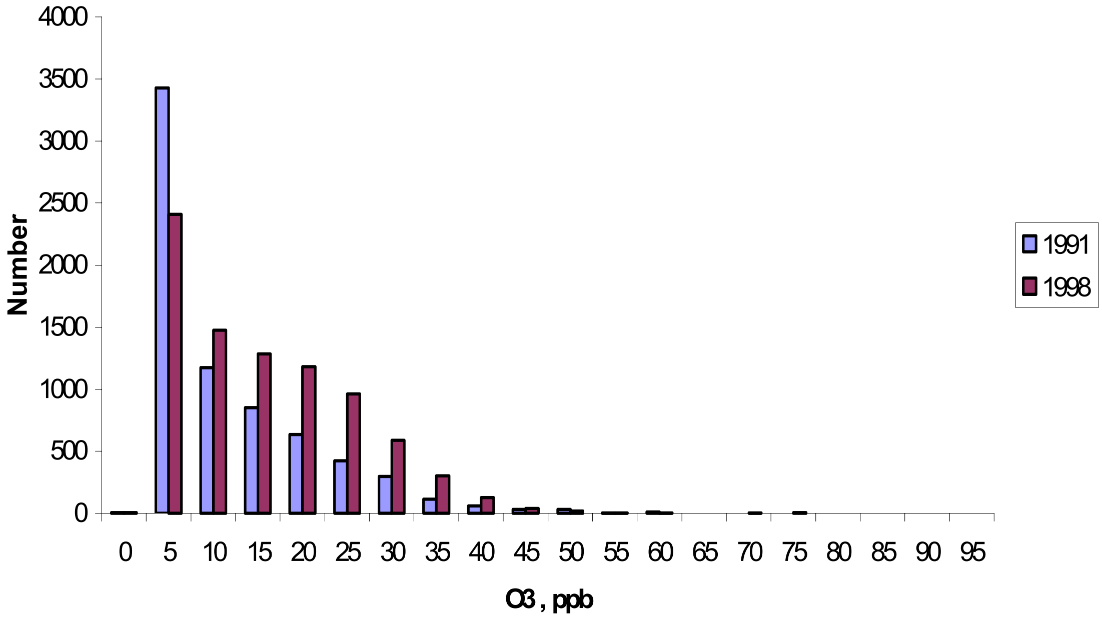


Figure 2.3: The Histogram of the Hourly Ozone Concentrations Measured during 1991 and 1998 at a Typical Urban Background Site in Inner London (Bridge Place).

Figure 2.4 shows the temporal trend of the following percentiles – 10th, 30th, 50th, 70th, 90th, 92nd, 94th, 96th, 98th and the maximum – are plotted at UK rural and London urban sites for the years 1990 to 2003. At all sites and restating the result of Figure 2.2, the maximum hourly ozone concentration shows a downward trend. The upward trend in the maximum hourly concentration at the London North Kensington site is driven by the high value in 2003 (240 $\mu g\ m^{-3}$) and its influence on the trend derived from a limited time series. If this measurement were to be excluded, the maximum hourly concentration would show a strong decrease. Upward trends are generally seen in the lower percentiles at all the sites. Although based on fewer years of monitoring, the two London sites show much stronger upward trends in all percentiles up to the 98th percentile.

The analysis of hourly ozone concentrations measured at UK ozone monitoring sites provides clear evidence of a downward trend in the maximum hourly ozone concentration and of percentiles above the 90th to 95th percentile and upward trends in the lower percentiles. As before, these are a result of

- regional controls on NO_x and VOC emissions, reducing peak ozone concentrations;
- a reduction in the NO_x titration effect, especially in urban areas;
- an increasing background concentration arising from global changes in atmospheric composition and hemispheric circulation.

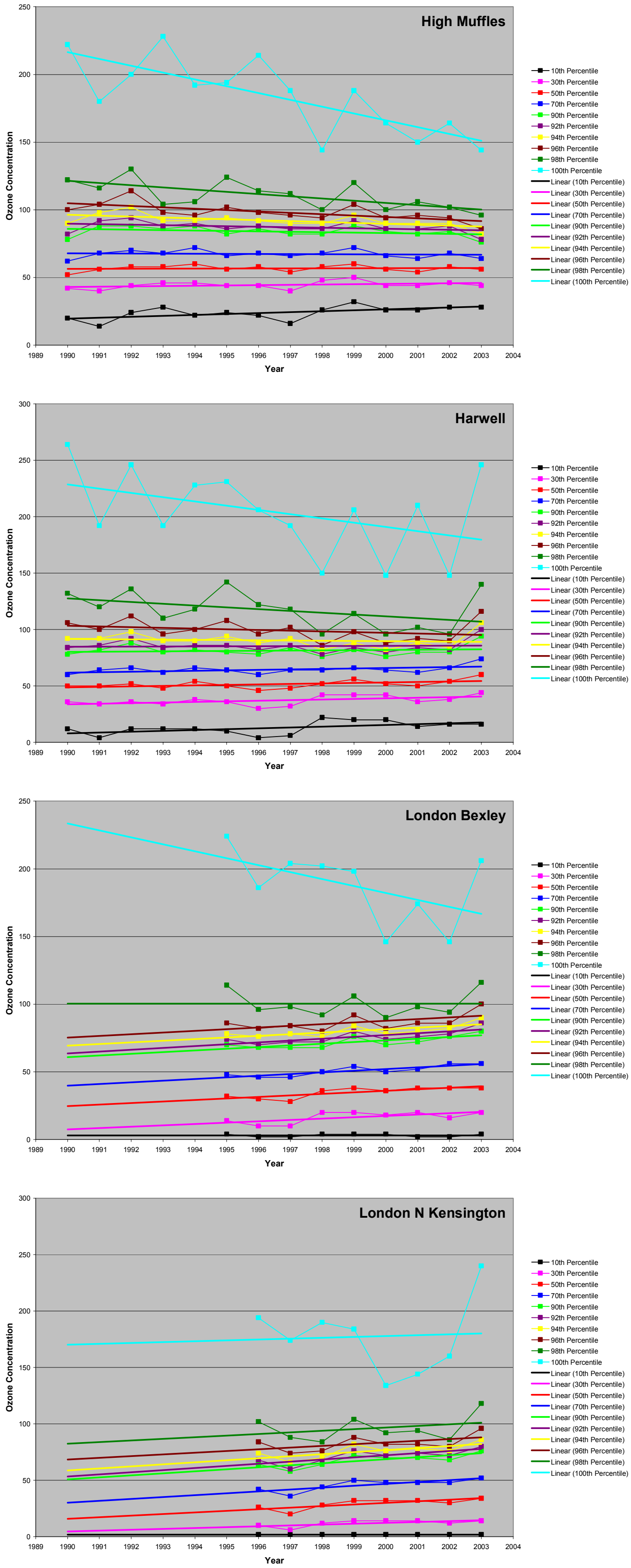
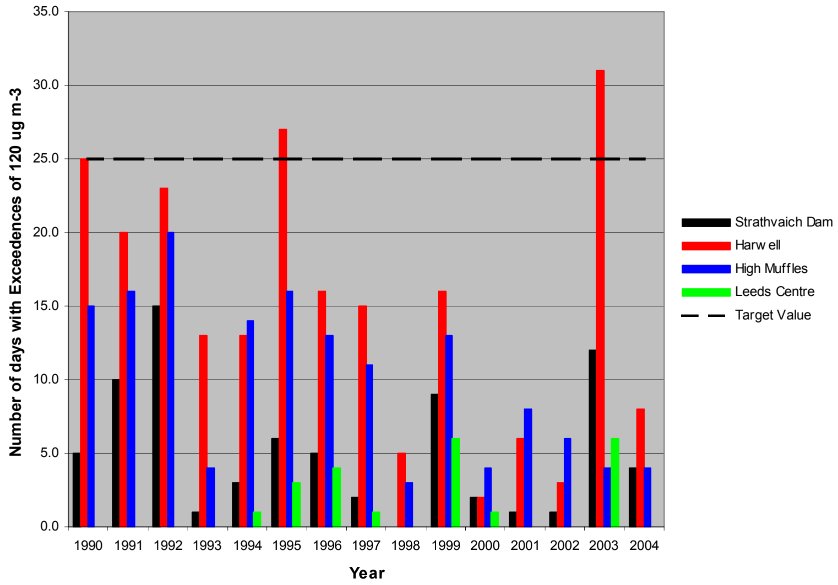


Figure 2.4: The Trend in Ozone Concentration Percentiles between 1990 and 2003 at 4 UK Ozone Monitoring Sites.

Numerical models need to incorporate these features if accurate forecasts of future ozone air quality are to be made and the effectiveness of emission control policies are to be assessed.

2.3 OZONE IN 2003

2003 was one of the hottest years on record, with the highest UK temperature (38.1 ºC) recorded at Gravesend in Kent on 10th August 2003. It was a photochemically-active year with major photochemical episodes in August and July. The peak concentrations during these episodes were 246 $\mu g\ m^{-3}$ at Harwell (15th July), 238 $\mu g\ m^{-3}$ at London Brent (6th August), 236 $\mu g\ m^{-3}$ at London Brent and Lullington Heath (11th August). These were classical UK photochemical ozone episodes: high pressure conditions existed with easterly airflows bringing polluted air to the UK from Europe. Although ozone concentrations were higher than those recorded in more recent years, the episodes were largely limited to the central and southern parts of the UK. Figure 2.5 shows a time series from 1990 to 2004 of the two ozone metrics of relevance for the 3rd Daughter Directive for 4 UK monitoring sites – Strathvaich Dam (Scotland), Harwell (Oxfordshire), High Muffles and Leeds Centre (Yorkshire).



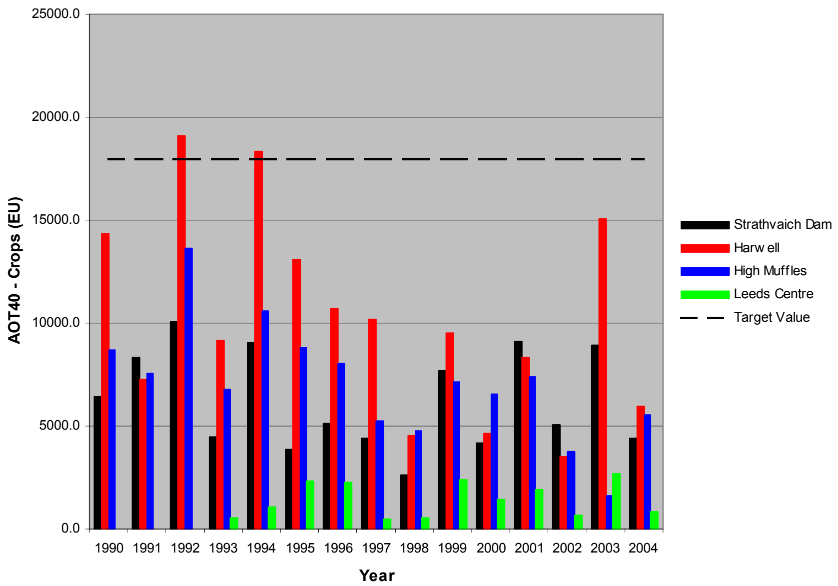


Figure 2.5: Time Series from 1990 to 2004 of the 2 Ozone Metrics of Relevance for the 3rd Daughter Directive (Number of Days on which the Maximum Daily Running 8-hour Mean Concentration exceeds 120 $\mu g\ m^{-3}$ (upper panel) and AOT40 – Crops (lower panel) for 4 UK monitoring sites. The Dotted Lines indicate the Target Values specified in the Directive for the Metrics

For Harwell, 2003 had the highest number of days on which the maximum daily running 8-hour mean concentration exceeded 120 μg m^{-3}. Although AOT40 – Crops was significantly elevated in 2003, it was not the highest recorded in the period between 1990 and 2004. Similarly, AOT40 – Crops was elevated at Strathvaich Dam but it was not the highest value between 1990 and 2004. For these metrics at Leeds Centre, 2003 was a comparable year to 1999. The values of the two metrics calculated for High Muffles for 2003 were lower than those determined for other years.

3 The Ozone Source-Receptor Model

3.1 BRIEF DESCRIPTION OF THE MODEL

The Ozone Source-Receptor Model (OSRM) is a recently developed model to describe photochemical ozone production in the UK [Hayman *et al.*, 2002, 2004, 2005, 2006]. The OSRM covers the EMEP model domain and uses global meteorological datasets provided by the Met Office to derive 96-hour back trajectories to specified receptor sites (UK/EMEP monitoring sites or a 10km x 10km grid covering the UK). The chemical scheme is based on that used in the STOCHEM model [Collins *et al.,* 1997; 2000; Stevenson *et al.,* 1997]. The mechanism has ~70 chemical species involved in ~180 thermal and photochemical reactions. The mechanism represents ozone formation using 10 VOCs, which provides an appropriate description of ozone formation on the regional scale. The emission inventories are taken from EMEP for Europe with the option to use NAEI emission inventories for the UK, which have been aggregated to 10 km x 10 km and into 8 key sectors.

The OSRM is similar in concept to the UK Photochemical Trajectory Model (UK PTM) [Derwent *et al.*, 1998, 2004] in that it simulates the chemical development of species in an air parcel moving along a trajectory and to the ELMO source-receptor model [Metcalfe *et al.*, 2002] in that calculations can be undertaken to a 10 km x 10 km grid covering the UK. The OSRM has a number of notable enhancements and advantages to these models:

- **Air Mass Trajectories**: Realistic air mass trajectories are derived from wind fields extracted from meteorological datasets. The UK PTM and ELMO model use linear trajectories. Meteorological datasets are available for use with the OSRM for the years 1995 to 2003;
- **Meteorology**: The boundary layer depth and other meteorological parameters characterising the boundary layer are interpolated in space and time from the input meteorological datasets;
- **Chemical Mechanisms**: The chemical mechanism used in the OSRM is an updated and extended version of chemical mechanism used in the ELMO or STOCHEM models. The chemical mechanism has been modified to include the formation of HONO and organic nitrates and a more extensive chemistry of NO_3. Table 3.1 provides details of the chemical mechanism;

Table 3.1: Details of the Modified STOCHEM Chemical Mechanisms used in the OSRM

	Modified STOCHEM
# of Species	70
# of Reactions	180
# of VOCs	12
Emitted VOCs	➢ **alkanes** (ethane, propane, *n*-butane) ➢ **alkenes** (ethane, propene) ➢ **aromatics** (toluene, *o*-xylene) ➢ **oxygenated VOCs** (methanol, acetone, methyl ethyl ketone, formaldehyde, acetaldehyde)
Biogenic VOCs	isoprene
VOC speciation	NAEI

- **Photolysis Rates**: Photolysis rates have been calculated off line using a modified version of the PHOTOL code. The input database contains the dependence of photolysis rates for 17 species on zenith angle, cloud cover, land surface type and column ozone;
- **Emissions:** The model uses up-to-date emission inventories for nitrogen oxides, volatile organic compounds, carbon monoxide and sulphur dioxide taken from UK (National Atmospheric Emission Inventory) and European (EMEP) sources. The emissions of each pollutant have been

divided into to 8 broad source categories (solvent usage, road transport, industrial processes, power generation, fossil fuel extraction and delivery, domestic combustion, natural and other). The assignment of the ~600 VOCs in the UK speciated VOC emission inventory to the 13 model VOCs was based on reactivity and structural considerations.

- **Temporal Emission Factors**: The OSRM converts the annual emission estimates to instantaneous emission rates using temporal profiles for the emissions of NO_x, VOCs, SO_2 and CO generated by Jenkin *et al*. [2000]. These profiles were derived either from real activity data or by using one of a small set of default profiles.
- **Biogenic VOC Emissions:** An additional emission term is added to the emission rate of isoprene to represent the natural biogenic emissions from European forests and agricultural crops. The emission estimates can either be the same as those used in the UK PTM and taken from Simpson *et al.* [1995] or the new biogenic inventory produced using the PELCOM land cover dataset and the TNO tree species inventory. The later emission inventory gives emission potentials aggregated to the EMEP 50 km x 50 km grid for isoprene (from deciduous and evergreen trees: temperature and light[1] sensitive), monoterpenes (from deciduous and evergreen trees: temperature or temperature and light sensitive) and other VOCs (OVOCs, from deciduous and evergreen trees: temperature sensitive);
- **Dry Deposition**: Dry deposition processes are represented using a conventional resistance approach, in which the rate of dry deposition is characterised by a deposition velocity. Different deposition velocities are used over land and sea. The ozone deposition velocity over land has an imposed diurnal and seasonal cycle.
- **Initialisation**: The concentrations of O_3, CO, CH_4, C_2H_6, HNO_3 and PAN are initialised on each OSRM trajectory using output from the global tropospheric STOCHEM model . This improves the realism of the model as the seasonal cycle in ozone is now represented. It also allows for coupling between regional scale ozone production and the hemispheric circulation. A full set of daily concentration fields are currently available for 2 calendar years, one representing the climatology of the late 1990's (actually 1998) and the second a future atmosphere (IPCC SRES scenarios for 2030). This will allow model runs to be undertaken to assess the effect of climate change on regional ozone concentrations.

The model was originally designed to use the variable-order GEAR solver that is employed in the FACSIMILE numerical integration programme. To speed up the OSRM model, a backwards-iterative EULER solver has been incorporated into the model and this has led to a factor of 6 improvement in runtime with no loss of accuracy. A single trajectory calculation using the backwards-iterative EULER solver with a chemical timestep of 240s now takes ~0.015 s (*i.e.*, ~60 trajectories per second) using a Dell Precision Workstation 650 MiniTower (containing dual Intel® Xeon 3.06GHz processors). Making use of the two available processors on the workstation gives a runtime of ~2.6-2.8 days for a UK-scale model run to ~3,000 receptor sites for a calendar year.

3.2 THE OSRM POST-PROCESSOR

3.2.1 Ozone and Nitrogen Oxide Metrics

A post-processor code has also been developed to process the hourly concentrations generated by the OSRM. The post-processor code currently calculates a large number of metrics for ozone and nitrogen dioxide and produces output datafiles for generating maps of these metrics:

<u>**Ozone:**</u>

(1) annual mean concentration
(2) AOT30 for the protection of crops (EU and UN ECE[2])
(3) AOT30 for the protection of forests (EU and UN ECE)
(4) AOT40 for the protection of crops (EU and UN ECE)
(5) AOT40 for the protection of forests (EU and UN ECE)
(6) AOT60 for the protection of human health (EU and UN ECE)
(7) maximum hourly concentration in the year

[1] This is the photosynthetically active radiation, typically about 45-50% of total global radiation, covering the wavelength range 400-700nm.
[2] The EU methodology uses fixed hours (08:00-20:00 Central European Time) during the relative accumulation period, whereas the UN ECE calculation uses daylight hours, defined by the incident UV radiation being greater than 50 mW m^{-2}.

(8) maximum 8-hour running mean concentration in the year
(9) annual mean of the maximum of the 24 possible 8-hour running mean concentrations in each day
(10) number of days when the maximum of the 24 possible 8-hour running mean concentrations in each day exceeds 100 μg m^{-3} (metric in the UK Air Quality Strategy)
(11) number of days when the maximum of the 24 possible 8-hour running mean concentrations in each day exceeds 120 μg m^{-3} (metric in the EU 3rd Daughter Directive)
(12) AOT30 for the protection of horticulture (EU and UN ECE)
(13) AOT30 for the protection of semi-natural vegetation (EU and UN ECE)
(14) AOT40 for the protection of horticulture (EU and UN ECE)
(15) AOT40 for the protection of semi-natural vegetation (EU and UN ECE)
(16) annual mean of those maxima of the 24 possible 8-hour running mean concentrations in each day > 35 ppb
(17) maximum hourly concentration in the summer
(18) annual mean of the difference between the maximum of the 24 possible 8-hour running mean concentrations in each day and 35 ppb (or 70 μg m^{-3}) for the protection of human health
(19) annual mean of the difference between the maximum of the 24 possible 8-hour running mean concentrations in each day and 50 ppb (or 100 μg m^{-3}) for the protection of human health

<u>**Nitric Oxide:**</u>
(20) annual mean concentration

<u>**Nitrogen Dioxide:**</u>
(21) annual mean concentration
(22) maximum hourly concentration in the year
(23) number of hours in the year when the hourly concentration exceeds 200 μg m^{-3}

The metrics highlighted in bold above were used in this study.

3.2.2 Surface Conversion Algorithm

The OSRM describes the boundary layer by a single box and assumes that this is well mixed. When the model is required to handle and generate concentrations of species near to the surface, account must be taken of surface removal processes (dry deposition and chemical reactions) and emissions that will generate gradients in the concentrations of ozone and oxides of nitrogen. This will result in lower and higher concentrations, respectively, of these species compared to their corresponding mid-boundary layer concentrations. These effects are of particular significance in urban areas.

An algorithm has been developed and implemented in the OSRM post-processor to convert the hourly mid-boundary layer concentrations to surface concentrations. The algorithm uses the meteorological parameters characterising the boundary layer, surface roughness appropriate for the surface types considered, resistance parameters for O_3 and NO_2, the local NO_x emission rates and a simple nitric oxide (NO)/nitrogen dioxide (NO_2)/ozone (O_3) photostationary-state chemistry [reactions (1) and (2)].

$$NO + O_3 \rightarrow NO_2 + O_2 \qquad (1)$$

$$NO_2 + h\nu \rightarrow NO + O(^3P) \qquad (2)$$

The algorithm solves the following set of coupled differential equations, which presumes mass balance for each species:

NO $$\frac{\partial}{\partial z}\left(\frac{ku^* z}{\phi}\frac{\partial[NO]}{\partial z}\right) - k_1[NO][O_3] + J[NO_2] = 0 \qquad (3)$$

O_3 $$\frac{\partial}{\partial z}\left(\frac{ku^* z}{\phi}\frac{\partial[O_3]}{\partial z}\right) - k_1[NO][O_3] + J[NO_2] = 0 \qquad (4)$$

NO_2 $$\frac{\partial}{\partial z}\left(\frac{ku^{*}z}{\phi}\frac{\partial[NO_2]}{\partial z}\right)+k_1[NO][O_3]-J[NO_2]=0 \quad (5)$$

where z is the height above the displacement layer, k_1 is the rate coefficient for the reaction between NO and O_3 [reaction (1)] and J is photodissociation rate coefficient of NO_2 [reaction (2)].

The assumption is then made that the stability parameter (ku^*/ϕ), defined by Equation (6), is constant throughout the surface boundary layer.

$$\frac{ku^{*}}{\phi}=\frac{1}{R_A}\ln\left(\frac{H/10}{z_0}\right) \quad (6)$$

where u* is the friction velocity, k is the von Karman constant, R_a is the aerodynamic resistance, H is the height of the boundary layer and z_0 is the surface-dependent Monin-Oblukov length. The differential equations (3) to (5) are transformed from a height-based co-ordinate system (z) to a resistance-based co-ordinate system (r) using the substitution:

$$r=\frac{\phi}{ku^{*}}\ln\left(\frac{z}{z_0}\right) \quad (7)$$

The differential equations (3) to (5) can be rewritten as:

$$\frac{\phi}{ku^{*}}\frac{\partial^2[NO]}{\partial r^2}-k_1[NO][O_3]z+J[NO_2]z=0 \quad (8)$$

with corresponding expressions for O_3 and NO_2.

The upper boundary conditions at $r=R_A$ are $[NO] = [NO]_{mbl}$, $[NO_2] = [NO_2]_{mbl}$ and $[O_3] = [O_3]_{mbl}$. The lower boundary conditions at r=0 is:

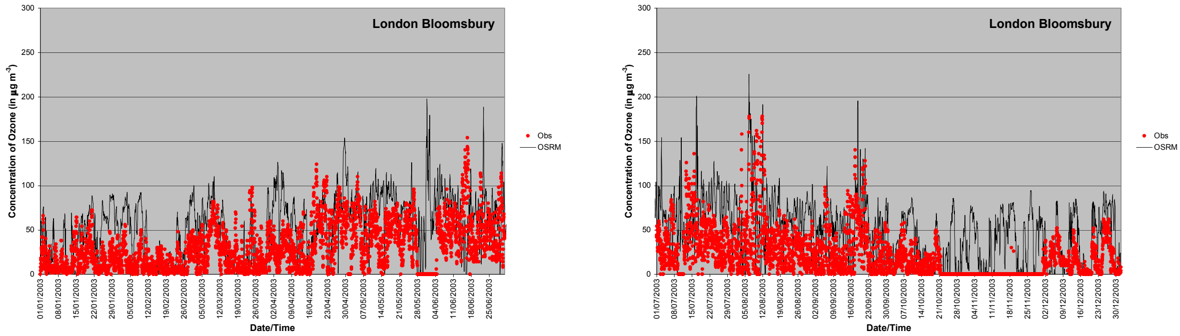
$$\frac{\partial[NO]}{\partial r}=-E_{NO}+v_d[NO] \quad (9)$$

where E_{NO} is the emission rate of nitric oxide and v_d is the non-aerodynamic deposition velocity ($=1/(r_b+r_{sur})$), with similar expressions for O_3 and NO_2.

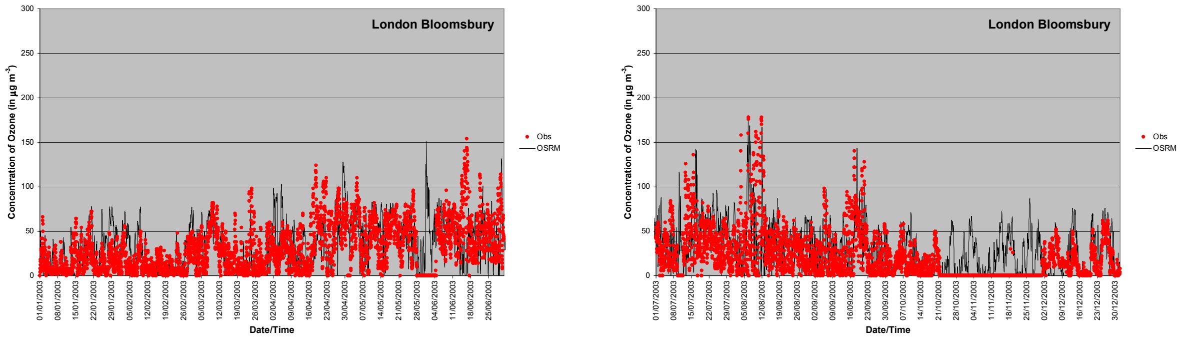
The differential terms in each of the equations are replaced by finite difference approximations and the resulting simultaneous linear equations solved by Gaussian elimination along the tridiagonal. As the chemical reaction term introduces some non-linearity, it is necessary to repeat the calculations a few times to obtain convergence with successive approximations to the non-linear terms. The parameters needed for the conversion are taken from a combination of additional output generated during the OSRM model run and databases calculated using the Surface Ozone Flux Model [Hayman *et al.*, 2005, 2006].

The effect of the surface correction algorithm can be seen in Figure 3.1. These figures compare the hourly concentrations of ozone observed at the London sites of Teddington and Bloomsbury in 2003 with those calculated using the OSRM. Bloomsbury is a site in central London while Teddington is a suburban site to the west of London. Panels (a) and (c) of Figure 3.1 compare the OSRM mid-boundary-layer output against the measurements while Panels (b) and (d) show the surface-corrected results. The effect of the surface conversion algorithm is more noticeable at London Bloomsbury site, which is in an area of higher NOx emissions. The effect of the surface conversion algorithm is smaller at London Teddington for two reasons (i) the site is in an area of lower emissions and (ii) the ozone measurements are made at 15 m compared to the more typical 2-3 m at other sites.

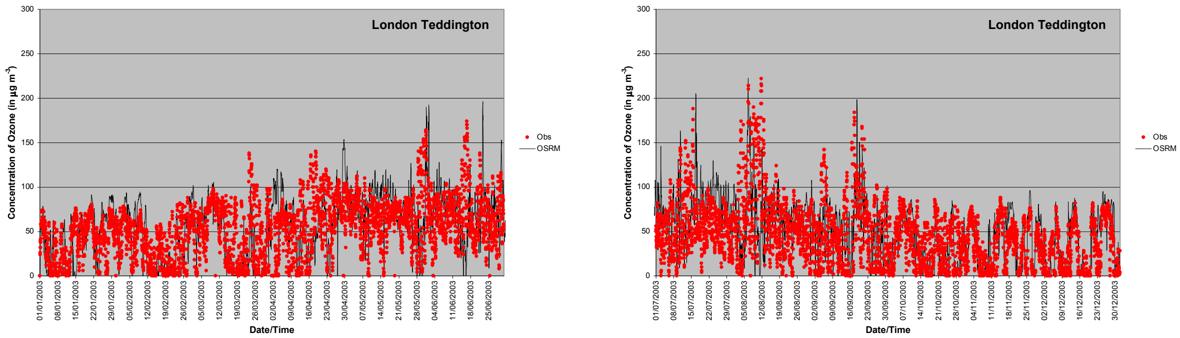
(a) Ozone – No OSRM Post-processor Surface Conversion



(b) Ozone – OSRM Post-processor Surface Conversion



(c) Ozone – No OSRM Post-processor Surface Conversion



(d) Ozone – OSRM Post-processor Surface Conversion

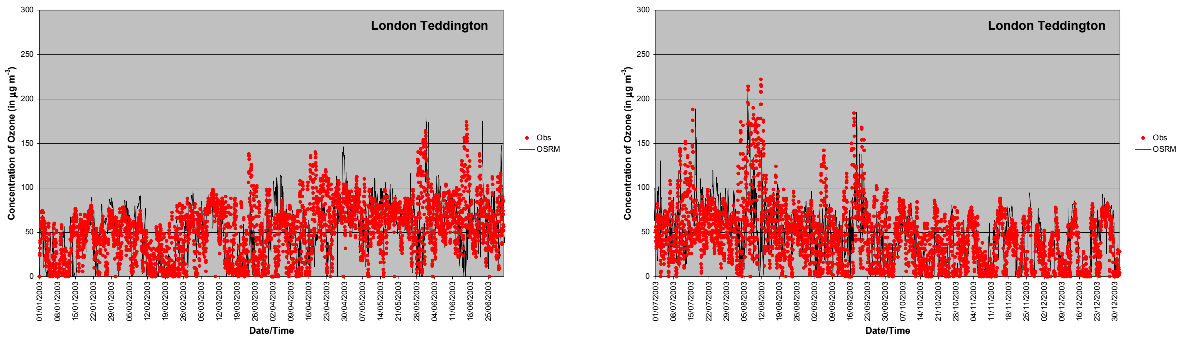


Figure 3.1: Comparison of the Observed and Modelled Hourly Concentrations (in $\mu g\ m^{-3}$) of Ozone for the London Bloomsbury and London Teddington Sites in 2003. The Modelled Concentrations are shown with (Panels b and d) and without (Panels a and c) Surface Conversion

3.3 OSRM PERFORMANCE

3.3.1 Comparison with Measurements

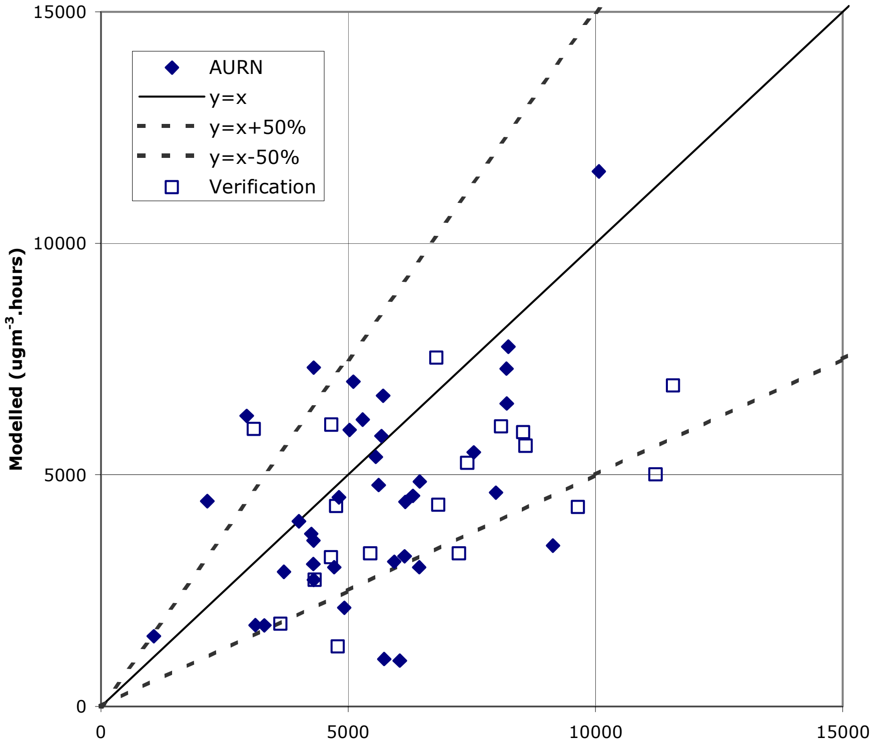
Table 3.2 compares the performance of the OSRM against observations made at 41 UK ozone monitoring sites in 1999 for the annual mean of the maximum daily running 8-hour mean ozone concentration ($\mu g\ m^{-3}$) and the number of days when the running 8-hour mean ozone concentration exceeds 100 $\mu g\ m^{-3}$. The table presents the OSRM results for the uncorrected and surface-corrected output. There is a significant improvement in the performance of the OSRM, particularly for the London and other urban sites, when the surface correction is applied. The surface-correction algorithm was therefore used in the processing of all the subsequent OSRM output.

Table 3.2: Comparison of the Uncorrected and Surface-Corrected OSRM Output for the Annual Mean of Maximum Daily Running 8-Hour Mean Ozone Concentration ($\mu g\ m^{-3}$) and the Number of Days when the Running 8-hour Mean Ozone Concentrations exceeds 100 $\mu g\ m^{-3}$ for 1999 against the Values derived from the Measured Ozone Concentrations.

	Annual Mean of the Daily Maximum of the 24 Daily Running 8-hour Mean Ozone Concentrations			Number of days with Exceedences of 100 ug m-3		
Site	Obs	OSRM - Without Surface Conversion	OSRM - With Surface Conversion	Obs	OSRM - Without Surface Conversion	OSRM - With Surface Conversion
Strathvaich Dam	83.8	83.2	76.6	45.0	66.0	41.0
Aston Hill	73.6	79.7	72.8	39.0	74.0	41.0
Bush	72.8	79.8	69.9	24.0	61.0	25.0
Eskdalemuir	66.0	80.8	74.9	18.0	61.0	40.0
Great Dun Fell	76.5	80.8	72.9	36.0	62.0	38.0
Harwell	80.3	77.3	65.6	65.0	73.0	33.0
High Muffles	66.0	78.7	73.0	15.0	58.0	42.0
Ladybower	70.9	73.5	65.8	27.0	48.0	27.0
Lullington Heath	81.3	80.9	76.5	57.0	100.0	75.0
Narberth	66.3	85.6	81.2	27.0	97.0	67.0
Rochester	76.8	71.5	66.2	54.0	61.0	38.0
Sibton	73.3	76.1	71.6	37.0	75.0	50.0
Somerton	78.0	83.3	74.9	46.0	88.0	55.0
Wharley Croft	-	80.4	73.2	0.0	62.0	37.0
Wicken Fen	72.0	75.3	67.0	44.0	65.0	30.0
Wray	-	79.1	72.8	0.0	60.0	36.0
Yarner Wood	79.2	86.6	78.7	48.0	102.0	61.0
Bottesford	67.2	74.1	63.6	31.0	47.0	22.0
Glazebury	58.0	72.6	66.9	14.0	42.0	27.0
Lough Navar	-	84.7	80.0	5.0	75.0	49.0
London Bexley	64.0	71.2	60.5	32.0	64.0	26.0
London Bloomsbury	45.8	70.3	46.4	14.0	56.0	11.0
London Brent	66.1	71.5	61.0	39.0	58.0	24.0
London Eltham	60.5	72.2	62.9	31.0	62.0	29.0
London Hackney	52.2	70.4	55.5	21.0	53.0	16.0
London Haringey	58.8	70.9	59.2	32.0	54.0	19.0
London Hillingdon	47.9	72.1	56.6	17.0	56.0	18.0
London North Kensington	58.7	70.5	54.4	29.0	57.0	14.0
London Teddington	71.7	71.3	61.9	49.0	55.0	27.0
London Westminster	50.3	71.0	53.5	19.0	62.0	14.0
Birmingham Centre	57.7	72.9	53.2	18.0	47.0	12.0
Birmingham East	63.2	72.6	60.5	33.0	47.0	20.0
Manchester Piccadilly	46.9	72.7	53.0	11.0	44.0	12.0
Leeds Centre	53.5	72.5	54.2	13.0	48.0	12.0
Newcastle Centre	57.6	79.8	62.9	15.0	54.0	23.0
Bristol Centre	57.1	79.1	62.4	13.0	76.0	24.0
Southampton Centre	60.0	80.4	71.8	26.0	83.0	45.0
Glasgow Centre	50.4	79.5	58.4	3.0	57.0	12.0
Edinburgh Centre	-	79.6	63.0	0.0	64.0	19.0
Belfast Centre	59.7	82.8	69.2	8.0	67.0	24.0
Cardiff Centre	59.0	78.7	63.0	20.0	67.0	24.0

A similar trend is seen when the OSRM model output is compared to measurements for other years (1999-2002).

Figure 3.2 presents regression plots of the modelled against the observed values of the two ozone metrics of relevance for the EU third Daughter Directive on Ozone – AOT40 – Crops and the Number of Days on which the maximum daily running 8-hour mean ozone concentration exceeded 60 ppb (or 120 $\mu g\ m^{-3}$). The figure also shows the 1:2 line and 2:1 lines, which define the data quality objective. The agreement is better for the AOT40 – Crops metric than for the Number of Days on which the maximum daily running 8-hour mean ozone concentration exceeded 60 ppb (or 120 µg m^{-3}). The latter metric is more sensitive to peak ozone concentrations and any over prediction of the ozone concentration will affect this metric more than the AOT40 – Crops metric.



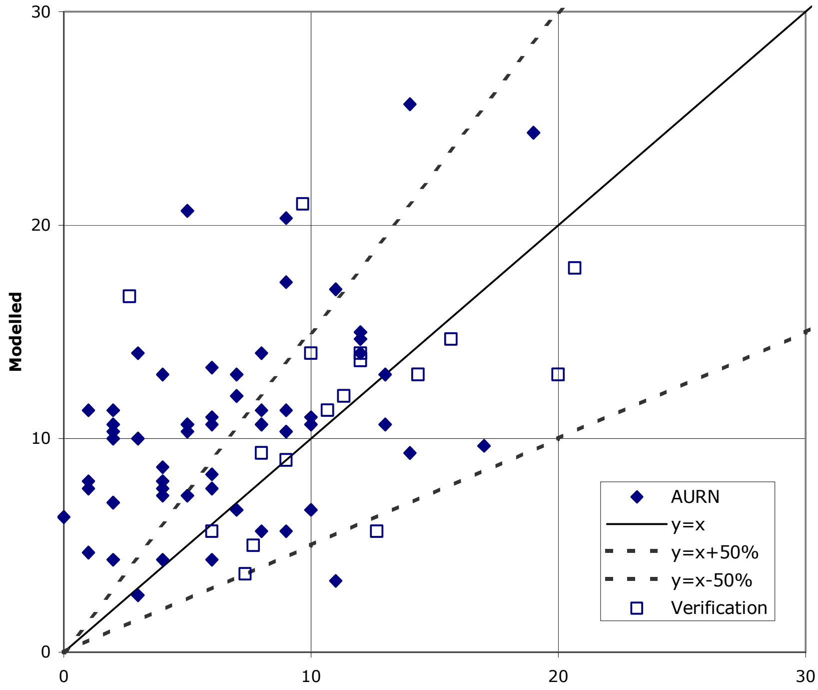


Figure 3.2: Scatter Plots of the Modelled against the Observed Values of the Ozone Metrics for the Target Values in the 3rd Daughter Directive: AOT40 – Crops, Averaged over the Years 1999-2003 (R^2 = 0.25) and the Number of Days on which the Maximum Daily Running 8-hour Mean Ozone Concentration exceeded 60 ppb (or 120 µg m^{-3}), Averaged over the Years 2001 to 2003 (R^2 = 0.22).

3.3.2 Comparison with Other Models

The output of the OSRM has been compared with that from the UK Photochemical Trajectory Model and the ADMS Urban Model.

(1) UK Photochemical Trajectory Model

The UK-Photochemical Trajectory Model (PTM) has been used extensively to assist the evaluation of ozone policy options [*e.g.*, Derwent *et al.*, 1998, 2004]. For the comparison, the model calculations used the idealised episode trajectory of the UK PTM from Central Europe to mid-Wales. The OSRM was configured to calculate ozone concentrations along the same linear trajectory. As far as was possible, the two models used (a) the same emission inventories (from EMEP and a biogenic emission inventory with no temporal emission factors), (b) the same VOC speciation and (c) the same treatment and parameter values for the photolysis and dry deposition processes. The remaining differences were the chemical mechanisms and solvers used in the two models (PTM: CRI Mechanism with a variable order Gear solver; OSRM: the modified STOCHEM mechanism with a backward Euler solver).

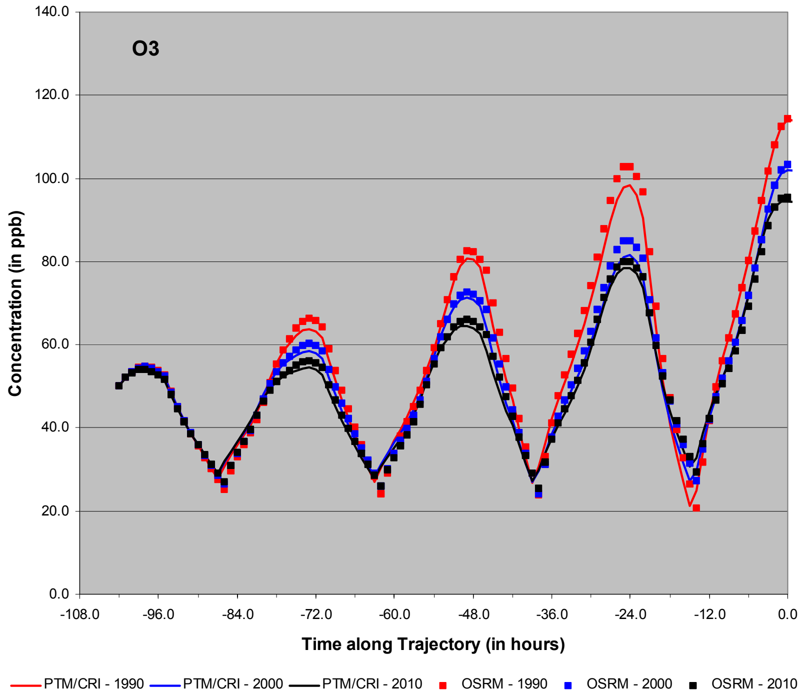


Figure 3.3: Comparison of the Ozone Concentrations Calculated by the OSRM and PTM for Three Different Emission Years along the Idealised Episode Trajectory of the PTM.

Figure 3.3 shows a comparison of the mid-boundary layer ozone concentrations calculated along the idealised episode trajectory by the two models for three different emission years. The peak ozone concentrations in these model runs, together with additional runs in which the VOC and NO_X emissions were reduced by 30% across-the-board, are presented in Table 3.3. The Surface-conversion algorithm was not necessary for this comparison. The agreement between the two models is excellent.

Table 3.3: Comparison of the Peak Ozone Concentrations Calculated by the PTM and OSRM for Different Emission Scenarios along the Idealised Episode Trajectory of the PTM.

Model Run	PTM Peak Ozone (in ppb)	OSRM Peak Ozone (in ppb)
1990 Base Case	114.9	115.1
2000 Base Case	102.6	103.9
2010 Base Case	95.1	96.2
2010 Base Case + 30% NOx Reduction	92.0	95.2
2010 Base Case + 30% VOC Reduction	86.5	85.2

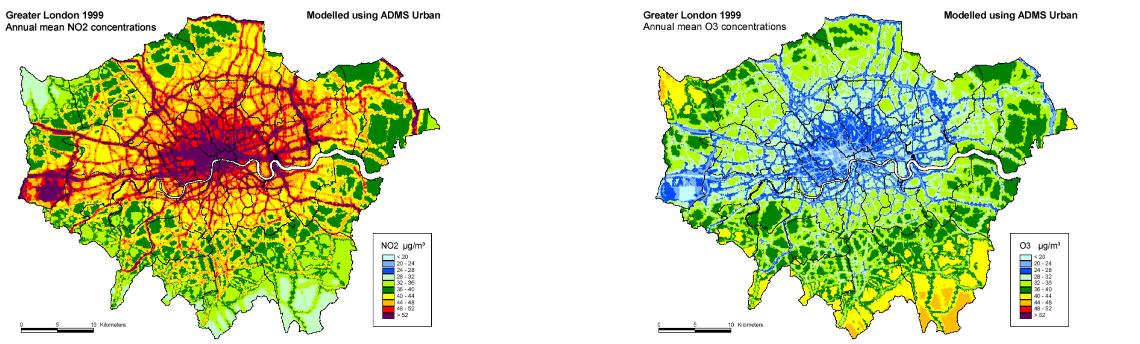
(2) ADMS Urban

The OSRM has been used to generate maps of ozone and nitrogen dioxide metrics for London for 2010 and a number of current years (1999-2003). Model runs were undertaken to calculate the hourly ozone and nitrogen dioxide concentrations for a model domain covering Outer London using meteorological data and UK and EMEP emission inventories for the relevant years. The model domain used a 1 km x 1 km grid of 1,639 receptor sites. From the hourly concentrations, maps were derived of the annual mean ozone and nitrogen dioxide concentrations. Both surface-converted and unconverted maps were prepared.

Under a separate contract let by Defra and the Devolved Administrations, CERC have used ADMS-Urban to generate concentrations maps of the annual mean ozone and nitrogen dioxide concentrations for the Greater London area for 1999 [CERC, 2003]. These are compared with the corresponding surface-corrected OSRM maps in Figure 3.4. While the OSRM maps do not have the detailed structure of the ADMS maps, the OSRM maps do show the high concentrations of NO_2 (and low concentrations of O_3) in central London and in the vicinity of Heathrow airport, which reflect the areas of high NO_x emissions in London. There is also evidence of the major London roads (*e.g.*, the M3, M4 and A40 to the west and the North Circular Road). The OSRM NO_2 concentrations are generally lower than those in the ADMS-Urban maps and as a result the OSRM maps show higher O_3 concentrations.

Both models show a reduction in the annual mean NO_2 concentration between 1999 and 2010 as the NO_x emissions are lower. There is a corresponding increase in the annual mean ozone concentration as a result of the reduced NO_x titration effect.

(a) (b)



(c) (d)

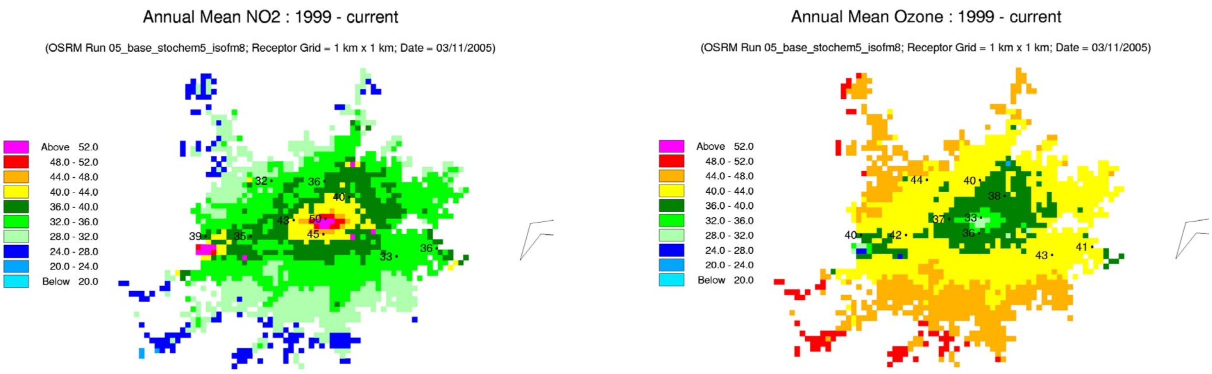


Figure 3.4: Comparison of Maps for Greater London of Annual Mean Concentrations (in µg m^{-3}) of NO_2 (left-hand panels) and O_3 (right-hand panels) calculated using ADMS-Urban (panels a and b) and the Ozone Source-receptor (panels c and d) Models for 1999.

3.4 SUITABILITY OF THE OSRM

Overall, the OSRM is a model, which now has a robust and flexible construction that makes it ideal for the demands of assisting in the development of policy. The improvements made to the OSRM during the current contract have produced a model that is able to reproduce boundary-layer concentrations of ozone and oxides of nitrogen, representative of the UK.

In the context of ozone formation, the OSRM and UK Photochemical Trajectory Model were found to give identical output and responses, on a like-for-like basis. For the determination of surface concentrations of ozone and oxides of nitrogen, the OSRM has post-processor options, which take account of local emissions and removal processes. The comparison of the OSRM with the ADMS Urban model gave similar responses and showed similar spatial patterns. These comparisons demonstrate that the OSRM is a robust model which can be used to assist the development of policy.

4 Model Scenarios, Inputs and Assumptions

4.1 INTRODUCTION

Table 4.1 list the emission control measures being considered for the Review of the Air Quality Strategy. The primary focus of most of these measures is to reduce the concentrations of particulate matter and nitrogen dioxide. Measure M (VOC emission control) was the only measure, which was specifically targeted for its impact on ozone. As the control of nitrogen oxide emissions may cause ozone concentrations to increase (through lower chemical titration) or to decrease (through lower photochemical ozone production), a number of other measures were also modelled to assess the benefits/disbenefits of these measures for ozone. The measures modelled using the OSRM are highlighted in bold in Table 4.1.

Table 4.1: The Measures being Considered as Part of the Review of the Air Quality Strategy with the Measures modelled by the OSRM highlighted in Bold.

Measure	Description
A	**Introduction of Euro V/VI Standards (Low Intensity)**
B	**Introduction of Euro V/VI Standards (High Intensity)**
C	**Programme of incentives for early uptake of Euro V/VI Standards (Low Intensity)**
D	Programme of incentives to phase out most polluting vehicles
E	**Programme of incentives to increase penetration of low emission vehicles**
F	Impact of All User Road Charging Schemes
G	Extend London Low Emission Zone to London + 7 largest urban areas
H	Retrofit of particulate traps to HDVs and captive fleets
I	Domestic combustion (switch from coal to oil and natural gas)
J & K	**Domestic (NO_x Standards for Gas-fired Appliances) and industrial combustion**
K	**Industrial combustion**
L	**Small combustion plant**
M	**VOC emission control at petrol stations and for on and offshore tanker loading operations**
N	Shipping measure through IMO
O	**Combined scenario for transport (Measures C and E)**
P	**Combined scenario for transport and industrial measures (Measures C and L)**
Q	**Combined scenario for transport and industrial measures (Measures C, E and L)**
M & Q	**Combined scenario for transport and industrial measures (Measures M and Q [=C, E and L])**

More detailed information on the activity and emission assumptions for these measures can be found in Appendix 1.

4.2 KEY FEATURES OF THE MODEL RUNS

The OSRM model runs

- were undertaken for the years 2010, 2015 and 2020;
- were undertaken at 10 km x 10 km resolution to ensure a consistent approach for the determination of the health benefits;
- used the NAEI emission projections developed for the Review of the Air Quality Strategy (see Section 4.3.1;
- took the projected national emission totals for European countries developed for the Clean Air for Europe (CAFÉ) programme. A limited number of runs were also undertaken using the emission totals agreed under the National Emissions Ceilings Directive for the EU member states (except for the UK) and the Gothenburg Protocol for the other UN ECE countries;

- used the meteorology for 2003. Although this was a high ozone year, it would ensure consistency with the NO_2/PM modelling and it could possibly become a typical ozone year in the future as a result of climate change. Sensitivity runs would be undertaken using meteorology for a current typical ozone year (e.g., 2002) and a low ozone year (2000, considering the headline air quality indicator);
- included the effects of climate change on atmospheric composition. The effect of climate change on atmospheric composition, especially ozone, was based on the monthly trends derived by Derwent [2005] for the business-as-usual scenario with climate change.

4.3 EMISSION INVENTORIES FOR THE OSRM MODEL RUNS

4.3.1 UK Emissions

As part of the Department's National Atmospheric Emission Inventory (NAEI) [Dore *et al.*, 2004] programme and using the latest available information, emission estimates were produced [Hobson, 2005] for the base case scenarios and for the various measures selected for modelling using the OSRM (highlighted in bold in Table 4.1). The total UK NO_x and VOC emissions for the base case and selected measures for 2010, 2015 and 2020 are given in Table 4.2 and Table 4.3.

Table 4.2: UK NO_x Emissions for the Base Case and the Measures Modelled using the OSRM for 2010, 2015 and 2020.

Measure(s)	Description	Total UK NO_x Emissions (ktonne per annum)		
		2010	2015	2020
Base	Base case projections	1118.52	992.07	869.12
A	Introduction of EURO V/VI (low reduction scenario)	1115.92	958.31	803.66
B	Introduction of EURO V/VI (high reduction scenario)	1109.58	914.06	727.77
B*	An earlier version of the Introduction of EURO V/VI (high reduction scenario)	1109.58	911.57	712.68
C	Early uptake of EURO V/VI	1107.80	946.47	799.41
E	Introduction of low emission vehicles	1116.98	986.58	857.91
J	Domestic combustion	1115.64	984.32	856.20
K & L	Control on power stations, iron and steel and oil refineries	924.06	795.92	784.95
L	Control on small combustion plant (20-50 MW) (= base case in 2010 as no NO_x emission reduction until 2013)	1118.52	976.43	852.89
M	Petrol vapour recovery from petrol stations and abatement of VOC emissions from on and offshore loading of crude oil (= base case emissions as only VOC emission reduction)	1118.52	992.07	869.12
O	A combination of Measures C and E	1106.35	941.78	790.09
P	A combination of Measures C and L	1107.80	930.83	783.18
Q	A combination of Measures C, E and L	1106.35	926.14	773.86
M & Q	A combination of Measures C, E, L (=Q) and M	1106.35	926.14	773.86

Table 4.3: UK VOC Emissions for the Base Case and the Measures Modelled using the OSRM for 2010, 2015 and 2020.

Measure(s)	Description	Total UK VOC Emissions (ktonne per annum)		
		2010	2015	2020
Base	Base Case projections	1026.17	1034.68	1061.25
M	Petrol vapour recovery from petrol stations and abatement of VOC emissions from on and offshore loading of crude oil	952.15	958.42	983.00
M & Q	Combination of selected NO_x and VOC control measures	952.15	958.42	983.00

Note: The above VOC emission totals include a contribution from natural sources of 178 ktonne per annum. This sectoral source was not used and the VOC emissions were generated using a biogenic emission potential inventory (see Section 4.3.4).

Measures A, B, C, E, J, K and L only affected the NO_x emissions. Measure M used the UK VOC cost curve to identify abatement of various on and offshore VOC emission sources. These included the application of petrol vapour recovery from petrol stations with throughputs > 3,000 m^3 and abatement of VOC emissions from on and offshore loading of crude oil. A more detailed breakdown of the emissions for the UK used in the OSRM model runs by OSRM source sector can be found in Appendix 2.

Spatially-disaggregated emission maps were prepared for the base case and scenario runs. These were based on the latest available 1 km x 1 km emission maps prepared by the NAEI (for the 2002 inventory year). For the four pollutants (SO_x, NO_x, VOCs and CO), a total of 46 maps were used which represented point or area source emissions from a specific SNAP Level 1 source sector. These maps were aggregated to a 10 km x 10 km grid for each OSRM source sectors to give a set of base OSRM inventory maps. The emission maps for other years and other emission scenario were derived from the base 2002 maps by scaling by the ratio of the emission total for each pollutant and OSRM source sector to the corresponding total in the 2002.

As the VOC emission controls in Measure M were based on specific sectoral activities with localised emissions, separate maps of VOC emissions from petrol stations and on and offshore loading of crude oil were created for 2010 for the OSRM source sector Fossil Fuel Extraction and Distribution and adjusted to produce the corresponding maps for 2015 and 2020. The maps for the other OSRM VOC source sectors were prepared as described previously.

4.3.2 Non-UK Emissions: Base Case Runs

It has long been known that European NO_x and VOC emission contribute to ozone production over the UK. Spatially-disaggregated emission inventories are therefore needed for the non-UK emissions on the OSRM model domain. As part of the UN ECE Convention on Long-range Transboundary Air Pollution, signatory countries are required to submit national emission estimates to EMEP. EMEP have taken these national estimates and used expert judgement to prepare emission inventories for current years (up to 2002) on a 50 km x 50 km grid covering the EMEP model domain (which is also the OSRM model domain). These inventories can be downloaded from the EMEP website [UNECE/EMEP Activity Data and Emission Database, http://webdab.emep.int/]. Examples of the emission inventories for NOx and NMVOCs are shown in Figure 4.1.

For the base case runs for 2010, 2015 and 2020, two sets of emission scenarios were investigated:

(a) **Scenario 1 - Compliance with the NECD or Gothenburg Protocol**: In this scenario, European countries were assumed to achieve the emission total that was agreed in the National Emissions Ceilings Directive for EU member states (except for the UK) and the Gothenburg Protocol for the other UN ECE countries. These emission limits were assumed to hold in 2015 and 2020. In other words, no further emission reduction was assumed to occur. The emission totals of other sources (e.g., natural marine emissions, volcanic) were assumed to be unchanged from the 2002 values.

(b) **Scenario 2 - Emission Projections developed for the CAFÉ programme**. IIASA have developed emission projections for the Clean Air for Europe (CAFÉ) programme for a number of policy options. The country emission totals used in the current work are based on the IIASA RAINS scenario NAT_CLE (Official national energy projections with climate policies). The emission totals of other sources (e.g., natural marine emissions, volcanic) were again assumed to be unchanged from the 2002 values.

For both cases, the base case emission inventories for 2010, 2015 and 2020 were derived from the latest available maps from EMEP (2002 calendar year). The country emission contribution in each EMEP grid square was scaled by the ratio of its projected emission total to its total in 2002. The revised country contributions were then summed. Appendix 3 gives the national emission totals used for the two emission cases for the 4 pollutants.

4.3.3 Non-UK Emissions: Scenario Runs

For Measures A, B, C, O, P, Q and the combination of Measures M and Q, the UK emission data were used to derive (a) the fraction of the total NO_x emissions produced by the road transport sector (based on the corresponding base case run) and (b) the scaling factors to reduce the road transport sectoral emissions (see Table 4.4). These two factors were assumed to apply to other European countries and were used to scale the total non-UK NO_x emissions.

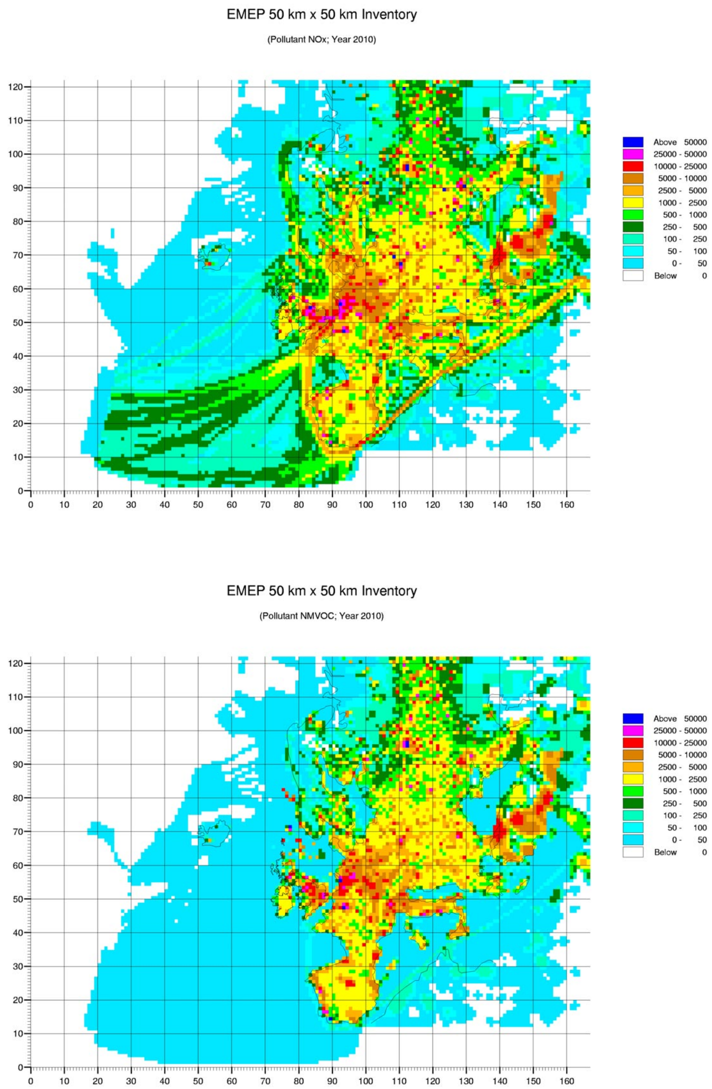


Figure 4.1: Example Inventories for non-UK Emissions of NO_x (Upper Panel) and NMVOC (Lower Panel) for 2010 Used in the OSRM Modelling.

Table 4.4: European Emission Scaling Factors for Road Transport NO_x Emissions (as Fraction of Relevant Base Case) for 2010, 2015 and 2020.

Measure(s)	Description	Scaling Factors for Road Transport NO_x Emissions		
		2010	2015	2020
Base	Base Case projections (January 2005)	1.00	1.00	1.00
A	Introduction of EURO V/VI (Low Reduction Scenario)	0.99	0.88	0.76
B	Introduction of EURO V/VI (High Reduction Scenario)	0.98	0.73	0.47
B*	Introduction of EURO V/VI (High Reduction Scenario)	0.98	0.72	0.42
C	Early uptake of Measure 1 + all road user charging schemes	0.99	0.88	0.76
O	Combined Transport Measures (C & E)	0.99	0.88	0.76
P	Combined Transport & Industrial Measures (C & L)	0.99	0.88	0.76
Q	Combined Transport & Industrial Measures (3b, 12 & 21)	0.99	0.88	0.76
M & Q	Combined Transport & Industrial Measures (3b, 12, 13 & 21)	0.99	0.88	0.76

The other measures modelled using the OSRM – the transport measure E, the domestic and industrial (Measures J, K and L) and VOC control (Measure M) measures – were assumed to be UK specific and no reduction was made of the European emissions. Scaling factors of unity were used, as in the base case runs.

4.3.4 Biogenic VOCs

The biogenic VOC emissions were treated differently. As described in Section 3.1, two approaches can be used: (a) annual emission estimates on a 150 km x 150 km grid, as prepared by Simpson *et al.* [1995] and used in the UK PTM and (b) an emission potential inventory derived using the PELCOM land cover dataset and the TNO tree species inventory [see Dore *et al.*, 2003].

The emission potential inventory provides emission potentials of the following VOC species, aggregated to the EMEP 50 km x 50 km grid:

- isoprene from deciduous and evergreen trees (both temperature and PAR sensitive)
- monoterpenes from deciduous and evergreen trees (both temperature sensitive)
- monoterpenes from deciduous and evergreen trees (both temperature and PAR sensitive)
- other VOCs (OVOCs) from deciduous and evergreen trees (both temperature sensitive)

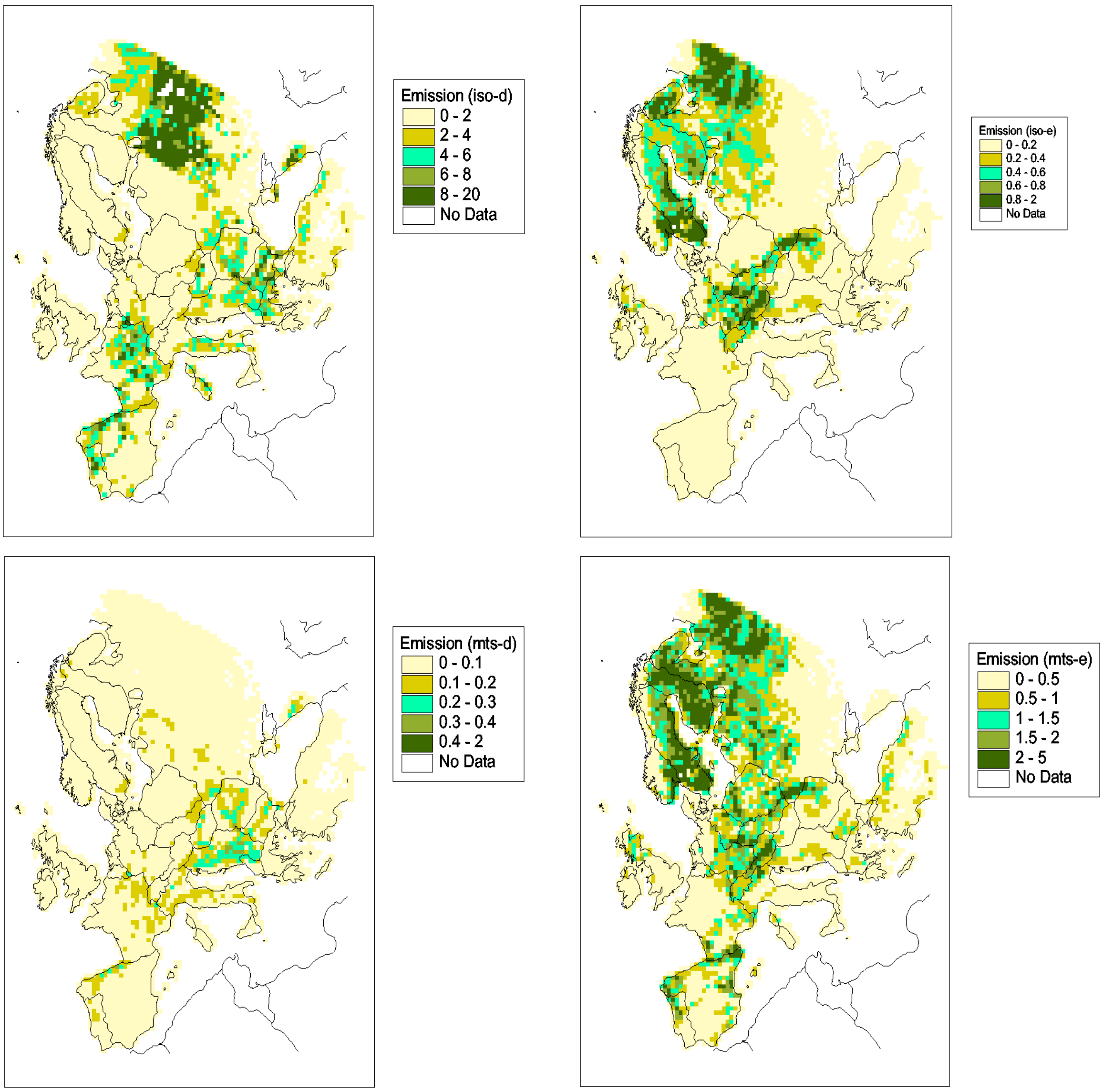


Figure 4.2 Biogenic VOC Emission Potentials for Europe (Upper Panels: Isoprene emissions from Deciduous and Evergreen trees; Lower Panels: Mono-terpene Emissions from Deciduous and Evergreen Trees).

Figure 4.2 shows maps of the biogenic VOC emission potentials for Europe for isoprene and mono-terpene emissions from deciduous and evergreen trees. The emission potentials, which give the emission rate at a reference temperature and light exposure, are converted into emission rates using environmental correction factors [CORINAIR, 2004].

This inventory has been introduced into the OSRM and the code modified to calculate the environmental correction factors along the trajectory. These emissions have all been assigned to isoprene as the only biogenic VOC in the chemical mechanism. The monoterpene emissions have been scaled to correct for the relative reactivity of isoprene and monoterpenes.

The emission potential inventory was used in the scenario calculations for the review of the Air Quality Strategy. The use of this inventory therefore allows for the effects of year-to-year variations in meteorology.

4.4 BOUNDARY CONDITIONS

4.4.1 Initialisation

Output from the global tropospheric STOCHEM model has been used to initialise the OSRM trajectories. Initial conditions have been derived for the species O_3, CO, CH_4, C_2H_6, HNO_3 and PAN from datasets of spatially-disaggregated daily concentration fields. Two datasets have been provided for 2 calendar years, one representing the climatology of the late 1990's (actually 1998) and the second a future atmosphere (IPCC SRES scenarios for 2030).

This will allow for the seasonal cycles in the concentrations of ozone and other trace gases and will make a link between regional scale ozone production and the hemispheric circulation. , the OSRM has been modified so that the concentration of ozone and other key trace species vary with location, time of year, etc.

4.4.2 Changing Atmospheric Composition

Derwent [2005] has calculated global ozone concentrations using the STOCHEM 3-D tropospheric ozone model for a number of climate-related emission scenarios. The output of the model runs has been used to derive monthly trends in ozone at Mace Head, as shown in Table 4.5. This would cause changes from 2003 concentrations ranging from –0.8 to +1.6 ppb on the initial daily ozone concentrations by 2010 and –1.9 to +3.8 ppb by 2020.

Table 4.5: Monthly Trends in Ozone Concentrations (in ppb per year) derived for Mace Head from STOCHEM Global Model Output [Derwent, 2005].

Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Business-as-Usual	0.084	0.074	0.204	0.185	0.090	0.120	0.118	0.150	0.101	0.025	0.081	0.082
Business-as-Usual with Climate Change	0.085	0.004	-0.074	0.200	0.225	0.039	-0.085	-0.120	0.066	0.086	0.097	0.127
Maximum Feasible Reduction	-0.139	-0.147	-0.117	-0.130	-0.184	-0.073	-0.017	0.026	-0.066	-0.143	-0.107	-0.131
IPCC SRES A2	0.153	0.191	0.214	0.270	0.170	0.158	0.113	0.074	0.177	0.051	0.148	0.146
IPCC SRES A2 with Climate change	0.188	0.263	0.287	0.362	0.150	-0.317	-0.168	-0.019	0.154	0.147	0.162	0.128

Following discussion with the Department and Prof Derwent, it was agreed to use the monthly trends for the Business-as-Usual with Climate Change scenario.

5 OSRM Model Results

5.1 THE MODEL RUNS UNDERTAKEN

The OSRM model runs comprised:

- Current Year runs using year-specific meteorology and emission inventories
- Base Case runs for 2010, 2015 and 2020
- Scenario runs
- Sensitivity runs to assess the impact of year-to-year variations in meteorology
- Sensitivity runs to assess the impact of changing atmospheric composition arising from climate change

The results of the model runs listed in Table 5.1 are described in this section.

Table 5.1: Summary of the OSRM Runs Undertaken for the Review of the Air Quality Strategy

Year/Scenario Model Run	2003	1999	2000	2001	2002	2010	2015	2020	Sensitivity to Meteorology - 2000	Sensitivity to Meteorology - 2002	With Changing Atmospheric Composition	Without Changing Atmospheric Composition
Current Year	✓	✓	✓	✓	✓						✓	
Base Case -NECD						✓	✓	✓			✓	
Base Case -CAFE						✓	✓	✓			✓	✓
Measure A						✓	✓	✓			✓	
Measure B						✓	✓	✓			✓	
Measure B*						(1)	✓	✓	✓	✓	✓	
Measure C						✓	✓	✓			✓	
Measure E						✓	✓	✓			✓	
Measure J						✓	✓	✓			✓	
Measures K and L						✓	✓	✓			✓	
Measure L						(2)	✓	✓			✓	
Measure M						✓	✓	✓	✓	✓	✓	
Measure O						✓	✓	✓			✓	
Measure P						(3)	✓	✓			✓	
Measure Q						(4)	✓	✓			✓	
Measures M and Q						✓	✓	✓			✓	

Notes (1) Equivalent to the Scenario B 2010 run; (2) Equivalent to the 2010 base case run; (3) Equivalent to the Scenario C 2010 run; (4) Equivalent to the Scenario O 2010 run.

5.2 MODEL OUTPUTS

The OSRM Post-processor was used to process the hourly concentrations calculated by the OSRM to generate UK maps for the 8 ozone and nitrogen dioxide metrics listed below. All the results presented in this report have been derived with the Surface Conversion algorithm activated (see Section 3.2).

Health-based Metrics:

(a) Annual Mean of the Maximum Daily Running 8-hour Average Ozone concentration (*i.e.*, with no cutoff)

(b) Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 35 ppb (or 70 $\mu g\ m^{-3}$) cutoff

(c) Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 $\mu g\ m^{-3}$) cutoff

(d) Number of Days when the maximum of the 24 possible 8-hour running mean concentrations in each day exceeds 100 $\mu g\ m^{-3}$ (metric in the UK Air Quality Strategy)

(e) Annual Mean NO_2 concentration

Non Health-based Metrics:

(f) Annual Mean O_3 concentration

(g) AOT40 for crops

(h) AOT40 for forests

Population-weighted means have been derived for the metrics associated with impacts on human health. Area- weighted means were derived for the non-health effects metrics. The population- and area-weighted means have been determined for the following regions: All UK, Scotland, Wales, Northern Ireland, Inner London, Outer London and the Rest of England.

These statistics were then used within the cost-benefit analysis being carried out for the Review of the Air Quality Strategy [Defra, 2006a, 2006b]. The ozone metrics (a), (b) and (c) have been used to assess the benefits/disbenefits to human health of the measures modelled by the OSRM. The metrics (f), (g) and (h) have been used to assess the non-health benefits/disbenefits for materials, crops and vegetation.

A complete set of the ozone and nitrogen dioxide metrics calculated by the OSRM for the current year, base case and scenario runs are given in Appendix 4.

5.3 BASE CASE RUNS

5.3.1 Overview

Overall, the base case runs show a progressive increase in the ozone metrics (*i.e.*, a decline in ozone air quality) from the current year to 2010 and beyond. This is shown in Figure 5.1 where maps of three of the seven ozone metrics used for the Review of the Air Quality Strategy (see previous Section) are presented for 2003, 2010, 2015 and 2020. There is generally a progressive reduction in the annual mean NO_2 concentration from the current year to 2010 and beyond (*i.e.*, an improvement in NO_2 air quality). The response of the annual mean NO_2 concentration to the different emission projections is generally in the opposite sense to the ozone metrics.

Elevated concentrations of ozone over the UK are generally associated with summertime photochemical production and easterly airflows. This is the situation modelled in the UK Photochemical Trajectory Model with its idealised trajectory from central Europe to the UK (and the OSRM when configured to use this idealised trajectory). Reduction of NO_x and/or VOC emissions are effective in reducing peak ozone concentrations [see Hayman *et al*, 2005]. In an OSRM model run, however, a calendar year is simulated and a wider range of trajectories is sampled, including those from other wind directions. These other trajectories may have little or no photochemical ozone production, especially if the trajectory has mainly passed over low emission areas (*e.g.*, the sea). It is likely that there will be a chemical titration of the ozone in such air masses when these air masses pass over NO_x emission sources (the same mechanism explains the lower ozone concentrations observed in urban centres). As the NO_x emissions are reduced, there will be less titration and hence higher ozone concentrations result.

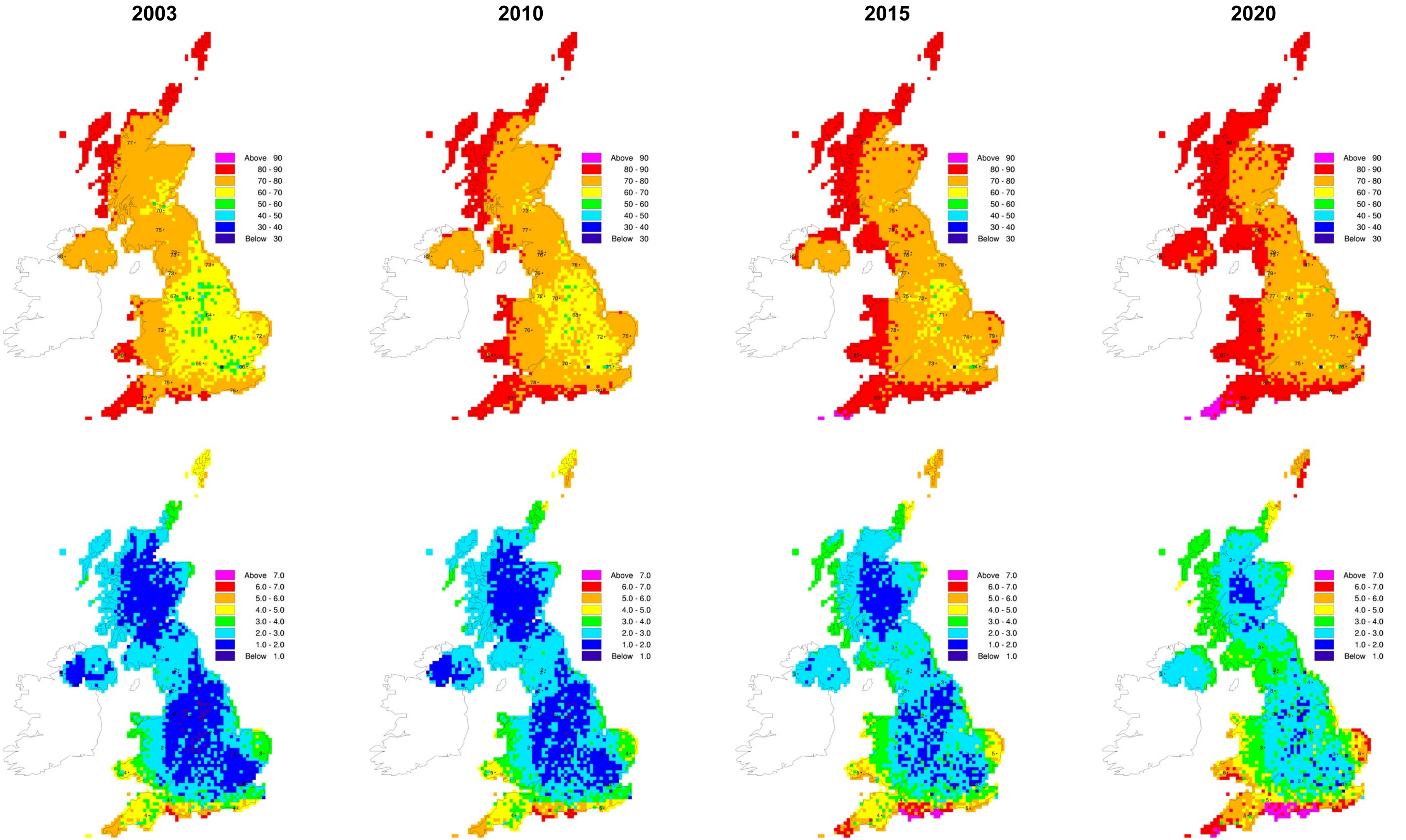


Figure 5.1: UK-scale Maps of generated from the OSRM Base Case Runs for 2003, 2010, 2015 and 2020 for the Metrics: Annual Mean of the Maximum Daily Running 8-hour Average Ozone concentration (*i.e.*, with no cutoff) [Upper Panels] and Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 $\mu g\ m^{-3}$) cutoff [Lower Panels].

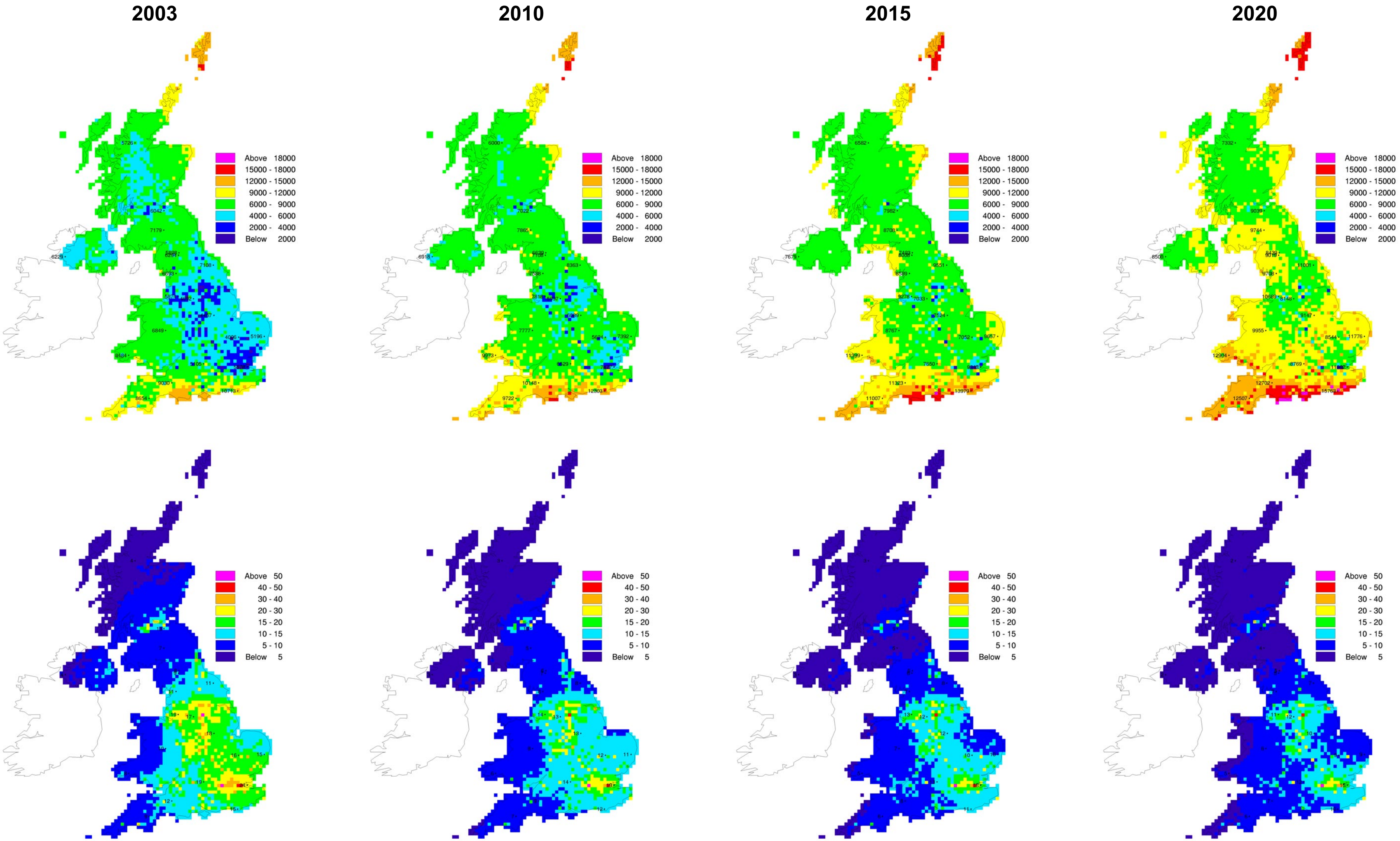


Figure 5.1: **UK-scale Maps of generated from the OSRM Base Case Runs for 2003, 2010, 2015 and 2020 for the Metrics: AOT40 - Crops [Upper Panels] and Annual Mean Nitrogen Dioxide Concentration [Lower Panels].**

In previous OSRM scenario calculations, VOC emission reductions alone led to an improvement in ozone air quality for all the ozone metrics calculated by the OSRM post-processor. NO_x emission reduction scenarios gave a more complex response, reflecting their role in the formation and removal of ozone. The response depended on the choice of ozone metric and could show regional differences for a given metric. Generally, there was a deterioration in ozone air quality if NO_x emissions alone were controlled. When both VOC and NOx emissions are reduced, as occurs in the current base case emission projections, these two effects compete and the overall response depends on the relative changes in emissions.

In the present base case runs, the UK emission projections show a greater decrease in the NO_x emissions out to 2020 than in the VOC emissions. Indeed, the 2020 total UK VOC emissions are actually higher than those in 2015 for both emission projections. In terms of emissions from other European countries, there are comparable changes in the NO_x and VOC emissions. Overall, there is a proportionately greater reduction in the emissions of NO_x, suggesting a smaller NOx titration effect and thus poorer ozone air quality, as evidenced by the increases in the ozone metrics.

The other major driver for the deterioration in ozone air quality is changing atmospheric composition. The OSRM base case runs described here have applied a ramp to the initial ozone concentrations, based on the monthly trends in ozone concentrations derived for a global business-as-usual scenario with climate change. Sensitivity runs were undertaken to investigate the effects of the changing atmospheric composition and these are discussed in Section 5.3.3 below.

5.3.2 Regional Differences

Population- or area-weighted means of the metrics were determined for the following regions: All UK, Scotland, Wales, Northern Ireland, Inner London, Outer London and the Rest of England.

Figure 5.2 shows the regional variation calculated in the population-weighted annual mean NO_2 concentration. The annual mean concentration shows the expected regional pattern, with Northern Ireland < Scotland < Wales < All UK < Rest of England < Outer London < Inner London.

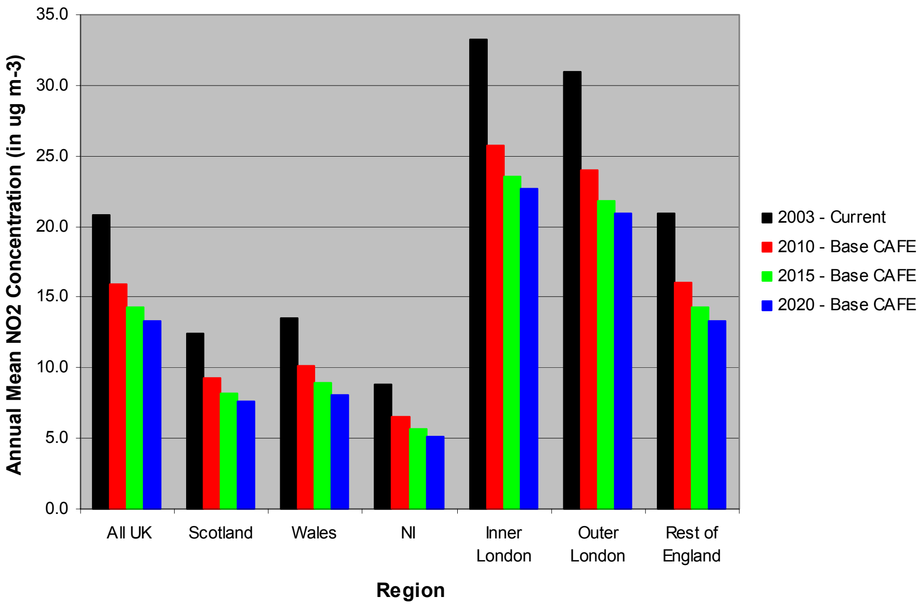
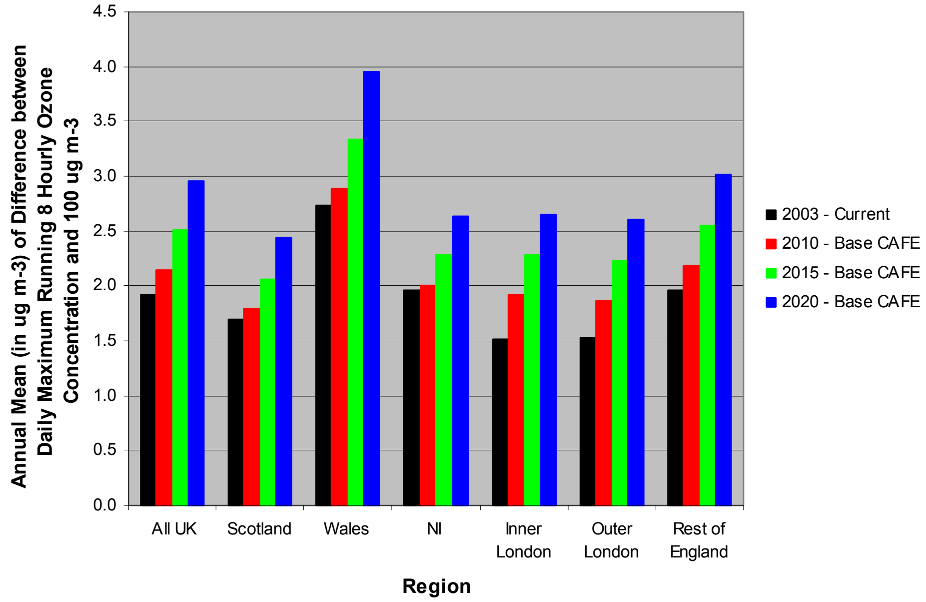


Figure 5.2: The Regional Pattern of the Annual Mean Nitrogen Dioxide Concentration Calculated by the OSRM for Different Regions of the UK for the 2003, 2010, 2015 and 2020 Base Case Runs.

As shown in Figure 5.3, the regional pattern of the ozone metrics, (a) Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 µg m-3) cutoff and (b) AOT40 – Forests, calculated by the OSRM for different regions of the UK is more variable. The ozone metrics are lowest in Inner London, followed by Outer London. The regional pattern reflects the controlling factors on ozone – photochemical production and removal by nitrogen oxides.



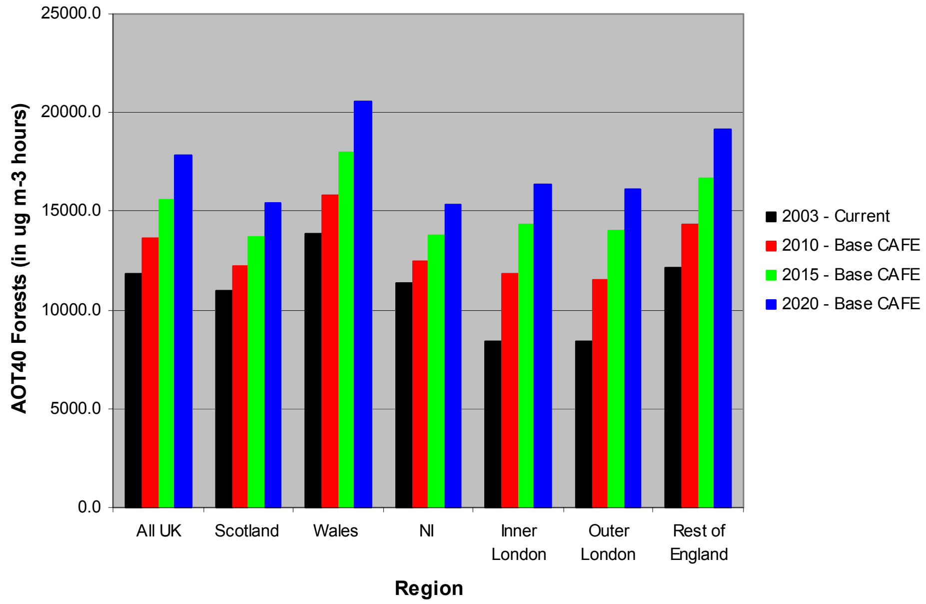


Figure 5.3: The Regional Pattern of the Ozone Metrics - Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 $\mu g\ m^{-3}$) cutoff (Upper Panel) and AOT40 – Forests (Lower Panel) Calculated by the OSRM for Different Regions of the UK for the 2003, 2010, 2015 and 2020 Base Case Runs.

5.3.3 Sensitivity Runs

A limited number of model runs were undertaken to assess the sensitivity to changes in (1) atmospheric composition and (2) the non-UK emission assumptions.

1. Changing Atmospheric Composition: The changes in atmospheric composition assumed will lead to higher ozone concentrations and hence a deterioration in ozone air quality. Sensitivity runs were undertaken for the CAFÉ emission projections for 2010 and 2020 with a current atmosphere (2003) and future atmospheric composition based on the business-as-usual scenario with climate change (see Section 4.4.2), as shown in Figure 5.4.

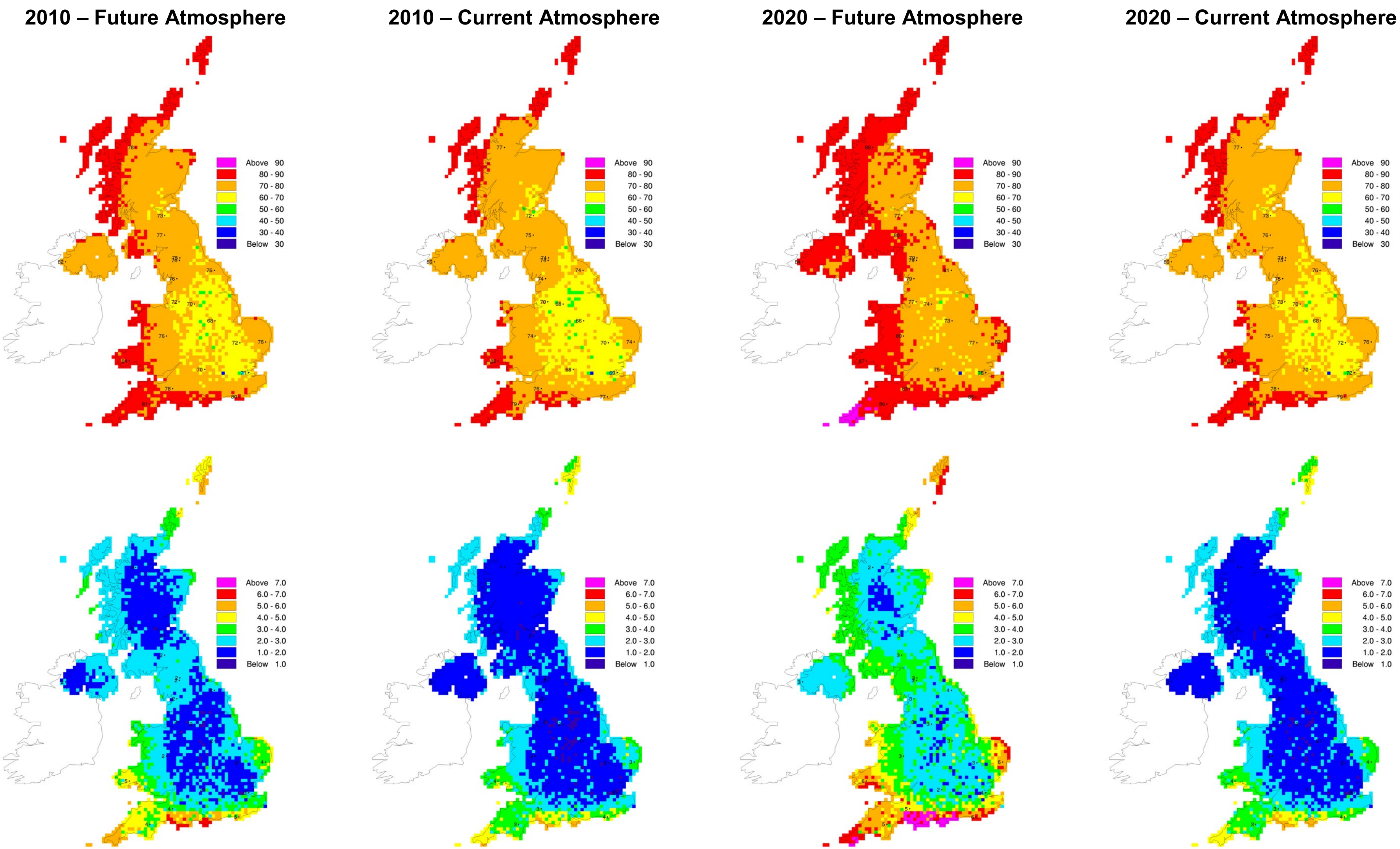


Figure 5.4: UK-scale Maps of generated from the OSRM Base Case Runs for 2010 and 2020 (with Future and Current Atmospheric Compositions) for the Metrics: Annual Mean of the Maximum Daily Running 8-hour Average Ozone concentration (*i.e.*, with no cutoff) [Upper Panels] and Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 μg m^{-3}) cutoff [Lower Panels].

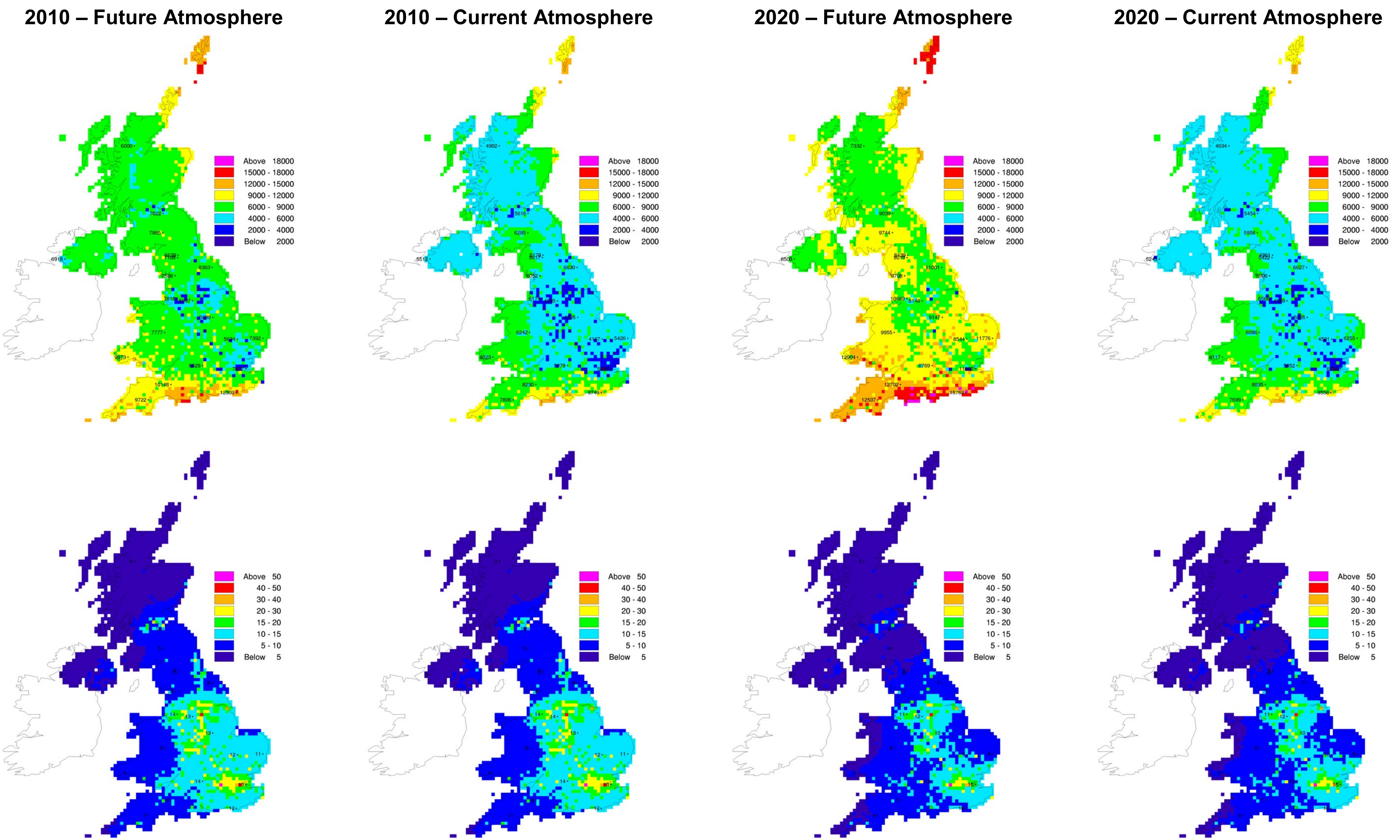


Figure 5.4: UK-scale Maps of generated from the OSRM Base Case Runs for 2010 and 2020 (with Future and Current Atmospheric Compositions) for the Metrics: AOT40 - Crops [Upper Panels] and Annual Mean Nitrogen Dioxide Concentration [Lower Panels].

The model runs illustrated in Figure 5.4 differed in initial concentrations used for ozone and other key species. A ramp was applied to the initial ozone concentration, based on the monthly trends in ozone concentrations at Mace Head derived for a global business-as-usual scenario with climate change. The effect of this ramp was to change ozone concentrations from their 2003 values by –0.8 to +1.6 ppb in 2010 (depending on the month) and by –1.9 to +3.8 ppb in 2020.

It is interesting to note that the runs without climate change would have led to lower values of the O_3 metrics in both 2010 and 2020 for the UK for the annual mean of the maximum daily running 8-hour average ozone concentration with a 50 ppb (or 100 µg m^{-3}) cut-off and the two AOT40 metrics. This is also seen in Figure 5.5, which shows the sensitivity of the different population and area-weighted ozone and nitrogen dioxide metrics for Inner London and the UK for the 2010 and 2020 base case runs, with and without changing atmospheric composition, relative to the 2003 current year (=1).

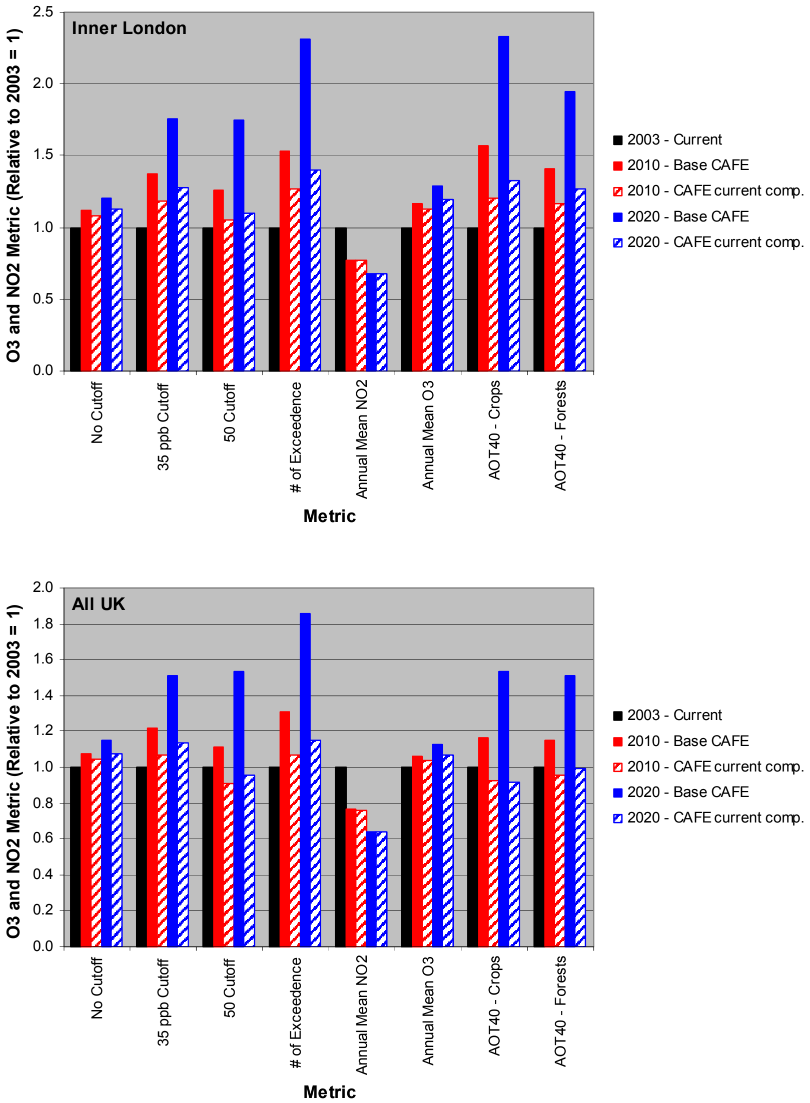


Figure 5.5: The Sensitivity of the Different Ozone and Nitrogen Dioxide Metrics Calculated by the OSRM for the 2010 and 2020 Base Case Runs (With and Without Changing Atmospheric Composition) Relative to 2003 (=1) for Inner London (Upper Panel) and the UK (Lower Panel).

There are significant and increasing differences for the ozone metrics between the runs undertaken with the current atmospheric composition and a future atmospheric composition based on the business-as-usual scenario with climate change. The greatest differences occur for the ozone metrics with an exceedence of a threshold, *i.e.*, annual mean of the maximum daily running 8-hour average ozone concentration with a 35 ppb (or 70 µg m^{-3}) or 50 ppb (or 100 µg m^{-3}) cut-off, the number of days when the maximum of the 24 possible 8-hour running mean concentrations in each day exceeds 100 µg m^{-3} and the two AOT40 metrics. There is little effect on the annual mean NO_2 concentrations between the runs with and without a changing atmospheric composition.

2. NECD against CAFÉ Emission Projections: The majority of the OSRM runs for the years 2010, 2015 and 2020 made use of projected national emission totals for European countries developed for the Clean Air for Europe (CAFÉ) programme. A limited number of runs were also undertaken using the emission totals agreed under the National Emissions Ceilings Directive for the EU member states (except for the UK) and the Gothenburg Protocol for the other UN ECE countries.

   Figure 5.6 shows the sensitivity of the different population and area-weighted ozone and nitrogen dioxide metrics for Inner London and the UK for the 2010, 2015 and 2020 base case runs (relative to 2003 metrics = 1) using these two emission projections.

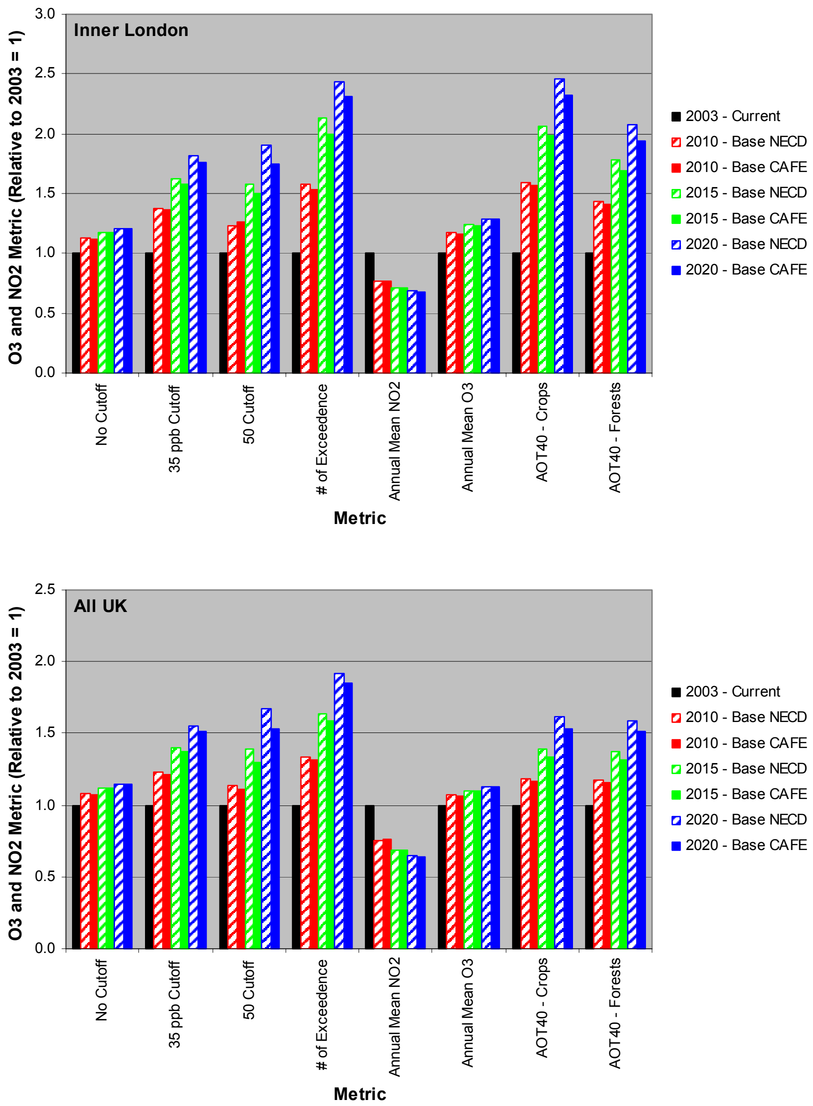


Figure 5.6: The Sensitivity of the Different Ozone and Nitrogen Dioxide Metrics Calculated by the OSRM for the 2010, 2015 and 2020 Base Case Runs Relative to 2003 (=1) for Inner London (Upper Panel) and the UK (Lower Panel).

The base case runs based on the NECD emission limits effectively used the same emission totals for 2010, 2015 and 2020 for all other European countries, whereas there was a progressive and comparable decline in the NO_x and VOC emissions in the CAFÉ projections. As noted earlier, the model runs using NECD emission projections for 2015 and 2020 give higher values, especially for the ozone metrics sensitive to peak ozone concentrations, than the corresponding model runs undertaken using the CAFÉ emission projections. The peak ozone concentrations are more likely to be associated with photochemical events (and 2003 was a photochemically-active year) and in this case the NO_x and VOC emission reductions are both likely to improve ozone air quality.

5.4 SCENARIO RUNS

5.4.1 NO_x Emission Control Measures

The OSRM has been used to model the impact on ozone concentrations across the UK of selected road transport and other NO_x abatement measures (Measures A, B, C, E, J and L) and of combinations of these measures (Measures K & L, O, P and Q). Table 4.2 provided information on the total UK NO_x emissions for the selected measures for 2010, 2015 and 2020. The full set of population and area-weighted metrics calculated by the OSRM can be found in Appendix 4.

Figure 5.7 shows the fractional response (relative to the corresponding base case =1) of the ozone and nitrogen dioxide metrics for the 2010 and 2020 base case and scenario runs for the UK and Inner London. As the emission controls of the measures are generally small compared to the changes in the base case emissions from the current year to 2010 and beyond, there is an overall progressive increase in all of the ozone metrics (*i.e.*, a decline in ozone air quality). There is a significant shift in the impact of the different NO_x measures between 2010 and 2020, reflecting the large effect of the short-term component of Measure K.

As the emissions of oxides of nitrogen have been reduced in these measures, there is generally a progressive reduction in the annual mean NO_2 concentration from the current year to 2010 and beyond (i.e., an improvement in NO_2 air quality). The annual mean NO_2 concentration follows the emission reductions in the different scenarios and the response is most often in the opposite sense to that of the ozone metrics.

The impacts of the selected measures are as follows:

- **Measure A - Introduction of EURO V/VI (Low Reduction Scenario):** There appears to be little, if any, change from the corresponding base case runs for all 8 metrics for the 2010 and 2015 model runs. This is not surprising given the relatively small reductions in the NO_x emissions. There is a slight change for the 2020 model runs, with an improvement in the annual mean nitrogen dioxide concentration and a general worsening of ozone air quality (i.e., the ozone metrics have increased). The largest relative changes occur in London where the road transport NO_x emissions represent a higher proportion of the total emissions for the regions considered.
- **Measure B - Introduction of EURO V/VI (High Reduction Scenario):** There appears to be little, if any, change from the corresponding base case runs for all 8 metrics for the 2010 model run. This is again not surprising given the relatively small reductions in the NO_x emissions (2% on road transport emissions). There is a slightly larger change for the 2015 and 2020 model runs. There is an improvement in the annual mean nitrogen dioxide concentration and a worsening of ozone air quality (*i.e.*, the ozone metrics have increased). However, there are some ozone metrics (AOT40 – Crops), which show a decrease in 2020 for some regions, indicating that NO_x emission control leads not to an increase but a decrease in ozone concentrations. The largest relative changes occur in London.
- **Measure C – Early Uptake of EURO V/VI (Low Reduction Scenario):** This measure is an earlier implementation of Measure A and therefore has slightly larger NO_x emission reductions. As a result, the responses of the two Measures follow the same pattern with a slightly larger response for Measure C.
- **Measure E – Low Emission Vehicles:** This measure has relatively small but increasing emission reductions compared to the corresponding base case projection. The responses follow the usual pattern of improving air quality for nitrogen dioxide and a deterioration in ozone air quality. The 2010 runs show little difference from the base case run. There is a slightly larger response in 2020, reflecting the proportionately larger emission reductions.
- **Measure J - Domestic Combustion:** The emission reductions of this measure are relatively small, increasing from ~3 ktonne per annum in 2010 to 13 ktonne per annum (see Table 4.2). As a result, there appears to be little, if any, change from the corresponding base case run. The largest relative changes occur in London.

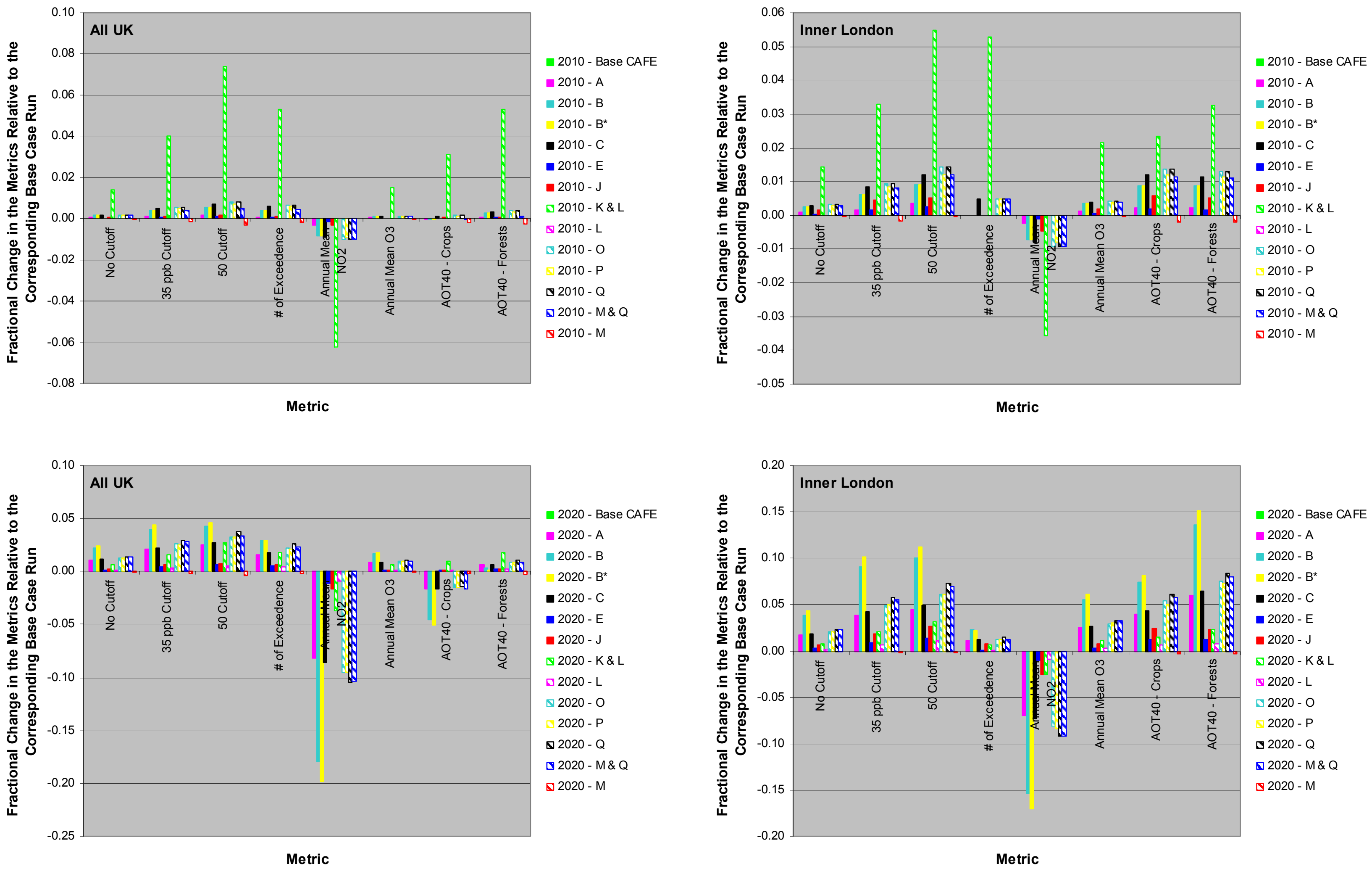


Figure 5.7: The Fractional Response of the Different Ozone and Nitrogen Dioxide Metrics Calculated by the OSRM for the Base Case and Scenario Runs for the UK (Left-hand Panels) and Inner London (Right-hand Panels) in 2010 (Upper Panels) and 2020 (Lower Panels).

- **Measures K and L - Controls on Power Stations, Iron and Steel, Oil refineries and Small Combustion Plants:** Measure K has two components: a short-term component leading to significant emission reductions between 2010 and 2016 and a smaller, long-term component. As a result, this combination of measures differ from the other measures considered above as a significant uptake is expected by 2010 resulting in the largest emission reduction in 2010. Thus, these measures have the greater impact on the ozone metrics in 2010, as can be seen in Figure 5.7. The other measures become more effective in 2020.
- **Measure L - Controls on Small Combustion Plants:** As this measure is implemented after 2010, there is no difference from the 2010 base case. The emission reductions of this measure are relatively small, ~16-17 ktonne per annum in 2015 and 2020 (see Table 4.2). As a result, there appears to be little, if any, change from the corresponding base case run. The largest relative changes occur in London.
- **Measure O (Combination of Measures C and E):** The emission reduction in this combination of road transport NO_x measures is dominated by those of Measure C. As a result, the response of the different ozone and nitrogen dioxide metrics for this combination of measures is very similar to, but slightly larger than, that of Measure C.
- **Measure P (Combination of Measures C and L):** As Measure L (NO_x reduction from small combustion plant) is only implemented after 2010, the response of the ozone and nitrogen dioxide metrics in 2010 are the same as those for Measure C. After 2010, Measure L provides a further abatement of 13 ktonne per annum. As a result, the response of the different ozone and nitrogen dioxide metrics for this combination of measures is similar to, but larger than, that of Measure C and also of Measure O.
- **Measure Q (Combination of Measures C, E and L):** As Measure L (NO_x reduction from small combustion plant) is only implemented after 2010, the response of the ozone and nitrogen dioxide metrics in 2010 are the same as those for Measure O and similar to that of Measure C. After 2010, Measure L provides a further abatement of 13 ktonne per annum. As a result, the response of the different ozone and nitrogen dioxide metrics for this combination of measures is similar to, but larger than, that of Measure P and also of Measures C and O.

Ranking the measures in terms of increasing response, the order would be:

All UK – 2010 (Note 1):	Base Case < E < A ~ J < B < C = P < O = Q < K & L
All UK - 2020:	Base Case < L < E < J < K & L < A < C < O ~ P < Q < B
Inner London – 2010 (Note 1)	Base Case < E < A ~ J < B < C = P < O = Q < K & L
Inner London - 2020	Base Case < L < E < J < K & L < A < C < O ~ P < Q < B

Note 1: Measure L is implemented after 2010.

Clearly, the ordering reflects the relative emission reductions of the different measures in 2010 and 2020 and their spatial distribution. For both Inner London and the UK as a whole, the industrial measures have the larger impact in 2010 but the road transport measures have the larger impact for the 2020 model runs.

5.4.2 VOC Emission Control Measures

The OSRM has also been used to model the impact on ozone concentrations across the UK of a VOC abatement measure (Measure M) and a combination of VOC and NO_x abatement measures (Measures M and Q). Table 4.2 and Table 4.3 provided information on the total UK NO_x and VOC emissions for the measures for 2010, 2015 and 2020. The population and area-weighted metrics calculated by the OSRM for these measures can be found in Appendix 4.

Figure 5.7 shows the fractional response (relative to the corresponding base case =1) of the ozone and nitrogen dioxide metrics for the 2010 and 2020 base case and scenario runs for the UK and Inner London. As the VOC emission controls in Measure M are based on specific sectoral activities with localised emissions, separate maps of VOC emissions from petrol stations and on and offshore loading of crude oil were created for 2010 and adjusted to produce the corresponding maps for 2015 and 2020. Consistent with previous work, VOC emission control led to an improvement in all the ozone metrics considered (*i.e.*, an improvement in ozone air quality) compared to the corresponding base case. The improvements in ozone air quality over the base case run were modest. This reflects the relatively small emission changes and the specific regions where the VOC emissions were controlled. There is little or no effect on the annual mean NO_2 concentration of the VOC control measure. As the emission controls of the measures are generally small compared to the changes in the base case emissions from the current year to 2010 and beyond, there is an overall progressive increase in all of the ozone metrics (*i.e.*, a decline in ozone air quality). The VOC emission reductions in Measure M do not offset this overall decline.

As for Measure M, the combination of NO_x and VOC control measures (M and Q) gave a similar small improvement in ozone air quality compared to the corresponding set of measures without the VOC control (*i.e.*, Measure Q). The improvement does not offset the effects of the NO_x emission reductions in this combination of measures, which led to poorer ozone air quality (*i.e.*, increases in the ozone metrics) compared to the corresponding base case and Measure M runs. Again, there does not appear to be any notable regional variations.

Two sets of additional model runs were undertaken to assess the response of Measure M. The first set of model runs used the same overall reduction in UK VOC emissions achieved by Measure M (~9% excluding the natural contribution) but assumed that the emission reduction was spread equally across all the UK non-natural OSRM source sectors. Model runs were undertaken for 2010, 2015 and 2020 and only UK VOC emissions were affected. The second set of runs applied the same emission reduction to the European VOC emissions as well. Figure 5.8 shows the response and fractional response of the AOT40 – Forests metric for the UK.

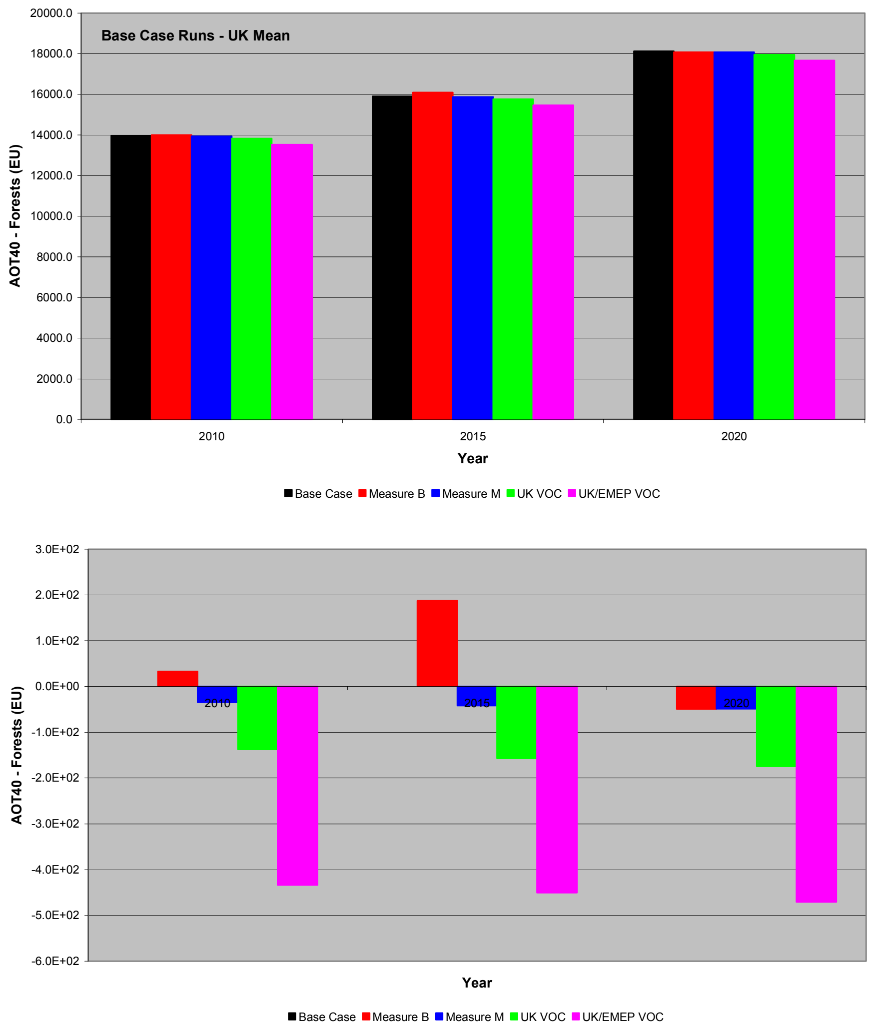


Figure 5.8: The Response (Upper Panel) and Fractional Response (Relative to Base Case =1, Lower Panels) of the AOT40 – Forests Metric Calculated by the OSRM for the Base Case and Scenario Runs for the UK.

Included in the figure is the response for Measure B for comparison. The results show that the response of Measure M is smaller than the response for an equivalent across-the-board emission reduction. The spatial location of the emission sources is significant. As expected, there is a larger response when both UK and European VOC emissions are controlled. It is also interesting to note that the sign of the response changes for the NO_x emission reductions of Measure B between 2015 and 2020.

5.5 SENSITIVITY TO METEOROLOGY

The base case and scenario model runs have used the meteorology for 2003. The highest UK temperature was recorded in 2003 and it was a photochemically-active year with several major episodes of elevated ozone concentrations, especially in South-East England, in July and August (see Section 2.3). It could therefore become a typical ozone year in the future as a result of climate change. Sensitivity runs were undertaken using meteorology for 2002 (a current typical ozone year) and 2000 (a low ozone year, considering the headline air quality indicator). The model runs used the same emission scenarios.

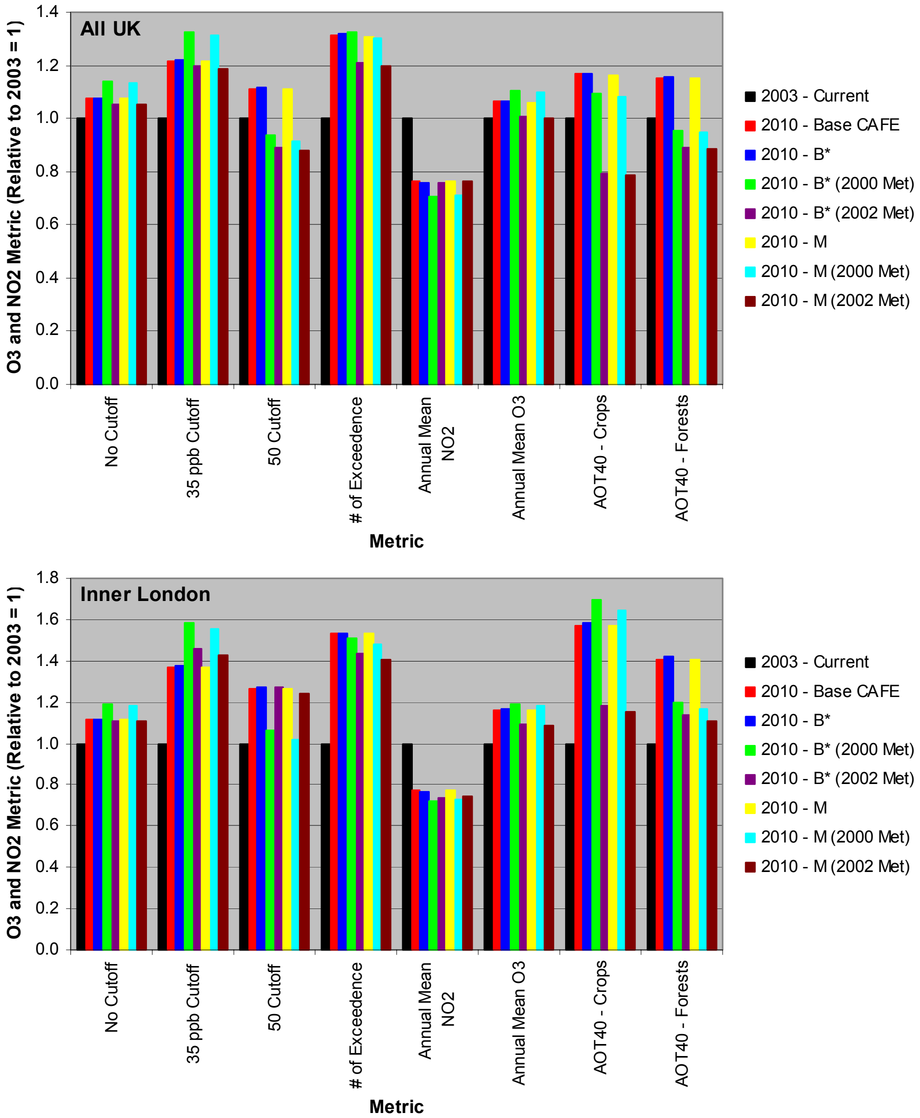


Figure 5.9: The Sensitivity of Different Ozone and Nitrogen Dioxide Metrics Calculated by the OSRM for Various Current and Future Base Case and Scenarios Runs to Meteorology for the UK (Upper Panel) and Inner London (Lower Panel).

Figure 5.9 shows the sensitivity of the different O_3 and NO_2 metrics to meteorology for Inner London and the UK for Measures B* (an earlier version of Measure B) and M. For the UK as a whole (see upper panel of Figure 5.9), 2003 gave the highest values of the following ozone metrics: Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 $\mu g\ m^{-3}$) cutoff, the Number of Days when the maximum of the 24 possible 8-hour running mean concentrations in each day exceeds 100 $\mu g\ m^{-3}$, AOT40 – Crops and AOT40 – Forests. These metrics are sensitive to elevated peak ozone concentrations and also extended photochemical episodes such as those that occurred in July and August 2003. Clearly, the meteorology in 2000, 2002 and 2003 will undoubtedly affect the trajectories, emission history and chemical evolution of the air masses arriving at the OSRM receptor sites.

The ozone metrics calculated for Inner London (see lower panel of Figure 5.9) show more variation and do not follow the same pattern as for the UK. There are some interesting features, in that the 2000 meteorology gave the higher value of the metric, AOT40 for crops, whereas the 2003 meteorology gave the higher values for the metric, AOT40 – Forests. As these metrics accumulate ozone concentrations for different times of the year, the results indicate the differing levels and distributions of photochemical activity and model performance for the years, 2000, 2002 and 2003.

A further observation to make is that the ozone metrics show (a) as much sensitive to meteorology as to the emission changes in the runs between 2000 and 2010 and (b) greater sensitivity to meteorology than to the changes associated with the emission reductions of Measures B and M. The annual mean nitrogen dioxide concentration is less sensitive than the ozone metrics to meteorology. Again, the sensitivity of the annual mean nitrogen dioxide concentration to meteorology is as great as the emission changes associated with the measures.

5.6 COMPARISON WITH AIR QUALITY OBJECTIVES

The Air Quality Strategy, the EU 3rd Daughter Directive and the UN ECE define air quality objectives and target values for ozone for the protection of human health and ecosystems, as shown in Table 5.2. This table also includes limit values, objective and target values for nitrogen dioxide.

Table 5.2: Air Quality Limit Values, Objectives and Target Values for O_3 and NO_2.

Metric	Limit Value/ Objective/Target	Limit Value/ Objective/Target
Annual mean ozone concentration (materials)		**40 $\mu g\ m^{-3}$**
AOT30 – crops (ecosystems)	UN ECE	8,000 $\mu g\ m^{-3}$ hours
AOT40 – crops (ecosystems)	**3DD LTO**	**6,000 $\mu g\ m^{-3}$ hours**
AOT40 – crops (ecosystems)	**3DD Target Value**	**18,000 $\mu g\ m^{-3}$ hours**
AOT40 – forests (ecosystems)	**UN ECE**	**20,000 $\mu g\ m^{-3}$ hours**
AOT60 (human health)	**UN ECE**	**5,800 $\mu g\ m^{-3}$ hours**
Number of days when the daily maximum running 8-hour mean ozone concentration > 100 $\mu g\ m^{-3}$ (human health)	**Air Quality Strategy Objective**	**10**
Number of days when the daily maximum running 8-hour mean ozone concentration > 100 $\mu g\ m^{-3}$ (human health)	EPAQS	0
Number of days when the daily maximum running 8-hour mean ozone concentration > 120 $\mu g\ m^{-3}$ (human health)	**3DD Target Value**	**25**
Number of days when the daily maximum running 8-hour mean ozone concentration > 120 $\mu g\ m^{-3}$ (human health)	3DD LTO	0
Annual mean nitrogen dioxide concentration (human health)	**Limit Value/ Air Quality Strategy Objective**	**40 $\mu g\ m^{-3}$**
Annual mean NO_x concentration (ecosystem)	Limit Value/ Air Quality Strategy Objective	30 $\mu g\ m^{-3}$
Number of hours when the hourly nitrogen dioxide concentration > 200 $\mu g\ m^{-3}$ (human health)	**Limit Value/ Air Quality Strategy Objective**	**18**

Table 5.3 summarises the number of 10 km x 10 km grid squares where the objective or target value for the metrics highlighted in bold are exceeded. There are 2,946 grid squares in total. The total shows that there are widespread exceedences of the objectives and target values for (a) annual mean O_3 concentrations, (b) AOT40 - Crops (long-term objective) and (c) the number of days when the daily maximum running 8-hour average ozone concentration exceeds 100 $\mu g\ m^{-3}$ is greater than zero or 10 (not shown for no exceedences as almost all the grid squares have one or more exceedences).

Table 5.3: Number of OSRM 10 km x 10km Grid Squares which have Exceedences of the O_3 or NO_2 Air Quality Objective or Target Value.

Run \ Metric	Annual Mean O_3 Concentration	AOT40 - Crops	AOT40 - Crops	AOT40 - Forests	AOT60	# of days when the daily maximum running 8-hour mean O_3 concentration > 100 µg m^{-3}	Number of days when the daily maximum running 8-hour mean O_3 concentration > 120 µg m^{-3}	Annual Mean NO_2 Concentration	# of hourly NO_2 concentrations > 200 µg m^{-3}
Objective	40 µg m^{-3}	6000 µg m^{-3} hr	18000 µg m^{-3} hr	20000 µg m^{-3} hr	5800 µg m^{-3} hr	10	25	40 µg m^{-3}	18
1999 – Current Year	2921	1319	0	46	0	2936	141	6	0
2000 – Current Year	2928	1796	0	23	3	2928	119	3	0
2001 – Current Year	2902	1308	0	0	0	2940	75	3	0
2002 – Current Year	2905	379	0	21	0	2917	64	2	0
2003 – Current Year	2920	1862	0	134	2	2936	166	4	43
2010 – NECD Projections	2943	2645	0	239	1	2943	270	3	17
2010 – CAFE Projections	2941	2611	0	215	0	2943	232	3	17
2010 – CAFE Projections - Current Atmospheric Composition	2939	1175	0	70	0	2940	91	3	14
2010 – Measure(s) A (CAFE Projections)	2941	2609	0	214	0	2943	235	3	17
2010 – Measure(s) B (CAFE Projections)	2942	2613	0	214	0	2943	238	3	17
2010 – Measure(s) B* (CAFE Projections)	2942	2617	0	214	0	2943	235	3	16
2010 – Measure(s) C (CAFE Projections)	2941	2612	0	215	0	2943	232	3	16
2010 – Measure(s) E (CAFE Projections)	2943	2733	0	278	0	2944	307	2	17
2010 – Measure(s) J (CAFE Projections)	2941	2611	0	215	0	2943	232	3	17
2010 – Measure(s) K & L (CAFE Projections)	2941	2611	0	215	0	2943	232	3	17
2010 – Measure(s) L (CAFE Projections)	2942	2621	0	214	0	2943	235	3	17
2010 – Measure(s) O (CAFE Projections)	2942	2621	0	214	0	2943	235	3	17
2010 – Measure(s) P (CAFE Projections)	2942	2617	0	214	0	2943	235	3	16
2010 – Measure(s) Q (CAFE Projections)	2942	2613	0	214	0	2943	238	3	17
2010 – Measure(s) M and Q (CAFE Projections)	2941	2612	0	214	0	2943	233	3	17
2010 – Measure(s) M (CAFE Projections)	2940	2608	0	211	0	2943	230	3	17
2010 – Measure B* (CAFE Projections)	2942	2613	0	214	0	2943	238	3	17
2010 – Measure B* (CAFE Projections) + 2000 Meteorology	2943	1944	0	88	0	2943	116	1	0
2010 – Measure B* (CAFE Projections) + 2002 Meteorology	2941	688	0	45	0	2942	91	2	0
2010 – Measure M (CAFE Projections)	2940	2608	0	211	0	2943	230	3	17
2010 – Measure M (CAFE Projections) + 2000 Meteorology	2943	1917	0	77	0	2943	109	1	0
2010 – Measure M (CAFE Projections) + 2002 Meteorology	2941	680	0	43	0	2942	81	2	0

Note: A total of 2,946 10 km x 10 km grid squares were used in the OSRM model runs.

Table 5.3: Number of OSRM 10 km x 10km Grid Squares which have Exceedences of the O3 or NO2 Air Quality Objective or Target Value. (Continued)

Run / Metric	Annual Mean O_3 Concentration	AOT40 - Crops	AOT40 - Crops	AOT40 - Forests	AOT60	# of days when the daily maximum running 8-hour mean O_3 concentration > 100 $\mu g\ m^{-3}$	Number of days when the daily maximum running 8-hour mean O_3 concentration > 120 $\mu g\ m^{-3}$	Annual Mean NO_2 Concentration	# of hourly NO_2 concentrations > 200 $\mu g\ m^{-3}$
Objective	40 $\mu g\ m^{-3}$	6000 $\mu g\ m^{-3}$ hr	18000 $\mu g\ m^{-3}$ hr	20000 $\mu g\ m^{-3}$ hr	5800 $\mu g\ m^{-3}$ hr	10	25	40 $\mu g\ m^{-3}$	18
2015 - NECD Projections	2944	2863	2	527	29	2945	483	3	10
2015 - CAFE Projections	2944	2843	1	449	4	2945	420	3	9
2015 - Measure(s) A (CAFE Projections)	2944	2851	0	466	7	2945	428	3	9
2015 - Measure(s) B (CAFE Projections)	2944	2855	0	484	14	2945	439	2	6
2015 - Measure(s) B* (CAFE Projections)	2944	2854	0	472	8	2945	429	3	8
2015 - Measure(s) C (CAFE Projections)	2944	2846	1	452	4	2945	422	3	9
2015 - Measure(s) E (CAFE Projections)	2944	2868	1	542	18	2945	464	1	9
2015 - Measure(s) J (CAFE Projections)	2944	2845	1	456	4	2945	422	3	10
2015 - Measure(s) K & L (CAFE Projections)	2944	2845	1	452	4	2945	422	3	10
2015 - Measure(s) L (CAFE Projections)	2944	2856	0	472	8	2945	428	3	8
2015 - Measure(s) O (CAFE Projections)	2944	2859	0	476	9	2945	430	2	6
2015 - Measure(s) P (CAFE Projections)	2944	2856	0	475	9	2945	430	2	8
2015 - Measure(s) Q (CAFE Projections)	2944	2855	0	484	14	2945	439	2	6
2015 - Measure(s) M and Q (CAFE Projections)	2944	2857	0	473	8	2945	428	1	8
2015 - Measure(s) M (CAFE Projections)	2944	2842	1	443	4	2945	414	3	10
2020 - NECD Projections	2944	2921	31	916	62	2945	770	2	10
2020 - CAFE Projections	2944	2906	15	732	33	2945	646	2	9
2020 - CAFE Projections - Current Composition	2943	1051	0	81	0	2943	81	2	8
2020 - Measure(s) A (CAFE Projections)	2944	2915	7	752	41	2945	636	2	5
2020 - Measure(s) B (CAFE Projections)	2945	2924	2	763	52	2945	578	2	4
2020 - Measure(s) B* (CAFE Projections)	2945	2915	7	756	41	2945	638	2	4
2020 - Measure(s) C (CAFE Projections)	2944	2909	15	738	35	2945	648	2	9
2020 - Measure(s) E (CAFE Projections)	2945	2911	16	788	38	2945	673	2	9
2020 - Measure(s) J (CAFE Projections)	2944	2907	15	739	36	2945	648	2	10
2020 - Measure(s) K & L (CAFE Projections)	2944	2909	14	740	36	2945	647	2	8
2020 - Measure(s) L (CAFE Projections)	2945	2918	7	762	42	2945	643	2	5
2020 - Measure(s) O (CAFE Projections)	2945	2918	7	768	43	2945	644	1	5
2020 - Measure(s) P (CAFE Projections)	2945	2917	7	764	42	2945	643	1	5
2020 - Measure(s) Q (CAFE Projections)	2945	2921	2	765	51	2945	579	2	5
2020 - Measure(s) M and Q (CAFE Projections)	2945	2918	7	762	42	2945	639	1	6
2020 - Measure(s) M (CAFE Projections)	2944	2906	15	718	32	2945	640	2	9

Note: A total of 2,946 10 km x 10 km grid squares were used in the OSRM model runs.

The response to the different emission control and sensitivity runs gives a similar picture to that described earlier.

5.7 CALCULATION OF BENEFITS

The population- and area-weighted means of the ozone metrics were passed to the teams involved in the cost-benefit analysis being carried out for the Review of the Air Quality Strategy [Defra, 2006a, 2006b]. Three of the ozone metrics [metric (a), (b) and (c) below] were used to assess the benefits/disbenefits to human health of the measures modelled by the OSRM. Another three of the metrics [metrics (f), (g) and (h) below] were used to assess the non-health benefits/disbenefits for materials, crops and vegetation.

5.8 SUMMARY

The Ozone Source-receptor model has been used to determine ozone air quality for future years and to assess the effectiveness of control measures on ozone precursor emissions (NO_x and VOC emissions) being considered for the Review of the Air Quality Strategy.

The analysis of the various base case and scenario runs considered seven ozone and one nitrogen dioxide metrics:

Health-based Metrics:

(a) Annual Mean of the Maximum Daily Running 8-hour Average Ozone concentration (*i.e.*, with no cutoff)

(b) Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 35 ppb (or 70 μg m^{-3}) cutoff

(c) Annual Mean of the Difference between the Maximum Daily Running 8-hour Average Ozone concentration and a 50 ppb (or 100 μg m^{-3}) cutoff

(d) Number of Days when the maximum of the 24 possible 8-hour running mean concentrations in each day exceeds 100 μg m^{-3} (metric in the UK Air Quality Strategy)

(e) Annual Mean NO_2 concentration

Non Health-based Metrics:

(f) Annual Mean O_3 concentration

(g) AOT40 for crops

(h) AOT40 for forests

Population-weighted means were derived for the metrics associated with impacts on human health. Area-weighted means were derived for the non-health effects metrics. The population- and area-weighted means have been determined for the following regions: All UK, Scotland, Wales, Northern Ireland, Inner London, Outer London and the Rest of England.

The key points to note from the model runs are that:

- The base case runs show a progressive worsening of ozone air quality for all metrics from 2003 to 2010 and beyond;
- There is however an improvement in nitrogen dioxide air quality as annual mean concentrations fall, especially for the NO_x control measures;
- The use of population-weighted means focuses the analysis on ozone in urban areas. In addition to the role of NO_x emissions in photochemical ozone production, lower NO_x emissions reduce the chemical titration effect, most notably in urban areas. This causes ozone concentrations to move towards the higher concentrations in surrounding rural areas. <u>The reduced chemical titration is a major factor in the increase in the ozone metrics and the deterioration of ozone air quality</u>;

- A second major factor leading to higher ozone concentrations is changing atmospheric composition arising from climate change. In the absence of such a change, the base case runs would have shown an improvement in ozone air quality for some metrics (AOT40 – Crops and AOT40 – Forests);
- The NO_x control measures generally increase ozone concentrations, although there are instances for some of the measures that ozone air quality is improved in 2020, as evidenced by a lower value of the ozone metric;
- The VOC control measures, on the other hand, lead to an improvement in ozone air quality for all ozone metrics;
- Meteorological effects and year-to-year variability in meteorology can have a larger effect on ozone air quality than some of the emission control measures considered.

As a result of the above, there will be widespread exceedences of ozone air quality standards and objectives in 2010 and beyond.

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Appendices

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Appendix 1
Emission Control Measures Considered in the Review of the Air Quality Strategy

CONTENTS

Table A1.1: The Measures being Considered as Part of the Review of the Air Quality Strategy with the Measures modelled by the OSRM highlighted in Bold.

Measure	Description
A	**Introduction of Euro V/VI Standards (Low Intensity Scenario)**: 20% reduction in NO_x from all diesel LDV, 50% NO_x reduction from diesel HDV, DPFs on LDVs. Dates of introduction 2010 for LDVs and 2013 for HDVs. Durability at 100,000km.
B	**Revised version of Measure 2**
B*	**Introduction of Euro V/VI Standards (High Intensity Scenario)**: 50% reduction in NO_x for petrol LDVs from 2010, 40% reduction in NO_x from all diesel LDVs from 2010 and 68% reduction in Nox from all LDVs from 2015, 75% reduction in NOx from HDVs, DPFs on all diesel vehicles (HDVs + LDVs). Dates of introduction: 2010 for LDVs (and 2015 for tighter NO_x) and 2013 for HDVs. Durability 100,000km.
C	**Programme of incentives for early uptake of Euro V/VI Standards** LDVs from 2007, HDVs from 2010 - Euro V Low Scenario.
D	**Programme of incentives to phase out most polluting vehicles (e.g. pre-Euro)**. Two scenarios are analysed: Scenario A models scrappage of all pre-Euro 1 cars (emissions and concentrations modelling) and Scenario B models scrappage of pre-Euro 1 and Euro 1 cars (costs and emissions modelling only).
E	**Introduction of Low Emission Vehicles:** 37.5% reduction petrol LEVs relative to Euro IV; 80% reduction diesel LEVs relative to Euro IV
F	**All user road charging scheme** starting in 2015.
G	**Extend London Low Emission Zone to London + 7 largest urban areas** (based on result from London LEZ feasibility study) Scenario for London used: HDVs only in 2007 and HDVs + Vans in 2010. Scenario for other 7 urban areas: HDvs only in 2010 and HDVs + VANs in 2015. Use data from 2007 and 2010 for London in 2010 and 2015 for other 8 urban areas
H	**Retrofit of particulate traps to all LDVs and HDVs diesel vehicles by 2010**. Emission scenario only
I	**Domestic combustion**: 100% switch from coal to natural gas where available, oil where not (for NI only)
J	**Domestic Combustion**: Product standards for gas fired appliances that require tighter NO_x emission standards. New appliances post 2008 to at least CEN 483 Class 4 for gas fired appliances. Replacement rate 5% of the population per year that is 20 year lifespan of existing 'high NO_x' boilers.
K	**Industrial Combustion**: Coal and gas fired power stations (>300mW) low NO_x burners, combustion modifications, over-fire air and SCR by 2010. SCR at iron and steel combustion plant and oil refineries by 2010.
L	**Small Combustion Plant**: 20-50 MW 50% reduction in NO_2 and SO_2 emissions following 2008 SCPD. To be implemented in 2013.
M	**VOC Emission Control**: Petrol Stations Stage II Controls @ >3000 m^3 per year throughput, chemicals and man–made fibre production – thermal oxidation, chemicals and man–made fibre production – road tanker vapour recovery, offshore loading of crude oil – modification to shuttle tankers, chemicals and man–made fibre production – storage tank replacement programme, offshore loading of crude oil – modification to floating production storage and off-take vessels, chemicals and man–made fibre production – leak detection and repair, offshore loading of crude oil – vapour recovery unit (From ship loading) chemicals and man–made fibre production – second stage vapour recovery unit chemicals and man–made fibre production – cryogenic condensation.
N	**Shipping Measure through IMO** - requirements on global fleet for all ships > 100 tonnes to use - 1% rather than 1.5% S fuel from 2010 and to reduce NOx emissions by 25% from new ships; introduction rate of 1/30th per year
O	**Combined scenario for Transport** (Measures C and E)
P	**Combined scenario for Transport and Industrial Measures** (Measures C and L)
Q	**Combined scenario for Transport and Industrial Measures** (Measures C, E and L)
-	**Combined scenario for Transport and Industrial Measures** (Measures M and Q)

Appendix 2
Current and Projected UK Emissions

CONTENTS

In Tables A2-2 to A2-4, emission estimates by OSRM source sector are given for the following measures:

Measure	Description
A	Introduction of Euro V/VI Standards (Low Intensity Scenario)
B	Introduction of Euro V/VI Standards (High Intensity Scenario)
B*	Introduction of Euro V/VI Standards (High Intensity Scenario) (Earlier Version)
C	Programme of incentives for early uptake of Euro V/VI Standards (Low Intensity Scenario)
E	Introduction of Low Emission Vehicles
J	Domestic Combustion
K & L	Industrial Combustion and Small Combustion Plant
L	Small Combustion Plant
M	VOC Emission Control
O	Combined scenario for Transport (Measures C and E)
P	Combined scenario for Transport and Industrial Measures (Measures C and L)
Q	Combined scenario for Transport and Industrial Measures (Measures C, E and L)
-	Combined scenario for Transport and Industrial Measures (Measures M and Q)

More detailed information on the activity and emission assumptions for these measures can be found in Appendix 1.

Table A2-1: Emission Estimates (in kt per annum) for Sulphur Dioxide, Oxides of Nitrogen, Volatile Organic Compounds and Carbon Monoxide by OSRM Source Sector for Current Years and the Base Cases for the Ozone Modelling Runs Undertaken.

Pollutant	OSRM_Sector	Annual Emission Estimate (in ktonne per annum)							
		1999	2000	2001	2002	2003	2010	2015	2020
SO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	13.6	6.0	3.4	3.0	3.0	0.8	0.8	0.8
	Industrial Processes (1)	321.0	264.3	274.7	241.8	228.6	238.3	240.0	244.1
	Fossil Fuel Extraction and Distribution	1.2	1.1	0.6	0.6	0.6	0.3	0.3	0.3
	Domestic Combustion	78.3	61.8	63.2	50.3	36.4	11.5	9.1	14.8
	Major Point Sources	776.4	821.0	741.5	680.4	677.2	210.1	123.5	77.1
	Other	38.9	35.0	30.3	26.4	32.8	23.4	23.2	22.6
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1229.4**	**1189.2**	**1113.7**	**1002.5**	**978.6**	**484.4**	**396.9**	**359.7**
NO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	909.7	826.4	760.3	710.8	632.1	396.2	290.5	267.8
	Industrial Processes (1)	276.2	248.5	243.5	246.2	279.3	219.1	226.1	234.7
	Fossil Fuel Extraction and Distribution	1.2	0.7	0.7	0.7	0.7	0.5	0.5	0.5
	Domestic Combustion	105.1	103.8	106.7	101.6	138.6	96.7	100.6	105.0
	Major Point Sources	338.2	365.5	378.8	379.2	378.5	280.3	248.7	136.7
	Other	179.5	172.7	156.9	143.0	140.5	125.8	125.8	124.5
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1809.9**	**1717.6**	**1646.9**	**1581.5**	**1569.7**	**1118.6**	**992.2**	**869.2**
VOC	Solvent Usage	461.6	429.1	404.0	389.7	376.6	342.4	357.0	371.7
	Road Transport	369.7	300.1	248.6	211.0	159.6	71.7	56.2	54.2
	Industrial Processes (1)	224.8	218.4	195.1	184.4	186.8	195.7	203.9	213.0
	Fossil Fuel Extraction and Distribution	283.3	289.1	287.5	277.3	259.6	162.6	163.5	163.4
	Domestic Combustion	44.6	35.9	39.0	35.5	30.3	19.6	19.6	23.6
	Major Point Sources	8.0	8.5	8.5	8.9	6.7	10.2	10.3	11.0
	Other	87.2	82.8	82.1	78.8	68.8	46.0	46.2	46.3
	Natural	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0
	Total	**1657.2**	**1541.9**	**1442.8**	**1363.6**	**1266.4**	**1026.2**	**1034.7**	**1061.2**
CO	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	3034.9	2548.3	2182.9	1915.5	1703.3	633.8	422.5	392.5
	Industrial Processes (1)	714.2	621.3	660.0	574.7	652.2	603.9	616.6	629.6
	Fossil Fuel Extraction and Distribution	1.1	0.7	0.5	0.7	0.7	2.7	2.9	3.1
	Domestic Combustion	262.1	233.0	246.5	224.8	306.5	150.6	159.5	193.8
	Major Point Sources	60.5	69.5	71.7	71.0	70.9	79.2	79.0	79.3
	Other	457.9	455.5	474.6	451.1	443.2	457.8	461.9	465.6
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**4530.7**	**3928.3**	**3636.2**	**3237.8**	**3176.8**	**1928.0**	**1742.4**	**1763.9**

Table A2-2: Emission Estimates (in kt per annum) for Sulphur Dioxide, Oxides of Nitrogen, Volatile Organic Compounds and Carbon Monoxide by OSRM Source Sector for the Base Case and the Scenario Runs Undertaken for 2010.

Pollutant	OSRM_Sector	Annual Emission Estimate (in ktonne per annum)								
		Base Case	A	B	B*	C	E	J	K & L	L
SO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	Industrial Processes (1)	238.3	238.3	238.3	238.3	238.3	238.3	238.3	238.3	238.3
	Fossil Fuel Extraction and Distribution	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Domestic Combustion	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
	Major Point Sources	210.1	210.1	210.1	210.1	210.1	210.1	210.1	210.1	210.1
	Other	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**484.4**	**484.4**	**484.4**	**484.4**	**484.4**	**484.4**	**484.4**	**484.4**	**484.4**
NO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	396.2	393.6	387.2	387.2	385.4	394.6	396.2	396.2	396.2
	Industrial Processes (1)	219.1	219.1	219.1	219.1	219.1	219.1	219.1	219.1	219.1
	Fossil Fuel Extraction and Distribution	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Domestic Combustion	96.7	96.7	96.7	96.7	96.7	96.7	93.9	96.7	96.7
	Major Point Sources	280.3	280.3	280.3	280.3	280.3	280.3	280.3	85.8	280.3
	Other	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1118.6**	**1116.0**	**1109.6**	**1109.6**	**1107.8**	**1117.0**	**1115.8**	**924.1**	**1118.6**
VOC	Solvent Usage	342.4	342.4	342.4	342.4	342.4	342.4	342.4	342.4	342.4
	Road Transport	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7
	Industrial Processes (1)	195.7	195.7	195.7	195.7	195.7	195.7	195.7	195.7	195.7
	Fossil Fuel Extraction and Distribution	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6
	Domestic Combustion	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
	Major Point Sources	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
	Other	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0
	Natural	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0
	Total	**1026.2**	**1026.2**	**1026.2**	**1026.2**	**1026.2**	**1026.2**	**1026.2**	**1026.2**	**1026.2**
CO	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	633.8	633.8	633.8	633.8	633.8	633.8	633.8	633.8	633.8
	Industrial Processes (1)	603.9	603.9	603.9	603.9	603.9	603.9	603.9	603.9	603.9
	Fossil Fuel Extraction and Distribution	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	Domestic Combustion	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6
	Major Point Sources	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Other	457.8	457.8	457.8	457.8	457.8	457.8	457.8	457.8	457.8
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1928.0**	**1928.0**	**1928.0**	**1928.0**	**1928.0**	**1928.0**	**1928.0**	**1928.0**	**1928.0**

Table A2-2: Emission Estimates (in kt per annum) for Sulphur Dioxide, Oxides of Nitrogen, Volatile Organic Compounds and Carbon Monoxide by OSRM Source Sector for the Base Case and the Scenario Runs Undertaken for 2010 (Continued).

Pollutant	OSRM_Sector	Annual Emission Estimate (in ktonne per annum)					
		Base Case	**M**	**O**	**P**	**Q**	**M & Q**
SO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	0.8	0.8	0.8	0.8	0.8	0.8
	Industrial Processes (1)	238.3	238.3	238.3	238.3	238.3	238.3
	Fossil Fuel Extraction and Distribution	0.3	0.3	0.3	0.3	0.3	0.3
	Domestic Combustion	11.5	11.5	11.5	11.5	11.5	11.5
	Major Point Sources	210.1	210.1	210.1	210.1	210.1	210.1
	Other	23.4	23.4	23.4	23.4	23.4	23.4
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**484.4**	**484.4**	**484.4**	**484.4**	**484.4**	**484.4**
NO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	396.2	396.2	384.0	385.4	384.0	384.0
	Industrial Processes (1)	219.1	219.1	219.1	219.1	219.1	219.1
	Fossil Fuel Extraction and Distribution	0.5	0.5	0.5	0.5	0.5	0.5
	Domestic Combustion	96.7	96.7	96.7	96.7	96.7	96.7
	Major Point Sources	280.3	280.3	280.3	280.3	280.3	280.3
	Other	125.8	125.8	125.8	125.8	125.8	125.8
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1118.6**	**1118.6**	**1106.4**	**1107.8**	**1106.4**	**1106.4**
VOC	Solvent Usage	342.4	342.4	342.4	342.4	342.4	342.4
	Road Transport	71.7	71.7	71.7	71.7	71.7	71.7
	Industrial Processes (1)	195.7	179.6	195.7	195.7	195.7	179.6
	Fossil Fuel Extraction and Distribution	162.6	104.6	162.6	162.6	162.6	104.6
	Domestic Combustion	19.6	19.6	19.6	19.6	19.6	19.6
	Major Point Sources	10.2	10.2	10.2	10.2	10.2	10.2
	Other	46.0	46.0	46.0	46.0	46.0	46.0
	Natural	178.0	178.0	178.0	178.0	178.0	178.0
	Total	**1026.2**	**952.1**	**1026.2**	**1026.2**	**1026.2**	**952.1**
CO	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	633.8	633.8	633.8	633.8	633.8	633.8
	Industrial Processes (1)	603.9	603.9	603.9	603.9	603.9	603.9
	Fossil Fuel Extraction and Distribution	2.7	2.7	2.7	2.7	2.7	2.7
	Domestic Combustion	150.6	150.6	150.6	150.6	150.6	150.6
	Major Point Sources	79.2	79.2	79.2	79.2	79.2	79.2
	Other	457.8	457.8	457.8	457.8	457.8	457.8
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1928.0**	**1928.0**	**1928.0**	**1928.0**	**1928.0**	**1928.0**

Table A2-3: Emission Estimates (in kt per annum) for Sulphur Dioxide, Oxides of Nitrogen, Volatile Organic Compounds and Carbon Monoxide by OSRM Source Sector for the Base Case and the Scenario Runs Undertaken for 2015.

Pollutant	OSRM_Sector	Annual Emission Estimate (in ktonne per annum)								
		Base Case	A	B	B*	C	E	J	K & L	L
SO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	Industrial Processes (1)	240.0	240.0	240.0	240.0	240.0	240.0	240.0	233.7	233.7
	Fossil Fuel Extraction and Distribution	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Domestic Combustion	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
	Major Point Sources	123.5	123.5	123.5	123.5	123.5	123.5	123.5	123.5	123.5
	Other	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**396.9**	**396.9**	**396.9**	**396.9**	**396.9**	**396.9**	**396.9**	**390.6**	**390.6**
NO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	290.5	256.7	212.5	210.0	244.9	285.0	290.5	290.5	290.5
	Industrial Processes (1)	226.1	226.1	226.1	226.1	226.1	226.1	226.1	210.5	210.5
	Fossil Fuel Extraction and Distribution	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Domestic Combustion	100.6	100.6	100.6	100.6	100.6	100.6	92.9	100.6	100.6
	Major Point Sources	248.7	248.7	248.7	248.7	248.7	248.7	248.7	68.1	248.7
	Other	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**992.2**	**958.4**	**914.2**	**911.7**	**946.6**	**986.7**	**984.5**	**796.0**	**976.6**
VOC	Solvent Usage	357.0	357.0	357.0	357.0	357.0	357.0	357.0	357.0	357.0
	Road Transport	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2
	Industrial Processes (1)	203.9	203.9	203.9	203.9	203.9	203.9	203.9	203.9	203.9
	Fossil Fuel Extraction and Distribution	163.5	163.5	163.5	163.5	163.5	163.5	163.5	163.5	163.5
	Domestic Combustion	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
	Major Point Sources	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
	Other	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2
	Natural	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0
	Total	**1034.7**	**1034.7**	**1034.7**	**1034.7**	**1034.7**	**1034.7**	**1034.7**	**1034.7**	**1034.7**
CO	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	422.5	422.5	422.5	422.5	422.5	422.5	422.5	422.5	422.5
	Industrial Processes (1)	616.6	616.6	616.6	616.6	616.6	616.6	616.6	616.6	616.6
	Fossil Fuel Extraction and Distribution	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	Domestic Combustion	159.5	159.5	159.5	159.5	159.5	159.5	159.5	159.5	159.5
	Major Point Sources	79.0	79.0	79.0	79.0	79.0	79.0	79.0	79.0	79.0
	Other	461.9	461.9	461.9	461.9	461.9	461.9	461.9	461.9	461.9
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1742.4**	**1742.4**	**1742.4**	**1742.4**	**1742.4**	**1742.4**	**1742.4**	**1742.4**	**1742.4**

Table A2-3: Emission Estimates (in kt per annum) for Sulphur Dioxide, Oxides of Nitrogen, Volatile Organic Compounds and Carbon Monoxide by OSRM Source Sector for the Base Case and the Scenario Runs Undertaken for 2015 (Continued).

Pollutant	OSRM_Sector	Annual Emission Estimate (in ktonne per annum)					
		Base Case	M	O	P	Q	M & Q
SO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	0.8	0.8	0.8	0.8	0.8	0.8
	Industrial Processes (1)	240.0	240.0	240.0	233.7	233.7	233.7
	Fossil Fuel Extraction and Distribution	0.3	0.3	0.3	0.3	0.3	0.3
	Domestic Combustion	9.1	9.1	9.1	9.1	9.1	9.1
	Major Point Sources	123.5	123.5	123.5	123.5	123.5	123.5
	Other	23.2	23.2	23.2	23.2	23.2	23.2
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**396.9**	**396.9**	**396.9**	**390.6**	**390.6**	**390.6**
NO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	290.5	290.5	240.2	244.9	240.2	240.2
	Industrial Processes (1)	226.1	226.1	226.1	210.5	210.5	210.5
	Fossil Fuel Extraction and Distribution	0.5	0.5	0.5	0.5	0.5	0.5
	Domestic Combustion	100.6	100.6	100.6	100.6	100.6	100.6
	Major Point Sources	248.7	248.7	248.7	248.7	248.7	248.7
	Other	125.8	125.8	125.8	125.8	125.8	125.8
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**992.2**	**992.2**	**941.9**	**931.0**	**926.3**	**926.3**
VOC	Solvent Usage	357.0	357.0	357.0	357.0	357.0	357.0
	Road Transport	56.2	56.2	56.2	56.2	56.2	56.2
	Industrial Processes (1)	203.9	185.7	203.9	203.9	203.9	185.7
	Fossil Fuel Extraction and Distribution	163.5	105.4	163.5	163.5	163.5	105.4
	Domestic Combustion	19.6	19.6	19.6	19.6	19.6	19.6
	Major Point Sources	10.3	10.3	10.3	10.3	10.3	10.3
	Other	46.2	46.2	46.2	46.2	46.2	46.2
	Natural	178.0	178.0	178.0	178.0	178.0	178.0
	Total	**1034.7**	**958.4**	**1034.7**	**1034.7**	**1034.7**	**958.4**
CO	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	422.5	422.5	422.5	422.5	422.5	422.5
	Industrial Processes (1)	616.6	616.6	616.6	616.6	616.6	616.6
	Fossil Fuel Extraction and Distribution	2.9	2.9	2.9	2.9	2.9	2.9
	Domestic Combustion	159.5	159.5	159.5	159.5	159.5	159.5
	Major Point Sources	79.0	79.0	79.0	79.0	79.0	79.0
	Other	461.9	461.9	461.9	461.9	461.9	461.9
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1742.4**	**1742.4**	**1742.4**	**1742.4**	**1742.4**	**1742.4**

Table A2-4: Emission Estimates (in kt per annum) for Sulphur Dioxide, Oxides of Nitrogen, Volatile Organic Compounds and Carbon Monoxide by OSRM Source Sector for the Base Case and the Scenario Runs Undertaken for 2020.

Pollutant	OSRM_Sector	Annual Emission Estimate (in ktonne per annum)								
		Base Case	A	B	B*	C	E	J	K & L	L
SO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	Industrial Processes (1)	244.1	244.1	244.1	244.1	244.1	244.1	244.1	237.8	237.8
	Fossil Fuel Extraction and Distribution	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Domestic Combustion	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
	Major Point Sources	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1
	Other	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**359.7**	**359.7**	**359.7**	**359.7**	**359.7**	**359.7**	**359.7**	**353.4**	**353.4**
NO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	267.8	202.4	126.5	111.4	198.1	256.6	267.8	267.8	267.8
	Industrial Processes (1)	234.7	234.7	234.7	234.7	234.7	234.7	234.7	218.4	218.4
	Fossil Fuel Extraction and Distribution	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Domestic Combustion	105.0	105.0	105.0	105.0	105.0	105.0	92.1	105.0	105.0
	Major Point Sources	136.7	136.7	136.7	136.7	136.7	136.7	136.7	68.7	136.7
	Other	124.5	124.5	124.5	124.5	124.5	124.5	124.5	124.5	124.5
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**869.2**	**803.8**	**727.9**	**712.8**	**799.5**	**858.0**	**856.3**	**784.9**	**852.9**
VOC	Solvent Usage	371.7	371.7	371.7	371.7	371.7	371.7	371.7	371.7	371.7
	Road Transport	54.2	54.2	54.2	54.2	54.2	54.2	54.2	54.2	54.2
	Industrial Processes (1)	213.0	213.0	213.0	213.0	213.0	213.0	213.0	213.0	213.0
	Fossil Fuel Extraction and Distribution	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4	163.4
	Domestic Combustion	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6
	Major Point Sources	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
	Other	46.3	46.3	46.3	46.3	46.3	46.3	46.3	46.3	46.3
	Natural	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0
	Total	**1061.2**	**1061.2**	**1061.2**	**1061.2**	**1061.2**	**1061.2**	**1061.2**	**1061.2**	**1061.2**
CO	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	392.5	392.5	392.5	392.5	392.5	392.5	392.5	392.5	392.5
	Industrial Processes (1)	629.6	629.6	629.6	629.6	629.6	629.6	629.6	629.6	629.6
	Fossil Fuel Extraction and Distribution	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	Domestic Combustion	193.8	193.8	193.8	193.8	193.8	193.8	193.8	193.8	193.8
	Major Point Sources	79.3	79.3	79.3	79.3	79.3	79.3	79.3	79.3	79.3
	Other	465.6	465.6	465.6	465.6	465.6	465.6	465.6	465.6	465.6
	Natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1763.9**	**1763.9**	**1763.9**	**1763.9**	**1763.9**	**1763.9**	**1763.9**	**1763.9**	**1763.9**

Table A2-2: Emission Estimates (in kt per annum) for Sulphur Dioxide, Oxides of Nitrogen, Volatile Organic Compounds and Carbon Monoxide by OSRM Source Sector for the Base Case and the Scenario Runs Undertaken for 2020 (Continued).

Pollutant	OSRM_Sector	Annual Emission Estimate (in ktonne per annum)					
		Base Case	**M**	**O**	**P**	**Q**	**M & Q**
SO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	0.8	0.8	0.8	0.8	0.8	0.8
	Industrial Processes (1)	244.1	244.1	244.1	237.8	237.8	237.8
	Fossil Fuel Extraction and Distribution	0.3	0.3	0.3	0.3	0.3	0.3
	Domestic Combustion	14.8	14.8	14.8	14.8	14.8	14.8
	Major Point Sources	77.1	77.1	77.1	77.1	77.1	77.1
	Other	22.6	22.6	22.6	22.6	22.6	22.6
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**359.7**	**359.7**	**359.7**	**353.4**	**353.4**	**353.4**
NO_x	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	267.8	267.8	188.8	198.1	188.8	188.8
	Industrial Processes (1)	234.7	234.7	234.7	218.4	218.4	218.4
	Fossil Fuel Extraction and Distribution	0.5	0.5	0.5	0.5	0.5	0.5
	Domestic Combustion	105.0	105.0	105.0	105.0	105.0	105.0
	Major Point Sources	136.7	136.7	136.7	136.7	136.7	136.7
	Other	124.5	124.5	124.5	124.5	124.5	124.5
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**869.2**	**869.2**	**790.2**	**783.2**	**773.9**	**773.9**
VOC	Solvent Usage	371.7	371.7	371.7	371.7	371.7	371.7
	Road Transport	54.2	54.2	54.2	54.2	54.2	54.2
	Industrial Processes (1)	213.0	192.5	213.0	213.0	213.0	192.5
	Fossil Fuel Extraction and Distribution	163.4	105.6	163.4	163.4	163.4	105.6
	Domestic Combustion	23.6	23.6	23.6	23.6	23.6	23.6
	Major Point Sources	11.0	11.0	11.0	11.0	11.0	11.0
	Other	46.3	46.3	46.3	46.3	46.3	46.3
	Natural	178.0	178.0	178.0	178.0	178.0	178.0
	Total	**1061.2**	**982.9**	**1061.2**	**1061.2**	**1061.2**	**982.9**
CO	Solvent Usage	0.0	0.0	0.0	0.0	0.0	0.0
	Road Transport	392.5	392.5	392.5	392.5	392.5	392.5
	Industrial Processes (1)	629.6	629.6	629.6	629.6	629.6	629.6
	Fossil Fuel Extraction and Distribution	3.1	3.1	3.1	3.1	3.1	3.1
	Domestic Combustion	193.8	193.8	193.8	193.8	193.8	193.8
	Major Point Sources	79.3	79.3	79.3	79.3	79.3	79.3
	Other	465.6	465.6	465.6	465.6	465.6	465.6
	Natural	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**1763.9**	**1763.9**	**1763.9**	**1763.9**	**1763.9**	**1763.9**

Appendix 3
Current and Projected European Emissions

CONTENTS

Table A3-1: National Emission Estimates (in kt per annum) for Sulphur Oxides for 2002 and the Projected Emissions for 2010, 2015 and 2020 (a) assuming Compliance with the National Emission Ceilings Directive or Gothenburg Protocol (2010-NECD) and (b) using the IIASA NAT_CLE_Aug04 (Nov04) Scenario Developed for the Clean Air for Europe Programme (2010/2015/2020-CAFÉ).

Country	SO_x Annual Emissions (in ktonne per annum)				
	2002	2010-NECD	2010-CAFE	2015-CAFÉ	2020-CAFE
Albania	58.0	30.0	30.0	30.5	31.0
Armenia	7.5	73.0	4.0	4.0	4.0
Austria	36.0	39.0	29.5	27.7	26.4
Azerbaijan	15.0	15.0	15.0	15.0	15.0
Belarus	143.0	480.0	350.0	323.0	296.0
Belgium	153.0	99.0	116.7	111.6	111.2
Bosnia and Herzegovina	419.0	411.0	411.0	395.5	380.0
Bulgaria	940.0	856.0	979.0	903.5	828.0
Croatia	58.0	70.0	69.0	67.0	65.0
Cyprus	51.0	18.0	14.4	14.9	7.9
Czech Republic	237.0	283.0	152.6	107.0	84.4
Denmark	25.0	55.0	32.4	28.8	30.1
Estonia	88.0	44.0	42.9	13.1	9.8
Finland	82.0	110.0	72.6	72.4	76.5
France	537.0	375.0	366.8	384.6	361.9
Georgia	6.0	9.0	9.0	9.0	9.0
Germany	611.0	520.0	387.3	348.7	332.2
Greece	485.0	523.0	151.6	134.1	109.7
Hungary	359.0	550.0	240.0	103.1	87.7
Iceland	27.0	29.0	29.0	29.0	29.0
Ireland	96.0	42.0	29.3	23.6	18.7
Italy	709.0	475.0	419.0	405.1	345.8
Kazakhstan	237.0	237.0	237.0	237.0	237.0
Latvia	12.0	107.0	10.3	9.2	7.6
Liechtenstein	-	0.1	0.0	0.0	0.0
Lithuania	43.0	145.0	36.5	26.3	21.7
Luxembourg	3.0	4.0	2.2	2.1	2.1
Malta	-	0.0	8.6	10.2	2.2
Netherlands	71.0	50.0	58.6	61.1	64.1
Norway	22.0	22.0	20.5	20.1	18.0
Poland	1564.0	1397.0	927.2	714.2	553.8
Portugal	205.0	160.0	102.0	89.5	79.5
Republic of Moldova	15.0	135.0	117.0	109.5	102.0
Romania	912.0	918.0	669.0	537.0	405.0
Russian Federation	2130.0	2470.0	2470.0	2244.5	2019.0
Serbia and Montenegro	382.0	277.0	277.0	222.5	168.0
Slovakia	102.0	110.0	48.7	38.1	32.9
Slovenia	71.0	27.0	20.9	16.6	16.5
Spain	1507.0	746.0	403.2	368.3	335.0
Sweden	58.0	67.0	57.6	60.0	62.4
Switzerland	19.0	26.0	16.0	14.5	13.4
TFYR of Macedonia	166.0	82.0	82.0	77.0	72.0
Turkey	2112.0	1821.0	1821.0	1821.0	1821.0
Ukraine	1329.0	1457.0	1146.0	994.0	842.0
United Kingdom	1002.0	585.0	525.3	529.1	274.6
North Africa	413.0	413.0	413.0	413.0	413.0
Remaining Asiatic areas	854.0	854.0	854.0	854.0	854.0
Baltic Sea	228.0	228.0	228.0	228.0	228.0
Black Sea	57.0	57.0	57.0	57.0	57.0
Mediterranean Sea	1189.0	1189.0	1189.0	1189.0	1189.0
North Sea	454.0	454.0	454.0	454.0	454.0
Remaining N-E Atlantic Ocean	901.0	901.0	901.0	901.0	901.0
Natural marine emissions	743.0	743.0	743.0	743.0	743.0
Volcanic emissions	2000.0	2000.0	2000.0	2000.0	2000.0

Table A3-2: National Emission Estimates (in kt per annum) for Oxides of Nitrogen for 2002 and the Projected Emissions for 2010, 2015 and 2020 (a) assuming Compliance with the National Emission Ceilings Directive or Gothenburg Protocol (2010-NECD) and (b) using the IIASA NAT_CLE_Aug04 (Nov04) Scenario Developed for the Clean Air for Europe Programme (2010/2015/2020-CAFÉ).

Country	NO_x Annual Emissions (in ktonne per annum)				
	2002	2010-NECD	2010-CAFE	2015-CAFÉ	2020-CAFE
Albania	29.0	27.0	27.0	30.5	34.0
Armenia	13.0	46.0	13.0	13.0	13.0
Austria	204.0	103.0	156.6	136.5	127.3
Azerbaijan	43.0	43.0	43.0	43.0	43.0
Belarus	137.0	255.0	266.0	275.5	285.0
Belgium	284.0	176.0	253.8	240.5	219.0
Bosnia and Herzegovina	55.0	53.0	53.0	54.5	56.0
Bulgaria	188.0	266.0	141.0	123.0	105.0
Croatia	77.0	87.0	91.0	96.0	101.0
Cyprus	22.0	22.0	19.5	18.3	18.4
Czech Republic	318.0	286.0	227.2	193.1	162.4
Denmark	200.0	127.0	175.4	145.1	121.8
Estonia	40.0	28.0	28.0	19.2	14.6
Finland	208.0	170.0	152.0	136.9	123.5
France	1352.0	810.0	1092.1	947.8	901.5
Georgia	44.0	30.0	30.0	30.0	30.0
Germany	1499.0	1051.0	1071.2	861.4	807.9
Greece	331.0	344.0	256.8	229.1	209.4
Hungary	180.0	198.0	131.3	98.7	83.5
Iceland	28.0	30.0	30.0	30.0	30.0
Ireland	125.0	65.0	93.5	76.3	63.0
Italy	1317.0	990.0	1031.2	915.2	754.8
Kazakhstan	50.0	50.0	50.0	50.0	50.0
Latvia	41.0	84.0	30.7	20.9	15.2
Liechtenstein	-	0.4	0.0	0.0	0.0
Lithuania	51.0	110.0	43.7	33.6	26.9
Luxembourg	17.0	11.0	25.1	18.6	17.8
Malta	-	0.0	4.9	3.8	3.5
Netherlands	406.0	260.0	281.9	246.0	239.6
Norway	213.0	156.0	192.1	172.9	165.9
Poland	805.0	879.0	567.3	480.5	364.4
Portugal	265.0	250.0	226.2	193.7	163.5
Republic of Moldova	25.0	90.0	62.0	61.0	60.0
Romania	319.0	437.0	269.0	231.0	193.0
Russian Federation	2566.0	2500.0	2500.0	2641.0	2782.0
Serbia and Montenegro	158.0	168.0	168.0	170.5	173.0
Slovakia	102.0	130.0	69.8	62.6	60.4
Slovenia	58.0	45.0	44.2	35.7	34.0
Spain	1339.0	847.0	964.0	815.1	681.2
Sweden	242.0	148.0	182.3	161.0	152.3
Switzerland	94.0	79.0	70.6	58.6	54.7
TFYR of Macedonia	37.0	37.0	37.0	38.5	40.0
Turkey	951.0	2044.0	2044.0	1497.5	951.0
Ukraine	587.0	1222.0	587.0	587.5	588.0
United Kingdom	1582.0	1167.0	1133.2	995.4	831.4
North Africa	96.0	96.0	96.0	96.0	96.0
Remaining Asiatic areas	169.0	169.0	169.0	169.0	169.0
Baltic Sea	352.0	352.0	352.0	352.0	352.0
Black Sea	86.0	86.0	86.0	86.0	86.0
Mediterranean Sea	1639.0	1639.0	1639.0	1639.0	1639.0
North Sea	648.0	648.0	648.0	648.0	648.0
Remaining N-E Atlantic Ocean	1266.0	1266.0	1266.0	1266.0	1266.0
Natural marine emissions	0.0	0.0	0.0	0.0	0.0
Volcanic emissions	0.0	0.0	0.0	0.0	0.0

Table A3-3: National Emission Estimates (in kt per annum) for Volatile Organic Compounds for 2002 and the Projected Emissions for 2010, 2015 and 2020 (a) assuming Compliance with the National Emission Ceilings Directive or Gothenburg Protocol (2010-NECD) and (b) using the IIASA NAT_CLE_Aug04 (Nov04) Scenario Developed for the Clean Air for Europe Programme (2010/2015/2020-CAFÉ).

Country	NO_x Annual Emissions (in ktonne per annum)				
	2002	2010-NECD	2010-CAFE	2015-CAFÉ	2020-CAFE
Albania	34.0	35.0	35.0	37.5	40.0
Armenia	14.0	81.0	28.0	28.0	28.0
Austria	193.0	159.0	151.9	143.3	138.4
Azerbaijan	9.0	9.0	9.0	9.0	9.0
Belarus	229.0	309.0	250.0	254.0	258.0
Belgium	264.0	139.0	150.7	149.6	149.0
Bosnia and Herzegovina	42.0	44.0	44.0	47.5	51.0
Bulgaria	123.0	185.0	118.0	104.0	90.0
Croatia	80.0	90.0	104.0	105.5	107.0
Cyprus	16.0	3.0	6.3	6.1	6.1
Czech Republic	203.0	220.0	162.4	144.9	131.2
Denmark	124.0	85.0	75.5	64.6	60.6
Estonia	38.0	34.0	25.4	19.3	17.0
Finland	151.0	130.0	105.5	90.1	79.8
France	1542.0	1050.0	1055.0	981.8	972.8
Georgia	29.0	19.0	19.0	19.0	19.0
Germany	1478.0	995.0	1080.7	896.7	809.3
Greece	268.0	261.0	167.3	150.3	144.0
Hungary	155.0	137.0	109.9	98.8	89.7
Iceland	10.0	7.0	7.0	7.0	7.0
Ireland	81.0	55.0	54.0	49.1	46.4
Italy	1467.0	1159.0	1008.4	854.8	766.4
Kazakhstan	50.0	50.0	50.0	50.0	50.0
Latvia	89.0	136.0	40.7	31.6	27.9
Liechtenstein	-	0.9	0.0	0.0	0.0
Lithuania	72.0	92.0	56.2	47.6	42.9
Luxembourg	15.0	9.0	8.2	7.7	7.7
Malta	-	0.0	2.1	2.1	1.9
Netherlands	243.0	185.0	209.8	204.1	202.8
Norway	345.0	195.0	122.2	97.6	82.3
Poland	576.0	800.0	416.3	357.6	319.6
Portugal	271.0	180.0	177.8	158.6	155.1
Republic of Moldova	28.0	100.0	38.0	38.0	38.0
Romania	638.0	523.0	369.0	328.0	287.0
Russian Federation	2777.0	2643.0	2643.0	2779.0	2915.0
Serbia and Montenegro	129.0	140.0	140.0	142.0	144.0
Slovakia	87.0	140.0	66.0	63.4	64.5
Slovenia	49.0	40.0	27.6	23.1	21.8
Spain	1459.0	662.0	783.3	723.0	691.7
Sweden	295.0	241.0	218.3	198.2	185.8
Switzerland	143.0	144.0	97.3	90.4	87.7
TFYR of Macedonia	17.0	31.0	31.0	33.5	36.0
Turkey	726.0	1935.0	1935.0	1330.5	726.0
Ukraine	282.0	797.0	282.0	282.0	282.0
United Kingdom	1186.0	1200.0	926.2	870.0	850.7
North Africa	96.0	96.0	96.0	96.0	96.0
Remaining Asiatic areas	204.0	204.0	204.0	204.0	204.0
Baltic Sea	8.0	8.0	8.0	8.0	8.0
Black Sea	2.0	2.0	2.0	2.0	2.0
Mediterranean Sea	34.0	34.0	34.0	34.0	34.0
North Sea	15.0	15.0	15.0	15.0	15.0
Remaining N-E Atlantic Ocean	25.0	25.0	25.0	25.0	25.0
Natural marine emissions	0.0	0.0	0.0	0.0	0.0
Volcanic emissions	0.0	0.0	0.0	0.0	0.0

Table A3-4: National Emission Estimates (in kt per annum) for Carbon Monoxide for 2002 and the Projected Emissions for 2010, 2015 and 2020 (a) assuming Compliance with the National Emission Ceilings Directive or Gothenburg Protocol (2010-NECD) and (b) using the IIASA NAT_CLE_Aug04 (Nov04) Scenario Developed for the Clean Air for Europe Programme (2010/2015/2020-CAFÉ).

Country	NO_x Annual Emissions (in ktonne per annum)				
	2002	2010-NECD	2010-CAFE	2015-CAFÉ	2020-CAFE
Albania	102.0	160.0	160.0	178.0	196.0
Armenia	106.0	104.0	104.0	104.0	104.0
Austria	812.0	727.0	727.0	711.0	695.0
Azerbaijan	293.0	293.0	293.0	293.0	293.0
Belarus	712.0	837.0	837.0	894.0	951.0
Belgium	1019.0	306.0	306.0	296.0	286.0
Bosnia and Herzegovina	193.0	160.0	160.0	181.5	203.0
Bulgaria	619.0	568.0	568.0	480.5	393.0
Croatia	402.0	480.0	480.0	497.0	514.0
Cyprus	83.0	85.0	85.0	85.0	85.0
Czech Republic	546.0	475.0	475.0	456.5	438.0
Denmark	577.0	358.0	358.0	333.5	309.0
Estonia	178.0	126.0	126.0	115.5	105.0
Finland	600.0	644.0	644.0	623.0	602.0
France	5954.0	4795.0	4795.0	4685.5	4576.0
Georgia	218.0	222.0	222.0	222.0	222.0
Germany	4311.0	1036.0	1036.0	1001.5	967.0
Greece	1366.0	1240.0	1240.0	1180.0	1120.0
Hungary	620.0	492.0	492.0	489.5	487.0
Iceland	40.0	19.0	19.0	19.0	19.0
Ireland	254.0	204.0	204.0	198.0	192.0
Italy	4965.0	365.0	365.0	337.0	309.0
Kazakhstan	279.0	279.0	279.0	279.0	279.0
Latvia	378.0	185.0	185.0	159.0	133.0
Liechtenstein	-	0.0	0.0	0.0	0.0
Lithuania	224.0	228.0	228.0	191.5	155.0
Luxembourg	49.0	42.0	42.0	39.5	37.0
Malta	-	0.0	0.0	0.0	0.0
Netherlands	653.0	622.0	622.0	650.0	678.0
Norway	530.0	1552.0	1552.0	1547.0	1542.0
Poland	3528.0	2863.0	2863.0	2965.5	3068.0
Portugal	644.0	1794.0	1794.0	1802.0	1810.0
Republic of Moldova	107.0	192.0	192.0	195.5	199.0
Romania	2325.0	1034.0	1034.0	939.5	845.0
Russian Federation	11517.0	9805.0	9805.0	8864.5	7924.0
Serbia and Montenegro	553.0	573.0	573.0	606.0	639.0
Slovakia	297.0	240.0	240.0	235.5	231.0
Slovenia	89.0	199.0	199.0	201.0	203.0
Spain	2623.0	3362.0	3362.0	3269.0	3176.0
Sweden	766.0	624.0	624.0	611.0	598.0
Switzerland	383.0	346.0	346.0	338.5	331.0
TFYR of Macedonia	81.0	214.0	214.0	231.0	248.0
Turkey	3778.0	3778.0	3778.0	3778.0	3778.0
Ukraine	2780.0	3055.0	3055.0	3439.5	3824.0
United Kingdom	3238.0	1924.0	1924.0	1867.0	1810.0
North Africa	336.0	336.0	336.0	336.0	336.0
Remaining Asiatic areas	449.0	131.0	131.0	131.0	131.0
Baltic Sea	29.0	15.0	15.0	15.0	15.0
Black Sea	8.0	8.0	8.0	8.0	8.0
Mediterranean Sea	139.0	3.0	3.0	3.0	3.0
North Sea	59.0	91.0	91.0	91.0	91.0
Remaining N-E Atlantic Ocean	111.0	133.0	133.0	133.0	133.0
Natural marine emissions	0.0	0.0	0.0	0.0	0.0
Volcanic emissions	0.0	0.0	0.0	0.0	0.0

Appendix 4
Population or Area-weighted Means of the Selected O_3 and NO_2 Metrics

CONTENTS

Table A4-1: Summary of the Population-Weighted Annual Means of Daily Maximum Running 8 Hourly Ozone Concentration (in $\mu g\ m^{-3}$) for the OSRM Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	Population-Weighted Annual Means of Daily Maximum Running 8 Hourly Ozone Concentration (in $\mu g\ m^{-3}$)						
	All UK	**Scotland**	**Wales**	**Northern Ireland**	**Inner London**	**Outer London**	**Rest of England**
1999 - Current Year	67.77	73.48	76.77	77.62	58.40	59.43	67.58
2000 - Current Year	67.86	73.95	76.89	79.06	59.95	60.50	67.37
2001 - Current Year	63.62	68.70	72.03	71.56	55.93	56.88	63.34
2002 - Current Year	63.62	68.01	70.57	70.97	57.71	58.22	63.28
2003 - Current Year	65.14	69.79	73.21	73.96	58.52	59.13	64.75
2010 - Base Case (NECD)	70.32	73.17	77.09	76.54	65.73	65.98	70.02
2010 - Base Case (CAFÉ)	69.96	73.03	76.73	76.42	65.30	65.51	69.65
2010 - Base Case (CAFÉ) – Current Composition	68.02	71.35	74.76	74.72	63.30	63.51	67.67
2015 - Base Case (NECD)	72.76	74.96	79.18	78.06	68.66	68.91	72.53
2015 - Base Case (CAFÉ)	72.58	74.85	79.01	77.96	68.40	68.62	72.34
2020 - Base Case (NECD)	74.88	76.61	81.28	79.54	70.83	71.10	74.71
2020 - Base Case (CAFÉ)	74.72	76.46	81.16	79.39	70.62	70.88	74.57
2020 - Base Case (CAFÉ) – Current Composition	70.16	72.56	76.51	75.49	65.85	66.13	69.93
2010 - Base Case	**69.96**	**73.03**	**76.73**	**76.42**	**65.30**	**65.51**	**69.65**
2010 - Measure A	70.00	73.04	76.76	76.43	65.35	65.56	69.69
2010 - Measure B	70.07	73.08	76.81	76.46	65.46	65.67	69.77
2010 - Measure B*	70.07	73.08	76.81	76.46	65.46	65.67	69.77
2010 - Measure C	70.08	73.09	76.81	76.46	65.48	65.68	69.77
2010 - Measure E	69.98	73.04	76.74	76.43	65.32	65.53	69.66
2010 - Measure J	70.00	73.05	76.75	76.44	65.39	65.58	69.68
2010 - Measures K & L	70.95	73.68	77.75	76.87	66.23	66.41	70.71
2010 - Measure L	69.96	73.03	76.73	76.42	65.30	65.51	69.65
2010 - Measure O	70.10	73.10	76.82	76.47	65.50	65.71	69.79
2010 - Measure P	70.08	73.09	76.81	76.46	65.48	65.68	69.77
2010 - Measure Q	70.10	73.10	76.82	76.47	65.50	65.71	69.79
2010 - Measures M & Q	70.07	73.08	76.79	76.45	65.48	65.69	69.77
2010 - Measure M	69.94	73.00	76.71	76.40	65.27	65.49	69.62
Sensitivity to Meteorology							
2010 - Base Case	69.96	73.03	76.73	76.42	65.30	65.51	69.65
2010 - Measure B*	70.07	73.08	76.81	76.46	65.46	65.67	69.77
2010 - Measure B* with 2000 meteorology	74.05	76.78	80.93	81.19	69.58	69.94	73.70
2010 - Measure B* with 2002 meteorology	68.73	70.74	74.10	73.15	64.99	65.35	68.54
2010 - Measure M	69.94	73.00	76.71	76.40	65.27	65.49	69.62
2010 - Measure M with 2000 meteorology	73.88	76.69	80.83	81.15	69.29	69.66	73.52
2010 - Measure M with 2002 meteorology	68.54	70.66	73.99	73.10	64.70	65.07	68.35

Table A4-1: Summary of the Population-Weighted Annual Means of Daily Maximum Running 8 Hourly Ozone Concentration (in $\mu g\ m^{-3}$) for the OSRM Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Population-Weighted Annual Means of Daily Maximum Running 8 Hourly Ozone Concentration (in $\mu g\ m^{-3}$)						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
2015 - Base Case	**72.58**	**74.85**	**79.01**	**77.96**	**68.40**	**68.62**	**72.34**
2015 - Measure A	73.01	75.05	79.29	78.05	69.04	69.26	72.79
2015 - Measure B	73.57	75.29	79.63	78.16	69.88	70.11	73.37
2015 - Measure B*	73.60	75.30	79.64	78.16	69.93	70.16	73.40
2015 - Measure C	73.14	75.12	79.37	78.10	69.23	69.45	72.92
2015 - Measure E	72.63	74.89	79.05	77.98	68.48	68.71	72.40
2015 - Measure J	72.68	74.93	79.06	78.00	68.65	68.81	72.43
2015 - Measures K & L	73.62	75.51	80.07	78.40	69.47	69.64	73.45
2015 - Measure L	72.66	74.90	79.07	77.98	68.54	68.74	72.43
2015 - Measure O	73.19	75.15	79.40	78.11	69.31	69.53	72.97
2015 - Measure P	73.22	75.17	79.43	78.12	69.38	69.57	73.01
2015 - Measure Q	73.28	75.20	79.46	78.13	69.46	69.65	73.06
2015 - Measures M & Q	73.25	75.17	79.43	78.11	69.44	69.62	73.03
2015 - Measure M	72.55	74.82	78.98	77.94	68.37	68.60	72.31
2020 - Base Case	74.72	76.46	81.16	79.39	70.62	70.88	74.57
2020 - Measure A	75.53	76.76	81.61	79.50	71.87	72.14	75.40
2020 - Measure B	76.40	77.01	82.01	79.52	73.37	73.61	76.31
2020 - Measure B*	76.56	77.05	82.07	79.52	73.66	73.90	76.47
2020 - Measure C	75.57	76.78	81.64	79.51	71.94	72.20	75.45
2020 - Measure E	74.85	76.52	81.23	79.43	70.81	71.06	74.69
2020 - Measure J	74.90	76.58	81.24	79.45	71.06	71.20	74.72
2020 - Measures K & L	75.18	76.73	81.60	79.57	71.16	71.37	75.05
2020 - Measure L	74.82	76.51	81.22	79.41	70.78	71.01	74.66
2020 - Measure O	75.67	76.84	81.70	79.54	72.10	72.36	75.55
2020 - Measure P	75.66	76.83	81.70	79.53	72.11	72.33	75.54
2020 - Measure Q	75.76	76.88	81.76	79.56	72.27	72.49	75.64
2020 - Measures M & Q	75.73	76.85	81.73	79.54	72.24	72.45	75.61
2020 - Measure M	74.69	76.43	81.13	79.37	70.59	70.85	74.54

Table A4-2: Summary of the Population-Weighted Annual Mean of the Difference (in µg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 70 µg m^{-3} for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	Population-Weighted Annual Mean of the Difference (in µg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 70 µg m^{-3}						
	All UK	**Scotland**	**Wales**	**Northern Ireland**	**Inner London**	**Outer London**	**Rest of England**
1999 - Current Year	9.68	10.94	14.16	13.10	6.42	6.75	9.61
2000 - Current Year	9.33	10.59	13.63	13.30	6.46	6.66	9.20
2001 - Current Year	8.19	8.34	12.27	8.96	5.90	6.20	8.22
2002 - Current Year	8.67	9.76	11.55	10.67	6.80	6.95	8.56
2003 - Current Year	9.14	9.63	13.38	11.51	6.77	6.93	9.09
2010 - Base Case (NECD)	11.23	11.18	15.26	12.81	9.29	9.38	11.22
2010 - Base Case (CAFÉ)	11.10	11.10	15.07	12.73	9.26	9.31	11.08
2010 - Base Case (CAFÉ) – Current Composition	9.75	9.87	13.50	11.40	8.04	8.08	9.70
2015 - Base Case (NECD)	12.77	12.40	16.79	13.92	10.95	11.09	12.79
2015 - Base Case (CAFÉ)	12.51	12.21	16.51	13.73	10.70	10.80	12.52
2020 - Base Case (NECD)	14.20	13.59	18.41	15.04	12.28	12.46	14.27
2020 - Base Case (CAFÉ)	13.82	13.29	18.02	14.73	11.87	12.03	13.88
2020 - Base Case (CAFÉ) – Current Composition	10.41	10.28	14.15	11.56	8.68	8.80	10.41
2010 - Base Case	11.10	11.10	15.07	12.73	9.26	9.31	11.08
2010 - Measure A	11.12	11.10	15.08	12.73	9.28	9.33	11.09
2010 - Measure B	11.15	11.12	15.10	12.74	9.32	9.37	11.12
2010 - Measure B*	11.15	11.12	15.10	12.74	9.32	9.37	11.12
2010 - Measure C	11.16	11.13	15.11	12.75	9.34	9.39	11.13
2010 - Measure E	11.11	11.10	15.07	12.73	9.28	9.32	11.09
2010 - Measure J	11.12	11.11	15.08	12.74	9.30	9.34	11.09
2010 - Measures K & L	11.55	11.43	15.67	12.95	9.57	9.64	11.56
2010 - Measure L	11.10	11.10	15.07	12.73	9.26	9.31	11.08
2010 - Measure O	11.17	11.13	15.11	12.75	9.35	9.40	11.14
2010 - Measure P	11.16	11.13	15.11	12.75	9.34	9.39	11.13
2010 - Measure Q	11.17	11.13	15.11	12.75	9.35	9.40	11.14
2010 - Measures M & Q	11.15	11.12	15.09	12.73	9.34	9.39	11.12
2010 - Measure M	11.09	11.08	15.05	12.71	9.25	9.30	11.06
Sensitivity to Meteorology							
2010 - Base Case	11.10	11.10	15.07	12.73	9.26	9.31	11.08
2010 - Measure B*	11.15	11.12	15.10	12.74	9.32	9.37	11.12
2010 - Measure B* with 2000 meteorology	12.12	11.80	15.88	14.43	10.72	10.89	12.03
2010 - Measure B* with 2002 meteorology	10.96	11.02	13.31	11.77	9.84	10.05	10.93
2010 - Measure M	11.09	11.08	15.05	12.71	9.25	9.30	11.06
2010 - Measure M with 2000 meteorology	12.01	11.74	15.81	14.40	10.53	10.72	11.92
2010 - Measure M with 2002 meteorology	10.86	10.98	13.26	11.75	9.68	9.90	10.83

Table A4-2: Summary of the Population-Weighted Annual Mean of the Difference (in μg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 70 μg m^{-3} for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Population-Weighted Annual Mean of the Difference (in μg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 70 μg m^{-3}						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
2015 - Base Case	12.51	12.21	16.51	13.73	10.70	10.80	12.52
2015 - Measure A	12.67	12.28	16.60	13.72	10.93	11.04	12.69
2015 - Measure B	12.88	12.36	16.71	13.71	11.23	11.38	12.91
2015 - Measure B*	12.89	12.36	16.71	13.71	11.25	11.39	12.92
2015 - Measure C	12.74	12.32	16.65	13.75	11.03	11.14	12.76
2015 - Measure E	12.54	12.23	16.53	13.74	10.75	10.85	12.56
2015 - Measure J	12.56	12.25	16.54	13.75	10.83	10.89	12.57
2015 - Measures K & L	13.01	12.56	17.16	13.93	11.13	11.22	13.05
2015 - Measure L	12.56	12.24	16.55	13.74	10.78	10.86	12.57
2015 - Measure O	12.76	12.34	16.67	13.75	11.07	11.18	12.79
2015 - Measure P	12.78	12.34	16.69	13.75	11.11	11.21	12.80
2015 - Measure Q	12.81	12.36	16.70	13.76	11.15	11.25	12.83
2015 - Measures M & Q	12.79	12.34	16.68	13.75	11.13	11.23	12.81
2015 - Measure M	12.49	12.19	16.49	13.71	10.69	10.79	12.50
2020 - Base Case	13.82	13.29	18.02	14.73	11.87	12.03	13.88
2020 - Measure A	14.11	13.35	18.13	14.66	12.33	12.54	14.18
2020 - Measure B	14.38	13.33	18.11	14.48	12.95	13.18	14.46
2020 - Measure B*	14.43	13.32	18.10	14.44	13.08	13.31	14.51
2020 - Measure C	14.13	13.37	18.15	14.67	12.37	12.58	14.20
2020 - Measure E	13.89	13.33	18.07	14.75	11.97	12.13	13.94
2020 - Measure J	13.90	13.36	18.07	14.76	12.10	12.20	13.95
2020 - Measures K & L	14.04	13.42	18.30	14.81	12.11	12.26	14.11
2020 - Measure L	13.87	13.32	18.06	14.74	11.95	12.09	13.93
2020 - Measure O	14.18	13.39	18.18	14.68	12.46	12.67	14.26
2020 - Measure P	14.18	13.38	18.18	14.67	12.46	12.65	14.25
2020 - Measure Q	14.23	13.41	18.21	14.69	12.55	12.74	14.30
2020 - Measures M & Q	14.21	13.39	18.18	14.67	12.53	12.72	14.28
2020 - Measure M	13.80	13.27	18.00	14.71	11.85	12.01	13.85

Table A4-3: Summary of the Population-Weighted Annual Mean of the Difference (in µg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 100 µg m^{-3} for the OSRM Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	Population-Weighted Annual Mean of the Difference (in µg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 100 µg m^{-3}						
	All UK	**Scotland**	**Wales**	**Northern Ireland**	**Inner London**	**Outer London**	**Rest of England**
1999 - Current Year	1.75	1.69	2.03	1.88	1.35	1.44	1.79
2000 - Current Year	1.65	1.32	2.24	2.09	1.06	1.07	1.73
2001 - Current Year	1.71	1.22	2.44	0.79	1.62	1.73	1.76
2002 - Current Year	1.47	1.62	1.26	1.41	1.67	1.58	1.44
2003 - Current Year	1.93	1.69	2.73	1.96	1.52	1.53	1.97
2010 - Base Case (NECD)	2.19	1.87	2.97	2.09	1.87	1.83	2.23
2010 - Base Case (CAFÉ)	2.14	1.80	2.89	2.01	1.92	1.86	2.18
2010 - Base Case (CAFÉ) – Current Composition	1.75	1.48	2.37	1.60	1.60	1.55	1.78
2015 - Base Case (NECD)	2.68	2.23	3.53	2.45	2.40	2.36	2.74
2015 - Base Case (CAFÉ)	2.50	2.06	3.34	2.29	2.28	2.23	2.55
2020 - Base Case (NECD)	3.22	2.66	4.22	2.86	2.89	2.86	3.30
2020 - Base Case (CAFÉ)	2.95	2.43	3.96	2.63	2.66	2.61	3.01
2020 - Base Case (CAFÉ) – Current Composition	1.83	1.50	2.46	1.61	1.68	1.64	1.87
2010 - Base Case	2.14	1.80	2.89	2.01	1.92	1.86	2.18
2010 - Measure A	2.15	1.80	2.89	2.01	1.92	1.87	2.19
2010 - Measure B	2.16	1.80	2.90	2.01	1.93	1.88	2.20
2010 - Measure B*	2.16	1.80	2.90	2.01	1.93	1.88	2.20
2010 - Measure C	2.16	1.80	2.90	2.01	1.94	1.89	2.20
2010 - Measure E	2.15	1.80	2.89	2.01	1.92	1.87	2.19
2010 - Measure J	2.15	1.80	2.89	2.01	1.93	1.87	2.19
2010 - Measures K & L	2.30	1.90	3.11	2.09	2.02	1.97	2.36
2010 - Measure L	2.14	1.80	2.89	2.01	1.92	1.86	2.18
2010 - Measure O	2.16	1.81	2.90	2.01	1.94	1.89	2.20
2010 - Measure P	2.16	1.80	2.90	2.01	1.94	1.89	2.20
2010 - Measure Q	2.16	1.81	2.90	2.01	1.94	1.89	2.20
2010 - Measures M & Q	2.15	1.80	2.89	2.00	1.94	1.89	2.19
2010 - Measure M	2.14	1.79	2.88	2.00	1.92	1.86	2.18
Sensitivity to Meteorology							
2010 - Base Case	2.14	1.80	2.89	2.01	1.92	1.86	2.18
2010 - Measure B*	2.16	1.80	2.90	2.01	1.93	1.88	2.20
2010 - Measure B* with 2000 meteorology	1.80	1.08	2.28	1.70	1.61	1.66	1.89
2010 - Measure B* with 2002 meteorology	1.72	1.79	1.58	1.51	1.93	1.87	1.70
2010 - Measure M	2.14	1.79	2.88	2.00	1.92	1.86	2.18
2010 - Measure M with 2000 meteorology	1.77	1.07	2.26	1.69	1.54	1.59	1.85
2010 - Measure M with 2002 meteorology	1.69	1.78	1.57	1.50	1.88	1.82	1.67

Table A4-3: Summary of the Population-Weighted Annual Mean of the Difference (in µg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 100 µg m^{-3} for the OSRM Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Population-Weighted Annual Mean of the Difference (in µg m^{-3}) between the Daily Maximum Running 8 Hourly Ozone Concentration and 100 µg m^{-3}						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
2015 - Base Case	2.50	2.06	3.34	2.29	2.28	2.23	2.55
2015 - Measure A	2.55	2.08	3.38	2.30	2.34	2.28	2.60
2015 - Measure B	2.60	2.11	3.42	2.31	2.42	2.36	2.66
2015 - Measure B*	2.61	2.11	3.42	2.31	2.42	2.37	2.66
2015 - Measure C	2.57	2.09	3.39	2.30	2.37	2.31	2.62
2015 - Measure E	2.51	2.06	3.35	2.29	2.30	2.24	2.56
2015 - Measure J	2.52	2.07	3.35	2.29	2.32	2.25	2.56
2015 - Measures K & L	2.68	2.19	3.61	2.36	2.42	2.37	2.74
2015 - Measure L	2.52	2.07	3.35	2.29	2.30	2.25	2.57
2015 - Measure O	2.58	2.10	3.40	2.31	2.39	2.33	2.63
2015 - Measure P	2.58	2.10	3.41	2.31	2.40	2.34	2.63
2015 - Measure Q	2.59	2.10	3.41	2.31	2.41	2.35	2.64
2015 - Measures M & Q	2.58	2.09	3.40	2.30	2.41	2.34	2.63
2015 - Measure M	2.50	2.05	3.33	2.28	2.28	2.22	2.55
2020 - Base Case	2.95	2.43	3.96	2.63	2.66	2.61	3.01
2020 - Measure A	3.02	2.45	3.99	2.61	2.77	2.73	3.09
2020 - Measure B	3.08	2.43	3.97	2.53	2.92	2.91	3.15
2020 - Measure B*	3.09	2.42	3.95	2.50	2.95	2.95	3.15
2020 - Measure C	3.03	2.46	4.00	2.61	2.79	2.75	3.10
2020 - Measure E	2.97	2.45	3.97	2.64	2.69	2.64	3.03
2020 - Measure J	2.97	2.45	3.97	2.64	2.73	2.65	3.03
2020 - Measures K & L	3.03	2.49	4.07	2.65	2.74	2.68	3.10
2020 - Measure L	2.97	2.44	3.97	2.63	2.69	2.63	3.03
2020 - Measure O	3.05	2.47	4.01	2.62	2.82	2.78	3.11
2020 - Measure P	3.05	2.46	4.01	2.61	2.82	2.77	3.11
2020 - Measure Q	3.06	2.47	4.02	2.62	2.85	2.80	3.13
2020 - Measures M & Q	3.05	2.46	4.01	2.60	2.84	2.79	3.11
2020 - Measure M	2.94	2.42	3.94	2.62	2.65	2.60	3.00

Table A4-4: Summary of the Population-Weighted Number of Days when the Daily Maximum Running 8 Hourly Ozone Concentration exceeds 100 µg m^{-3} for the OSRM Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	Population-Weighted Number of Days when the Daily Maximum Running 8 Hourly Ozone Concentration exceeds 120 µg m^{-3}						
	All UK	**Scotland**	**Wales**	**Northern Ireland**	**Inner London**	**Outer London**	**Rest of England**
1999 - Current Year	34.69	34.26	55.68	44.31	24.82	26.41	34.44
2000 - Current Year	29.73	32.69	44.04	44.37	23.25	22.80	28.97
2001 - Current Year	27.62	25.51	38.60	23.09	19.60	20.58	28.57
2002 - Current Year	26.19	31.55	35.70	34.08	20.31	21.35	25.47
2003 - Current Year	29.73	28.16	48.34	35.88	22.03	21.66	29.77
2010 - Base Case (NECD)	39.75	34.27	58.96	42.82	34.72	34.42	39.86
2010 - Base Case (CAFÉ)	38.99	34.11	57.89	42.98	33.71	34.28	38.96
2010 - Base Case (CAFÉ) – Current Composition	31.80	28.78	48.66	34.18	27.98	26.91	31.69
2015 - Base Case (NECD)	48.63	41.89	68.10	49.69	46.94	45.62	48.50
2015 - Base Case (CAFÉ)	47.23	41.27	66.84	49.00	44.09	43.20	47.17
2020 - Base Case (NECD)	56.99	50.43	78.33	56.43	53.73	52.97	56.97
2020 - Base Case (CAFÉ)	55.14	49.47	76.92	55.18	51.04	49.78	55.17
2020 - Base Case (CAFÉ) – Current Composition	34.16	30.28	51.77	33.80	30.76	30.06	34.09
2010 - Base Case	38.99	34.11	57.89	42.98	33.71	34.28	38.96
2010 - Measure A	39.01	34.10	57.87	42.92	33.71	34.32	38.99
2010 - Measure B	39.15	34.24	57.97	42.93	33.71	34.37	39.16
2010 - Measure B*	39.15	34.24	57.97	42.93	33.71	34.37	39.16
2010 - Measure C	39.22	34.24	58.00	42.98	33.88	34.66	39.21
2010 - Measure E	39.01	34.11	57.91	43.03	33.71	34.28	38.98
2010 - Measure J	39.03	34.14	57.94	43.03	33.71	34.35	39.00
2010 - Measures K & L	41.06	35.64	61.50	43.70	35.50	35.80	41.12
2010 - Measure L	38.99	34.11	57.89	42.98	33.71	34.28	38.96
2010 - Measure O	39.25	34.25	58.10	42.89	33.88	34.66	39.24
2010 - Measure P	39.22	34.24	58.00	42.98	33.88	34.66	39.21
2010 - Measure Q	39.25	34.25	58.10	42.89	33.88	34.66	39.24
2010 - Measures M & Q	39.15	34.19	57.96	42.78	33.88	34.64	39.13
2010 - Measure M	38.92	34.03	57.74	42.92	33.71	34.19	38.89
Sensitivity to Meteorology							
2010 - Base Case	38.99	34.11	57.89	42.98	33.71	34.28	38.96
2010 - Measure B*	39.15	34.24	57.97	42.93	33.71	34.37	39.16
2010 - Measure B* with 2000 meteorology	39.34	34.57	55.12	46.99	33.23	36.24	39.23
2010 - Measure B* with 2002 meteorology	36.03	37.76	45.32	39.38	31.56	32.76	35.68
2010 - Measure M	38.92	34.03	57.74	42.92	33.71	34.19	38.89
2010 - Measure M with 2000 meteorology	38.78	34.26	54.74	46.88	32.67	35.28	38.65
2010 - Measure M with 2002 meteorology	35.53	37.57	45.20	39.11	30.96	31.78	35.17

Table A4-4: Summary of the Population-Weighted Number of Days when the Daily Maximum Running 8 Hourly Ozone Concentration exceeds 100 µg m^{-3} for the OSRM Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Population-Weighted Number of Days when the Daily Maximum Running 8 Hourly Ozone Concentration exceeds 120 µg m^{-3}						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
2015 - Base Case	47.23	41.27	66.84	49.00	44.09	43.20	47.17
2015 - Measure A	47.84	41.66	67.27	47.85	45.39	43.97	47.83
2015 - Measure B	48.35	41.90	67.32	46.72	45.39	44.56	48.49
2015 - Measure B*	48.39	41.92	67.30	46.67	45.39	44.70	48.52
2015 - Measure C	48.11	41.96	67.46	47.79	45.90	44.41	48.08
2015 - Measure E	47.38	41.44	66.97	49.00	44.31	43.40	47.31
2015 - Measure J	47.44	41.55	67.04	49.09	44.75	43.56	47.32
2015 - Measures K & L	49.25	43.70	69.98	49.55	44.90	44.34	49.29
2015 - Measure L	47.41	41.48	67.11	48.98	44.31	43.37	47.34
2015 - Measure O	48.24	42.09	67.46	47.92	45.90	44.53	48.23
2015 - Measure P	48.33	42.22	67.65	47.77	45.90	44.76	48.30
2015 - Measure Q	48.44	42.32	67.77	47.91	46.18	44.78	48.42
2015 - Measures M & Q	48.33	42.13	67.61	47.79	45.90	44.68	48.32
2015 - Measure M	47.11	41.16	66.69	48.94	44.09	43.07	47.03
2020 - Base Case	55.14	49.47	76.92	55.18	51.04	49.78	55.17
2020 - Measure A	56.04	49.87	76.11	52.98	51.65	51.57	56.29
2020 - Measure B	56.74	49.35	75.05	49.41	52.25	52.90	57.36
2020 - Measure B*	56.77	49.23	74.63	48.87	52.19	53.01	57.46
2020 - Measure C	56.12	49.96	76.10	52.97	51.65	51.79	56.37
2020 - Measure E	55.43	49.81	77.07	55.16	51.05	50.12	55.49
2020 - Measure J	55.49	49.78	77.06	55.21	51.46	50.48	55.51
2020 - Measures K & L	56.11	50.60	78.07	55.14	51.38	50.39	56.22
2020 - Measure L	55.36	49.56	77.11	55.13	51.05	50.03	55.43
2020 - Measure O	56.36	50.07	76.28	52.96	51.65	52.19	56.63
2020 - Measure P	56.31	50.05	76.12	52.94	51.65	52.08	56.59
2020 - Measure Q	56.58	50.26	76.38	52.93	51.81	52.64	56.85
2020 - Measures M & Q	56.42	50.04	76.22	52.90	51.65	52.51	56.69
2020 - Measure M	55.03	49.34	76.79	55.12	51.04	49.78	55.04

Table A4-5: Summary of the Population-Weighted Annual Mean Nitrogen Dioxide Concentration (in µg m^{-3}) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	Population-Weighted Annual Mean Nitrogen Dioxide Concentration (in µg m^{-3})						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
1999 - Current Year	22.85	12.07	14.70	7.89	37.05	34.72	23.11
2000 - Current Year	21.20	11.13	13.29	7.50	33.70	31.77	21.56
2001 - Current Year	21.69	11.91	14.70	8.61	33.70	31.63	22.02
2002 - Current Year	21.01	11.71	14.36	8.32	31.73	30.06	21.43
2003 - Current Year	20.86	12.47	13.51	8.82	33.27	30.99	20.97
2010 - Base Case (NECD)	15.64	9.12	9.85	6.28	25.34	23.68	15.71
2010 - Base Case (CAFÉ)	15.93	9.24	10.14	6.50	25.70	24.03	16.01
2010 - Base Case (CAFÉ) – Current Composition	15.90	9.24	10.17	6.52	25.57	23.91	15.99
2015 - Base Case (NECD)	14.31	8.27	8.99	5.70	23.54	21.85	14.34
2015 - Base Case (CAFÉ)	14.26	8.19	8.94	5.66	23.52	21.82	14.28
2020 - Base Case (NECD)	13.56	7.81	8.32	5.35	22.89	21.11	13.54
2020 - Base Case (CAFÉ)	13.33	7.61	8.11	5.16	22.67	20.89	13.29
2020 - Base Case (CAFÉ) – Current Composition	13.30	7.62	8.18	5.20	22.46	20.72	13.28
2010 - Base Case	15.93	9.24	10.14	6.50	25.70	24.03	16.01
2010 - Measure A	15.88	9.22	10.11	6.48	25.64	23.96	15.96
2010 - Measure B	15.79	9.16	10.05	6.44	25.51	23.84	15.87
2010 - Measure B*	15.79	9.16	10.05	6.44	25.51	23.84	15.87
2010 - Measure C	15.79	9.16	10.05	6.44	25.49	23.83	15.87
2010 - Measure E	15.91	9.23	10.13	6.49	25.68	24.00	15.99
2010 - Measure J	15.88	9.21	10.12	6.48	25.59	23.94	15.97
2010 - Measures K & L	14.94	8.63	9.20	6.06	24.78	23.11	14.93
2010 - Measure L	15.93	9.24	10.14	6.50	25.70	24.03	16.01
2010 - Measure O	15.77	9.14	10.04	6.43	25.47	23.81	15.85
2010 - Measure P	15.79	9.16	10.05	6.44	25.49	23.83	15.87
2010 - Measure Q	15.77	9.14	10.04	6.43	25.47	23.81	15.85
2010 - Measures M & Q	15.77	9.14	10.04	6.43	25.47	23.80	15.85
2010 - Measure M	15.93	9.24	10.14	6.50	25.70	24.03	16.01
Sensitivity to Meteorology							
2010 - Base Case	15.93	9.24	10.14	6.50	25.70	24.03	16.01
2010 - Measure B*	15.79	9.16	10.05	6.44	25.51	23.84	15.87
2010 - Measure B* with 2000 meteorology	14.67	7.34	9.00	4.86	24.07	22.44	14.89
2010 - Measure B* with 2002 meteorology	15.82	8.63	10.75	6.19	24.51	23.02	16.08
2010 - Measure M	15.93	9.24	10.14	6.50	25.70	24.03	16.01
2010 - Measure M with 2000 meteorology	14.79	7.41	9.08	4.91	24.25	22.61	15.01
2010 - Measure M with 2002 meteorology	15.95	8.71	10.84	6.24	24.70	23.20	16.21

Table A4-5: Summary of the Population-Weighted Annual Mean Nitrogen Dioxide Concentration (in µg m^{-3}) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Population-Weighted Annual Mean Nitrogen Dioxide Concentration (in µg m^{-3})						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
2015 - Base Case	14.26	8.19	8.94	5.66	23.52	21.82	14.28
2015 - Measure A	13.72	7.86	8.59	5.41	22.74	21.06	13.74
2015 - Measure B	13.00	7.43	8.13	5.09	21.70	20.04	13.01
2015 - Measure B*	12.96	7.41	8.10	5.07	21.64	19.98	12.97
2015 - Measure C	13.56	7.77	8.50	5.35	22.51	20.83	13.58
2015 - Measure E	14.19	8.15	8.90	5.63	23.42	21.72	14.22
2015 - Measure J	14.13	8.09	8.88	5.60	23.19	21.58	14.17
2015 - Measures K & L	13.18	7.55	7.98	5.22	22.40	20.76	13.12
2015 - Measure L	14.14	8.14	8.87	5.63	23.32	21.67	14.17
2015 - Measure O	13.50	7.73	8.47	5.32	22.42	20.74	13.52
2015 - Measure P	13.45	7.71	8.43	5.32	22.30	20.67	13.46
2015 - Measure Q	13.39	7.67	8.39	5.30	22.21	20.58	13.40
2015 - Measures M & Q	13.39	7.67	8.39	5.30	22.21	20.59	13.40
2015 - Measure M	14.26	8.19	8.94	5.66	23.52	21.82	14.28
2020 - Base Case	13.33	7.61	8.11	5.16	22.67	20.89	13.29
2020 - Measure A	12.25	6.96	7.41	4.68	21.09	19.34	12.19
2020 - Measure B	10.94	6.18	6.59	4.11	19.18	17.46	10.86
2020 - Measure B*	10.69	6.03	6.44	4.00	18.80	17.09	10.60
2020 - Measure C	12.19	6.93	7.38	4.66	21.00	19.26	12.13
2020 - Measure E	13.19	7.52	8.02	5.10	22.45	20.68	13.15
2020 - Measure J	13.11	7.45	8.01	5.07	22.09	20.47	13.10
2020 - Measures K & L	12.83	7.32	7.69	4.98	22.10	20.36	12.76
2020 - Measure L	13.21	7.55	8.03	5.14	22.45	20.73	13.17
2020 - Measure O	12.07	6.85	7.31	4.61	20.82	19.07	12.00
2020 - Measure P	12.07	6.86	7.30	4.63	20.78	19.09	12.00
2020 - Measure Q	11.94	6.79	7.23	4.58	20.59	18.90	11.88
2020 - Measures M & Q	11.94	6.79	7.24	4.58	20.59	18.90	11.88
2020 - Measure M	13.33	7.61	8.11	5.16	22.66	20.89	13.29

Table A4-6: Summary of the Area-Weighted Annual Mean Ozone Concentration (in µg m^{-3}) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	**Area-Weighted Annual Mean Ozone Concentration (in µg m^{-3})**						
	All UK	**Scotland**	**Wales**	**Northern Ireland**	**Inner London**	**Outer London**	**Rest of England**
1999 - Current Year	58.99	65.18	63.90	66.65	40.54	41.18	53.91
2000 - Current Year	59.77	66.27	64.38	67.54	42.49	42.86	54.51
2001 - Current Year	54.85	60.04	59.75	60.60	39.46	40.09	50.52
2002 - Current Year	54.59	59.44	58.61	60.56	40.42	40.73	50.59
2003 - Current Year	57.91	63.02	61.89	63.56	43.18	43.46	53.81
2010 - Base Case (NECD)	61.84	65.54	65.52	66.18	50.77	50.57	58.74
2010 - Base Case (CAFÉ)	61.48	65.34	65.13	65.98	50.19	50.01	58.27
2010 - Base Case (CAFÉ) – Current Composition	59.91	63.94	63.49	64.54	48.52	48.36	56.60
2015 - Base Case (NECD)	63.58	66.81	67.17	67.49	53.53	53.33	60.81
2015 - Base Case (CAFÉ)	63.50	66.76	67.11	67.47	53.30	53.11	60.70
2020 - Base Case (NECD)	65.32	68.15	68.88	68.82	55.53	55.36	62.81
2020 - Base Case (CAFÉ)	65.34	68.14	68.94	68.84	55.47	55.30	62.86
2020 - Base Case (CAFÉ) – Current Composition	61.67	64.88	65.12	65.52	51.45	51.35	58.93
2010 - Base Case	61.48	65.34	65.13	65.98	50.19	50.01	58.27
2010 - Measure A	61.51	65.36	65.15	66.00	50.25	50.07	58.31
2010 - Measure B	61.56	65.38	65.20	66.02	50.37	50.18	58.38
2010 - Measure B*	61.56	65.38	65.20	66.02	50.37	50.18	58.38
2010 - Measure C	61.56	65.38	65.19	66.02	50.38	50.19	58.37
2010 - Measure E	61.49	65.35	65.14	65.99	50.22	50.03	58.28
2010 - Measure J	61.50	65.35	65.14	65.99	50.28	50.07	58.29
2010 - Measures K & L	61.48	65.34	65.13	65.98	50.19	50.01	58.27
2010 - Measure L	62.42	65.92	65.98	66.47	51.27	51.06	59.48
2010 - Measure O	61.57	65.38	65.20	66.03	50.40	50.21	58.39
2010 - Measure P	61.56	65.38	65.19	66.02	50.38	50.19	58.37
2010 - Measure Q	61.57	65.38	65.20	66.03	50.40	50.21	58.39
2010 - Measures M & Q	61.55	65.36	65.18	66.01	50.39	50.19	58.36
2010 - Measure M	61.46	65.33	65.11	65.97	50.17	49.99	58.25
Sensitivity to Meteorology							
2010 - Base Case	61.48	65.34	65.13	65.98	50.19	50.01	58.27
2010 - Measure B*	61.56	65.38	65.20	66.02	50.37	50.18	58.38
2010 - Measure B* with 2000 meteorology	63.83	68.14	68.16	69.91	51.45	51.64	60.05
2010 - Measure B* with 2002 meteorology	58.13	61.44	61.68	62.68	47.24	47.49	55.23
2010 - Measure M	61.46	65.33	65.11	65.97	50.17	49.99	58.25
2010 - Measure M with 2000 meteorology	63.73	68.10	68.07	69.86	51.22	51.42	59.90
2010 - Measure M with 2002 meteorology	58.02	61.39	61.60	62.63	46.99	47.24	55.08

Table A4-6: Summary of the Area-Weighted Annual Mean Ozone Concentration (in µg m^{-3}) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Area-Weighted Annual Mean Ozone Concentration (in µg m^{-3})						
	All UK	**Scotland**	**Wales**	**Northern Ireland**	**Inner London**	**Outer London**	**Rest of England**
2015 - Base Case	63.50	66.76	67.11	67.47	53.30	53.11	60.70
2015 - Measure A	63.79	66.87	67.37	67.60	54.01	53.81	61.12
2015 - Measure B	64.16	67.00	67.68	67.76	54.96	54.74	61.65
2015 - Measure B*	64.18	67.00	67.70	67.76	55.01	54.79	61.68
2015 - Measure C	63.86	66.90	67.42	67.64	54.21	54.00	61.21
2015 - Measure E	63.53	66.77	67.14	67.49	53.39	53.19	60.75
2015 - Measure J	63.55	66.78	67.15	67.50	53.56	53.29	60.76
2015 - Measures K & L	63.57	66.79	67.17	67.50	53.47	53.24	60.79
2015 - Measure L	64.46	67.31	67.98	67.95	54.54	54.29	61.96
2015 - Measure O	63.89	66.91	67.44	67.65	54.29	54.08	61.25
2015 - Measure P	63.92	66.92	67.48	67.66	54.39	54.14	61.30
2015 - Measure Q	63.95	66.94	67.50	67.68	54.47	54.22	61.34
2015 - Measures M & Q	63.93	66.92	67.48	67.66	54.45	54.20	61.32
2015 - Measure M	63.48	66.74	67.09	67.46	53.28	53.09	60.68
2020 - Base Case	65.34	68.14	68.94	68.84	55.47	55.30	62.86
2020 - Measure A	65.87	68.31	69.39	69.05	56.89	56.70	63.64
2020 - Measure B	66.42	68.44	69.83	69.24	58.54	58.33	64.50
2020 - Measure B*	66.52	68.45	69.91	69.27	58.85	58.64	64.65
2020 - Measure C	65.89	68.32	69.41	69.06	56.96	56.77	63.68
2020 - Measure E	65.40	68.17	68.99	68.88	55.66	55.49	62.95
2020 - Measure J	65.41	68.18	69.00	68.88	55.92	55.62	62.96
2020 - Measures K & L	65.40	68.17	69.00	68.87	55.66	55.45	62.95
2020 - Measure L	65.74	68.36	69.30	69.04	56.08	55.85	63.40
2020 - Measure O	65.94	68.33	69.44	69.09	57.12	56.92	63.75
2020 - Measure P	65.95	68.34	69.46	69.09	57.15	56.92	63.76
2020 - Measure Q	66.00	68.36	69.50	69.11	57.31	57.07	63.84
2020 - Measures M & Q	65.98	68.34	69.48	69.10	57.28	57.05	63.81
2020 - Measure M	65.32	68.12	68.92	68.83	55.45	55.28	62.83

Table A4-7: Summary of the Area-Weighted AOT40 - Crops (in µg m^{-3} hours) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	Area-Weighted AOT40 - Crops (in µg m^{-3} hours)						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
1999 - Current Year	5808	4694	6769	4778	4921	4896	6469
2000 - Current Year	6353	6240	6847	6177	3573	3685	6396
2001 - Current Year	5692	5010	6797	2863	3790	3952	6281
2002 - Current Year	4061	4183	4144	2861	2241	2475	4152
2003 - Current Year	6385	6690	7222	5824	3877	3772	6181
2010 - Base Case (NECD)	7555	7374	8545	6763	6144	5883	7634
2010 - Base Case (CAFÉ)	7456	7249	8451	6706	6094	5836	7544
2010 - Base Case (CAFÉ) – Current Composition	5925	5874	6761	5290	4680	4446	5928
2015 - Base Case (NECD)	8881	8399	9962	7845	7989	7711	9147
2015 - Base Case (CAFÉ)	8525	8003	9626	7593	7705	7407	8799
2020 - Base Case (NECD)	10342	9565	11563	9013	9528	9265	10794
2020 - Base Case (CAFÉ)	9769	8944	11028	8557	9027	8750	10231
2020 - Base Case (CAFÉ) – Current Composition	5868	5580	6757	5179	5134	4910	6004
2010 - Base Case	7456	7249	8451	6706	6094	5836	7544
2010 - Measure A	7452	7242	8443	6704	6107	5847	7542
2010 - Measure B	7455	7236	8440	6704	6147	5884	7549
2010 - Measure B*	7455	7236	8440	6704	6147	5884	7549
2010 - Measure C	7466	7244	8453	6711	6166	5903	7563
2010 - Measure E	7459	7250	8453	6708	6105	5847	7548
2010 - Measure J	7460	7250	8453	6708	6130	5860	7549
2010 - Measures K & L	7456	7249	8451	6706	6094	5836	7544
2010 - Measure L	7690	7367	8734	6860	6237	5997	7848
2010 - Measure O	7469	7245	8455	6712	6177	5913	7567
2010 - Measure P	7466	7244	8453	6711	6166	5903	7563
2010 - Measure Q	7469	7245	8455	6712	6177	5913	7567
2010 - Measures M & Q	7453	7230	8441	6700	6164	5900	7551
2010 - Measure M	7441	7235	8436	6694	6081	5823	7528
Sensitivity to Meteorology							
2010 - Base Case	7456	7249	8451	6706	6094	5836	7544
2010 - Measure B*	7455	7236	8440	6704	6147	5884	7549
2010 - Measure B* with 2000 meteorology	6979	5732	7863	5767	6561	6660	7726
2010 - Measure B* with 2002 meteorology	5049	4874	4890	3247	4595	4732	5411
2010 - Measure M	7441	7235	8436	6694	6081	5823	7528
2010 - Measure M with 2000 meteorology	6917	5728	7801	5739	6373	6472	7628
2010 - Measure M with 2002 meteorology	5024	4870	4891	3249	4480	4623	5367

Table A4-7: Summary of the Area-Weighted AOT40 - Crops (in µg m^{-3} hours) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Area-Weighted AOT40 - Crops (in µg m^{-3} hours)						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
2015 - Base Case	8525	8003	9626	7593	7705	7407	8799
2015 - Measure A	8477	7915	9541	7533	7893	7581	8778
2015 - Measure B	8409	7798	9430	7440	8137	7805	8747
2015 - Measure B*	8404	7790	9422	7433	8149	7816	8743
2015 - Measure C	8496	7916	9555	7540	7998	7678	8809
2015 - Measure E	8534	8004	9633	7597	7753	7452	8814
2015 - Measure J	8535	8004	9633	7597	7821	7484	8815
2015 - Measures K & L	8538	8006	9635	7601	7758	7446	8819
2015 - Measure L	8763	8110	9910	7714	7913	7617	9122
2015 - Measure O	8503	7917	9560	7543	8039	7717	8821
2015 - Measure P	8507	7919	9563	7546	8052	7717	8827
2015 - Measure Q	8515	7919	9569	7549	8094	7756	8839
2015 - Measures M & Q	8497	7903	9552	7536	8075	7738	8819
2015 - Measure M	8508	7987	9609	7580	7688	7390	8780
2020 - Base Case	9769	8944	11028	8557	9027	8750	10231
2020 - Measure A	9607	8703	10780	8344	9383	9068	10128
2020 - Measure B	9331	8345	10400	7997	9699	9348	9918
2020 - Measure B*	9273	8271	10321	7925	9761	9402	9872
2020 - Measure C	9612	8702	10783	8345	9424	9106	10137
2020 - Measure E	9787	8943	11040	8561	9136	8851	10260
2020 - Measure J	9785	8944	11039	8561	9251	8894	10257
2020 - Measures K & L	9782	8945	11036	8561	9090	8795	10251
2020 - Measure L	9861	8970	11128	8588	9163	8864	10366
2020 - Measure O	9622	8698	10789	8346	9513	9188	10157
2020 - Measure P	9621	8699	10788	8346	9487	9150	10153
2020 - Measure Q	9630	8695	10793	8347	9576	9232	10172
2020 - Measures M & Q	9610	8678	10774	8333	9552	9209	10149
2020 - Measure M	9749	8926	11009	8543	9005	8729	10208

Table A4-8: Summary of the Area-Weighted AOT40 - Forests (in µg m^{-3} hours) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy.

Run Description	Area-Weighted AOT40 - Forests (in µg m^{-3} hours)						
	All UK	**Scotland**	**Wales**	**Northern Ireland**	**Inner London**	**Outer London**	**Rest of England**
1999 - Current Year	10183	9652	12175	8372	7644	7552	10456
2000 - Current Year	10100	9907	11547	9672	5754	5717	10094
2001 - Current Year	9223	8101	11757	5922	6839	6949	9909
2002 - Current Year	8848	9286	9288	7811	5972	6042	8701
2003 - Current Year	11830	11011	13854	11349	8423	8432	12113
2010 - Base Case (NECD)	13938	12423	16151	12461	12024	11733	14706
2010 - Base Case (CAFÉ)	13634	12198	15772	12462	11837	11559	14329
2010 - Base Case (CAFÉ) – Current Composition	11321	10183	13186	10416	9807	9549	11847
2015 - Base Case (NECD)	16225	14149	18643	14131	15053	14766	17356
2015 - Base Case (CAFÉ)	15608	13674	17997	13794	14297	14017	16628
2020 - Base Case (NECD)	18780	16173	21517	16047	17507	17269	20250
2020 - Base Case (CAFÉ)	17855	15438	20566	15371	16359	16137	19190
2020 - Base Case (CAFÉ) – Current Composition	11785	10301	13813	10290	10694	10466	12552
2010 - Base Case	13634	12198	15772	12462	11837	11559	14329
2010 - Measure A	13644	12199	15781	12458	11864	11584	14347
2010 - Measure B	13671	12207	15806	12461	11941	11657	14388
2010 - Measure B*	13671	12207	15806	12461	11941	11657	14388
2010 - Measure C	13680	12214	15815	12472	11972	11688	14398
2010 - Measure E	13641	12201	15779	12464	11857	11579	14339
2010 - Measure J	13643	12202	15781	12466	11899	11601	14342
2010 - Measures K & L	13634	12198	15772	12462	11837	11559	14329
2010 - Measure L	14360	12692	16657	12803	12223	11972	15215
2010 - Measure O	13687	12216	15821	12474	11992	11706	14407
2010 - Measure P	13680	12214	15815	12472	11972	11688	14398
2010 - Measure Q	13687	12216	15821	12474	11992	11706	14407
2010 - Measures M & Q	13652	12183	15780	12450	11967	11681	14371
2010 - Measure M	13599	12165	15731	12437	11813	11534	14294
Sensitivity to Meteorology							
2010 - Base Case	13634	12198	15772	12462	11837	11559	14329
2010 - Measure B*	13671	12207	15806	12461	11941	11657	14388
2010 - Measure B* with 2000 meteorology	11286	9464	13456	9671	10118	10041	12235
2010 - Measure B* with 2002 meteorology	10547	10368	10729	8587	9568	9497	10898
2010 - Measure M	13599	12165	15731	12437	11813	11534	14294
2010 - Measure M with 2000 meteorology	11194	9445	13366	9620	9859	9782	12095
2010 - Measure M with 2002 meteorology	10473	10342	10699	8569	9321	9276	10782

Table A4-8: Summary of the Area-Weighted AOT40 - Forests (in µg m^{-3} hours) for the OSRM Scenario Runs Undertaken for the Review of the Air Quality Strategy (Continued).

Run Description	Area-Weighted AOT40 - Forests (in µg m^{-3} hours)						
	All UK	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England
2015 - Base Case	15608	13674	17997	13794	14297	14017	16628
2015 - Measure A	15717	13671	18070	13715	14726	14450	16827
2015 - Measure B	15843	13647	18141	13598	15349	15067	17072
2015 - Measure B*	15848	13643	18142	13589	15385	15102	17085
2015 - Measure C	15771	13691	18119	13732	14915	14631	16905
2015 - Measure E	15634	13684	18021	13802	14381	14098	16665
2015 - Measure J	15635	13685	18021	13804	14496	14154	16666
2015 - Measures K & L	15652	13698	18045	13810	14403	14100	16687
2015 - Measure L	16382	14176	18927	14132	14885	14588	17592
2015 - Measure O	15792	13698	18139	13739	14989	14704	16936
2015 - Measure P	15814	13713	18165	13747	15026	14718	16962
2015 - Measure Q	15835	13720	18184	13753	15101	14791	16992
2015 - Measures M & Q	15792	13681	18134	13726	15064	14754	16947
2015 - Measure M	15565	13634	17948	13766	14264	13983	16584
2020 - Base Case	17855	15438	20566	15371	16359	16137	19190
2020 - Measure A	17963	15287	20542	15119	17344	17097	19503
2020 - Measure B	17909	14927	20264	14673	18582	18259	19697
2020 - Measure B*	17879	14841	20182	14577	18830	18487	19712
2020 - Measure C	17979	15290	20554	15124	17421	17169	19528
2020 - Measure E	17906	15452	20612	15388	16554	16323	19267
2020 - Measure J	17900	15453	20605	15389	16741	16396	19255
2020 - Measures K & L	17900	15458	20614	15388	16488	16236	19253
2020 - Measure L	18171	15612	20923	15507	16729	16454	19604
2020 - Measure O	18014	15294	20581	15134	17589	17328	19583
2020 - Measure P	18016	15301	20590	15136	17556	17272	19583
2020 - Measure Q	18050	15305	20614	15146	17724	17431	19637
2020 - Measures M & Q	18001	15264	20561	15115	17673	17381	19582
2020 - Measure M	17805	15393	20510	15340	16315	16093	19137