Report

Projections of Air Quality in the UK for Additional Measures for the 2006 Review of the Air Quality Strategy

Report to The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland

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Report

AEAT/ENV/R/1986 Issue 1
April 2006

Title	Projections of Air Quality in the UK for Additional Measures for the 2006 Review of the Air Quality Strategy
Customer	The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland
Customer reference	CPEA 15
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File reference	W:\dd2003\aqsreview2005reporting\ measureprojectionsreport7.doc
Reference number	AEAT/ENV/R/1986

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Executive Summary

The UK Government and the devolved administrations published an Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS) in January 2000. It sets air quality standards and objectives for eight key pollutants to be achieved between 2003 and 2008. An addendum to the AQS was subsequently published in 2003. 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.

This report describes the GIS-based model predictions of air quality for a range of proposed additional policy measures for NO_2 and PM_{10} from a base year of 2003. These projections of air pollution concentrations are our best estimate of the likely impact of the proposed additional policy measures on the future concentrations of air pollutants. The results of our assessment of air quality for these measures are presented in terms of the expected extent of exceedence of AQS objectives and population-weighted mean concentrations. Assessments have been carried out for the years for which the objectives have been set or for years under consideration within the review of possible additional measures (2010, 2015 and 2020). For a selection of the measures, NO_2 and PM_{10} concentrations have been calculated using base years of 2002 and 2003 in order to reflect the impact of different meteorology on predicted air quality.

Concentrations of $PM_{2.5}$ across the UK have also been calculated for additional policy measures as part of this report. Modelling of $PM_{2.5}$ has only been done for a selection of the measures covered for PM_{10} and NO_2.

Table ES1 contains a summary of the measures for which pollutant concentrations have been modelled in this report.

Table ES1 Proposed additional policy measures considered in this report

Measure	Description	Pollutants modelled
baseline	Current policies	All AQS polluntants*
A	Euro 5 and VI low	NO_2 PM_{10}
B	Euro 5 and VI high	NO_2 PM_{10}
C	Euro 5 and VI low including early introduction	NO_2 PM_{10}
D	Phase out of pre-Euro and Euro 1	NO_2 PM_{10}
E	LEV scenario	NO_2 PM_{10}
F	road user charging scenario	NO_2 PM_{10}
G	Low Emission zone	NO_2 PM_{10}
J	Domestic gas combustion NO_X: new product standards	NO_2 PM_{10}
K	NOx reductions at power stations, refineries, iron and steel	NO_2 PM_{10}
L	Small Combustion Plant Directive: NO_X and SO_2 (NB does not start until 2013, so no impact in 2010)	NO_2 PM_{10}
N	Shipping measure: NO_X and SO_2 reductions	NO_2 PM_{10}
O	Combined C + E	NO_2 PM_{10}
P	Combined C + L	NO_2 PM_{10} $PM_{2.5}$
Q	Combined C +L + E	NO_2 PM_{10} $PM_{2.5}$

* Full baseline results are presented in Grice et al (2006)

For NO_2, the modelling shows that measures K and B are predicted to be the most effective individual measures for reducing the extent of exceedences of the 40 μgm^{-3} annual mean objective and population-weighted mean concentrations. The combined measures (measures O, P and Q) are also predicted to be very effective. None of the proposed additional policy measures entirely eliminate exceedences of the objective.

For PM_{10}, an annual mean concentration of 31.5 $\mu g\ m^{-3}$ (equivalent to the 2004 24-hour AQS objective) is predicted to be exceeded at relatively few locations even under baseline conditions. The annual mean objective of 20 μgm^{-3} is predicted to be far more widely exceeded under baseline conditions. Individual measures K, B and N along with the combined measures (O, P and Q) are projected to be the most effective at reducing the extent of exceedences of this annual mean objective of 20 μgm^{-3} and the population weighted mean concentration for PM_{10}. As with the 40 μgm^{-3} annual mean objective for NO_2, none of the measures are predicted to entirely eliminate exceedences of the 20 μgm^{-3} annual mean objective for PM_{10}.

Uncertainty in the modelling process is also considered for the baseline and additional policy measures as part of this report. Three elements are concluded to contribute the greatest uncertainty to model outputs for NO_2, PM_{10} and $PM_{2.5}$. These are:

- weather in the future year in question will have a large impact on the extent of exceedences of objectives;
- uncertainties about the response of PM concentrations to changes in emissions of precursor gases; and
- uncertainties about the source apportionment of PM

This report describes our best estimates of future air quality for a wide range of proposed additional policy measures on future PM_{10}, NO_2 and $PM_{2.5}$ concentrations. Baseline projections for these pollutants and for SO_2, benzene and CO are presented in the accompanying technical report (Grice et al, 2006).

Contents

1 Introduction

1.1 THE AIR QUALITY STRATEGY

The UK Government and the devolved administrations published an Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS) (DETR et al, 2000) in January 2000. It sets air quality standards and objectives for eight key pollutants to be achieved between 2003 and 2008. For seven of these pollutants local authorities are 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 AQS objectives for particles (PM_{10}), benzene and carbon monoxide were reviewed in 2000/01. An Addendum (Defra et al, 2003) was published in 2003 and incorporated tighter objectives for these pollutants and introduced an objective for polycyclic aromatic hydrocarbons.

The AQS 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 of 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.

1.2 THE EU FRAMEWORK AND DAUGHTER DIRECTIVES

Directive 96/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive (Council Directive 96/62/EC)) establishes a framework under which the EU sets limit values or target values for the concentrations of specified air pollutants in ambient air.

The first Daughter Directive (Council Directive 1999/30/EC) sets the limit values to be achieved for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particles and lead. The second Daughter Directive (Council Directive 2000/69/EC) sets out the limit values to be achieved for benzene and carbon monoxide. The third Daughter Directive (Council Directive 2002/3/EC) sets target values and long-term objectives for ozone. The fourth Daughter Directive (Council Directive 2004/107/EC) sets target values for arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons.

1.3 2006 REVIEW OF THE AQS

The UK Government and the devolved administrations are currently undertaking a review of the Air Quality Strategy. Amongst other things, 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.

1.4 BASELINE PROJECTIONS OF AIR QUALITY

GIS-based modelling predictions of our best estimates of air quality using baseline conditions (i.e. under current policies) are presented in the accompanying technical report (Grice et al, 2006). These have been calculated for NO_2, PM_{10} and $PM_{2.5}$ for 2005, 2010, 2015 and 2020.

1.5 MEASURE PROJECTIONS OF AIR QUALITY

This report describes the GIS-based model predictions of air quality using a variety of emissions measures carried out by netcen in support of the 2006 AQS review. These measure predictions are our best estimate of the likely impact of possible proposed national and international air quality policies on the future concentrations of air pollutants. The results of our assessment for these air quality measures are presented in terms of the expected extent of exceedence of AQS objectives and limit values and population-weighted mean concentrations. Comparison is made between these statistics for the measures and the baseline. Modelling of measures has been carried out for NO_2 and PM_{10} for 2010, 2015 and 2020. This is because the GIS-based modelling predictions using baseline conditions showed that concentrations of both these pollutants are not expected to meet the relevant AQS objectives under baseline conditions in all locations.

This report does not estimate the health impacts off the measures, nor their costs. This is carried out elsewhere as part of the review of the Air Quality Strategy. The change in concentration of air pollutants estimated for the measures are a key input to the review of the Air Quality Strategy. This report should be read in conjunction with the air quality strategy review consultation document (DEFRA et al, 2006a; DEFRA et al, 2006b) and An Economic Analysis to Inform the Air Quality Strategy Review Consultation: Third Report of the Interdepartmental Group on Costs and Benefits (DEFRA et al, 2006c) published simultaneously. Full details of the Cost Benefit analysis including an assessment of health impacts are included in the Economic Analysis document.

The emissions projections used to calculate the predictions of future air quality for the measures are discussed in section 2. Broadly three sets of measures are covered:

- Measures that affect road transport emissions
- Measures affecting stationary source emissions
- Combined measures

The modelling method used for projecting concentrations for the measures for 2010, 2015 and 2020 is described in section 3. Results for each measure using a 2003 base year are presented in sections 4 and 5 for NO_2 and PM_{10} respectively. 2003 was chosen because this was the most recent year for which monitoring results and baseline projections were available at the start of the AQS review.

For the combined measures, projections for NO_2 and PM_{10} have also been calculated using a base year of 2002 in order to reflect the impact of different meteorology on predicted air quality.

There are currently no limit values or objectives for $PM_{2.5}$. It is however possible that limit values and objectives may be set in the future and an assessment of concentrations for the combined measure projections for future years have therefore been calculated to support policy development. Projections for the combined measures for $PM_{2.5}$ are presented in section 6.

Baseline and measures modelling results for ozone for the AQS review are presented in (Hayman et al, 2006).

2 Emissions Measures

2.1 INTRODUCTION

Emissions projections for 2010, 2015 and 2020 for the measures listed in Tables 2.1 - 2.3 have been used in this report. These measures fall into three groups:

- road transport (measures A-H);
- stationary sources (I-N);
- combined measures (O-Q).

Air quality concentration modelling has only been carried out for selected measures as indicated in the level of analysis column in tables 2.1-2.3. For measures where concentration modelling has been carried out, emissions projections have been mapped using the same method as used in the baseline projections report (see Grice et al, 2006).

Table 2.1 UK road transport emissions projection measures

	Name of measure	Description of measure	When it applies	Where it applies	Level of analysis
A	New Euro Standard V/VI – Low intensity	This measure proposes: 20% reduction in NOX from all new diesel LDVs (Euro V) 90% reduction in PM emissions from all new LDVs (Euro V) 50% reduction in NOX from new diesel HDVs (Euro VI). Durability at 100,000km	This measure is introduced from: 2010 for cars and LDVs 2013 for HDVs.	This measure applies to all EU countries	Concentrations modelled
B	New Euro Standard V/VI – High intensity	This measure proposes: 50% reduction in NOX from all new petrol LDVs (Euro V) from 2010 40% reduction in NOX from new diesel HDVs (Euro V, stage 1) from 2010 68% reduction in NOX from all new LDVs (Euro V, stage 2) from 2015 75% reduction in NOX from new HDVs (Euro VI) from 2013 90% reduction in PM from all new diesel vehicles (LDVs + HDVs) (Euro V) Durability at 100,000km	This measure is introduced from: 2010 for LDVs (for initial reduction in NOX) 2015 for LDVs (for tighter reduction in NOX) 2013 for HDVs	This measure applies to all EU countries	Concentrations modelled
C	Programme of incentives for early uptake of Euro V and VI Standards	This measure assumes that a programme of incentives is introduced for early introduction of Euro V and Euro VI. This measure is to be implemented based on Measure A i.e. the policy reverts back to Measure A after the incentives have taken effect The uptake rates of these incentives are: 2006: 0% Euro V LDVs 0% Euro V HDVs 2007: 25% Euro V LDVs 15% Euro V HDVs 2008: 50% Euro V LDVs 23% Euro V HDVs 2009: 75% Euro V LDVs (Euro V now mandatory for HDVs) 2010: 25% Euro VI HDVs (Euro V now mandatory for LDVs) 2011: 50% Euro VI HDVs 2012: 75% Euro VI HDVs 2013+ (Euro VI now mandatory for HDVs)	This measure is introduced from: 2007 for LDVs (Euro V) 2010 for HDVs (Euro VI)	This measure applies to UK	Concentrations modelled
D	Programme of incentives to phase out the most polluting vehicles (divided into two sub-measures)	Measure D1: This scenario models scrappage of all pre-Euro cars (emissions only modelled) Measure D2: This scenario models scrappage of all pre Euro and Euro-I cars (concentrations modelling) All pre-Euro cars in Measure D1 and the Euro-I passenger cars in Measure D2 are assumed to be scrapped at rates of: 25% by 2007, 50% by 2008 and 100% by 2009 and replaced by Euro IV	This measure is introduced from 2007	This measure applies to UK	D1: Emissions data only D2: Concentrations modelled

	Name of measure	Description of measure	When it applies	Where it applies	Level of analysis
E	Programme of incentives to increase penetration of low emission vehicles (LEV)	Petrol LEVs assumed to deliver 38% reduction in NOX and 34% reduction in CO2 compared to Euro IV petrol cars. Penetration of petrol LEVs 10% by 2010, 25% by 2020 Diesel LEVs assumed to deliver 80% reduction in NOX, 92% reduction in PM10 and 28% reduction in CO2 compared to Euro IV diesel cars. Penetration of diesel LEVs 5% by 2010, 20% by 2020 It is assumed that petrol LEVs replace non-LEV petrol cars, diesel LEVs replace non-LEV diesel cars	This measure is introduced from 2006	This measure applies to UK	Concentrations modelled
F	Impact of national road pricing scheme on air quality	The measure is based on the work that was done for the Road User Charging Feasibility study. Emissions based on the analytical work that assumed marginal cost pricing, using 10 charges capped at 80p. The emissions from the modelling have then been used as a basis for projections from 2015	This measure is introduced from 2015	This measure applies to UK	Concentrations modelled
G	Low Emission Zones (divided into three sub-measures)	Measures for London: Measure G1: 2007 – HDVs adopt Euro II + RPC Measure G2: 2010 – HDVs adopt Euro III + RPC Measure for 7 largest urban areas outside London: Measure G3: 2010 – HDVs adopt Euro II + RPC. 2013 – HDVs adopt Euro III + RPC	This measure is introduced from: G1: 2007 for London G2: 2010 for London G3: 2010 for 7 largest urban areas outside London	G1: London G2: London G3: 7 largest urban areas outside London	G1: Emissions data only G2 and G3 combined: concentrations modelled
H	Retrofit (Diesel Particulate Filters) DPFs on HDV and captive fleets (buses and coaches)	Measure H1: 65% pre-Euro I to Euro IV HDVs retrofitted with Diesel Particulate Filters (DPFs) + Fuel Borne Catalysts (FBCs) by 2010 Measure H2: 20% pre-Euro I to Euro IV HDVs retrofitted with Pt-coated DPFs by 2010. Measure H3: 35% pre-Euro I to Euro IV HDVs retrofitted with Pt-coated DPFs by 2010	This measure is introduced from 2006	This measure applies to UK	Emissions data only

Table 2.2 UK non-road transport emissions projection measures

	Name of measure	Description of measure	When it applies	Where it applies	Level of analysis
I	Domestic combustion: switch from coal to natural gas or oil	The switch from coal to natural gas (70% in GB) or to oil (30% in GB) is assumed. However, in Northern Ireland a larger switch from coal to oil (70%) and smaller switch to gas (30%) is assumed.	This measure is introduced from 2006, and fully implemented by 2010	This measure applies to UK	Emissions data only
J	Domestic combustion : Product standards for gas fired appliances which require tighter NOX emission standards.	New appliances post 2008 fitted to at least CEN 483 Class 4 for gas fired appliances. Replacement rate of 5% of the boilers assumed per year i.e. assumes a 20 year lifespan of existing older 'high NOX' boilers.	This measure is introduced from 2008	This measure applies to all EU countries	Concentrations modelled
K	Large combustion plant measure	Measure K1: brings forward to 2010 the implementation of SCR on coal fired power stations with generating capacity > 300 MW) Measure K2: assumes SCR on gas fired power stations, iron and steel plants and petrol refineries by 2010.	This measure is introduced from 2010	K1: Measure applies to UK K2: This measure applies to all EU countries	K1: Emissions data only K2: Concentrations modelled
L	Small combustion plant measure	50% reduction in NO2 and SO2 in small combustion plants (20-50 MW). This measure is due to be applied following a potential EU Small Combustion Plant Directive or revision of existing IPPC or LCPD Directive in 2008.	This measure is due to be implemented in 2013	This measure applies to all EU countries	Concentrations modelled
M	Reducing national VOC emissions by 10%	The various measures used to achieve this target are: Petrol stations Stage II controls (> 3000m3 throughput) Chemical and man made fibre production: thermal oxidation (TO) road tanker vapour recovery storage tank replacement programme (TRP) leak detection & repair (LDAR) - BAU second stage vapour recovery unit (VRU) cryogenic condensation (CC) Offshore loading of crude oil modification to shuttle tankers (MST) modification to floating production, storage & off-take vessels (MFPSO) vapour recovery unit (from ship loading)	This measure is introduced from 2010	This measure applies to UK	Concentrations modelled

	Name of measure	Description of measure	When it applies	Where it applies	Level of analysis
N	Shipping Measure through IMO	Requirements on global fleet (for all ships > 100 tonnes) to: Use 1% rather than 1.5% Sulphur fuel from 2010 (applies to old and new vessels from 2010) Reduce NOX emissions by 25% from new ships from 2010 The introduction rate of new ships is assumed to be 1/30th of fleet per year.	The scheme is due to start from 2010	This measure applies to UK and all maritime	Concentrations modelled

Table 2.3 Combined measures affecting UK emissions projections

	Name of measure	Description of measure	Level of analysis
O	Combined measures C + E	See Measures C and E above.	Concentrations modelled
P	Combined measures C + L	See Measures C and L above	Concentrations modelled
Q	Combined measures C + E + L	See Measures C, E and L above	Concentrations modelled

2.2 ROAD TRAFFIC MEASURES

Emissions on individual road links and the background area source road transport emissions maps have been calculated for each measure. Details of assumptions made in generating emissions projections for each measure are given in Appendix 1.

The majority of the road transport measures (measures A-E and G) affect emissions through changes in the overall make up of the vehicle fleet. This affects the emission factors (i.e. how much of a given pollutant is emitted per vehicle km travelled) for each vehicle class (e.g. car, LGV) and area type due to technology changes without changing the number of vehicle km travelled by each vehicle class on each road link or in each grid square. To map road transport emissions for these measures, the method set out in Grice et al (2006) has been followed with the emission factors for each measure rather than the baseline being used.

Measure G only has an affect on area types 1 to 5 (London and large conurbations) and so baseline numbers have been used for area types 6 to 11 for this measure. For minor road emissions, the baseline map was used as total emissions for this sector showed very little deviation from the baseline. The baseline map was also used for cold start emissions because this measure should only effect heavy vehicles and cold start emissions tend to be associated with light vehicles.

Measure F affects the distribution and number of vehicles on the road and therefore the activity data (i.e. number of vehicle km per vehicle type and area type) as well as emission factors. Therefore for this measure emission factors and vehicle km data have been calculated for each road link and new vehicle km maps have been calculated for distributing minor road and brake and tyre wear maps across the UK. Measure F has no effect on Northern Ireland and so the baseline maps have been used in Northern Ireland for this measure.

A summary of projected emissions from road transport and UK total projected emissions are presented in tables 2.4 to 2.7. Modelling for the measures has only been carried out for 2010, 2015 and 2020 so numbers are presented for these years only. Tables 2.1-2.3 detail for which of these measures, GIS-based concentration modelling has been done.

Table 2.4 Projections of road transport NO_X emissions (ktonnes yr^{-1})

AQS Measure ref	2003	2005	2010	2015	2020
Base	654.9	572.3	396.2	290.5	267.8
A			393.6	256.7	202.4
B			387.2	212.5	126.5
C			385.4	244.9	198.1
D1			395.3	290.5	267.8
D2			387.9	290.3	267.8
E			394.6	285	256.6
F			396.2	284.7	262.5
G			395.4	290.4	267.8
H1			396.2	290.5	267.8
H2			396.2	290.5	267.8
H3			396.2	290.5	267.8
O			384.0	240.2	188.8

Table 2.5 Projections of UK total NO_X emissions (ktonnes yr^{-1})

AQS Measure ref	2003	2005	2010	2015	2020
Base	1529.8	1429.3	1151.0	1030.3	910.7
A			1148.4	996.5	845.3
B			1142.1	984.7	841.0
C			1140.3	984.7	841.0
D1			1150.2	1030.3	910.7
D2			1142.8	1030.1	910.7
E			1149.5	1024.8	899.5
F			1151.0	1024.5	905.4
G			1150.2	1030.2	910.7
H1			1151.0	1030.3	910.7
H2			1151.0	1030.3	910.7
H3			1151.0	1030.3	910.7
O			1138.8	980.0	831.7

Table 2.6 Projections of road transport PM_{10} emissions (ktonnes yr^{-1})

AQS Measure ref	2003	2005	2010	2015	2020
Base	28.2	25.4	18.7	14.5	14.0
A			17.7	8.9	5.0
B			17.7	8.4	3.9
C			16.3	7.9	4.6
D1			18.7	14.5	14.0
D2			18.5	14.5	14.0
E			18.6	14.3	13.5
F			18.7	14.2	13.7
G			18.5	14.5	14.0
H1			16.7	14.1	14.0
H2			18.2	14.4	14.0
H3			17.7	14.3	14.0
O			16.3	7.9	4.6

Table 2.7 Projections of UK total PM_{10} emissions (ktonnes yr^{-1})

AQS Measure ref	2003	2005	2010	2015	2020
Base	156.5	148.5	134.9	135.4	143.5
A			133.9	129.7	134.6
B			133.9	129.2	133.5
C			132.5	128.8	134.2
D1			134.9	135.4	143.5
D2			134.7	135.4	143.5
E			134.9	135.1	143.0
F			134.9	135.1	143.3
G			134.8	135.3	143.5
H1			133.0	134.9	143.5
H2			134.4	135.2	143.5
H3			133.9	135.1	143.5
O			132.5	128.7	134.1

2.3 STATIONARY SOURCE MEASURES

For measures affecting stationary source emissions, emissions projections for sectors affected for each measure are presented in tables 2.8 to 2.11. Sectors not included in these tables have been assumed to remain at baseline levels for the measure in question.

Table 2.8 Projected emissions for measure J (Domestic combustion : Product standards for gas fired appliances which require tighter NOx emission standards) (ktonnes yr^{-1})

NO_X emissions							
Source	**Fuel**	**2010**		**2015**		**2020**	
		Base	**J**	**Base**	**J**	**Base**	**J**
Domestic	natural gas	58.3	55.5	59.0	51.2	60.5	47.6

Table 2.9 Projected emissions for measure K (Large combustion plant measure) (ktonnes yr^{-1})

NO_X emissions							
Source	**Fuel**	**2010**		**2015**		**2020**	
		Base	**K**	**Base**	**K**	**Base**	**K**
Refineries_(Combustion)	all fuels	30.1	9.6	30.2	9.7	30.3	9.7
Power stations	natural gas	35.0	7.0	41.9	8.38	35.8	7.2
Power stations	coal	159.1	31.8	134.7	26.9	32.0	32.0
Iron and steel	all fuels	23.5	4.7	23.4	4.7	23.4	4.7

Table 2.10 Projected emissions for measure L (Small combustion plant measure) (ktonnes yr^{-1})

NO_X emissions					
Source	**Fuel**	**2015**		**2020**	
		Base	**L**	**Base**	**L**
Miscellaneous	all fuels	14.3	13.7	14.7	14.1
Public services	all fuels	17.2	16.6	18.5	17.9
Autogenerators	all fuels	15.7	15.6	16.5	16.4
Other industry combustion	all fuels	77.7	67.8	81.9	71.4
SO_2 emissions					
Source	**Fuel**	**2015**		**2020**	
		Base	**L**	**Base**	**L**
Public services	all fuels	5.2	4.7	5.11	4.61
Autogenerators	all fuels	17.6	17.4	16.91	16.65
Other industry combustion	all fuels	43.1	38.3	42.9	38.1

Table 2.11 Projected emissions for measure N (Shipping Measure through IMO) (ktonnes yr^{-1})

NO_X emissions							
Source	**Fuel**	**2010**		**2015**		**2020**	
		Base	**N**	**Base**	**N**	**Base**	**N**
Coastal	Fuel & gas oil	30.5	29.7	30.1	25.6	28.9	20.9
fishing	gas oil	3.9	3.8	3.9	3.3	3.7	2.7
SO_2 emissions							
Source	**Fuel**	**2010**		**2015**		**2020**	
		Base	**N**	**Base**	**N**	**Base**	**N**
Coastal	Fuel oil	1.6	1.0	1.5	1.0	1.4	0.9

2.4 COMBINED MEASURES

The combined measures are listed in table 2.12.

Table 2.12 Measure descriptions

Measure	**Description**
O	C + E
P	C + E + L
Q	C + L

Where:
- C = Programme of incentives for early uptake of Euro V and VI Standards
- E = Updated programme of incentives to increase penetration of low emissions vehicles
- L = Small combustion plant measure

Projected emissions for NO_X and PM_{10} from road transport and UK total projected emissions for measure C (used in measure P) and measure O (also used in measure Q) are included in tables 2.4 to 2.7. Sectoral emissions from the non-traffic measure L (used in measures Q and P are listed in table 2.10.

Emissions of $PM_{2.5}$ on individual road links for combined road transport measures have been calculated as PM_{10} road link emissions for the relevant measure multiplied by a factor of 0.9 as recommended by AQEG (AQEG, 2005).

Road transport emissions maps used in the area source model for $PM_{2.5}$ have been calculated by scaling the baseline $PM_{2.5}$ maps of this for the relevant year by the ratio of the road transport area source PM_{10} map for the relevant measure to the baseline PM_{10} area source road transport map. Similarly brake and tyre wear emission maps for the area source model have been scaled using the ratio of these maps for PM_{10} for the relevant measure divided by the baseline for the relevant year.

3 Modelling method

3.1 INTRODUCTION

Using the emissions data set out in section 2, projected annual mean concentrations of NO_2 and PM_{10} have been modelled for 2010, 2015 and 2020 for 7 road traffic measures, 4 stationary source measures and 3 combined measures. Table 3.1 presents a summary of the emissions measures used in concentration modelling.

Table 3.1 Summary of emissions measures used for concentration modelling.

Measure	Description
baseline	Current policies
A	Euro 5 and VI low
B	Euro 5 and VI high
C	Euro 5 and VI low including early introduction
D	Phase out of pre-Euro and Euro 1
E	LEV scenario
F	road user charging scenario
G	Low Emission zone
J	Domestic gas combustion NO_X: new product standards
K	NOx reductions at power stations, refineries, iron and steel
L	Small Combustion Plant Directive: NO_X and SO_2 (NB does not start until 2013, so no impact in 2010)
N	Shipping measure: NO_X and SO_2 reductions
O	Combined C + E
P	Combined C + L
Q	Combined C +L + E

A description of the modelling methods used to produce projected concentration maps for 2005, 2010, 2015 and 2020 for the baseline (i.e. under current policies) is given in Grice et al (2006). A similar method has been used to calculate projected concentration maps for each additional policy measure considered in this report. The basic modelling method used involves calculating background annual mean concentrations for each pollutant at a 1km^2 resolution. Background concentrations are made up from contributions from a number of sources (e.g. NO_x modelling has contributions from distant sources, large and small point sources and area sources). A roadside increment is then calculated for major roads in built up areas and added to the background concentration. This roadside concentration only applies within 10m of the road modelled.

For all the measures for NO_2 and PM_{10}, projections have been calculated using a base year of 2003. For measures Q and P, which are combined measures, a base year of 2002 has also been used. This enables a comparison of the baseline projections under different meteorological conditions and a comparison of the effectiveness of the combined measures under different meteorological conditions. This provides an estimate of the sensitivity of results to assumptions about the weather in a future year.

Projected annual mean $PM_{2.5}$ concentrations have only been modelled for the measures Q and P using a 2003 base year.

A description of how these emissions measures have been implemented in the concentration modelling for NO_2 and NO_X, PM_{10} and $PM_{2.5}$ is given below.

3.2 NO_2/NO_X

Modelling projected NO_x and NO_2 concentrations closely follows the method for the base year set out in Stedman et al (2005) and the baseline projections described in Grice et al (2006). A fuller description of the modelling methods used is given in these reports with a brief summary presented here.

Background annual mean NO_X concentrations have been considered to be made up from contributions from

- Distant sources (characterised by rural background concentrations)
- Large point sources (i.e. point sources with emissions of greater than 500 tonnes yr^{-1} in the 2002 NAEI)
- Small point sources (i.e. point sources with emissions of less than 500 tonnes yr^{-1} in the 2002 NAEI)
- Local area sources

In line with the baseline modelling, the area source calibration from 2003 for NO_X has been used for the projected measures.

At locations close to busy roads an additional projected roadside contribution, the roadside increment, has been added to account for contributions to total NO_X from road traffic sources:

Roadside NO_X concentration = background NO_X concentration + roadside NO_X increment

The method for projecting annual mean concentration of NO_X and NO_2 for 2010, 2015 and 2020 for the measures closely follows the method for baseline projections as set out in Grice et al (2006). Differences are described below.

3.2.1 Road traffic measures

The contribution of area source emissions to background annual mean NO_X concentration has been modelled using the new 1 x 1 km area source NO_X road transport emissions maps for each road traffic measure described in section 2.2.

The roadside increment for road traffic measures has been modelled using the new estimates of NO_X emissions from major road links for 2010, 2015 and 2020 for each measure (see section 2.2).

Rural NO_X concentrations have been predicted by scaling the base year concentration field by the predicted change in UK total NO_X emissions for each measure.

3.2.2 Stationary measures

For measure J (Domestic combustion : Product standards for gas fired appliances which require tighter NOx emission standards) the area source contribution to background NO_X has been modelled with the reduction in domestic emissions, which is the sector that this measure affects.

Large point sources for the relevant sectors have been modelled for measure K (Large combustion plant measure) using the measure K emissions projections for these sectors.

In measure L (Small combustion plant measure), the area source contribution to background NO_X has been modelled to take into account the reduction in emissions for the relevant sectors. This measure has no effect until 2013, so only 2015 and 2020 have been modelled for this measure.

For measure N (Shipping Measure through IMO), area source shipping emissions have been reduced by the relevant amounts.

Rural NO_X has been estimated for each of the stationary source measures on the basis of the change in the UK total NO_X emissions. Total maritime NO_X emissions have been assumed to contribute 10% of the rural NO_X concentration field for measure N. This compares well with a source apportionment of regional NO_x concentrations at a 50 x 50 km^2 spatial scale carried out by Imperial College (Oxley, T. personal communication, 2005).

3.2.3 Combined measures

For Measure O (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + E (Updated programme of incentives to increase penetration of low emissions vehicles)), emissions projections for this measure have been used (see section 2.2) and then this measure has been modelled in the same way as the other road transport measures.

Measure P (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure)) combines the emissions reductions for road transport in measure C and the sectors in measure L in the area source model.

Measure Q (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) combines the reductions in emissions projections for road transport in measure O (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) and the sectors in measures L (Small combustion plant measure) in the area source model.

3.3 PM_{10}

Modelling projected annual mean PM_{10} concentrations closely follows the method for the base year set out in Stedman et al (2005) and the baseline projections described in Grice et al (2006). A fuller description of the modelling methods used is given in these reports with a brief summary presented here.

Similar to Stedman et al (2005) the projected maps of annual mean background concentrations are made up of contributions from:

- Large point sources of primary particles (i.e. point sources with emissions of greater than 200 tonnes yr^{-1} in the 2002 NAEI)
- Small point sources of primary particles (i.e. point sources with emissions of less than 200 tonnes yr^{-1} in the 2002 NAEI)
- Area sources of primary particles
- Secondary particles
- Residual particle concentrations, not explicitly modelled.

An additional roadside increment is added for roadside locations.

The method for projecting annual mean concentration of PM_{10} for 2010, 2015 and 2020 for the measures closely follows the method for baseline projections as described in Grice et al (2006). Differences are described below.

3.3.1 Road traffic measures

The contribution of area source emissions to background annual mean PM_{10} concentration has been modelled using the new 1 x 1 km area source PM_{10} road transport emissions maps for each road transport measure described in section 2.2. Additionally, for measure F for PM_{10}, new brake and tyre wear maps have been used in the area source model.

The roadside increment for road traffic measures has been modelled using the new estimates of PM_{10} emissions from major road links for 2010, 2015 and 2020 (see section 2.2).

Secondary PM_{10} has been estimated for each road transport measure on the basis of reductions in nitrates resulting from reductions in emissions of NO_X relative to the baseline in the road traffic measures.

3.3.2 Stationary measures

Primary emissions of PM_{10} are unaffected by the stationary source measures.

Secondary PM_{10} has been estimated for each of the stationary source measures on the basis of reductions in sulphates and nitrates resulting from reductions in emissions of SO_2 and NO_X relative to the baseline measures for the non-traffic measures.

3.3.3 Combined measures

Road transport emissions area source maps and link emissions from measure C (Programme of incentives for early uptake of Euro V and VI Standards) have been used in modelling measure P (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure)). Road transport emissions area source maps and link emissions from measure O (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) have been used in modelling measures O and Q (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure) + E (Updated programme of incentives to increase penetration of low emissions vehicles)).

Secondary PM_{10} has been estimated on basis of reductions in emissions in all sectors included in combined measures relative to baseline projections for the relevant year. Baseline projections have been derived from the EMEP model as described in Grice et al (2006).

3.4 $PM_{2.5}$

Projected maps of annual mean $PM_{2.5}$ concentrations for the measures P and Q have been calculated. As in Grice et al (2006), gravimetric concentrations of $PM_{2.5}$ have been modelled directly. This has been done using the same method as in the baseline projections, with the following differences:

Road transport emissions area source maps and link emissions for measure for the relevant measures have been used in measures P (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) and Q (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure)+ L (Small combustion plant measure)).

Secondary $PM_{2.5}$ has been estimated on basis of reductions in sulphates and nitrates caused by reduced emissions of SO_2 and NO_X in all sectors included in combined measures relative to baseline projections for the relevant year. Baseline projections have been derived from the EMEP model as described in Grice et al (2006).

4 NO_2 Results

4.1 ALL MEASURES USING A 2003 BASE YEAR

The modelling results for the baseline and each of the measures for 2010, 2015 and 2020 are summarised in tables 4.1 to 4.3 in terms of a comparison of modelled concentrations with the annual mean objective for NO_2 of 40 µg m^{-3}. As with the 2003 modelling results described in Stedman et al (2005), estimates of area exceeding and population exposed have been derived from the background maps. No attempt has been made to derive estimates of population exposed using roadside concentrations because these maps will only apply within approximately 10 metres of the road kerb. Accurately representing the population distribution at an appropriate level of detail for this would be impractical in a national scale assessment. The estimates of population exposed may therefore underestimate actual population exposure where members of the population live near roads.

All of the measures are predicted to reduce the extent of exceedences relative to the baseline for the years in which they operate except measure D (Programme of incentives to phase out the most polluting vehicles) in 2020. The most effective measure is measure K (Large combustion plant measure) in 2010 and measure B (New Euro Standard V/VI – High intensity) in 2015 and 2020. For all years, the combined measures (O, Q and P) and measure C (Programme of incentives for early uptake of Euro V and VI Standards) perform well, with measure A (New Euro Standard V/VI - Low intensity) also having a significant impact in 2015 and 2020.

Population-weighted annual mean NO_2 concentrations at background locations are presented in Table 4.4. This statistic represents the average concentration exposure of the UK population and can be used to calculate the health impacts of air pollutants and the expected health benefits resulting from reductions in ambient concentrations. The population-weighted mean concentrations for the measures show a similar, but not identical pattern of changes with the different measures to the extent of exceedences. The effectiveness of the measures for population-weighted mean is:

- 2010: K > O = Q = C > P > B > D > J > A > E > G > N > baseline = L = F
- 2015: B > Q > P > K > O > C > A > F > L > J > E > N > D > G > baseline
- 2020: B > Q > P > O > C > A > J > K > L > F > E > N > G > baseline = D

The concentrations presented in table 4.4 are given to a higher degree of precision than the modelling method warrants so that small differences in the model outputs can be seen. This is useful when certain measures only result in small changes, for example in the 3rd decimal place.

Table 4.1 Total road length (km) exceeding the NO_2 annual mean objective of 40 μg m^{-3}

2010																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	1886	1023.6	1006.0	988.7	991.7	993.0	1013.8	1023.6	988.7	1013.8	983.4	1023.6	1021.9	988.6	991.7	988.6
Rest of England	9430	1372.1	1352.0	1306.4	1300.8	1306.2	1358.6	1372.1	1357.2	1359.6	1290.7	1372.1	1369.7	1298.1	1300.8	1298.1
Scotland	1085	111.8	111.8	108.5	106.2	110.1	111.8	111.8	111.8	111.8	110.1	111.8	111.8	106.2	106.2	106.2
Wales	640	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	40.7	42.2	40.7
Northern Ireland	1044	17.6	17.6	17.6	14.0	14.0	17.6	17.6	17.6	17.6	17.6	17.6	17.6	14.0	14.0	14.0
Total	14084	2567.4	2529.7	2463.5	2455.0	2465.6	2544.0	2567.4	2517.5	2545.0	2443.9	2567.4	2563.2	2447.6	2455.0	2447.6
Percentage >40 μgm^{-3}		18.2%	18.0%	17.5%	17.4%	17.5%	18.1%	18.2%	17.9%	18.1%	17.4%	18.2%	18.2%	17.4%	17.4%	17.4%
2015																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	1886	651.5	534.0	398.7	511.4	651.5	634.6	490.4	643.7	632.4	616.7	625.9	646.1	496.2	488.6	478.0
Rest of England	9430	679.7	546.6	390.4	488.6	677.8	651.6	627.6	678.7	667.4	644.4	656.4	677.8	482.8	482.9	467.8
Scotland	1085	51.4	43.1	23.4	39.4	50.8	47.7	44.7	50.8	47.7	47.7	47.7	50.8	32.2	34.5	32.2
Wales	640	22.3	17.5	12.9	15.1	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	15.1	15.1	12.9
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	1404.9	1141.2	825.4	1054.6	1402.4	1356.3	1185.0	1395.5	1369.8	1331.1	1352.4	1397.0	1026.3	1021.1	990.9
Percentage >40 μgm^{-3}		10.0%	8.1%	5.9%	7.5%	10.0%	9.6%	8.4%	9.9%	9.7%	9.5%	9.6%	9.9%	7.3%	7.3%	7.0%
2020																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	1886	564.2	377.6	171.0	371.4	564.2	532.2	412.5	564.2	527.4	552.8	540.1	561.9	333.7	340.9	310.0
Rest of England	9430	569.6	281.5	15.9	238.7	569.6	529.7	527.8	569.6	557.8	555.9	557.5	561.8	182.0	221.9	179.7
Scotland	1085	42.6	17.6	0.0	14.3	42.6	37.9	37.9	42.6	41.0	41.0	41.0	41.0	9.3	10.8	5.5
Wales	640	17.5	5.7	0.0	3.7	17.5	17.5	15.1	17.5	17.5	17.5	17.5	17.5	3.7	3.7	3.7
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	1193.8	682.4	186.9	628.0	1193.8	1117.3	993.4	1193.8	1143.8	1167.2	1156.1	1182.2	528.6	577.3	498.9
Percentage >40 μgm^{-3}		8.5%	4.8%	1.3%	4.5%	8.5%	7.9%	7.1%	8.5%	8.1%	8.3%	8.2%	8.4%	3.8%	4.1%	3.5%

Table 4.2 Total background area (km^2) exceeding the NO_2 annual mean objective of 40 $\mu g\ m^{-3}$

2010

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	55	55	54	54	54	55	55	54	54	49	55	55	54	54	54
Rest of England	128770	19	19	17	17	17	19	19	19	19	16	19	19	16	17	16
Scotland	77791	2	1	1	1	1	2	2	2	1	1	2	2	1	1	1
Wales	20745	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	242248	76	75	72	72	72	76	76	75	74	66	76	76	71	72	71
Percentage >31.5 μgm^{-3}		0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%

2015

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	39	38	35	36	39	39	36	39	39	38	38	37	36	35	35
Rest of England	128770	12	9	8	9	12	11	10	12	12	11	10	11	8	8	8
Scotland	77791	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	242248	51	47	43	45	51	50	46	51	51	49	48	48	44	43	43
Percentage >31.5 μgm^{-3}		0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%

2020

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	38	35	30	35	38	38	35	38	36	38	35	38	35	32	31
Rest of England	128770	15	9	6	8	15	13	14	15	13	13	13	15	8	8	8
Scotland	77791	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	242248	53	44	36	43	53	51	49	53	49	51	48	53	43	40	39
Percentage >31.5 μgm^{-3}		0.02%	0.02%	0.01%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%

Table 4.3 Population in area exceeding the NO_2 annual mean objective of 40 μg m^{-3}

2010																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	7730326	319019	319019	305296	305296	305296	319019	319019	305296	305296	250184	319019	319019	305296	305296	305296
Rest of England	41011137	17395	17395	12817	12817	12817	17395	17395	17395	17395	11528	17395	17395	11528	12817	11528
Scotland	4944573	6547	1547	1547	1547	1547	6547	6547	6547	1547	1547	6547	6547	1547	1547	1547
Wales	2850727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	58160071	342961	337961	319661	319661	319661	342961	342961	329238	324238	263260	342961	342961	318371	319661	318371
Percentage >31.5 μgm^{-3}		0.59%	0.58%	0.55%	0.55%	0.55%	0.59%	0.59%	0.57%	0.56%	0.45%	0.59%	0.59%	0.55%	0.55%	0.55%
2015																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	7730326	156502	154748	120633	135142	156502	156502	135142	156502	154748	154748	145604	156502	135142	120633	120633
Rest of England	41011137	5946	4837	4668	4837	5946	5224	4966	5946	5224	4966	5224	5224	4668	4668	4668
Scotland	4944573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	58160071	162448	159584	125301	139979	162448	161726	140108	162448	159972	159714	150829	161726	139810	125301	125301
Percentage >31.5 μgm^{-3}		0.27%	0.27%	0.22%	0.24%	0.28%	0.28%	0.24%	0.28%	0.28%	0.27%	0.26%	0.28%	0.24%	0.22%	0.22%
2020																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	7730326	154748	120633	102236	120633	154748	154748	120633	154748	135142	154748	120633	154748	120633	108313	104328
Rest of England	41011137	6071	4837	3384	4668	6071	5998	5812	6071	5998	5998	5998	6071	4668	4668	4668
Scotland	4944573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	58160071	160819	125470	105621	125301	160819	160746	126446	160819	141140	160746	126631	160819	125301	112980	108995
Percentage >31.5 μgm^{-3}		0.22%	0.22%	0.18%	0.22%	0.28%	0.28%	0.22%	0.28%	0.24%	0.28%	0.22%	0.28%	0.22%	0.19%	0.19%

Table 4.4 Population weighted mean NO_2 concentration using a 2003 base year (µg m^{-3})

2010														
	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
Scotland	13.410	13.368	13.266	13.257	13.273	13.383	13.410	13.399	13.342	12.814	13.410	13.401	13.232	13.257	13.232
Wales	13.531	13.495	13.401	13.390	13.405	13.509	13.531	13.528	13.480	12.440	13.531	13.519	13.367	13.390	13.367
Northern Ireland	9.249	9.215	9.136	9.137	9.119	9.232	9.249	9.247	9.237	8.582	9.249	9.240	9.120	9.137	9.120
Inner London	34.022	33.909	33.708	33.738	33.781	33.981	34.022	33.823	33.820	33.036	34.022	34.010	33.699	33.738	33.699
Outer London	27.774	27.697	27.531	27.541	27.553	27.738	27.774	27.643	27.620	26.784	27.774	27.762	27.506	27.541	27.506
Rest of England	19.274	19.230	19.113	19.094	19.116	19.247	19.274	19.264	19.208	18.177	19.274	19.260	19.067	19.094	19.067
UK	19.522	19.473	19.352	19.339	19.359	19.494	19.522	19.494	19.445	18.493	19.522	19.509	19.311	19.339	19.311
2015															
	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
Scotland	11.853	11.346	10.603	11.158	11.849	11.758	11.645	11.851	11.653	11.271	11.585	11.585	11.079	10.888	10.806
Wales	11.966	11.467	10.707	11.296	11.963	11.879	11.829	11.966	11.808	10.864	11.730	11.730	11.209	11.033	10.943
Northern Ireland	7.960	7.608	7.065	7.487	7.956	7.882	7.909	7.959	7.918	7.327	7.871	7.871	7.407	7.384	7.311
Inner London	31.591	30.723	29.528	30.494	31.585	31.444	30.293	31.557	31.036	30.728	30.914	30.914	30.367	29.812	29.684
Outer London	25.535	24.814	23.779	24.597	25.529	25.405	24.833	25.518	25.113	24.674	25.172	25.172	24.483	24.231	24.116
Rest of England	17.336	16.728	15.862	16.515	17.332	17.229	17.142	17.335	17.139	16.257	17.095	17.095	16.419	16.263	16.168
UK	17.608	17.001	16.132	16.794	17.604	17.500	17.332	17.604	17.383	16.610	17.340	17.340	16.697	16.516	16.420
2020															
	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
Scotland	11.314	10.327	9.098	10.261	11.314	11.112	11.120	11.314	10.972	11.072	11.023	11.023	10.104	9.975	9.807
Wales	11.176	10.170	8.948	10.102	11.176	10.963	11.031	11.176	10.892	10.727	10.898	10.898	9.938	9.833	9.669
Northern Ireland	7.378	6.722	5.965	6.674	7.378	7.220	7.330	7.378	7.311	7.156	7.282	7.282	6.555	6.584	6.457
Inner London	30.927	29.367	27.504	29.277	30.927	30.625	29.709	30.924	29.997	30.617	30.191	30.191	29.021	28.533	28.276
Outer London	24.818	23.466	21.820	23.384	24.818	24.547	24.156	24.817	24.103	24.503	24.422	24.422	23.156	22.987	22.756
Rest of England	16.435	15.200	13.626	15.116	16.435	16.210	16.252	16.435	16.096	16.025	16.168	16.168	14.915	14.833	14.629
UK	16.777	15.568	14.046	15.487	16.777	16.549	16.516	16.777	16.392	16.397	16.482	16.482	15.290	15.181	14.980

4.2 MEASURES P AND Q USING A 2003 AND 2002 BASE YEAR

Tables 4.5 to 4.7 present the results of measures P (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure)) and Q (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) in terms of a comparison of modelled concentrations with the annual mean objective for NO_2 of 40 µg m^{-3} for a 2003 and 2002 base year. Population-weighted annual mean NO_2 concentrations for the two different base years at background locations are presented in Table 4.8.

The combined measures are predicted to have a similar impact on concentrations in 2010, 2015 and 2020 for the two different base years. The relative effectiveness of the different measures remains the same for the two different base years. The extent of exceedence for these years is lower for the 2002 base year and this is reflected in the changes in percentage exceedence.

The population-weighted mean concentrations show a similar, but not identical pattern of changes with the different measures to the extent of exceedences. The change in population-weighted mean for each measure relative to the baseline measure is shown in Table 4.9. The predicted population-weighted mean background concentrations predicted from 2002 are typically about 85% of those predicted from 2003 and this is reflected in the changes in concentrations for the measures, which are also about 85% of those predicted from the 2003 base year.

Table 4.5 Total road length (km) exceeding the NO_2 annual mean objective of 40 µg m^{-3} using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	1023.6	993.0	1006.0	724.0	687.4	683.8
Rest of England	9430	1372.1	1306.2	1352.0	834.2	792.4	785.1
Scotland	1085	111.8	110.1	111.8	61.9	57.4	57.4
Wales	640	42.2	42.2	42.2	27.3	22.7	22.7
Northern Ireland	1044	17.6	14.0	17.6	7.5	0.0	0.0
Total	14084	2567.4	2465.6	2529.7	1655.0	1559.9	1549.1
Percentage >40 µg m^{-3}		18.23%	17.51%	17.96%	11.75%	11.08%	11.00%

2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	651.5	478.0	488.6	420.8	285.7	275.6
Rest of England	9430	679.7	467.8	482.9	465.0	311.3	299.6
Scotland	1085	51.4	32.2	34.5	31.4	10.8	7.0
Wales	640	22.3	12.9	15.1	15.1	8.2	3.7
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	1404.9	990.9	1021.1	932.3	616.0	585.9
Percentage >40 µg m^{-3}		9.98%	7.04%	7.25%	6.62%	4.37%	4.16%

2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	564.2	310.0	340.9	358.5	151.0	140.6
Rest of England	9430	569.6	179.7	221.9	384.5	69.3	59.8
Scotland	1085	42.6	5.5	10.8	21.4	2.8	2.8
Wales	640	17.5	3.7	3.7	12.9	1.3	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	1193.8	498.9	577.3	777.4	224.5	203.2
Percentage >40 µg m^{-3}		8.48%	3.54%	4.10%	5.52%	1.59%	1.44%

Table 4.6 Total background area (km^2) exceeding the NO_2 annual mean objective of 40 µg m^{-3} using a 2003 and 2002 base year

2010							
		2003 base year			2002 base year		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	55	54	54	30	29	28
Rest of England	128770	19	16	17	2	2	2
Scotland	77791	2	1	1	0	0	0
Wales	20745	0	0	0	0	31	0
Northern Ireland	13318	0	0	0	0	0	0
Total	242248	76	71	72	32	31	30
Percentage >40 µg m^{-3}		0.03%	0.03%	0.03%	0.01%	0.01%	0.01%
2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	39	35	35	24	16	16
Rest of England	128770	12	8	8	2	0	0
Scotland	77791	0	0	0	0	0	0
Wales	20745	0	0	0	0	16	0
Northern Ireland	13318	0	0	0	0	0	0
Total	242248	51	43	43	26	16	16
Percentage >40 µg m^{-3}		0.02%	0.02%	0.02%	0.01%	0.01%	0.01%
2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	38	31	32	24	15	15
Rest of England	128770	15	8	8	4	0	0
Scotland	77791	0	0	0	0	0	0
Wales	20745	0	0	0	0	15	0
Northern Ireland	13318	0	0	0	0	0	0
Total	242248	53	39	40	28	15	15
Percentage >40 µg m^{-3}		0.02%	0.02%	0.02%	0.01%	0.01%	0.01%

Table 4.7 Population in area exceeding the NO_2 annual mean objective of 40 µg m^{-3} using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	319019	305296	305296	114925	113745	107896
Rest of England	41011137	17395	11528	12817	308	308	308
Scotland	4944573	6547	1547	1547	0	0	0
Wales	2850727	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0
Total	58160071	342961	318371	319661	115233	114053	108204
Percentage >40 µg m^{-3}		0.59%	0.55%	0.55%	0.20%	0.20%	0.19%
2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	156502	120633	120633	86112	24890	24890
Rest of England	41011137	5946	4668	4668	308	0	0
Scotland	4944573	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0
Total	58160071	162448	125301	125301	86420	24890	24890
Percentage >40 µg m^{-3}		0.27%	0.22%	0.22%	0.15%	0.04%	0.04%
2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	154748	104328	108313	80938	22329	22329
Rest of England	41011137	6071	4668	4668	2346	0	0
Scotland	4944573	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0
Total	58160071	160819	108995	112980	83284	22329	22329
Percentage >40 µg m^{-3}		0.22%	0.19%	0.19%	0.14%	0.04%	0.04%

Table 4.8 Population weighted mean NO_2 concentration for a 2003 and 2002 base year for combined measures (µg m^{-3})

2010						
	2003 base year			**2002 base year**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	13.410	13.232	13.257	11.263	11.138	11.119
Wales	13.531	13.367	13.390	11.464	11.334	11.316
Northern Ireland	9.249	9.120	9.137	6.984	6.902	6.888
Inner London	34.022	33.699	33.738	29.783	29.545	29.513
Outer London	27.774	27.506	27.541	24.056	23.864	23.836
Rest of England	19.274	19.067	19.094	16.296	16.145	16.123
UK	19.522	19.311	19.339	16.566	16.413	16.391
2015						
	2003 base year			**2002 base year**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	11.853	10.806	10.888	10.002	9.217	9.150
Wales	11.966	10.943	11.033	10.143	9.401	9.338
Northern Ireland	7.960	7.311	7.384	6.022	5.622	5.570
Inner London	31.591	29.684	29.812	27.826	26.310	26.204
Outer London	25.535	24.116	24.231	22.281	21.190	21.094
Rest of England	17.336	16.168	16.263	14.697	13.792	13.713
UK	17.608	16.420	16.516	14.998	14.085	14.006
2020						
	2003 base year			**2002 base year**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	11.314	9.807	9.975	9.569	8.463	8.324
Wales	11.176	9.669	9.833	9.475	8.429	8.296
Northern Ireland	7.378	6.457	6.584	5.644	5.052	4.958
Inner London	30.927	28.276	28.533	27.338	25.316	25.104
Outer London	24.818	22.756	22.987	21.748	20.212	20.022
Rest of England	16.435	14.629	14.833	13.939	12.591	12.420
UK	16.777	14.980	15.181	14.313	12.978	12.810

Table 4.9 Change in population weighted mean NO_2 concentration for the combined measures relative to the base line (µg m^{-3})

2010				
	2003 base year		**2002 base year**	
	P	**Q**	**P**	**Q**
Scotland	-0.143	-0.153	-0.125	-0.144
Wales	-0.129	-0.140	-0.130	-0.148
Northern Ireland	-0.113	-0.112	-0.082	-0.097
Inner London	-0.314	-0.284	-0.238	-0.270
Outer London	-0.243	-0.233	-0.192	-0.220
Rest of England	-0.161	-0.181	-0.151	-0.173
UK	-0.170	-0.183	-0.153	-0.175
2015				
	2003 base year		**2002 base year**	
	P	**Q**	**P**	**Q**
Scotland	-1.250	-0.965	-0.785	-0.852
Wales	-1.259	-0.933	-0.742	-0.805
Northern Ireland	-0.895	-0.576	-0.400	-0.452
Inner London	-2.063	-1.779	-1.517	-1.623
Outer London	-1.756	-1.305	-1.091	-1.188
Rest of England	-1.475	-1.073	-0.905	-0.984
UK	-1.476	-1.092	-0.914	-0.993
2020				
	2003 base year		**2002 base year**	
	P	**Q**	**P**	**Q**
Scotland	-2.216	-1.339	-1.106	-1.245
Wales	-2.228	-1.343	-1.046	-1.179
Northern Ireland	-1.413	-0.794	-0.592	-0.686
Inner London	-3.423	-2.394	-2.022	-2.234
Outer London	-2.998	-1.831	-1.536	-1.726
Rest of England	-2.808	-1.602	-1.348	-1.519
UK	-2.731	-1.596	-1.335	-1.503

5 PM_{10} Results

5.1 ALL MEASURES USING A 2003 BASE YEAR

Modelling results for PM_{10} for the baseline and each of the measures for 2010, 2015 and 2020 are summarised in tables 5.1 to 5.3 in terms of a comparison of modelled concentrations with an annual mean concentration of 31.5 µg m^{-3} (roughly equivalent to the 2004 24-hour AQS objective (Stedman et al, 2001)). Tables 5.4 to 5.6 present the same results in terms of a comparison with the annual mean objctive of 20 µg m^{-3}. No results are presented for the annual mean objective of 40 µg m^{-3} because exceedences of this objective were predicted to have been almost entirely eliminated by 2010 under baseline conditions and for all the measures.

Model results for the additional measures have been compared with an annual mean threshold of 20 µg m^{-3} for the whole of the UK in order to simplify the presentation of the results for the large number of measures. 20 µg m^{-3} is the 2010 stage 2 indicative limit value and the 2010 AQS objective for England, excluding London, Wales and Northern Ireland. A comparison of predicted baseline concentrations with the AQS objectives for 2010 of 18 µg m^{-3} for Scotland and 23 µg m^{-3} for London has been presented by Grice et al (2006).

Estimates of area and population exposure have been derived from background maps only. No attempt has been made to derive estimates of population exposed using roadside concentrations because these maps will only apply within approximately 10 metres of the road kerb. Accurately representing the population distribution at an appropriate level of detail for this would be impractical in a national scale assessment. The estimates of population exposed may therefore underestimate actual population exposure where members of the population live near roads.

All of the measures are predicted to reduce the extent of exceedences relative to the baseline except for measures L (Small combustion plant measure) and F (Impact of all user road charging schemes on air quality) in 2010 and measure D (Programme of incentives to phase out the most polluting vehicles) in 2020. This is because measures L and F don’t take effect until after 2010 and by 2020 the baseline has very few pre-euro cars left so has effectively caught up with measure D which phases these out earlier.

Background Exceedences of 31.5 µg m^{-3} for the baseline in 2010, 2015 and 2020 are predicted to be very limited (4-6km^2 out of 242248km^2 assessed). For roadside locations, in 2010 measures O (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) and Q (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) are most effective at reducing the extent of exceedences of 31.5 µg m^{-3}. Measures O and P (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure)) are also predicted to have a significant effect. In 2015, measure Q is predicted to be most effective, while the other combined measures (O and P) and road transport measures B (New Euro Standard V/VI – High intensity) and C (Programme of incentives for early uptake of Euro V and VI Standards) also significantly reduce the extent of exceedences. In 2020 measures C, B, O, Q and P are predicted to eliminate roadside exceedences completely while measure A nearly achieves this.

Exceedences of 20 $\mu g\ m^{-3}$ are predicted to be more widespread at both roadside and background locations. Measure K (Large combustion plant measure), B (Programme of incentives for early uptake of Euro V and VI Standards) and B again are predicted to be the most effective measures reducing the extent of background exceedences of 20 $\mu g\ m^{-3}$ in 2010, 2015 and 2020 respectively. At roadside locations, the combined measures are predicted to be most effective in 2010 and 2015, while in 2020 measure B is most effective.

Population-weighted annual mean PM_{10} concentrations at background locations are illustrated in Table 5.7. This statistic represents the average concentration exposure of the UK population and can be used to calculate the health impacts of air pollutants and the expected health benefits resulting from reductions in ambient concentrations. The population-weighted mean concentrations show a generally similar pattern of changes with the different traffic measures to the extent of exceedences. The relative effectiveness of the measures for population-weighted mean is:

- 2010: K > N > O = Q > C = P > B > A > D > G > J > E > baseline = L = F
- 2015: B > Q > P > O > C > N > A > K > F > L > E > J > G > D > baseline
- 2020: B > Q > P > O > C > A > N > K > F > L > E > J > G > baseline = D

The concentrations presented in table 5.7 are given to a higher degree of precision than the modelling method warrants so that small differences in the model outputs can be seen. This is useful when certain measures only result in small changes, for example in the 3rd decimal place.

Table 5.1 Total road length (km) exceeding an annual mean PM_{10} concentration of 31.5 µg m^{-3}, gravimetric

2010

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1886	139.9	111.8	106.5	84.5	132.1	138.3	139.9	70.3	139.8	109.9	139.9	110.7	75.4	84.5	75.4
Rest of England	9430	158.1	129.4	129.4	94.3	152.0	157.1	158.1	123.6	157.3	131.8	158.1	131.8	94.3	94.3	94.3
Scotland	1085	2.8	0.0	0.0	0.0	0.0	2.8	2.8	0.0	2.8	0.0	2.8	0.0	0.0	0.0	0.0
Wales	640	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	300.9	241.2	235.9	178.7	284.0	298.2	300.9	193.9	299.9	241.7	300.9	242.5	169.6	178.7	169.6
Percentage >31.5 µgm^{-3}		2.14%	1.71%	1.67%	1.27%	2.02%	2.12%	2.14%	1.38%	2.13%	1.72%	2.14%	1.72%	1.20%	1.27%	1.20%

2015

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1886	31.1	2.8	1.3	2.2	31.1	29.6	1.8	26.5	31.1	26.0	29.8	25.8	0.8	2.2	0.8
Rest of England	9430	40.6	6.0	4.8	4.8	37.6	34.8	26.1	37.6	37.6	26.2	37.6	21.6	4.8	4.1	4.1
Scotland	1085	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wales	640	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	71.7	8.8	6.2	7.0	68.7	64.5	27.9	64.0	68.7	52.2	67.3	47.4	5.6	6.2	4.9
Percentage >31.5 µgm^{-3}		0.51%	0.06%	0.04%	0.05%	0.49%	0.46%	0.20%	0.45%	0.49%	0.37%	0.48%	0.34%	0.04%	0.04%	0.03%

2020

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1886	20.6	0.0	0.0	0.0	20.6	18.6	0.8	19.7	20.2	19.6	20.2	17.6	0.0	0.0	0.0
Rest of England	9430	27.7	1.9	0.0	0.0	27.7	19.6	17.3	27.7	25.7	19.6	24.7	16.0	0.0	0.0	0.0
Scotland	1085	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wales	640	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	48.4	1.9	0.0	0.0	48.4	38.2	18.1	47.4	45.9	39.2	44.8	33.7	0.0	0.0	0.0
Percentage >31.5 µgm^{-3}		0.34%	0.01%	0.00%	0.00%	0.34%	0.27%	0.13%	0.34%	0.33%	0.28%	0.32%	0.24%	0.00%	0.00%	0.00%

Table 5.2 Total background area (km^2) exceeding an annual mean PM_{10} concentration of 31.5 µg m^{-3}, gravimetric

2010

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rest of England	128770	6	4	4	3	4	5	6	4	5	2	6	2	3	3	3
Scotland	77791	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	242248	6	4	4	3	4	5	6	4	5	2	6	2	3	3	3
Percentage >31.5 µgm^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

2015

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rest of England	128770	4	2	2	2	4	3	3	4	3	2	3	2	2	2	2
Scotland	77791	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	242248	4	2	2	2	4	3	3	4	3	2	3	2	2	2	2
Percentage >31.5 µgm^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

2020

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rest of England	128770	5	3	2	3	5	4	4	5	4	4	4	2	3	2	2
Scotland	77791	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	242248	5	3	2	3	5	4	4	5	4	4	4	2	3	2	2
Percentage >31.5 µgm^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 5.3 Population in area exceeding an annual mean PM_{10} concentration of 31.5 μg m^{-3}, gravimetric

2010																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	7730326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rest of England	41011137	10242	5292	5292	3463	5292	7591	10242	5292	7591	671	10242	671	3463	3463	3463
Scotland	4944573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	58160071	10242	5292	5292	3463	5292	7591	10242	5292	7591	671	10242	671	3463	3463	3463
Percentage >31.5 μgm^{-3}		0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.01%	0.00%	0.02%	0.00%	0.01%	0.01%	0.01%
2015																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	7730326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rest of England	41011137	3477	671	671	671	3477	3463	3463	3477	3463	671	3463	671	671	671	671
Scotland	4944573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	58160071	3477	671	671	671	3477	3463	3463	3477	3463	671	3463	671	671	671	671
Percentage >31.5 μgm^{-3}		0.01%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
2020																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	7730326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rest of England	41011137	5306	686	671	686	5306	3477	3477	5306	3477	3477	3477	671	686	671	671
Scotland	4944573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	58160071	5306	686	671	686	5306	3477	3477	5306	3477	3477	3477	671	686	671	671
Percentage >31.5 μgm^{-3}		0.01%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%

Table 5.4 Total road length (km) exceeding an annual mean PM_{10} concentration of 20 µg m^{-3}, gravimetric

2010																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	1886	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6
Rest of England	9430	8375.7	8289.7	8271.1	8110.0	8340.9	8368.0	8375.7	8361.7	8364.9	8108.5	8375.7	8108.4	8100.5	8100.5	8100.5
Scotland	1085	187.3	157.7	156.8	128.4	180.8	183.6	187.3	173.9	187.3	161.8	187.3	158.3	128.4	128.4	128.4
Wales	640	336.4	319.7	317.3	286.6	330.5	336.3	336.4	336.4	336.3	293.9	336.4	293.9	285.5	285.5	285.5
Northern Ireland	1044	148.9	144.2	144.2	144.2	144.2	144.2	148.9	148.9	148.9	144.2	148.9	144.2	144.2	144.2	144.2
Total	14084	10932.9	10795.9	10774.0	10553.9	10881.1	10916.7	10932.9	10905.6	10922.0	10592.9	10932.9	10589.4	10543.3	10543.3	10543.3
Percentage >20 µg m^{-3}		77.63%	76.65%	76.50%	74.93%	77.26%	77.51%	77.63%	77.43%	77.55%	75.21%	77.63%	75.19%	74.86%	74.86%	74.86%
2015																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	1886	1884.6	1881.4	1875.6	1877.3	1884.6	1884.6	1884.6	1884.6	1884.6	1881.4	1884.6	1881.4	1875.6	1875.3	1874.7
Rest of England	9430	7202.7	5485.3	5006.7	5042.5	7186.8	7136.4	7055.6	7174.0	7166.9	6692.6	7131.8	6536.2	5003.7	4905.4	4884.5
Scotland	1085	79.5	31.2	25.1	18.8	79.5	74.1	63.4	79.5	79.5	74.1	76.7	71.9	16.4	16.4	16.4
Wales	640	193.5	104.9	96.2	94.1	193.5	189.5	181.6	193.5	192.3	147.6	189.3	141.0	92.8	92.8	92.8
Northern Ireland	1044	119.3	70.4	70.4	70.4	119.3	119.3	119.3	119.3	119.3	115.6	119.3	115.6	70.4	70.4	70.4
Total	14084	9479.6	7573.2	7074.1	7103.0	9463.8	9404.0	9304.6	9451.0	9442.7	8911.3	9401.8	8746.2	7058.9	6960.3	6938.7
Percentage >20 µg m^{-3}		67.31%	53.77%	50.23%	50.43%	67.20%	66.77%	66.06%	67.10%	67.05%	63.27%	66.75%	62.10%	50.12%	49.42%	49.27%
2020																
	Total	**Base**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
London	1886	1880.8	1654.1	1346.8	1606.2	1880.8	1880.8	1879.9	1880.8	1880.8	1880.8	1880.8	1861.3	1561.3	1576.6	1511.9
Rest of England	9430	6292.1	2568.5	1742.8	2379.7	6292.1	6073.1	6068.4	6290.9	6222.2	6034.8	6186.2	5195.9	2336.2	2272.8	2227.3
Scotland	1085	66.5	3.7	3.7	3.7	66.5	65.1	58.4	66.5	65.8	65.8	65.8	61.5	3.7	3.7	3.7
Wales	640	141.0	50.8	30.5	39.4	141.0	126.7	133.0	141.0	135.4	126.7	131.6	108.4	39.4	35.1	35.1
Northern Ireland	1044	146.0	98.4	72.6	98.4	146.0	144.6	146.0	146.0	146.0	146.0	146.0	134.0	98.4	94.7	94.7
Total	14084	8526.4	4375.5	3196.4	4127.5	8526.4	8290.3	8285.6	8525.2	8450.1	8254.1	8410.4	7361.2	4039.0	3983.0	3872.6
Percentage >20 µg m^{-3}		60.54%	31.07%	22.70%	29.31%	60.54%	58.86%	58.83%	60.53%	60.00%	58.61%	59.72%	52.27%	28.68%	28.28%	27.50%

Table 5.5 Total background area (km^2) exceeding an annual mean PM_{10} concentration of 20 μg m^{-3}, gravimetric

2010

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	1621	1621	1621	1621	1621	1621	1621	1621	1621	1601	1621	1602	1621	1621	1621
Rest of England	128770	17192	16686	16330	15739	16808	15651	17192	17151	16993	11841	17192	12028	15651	15651	15651
Scotland	77791	25	22	22	20	25	20	25	25	25	21	25	20	20	20	20
Wales	20745	267	263	256	240	263	240	267	267	266	216	267	211	240	240	240
Northern Ireland	13318	19	17	17	15	19	14	19	19	19	13	19	13	14	14	14
Total	242248	19124	18609	18246	17635	18736	17546	19124	19083	18924	13692	19124	13874	17546	17546	17546
Percentage >20 μg m^{-3}		7.89%	7.68%	7.53%	7.28%	7.73%	7.24%	7.89%	7.88%	7.81%	5.65%	7.89%	5.73%	7.24%	7.24%	7.24%

2015

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	1523	1399	1299	1351	1518	1511	1489	1516	1513	1408	1504	1371	1333	1307	1302
Rest of England	128770	8207	5721	4751	5220	8123	7976	7814	8117	7969	5582	7730	5082	5143	4894	4857
Scotland	77791	18	16	13	14	18	18	16	18	18	18	18	18	13	13	13
Wales	20745	180	164	154	159	180	179	178	180	180	163	179	152	159	155	154
Northern Ireland	13318	10	4	3	3	10	10	10	10	10	8	10	8	3	3	3
Total	242248	9938	7304	6220	6747	9849	9694	9507	9841	9690	7179	9441	6631	6651	6372	6329
Percentage >20 μg m^{-3}		4.10%	3.02%	2.57%	2.79%	4.07%	4.00%	3.92%	4.06%	4.00%	2.96%	3.90%	2.74%	2.75%	2.63%	2.61%

2020

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	1624	1291	617	383	583	1291	1261	1166	1289	1267	1188	1257	877	552	536	508
Rest of England	128770	4682	2490	1913	2414	4682	4478	4481	4682	4473	4050	4402	2797	2380	2286	2248
Scotland	77791	18	12	10	12	18	16	16	18	18	16	18	13	12	12	12
Wales	20745	163	122	109	120	163	160	160	163	159	150	158	120	119	117	117
Northern Ireland	13318	32	16	13	14	32	29	31	32	31	29	31	23	14	14	14
Total	242248	6186	3257	2428	3143	6186	5944	5854	6184	5948	5433	5866	3830	3077	2965	2899
Percentage >20 μg m^{-3}		2.55%	1.34%	1.00%	1.30%	2.55%	2.45%	2.42%	2.55%	2.46%	2.24%	2.42%	1.58%	1.27%	1.22%	1.20%

Table 5.6 Population in area exceeding an annual mean PM_{10} concentration of 20 μg m^{-3}, gravimetric

2010

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	7730326	7727768	7727768	7727768	7727768	7727768	7727768	7727768	7727768	7727768	7702632	7727768	7704803	7031193	6945295	6931710
Rest of England	41011137	20904147	20462818	20219398	19568112	20647609	20817477	20904147	20833367	20783231	17165921	20904147	17233544	8364680	8009789	7962879
Scotland	4944573	41611	39594	39594	32715	41611	41611	41611	41611	41611	39398	41611	39299	17213	17213	17213
Wales	2850727	352663	340942	334026	300954	340942	352601	352663	352663	352601	272940	352663	262710	109797	108077	106965
Northern Ireland	1623309	65651	53633	53633	48009	65651	65651	65651	65651	65651	42035	65651	42035	9156	9156	9156
Total	58160071	29091840	28624754	28374418	27677558	28823580	29005107	29091840	29021059	28970861	25222926	29091840	25282391	15532039	15089529	15027922
Percentage >20 μg m^{-3}		50.02%	49.22%	48.79%	47.59%	49.56%	49.87%	50.02%	49.90%	49.81%	43.37%	50.02%	43.47%	26.71%	25.94%	25.84%

2015

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	7730326	7544505	7230341	6927540	7098104	7535140	7516247	7471956	7531669	7521916	7254100	7505543	7164291	7031193	6945295	6931710
Rest of England	41011137	13140915	9257798	7898054	8478170	13024505	12806329	12446663	13018165	12830538	9718513	12485378	8918769	8364680	8009789	7962879
Scotland	4944573	32421	25873	17213	19711	32421	32421	25873	32421	32421	32421	32421	32421	17213	17213	17213
Wales	2850727	180796	119659	106965	109797	180796	173117	170301	180796	180796	146239	173117	121273	109797	108077	106965
Northern Ireland	1623309	30106	10810	9156	9156	30106	30106	30106	30106	30106	22227	30106	22227	9156	9156	9156
Total	58160071	20928742	16644481	14958927	15714939	20802967	20558220	20144899	20793156	20595777	17173499	20226564	16258980	15532039	15089529	15027922
Percentage >20 μg m^{-3}		35.98%	28.62%	25.72%	27.02%	35.77%	35.35%	34.64%	35.75%	35.41%	29.53%	34.78%	27.96%	26.71%	25.94%	25.84%

2020

	Total	Base	A	B	C	D	E	F	G	J	K	L	N	O	P	Q
London	7730326	6919180	3799410	2369898	3623145	6919180	6798323	6421833	6915267	6827052	6566662	6784360	5210829	3444545	3350423	3151906
Rest of England	41011137	8313678	4058119	3118286	3928736	8313678	7956393	7921046	8313678	7997116	7396532	7906987	5213498	3858831	3698493	3652434
Scotland	4944573	32421	13928	8124	13928	32421	25873	25873	32421	32421	25873	32421	17213	13928	13928	13928
Wales	2850727	136343	69847	61898	69349	136343	131453	131453	136343	131126	115959	131008	88142	68467	67825	67825
Northern Ireland	1623309	115537	52720	43289	46373	115537	100324	110155	115537	110155	100324	110155	80657	46373	46373	46373
Total	58160071	15517158	7994023	5601494	7681530	15517158	15012366	14610360	15513245	15097870	14205351	14964931	10610339	7432144	7177042	6932466
Percentage >20 μg m^{-3}		26.68%	13.74%	9.63%	13.21%	26.68%	25.81%	25.12%	26.67%	25.96%	24.42%	25.73%	18.24%	12.78%	12.34%	11.92%

Table 5.7 Population weighted mean PM_{10} concentration using a 2003 base year ($\mu g\ m^{-3}$, gravimetric)

2010														
	Base	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
Scotland	15.479	15.437	15.426	15.370	15.462	15.474	15.479	15.471	15.474	15.284	15.479	15.249	15.366	15.370	15.366
Wales	17.991	17.955	17.937	17.891	17.970	17.985	17.991	17.991	17.982	17.665	17.991	17.636	17.885	17.891	17.885
Northern Ireland	16.239	16.213	16.202	16.169	16.225	16.235	16.239	16.239	16.234	16.053	16.239	16.009	16.165	16.169	16.165
Inner London	23.567	23.444	23.405	23.253	23.518	23.553	23.567	23.434	23.553	23.078	23.567	23.092	23.231	23.253	23.231
Outer London	22.697	22.600	22.568	22.444	22.655	22.685	22.697	22.619	22.683	22.206	22.697	22.222	22.430	22.444	22.430
Rest of England	20.143	20.087	20.065	19.991	15.270	20.135	20.143	15.278	20.132	19.738	20.143	19.744	19.984	19.991	19.984
UK	19.880	19.821	19.798	19.721	19.851	19.871	19.880	19.862	19.869	19.492	19.880	19.493	19.713	19.721	19.713
2015															
	Base	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
Scotland	15.021	14.743	14.659	14.687	15.015	15.000	14.966	15.014	15.004	14.831	14.986	14.748	14.681	14.655	14.651
Wales	17.347	17.078	16.949	17.017	17.337	17.321	17.309	17.338	17.319	17.030	17.290	16.918	17.007	16.965	16.960
Northern Ireland	15.889	15.704	15.629	15.663	15.883	15.872	15.871	15.883	15.873	15.708	15.855	15.620	15.658	15.632	15.629
Inner London	22.460	21.670	21.425	21.512	22.446	22.403	21.809	22.411	22.419	21.985	22.379	21.869	21.459	21.437	21.391
Outer London	21.647	21.000	20.781	20.866	21.632	21.596	21.319	21.614	21.605	21.170	21.565	21.054	20.836	20.791	20.768
Rest of England	19.326	18.929	18.762	18.842	14.672	19.292	19.259	14.669	19.292	18.932	19.259	18.831	18.829	18.780	18.773
UK	19.084	18.672	18.509	18.584	19.073	19.049	18.975	19.069	19.051	18.707	19.019	18.606	18.569	18.524	18.515
2020															
	Base	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**J**	**K**	**L**	**N**	**O**	**P**	**Q**
Scotland	14.794	14.339	14.186	14.315	14.794	14.763	14.746	14.794	14.772	14.723	14.762	14.493	14.307	14.283	14.275
Wales	16.886	16.433	16.204	16.407	16.886	16.851	16.858	16.886	16.849	16.767	16.834	16.407	16.393	16.355	16.341
Northern Ireland	16.110	15.801	15.669	15.783	16.110	16.085	16.098	16.110	16.089	16.042	16.079	15.815	15.775	15.752	15.744
Inner London	21.772	20.472	20.046	20.404	21.772	21.678	21.124	21.765	21.717	21.593	21.697	21.100	20.332	20.330	20.258
Outer London	20.920	19.850	19.462	19.792	20.920	20.841	20.601	20.917	20.865	20.740	20.845	20.247	19.751	19.717	19.677
Rest of England	18.742	18.079	17.780	18.042	14.264	18.693	18.687	14.264	18.696	18.594	18.680	18.180	18.024	17.980	17.962
UK	18.543	17.858	17.567	17.820	18.543	18.493	18.445	18.543	18.500	18.401	18.484	18.002	17.800	17.761	17.740

5.2 MEASURES P AND Q USING A 2003 AND 2002 BASE YEAR

Tables 5.8 to 5.13 present a comparison of the results for the combined measures P (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure)) and Q (Combined measures C (Programme of incentives for early uptake of Euro V and VI Standards) + L (Small combustion plant measure) + E (Updated programme of incentives to increase penetration of low emissions vehicles)) using a 2002 and 2003 base year. The combined measure measures are predicted to have a similar impact on concentrations in 2010, 2015 and 2020 for the two different base years. The relative effectiveness of the different measures remains the same for the two different base years. The extent of exceedence for these years is lower for the 2002 base year and this is reflected in the changes in percentage exceedence.

Population-weighted annual mean PM_{10} concentrations at background locations are also illustrated in Table 5.14 for the different base years. The population-weighted mean concentrations show a similar, but not identical pattern of changes with the different measures to the extent of exceedences. The change in population-weighted mean for each measure relative to the baseline measure is shown in Table 5.15. The predicted population-weighted mean background concentrations predicted from 2002 are typically about 90% of those predicted from 2003. Concentrations were higher in 2003 than in 2002 largely because of the higher secondary PM concentrations (AQEG, 2005).

Table 5.8 Total road length (km) exceeding an annual mean PM_{10} concentration of 31.5 μg m^{-3}, gravimetric using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	139.9	75.4	84.5	8.0	1.5	1.3
Rest of England	9430	158.1	94.3	94.3	12.3	6.0	6.0
Scotland	1085	2.8	0.0	0.0	0.0	0.0	0.0
Wales	640	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	300.9	169.6	178.7	20.2	7.5	7.4
Percentage >31.5 μg m^{-3}		2.14%	1.20%	1.27%	0.14%	0.05%	0.05%
2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	31.1	0.8	2.2	0.8	0.0	0.0
Rest of England	9430	40.6	4.1	4.1	0.4	0.0	0.0
Scotland	1085	0.0	0.0	0.0	0.0	0.0	0.0
Wales	640	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	71.7	4.9	6.2	1.2	0.0	0.0
Percentage >31.5 μg m^{-3}		0.51%	0.03%	0.04%	0.01%	0.00%	0.00%
2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	20.6	0.0	0.0	0.8	0.0	0.0
Rest of England	9430	27.7	0.0	0.0	2.3	0.0	0.0
Scotland	1085	0.0	0.0	0.0	0.0	0.0	0.0
Wales	640	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	48.4	0.0	0.0	3.1	0.0	0.0
Percentage >31.5 μg m^{-3}		0.34%	0.00%	0.00%	0.02%	0.00%	0.00%

Table 5.9 Total background area (km^2) exceeding an annual mean PM_{10} concentration of 31.5 µg m^{-3}, gravimetric using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	0	0	0	0	0	0
Rest of England	128770	6	3	3	0	0	0
Scotland	77791	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0
Total	242248	6	3	3	0	0	0
Percentage >31.5 µg m^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	0	0	0	0	0	0
Rest of England	128770	4	3	3	0	0	0
Scotland	77791	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0
Total	242248	4	3	3	0	0	0
Percentage >31.5 µg m^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	0	0	0	0	0	0
Rest of England	128770	5	2	2	2	1	1
Scotland	77791	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0
Total	242248	5	2	2	2	1	1
Percentage >31.5 µg m^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 5.10 Population in area exceeding an annual mean PM_{10} concentration of 31.5 µg m^{-3}, gravimetric using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	0	0	0	0	0	0
Rest of England	41011137	10242	3463	3463	0	0	0
Scotland	4944573	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0
Total	58160071	10242	3463	3463	0	0	0
Percentage >31.5 µg m^{-3}		0.02%	0.01%	0.01%	0.00%	0.00%	0.00%
2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	0	0	0	0	0	0
Rest of England	41011137	3477	671	671	0	0	0
Scotland	4944573	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0
Total	58160071	3477	671	671	0	0	0
Percentage >31.5 µg m^{-3}		0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	0	0	0	0	0	0
Rest of England	41011137	5306	671	671	671	177	177
Scotland	4944573	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0
Total	58160071	5306	671	671	671	177	177
Percentage >31.5 µg m^{-3}		0.01%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 5.11 Total road length (km) exceeding the PM_{10} annual mean objective of 20 µg m^{-3}, gravimetric using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	1884.6	1884.6	1884.6	1828.2	1744.5	1739.2
Rest of England	9430	8375.7	8100.5	8100.5	4550.7	3799.4	3784.0
Scotland	1085	187.3	128.4	128.4	56.4	46.2	46.2
Wales	640	336.4	285.5	285.5	81.4	62.1	60.6
Northern Ireland	1044	148.9	144.2	144.2	38.1	32.3	32.3
Total	14084	10932.9	10543.3	10543.3	6554.8	5684.5	5662.5
Percentage >20 µg m^{-3}		77.63%	74.86%	74.86%	46.54%	40.36%	40.20%
2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	1884.6	1511.9	1576.6	1591.8	810.0	747.0
Rest of England	9430	7202.7	2227.3	2272.8	2787.9	1229.7	1215.8
Scotland	1085	79.5	3.7	3.7	31.7	0.0	0.0
Wales	640	193.5	35.1	35.1	56.9	15.0	15.0
Northern Ireland	1044	119.3	94.7	94.7	24.2	0.0	0.0
Total	14084	9479.6	3872.6	3983.0	4492.5	2054.8	1977.9
Percentage >20 µg m^{-3}		67.31%	27.50%	28.28%	31.90%	14.59%	14.04%
2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	1880.8	1874.7	1875.3	1388.5	347.6	285.8
Rest of England	9430	6292.1	4884.5	4905.4	2315.5	715.6	711.8
Scotland	1085	66.5	16.4	16.4	31.7	0.0	0.0
Wales	640	141.0	92.8	92.8	56.0	8.0	8.0
Northern Ireland	1044	146.0	70.4	70.4	86.2	6.4	6.4
Total	14084	8526.4	6938.7	6960.3	3877.9	1077.5	1012.0
Percentage >20 µg m^{-3}		60.54%	49.27%	49.42%	27.53%	7.65%	7.19%

Table 5.12 Total background area (km^2) an annual mean PM_{10} concentration of 20 μg m^{-3}, gravimetric using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	1621	1621	1621	612.0	472.0	470.0
Rest of England	128770	17192.0	15651.0	15651.0	2131.0	1860.0	1857.0
Scotland	77791	25.0	20.0	20.0	8.0	8.0	8.0
Wales	20745	267.0	240.0	240.0	75.0	71.0	71.0
Northern Ireland	13318	19.0	14.0	14.0	1.0	1.0	1.0
Total	242248	19124.0	17546.0	17546.0	2827.0	2412.0	2407.0
Percentage >20 μg m^{-3}		7.89%	7.24%	7.24%	1.17%	1.00%	0.99%

2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	1523.0	1302.0	1307.0	233.0	75.0	69.0
Rest of England	128770	8207.0	4857.0	4894.0	1377.0	1042.0	1037.0
Scotland	77791	18.0	13.0	13.0	8.0	6.0	6.0
Wales	20745	180.0	154.0	155.0	67.0	54.0	54.0
Northern Ireland	13318	10.0	3.0	3.0	0.0	0.0	0.0
Total	242248	9938.0	6329.0	6372.0	1685.0	1177.0	1166.0
Percentage >20 μg m^{-3}		4.10%	2.61%	2.63%	0.70%	0.49%	0.48%

2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	1291.0	508.0	536.0	147.0	29.0	27.0
Rest of England	128770	4682.0	2248.0	2286.0	1206.0	843.0	837.0
Scotland	77791	18.0	12.0	12.0	7.0	6.0	6.0
Wales	20745	163.0	117.0	117.0	65.0	51.0	51.0
Northern Ireland	13318	32.0	14.0	14.0	8.0	0.0	0.0
Total	242248	6186.0	2899.0	2965.0	1433.0	929.0	921.0
Percentage >20 μg m^{-3}		2.55%	1.20%	1.22%	0.59%	0.38%	0.38%

Table 5.13 Population in area exceeding an annual mean PM_{10} concentration of 20 μg m^{-3}, gravimetric using a 2003 and 2002 base year

2010							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	7727768	6931710	6945295	3891107	3131630	3121135
Rest of England	41011137	20904147	7962879	8009789	4053831	3516700	3506934
Scotland	4944573	41611	17213	17213	6919	6919	6919
Wales	2850727	352663	106965	108077	49477	39498	39498
Northern Ireland	1623309	65651	9156	9156	6316	6316	6316
Total	58160071	29091840	15027922	15089529	8007649	6701061	6680801
Percentage >20 μg m^{-3}		50.02%	25.84%	25.94%	13.77%	11.52%	11.49%
2015							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	7544505	6931710	6945295	1627515	300080	249653
Rest of England	41011137	13140915	7962879	8009789	2560282	1800530	1799058
Scotland	4944573	32421	17213	17213	6919	3910	3910
Wales	2850727	180796	106965	108077	30875	19886	19886
Northern Ireland	1623309	30106	9156	9156	0	0	0
Total	58160071	20928742	15027922	15089529	4225590	2124406	2072506
Percentage >20 μg m^{-3}		35.98%	25.84%	25.94%	7.27%	3.65%	3.56%
2020							
		2003 base year			**2002 base year**		
	Total	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	6919180	3151906	3350423	990805	64809	55906
Rest of England	41011137	8313678	3652434	3698493	2212135	1427733	1419295
Scotland	4944573	32421	13928	13928	5148	3910	3910
Wales	2850727	136343	67825	67825	28907	18840	18840
Northern Ireland	1623309	115537	46373	46373	22227	0	0
Total	58160071	15517158	6932466	7177042	3259222	1515292	1497950
Percentage >20 μg m^{-3}		26.68%	11.92%	12.34%	5.60%	2.61%	2.58%

Table 5.14 Population weighted mean PM_{10} concentration for a 2003 and 2002 base year for combined measures (µg m^{-3}, gravimetric)

2010						
	2003 base year			**2002 base year**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	15.479	15.366	15.370	14.145	14.039	14.038
Wales	17.991	17.885	17.891	15.771	15.642	15.641
Northern Ireland	16.239	16.165	16.169	14.871	14.810	14.809
Inner London	23.567	23.231	23.253	20.750	20.437	20.422
Outer London	22.697	22.430	22.444	19.795	19.550	19.543
Rest of England	20.143	19.984	19.991	17.794	17.637	17.635
UK	19.880	19.713	19.721	17.587	17.425	17.422
2015						
	2003 base year			**2002 base year**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	15.021	14.651	14.655	13.810	13.495	13.491
Wales	17.347	16.960	16.965	15.333	14.994	14.987
Northern Ireland	15.889	15.629	15.632	14.649	14.448	14.444
Inner London	22.460	21.391	21.437	19.909	18.965	18.917
Outer London	21.647	20.768	20.791	19.016	18.258	18.233
Rest of England	19.326	18.773	18.780	17.193	16.719	16.710
UK	19.084	18.515	18.524	17.003	16.514	16.503
2020						
	2003 base year			**2002 base year**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	14.794	14.275	14.283	13.709	13.265	13.260
Wales	16.886	16.341	16.355	15.088	14.624	14.615
Northern Ireland	16.110	15.744	15.752	15.010	14.724	14.719
Inner London	21.772	20.258	20.330	19.523	18.176	18.111
Outer London	20.920	19.677	19.717	18.587	17.506	17.472
Rest of England	18.742	17.962	17.980	16.835	16.170	16.158
UK	18.543	17.740	17.761	16.686	15.998	15.983

Table 5.15 Change in population weighted mean PM_{10} concentration for the combined measures relative to the baseline (μg m^{-3}, gravimetric)

2010				
	2003 base year		**2002 base year**	
	P	**Q**	**P**	**Q**
Scotland	-0.110	-0.114	-0.106	-0.107
Wales	-0.100	-0.106	-0.129	-0.130
Northern Ireland	-0.070	-0.074	-0.061	-0.062
Inner London	-0.314	-0.336	-0.313	-0.328
Outer London	-0.253	-0.268	-0.245	-0.252
Rest of England	-0.152	-0.159	-0.157	-0.159
UK	-0.158	-0.167	-0.163	-0.165
2015				
	2003 base year		**2002 base year**	
	P	**Q**	**P**	**Q**
Scotland	-0.366	-0.369	-0.315	-0.319
Wales	-0.382	-0.387	-0.339	-0.345
Northern Ireland	-0.256	-0.260	-0.201	-0.205
Inner London	-1.023	-1.069	-0.944	-0.993
Outer London	-0.856	-0.878	-0.758	-0.783
Rest of England	-0.547	-0.553	-0.474	-0.482
UK	-0.560	-0.569	-0.489	-0.500
2020				
	2003 base year		**2002 base year**	
	P	**Q**	**P**	**Q**
Scotland	-0.511	-0.520	-0.443	-0.449
Wales	-0.531	-0.545	-0.464	-0.473
Northern Ireland	-0.358	-0.366	-0.286	-0.291
Inner London	-1.442	-1.514	-1.346	-1.412
Outer London	-1.203	-1.243	-1.081	-1.115
Rest of England	-0.762	-0.780	-0.665	-0.677
UK	-0.783	-0.803	-0.688	-0.703

6 $PM_{2.5}$ Results

There are currently no limit values or objectives for $PM_{2.5}$. Therefore modelled concentrations have been compared with indicative threshold concentrations of 12, 16 and 20 $\mu g\ m^{-3}$ to illustrate the changes in predicted concentration in different years and for different measures. This comparison is shown in tables 6.1 to 6.3. Estimates of area and population exposure have been derived from background maps only. No attempt has been made to derive estimates of population exposed using roadside concentrations because these maps will only apply within approximately 10 metres of the road kerb. Accurately representing the population distribution at an appropriate level of detail for this would be impractical in a national scale assessment. The estimates of population exposed may therefore underestimate actual population exposure where members of the population live near roads.

Measures Q and P are predicted to reduce $PM_{2.5}$ concentrations and the extent of exceedences relative to the baseline measure.

Population-weighted annual mean $PM_{2.5}$ concentrations at background locations are illustrated in Table 6.4 for the different measures. The population-weighted mean concentrations show a similar, but not identical pattern of changes with the different measures to the extent of exceedences. Population-weighted means for PM_{10} for the baseline and combined measures are also listed in Table 6.4 for comparison with the results for $PM_{2.5}$. The change in population-weighted mean concentrations for each measure relative to the baseline measure is shown in Table 6.5.

Table 6.5 also shows the changes in predicted population-weighted means for the measures for $PM_{2.5}$ as a percentage of those for PM_{10}. These differences are caused by the relative proportions of the changes in PM concentration resulting from changes to primary and secondary PM. These differences may in part reflect differences in the modelling methods adopted for PM_{10} and $PM_{2.5}$. The PM_{10} model was calibrated using TEOM measurement data and then scaled by 1.3 to calculate gravimetric equivalent concentrations. $PM_{2.5}$ measurement data are only available from a very limited number of monitoring sites. The $PM_{2.5}$ model represents gravimetric concentrations directly. A more detailed discussion of how the $PM_{2.5}$ modelling has been done is given in Grice et al (2006).

Table 6.1 Summary statistics for combined measures $PM_{2.5}$ projections comparison with 12 µg m^{-3}, gravimetric

Total road length (km) exceeding an annual mean value of 12 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	**P**	**Q**	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	1884.6	1884.6	1884.6	1884.6	1884.6	1884.6	1881.8	1526.4	1388.0
Rest of England	9430	8028.8	7720.6	7702.7	6274.2	4479.0	4448.2	4646.9	862.0	802.0
Scotland	1085	38.1	28.5	28.5	5.1	0.0	0.0	4.0	0.0	0.0
Wales	640	233.5	185.5	182.0	91.9	33.5	33.1	50.1	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	10185.1	9819.2	9797.9	8255.9	6397.1	6365.9	6582.9	2388.4	2190.0
Percentage > 12 µg m^{-3}		72.32%	69.72%	69.57%	58.62%	45.42%	45.20%	46.74%	16.96%	15.55%

Total background area (km^2) exceeding an annual mean value of 12 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	**P**	**Q**	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	1624	1624	1624	1624	1616	1615	1468	280	227
Rest of England	128770	57524	56267	56147	21866	9263	9099	3510	523	495
Scotland	77791	0	0	0	0	0	0	0	0	0
Wales	20745	93	78	76	25	16	16	13	8	8
Northern Ireland	13318	0	0	0	0	0	0	0	0	0
Total	242248	59241	57969	57847	23515	10895	10730	4991	811	730
Percentage > 12 µg m^{-3}		24.45%	23.93%	23.88%	9.71%	4.50%	4.43%	2.06%	0.33%	0.30%

Total population in area exceeding an annual mean value of 12 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	**P**	**Q**	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	7730326	7730326	7730326	7730326	7723708	7723221	7422172	1850716	1434730
Rest of England	41011137	24995661	24174933	24134137	17266493	10890830	10765033	6146668	891518	836242
Scotland	4944573	0	0	0	0	0	0	0	0	0
Wales	2850727	206009	173280	168408	32847	14690	14690	10010	3043	3043
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0
Total	58160071	32931996	32078539	32032871	25029665	18629229	18502944	13578851	2745277	2274015
Percentage > 12 µg m^{-3}		56.62%	55.16%	55.08%	43.04%	32.03%	31.81%	23.35%	4.72%	3.91%

Table 6.2 Summary statistics for combined measures $PM_{2.5}$ projections comparison with 16 µg m^{-3}, gravimetric

Total road length (km) exceeding an annual mean value of 16 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	P	Q	Baseline	P	Q	Baseline	P	Q
London	1886	943.2	662.4	646.6	256.9	28.9	21.6	104.7	0.8	0.0
Rest of England	9430	587.1	391.3	383.3	73.4	0.9	0.9	25.8	0.0	0.0
Scotland	1085	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wales	640	5.7	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	1535.9	1054.9	1031.3	330.3	29.8	22.5	130.5	0.8	0.0
Percentage > 12 µg m^{-3}		10.91%	7.49%	7.32%	2.35%	0.21%	0.16%	0.93%	0.01%	0.00%

Total background area (km^2) exceeding an annual mean value of 16 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	P	Q	Baseline	P	Q	Baseline	P	Q
London	1624	2	0	0	0	0	0	0	0	0
Rest of England	128770	21	15	15	3	3	2	2	1	1
Scotland	77791	0	0	0	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0
Total	242248	23	15	15	3	3	2	2	1	1
Percentage > 12 µg m^{-3}		0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Total population in area exceeding an annual mean value of 16 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	P	Q	Baseline	P	Q	Baseline	P	Q
London	7730326	9814	0	0	0	0	0	0	0	0
Rest of England	41011137	24332	14460	14460	1751	1751	1735	1735	62	62
Scotland	4944573	0	0	0	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0
Total	58160071	34146	14460	14460	1751	1751	1735	1735	62	62
Percentage > 12 µg m^{-3}		0.06%	0.02%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 6.3 Summary statistics for combined measures $PM_{2.5}$ projections comparison with 20 µg m^{-3}, gravimetric

Total road length (km) exceeding an annual mean value of 16 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	**P**	**Q**	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1886	21.6	11.6	9.8	0.8	0.0	0.0	0.0	0.0	0.0
Rest of England	9430	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scotland	1085	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wales	640	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern Ireland	1044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14084	24.2	11.6	9.8	0.8	0.0	0.0	0.0	0.0	0.0
Percentage > 20 µg m^{-3}		0.17%	0.08%	0.07%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%

Total background area (km^2) exceeding an annual mean value of 16 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	**P**	**Q**	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	1624	0	0	0	0	0	0	0	0	0
Rest of England	128770	0	0	0	0	0	0	0	0	0
Scotland	77791	0	0	0	0	0	0	0	0	0
Wales	20745	0	0	0	0	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0	0	0	0	0
Total	242248	0	0	0	0	0	0	0	0	0
Percentage > 20 µg m^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Total population in area exceeding an annual mean value of 16 µg m^{-3}

	Total	2010			2015			2020		
		Baseline	**P**	**Q**	**Baseline**	**P**	**Q**	**Baseline**	**P**	**Q**
London	7730326	0	0	0	0	0	0	0	0	0
Rest of England	41011137	0	0	0	0	0	0	0	0	0
Scotland	4944573	0	0	0	0	0	0	0	0	0
Wales	2850727	0	0	0	0	0	0	0	0	0
Northern Ireland	1623309	0	0	0	0	0	0	0	0	0
Total	58160071	0	0	0	0	0	0	0	0	0
Percentage > 20 µg m^{-3}		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 6.4 Population weighted mean $PM_{2.5}$ and PM_{10} concentrations using a 2003 base year (µg m^{-3}, gravimetric)

2010						
	$PM_{2.5}$			**PM_{10}**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	8.256	8.190	8.187	15.479	15.370	15.366
Wales	10.724	10.656	10.651	17.991	17.891	17.885
Northern Ireland	8.349	8.305	8.301	16.239	16.169	16.165
Inner London	14.642	14.467	14.453	23.567	23.253	23.231
Outer London	14.332	14.184	14.173	22.697	22.444	22.430
Rest of England	12.349	12.252	12.245	20.143	19.991	19.984
UK	12.064	11.965	11.958	19.880	19.721	19.713
2015						
	$PM_{2.5}$			**PM_{10}**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	7.846	7.599	7.596	15.021	14.655	14.651
Wales	10.109	9.817	9.811	17.347	16.965	16.960
Northern Ireland	8.014	7.833	7.830	15.889	15.632	15.629
Inner London	13.617	12.995	12.970	22.460	21.437	21.391
Outer London	13.357	12.798	12.783	21.647	20.791	20.768
Rest of England	11.587	11.188	11.181	19.326	18.780	18.773
UK	11.322	10.925	10.918	19.084	18.524	18.515
2020						
	$PM_{2.5}$			**PM_{10}**		
	Baseline	**P**	**Q**	**Baseline**	**P**	**Q**
Scotland	7.520	7.178	7.168	14.794	14.283	14.275
Wales	9.551	9.147	9.131	16.886	16.355	16.341
Northern Ireland	7.798	7.548	7.540	16.110	15.752	15.744
Inner London	12.799	11.935	11.890	21.772	20.330	20.258
Outer London	12.533	11.756	11.725	20.920	19.717	19.677
Rest of England	10.914	10.360	10.341	18.742	17.980	17.962
UK	10.680	10.129	10.109	18.543	17.761	17.740

Table 6.5 Change in population weighted mean $PM_{2.5}$ concentration for the combined measures relative to the base line

2010				
	Measure – baseline $PM_{2.5}$ ($\mu g\ m^{-3}$)		$(Measure – baseline PM_{2.5})/(Measure – baseline PM_{10})$ (%)	
	P	Q	P	Q
Scotland	-0.066	-0.070	60.2	61.2
Wales	-0.067	-0.073	67.2	68.9
Northern Ireland	-0.044	-0.047	62.5	64.0
Inner London	-0.174	-0.189	55.6	56.3
Outer London	-0.148	-0.160	58.6	59.6
Rest of England	-0.097	-0.104	64.0	65.5
UK	-0.099	-0.106	62.5	63.8
2015				
	Measure – baseline $PM_{2.5}$ ($\mu g\ m^{-3}$)		(Measure – baseline $PM_{2.5}$)/(Measure – baseline PM_{10}) (%)	
	P	Q	P	Q
Scotland	-0.246	-0.249	67.3	67.5
Wales	-0.293	-0.298	76.6	77.0
Northern Ireland	-0.181	-0.185	70.8	71.1
Inner London	-0.622	-0.647	60.8	60.6
Outer London	-0.560	-0.574	65.4	65.4
Rest of England	-0.399	-0.406	73.0	73.3
UK	-0.397	-0.405	70.9	71.1
2020				
	Measure – baseline $PM_{2.5}$ ($\mu g\ m^{-3}$)		(Measure – baseline $PM_{2.5}$)/(Measure – baseline PM_{10}) (%)	
	P	Q	P	Q
Scotland	-0.352	-0.343	67.7	67.0
Wales	-0.420	-0.405	77.1	76.3
Northern Ireland	-0.259	-0.250	70.7	69.9
Inner London	-0.909	-0.864	60.1	59.9
Outer London	-0.808	-0.777	65.0	64.6
Rest of England	-0.573	-0.554	73.5	72.7
UK	-0.571	-0.551	71.1	70.5

7 Uncertainty and sensitivity of the air quality assessment

7.1 INTRODUCTION

The modelling air pollution concentrations for both the baseline (see Grice et al, 2006) and additional measures presented in this report is based on a combination of measurement and modelling. There are both reducible and inherent uncertainties associated with all these elements. Predicting the future is inherently uncertain. Consequently the conclusions drawn within the AQS review about projected air quality are inherently uncertain.

This section discusses the main sources of uncertainty associated with assessment of future air quality and presents a sensitivity analysis to test the vulnerability of conclusions to unavoidable uncertainties.

7.2 UNCERTAINTY ASSOCIATED WITH THE AIR QUALITY ASSESSMENT

Air quality assessment is a complex procedure with many inputs, assumptions and some less well-characterised parameters. In this section, we present analysis and discussion of the uncertainty and sensitivity of outcomes to the following factors:

- measurements of current pollutant concentrations;
- accuracy of the GIS-based models;
- geographic scale – national v local;
- estimates of current air pollutant emissions;
- meteorology of the future year in question;
- for PM, assumptions about source apportionment of different components;
- estimates of the effectiveness of additional measures to mitigate emissions of air pollutants;

Ideally, we would quantify and combine the uncertainties associated with these elements into a single estimate of total uncertainty associated with the assessment. This is impractical because of the complexity of the interactions between the different sources of uncertainty. Instead, this section first discusses, in the context of the review, the overall level of uncertainty aimed for in the assessment of current air quality. It then assesses the sensitivity of model results for PM_{10} and NO_2 - the priority pollutants for additional measures - to changes in certain input assumptions. This sensitivity analysis tests how model results are influenced by changes in input assumptions and so indicates the vulnerability of the conclusions drawn in this review.

7.2.1 Overall uncertainty for measurement and modelling – current year

The aim for the overall level of uncertainty in the air quality assessment is to meet the data quality objectives (DQOs) that define the required overall level of accuracy for monitoring and modelling required by European air quality directives that have been transposed into UK regulations.

Measurement
These directives set out that uncertainties for measured individual data points should be between less than 15 percent to less than 25 percent of the true value, depending on the pollutant, and between less than 30 and less than 50 percent of the true value for modelled data. The most recent calculations for pollutants recorded at sites in the UK national monitoring network gave an accuracy range of around 8 per cent to 11 per cent.

Modelling
Uncertainty in the national GIS-based models is much more difficult to quantify. One of the surest ways to judge the accuracy of the models is to compare measurements with model results.

The GIS-based models used to calculate the maps of air pollutants presented in this report have been calibrated using the measurements from the Automatic Urban and Rural Network (AURN) of monitoring sites. Data from these sites alone cannot, therefore, be used to assess the reliability of the mapped estimates. Measurement data from sites not included in the calibration are required to make this assessment. Data from quality assured sites that are not part of the AURN, including appropriate Local Authority sites, have been used for the verification of the modelled estimates.

Verification of model results with measurements at monitoring sites not used to calibrate the model shows that model predictions are largely well within +/- 30% to +/- 50% of measurements, depending on the pollutant and metric modelled (Stedman et al, 2005; Grice et al, 2006).

For example, for 2003, all annual mean modelled NO_2 results were within +/- 30% of measurements at verification sites; and, for 2003, all annual mean modelled PM_{10} results were within +/- 50% of measurements at verification sites. This represents uncertainty at individual sites in a particular year.

Geographic scale of assessment
The national assessment used in the Air Quality Strategy was developed to estimate air quality for the whole of the UK. It is based on the National Atmospheric Emissions Inventory (NAEI) that estimates emissions of air pollutants at a scale of $1km^2$ and is calibrated to measurements from the AURN.

The national assessment provides a robust estimate of air quality throughout the UK that is appropriate for the review. There will however inevitably be some differences with assessments carried out at different scales, using different emissions inventories. For example, air quality assessments carried out by local authorities as part of their LAQM duties are based on local emissions estimates and air quality measurements. There are consequently cases where local authorities identify pollution problems not identified by the national assessment and vice versa. This will be particularly the case for local hot spots of air pollution, for example close to busy roads. It’s highly unlikely that any inconsistencies would change the overall conclusions of the national assessment, particularly for the pollutants and objectives identified in this review as challenges in future years.

The national assessment is continually developed and improved to take better account of local circumstances, particularly where inconsistencies with local assessments have been identified.

7.3 SENSITIVITY ANALYSIS

The air quality assessment presented in this report and the accompanying baseline report (Grice et al, 2006) is too complex and has too many inputs to be able allow a practical single estimate of uncertainty associated with the results. We have therefore carried out sensitivity analysis of important assumptions and inputs that influence the outcome and consequently conclusions drawn in the review.

7.3.1 Effect of base year on baseline projections

Day-to-day changes in weather have a great influence on air quality. Levels of pollutants that are relatively high on a still day when dispersion is limited can be much lower the next day, or even hour, if a wind starts to blow. Emissions of air pollutants may not have changed in that period, but measured concentrations will be much lower. When these effects are averaged out over a year, there can be quite large differences in average concentrations, or in the number of days that an objective has been exceeded between different years. NO_x and primary PM_{10} emissions changed little between 2002 and 2003 but there were large differences in air pollution climate.

The Government and the Devolved Administrations annually update projections of future air quality. Experience has shown that the point from which the projections starts has a great influence on projected air quality in a future year. Starting projections from a relatively poor year for air quality will result in higher projected air quality than starting projections from a year of relatively good air quality. Air pollutant emissions generally do not change substantially from one year to the next, so these large inter-annual variations are mostly a result of the different weather patterns between years.

Assessing trends in air pollution over several years, or assessing rolling averages over say three years, will diminish the impact annual weather variation. This is why it's important to look at a few years' worth of air quality data to draw conclusions on trends.

The baseline and all additional measures were modelled using 2003 as a base year. This is because 2003 was the latest year for which a full year's worth of ratified air quality monitoring data were available at the time the modelling work started.

We recognise that 2003 was a relatively poor year for air quality in some areas of the UK, compared to other years this decade. For example, the August 2003 heatwave resulted in an unusually widespread and long summer smog episode. Consequently, we have also modelled base case projections and projections for a selection of additional measures for PM_{10} and NO_2 starting from 2002, a relatively typical year for air quality in recent years. Modelling the base case for these two years should provide an estimate of the likely range of future air quality outcomes that are influenced by the weather.

Table 7.1 summarises model results for PM10 base line projections starting in 2002 or 2003. Full details of baseline projections are given in Grice et al (2006).

Table 7.1: model results for PM_{10} baseline projections starting in 2002 or 2003

	2010		2020	
	2002	2003	2002	2003
Population weighted mean PM_{10} concentration ($\mu g.m^{-3}$, gravimetric)	17.6	19.9	16.7	18.5
Percentage of total road length exceeding an PM_{10} annual average of 31.5 $\mu g.m^{-3}$, gravimetric*	0.1	2.1	0	0.3
Percentage of total background area exceeding a PM_{10} annual mean value of 31.5 $\mu g.m^{-3}$, gravimetric	0	0	0	0
Percentage of population in area exceeding a PM_{10} annual mean value of 31.5 $\mu g.m^{-3}$, gravimetric	0	0	0	0
Percentage of total road length exceeding an PM_{10} annual average of 20.µg m-3, gravimetric**	46.5	77.6	27.5	60.5
Percentage of total background area exceeding a PM_{10} annual mean value of 20 $\mu g.m^{-3}$, gravimetric	1.2	7.9	0.6	2.6
Percentage of population in area exceeding a PM_{10} annual mean value of 20 $\mu g.m^{-3}$, gravimetric	13.8	50.0	5.6	26.7

* equivalent to 36 exceedences of the a 24 hour average of $50 \mu g.m^{-3}$
** Stage 2 indicative limit value in 2010

Table 7.1 shows that projected air quality in 2010 and 2020 differs appreciably depending on the base year used. However, where exceedences are projected for 2003, they are also projected for 2002, except for total road length exceeding a PM_{10} annual average of 31.5 $\mu g\ m^{-3}$ in 2020. It is the extent of exceedences that differs.

Population weighted mean concentrations are about 10 per cent higher in 2010 and 2020 when projected from 2003 compared to 2002.

Table 7.2 shows results for model outputs for NO_2 projections starting in 2002 or 2003.

Table 7.2: results for model outputs for NO_2 projections starting in 2002 or 2003

	2010		2020	
	2002	2003	2002	2003
Population weighted mean NO_2 concentration ($\mu g.m^{-3}$)	16.6	19.5	14.3	16.8
Percentage of total road length exceeding an NO2 annual average of 40 $\mu g.m^{-3}$	11.8	18.2	5.5	8.5
Percentage of total background area exceeding a NO2 annual mean value of 40 $\mu g.m^{-3}$	0	0	0	0
Percentage of population in area exceeding a NO2 annual mean value of 40 $\mu g.m^{-3}$	0.2	0.6	0.1	0.3

Table 7.2, shows similarly for NO_2 that projected air quality in 2010 and 2020 differs appreciably depending on the base year used. However where exceedences are projected for 2003, in all cases they are also projected for 2002. Again, it is the extent of exceedences that differs.

7.3.2 Effect of choice of base year on the impact of additional measures

The influence of the base year chosen on the impact of additional measures is much less than on absolute levels of PM_{10} and NO_2. This is mainly because the assessment of the impact of measures focuses on changes in concentrations resulting from changes in relevant pollutant emissions. Effects of uncertainties in the base year assumptions are the same for both the starting year and the year of the projection. Changes to concentrations are independent of these uncertainties. This is particularly important when assessing the impact of measures on a pollutant that has no discernable threshold for health impacts, such as PM_{10}. The impacts of PM_{10} from air quality measures are directly related to the change in concentration, not the absolute concentration.

Comparison of results for measures P and Q using 2002 and 2003 base year shows combined measures are predicted to have a similar impact on concentrations in 2010, 2015 and 2020 for the two different base years (see sections 4-6 for full details of results). The relative effectiveness of the different measures remains the same for the two different base years. Consequently the choice of base year is unlikely to change the conclusions arising from the cost benefit analysis (DEFRA et al, 2006c)

7.3.3 Uncertainty associated with projected air quality – projected emissions

Projected air quality depends fundamentally on assumption about projected emissions of air pollutants. A discussion of uncertainties associated with estimating emissions is given in appendix 2. We have tested the sensitivity of projected estimates of PM_{10} and $PM_{2.5}$ population-weighted mean concentration estimates to changes in future total emissions of SO_2 and NO_x. These are important precursor gases for secondary PM formation and so changes in their emissions has an important impact on PM background concentrations and associated health impacts.

This differs to the sensitivity in section 7.2.4 below, in which the sensitivity of assumptions about the source apportionment of current PM was tested. The source apportionment of current concentrations has not been changed in this assessment, instead we consider the sensitivity to changes in future emission trends. As an example, we have tested the impact of higher national SO_2 and NO_x emissions in 2020 than estimated in the current base case. This reflects hypothetical changes in any sources of SO_2 and NO_x.

Table 7.4 shows the changes to projected population-weighted PM_{10} and $PM_{2.5}$ concentrations from an increase in SO_2 emissions of 10% and NO_x emissions of 2.5% compared to the current base case estimate in 2020. These values were chosen as hypothetical examples of how emissions may change if for example there was more coal burnt in 2020 than currently forecast.

Table 7.4 Effect on projected population-weighted PM_{10} and $PM_{2.5}$ concentrations of changes to future estimates of SO_2 and NO_x emissions

	UK population weighted PM_{10} concentration 2020	**Percentage difference**	**UK population weighted $PM_{2.5}$ concentration 2020**	**Percentage difference**
Base case	18.54		10.68	
+10% SO_2 emission and +2.5% NO_x emissions	18.62	0.4%	10.75	0.6%

As expected, increases in estimated precursor emissions results in higher PM calculated population-weighted concentrations. The changes in concentrations are slightly greater for $PM_{2.5}$ than PM_{10} because $PM_{2.5}$ has a higher proportion of secondary PM than PM_{10}.

Population-weighted PM concentration is a good indicator of health impacts, as the major health impacts of air pollution are related to population-weighted concentrations of PM.

Consequently these changes would translate approximately linearly to changes in quantified health impacts. Whilst important, this analysis indicates that population-weighted concentrations are not highly sensitive to changes in estimates of future total emissions of PM precursor gases.

7.3.4 Sensitivity of key assumptions in model inputs for PM_{10}

We have also assessed the impact of changing the assumptions about the contribution of different emissions sources to future concentrations of PM_{10} and NO_2.

For PM_{10} the changes on the input assumptions were:

- Source apportionment of emissions. This explores the impact of changes to the apportionment of primary PM_{10} emissions sources in 2003 and hence for projections for 2010. Total primary PM emissions are unchanged, but the contribution of different sectors is altered. This explores the impact on the results if current model assumptions are significantly wrong. The sensitivity analysis explored the impact of increasing primary PM_{10} emissions from stationary or from road transport sources by 25%.

- Residual PM_{10}. The residual PM_{10} (mainly coarse fraction PM_{10}-$PM_{2.5}$) material contributes approximately one third of measured PM_{10} in all projected years. What if this assumption is significantly incorrect?

- Secondary PM_{10}. Secondary particulate matter contribute approximately one third of measured PM_{10} on average in 2003 . What if this assumption is significantly incorrect?

Table 7.5 compares the impact of changing other inputs on key model outputs.

Table 7.5 Change in PM_{10} model outputs for 2010 (percentages are of UK totals)

Model output	**Model input varied**			
	Increase in stationary source emissions by 25%	**Increase in road transport emissions by 25%**	**Increase in residual PM_{10} fraction by 25%**	**Increase in secondary PM_{10} fraction by 25%**
Population weighted mean ($\mu g.m^{-3}$)	0	-0.1	1.2	0.9
Area of country exceeding annual average 20 $\mu g.m^{-3}$	0.2%	-0.4%	22%	21%
Proportion of length of road exceeding 20$\mu g.m^{-3}$	-1%	1%	9%	6%

In all cases these changes represent changes in the source apportionment of 2003 concentrations because the model has been calibrated using 2003 measurements.

The PM_{10} model shows little sensitivity to changes in the source apportionment of the primary PM_{10} stationary and road traffic emissions. This is due to the internal model calibration of the empirical dispersion coefficients. However, the model does show some sensitivity to changes in the residual PM_{10} concentration and concentration of secondary particles.

In 2003 increasing the assumed residual PM_{10} concentration increases exceedences at background locations and reduces exceedences at roadside locations. In increasing this component by 25%, background concentrations are proportionally raised in all locations and as a result, the dispersion coefficient for road link emissions will tend to be smaller leading to proportionally lower concentrations at the roadside. In 2010, this sensitivity test results in more exceedences because the residual is set at 2003 levels and remains constant through to 2010.

An increase in secondary particles causes a reduction in exceedences at both roadside and background locations in 2003. This is because the magnitude of the secondary PM_{10} concentrations and urban primary PM_{10} emissions has a broadly similar southeast to northwest gradient. Thus an increase in the assumed secondary PM_{10} concentrations within the source apportionment of the 2003 concentrations results in a reduction in the primary PM_{10} contribution. In 2010, this sensitivity test causes an increase in exceedences at the roadside and background locations as a result of the slower decrease in emissions of secondary particles relative to primary emissions.

The particulate matter model is relatively insensitive to changes in primary emissions but shows more sensitivity to changes in assumptions about the contribution from secondary particulates.

7.3.5 Change in NO_2 outputs in 2010

For NO_2 (table 7.6) the changes on the input assumptions were:

- Source apportionment of emissions . This explores the impact of incorrect apportionment of NO_x emissions sources in 2003 and thus in 2010. The sensitivity analysis explored the impact of increasing NO_x emissions from stationary, road transport or rural background (roughly 50% imported) sources by 25%.
- Increasing background ozone (regional oxidant) by 9%.
- Increasing primary NO_2 emissions (local oxidant) by 78%.
- A combination of increases in background ozone (regional oxidant) and primary NO_2 (local oxidant).

Table 7.6: Change in NO_2 outputs in 2010

Model output	**Model input varied**					
	Increase in stationary source NO_x emissions by 25%	**Increase in road transport NO_x emissions by 25%**	**Increase in rural background NO_x emissions by 25%**	**Increase in regional oxidant by 9%**	**Increase in local oxidant by 78%**	**Increase in regional oxidant by 9% and local oxidant by 79%**
Population weighted mean ($\mu g.m^{-3}$)	-0.1	-0.6	0.7	1.5	0.7	2.1
Area of country exceeding annual average 40 $\mu g.m^{-3}$	0%	0%	0%	0.1%	0.1%	0.1%
Proportion of length of road exceeding 40$\mu g.m^{-3}$	0.4%	-0.3%	0.4%	8%	4%	12%

Table 7.6 shows that the NO_2 model is relatively insensitive to changes in the source apportionment. An increase in the assumed traffic emissions in 2003 leads to a small decrease in the projected roadside exceedence in 2010 and a small increase in the projected roadside exceedence results from an increase in the assumed stationary source emissions or rural concentrations.

Using a combination of 2002 meteorological data and 2002 AURN measurement data has a significant effect on the modelled concentrations as shown in section 7.2.1. Adjusting the meteorological data only (not shown) has very little impact on the outputs. The models are much more sensitive to the choice of calibration measurement data than the choice of meteorological data. Table 7.6 does, however, show that the NO_2 model is sensitive to changes in both the regional and local oxidant (OX[1]) availability. OX converts emitted NO to NO_2 in the atmosphere. In these sensitivity tests, the regional oxidant field has been increased by approximately 9% (up to a maximum of 40 ppb of OX) and the local oxidant increased by 78% (up to a maximum of 25% of NOx emitted as primary NO_2).

In both scenarios the changes effectively increase the availability of OX resulting in corresponding increases in predicted NO_2. The increases in exceedences provide and indication of the likely effect of individual and combined increases in hemispheric ozone levels (regional OX) and primary NO_2 (local OX). Interestingly, it should be noted that the model appears to be far more sensitive to changes in regional than local OX. In this example a 9% increase in regional OX results in broadly equivalent change in exceedences as a 78% change in local OX. This is consistent with direct emission of primary NO_2 making a relatively small contribution to total oxidant up to a maximum of 25% of NOx emitted as primary NO_2. The contribution of local oxidant could be greater at higher percentages of primary NO_2.

The sensitivity analysis shows that the NO_2 model is relatively insensitive to emissions changes of the scale investigated.

7.3.6 Sensitivity of response of PM_{10} concentrations to changes in emissions of precursor gases

The uncertainty of the response of future PM concentrations to changes in emissions of precursor gases is related to the inherent unpredictability of atmospheric properties and how these may change in the future. For example, how will future concentrations of particulate sulphate (SO_4) change in response to changes in emissions of sulphur dioxide (SO_2)?

AQEG (2005) noted that although particulate sulphate levels have been falling steadily across Europe in response to the reduction in regional SO_2 emissions, the observed trend in UK particulate sulphate levels are somewhat smaller than the decline in UK SO_2 emissions over the same period. This would point to an increasing fraction of the emitted SO_2 being oxidised and present in the atmosphere as particulate sulphate. This may have resulted as a by-product of the decreased NO_x emissions and hence increased photochemical oxidation rate for SO_2 to sulphate. This is described in detail in the AQEG report on air quality and climate change (AQEG, 2006)

This suggests that future changes in PM concentrations will not be proportional to future changes in precursor gases. This "non linearity" of changes to emissions and concentrations has been included in the base case projections for PM_{10}. The GIS-based modelling assumes for the base case the same relationship between emissions and concentration as assumed by the EMEP assessment for Europe (Convention on Long Range Transboundary Pollution, 2006). The percentage change in secondary PM concentration is roughly 50% of the percentage change in precursor emissions. This results from the treatment of the oxidation chemistry within the EMEP model, which has been shown to provide good agreement with historical measured trends in secondary PM concentrations.

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[1] $OX = O_3 + NO_2$

It may however be a different case for the impact of measures. The estimated impact of additional measures on future PM concentrations assumes a simple linear and proportionate (i.e. 1:1) relationship between the changes in future emissions and change in future concentrations brought about by the measures. This suggests that the impact of the measures on the secondary PM component might be over-optimistic.

We cannot also be fully confident that the relationship between emissions and concentrations assumed for the base case will continue into the future. The atmosphere is likely to be more oxidising in future because of a continuing reduction in NO_x emissions and a gradual increase in background ozone concentrations (Hayman et al, 2006). This may lead to a greater rate of conversion of SO_2 to sulphate in the future atmosphere and consequently less response of changes PM concentrations to changes in SO_2 emissions.

Consequently we have carried out a sensitivity analysis of the relationship between precursor emissions and PM concentrations.

Two sets of uncertainties are assessed in this sensitivity analysis: those in the base case and those associated with the impact of measures.

The following sensitivity tests have been carried out:

- **SENSIVITY A** 50% response of secondary PM to additional measures. This is more consistent with the changes in secondary PM assumed in the baseline and the measures are applied to the standard baseline.
- **SENSIVITY B** 25% response of secondary PM for the baseline. This is a more pessimistic baseline in which the response of secondary PM to the baseline changes in emissions is half of that assumed in the standard baseline (roughly a 25% response to changes in emissions). This sensitivity test shows what would happen if the atmosphere does not respond as the national model predicts.
- **SENSIVITY C** 25% response of secondary PM to additional measures. This is consistent with the changes in secondary PM assumed in the 25% response of secondary PM for the baseline and the measures are applied to this baseline.

The following section presents a summary of the impact of these sensitivities on the population-weighted concentrations. Results of the sensitivity analysis for exposure reduction (Laxen and Moorcroft, 2006) are discussed in appendix 3.

The predicted extent of exceedences is also dependent on the relationship between precursor emissions and PM concentrations. Table 7.7 below shows the percentage of UK urban major roads predicted to exceed 20 μg m^{-3}, gravimetric in 2020.

Table 7.7 Percentage exceedence of 20 μg m^{-3}, gravimetric in 2020

	PM_{10}
Standard baseline	61%
Standard measure Q	27%
SENSIVITY A 50% response of secondary PM to additional measures: measure Q	30%
SENSIVITY B 25% response of secondary PM for the baseline	77%
SENSIVITY C 25% response of secondary PM to additional measures: measure Q	61%

Tables 7.8-7.10 show the changes in UK population-weighted mean PM concentrations for the additional measures relative to the relevant baseline. These concentrations are for the whole UK population. The changes in population-weighted mean provide a good indication of the changes to health impacts.

Measure Q (combined measure) has reductions in both primary and secondary PM; measure N (shipping) has reductions in secondary PM only.

Table 7.8. Changes in population-weighted mean $PM_{2.5}$ concentrations for measure Q relative to the baseline in 2010 and 2020 ($\mu g\ m^{-3}$, gravimetric)

Year	Standard	SENSIVITY A 50% response of secondary PM to additional measures	Per cent difference between sensitivity A and standard case	SENSIVITY C 25% response of secondary PM to additional measures	Per cent difference between sensitivity C and standard case
2010	-0.106	-0.082	-23%	-0.076	-28%
2020	-0.571	-0.406	-29%	-0.347	-39%

Table 7.9. Changes in population-weighted mean PM_{10} concentrations for measure Q relative to the baseline in 2010 and 2020 ($\mu g\ m^{-3}$, gravimetric)

Year	Standard	SENSIVITY A 50% response of secondary PM to additional measures	Difference between sensitivity A and standard case	SENSIVITY C 25% response of secondary PM to additional measures	Difference between sensitivity C and standard case
2010	-0.167	-0.145	-23%	-0.139	-27%
2020	-0.803	-0.648	-19%	-0.594	-26%

Table7.10. Changes in population-weighted mean PM_{10} concentrations for measure N relative to the baseline in 2010 and 2020 ($\mu g\ m^{-3}$, gravimetric)

Year	Standard	SENSIVITY A 50% response of secondary PM to additional measures	Difference between sensitivity A and standard case	SENSIVITY C 25% response of secondary PM to additional measures	Difference between sensitivity C and standard case
2010	-0.378	-0.191	-49%	-0.118	-69%
2020	-0.541	-0.266	-51%	-0.175	-68%

The above analysis shows that population-weighted concentrations are significantly sensitive to assumptions about the response of PM concentrations to changes in precursor emissions. This is potentially important because of the influence that changes to population-weighted concentration have on estimates of health impact in Chapter 3.

Applying the same assumption to measure Q as for the base case (Sensitivity A) reduces the change to population-weighted $PM_{2.5}$ concentration by 29% in 2020 (Table 7.8). The change to population-weighted PM_{10} concentration is smaller (-19% in 2020, Table 7.9) because secondary PM contributes a smaller proportion to PM_{10} concentrations than $PM_{2.5}$.

7.4 CONCLUSIONS ABOUT UNCERTAINTY IN MODELLING AIR POLLUTION

7.4.1 NO_2

Choice of base year has little impact on the absolute projected attainment or exceedence of objectives for NO_2. It does however have an important impact on the extent of projected exceedences.

Furthermore, AQEG (2004) noted that NO_2, future concentrations are likely to be higher than currently projected because of the influence of higher primary NO_2 emissions and the increasing background concentrations of ozone.

Consequently we are confident that future NO_2 concentrations will exceed objectives in 2010 and 2020, without further measures. AQEG also concluded that there are likely to be some exceedences of the annual mean objectives and limit value for NO_2 in 2010. AQEG noted that "there are reasons to believe that the current projections for future urban NO_2 concentrations may be optimistic. If northern hemisphere baseline O_3 concentrations continue to rise and influence rural O_3 concentrations in the UK, then the relationships between urban NO_2 and NO_x concentrations will alter resulting in higher than expected future annual mean NO_2 concentrations. Furthermore, if catalytically-regenerative particulate traps that are being retrofitted to diesel powered vehicles dramatically increase direct emissions of NO_2, as indicated by studies carried out in the USA, there will be further breaches of the air quality objective and limit value".

7.4.2 PM_{10}

For PM_{10}, the sensitivity analysis indicates that we can be confident that limited exceedences of the 24-hour objective will still exist near busy roads in 2010 and 2020 but that the annual average 2004 objective will continue to be attained nearly everywhere.

There is highly likely to be widespread exceedence of an annual average concentration of 20 μgm^{-3} near to major roads in 2010 and 2020. The extent of exceedence of this concentration at background locations is highly dependent on the weather in any future year and assumptions about the contribution of secondary particulates to PM levels. These two dependencies are related. Consequently we are less confident about the extent of exceedences of 20µgm-3 in future years.

AQEG (2005) independently drew similar conclusions that the annual mean objective and limit value set for 2005 would be met nearly everywhere, but with some exceedences of the limit of 35 days with 24-hour averages above 50μgm^{-3}, especially in London. AQEG also concluded there are likely to be substantial exceedences of 20 μgm^{-3} near to major roads in 2010.

Population weighted PM_{10} concentrations are approximately 10% lower for projections starting in 2002 compared to 2003. In other words, if the weather in 2010 were similar to 2002, the estimated health impacts would be around 10% lower than in the base case.

The impact of measures is not subject to the same degree of base year uncertainty because the change in concentration is relatively independent of the base year.

7.4.3 Effectiveness of additional measures

There is a significant risk that the effectiveness of measures in the base case and additional measures could be lower than estimated. Consequently there is a real risk that future concentrations of PM_{10} will be higher than forecast. This is because of uncertainties about:

- The composition of the atmosphere in the future and the responsiveness of PM concentrations to changes in precursor gas emissions

- apportionment of sources of PM. This is potentially important because of the influence that changes to population-weighted concentration have on estimates of health impact.

7.4.4 Summary

In summary, there are three elements that contribute the greatest uncertainty to model outputs for NO_2, PM_{10} and $PM_{2.5}$. These are:

- weather in the future year in question will have a large impact on the extent of exceedences of objectives;
- uncertainties about the response of PM concentrations to changes in emissions pf precursor gases; and
- uncertainties about the source apportionment of PM

Finally it should also be noted that the assessment has been carried out using the best national model available that is appropriate for a national assessment. However, the national model cannot represent all the possible local exceedences, which are often found as a result of local assessment (such as those carried out by Local Authorities and Environment and Highways Agencies) which are by definition only detectable at a more detailed, local level. Likewise the national GIS-based models may underestimate the impact on air quality of measures at the local scale.

8 Conclusions

GIS-based modelling predictions of air quality for a range of measures (table 8.1) have been produced for NO_2, PM_{10} and $PM_{2.5}$ for 2010, 2015 and 2020. A summary of the modelling results is presented in tables 8.2 to 8.5 for NO_2 and PM_{10} respectively in terms of the relative effectiveness of the measures in meeting objectives and reducing the population weighted mean concentration. Note the ranking is arbitrary where there are no exceedences or the percentage of exceedences is identical or the population-weighted-mean concentrations are identical.

Table 7.1: summary of additional policy measures considered in this report

Measure	Description
baseline	Current policies
A	Euro 5 and VI low
B	Euro 5 and VI high
C	Euro 5 and VI low including early introduction
D	Phase out of pre-Euro and Euro 1
E	LEV scenario
F	road user charging scenario
G	Low Emission zone
J	Domestic gas combustion NO_X: new product standards
K	NOx reductions at power stations, refineries, iron and steel
L	Small Combustion Plant Directive: NO_X and SO_2 (NB does not start until 2013, so no impact in 2010)
N	Shipping measure: NO_X and SO_2 reductions
O	Combined C + E
P	Combined C + L
Q	Combined C +L + E

The traffic measures are typically the most effective at reducing concentrations at the roadside, but the traffic measures also lead to reductions in background concentrations. The non-traffic measures reduce background concentrations but this also has an impact on roadside concentrations. Thus the ranking of the impact of measures can be different for the extent of roadside and background exceedences.

8.1 NO_2

The most effective measure for meeting the annual mean objective for NO_2 of 40 µg m^{-3} at roadside locations is expected to be measure K in 2010 and measure B in 2015 and 2020. At background locations and in terms of total population in areas exceeding the objective, the most effective measures are predicted to be measure K in 2010, measures B, Q and P in 2015 and measure B in 2020. Over all the combined measures are generally most effective at reducing exccedences followed by the road traffic measures.

The modelling results show that even with additional policy measures in place, it is still projected that there will be exceedences of the objective of 40 µgm^{-3} in 2010, 2015 and 2020. However the measures do significantly impact on the extent of projected exceedences across the UK.

In terms of relative effectiveness of the measures in reducing the population weighted mean NO_2 concentration, measure K is predicted to be most effective in 2010 (1.03 µg m^{-3} reduction relative to the baseline) and measure B is predicted to be most effective in

2015 (1.48 µg m^{-3} reduction) and 2020 (2.73 µg m^{-3} reduction). In 2010, 2015 and 2020 the second most effective measures are expected to be measures O, Q and P respectively.

8.2 PM_{10}

For PM_{10}, the majority of exceedences of objectives are predicted to be of the annual mean objective of 20 µg m^{-3}. The most effect measures at reducing exceedences of this objective at roadside locations are the combined measures (O, P and Q) in 2010, measure Q in 2015 and measure B in 2020. At background locations, measure K is predicted to be most effective in 2010 and measure B in 2015 and 2020.

The modelling results show that even with additional policy measures in place, there are still likely to be exceedences of the annual mean objective of 20 µg m^{-3} by 2020 at both roadside and background locations. However the extent of the exceedences will be significantly affected by which policy measures are adopted.

In terms of relative effectiveness of the measures in reducing the population weighted mean PM_{10} concentration, measures K, B and B are expected to perform best in 2010 (0.39 µg m^{-3} reduction relative to the baseline), 2015 (0.575 µg m^{-3} reduction) and 2020 (0.976 µg m^{-3} reduction) respectively. Measures N, Q and Q are expected to result in the second lowest population weighted mean PM_{10} concentrations for these years respectively.

8.3 EFFECT OF USING DIFFERENT MET YEARS

Using two different met years for modelling measures P and Q showed the same overall pattern of reductions from the baseline although as with the baseline the absolute number of modelled exceedences for a 2002 met year were lower than for a 2003 met year for both PM_{10} and NO_2. Altering the base year between 2003 and 2002 did not affect which limit values were exceeded, but rather the extent of the area/total road length modelled exceeding each objective changed.

8.4 $PM_{2.5}$

Modelling predictions have also been produced for $PM_{2.5}$ for measures P and Q combining some of the individual measures. Again measure Q is the most effective of the combined measures at reducing exceedences of the thresholds set.

8.5 UNCERTAINTIES

For NO_2 AQEG (2004) suggests that:

- primary NO_2 emissions are likely to increase as a proportion of total NO_x emissions
- increasing regional oxidant levels in the future will cause a higher percentage of NO_X to be converted to be converted to NO_2.

Both these factors suggest that the model results presented in this and the accompanying baseline report are likely to under predict NO_2 concentrations in future years. Therefore, we can be confident that there will still be exceedences of the NO_2 annual mean objective in the 2010, 2015 and 2020.

For PM_{10}, the sensitivity analysis indicates that we can be confident that limited exceedences of the 24-hour objective will still exist near busy roads in 2010 and 2020 but that the annual average 2004 objective of 40 μg m^{-3} will continue to be attained nearly everywhere.

Sensitivity analysis of modelling PM_{10} annual mean concentrations suggest the accuracy of predictions of exceedences of the 20 μg m^{-3} annual mean objective is likely to be highly dependent on:

- the weather in any future year
- uncertainties in the response of PM concentrations to changes in emissions of precursor gases
- Uncertainties about the source apportionment of PM

Table 8.2 Ranking of the relative effectiveness of the measures in meeting 40 µg m^{-3} objective for NO_2 (Percentage of total assessed exceeding this objective is shown in brackets)

Total road length (km) exceeding an annual mean value of 40 µg m^{-3}															
2010	K (17.4%)	O (17.4%)	Q (17.4%)	C (17.4%)	P (17.4%)	B (17.5%)	D (17.5%)	G (17.9%)	A (18%)	E (18.1%)	J (18.1%)	N (18.2%)	baseline (18.2%)	L (18.2%)	F (18.2%)
2015	B (5.9%)	Q (7%)	P (7.3%)	O (7.3%)	C (7.5%)	A (8.1%)	F (8.4%)	K (9.5%)	L (9.6%)	E (9.6%)	J (9.7%)	G (9.9%)	N (9.9%)	D (10%)	baseline (10%)
2020	B (1.3%)	Q (3.5%)	O (3.8%)	P (4.1%)	C (4.5%)	A (4.8%)	F (7.1%)	E (7.9%)	J (8.1%)	L (8.2%)	K (8.3%)	N (8.4%)	baseline (8.5%)	D (8.5%)	G (8.5%)
Total background area (km^{-2}) exceeding an annual mean value of 40 µg m^{-3}															
2010	K (0.03%)	O (0.03%)	Q (0.03%)	C (0.03%)	P (0.03%)	B (0.03%)	D (0.03%)	J (0.03%)	A (0.03%)	G (0.03%)	baseline (0.03%)	L (0.03%)	N (0.03%)	E (0.03%)	F (0.03%)
2015	Q (0.02%)	P (0.02%)	B (0.02%)	O (0.02%)	C (0.02%)	F (0.02%)	A (0.02%)	K (0.02%)	L (0.02%)	J (0.02%)	N (0.02%)	E (0.02%)	baseline (0.02%)	D (0.02%)	G (0.02%)
2020	B (0.01%)	Q (0.02%)	P (0.02%)	O (0.02%)	C (0.02%)	A (0.02%)	L (0.02%)	J (0.02%)	F (0.02%)	K (0.02%)	E (0.02%)	baseline (0.02%)	N (0.02%)	D (0.02%)	G (0.02%)
Total population in area exceeding an annual mean value of 40 µg m^{-3}															
2010	K (0.5%)	O (0.5%)	Q (0.5%)	C (0.5%)	P (0.5%)	B (0.5%)	D (0.5%)	J (0.6%)	G (0.6%)	A (0.6%)	baseline (0.6%)	L (0.6%)	N (0.6%)	E (0.6%)	F (0.6%)
2015	Q (0.2%)	P (0.2%)	B (0.2%)	O (0.2%)	C (0.2%)	F (0.2%)	L (0.3%)	A (0.3%)	K (0.3%)	J (0.3%)	N (0.3%)	E (0.3%)	baseline (0.3%)	D (0.3%)	G (0.3%)
2020	B (0.2%)	Q (0.2%)	P (0.2%)	O (0.2%)	C (0.2%)	A (0.2%)	F (0.2%)	L (0.2%)	J (0.2%)	K (0.3%)	E (0.3%)	baseline (0.3%)	N (0.3%)	D (0.3%)	G (0.3%)

Table 8.3 Ranking of the relative effectiveness of the measures in lowering the population weighed mean NO_2 concentration (population weighted mean concentration, µg m^{-3}, shown in brackets)

Population Weighted mean concentration (µg m^{-3})															
2010	K (18.493)	O (19.311)	Q (19.311)	C (19.339)	P (19.339)	B (19.352)	D (19.359)	J (19.445)	A (19.473)	E (19.494)	G (19.494)	N (19.509)	baseline (19.522)	L (19.522)	F (19.522)
2015	B (16.132)	Q (16.42)	P (16.516)	K (16.61)	O (16.697)	C (16.794)	A (17.001)	F (17.332)	L (17.34)	J (17.383)	E (17.5)	N (17.531)	D (17.604)	G (17.604)	baseline (17.608)
2020	B (14.046)	Q (14.98)	P (15.181)	O (15.29)	C (15.487)	A (15.568)	J (16.392)	K (16.397)	L (16.482)	F (16.516)	E (16.549)	N (16.65)	G (16.777)	baseline (16.777)	D (16.777)

Table 8.4 Ranking of the relative effectiveness of the measures in meeting 20 µg m^{-3} annual mean objective for PM_{10} (Percentage of total assessed exceeding this objective is shown in brackets)

Total road length (km) exceeding an annual mean value of 20 µg m^{-3}															
2010	O (74.9%)	Q (74.9%)	C (74.9%)	P (74.9%)	N (75.2%)	K (75.2%)	B (76.5%)	A (76.7%)	D (77.3%)	G (77.4%)	J (77.5%)	baseline (77.6%)	L (77.6%)	E (77.6%)	F (77.6%)
2015	Q (49.3%)	P (49.4%)	O (50.1%)	B (50.2%)	C (50.4%)	A (53.8%)	N (62.1%)	K (63.3%)	F (66.1%)	L (66.8%)	E (66.8%)	J (67%)	G (67.1%)	D (67.2%)	baseline (67.3%)
2020	B (22.7%)	Q (27.5%)	P (28.3%)	O (28.7%)	C (29.3%)	A (31.1%)	N (52.3%)	K (58.6%)	F (58.8%)	E (58.9%)	L (59.7%)	J (60%)	G (60.5%)	baseline (60.5%)	D (60.5%)
Total background area (km^{-2}) exceeding an annual mean value of 20 µg m^{-3}															
2010	K (5.7%)	N (5.7%)	O (7.2%)	Q (7.2%)	C (7.3%)	P (7.3%)	B (7.5%)	A (7.7%)	D (7.7%)	J (7.8%)	E (7.8%)	G (7.9%)	baseline (7.9%)	L (7.9%)	F (7.9%)
2015	B (2.6%)	Q (2.6%)	P (2.6%)	N (2.7%)	O (2.7%)	C (2.8%)	K (3%)	A (3%)	L (3.9%)	F (3.9%)	J (4%)	E (4%)	G (4.1%)	D (4.1%)	baseline (4.1%)
2020	B (1%)	Q (1.2%)	P (1.2%)	O (1.3%)	C (1.3%)	A (1.3%)	N (1.6%)	K (2.2%)	F (2.4%)	L (2.4%)	E (2.5%)	J (2.5%)	G (2.6%)	baseline (2.6%)	D (2.6%)
Total population in area exceeding an annual mean value of 20 µg m^{-3}															
2010	K (43.4%)	N (43.5%)	O (47.5%)	Q (47.5%)	C (47.6%)	P (47.6%)	B (48.8%)	A (49.2%)	D (49.6%)	J (49.8%)	E (49.9%)	G (49.9%)	baseline (50%)	F (50%)	L (50%)
2015	B (25.7%)	Q (25.8%)	P (25.9%)	O (26.7%)	C (27%)	N (28%)	A (28.6%)	K (29.5%)	F (34.6%)	L (34.8%)	E (35.3%)	J (35.4%)	G (35.8%)	D (35.8%)	baseline (36%)
2020	B (9.6%)	Q (11.9%)	P (12.3%)	O (12.8%)	C (13.2%)	A (13.7%)	N (18.2%)	K (24.4%)	F (25.1%)	L (25.7%)	E (25.8%)	J (26%)	G (26.7%)	baseline (26.7%)	D (26.7%)

Table 8.5 Ranking of the relative effectiveness of the measures in lowering the population weighed mean PM_{10} concentration (population weighted mean concentration, µg m^{-3}, shown in brackets)

Population Weighted mean concentration (µg m^{-3})															
2010	K (19.492)	N (19.493)	O (19.713)	Q (19.713)	C (19.721)	P (19.721)	B (19.798)	A (19.821)	D (19.851)	G (19.862)	J (19.869)	E (19.871)	baseline (19.88)	L (19.88)	F (19.88)
2015	B (18.509)	Q (18.515)	P (18.524)	O (18.569)	C (18.584)	N (18.606)	A (18.672)	K (18.707)	F (18.975)	L (19.019)	E (19.049)	J (19.051)	G (19.069)	D (19.073)	baseline (19.084)
2020	B (17.567)	Q (17.74)	P (17.761)	O (17.8)	C (17.82)	A (17.858)	N (18.002)	K (18.401)	F (18.445)	L (18.484)	E (18.493)	J (18.5)	G (18.543)	baseline (18.543)	D (18.543)

9 Acknowledgements

This work was funded by the UK Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland.

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Appendix 1 Detailed Assumptions Made for AQS Measures A-H Affecting Emissions from Road Transport

A1.1 MEASURE A: EURO 5/VI LOW INTENSITY

Euro 5 for diesel cars and diesel LGVs introduced from 2010. Euro VI HGVs introduced from 2013.

NOx	Petrol cars and LGVs	No change	
	Diesel cars and LGVs	20% reduction relative to Euro 4	100,000 km durability, hence no change in degradation rate
	HGVs and buses	50% reduction relative to Euro 5	
PM	Petrol cars and LGVs	No change	
	Diesel cars and LGVs	DPFs fitted on all vehicles: 90% reduction relative to Euro 4	100,000 km durability, hence no change in degradation rate
	HGVs and buses	No change	
CO_2	Petrol cars and LGVs	No change	
	Diesel cars and LGVs	3.5% fuel efficiency penalty, increase in CO_2 emissions	
	HGVs and buses	Fuel efficiency penalty: return to 2005 vintage levels, equivalent to 6% increase in CO_2	

A1.2 MEASURE B: EURO V/VI HIGH INTENSITY

Euro 5 for petrol cars and LGVs introduced from 2010. Euro 5 for diesel cars and diesel LGVs introduced in two stages: Stage I from 2010, Stage II from 2015. Euro VI HGVs introduced from 2013.

NOx	Petrol cars and LGVs	50% reduction relative to Euro IV	100,000 km durability, hence no change in degradation rate
	Diesel cars and LGVs	40% reduction relative to Euro IV from 2010 (Stage I); 68% reduction relative to Euro IV from 2015 (Stage II). 5% pa failure rate and higher cold start emissions assumed for Stage II vehicles	100,000 km durability, hence no change in degradation rate
	HGVs and buses	75% reduction relative to Euro V	
PM	Petrol cars and LGVs	No change	
	Diesel cars and LGVs	DPFs fitted on all vehicles: 90% reduction relative to Euro 4	100,000 km durability, hence no change in degradation rate
	HGVs and buses	DPFs fitted on all vehicles: 90% reduction relative to Euro 4	
CO_2	Petrol cars and LGVs	4% fuel efficiency benefit, decrease in CO_2 emissions	
	Diesel cars and LGVs	7% fuel efficiency penalty, increase in CO_2 emissions in new vehicles from 2010 (Stage I); 8.5% fuel efficiency penalty, increase in CO_2 emissions in new vehicles from 2015 (Stage II)	
	HGVs and buses	Fuel efficiency penalty: return to 3% above 2005 vintage levels, equivalent to 9% increase in CO_2	

A1.3 MEASURE C: EARLY EURO 5/VI LOW INTENSITY

Same as Measure A, but with earlier introduction of Euro 5 for diesel cars and LGVs and Euro 5 and VI HGVs and buses, as shown below. The balance of vehicle sales are Euro 4.

		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013+**
Cars and LGVs	Euro 5	0%	25%	50%	75%	100%	100%	100%	100%
HGVs and buses	Euro 5	0%	15%	47.5%	100%	75%	50%	25%	0%
	Euro 4	0%	0%	0%	0%	25%	50%	75%	100%

A1.4 MEASURE D: SCRAPPAGE SCHEMES

A1.4.1 Measure D1

Scrappage of pre-Euro 1 petrol and diesel cars and replacement with Euro 4 cars.
The percentages of pre-Euro 1 cars replaced with Euro 4 are:

	2007	**2008**	**2009**
% pre-Euro 1 replaced	**25%**	**75%**	**100%**

A1.4.2 Measure D2

Scrappage of pre-Euro 1 and Euro 1 petrol and diesel cars and replacement with Euro 4 cars.
The percentages of pre-Euro 1 and percentage of Euro 1 cars replaced with Euro 4 are:

	2007	**2008**	**2009**
% pre-Euro 1 and Euro 1 replaced	**25%**	**75%**	**100%**

A1.5 MEASURE E: UPDATED LEV INCENTIVE SCHEME

Penetration of petrol car LEV and diesel car LEV at the following rates:

	Petrol LEVs	**Diesel LEVs**
2006	2%	1%
2007	4%	2%
2008	6%	3%
2009	8%	4%
2010	10%	5%
2011	11.5%	6.5%
2012	13%	8%
2013	14.5%	9.5%
2014	16%	11%
2015	17.5%	12.5%
2016	19%	14%
2017	20.5%	15.5%
2018	22%	17%
2019	23.5%	18.5%

2020	25%	20%
2021	25%	20%
2022	25%	20%
2023	25%	20%
2024	25%	20%
2025	25%	20%

Petrol LEVs are assumed to displace non-LEV Euro 4 petrol cars; diesel LEVs are assumed to displace non-LEV Euro 4 diesel cars

The reduction in emissions relative to Euro 4 is as follows:

	NOx	**PM_{10}**	**CO_2 and fuel consumption**
Diesel	80%	92%	28%
Petrol	37.5%	0%	34%

No emission degradation is assumed for an LEV car

A1.6 MEASURE F: ALL USER ROAD CHARGING SCHEME INTRODUCED FROM 2015

This measure is based on work that was done for the Road User Charging Feasibility study (DfT, 2004). It uses emission estimates for each vehicle type in 10 area types calculated by DfT using the National Transport Model for a road user charging scheme introduced in GB in 2010. It is then assumed that the relative effect of the scheme on emissions in 2010 for each vehicle and area type compared with the basecase (no scheme) applies to the basecase emissions in 2015 if the scheme is introduced then. The same relative change in emissions compared with the basecase is also assumed for all years after 2015.

It is assumed that the scheme is only introduced in GB. The measure assumes introduction of the scheme on a high traffic growth scenario. The relative effect of the scheme against the base for the high growth scenario is assumed to apply for the central growth scenario that is used in the NAEI emission projections.

The relative change in emissions by vehicle type averaged over all urban and rural areas of GB indicated by the NTM is shown by the following scaling factors:

	NOx		**PM**		**CO_2**	
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Cars	0.925	0.998	0.906	0.998	0.887	0.987
LGVs	0.970	1.005	0.976	1.019	0.957	1.005
Rigid HGVs	0.943	0.996	0.919	0.992	0.945	0.999
Artic HGVs	0.960	1.000	0.938	0.998	0.966	1.001
Buses	0.954	0.993	0.928	0.985	0.947	0.995

The changes are due to changes in the volume of traffic (i.e. vehicle km) and levels of congestion brought about by the road user charging scheme. For the air quality modelling, scaling factors representing the changes in emissions in different area types were used. This measure also affected PM emissions from tyre and brake wear due to changes in the number of vehicle km.

A1.7 MEASURE G: LEZ

An LEZ Scheme is applied to HGVs and Buses only in 7 major GB Cities from 2010, and London from 2007. The 7 major cities are:

West Midlands
Greater Manchester
Merseyside
West Yorkshire
South Yorkshire
Tyne & Wear
Glasgow

For these cities, from 2010, all pre-Euro 1 and Euro 1 HGVs and buses and coaches are taken out and replaced by a fleet mix of Euro II/III/IV/V and all Euro II HDVs are fitted with a PM trap

For London, the same scheme starts in 2007 (Phase 1). The scheme is extended to include the replacement of Euro II HDVs in London from 2010 and all Euro III HDVs are fitted with PM traps.

Emission factors are calculated for each Euro standard and area type consistent with the basecase. The emission factors were calculated for speeds relevant to those used in the basecase for the NTM area types 1-3 (for London) and 4-5 (for the 7 cities) and emissions calculated using the projected vehicle km data for these 5 area types. The change in emissions was calculated by switching between Euro standard emission factors, but no change in the volume of traffic (i.e. the vehicle km) or speeds was assumed as a result of the measure. In other words, the Measure was assumed only to modify the make-up of the fleet in terms of Euro standard composition.

A1.8 MEASURE H: HDV RETROFIT

This Measure involves the retrofitting of DPFs to pre-Euro I to Euro IV HGVs and buses. The Scheme is rolled in gradually from a basecase rate of 2.6% in 2006 to a target rate in 2010, after which it remains constant. The Scheme is applied equally to each Euro standard. The rolling-in of the Scheme is assumed to occur at a linear rate between 2006 and 2010.

Three different retrofit schemes were modelled:

A1.8.1 H1

65% of pre-Euro I to Euro IV HDVs retrofitted with Pt-coated DPFs with fuel-borne catalyst (FBCs) by 2010. The technology shows:

- 95% PM reduction
- NOx neutral (no change in emissions)
- 1% fuel efficiency saving and reduction in CO_2

A1.8.2 H2

20% of pre-Euro I to Euro IV HDVs retrofitted with Pt-coated DPFs by 2010. The technology shows:

- 95% PM reduction
- NOx neutral (no change in emissions)
- 1% fuel efficiency penalty and increase in CO_2

A1.8.3 H3

35% of pre-Euro I to Euro IV HDVs retrofitted with Pt-coated DPFs by 2010. The technology shows:

- 95% PM reduction
- NOx neutral (no change in emissions)
- 1% fuel efficiency penalty and increase in CO_2

A1.9 MEASURE O: COMBINATION OF MEASURES C (EARLY EURO V (LOW)) AND E (LEV)

The penetration rates defined for Measure E define the LEV penetration rates in this combined scenario. Diesel LEVs displace Euro 4 diesel cars from 2006-2009 and Euro 5 diesel cars from 2010. The Euro 5 early penetration rates for diesel cars between 2007-2009 are defined by Measure C. This means that in years between 2007-2009 there is a mix of Euro 4, Euro 5 and LEVs among new diesel car sales. Petrol LEVs penetrate as defined for Measure E.

Appendix 2 Uncertainties associated with current estimates of pollutant emissions

The NAEI provides in its annual report a quantitative estimate of the uncertainty in emission inventories (Dore et al, 2004).

Table A2.1 summarises the range of uncertainty for the pollutants and ozone precursors included in the Air Quality Strategy.

Table A2.1 Uncertainty of the Emission Inventories (From Dore et al, 2004)

Pollutant	Estimated Uncertainty %
Sulphur Dioxide	+/- 3
Oxides of Nitrogen	+/- 8
Non-Methane Volatile Organic Compounds	+/- 10
Ammonia	+/- 20
Carbon Monoxide	+/- 20
Benzene	-20 to + 30
1,3-butadiene	+/- 20
PM10	-20 to +50
PAH (Benzo[a]pyrene)	-70 to +200
Lead	-20 to +30

Estimates of emissions for the main pollutants from fuel combustion are generally quite certain.

A2.1 Sulphur dioxide

SO_2 emissions can be estimated with most confidence as they depend largely on the level of sulphur in fuels. Hence the inventory, being based on comprehensive analysis of coals and fuel oils consumed by power stations and the agriculture, industry and domestic sectors, contains accurate emissions estimates for the most important sources.

A2.2 Oxides of nitrogen

NO_x emission estimates are less accurate then SO_2 because they are calculated using measured emissions factors. These emissions factors can however vary widely with combustion conditions. In the case of road transport emissions, while the inventory methodology takes into account variations in the amount of NO_x emitted as a function of speed and vehicle type, significant variations in measured emission factors have been found even when keeping these parameters constant.

The overall uncertainty in the NO_x emissions inventory is low because activity data is relatively certain. This contrasts with inventories for pollutants such as volatile organic compounds, PM_{10}, metals, and persistent organic pollutants, where some of the activity data are very uncertain. Second, the NO_x inventory is made up of a large number of emission sources with many of similar size and with none dominating (the largest source category contributes just 18% of emissions, and a further 42 sources must be included to cover 90% of the emission). This leads to a large potential for error compensation, where an underestimate in emissions in one sector is very likely to be compensated by an overestimate in emissions in another sector.

A2.3 Non-Methane Volatile Organic Compounds

The NMVOC inventory is more uncertain than those for SO_2 and NO_x. This is due in part to the difficulty in obtaining good emission factors or emission estimates for some sectors (e.g. fugitive sources of NMVOC emissions from industrial processes, and natural sources) and partly due to the absence of good activity data for some sources. As with NO_x, there is a high potential for error compensation, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI.

A2.4 Ammonia
Ammonia emission estimates are more uncertain than those for SO_2, NO_x and NMVOC due largely to the nature of the major agricultural sources. Emissions depend on animal species, age, weight, diet, housing systems, waste management and storage techniques. Hence emissions are affected by a large number of factors that make the interpretation of experimental data difficult and emission estimates uncertain (DOE, 1994). Emission estimates for non-agricultural sources such as wild animals are also highly uncertain. Unlike the case of NO_x and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

A2.5 Carbon Monoxide
Carbon monoxide emissions occur almost exclusively from combustion of fuels, particularly by road transport. Emission estimates for road transport are highly uncertain, due to the relatively small number of measurements made of emissions that appear to be highly variable. Emissions from stationary combustion processes are also variable and depend on the technology employed and the specific combustion conditions. The emission factors used in the inventory have been derived from relatively few measurements of emissions from different types of boiler. As a result of the high uncertainty in major sources, emission estimates for CO are much more uncertain than other pollutants such as NO_x, CO_2 and SO_2 which are also emitted mainly from combustion processes.

A2.6 Benzene and 1,3-Butadiene
There has been much improvement in the benzene and 1,3-butadiene emission estimates in recent years. Information gained in speciating the emissions of NMVOC has helped the generation of more robust emission inventories for both benzene and 1,3-butadiene. However, due in particular to the uncertainty in the levels of both pollutants in NMVOC emissions from road transport and other combustion processes, the uncertainty in these inventories is much higher than the uncertainty in the NMVOC inventory.

A2.7 Particulate Matter
The assessment of uncertainty below is based on primary PM_{10}. The emissions inventory for primary $PM_{2.5}$ is derived from the PM_{10} inventory, so the $PM_{2.5}$ inventory incorporates many of the uncertainties associated with the PM_{10} inventory. The $PM_{2.5}$ inventory also includes added uncertainty associated with estimates of the size distribution of the PM emissions, i.e. the proportion of PM emissions that is PM_{10} or $PM_{2.5}$.

Emission estimates for combustion of fuels are generally considered more reliable than those for industrial processes, quarrying and construction.

The emission inventory for PM_{10} has undergone considerable revision over the last three versions of the NAEI and must be considered significantly more robust now than, say, in 1997. Nonetheless, the uncertainties in the emission estimates must still be considered high. These uncertainties stem from uncertainties in the emission factors themselves, the activity data with which they are combined to quantify the emissions and the size distribution of particle emissions from the different sources.

Emission factors are generally based on a few measurements on an emitting source that is assumed to be representative of the behaviour of all similar sources. Emission estimates for PM_{10} are based whenever possible on measurements of PM_{10} emissions from the source, but sometimes measurements have only been made on the mass of total particulate matter and it has been necessary to convert this to PM_{10} based either on the size distribution of the sample collected or, more usually, on size distributions given in the literature. Many sources of particulate matter are diffuse or fugitive in nature e.g. emissions from coke ovens, metal processing, or quarries. These emissions are difficult to measure and in some cases it is likely that no entirely satisfactory measurements have ever been made.

A2.8 PAH (Benzo[a]pyrene, B[a]P)

Inventories for persistent organic pollutants such as B[a]P are more uncertain than those for gaseous pollutants. PM10 and metals. This is due largely to the paucity of emissions factor measurements on which to base emissions estimates, coupled with a lack of good activity data for some important sources.

A2.9 Lead

The inventory for lead is relatively certain compared to other metals in the NAEI because of the reliability of estimates.

Appendix 3 Sensitivity analysis of exposure reduction results

Table A3.1 lists the percentage changes in population-weighted mean PM concentrations between 2010 and 2020 for the standard calculations and for the sensitivity tests. These concentrations have been calculated for UK agglomerations with a population of at least 100,000 only for comparison with the proposed exposure reduction target for $PM_{2.5}$. Results for PM_{10} are also presented for comparison. See Laxen and Moorcroft (2006) and the AQS consultation documents (DEFRA et al, 2006 a; DEFRA et al, 2006 b) for more information on exposure reduction targets.

Table A3.1 Exposure reduction results between 2010 and 2020 (%)

	$PM_{2.5}$	PM_{10}
Standard baseline	-11.5	-6.7
Standard measure Q	-16.1	-10.7
SENSIVITY A 50% response of secondary PM to additional measures: measure Q	-14.9	-10.1
SENSIVITY B 25% response of secondary PM for the baseline	-5.7	-3.1
SENSIVITY C 25% response of secondary PM to additional measures: measure Q	-8.4	-6.1

The change in future concentrations of PM is sensitive to assumptions made about the impact of changes in emissions of secondary PM precursor gases on ambient concentrations of PM. If future atmospheric conditions are less conducive than current conditions, (i.e. the conversion of sulphur dioxide to particulate sulphate is increased) then the effectiveness of measures will be reduced.

The percentage reduction of PM_{10} from 2010 to 2020 for the baseline is likely to be in the range 3.1 to 6.7 percent. The percentage reduction of $PM_{2.5}$ from 2010 to 2020 is likely to be in the range 5.7 to 11.5%.

The upper end of the ranges assumes that the current atmospheric conditions prevail. The lower end of the range represents a pessimistic assumption about the future atmosphere.

The impact of additional measures is likely to be over-estimated because it assumes a 1:1 relationship between reductions in precursor gases and secondary PM concentrations. Therefore it's safer to assume the same relationship applies to additional measures as those included in the basecase. This is Sensitivity A in the above table.

For measure Q, the percentage reduction for PM_{10} is 6.1 to 10.7 per cent reduction between 2010 and 2020; and 8.4 to 16.1 per cent for $PM_{2.5}$. The reduction would be 15 per cent, assuming the same response relationship (Sensitivity A) as for the basecase. This assumes current atmospheric conditions prevail in 2020. The lower end of the range represents a pessimistic assumption about the future atmosphere